Reliability: Theory and Applications

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Guest Editors

This special issue on "Reliability: Theory and Applications" contains high quality articles on innovative approaches to climate change risk reduction. All articles were presented at the 6th Eurasian Conference "Innovations in Minimising of Natural and Technological Risks of Climate Change: Methodology and Practice" held under the auspices of COP-29 in Baku, Azerbaijan on 27-29 November, 2024.

We would like to thank all RISK-2024 conference participants from 38 countries for submitting papers and the reviewers for their efficient work in evaluating the submissions. We sincerely appreciate their excellent and timely responses.

The Guest Editors are also very grateful to the Secretary, Dr. Alexander Bochkov, for his continued support and constructiveness in the process of reviewing and preparing the proposal for the Special Issue. We hope that this special issue will make a significant contribution to improving the scientific field of assessment, analysis and management of natural and anthropogenic risks of climate change.

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The Sixth Eurasian Conference RISK-2024
under the auspices of COP-29

Innovations in Minimising of Natural and Technological Risks
of Climate Change: Methodology and Practice

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ORGANIZERS:

- AMIR Technical Services Company, Azerbaijan
- Azerbaijan Technical University
- Politecnico di Milano, Italy
- International Group on Reliability - Gnedenko Forum, the USA
- The UN Framework Convention on Climate Change

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DECLARATION

of the Sixth Eurasian Conference RISK-2024 under the auspices of the UN COP29 "Innovations in Minimizing of Natural and Technological Risks of Climate Change: Methodology and Practice" 27-29 November 2024, Baku (AZERBAIJAN)

Global climate change is the greatest existential threat to human existence. The COP29 conference, like the Stockholm conference 1972, discussed this threat from the perspective of the countries (top-down), while the RISK-2024 conference discussed the same problem from the perspective of the scientific community and experts (bottom-up), thus complementing the UN COP29. This declaration reinforces the decisions of the UN COP29 in terms of the involvement of every Earth inhabitant in everyday purposeful activity related to problem-solving and attaining the common goal of reducing the negative impact of technological greenhouse gas emissions on the Earth's biosphere.

We, the participants and organizers of the 6th Eurasian Conference "Innovations in Minimizing of Natural and Technological Risks of Climate Change: Methodology and Practice" (RISC-2024) under the auspices of the UN COP29 from 38 countries around the world, meeting in Baku (Azerbaijan) from 27 to 29 November 2024, understanding the need to develop a unified risk-based approach and to consolidate common principles of sustainable development in preserving and improving the human environment, proclaim that:

- Preserving and improving the quality of the human environment under the climate change is an important issue affecting the well-being of people and the economic development of all countries of the world, an expression of the will of their people and the duty of all governments.
- We reaffirm our commitment to play an active role in the formation of national and interтnational mechanisms to ensure the security of population and territories. We consider it important to involve all stakeholders in the analysis, assessment and management of the climate change risks.
- We express our concern about the increasing greenhouse gases emissions into the Earth's atmosphere and the scale of loss and damage from accidents and disasters caused by climate change and man-made disasters and call for joint efforts of scientists and specialists of the Eurasian countries to improve the effectiveness and responsibility of solutions to minimize the risks of natural and man-made emergencies.
- The Eurasian Risk Platform, created by the company "AMIR Technical Services", having the experience of successfully holding six multilateral conferences, which became an effective platform for generating ideas and meanings of risk theory, searching for ways to stimulate innovations to minimize existing and emerging climate change risks, claims to be the international coordinating center of the Green Planet 2060 Initiative Root Movement (GPM 2060).
- We define the objective of the Green Planet 2060 initiative movement as the development of an interdisciplinary approach to the risk-oriented management of intelligent socio-technical infrastructures and territories and the search for sustainable development pathways in the context of climate change.
- In order to achieve this goal, the Green Planet 2060 initiative movement intends to contribute to the accumulation and dissemination of innovative and advanced knowledge on climate, natural and anthropogenic risks, as well as technologies and methods for (1) minimizing greenhouse gas emissions, (2) local and atmospheric carbon dioxide sequestration, (3) advanced development of low-carbon energy sources, (4) methods for ensuring safety of agricultural soil and maintaining its fertility, (5) innovative approach to identifying various climate-related risks, and (6) developing innovative mitigation and adaptation approaches to climate change.

- Sustainable development and risk management are imperative research areas that overlap and influence each other. Sustainable development is defined as development that meets current societal needs without compromising the ability of future generations to meet their own needs.
- Risk management, in turn, plays a key role in achieving sustainable development by making science-based decisions, minimizing negative impacts on ecosystems and communities, and enhancing their sustainability.
- The Green Planet 2060 innovation movement will promote mutual understanding and deepen professional interaction between industry stakeholders, scientific and academic institutions to minimize the risks of climate change and ensure the safety of the population and sustainable social and economic development of the regions of the Eurasian continent.
- We believe it is important to establish an organic link between minimizing the risks of climate change, emergencies on the one hand and sustainable development of countries, on the other hand, involving all stakeholders and the general public in the analysis, assessment and management of risks, including the popularization of the ideas of sustainable development in all media, educational and scientific environments.
- We fully support further development of innovative approaches and actions within the framework of multilateral and regional cooperation and exchange of best practices and solutions in the field of climate change risk reduction based on the main decisions and outcomes of the UN COP29.
- The Eurasian Risk Platform, AMIR Technical Services, Gnedenko Forum, Research Center *Reliability and Safety of Large Systems* Ural Branch, Russian Academy of Sciences are launching the International Journal of Sustainabil-ity and Risk Management, which aim is to publish the latest theoretical and empirical re-search and commentary on communication, regulation and risk management with the sus-tainable development paradigm.

On behalf of the Organizing Committee

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PART-1
SECURITY OF COMPLEX TECHNICAL, SOCIO-TECHNICAL, CYBER-PHYSICAL, TRANSPORT AND LOGISTICS SYSTEMS IN THE CONTEXT OF INCREASING CLIMATE CHANGE

THE DUAL ROLE OF GLOBAL INFRASTRUCTURE IN CLIMATE CHANGE: NEW RISKS AND CHALLENGES

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Abstract

The paper (opening keynote lecture of the 6-th Eurasia Risk 2024 Conference) examines, from the interdisciplinary positions of the infranetics umbrella science and MABICS convergent technologies, the problem of climate change as a generally recognized consequence of the heating of the Earth's atmosphere due to uncontrolled emissions of greenhouse gases (GHG) by the global infrastructure (GI) – the second, artificial, nature created by man. An overview is given of the state of the problem of reducing the carbon footprint (CF) of the global system of infrastructure systems, which, on the one hand, ensures the sustainable development of the mankind, and on the other hand, is the main cause of global warming, which, if not combated, poses an existential threat to humanity. It is shown that the problem of restoring and maintaining the homeostasis of planetary ecology consists in ensuring a balance between two opposite processes – sustainable socio-economic development of the world community and greenhouse gas (GHG) emissions, by achieving net zero emissions. The problem of quantitative accounting, assessing and minimizing the infrastructures CF at all stages of their life cycle (LC), including diagnostics, monitoring, maintenance, recovery from accidents and disasters, is considered. Significant information gaps and scatter in CF estimates are noted, which indicate insufficient accuracy of the currently used methods. It is shown that it is necessary to develop a working algorithm for solving the global carbon balance equation considering climate change, according to the top-down scheme, which shows the contribution to the global CF of each infrastructure over time, according to the criterion of achieving zero CO_2 *emissions by 2060, in accordance with countries' obligations under the Paris Protocol of 2015.*

Keywords: global warming, global carbon budget, greenhouse gas emissions, economic and digital footprints of infrastructure, decarbonization, carbon offsetting

I. Introduction

The heating of the Earth's atmosphere has led to an increase in the frequency, strength and duration of geometeorological phenomena (drought, wind speed, precipitation amount), the emergence of new climatic phenomena (reduction of the ice cover of the Arctic Ocean, thawing of the Arctic tundra, accelerated melting of the Antarctic and Greenland ice, rising sea levels, thermal domes/islands), which have led to the emergence of new existential threats and risks, and imperatively requires a revision of almost all ideas about how to design and operate the global cyber-physical infrastructure of the 21st century in order to ensure its reliability, resilience and security.

The paper presents a system classification and structuring of greenhouse gas (GHG) emissions and absorption on a global scale. It analyzes the global, country, sector and corporate (dis)balance of the CF in the context of each individual infrastructure's CF during its creation, operation and disposal. It considers a risk-oriented problem of Pareto optimization of an infrastructure system based on its CF indicator, with given country, sector and/or corporate time-based restrictions on GHG emissions. It presents data on existing methods of GHG extraction from the planet's atmosphere and its burial at the bottom of deep oceans or in fractured rocks of the Earth's mantle (Nobel Peace Prize 2007).

The problem of preserving the vitality and fertility of agricultural lands and soils, which arose due to global warming and directly affects the food security of mankind, is also considered.

The role of the human factor in the problem of mitigating the consequences of the climate change when managing the second nature is considered. It is shown that all decision-makers (DMs) at all levels of the global, national, regional and corporate hierarchy, every inhabitant of planet Earth must be involved in solving this existential problem. It is necessary to find (in addition to existing ones) new ways to support, stimulate and finance all scientific, technical and organizational efforts aimed at solving this global problem.

At all stages of the presentation, an interdisciplinary approach to solving the problem is traced based on the use of convergent MABICS-technologies of the infranetics umbrella science.

II. Status of the problem: a brief review

We are interested in the problem of anthropogenic climate change as a generally recognized consequence of the heating of Earth's atmosphere due to uncontrolled emissions of greenhouse gases (GHG) by the global infrastructure (GI) – the second, man created artificial nature. A greenhouse gas (GHG) is a gas of natural or anthropogenic origin that absorbs and emits radiant energy in the thermal infrared range, causing the greenhouse effect (GE).

The main GHG is carbon dioxide (CO_2). Although other GHGs are more effective per molecule in warming the planet than CO_2, the enormous amount of CO_2 emitted by human activity and the fact that some emissions remain in the atmosphere for hundreds or thousands of years make CO_2 the single biggest problem in the fight against climate change. Emissions of all other GHGs are converted to carbon dioxide using special formulas and expressed in terms of mass of CO_2-eq. Carbon footprint is the amount of CO_2-equivalent that enters the atmosphere through human activity. Of the total estimated GHGs emitted into the Earth's atmosphere, about 90 % is due to human activities.

Without GHGs, the average surface temperature of the Earth would be about -18 °C, rather than the current average of +15 °C. The main GHGs in the Earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).

For a long time, the atmosphere contained a safe amount of GHGs, emitted by evaporation of the oceans, volcanic activity and forest fires. Human activity since the beginning of the Industrial Revolution (around 1750) has led to an increase in the concentration of carbon dioxide in the atmosphere by more than 50 % by now. The planet has become increasingly warm, and the threat of global warming has loomed.

At the current rate of GHG emissions, the Earth's temperature could increase by 2 °C by 2050, which, according to the UN Intergovernmental Panel on Climate Change (IPCC), is the upper limit that still allows avoiding "dangerous" levels of atmospheric heating [1]. It is necessary to reduce carbon emissions so that the observed increase in the average temperature of the Earth's atmosphere does not exceed the critical 1.5 °C. To do this, the global average human CF (in t CO_2-eq./person·year) must be reduced to 2.5t by 2030 and to 0.7t by 2050. Today, according to statistics from the Global Carbon Project [2], the CF of a US resident is 16.4t, the EU – 6.8t, China – 7.4t, and Russia – 12.5t. The global average is about 5 tons of CO_2-eq./person·year.

Signs of a climate crisis include heat waves, fires, floods and powerful storms, flooding of cities, extinction of biological species, drought and other natural disasters. If the situation is not changed, then very soon we will experience an increase in the frequency of natural disasters, the planet will have significantly reduced supplies of drinking water, existing desert zones will expand, outbreaks of epizootics, epidemics, infectious diseases, and famine will occur in many regions. In the most negative forecasts, all life on Earth may be under threat.

The anthropogenic factor has a huge impact on the manifestation of natural emergencies. Human activity disrupts the balance in the natural environment. Already now, the features of the global ecological crisis caused by the growth in the scale of use of natural resources are noticeably manifested. The main causes of natural hazards are:

- increasing anthropogenic impact on the environment;
- irrational placement of economic facilities;
- settlement of people in areas of potential natural hazard;
- insufficient efficiency and underdevelopment of hazard monitoring systems;
- absence or poor condition of hydraulic engineering, anti-landslide, anti-mudflow and other protective engineering structures, as well as protective forest plantations;
- lack and low rates of earthquake-resistant construction, strengthening of buildings and structures in seismically hazardous areas.

Currently there is a general understanding that natural disasters are a global problem that causes profound humanitarian shocks and are one of the most important factors determining sustainable economic development. Climate change increases the frequency and extremeness of severe weather events, which remain a major obstacle to sustainable development in cases where economic incentives for the development of hazardous areas do not exceed the expected disaster risks.

Extreme weather caused by climate change has pushed nearly 100 million people into hunger and increased heat-related deaths by 68 % among vulnerable groups. Globally, burning coal, oil, natural gas and biomass causes air pollution that kills 1.2 million people each year.

According to a new report published by the UN Office, the financial losses on global markets between 1998 and 2017 due to natural disasters increased by 251 %. In just 20 years, there were 7,255 major natural disasters in the world (i.e. one disaster per day). The most common disasters, based on the data in Fig. 1, are floods (43.4 %) and storms (28.2 %) [3]. Today, the concentration of CO_2 in the atmosphere is 0.04 % and this figure is growing. Global carbon dioxide emissions have reached 36 gigatons per year, and the average global temperature has already increased by 1.1 °C (in some places on the planet by 1.5 °C) [4].

III. Global carbon budget

The world's carbon budget includes all CO_2 emissions and absorption that are the direct or indirect result of human activity. The largest component of emissions comes from the combustion of fossil fuels (coal, oil and gas), which accounts for almost 90 % of all CO_2 emissions. The next smallest component comes from cement production. The remaining emissions come from land use changes (e.g. deforestation).

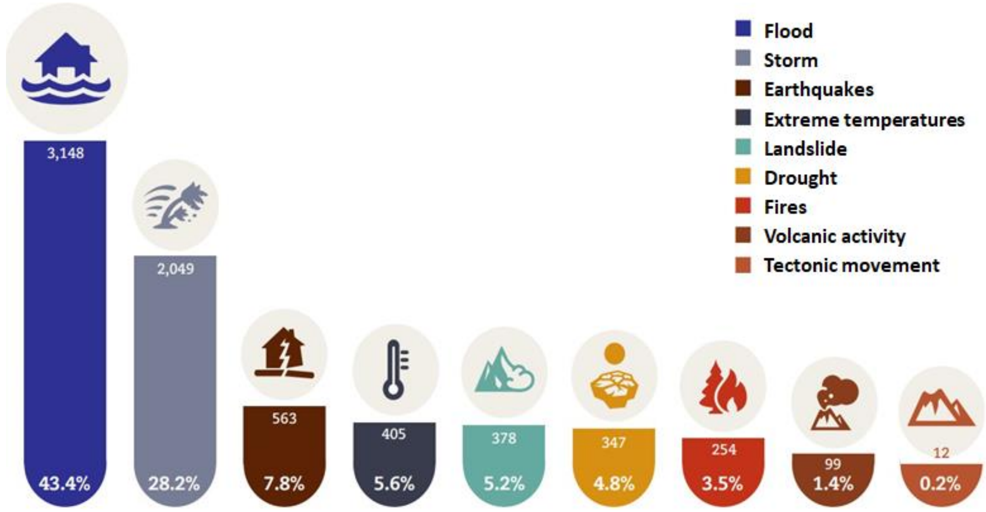

Figure 1: *Statistics of natural disasters in the world in the period 1998-2017*

The good news is that of all the CO_2 emitted by humans into the atmosphere, only about half remains in the atmosphere, causing climate change; the other half is removed by CO_2 sinks on land (vegetation through photosynthesis) and the oceans (through diffusion). The impact on climate change is therefore only half of what it would be without the help of these natural CO_2 sinks. Monitoring and predicting the evolution of CO_2 sinks allows to quantitatively estimate the speed of climate change.

The assessment of the global carbon budget is carried out by the Global Carbon Project (GCP), which unites more than 50 research institutes around the world that collect observations, maintain statistics, and develop global models for annual updating and improvement of the carbon budget. The key point of the GCP Global Carbon Budget 2023 report [2] is the conclusion:

- If current CO_2 emissions levels continue, the remaining carbon budget for a 50 % chance of limiting warming to 1.5 °C could be exceeded in 7 years, and for 1.7 °C in 15 years;
- Returning global temperatures below these thresholds once they are crossed will require a massive increase in carbon dioxide removal after net-zero global emissions are achieved.

IV. The Role of the global infrastructure associated with climate change

Anthropogenic heating of the Earth's atmosphere has led to the intensification of existing and the emergence of many new climate phenomena that threaten the sustainable development of regions, territories, countries and continents, as well as to the destabilization and destruction of the Earth's ecosystem. This heating has already affected the astronomical parameters of the Earth as a planet. Typical examples of such phenomena are:

- Rising sea levels caused by melting Antarctic and Greenland glaciers will eventually flood coastal regions and cause the disappearance of a number of Pacific island-states.
- Changes in precipitation patterns, leading to desertification and an increase in floods, hurricanes and tsunamis.
- Decreased crop yields and, consequently, a food crisis and famine.
- Lack of drinking water.
- Death of flora and fauna.
- Slowing down of the Atlantic Meridional Overturning Circulation (AMOC) conveyor belt as new freshwater flows from melting Greenland ice upsetting the existing balance of salt and fresh water in the circulation. Scientists fear that if the engine slows too much, it could stall, changing weather patterns (for the worse) for billions of people in Europe and the tropics. The

timing of such a tipping point is not yet predictable.

- A decline in the West African monsoon could transform tropical forests into grassy savannas.
- The thawing of the Arctic tundra, accompanied by the appearance of *batagaykas* – giant funnels (craters) in the Siberian tundra, which were apparently caused by huge bubbles of methane from melting clathrates (methane ice) erupting onto the surface. The first of these craters, discovered in 2014, was 30 meters in diameter and more than 70 meters deep, which gives some idea of the force of the eruption and the pressure of the methane accumulated beneath it. Batagayka is a newspeak, comes from the word Batagay – the name of a city built in the Chersky Ridge area in the Verkhoyansk region of Yakutia (Russia) for tin deposit developers. In 1969, geologists discovered the largest Batagay permafrost crater in the world near this city, or Batagayka (nicknamed in the media – Gates of Hell) [5].

As the soil thaws, the methane ice melts quite fast. Scientists believe that of all the possible events that could push the world toward abrupt, catastrophic, and irreversible climate change, only one—clathrate release—poses an immediate potential threat. Extraction of methane from seafloor clathrates could trigger massive underwater landslides and subsequent tsunamis.

To have a real chance of avoiding catastrophic climate change, it is not enough to slow the process; we must find a way to reverse it. This means removing CO_2 from the atmosphere and, ideally, returning the planet's atmosphere to pre-industrial CO_2 levels.

Effective carbon capture and storage can provide zero-emissions electricity, as renewable energy does now. But this is not enough to stop the runaway climate change that climate scientists believe may be underway. More must be done, namely (1) removing carbon from the atmosphere and (2) breaking the vicious cycle of methane release from the melting permafrost.

Virgin Enterprises founder Richard Branson launched the largest $25 million science prize ever in 2007 for a way to extract one gigaton (a billion tons) of carbon from the atmosphere each year. There are currently 11 finalists working toward that goal [6].

One of the fastest ways to capture atmospheric carbon is to grow fast-growing algae that can be turned into biochar through pyrolysis. This could go beyond zero human emissions and reduce methane emissions in the Arctic, but it would require a significant increase in the price of the carbon sequestered in this way to make it possible. The funds needed to do this, according to the Paris Agreement, could come from the developed world, which must raise (according to the COP 29 Resolution) $300 billion a year (by 2030) to help poorer nations achieve sustainable development.

On a planetary scale, the permafrost layer of the Earth contains about 1.6 trillion tons of CO_2—about twice as much as the Earth's atmosphere currently contains. Scientists call this carbon, made up of plants and animals that froze before they could decompose, *deep legacy carbon* [7]. All of this creates a new, previously non existing threat of collapse for the entire Arctic infrastructure: port facilities, railways, roads, airports, oil and gas pipelines, LNG plants, buildings and structures

(Figs. 2, 3, a, b [8]):

- Thermal domes (islands), not only in countries with a hot climate, but also in regions with a moderate climate (for example, East Canada), where the temperature reaches +50 °C and + 40 °C and higher, respectively, and lasts for several weeks, including at night. This leads to a decrease in human cognitive abilities, and to a mass manifestation of subresilience of people living under such a dome (on such an island), and corresponding expenses to cure this illness;
- Change in the relief of the Earth's surface;
- Change in the tilt of the Earth's rotation axis due to the melting of Antarctica ice;
- Increase in the time of the Earth's daily rotation (yet, by several milliseconds);
- Change in the dynamics of the Earth's crust, its interaction with the mantle and the Earth's surface, which must be considered for achieving needed accuracy of space navigation;
- Rising ocean temperatures are causing corals to expel the symbiotic algae that live inside their tissues. This bleaching is fatal to corals. Scientists predict that even if humanity quickly takes action to curb global warming, 70 to 90 percent of today's reef-forming corals could die in the coming decades. If not, the loss could be 99 percent or more;
- Deforestation of the Amazon could reduce rainfall in the region, causing the remaining forest to degrade and turn into grassy savannah. Researchers estimate that by 2050, a good half of today's Amazon forests could be at risk of this fate.

I. Classification of environmental emergencies associated with changes in

Land conditions:

- intensive soil degradation;
- catastrophic subsidence, landslides, collapses of the earth's surface due to subsoil development or mining;
- the presence of heavy metals and other harmful substances in the soil more than maximum permissible concentrations;
- depletion of non-renewable natural resources;
- overflow of storage facilities (landfills) with industrial and household waste, pollution of the environment by them.

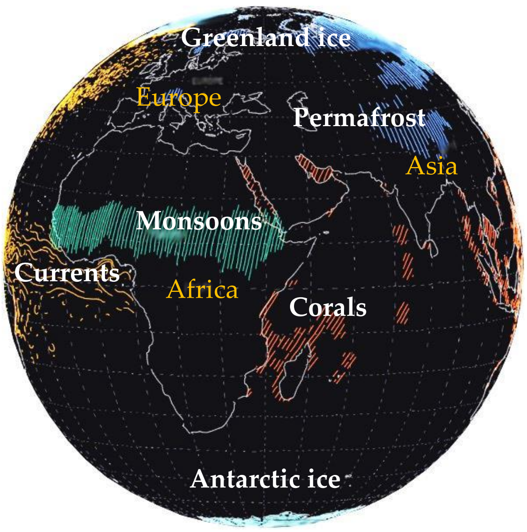

Figure 2: *Changes in the Earth's ecosystem because of global warming*

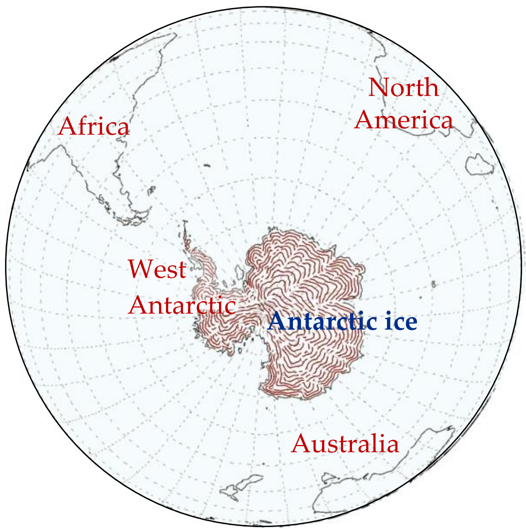

Figure 3: **a.** *Changes in the Earth's ecosystem because of global warming*

Figure 3: b. *Changes in the Earth's ecosystem because of global warming*

Composition and properties of the atmosphere:

- abrupt changes in weather or climate because of anthropogenic activity;
- temperature inversions over cities;
- severe oxygen starvation in cities;
- significant excess of the maximum permissible level of urban noise;
- exceeding the maximum permissible concentrations of harmful impurities in the atmosphere;
- formation of a vast zone of acid precipitation;
- destruction of the ozone layer of the atmosphere;
- significant change in the transparency of the atmosphere.

Composition of the hydrosphere:

- a sharp shortage of drinking water due to the depletion/ pollution of water sources.

II. The global carbon footprint (GCF)

The main emitting sectors in both the global and national economies are: (1) energy, (2) industry (non-energy processes), (3) agriculture, forestry and land use, and (4) waste disposal and recycling. The contributions of each sector, as well as the shares of subsectors of industries, to global emissions (according to World Resources Institute (WRI) data for 2016 [9]) are graphically presented in Figs. 4, 5.

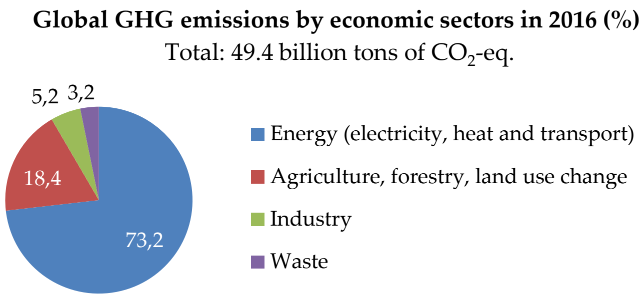

Figure 4: *Distribution of global greenhouse gas emissions (GGHG) by economic sectors in 2016 (%)*

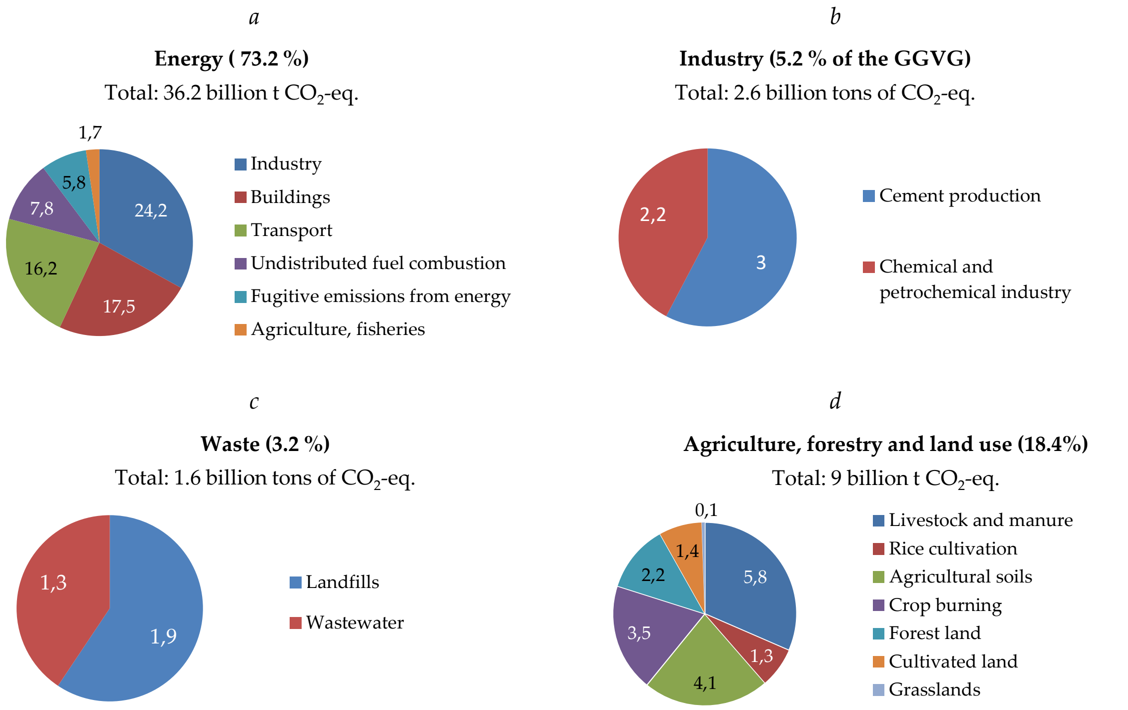

Figure 5: *Distribution of GHG emissions in 2016 (% of the GGHG):*
a – in the energy sector; b – in the industrial sector; c – in the waste sector; d – in the agriculture, forestry and land use change

The global carbon footprint of the world for a period t is the sum of the carbon footprints of all countries for the same period *t*:

$$CF_{\text{glob.}} = \sum_i CF_{\text{country}} , \qquad (1)$$

where $CF_{\text{glob.}}$ is the global CF, CF_{country} is the CF of the *i*-th country.

According to the European Commission's GHG data (EDGAR – Emissions Database for Global Atmospheric Research), in 2023 the global economy produced 52.9629 billion tons of CO_2-eq. [10]. The distribution of countries' contributions to the global CF is presented in Fig. 6.

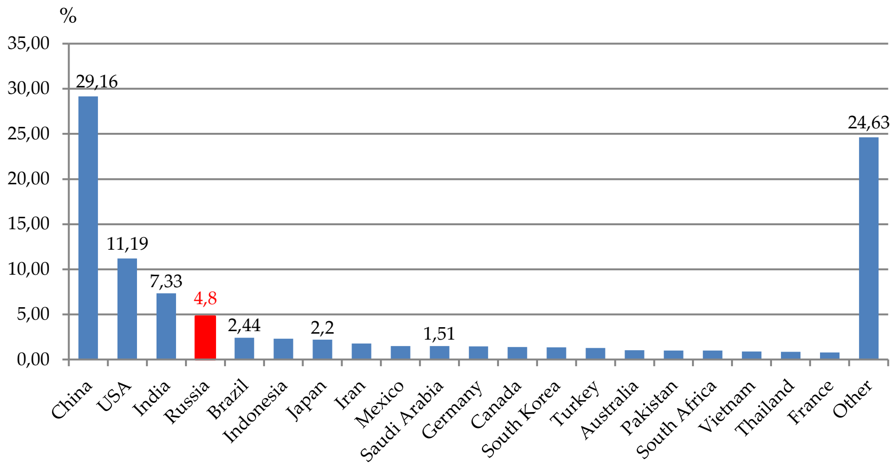

Figure 6: *GHG emissions by country in 2022 (% of global emissions)*

The GCF can also be represented as the sum of emissions from all sectors of the global economy:

$$CF_{\text{glob.}} = \sum_i CF_{\text{sector}} , \tag{2}$$

where CF_{sector} is the CF of the i-th sector of the world economy.

A country's GHG emissions are formed from emissions from all sectors of its economy:

$$CF_{\text{country}} = \sum_i CF_{\text{s},i} , \tag{3}$$

where $CF_{\text{s},i}$ is the GHG emission of the i-th sector of the country's economy.

The GCF, expressed in terms of country sector emissions, can be written as

$$CF_{\text{glob.}} = \sum_i \sum_j CF_{i,\text{s},j} , \tag{4}$$

where $CF_{i,\text{s},j}$ is the GHG emission of the j-th sector of the economy of the i-th country.

The contributions of economic sectors of Russia, as well as the shares of subsectors of industries, to total country emissions are graphically presented in Figs. 7, 8 [11].

Russia. GHG emissions by economic sector in 2020 (%)
Total: 2051.4 million tons of CO_2-eq.

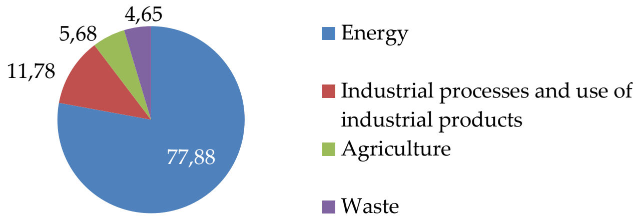

Figure 7: *Distribution of GHG emissions by economic sectors of Russia in 2020 (%)*

a *b*

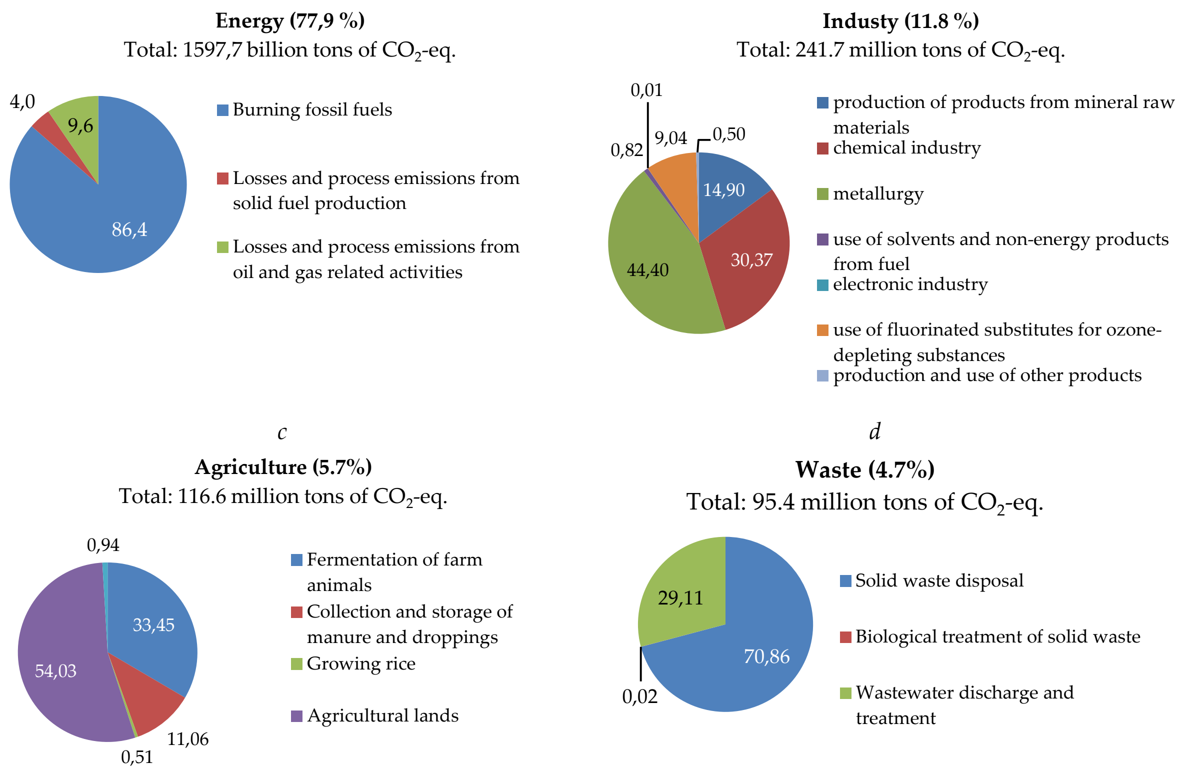

Figure 8: *Distribution of GHG emissions of Russia in 2020 (% of total CF):*
a – in the energy sector; b – in the industrial sector; c – in the agriculture; d – in the waste sector

V. Tasks of modern risk analysis of infrastructures in the context of climate change

The awareness that any human action is inevitably accompanied by an ecological trail, carbon emissions, economic and social footprint, allows setting and solving tasks of modern risk analysis in a new way. First, the CF must be considered as a planetary/country/industry boundary/maximum permissible condition (BC/MPC) acceptability of creating and operating each specific socio-technical system/infrastructure.

Infrastructure design must explicitly consider the impact of climate change on the magnitude of loads, impacts and any other stressors on the system being designed to prevent future incidents and accidents due to failure to consider increased impact values due to climate change. It is necessary to develop:

1) stochastic load and impact models, in the context of considering king-dragon events using heavy-tailed PDFs, as well as advanced degradation models of materials and structures;

2) risk-based design and maintenance standards for buildings and structures for thermal, wind, wave loads and impacts, and

3) full life cycles that consider climate change and the size of the carbon (as well as economic and digital) footprint of each infrastructure.

Particular attention should be paid to thermal loads in the Arctic Zone of the Russian Federation (AZRF), where the rate of warming is twice as high as the rate of global warming. Maintaining the reliability, resilience and safety of critical and strategic infrastructures in the context of global warming requires ever greater resources. This objectively reduces the economic efficiency of the oil, gas and transport sectors located in the AZRF.

A feature of modern risk analysis is that more and more attention is paid to the integrated economic consequences (damage) from undesirable events associated with a decrease in the physiological, cognitive and social abilities of an individual (and the affected community as a whole) over time from such stressors as active radiation, mass poisoning with chemicals (i.e., pesticides used in Vietnam), post-traumatic syndrome, etc. This problem is studied in the theory of sub-resilience.

I. Full life cycle (FLC) of the infrastructure

In the context of climate change, risk analysis must be carried out based on the FLC of the infrastructure/system/network. This relatively new task has a short history of its development.

In essence, the FLC is a forecast scenario for the entire period of the system's existence – from conception to disposal. The exception is infrastructures that have no visible end to operation. They exist almost forever: large cities, railways and highways, seaports, etc.

For a qualified and consistent assessment of the ecological/carbon footprint of the global artificial nature (GI), it is necessary to conduct a specific FLC analysis of each global infrastructure component (GIC) to assess (1) the magnitude of the ecological footprint and CF of the GIC as a random function of time and (2) its contribution to the global CF, influencing climate change on the planet.

The full life cycle of any GIC consists of following stages:

I) production of materials from which the GIC will be manufactured (extraction of raw materials to produce materials is usually not considered in the calculation of the CF);

II) production of the GIC;

III) construction of the GIC, including transportation, welding, installation of equipment, protection from external influences, acceptance tests;

IV) operation of the GIC in a stationary mode, including scheduled and unscheduled diagnostics, monitoring, technical repairs, maintenance, as well as restoration of the infrastructure after each accident, emergency or disaster;

V) recycling/disposal of the GIC after the end of its operation.

The infrastructure CF is an indicator of the environmental efficiency of its use at all stages of its LC and is therefore of great interest to the public and investors. Decision makers (DMs) when deciding on GI operation methods should (in the context of the Paris Protocol) separately consider the sizes of the current and the cumulative CF they create and the discounted cost of their neutralization, considering the impact of climate change.

In the conditions of dynamic multifactorial uncertainty of the modern world, the management of the GIC is carried out according to safety and risk criteria. In this case, the target function (TF) of risk management is reduced to minimizing the generalized cost of operating the GIC over the period "from conception/cradle to grave".

The problem of managing the GIC risk is posed as a problem of optimizing the target function, which should adequately reflect the total NPV of costs during its entire LC for:

1) creating and disposing GIC;

2) technical maintenance, repair and restoration due to possible emergency situations;

3) restoring the disturbed (due to system operation) ecological balance of the environment;

4) compensating the system's CF;

5) restoring lost human health and monetary compensation for the possible loss of lives and limbs during the GIC operation.

In the most general case, the problem of determining the man-made risk, interpreted as the product of the probability of failure (POF) and its consequences (losses/damage), expressed in monetary form, is formulated as a problem of Pareto-optimizing the target function, which is reduced to the integral cost of owning the GIC over its FLC:

$$_{\text{GIC}}C_{\Sigma} = C_{\Sigma,c} + C_{\Sigma,in} + C_{\Sigma,r} + C_{\Sigma,cf} + C_{\Sigma,hl}\,. \tag{5}$$

Here $C_{\Sigma,c}$ is the total cost of design, construction and commissioning of the GIC, as well as its disposal after the end of its service life; $C_{\Sigma,in}$ is the total cost of all inspections on the GIC life cycle; $C_{\Sigma,r}$ is the total cost of all repairs/restorations during the life cycle of the GIC, including after accidents and disasters; $C_{\Sigma,cf}$ is the total costs of compensation for damage from CF; $C_{\Sigma,hl}$ is the cost of restoring lost human health and the amount of monetary compensation for possible loss of lives and limbs during the GI life cycle.

When solving the problem of assessing and minimizing the CF size, it is necessary to consider following circumstances.

The size of the CF when creating the GIC is determined by the facility design goals; at the same time, the CF size is subordinated to these goals and cannot be a limiting factor. It follows from this that compensation for the CF caused by the construction and commissioning of the GIC may require the use of special financial instruments (for example, planting a certain number of fast-growing and highly CO_2 absorbent tree species). At the same time, the size of the CF when utilizing such a GIC is also a certain function of its original goal.

The main CF occurs during the operation of the GIC. It is a function of the volume and quality of diagnostics, monitoring, maintenance, as well as the consequences of GIC pipelines and vessels depressurization because of incidents, accidents and disasters.

Since all these operational events are modeled when constructing a set of GIC life cycle scenarios required to assess and minimize operational risk, the value of the CF is obtained as a natural consequence of the scenario under consideration. In this case, minimization of the CF for each virtual violation of the integrity of the GIC pipeline or vessel is possible in the process of making the next decision. This allows for effective management of the CF size by selecting optimal system design, inspection technologies, scheduled repairs, and restoration of GIC after depressurization or accident.

II. General algorithm for assessing the carbon footprint of a GIC over its life cycle

Since the sectoral CF is formed by individual infrastructures of companies/states, its reduction is accomplished by reducing the CF of each infrastructure that comprises the sector, starting from the initial stage of the GIC life cycle – the production of its structural components and the construction itself. By analogy with the name of the life cycle stage, the emissions of this stage are called initial CF of the GIC.

The design CF of an infrastructure is the CF emitted during its construction and normal operation, without accounting for any unplanned emissions due to accidents and subsequent restorations. For newly designed facilities, this value will be legislatively reduced. This will demand using new low-carbon technologies for building the structures, improved risk-oriented methods of facility operation, and advanced technologies for capturing the carbon emitted by the GIC.

In general, the calculation of the GIC CF considers emissions of all types of GHG, as well as indicators of energy expended per unit of production generated at all stages of its LC.

VI. Methods for reducing atmospheric carbon masses

There are two ways to decarbonize the Earth's atmosphere: through natural CO_2 absorbers and through technical and economic measures.

Natural CO_2 absorbers are:

- Healthy forests;
- Marsh and peat ecosystems (main absorbers of atmospheric CO_2);
- Brown algae.

Technical and economic measures are:

- Sequestration directly at plants and enterprises emitting GHGs;
- Minimization of fugitive gas leaks;
- Renewable energy sources;
- Alternative (low-carbon hydrogen) fuel;
- Use of electric vehicles, electric and hydrogen aircraft;
- Technologies for removing CO_2 from the atmosphere;
- Policy of "green" loans.

VII. Nuclear power carbon footprint

In nuclear power, the fulfillment of the undertaken obligations to reduce CO_2 emissions and achieve carbon neutrality is realized by replacing *dirty* electricity with *environmentally friendly* electricity.

The production of 1 kWh of electricity by burning coal produces 1700 g of GHG; when burning natural gas, the emission is about 900 g; at a hydroelectric power station – about 50 g; at a wind power plant – about 50 g; at a solar power plant – about 100 g; for nuclear energy – from 2 to 130 g CO_2-eq./kWh, with an average value of 29 CO_2-eq./kWh [12].

I. Recommendations for reducing the nuclear fuel cycle emissions

- When mining uranium, it is recommended to carry out underground leaching (characterized by the lowest energy and material costs).
- In the process of ore enrichment, gas centrifugation is more environmentally friendly than gas diffusion, since electricity from renewable energy sources is used.
- When choosing a site for the construction of a nuclear power plant (NPP), the potential loss of carbon by vegetation should be considered. During the construction period, the amount of materials and energy used can be reduced by reducing design redundancy, optimizing the design and shortening the construction period.
- During operation, it is recommended to use 5G and artificial intelligence (AI) technologies to enhance the digital transformation capabilities of the NPP, so that it can be operated with less dependence on personnel and, consequently, with lower emissions. At the end of the nuclear fuel cycle, a closed fuel cycle (CFC) strategy is recommended, where the spent nuclear fuel is reprocessed to extract unburned uranium U and accumulated plutonium Pu, which are then used to manufacture new fuel elements.

Effective management of carbon forests can potentially provide Russian nuclear power plants with conditions in which up to 20–25 % of all carbon emissions will be offset by an increase in phytomass in forests located within the sanitary protection zones of NPPs [12]. According to the statement by Russian Prime Minister M. Mishustin at the UN COP 29 conference on November 13, 2024 in Baku, Russian forests make up 20 % of the world's forest lands and absorb one billion tons

CO_2 per year.

VIII. Hydrogen energy carbon footprint

In hydrogen energy, the fulfillment of the undertaken obligations to reduce CO_2 emissions and achieve carbon neutrality is realized through the production of low-carbon hydrogen [13]:

- from fossil raw materials, including using CO_2 capture technologies;
- based on a nuclear power plant (with CO_2 capture);
- by water electrolysis based on a NPPs, hydroelectric power plants and electricity from power systems, subject to ensuring a low-carbon footprint, as well as
- based on renewable energy sources in those regions where the cost of hydrogen produced based on such sources is competitive.

IX. Carbon offset measures

1) Purchasing emission quotas from oil and gas transportation companies that have been able to reduce their emissions below established limits;
2) Investing in emission reduction projects (e.g., renewable energy sources) or offset projects (reforestation);
3) Purchasing certificates from specialized organizations that finance GHG emission reduction projects.

X. Measures to prevent accidental emissions

To prevent malfunctions and emergency situations of the GIC such as oil and gas pipelines, pressure and temperature monitoring are carried out – the main operational parameters of pipelines and pressure vessels, as well as their regular diagnostics and inspection to detect and assess deformations, welding defects, dents, damage to the protection of pipelines, pressure vessels, as well as possible leaks of natural gas.

The main reason for the cumulative growth of the CF of the gas-oil complex is the depressurization of its pressure vessels and pipelines, accompanied by the release of gas condensate or crude oil due to corrosion or crack formation. To reduce the likelihood of these risks passive or active preventive barriers are used.

Preventive barriers (i.e., corrosion allowance, external anti-corrosion coating, cathodic protection) reduce the probability of risks and the severity of their consequences. Since they (even all together) do not guarantee the GIC against depressurization, they are supplemented by parry barriers (i.e., leak detection system; emergency shutdown, accident elimination plan), which are designed to reduce the consequences of GIC depressurization [14].

The task of minimizing the CF of a specific infrastructure during its life cycle to achieve the planetary planned CF values (based on the Paris Protocol of 2015) is solved using the target function, which includes direct and indirect GHG emissions as a function of time. The CF value is managed by the Pareto optimization method based on risk-oriented monitoring and maintenance, with given values of the initial and final (considering climate change) CF permissible values. This formulation of the optimization problem allows each enterprise to implement the task of reducing CF, the likelihood and consequences of incidents, accidents and disasters.

XI. The agro-industrial complex carbon footprint

The CF of the agribusiness sector has its own specifics. When forests are cleared for agriculture (and land use changes occur), the carbon stored in the trees is released into the atmosphere as CO_2. These emissions need to be considered in life cycle assessment (LCA) studies of agricultural production. In Europe, CF and LCA information is becoming increasingly important for feed and food producers (in some countries, providing this data is already mandatory).

In addition, in recent years, soil security has emerged as a new paradigm for addressing sustainable soil management. Soil security is defined as maintaining and improving the world's soil resources so that they can continue to provide food and freshwater, make significant contributions to energy and climate sustainability, and support biodiversity conservation and the overall protection of ecosystem goods and services [15, 16].

The European Commission has identified the following seven soil functions that should be protected:

- Biomass production, including in agriculture and forestry;
- Storage, filtration and transformation of nutrients, substances and water;
- Biodiversity pool (habitats, species and genes);
- Physical and cultural environment for humans and their activities;
- Source of raw materials;
- Carbon pool;
- Archive of geological and archaeological heritage.

Food and nutrition security (FNS), like soil security, has its own parameters: availability, access, utilization, and stability.

Food security is becoming increasingly challenging over time due to changes in supply and demand caused by population growth, climate change and environmental conditions. For a nation, community or individual to be food secure, it must *always* have access to sufficient, safe and nutritious food to support an active and healthy life.

Accessibility is the physical availability of sufficient food of adequate quality. This aspect of food security is directly linked to agricultural management and the availability of land for crop production.

XII. Conclusions

- To achieve a zero-carbon balance on a planetary scale, it is necessary, using the Paris Agreement limits on country emissions, to establish maximum permissible emissions (MPEs) within each country for each industry and life activity.
- Within each economic sector, it is necessary to establish MPEs for each and every network infrastructure and system. These MPEs are limitations that must be considered when designing new and operating existing infrastructures. This introduces a limitation on the CF during diagnostics, monitoring, maintenance, recovery after an accident and disposal of infrastructures and their components. In addition, it becomes possible to estimate the CF size of each incident, accident and man-made disaster. All these values must be optimally minimized.
- Considering the Paris Protocol on reducing the carbon load and achieving carbon neutrality by all countries to reduce the temperature of the atmosphere by two degrees, risk analysis procedures carried out at the design stage of the GIC should not only assess their level of safety, but also provide an assessment of the project CF.
- At the stage of risk-oriented operation of the GIC, it is necessary to plan and implement organizational and technical measures to minimize the CF, by ensuring high reliability of the GIC according to its integrity criterion.
- The initial and boundary conditions on the infrastructure CF organically converge social and cognitive sciences with engineering mechanics, computer science and artificial intelligence, forming a MABICS-technology, under the umbrella science of infranetics.

- In connection with the above, it seems appropriate to initiate a research topic on assessing the magnitude of the emissions arising from leaks and accidents of the GIC, which do not currently fall under the Order of the Ministry of Natural Resources and Environment of the Russian Federation dated 05/27/2022 No. 371 [17].
- It is advisable to introduce mandatory certification of each GIC for its emissions. This certificate must be confirmed annually. This certificate allows monitoring emissions of all sectors of the national economy and the rate at which the country (and global) emissions approach zero emissions.
- Certification of all lands from the viewpoint of (1) the safety of their soils and vegetation, (2) biocapacity/productivity and (3) CF will allow forming of a "reference point" for assessing the population quality of life, and the quality of services and industries. Completion of the first point will allow assessing (apparently for the first time) the country's bioproductive capacity and its ultimate capacity to absorb pollution as a function of time.
- When assessing the financial availability of food, it is necessary to consider the region's life quality index (LQI); when assessing its transport accessibility the reliability of transport networks (primarily highways) has to be considered, and when assessing the availability of food in a store it is necessary to assess the reliability of the supply chain and the level of reserves over time with random demand.
- The *supply–demand problem* (analogous to the classical *load-resistance* problem of the structural reliability theory) as applied to the food security problem has its own specific characteristics: the demand for civilization products, primarily food, can be regulated by social instruments; supply (production of edible biomass) is solved by ensuring agricultural soil reliability and safety, using advanced AI-based agricultural technologies and probabilistic forecasting of crops.
- Risk managers and risk analysts must be prepared for climate change shocks (and their implications for artificial intelligence, politics, finance, energy systems, food and water supplies, and pandemics) in the next few years, not at some unspecified time in the future.
- The largest emissions in the life cycle of a GIC are generated during its construction and operation phases.
- The main way to reduce GHG emissions is by using of energy-efficient technology and process equipment (e.g., new generation gas pumping units with low-emission combustion chambers).
- The Russan oil industry should: (1) lobby for a carbon price that will help it take market share from coal faster, (2) ask the government for financial incentives to capture Arctic methane emissions, produce and sequester biochar; (3) minimize methane leakage throughout the gas supply chain; (4) identify financial incentives that will make capturing methane leakage from permafrost profitable; (5) explore ways to convert atmospheric carbon dioxide into biochar for long-term storage and (6) identify financial incentives that will make this profitable [5].
- The super task of decarbonizing the Earth's atmosphere is the creation of nature-like, low-energy technologies and low-temperature processes that imitate the efficiency of those observed in nature.

References

[1] Greenhouse gas. – URL: https://en.wikipedia.org/wiki/Greenhouse_gas (date of access: 22.07.2024).

[2] The Global Carbon Project. – URL: https://www.globalcarbonproject.org/ (date of access: 18.10.2024).

[3] The CRED presents the bill: the socio-economic cost of natural hazards. – URL:

https://blogs.egu.eu/divisions/nh/2019/03/20/the-cred-presents-the-bill-the-socio-economic-cost-of-natural-disasters/ (date of access: 28.09.2024).

[4] Carbon dioxide in the Earth's atmosphere. – URL: https/en.wikipedia.org/wiki/Carbon dioxide in Earth%27s atmosphere (date of access: 12.10.2024).

[5] Hopkins A. From climate pariah to climate savior?, Australian National University, 2016.

[6] Richard Branson. – URL: https/en.wikipedia.org/wiki/Richard Branson (date of access: 20.10.2024).

[7] Permafrost carbon cycle. – URL: https/en.wikipedia.org/wiki/Permafrost_carbon_cycle? (date of access: 06.11.2024).

[8] How close are the planet's climate tipping points? The New York Times, 11 august 2024. – URL: https://www.nytimes.com/interactive/2024/08/11/climate/earth-warming-climate-tipping-points.html (date of access: 06.09.2024).

[9] Sector by sector: where do global greenhouse gas emissions come from? – URL: https://ourworldindata.org/ghg-emissions-by-sector (date of access: 18.08.2024).

[10] Greenhouse Gas Emissions Worldwide. Report 2024. – URL: https://edgar.jrc.ec.europa.eu/report_2024?vis=ghgtot#emissions_table (date of access: 25.08.2024).

[11] Environmental Protection in Russia. 2022: statistical collection, M.: Rosstat, 2022. 115 p.

[12] Rubleva M. E., et al. (2018). Nuclear energy in the discussion about the carbon footprint: clean among the main ones, stable among the clean ones. *Problems of regional ecology*, No. 1. Pp. 73–80.

[13] Mitrova T., Melnikov Yu., Chugunov D. (2019). Hydrogen Economy – the Path to Low-Carbon Development. Energy Center of the Moscow School of Management SKOLKOVO. DOI: 10.13140/RG.2.2.15540.91524.

[14] Sivokon I.S. Risks: structure and analysis, M.–Vologda: Info-Engineering, 2024.

[15] Koch A., et al. (2013). Soil Security: Solving the Global Soil Crisis. *Global Policy*. DOI: 10.1111/1758-5899.12096.

[16] McBratney A., et al. (2014). The dimensions of soil security. *Geoderma*, Vol. 213. Pp. 203–213. DOI: 10.1016/j.geoderma.2013.08.013.

[17] Order of the Ministry of Natural Resources and Environment of the Russian Federation dated 05/27/2022 No. 371 "On approval of methods for quantitative determination of greenhouse gas emissions and greenhouse gas absorption".

CLIMATE CHALLENGES AND RISKS: INTERNATIONAL SYSTEM OF ADAPTIVE GOVERNANCE

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Abstract

Due to failures in adaptation to global climate change impacts and related risks of natural disasters the safety of human wellbeing, economic sectors, and infrastructure is challenged worldwide both in developing and developed countries. We analyze major features, trends and transformations in societal responses to adverse climate consequences and in global adaptation to escalating disaster risks attributed to climate variability. The focus is on the recently dynamic formation of international system of adaptive governance - an integral segment of global climate policy along with climate mitigation: its formation is based on cross-level coordination, interplay and interaction between its actors, and on combination of context-specific factors from different geographies. Recent shifts in international discourse on climate loss and damage which is among the key indicators in assessment of climate risks and responses are outlined; problems in its incorporation into the climate international regime under the UNFCCC and controversies in global North-South dialogue on climate responsibility, liability and compensation are explored. It is followed by analysis of the recent breakthrough in climate multilateral negotiations underway during the last three decades over the institutional architecture of climate adaptation regime and its mechanisms of international aid for climate risks reduction in the global South. Prospects for performance of the novel international financial mechanism under the UNFCCC, i.e. the multilateral Fund for climate loss and damage in most vulnerable developing countries are discussed, along with its expected contributions to sustainable development.

Keywords: climate risks, adaptation to climate impacts, adaptive governance system, international regime, Fund for loss and damage, international aid for sustainable development

I. Introduction

Today, climate change challenges are at the top of global risks agenda and active international discussion about design of possible responses to growing climate variability and its impacts on ecosystems and societies are among priorities within dynamic global discourse. According to the last *Global Risks Report* [1] during the recent years climate risks acquired stable ranking among top-5 global risks along with geo-political and socio-economic challenges to global sustainable development, to well-being of the planet and its residents. Combination of two major interlinked segments in the system of human responses to climate change, i.e. *mitigation* through limitation of greenhouse gases emissions (GHG), and *adaptation* through reduction of climate risks and societal vulnerability - are among its core attributes.

So far, certain imbalance in climate actions of the international community along these two tracks is noted. The priority is the innovative set of measures for emission reduction through global transfer to low carbon development to meet long-term targets of the 2015 Paris agreement to limit global warming by 1.5-2.0˚C by the end of the century. But, due to serious gaps in mitigation profile it might be rather difficult to achieve these ambitions[1]. As a result human society would be facing a challenge of *living with risks* of climate change. At the same time disproportionally modest attention has been paid to advances in human responses and to adaptation to climate impacts, particularly to emergency natural disasters such as floods, forest fires, heat-waves, cyclones, etc., and to slow on-set processes like sea level rise, desertification, permafrost destruction, etc. Until recently, this segment of climate policy and measures has been overlooked, and adaptation of countries, regions, economic sectors, infrastructure and communities worldwide has been proceeding too slowly, it had been underfinanced and poorly prepared. Disproportion in global climate financing is recorded: about one third of total climate finance is allocated to adaptation, while the rest is transferred to emission reduction actions [2].

The World Meteorological Organisation (WMO) warns that each consecutive year of the current decade has been warmer than the previous one, and this trend is accompanied by increase in intensity and scales of floods, heat waves, storms, droughts and wildfires. Safety of human wellbeing, economic sectors, and infrastructure are seriously challenged. Recent global loss and damage statistics alarm. In 2023 about 185 million people were affected by extreme events, while fatalities reported as 95 000 were of highest figure on record since 2010 [3]. Natural disasters culminated in US$380 billion world economic losses, and this year is considered as the 'most expensive' in the current century in terms of climate disasters mitigation costs. According to expert assessment future loss and damage mitigation costs might be rocketing.

These trends towards escalating climate risks are attributed to a combination of natural and societal factors: they are defined not only by exposure of countries and individuals to climate change impacts and related disasters depending on their geographical location, but also by unwise, or ineffective human actions. Settlements in river floodplains and flood prone marine coastal areas, violation of construction norms, failures in territorial planning often result in aggravated risks [4]. They are faced by all groups of countries worldwide independently from the level of socio-economic development; although their vulnerability might be inversely proportional to success in their sustainability advances and capacity-building for response action. Significant spatial variations from the standpoint of societal resilience, vulnerability and adaptation response are tracked globally. Climate action failure at various governance levels is also among important drivers: part of the reason - adaptation gaps to adverse climate change consequences worldwide. In some cases, 'black swans' and possible surprises from climate impacts might also be amidst a combination of factors, particularly due to high uncertainty in future scenarios of climate dynamics, its impacts on ecosystems, and results of natural and societal systems interaction.

Climate change bears cumulative consequences both for ecosystems and human systems. As a result it has societal implications, including for socio-economic development, human welfare, infrastructure and services, institutional and technological shifts. Our research suggests that a variety of climate change impacts worldwide envisage assessment of both - their negative consequences and potential development opportunities, although the former ones appear to be dominant. Among possible benefits, for example, might be a accelerating seasonal decline of the Arctic sea ice cover which possibly provides for new access to remote areas and transportation opportunities in the North. Today, the resilience of societies to climate change impacts is far from desired and vulnerability (sensitivity and deficit in response capacity) to harm from natural disasters has been growing both in countries of global South and global North. We base our discussion about climate change challenges and risks to the society on the International Panel on Climate Change (IPCC) approach according to which the risk is the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. In the context of climate change impacts, risks result from dynamic

[1]. Meeting by the end of the century the Paris agreement's goal to limit global warming by 1.5°C requires reduction of world GHG emissions by 45% by 2030 (2°C - by 30%). Assessment of 192 climate national reports of its member-states according to standard criteria of 'nationally determined contributions' indicates that by 2030 the world emissions might be 58.7% higher than their base level in 1990.

interactions between climate-related hazards with exposure and vulnerability of the affected human or ecological system to hazards.

This article focuses on analysis of human responses to climate risks and how they are addressed through adaptive governance at local, national, international levels. In this package we concentrate on major features and trends in international adaptation system which is characterized by a combination of significant innovations along with serious gaps. It is being gradually shaped and *international regime for global climate change adaptation* is currently under formation, particularly within the 1992 United Nations Framework convention on climate change (UNFCCC) with its 2015 Paris agreement and related institutions.

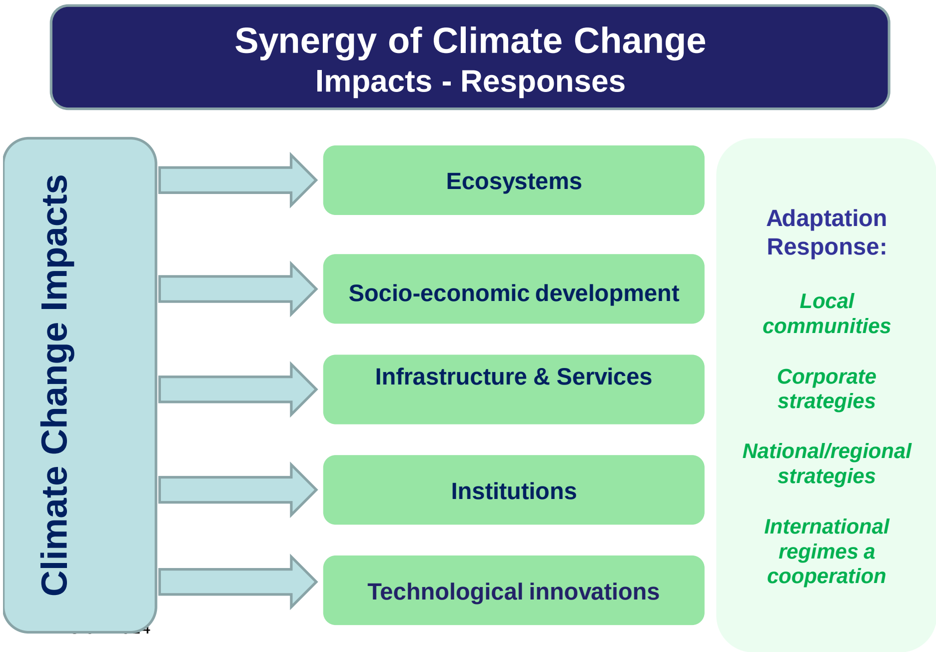

Figure 1: *Synergy of climate change impacts-responses*

II. Methods

A *mixed methods approach* was used in this study, including a combination of qualitative research methodologies and case studies [5]. Qualitative analysis drove the initial identification of major dimensions, trends, combination of drivers and general features of the current system of adaptive governance of climate change impacts [6]. Verification of its core attributes and exploration of their correlations (or deviations) with the major properties in formation of international regime on climate adaptation under the UNFCCC, including assessment of its design and features in implementation of its regulatory frameworks was undertaken. Qualitative approach was also used to help interpret and illustrate major findings. Case study analysis provided the evidence about approaches and practices in natural disaster risk reduction in a number of countries in Asia, and about trends in problem-solving in climate related risk reduction in case of floods as a result of (a) ice melt and sea level rise, and (b) regular river flooding. Application of polycentric approaches [7; 8] in analysis of adaptive governance system and its international frameworks allowed to unpack the causal linkages within the 'impact-response' governance chain, the drivers and limitations from the local contexts, interplay of actors and institutions. Its use application is s results are highly important for explanatory analysis and assessment of outcomes from cross-scale actions of actors and of instruments used for enhancing compliance both with the frameworks of international climate adaptation regime and domestic regulations. On the basis of assemblage thinking [9] we approached the quest of international coordination, integration, interplay of conflicting interests and compromises not only in climate policy decision-making but also towards meeting the 2030 sustainable development goals [10]. The list of research methods and approaches applied includes:

- Qualitative analysis
- Case-study research
- Polycentric approaches
- Assemblage approaches

This study aggregates our findings from a set of research projects in the field of sustainable development, international and regional cooperation in climate adaptation and disaster risk reduction, implementation and effectiveness of international environmental regimes. Among sources of information are data-bases of the UNFCCC, including documents and proceedings from the conference of the parties, reports of its Warsaw International Mechanism (WIM), the set of submitted eight national communications from Annex I and Non-Annex I parties and aggregated inventory data. A series of the recent international assessment reports on state-of- the-art in global and regional climate adaptation, IPCC reports, updates on climate change impacts and climate risks served as sources for analytical interpretation.

III. Results

This article contributes to research exploring the major features and trends in development of the new global system of adaptive governance dealing with human responses to climate change impacts, and particularly to extreme natural disasters which are resulting in regular annual growth of loss and damage worldwide. Its major innovation - formation of the international regime on adaptation to climate change, which is among the top challenges at the global risks agenda. Results presented for discussion are the following:

Our analysis indicates that adaptation to climate change impacts although being an equally important (along with mitigation) segment in global climate governance had not been its major priority until recently. As a result, the latest international assessments point at failures in adaptation response with safety of population, economic sectors and infrastructure being under risk worldwide, and particularly in vulnerable countries of the global South. Today, encouraging innovations in adaptation are starting to shape across different levels – international, regional, national and local, across groups of stakeholders and geographies. The system of adaptive governance emerges, and its design is rooted in synergy and coordination of responses to current and future climate risks and to development opportunities. It aims at taking into account and making flexible adjustments to the specifics of the environmental and socio-economic contexts in different geographies, combination of drivers and barriers, including possible 'black swans' effects with unforeseen consequences under high climate uncertainty, as well as causal linkages and interplay of actors and institutions involved in adaptation action.

Climate adaptation turns into a new important cluster in global architecture of interactions between the states and in international climate policy and measures. Today, this process is accompanied by (a) the transfer from concept to practice, and (b) dynamic formation of international regime on climate change adaptation with a set of principles, norms, rules and institutional procedures coordinated between its parties. It is progressing under the 1992 United Nations Framework convention on climate change (art.7) and its 2015 Paris agreement containing the adaptation regulations (art.42-65). Shifts towards implementation are enacted by its recent Framework for Global Climate Resilience in order to perform the Global Goal on Adaptation with its step-by-step strategy, concrete time-frames and instruments for adaptation action worldwide. In 2022 the breakthrough in adaptation regime was marked by the culmination in the global North-South climate negotiations which have been underway during the last three decades: the adaptation finance mechanism for international development with its multilateral Fund on Loss and Damage (FLD) to support adaptation and damage reduction in developing countries vulnerable to climate impacts was established.

We suggest that loss and damage (LD) attributed to impacts of climate change is among the core indicators in assessment of climate risks worldwide and in design of response adaptation, including the global level. So far, there is no unified definition of climate LD and expert approaches and perceptions within the ongoing international discourse are diverse, especially regarding concepts, typology, methods for cost estimate. The major controversy in the North-South climate dialogue is centered on the issue of climate responsibility, liability and compensation of LD attributed to climate change impacts for the developing countries; particularly conflicting approaches of the parties relate to interpretation of compensation of harm caused. They appeared to be a long-standing barrier in adaptation regime formation. By 2022 part of the impediments had been lifted via a compromise in North-South dialogue based on coordination of approaches on adaptation finance with establishing the mechanisms of international support for adaptation in most vulnerable developing countries. At the same time no accord had been reached on liability and compensation: Paris agreement includes general LD provisions, but it lacks jointly agreed norms on climate liability and compensation.

The newly established international climate finance mechanism with its multilateral FLD marks a special track in formation of international regime on climate adaptation, and advances in its financial mechanisms. It is to be seen how effective its performance would be after its mechanisms are enacted. But, it signals about creation of a niche for institutionalizing and channeling the international support for adaptation in the global South, which had been significantly underfinanced being about 10-18 times lower than the needs of the most vulnerable countries. It is supposed also to be an integral part in already quite diversified international system of climate finance with its specific focus on climate adaptation and international development cooperation through funding, technological support and domestic capacity building in developing countries vulnerable to adverse climate impacts. We conclude that international development funding should be always packaged with transfer of technology, competences and best practices, because as a single, although quite appealing instrument, it is not able to solve the complexity of international development problems and adaptation capacity building in recipients.

The role of this new adaptation finance mechanism and its FLD within the current constellation of international climate development agencies is supposed to be defined by its ambition to refine international adaptation funding channels and promote easier access to resources for its recipients, through involving innovative schemes for preferential funding, climate risk financial management, operational access to allocated funds in case of disaster emergencies. Among its functions – institutional coordination at the global level between international agencies involved in actions for climate LD reduction. The recent estimate of FLD total funding pledges from potential donors is quite modest so far in contrast, for example, to the Green Climate Fund with its record of mobilized funding ($ 12.8 billion). Fragmentation and insufficient coordination between climate development agencies could be considered as a significant flaw in their multilateral climate action. Despite the targeted annual international climate finance is planned to be increased up to US$ 100 billion level starting from 2025, the existing global profile indicates that there might be some concerns about its feasibility in practice. On the other hand, the existing assemblage and growing interplay of climate funds at various levels indicate at emerging global trend towards tighter partnerships between global agencies and organizations contributing to various aspects of climate adaptation and disaster risk reduction, including WMO, UNEP, UN Disaster Risk Reduction (UNDRR) and The Global Facility for Disaster Reduction and Recovery (GFDRR): the results of their combined efforts might be important in such priority areas as enhancing climate resilience, global systems of operational forecasting, Big Data, climate services and exchange of adaptation knowledge. Contribution of such partnership for meeting the 2030 global sustainable development goals might be among its effective outcomes.

IV. Discussion

I. Adaptive governance system

Adaptation is the process of adjustments of the society to actual or expected climate and its effects in order to either lessen or avoid harm, or exploit opportunities for sustainable development [11]. Ensuring safety of the population, critical infrastructure and economic sectors is the top priority of the emerging global *adaptive governance* system and its actors. Since recently adaptation instruments and measures are becoming diverse worldwide, but still adaptation is proceeding too slowly and adaptation practices are highly fragmented to effectively address risks and ensure human safety.

Our approach suggests that to be of a success the system of adaptive governance should be further refined. It is to be rooted in integration of climate adaptation policy and measures performed at international, national and local levels, while adaptation strategies, mechanisms, tools, monitoring and verification procedures over implementation be coordinated across geographies, levels and with stakeholders. Innovations in this package involve transformations in institutions, legal and socio-economic instruments, technologies, financing and changes in population behavior to reduce vulnerability to climate risks. Effective adaptation strongly relies on taking into account the specifics of the domestic environmental and socio-economic factors. Selection of adaptation options is a tricky task, as it requires multidisciplinary approaches and stronger links between natural and social sciences. Institutions should be flexible and maneuvering [12] under high climate uncertainty deriving from scenarios of global warming and variety of risks and surprises to society, depending on ecosystem change and socio-economic and geopolitical dynamics; climate institutions might be vulnerable to 'black swans', i.e. unpredictable events with unforeseen consequences. The overall quest relates to design of response and adaptation actions for implementation of global climate change regime.

Recent trends indicate at certain advances in global development of both domestic and international adaptation practices. Today the adaptation is launched by many countries and communities. About 84% of the parties to the UNFCCC elaborated their adaptation policy and measures; the number of such countries is constantly growing – by about 5% annually. Their adaptation policies are quite diverse, and include plans and strategies, domestic legislation, national- regional policy and measures, institutions, socio-economic and financial instruments, engineering tools and structural measures (dams, levies, construction requirements, territorial planning, relocation of settlements and business from areas under disaster risk, etc.). In some countries economic instruments applied suggest credits and subsidies for house construction reinforced against floods, incentives for adaptation of local production, support of small business and indigenous communities, insurance services, etc.

A number of serious gaps in adaptation is indicated worldwide, both in developed and developing countries. Among them, is inadequate funding for measures against risks of extreme events, particularly in developing countries. Today, international allocation of funds to climate adaptation in developing countries is about 10-18 times lower than their actual needs, and this divide is constantly growing. International public finance flows to developing countries in 2021 accounted for US$21 billion [2]. According to recent international estimates annual costs of adaptation in developing countries could increase up to US$ 215-387 billion per year during the decade 2021-2030 and up to $315-565 billion by 2050[13]. At the same time experts note that high level of funding cannot compensate for adaptation shortages. To be of success the system of adaptive governance needs to be wisely designed as many failures in response to climate risks are associated with mistakes in selecting governance options. For example, in North-South international aid to adaptation, the finance is among its key elements, but at the same time in many cases, the technology transfers and domestic capacity building is underestimated. Fragmentation of current domestic and international practices is among flaws of adaptation, while exchange of good practices is insufficient. The list of gaps in adaptation governance also include: 1) deficit in coordination between institutes, sectors and stakeholders; 2) problems with integration of adaptation mechanisms into territorial planning; 3) insufficient participation of local population in risk reduction and involvement of different stakeholders; 4) corruption related to resources transfer from the center to locales; 5) focus on short term projects versus sustainability within a long perspective, etc. Most of them refer to both developing and developed countries.

Adaptation to impacts of global climate change is becoming an important new area of climate international law and policy. Today, the *international regime on climate adaptation* is under formation within the 1992 UNFCCC and its 2015 Paris Agreement. The Paris Agreement establishes the long-term global goal to carry out measures and policies to "enhance adaptive capacity and resilience and reduce vulnerability, with a view to contributing to sustainable development" (Art. 7, c. 1). It describes adaptation as a global challenge "faced by all within local, subnational, national, regional and international dimensions, and a key component to the long-term global response to climate change to protect people, livelihoods and ecosystems". Adaptation measures take into consideration the individual characteristics of countries and regions, "vulnerable groups, communities and ecosystems, and should be based on and guided by the best available science and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems" (Art. 7, c. 1, 2, 5).

Common international standards, norms and regulatory procedures had been introduced. For example, country-parties contribute to the implementation of their commitments under the global climate regime by regularly submitting to the UNFCCC secretariat their national communications according to the standard format of reporting on adaptation work undertaken and for follow-on verification. Adaptation section in national reports contains the following data: (1) assessment of risks and consequences of climate change for territories, industries, and populations; (2) policies; (3) strategies and programs; (4) measures, mechanisms, and instruments; (5) climate services for end-users; (6) research results; (7) implementation of plans, and related gaps; (8) international cooperation; (9) assistance to developing countries. For disaster prone regions the regulatory norms of the Paris agreement relating to climate risk reduction, damage prevention and exchange of competences are particularly relevant, including international provisions for early warning systems, emergency preparedness, rescue and evacuation, rehabilitation of affected territories, risk assessment and management.

The novel trend is in shifts from earlier declarative to concrete step-by-step approach in implementation of international adaptation regime. It is applied for the entire adaptation cycle – from (a) assessment of the core climate impacts and vulnerabilities of countries, to (b) domestic planning, (c) voluntary adaptation action, (d) monitoring and assessment of results, (e) exchange of good practices, including technology-engineering solutions, funding, capacity-building. In 2023, the *UAE Framework for Global Climate Resilience* was adopted at COP-28 (UEA, Sharm-el-Sheikh) [2]. For the first time, this program builds the multilateral adaptation system for realization of the Paris agreement *Global Goal on Adaptation* in order to jointly contribute to safety of world population, economic sectors, infrastructure, and ecosystems facing current and future adverse consequences of climate variability. The innovation is in clear norms for structuring the governing institutions, adaptation strategies, instruments and verification tools, enhancing transparency and compatibility of multiple domestic practices. Refining the system of international indicators and adaptation metrics to measure the progress in reaching global adaptation goals and to verify reporting of the parties is among its tasks. New adaptation funding mechanisms and instruments are to be developed in order to increase financial flows, and to provide direct and easier access to them by developing countries, including wider use of preferential finance and grants.

Importantly, particular time frames are set for this process. For example, by 2025 it is planned to finalize development of national adaptation plans, policies and measures with their

[2] UN FCCC. Decision -/CMA.5 Glasgow–Sharm-el-Sheikh work programme on the global goal on adaptation referred to in decision 7/CMA.3 https://unfccc.int/documents/636595

disaggregation across sectors, regions and communities; by 2027 - to enact international and national system of monitoring, assessment of climate risks and inventory of states/regions vulnerability to risks. Among major problems today is that about one third of the world territory is within the risk-prone zone because it has no access to systems of early warnings on disaster emergency, to climate information and services. It is planned to combine a network of multilateral, regional, national systems (with universal coverage by disaster early warnings, regular risk monitoring and assessment, climate services, Big Datat). It is suggested that their development by 2030 would serve as a basis for the UNFCCC plans to undertake the global assessment of implementation results of national adaptation plans with global inventory of domestic practices, and a follow-on refinements of the adaptive governance system.

II. Loss and Damage

Loss and damage (LD) attributed to impacts of climate change is among the core attributes in assessment of climate risks and possible adaptation measures. So far, there is no unified definition of LD. Current discourse on the issue centers either (a) on evaluation of harm (economic and non-economic [3]) from observed and expected climate change negative consequences and risks, or (b) on critical assessment of international North-South debate on legal procedures for its mitigation under the UNFCCC. Usually LD is understood as adverse effects of climate change that are not avoided through climate adaptation, or mitigation efforts. Loss is linked with irreversible harm, for instance through complete destruction in functioning of assets, infrastructure, sectors (for example, as a result of flooding from sea level rise in small island states). Damage refers to negative effects and costs associated with climate change impacts that could be quantified, and often could be dealt with involving repair and restoration, or compensation.

Still, there is a great deal of uncertainties and diversity in approaches regarding concepts, typology, methods for costs assessment, and structure of measures to deal with the problem; altogether, it sets barriers for dealing with climate LD. Existing estimates of LD and high current and future costs to address them vary significantly. For example, it is suggested that LD costs in vulnerable developing countries might account for $ 400 billion in 2030 and raise up to $ 1-2 trillion by 2050 [14]. Most countries worldwide are under risk of climate disasters, and LD costs vary across countries and regions depending on their vulnerability and exposure to different extreme weather and emergencies. Developing countries face higher risks due to their comparatively lower domestic capacity to mitigate disasters.

International regime formation to address climate LD [15] highlights three important features and new trends. *First*, the process of its dynamic North-South international dialogue over the last three decades resulted in the progress towards multilateral coordination of various approaches and stakes of its parties. It culminated in 2022 in historical decision to establish international financial mechanism for reduction of LD and related risks in most vulnerable developing countries. *Second*, its formation is marked by particular stages in designing its institutions and regulatory norms; it clearly demonstrates transition from perceptions to actions in coordination of joint efforts. *Third*, being rooted mostly within the UNFCCC climate regime, its main vector directs towards designing the global architecture for climate adaptation and addressing LD issues through tighter synergy between currently fragmented efforts of various international agencies at different levels.

The core of the LD multilateral problem has been rooted within the global South- North dialogue, and particularly, in interpretation of *compensation* and *liability* for climate LD. Climate aid to most vulnerable countries and financial compensation schemes for damage caused by historical GHG emissions from developed countries had been the red thread in long multilateral

[3] Economic LD is calculated on the basis of monetary value of damage to economic sectors, infrastructure, individual assets; non-economic LD is more difficult to evaluate as it is associated with non-monetary values like loss of life, health, territory, cultural heritage, biodiversity

debates. Climate justice, 'moral responsibility' and possible climate reparations for damage had been also a part of regular international narrative. Due to complexity of the problem with a great deal of conceptual uncertainties and controversies in North-South approaches to problem-solving, it took over three decades of active debates to reach the compromise through a joint agreement to institutionalize the LD issue.

Indeed, there is a diversity of parties' perceptions regarding options and tools for compensation of climate change damage for developing states. Enacting mechanisms for LD compensation had been the goal of the vulnerable least developed countries, while developed countries had been its opponents. As a result financial support and compensation were in foci of international discussion. Until recently within the climate diplomacy industrialized countries usually managed to block attempts of developing countries to negotiate financial aid for implementation of their domestic adaptation plans. The result has been in 'underfinancing' of global adaptation actions according to the last assessment of UNEP. Among the reasons had been also the existing gap in international legal framework for financing adaptation, as well as in the international legal norms for LD obligations and responsibilities of the countries. Despite recent progress in institutionalizing the funding arrangements, at the last moment of negotiations the developed countries succeeded in reaching a compromise by focusing the international finding discourse on 'cooperation and facilitation' rather than 'liability and compensation'.

A number of stages in International regime formation related to LD regulation and norms could be tracked. In fact, the LD issue entered the international policy agenda under the UNFCCC just from the start of climate negotiations in 1991, when the problem was initially raised by the *Alliance of Small Island States* (AOSIS) by proposing the creation of an international pool to compensate for LD from the sea level rise to the most vulnerable small islands and low-lying coastal developing states. Particularly dynamic this process became during the last decade. After a long period of general discourse on conceptual approaches to liability and compensation the LD reentered negotiations, and with the 2010 Cancun work-programme on LD concrete steps towards its institutional design were taken. In 2013 the *Warsaw International Mechanism* (WIM) for LD was enacted to serve as the lead international structure to coordinate international action towards LD risk management, to enhance knowledge from science and practice in order to develop mechanisms for support and capacity building in the most vulnerable states; it was focused on research, dialogue and knowledge exchange, rather than liability and compensation. In 2015, the important milestone has been the incorporation into the Paris agreement of special provisions to regulate international efforts to 'avert, minimize and address LD' (art.8). In 2019 the *Santiago Network for Loss and Damage* (SNLD) was mandated to focus particularly on procedures and technical aspects of international climate aid to developing countries and to define effective instruments for facilitating access to finance, information, best practices, technologies and capacity building.

Finally, the recent mutual compromise in negotiations suggests that the Paris agreement envisions the continuation of WIM, but explicitly outlines that involvement of the latter does not provide for any liability, or compensation. The inclusion of this clause was a condition on which developed countries, and particularly the USA, agreed to include a reference to LD into the international accord. As a result, a novel architecture for North-South cooperation within international system of climate adaptive governance is developing. Creation in 2022 of the new financial mechanism for support of adaptation in developing countries with its multilateral Fund on LD is important landmark in this process.

III. Multilateral Fund on Loss and Damage

Launch of international financial mechanism with its special multilateral *Fund for Loss and Damage, FLD* at COP 27 (Sharm-el-Sheikh, UAE) in 2022 is regarded as a breakthrough. It is based on joint multilateral agreement on funding to least developed and most vulnerable states to adverse climate change. Today the operationalisation of FDL is at the agenda, and the key issues include: 1) governance design; 2) recipients of finance; 3) donors and sources of funding; 4) principles and instruments for actual LD assessment; 5) fund's role in the system of international climate finance. Answers to these basic questions require further detailing and coordination between the parties involved in the regular UNFCCC process.

Governance and *operationalization* are the basic issues in the FLD performance. Currently, the decision–making is underway regarding its goals, activity, legal status, governance and institutional procedures, its structure, membership, funding sources, selection of recipients, norms for access to finance, financial instruments, monitoring, reporting and verification procedures, interaction with other international climate finance mechanisms. It is supposed to serve as an operational LD finance mechanism under the UNFCCC. At initial stage the World Bank is supposed to provide the administrative support, consulting and maintenance of its secretariat.

FLD Governing Board is the major organ for consensus decision-making and strategic planning. It consists of 26 members, including 12 from developed countries, 14 from developing states and regional groups, including 3 from each - Asia-Pacific, Africa, Latin America and Caribbean region; 2 each from developing small islands states, and from least developed countries; 1 from developing state - nonmember of the regional groups. The Board has 2 co-chairs – from developed and developing countries. The Secretariat serves as its working body and it is headed by the executive director of the Fund; regional departments are part of its structure.

Recipients eligible for funding are selected basing on the key goal of the fund – support for least developed countries vulnerable to extreme natural disasters and slow on-set processes. Funds are to be transferred to actions in LD reduction and for capacity building to prevent both economic and non-economic damage. They cover rehabilitation of affected areas and support to local population, to reconstruction and restoration of economic assets and infrastructure. International aid is provided to develop national adaptation plans and programs on LD reduction, or to assess the financial needs of the recipients to perform protection measures and develop national finance systems for LD compensation. Perspective direction of action eligible for funding - production of climate data and operational dissemination of climate services to end-users, support for relocation and mobility of people seriously affected by disasters.

Among its main finance instruments destined to the global South are grants and preferential loans. Application of additional financial products are currently discussed, such as guarantees, direct budget funding, politically motivated finance, shares, insurance, risk-sharing, performance-based programs. They are regarded as supplementary to national resources directed to LD reduction measures. Specifics in the national context is taken into account in decision-making on selecting the recipients and instruments applied: climate vulnerability indicators in combination with socio-economic and sustainability parameters are assessed in detail. FDL is developing specific norms for funds distribution, including assessment of potential recipient priorities based on risk indicators, LD indices, national capacity in adaptation, general level of international funding, estimate of costs for post-crisis rehabilitation and reconstruction, etc.

FLD puts is its special accent on procedures and instruments to ensure direct and simplified access of an applicant from a developing country to funding, and to lift administrative barriers for international finance. Funding support in emergency situations should reach its consumers before it's too late. It could be provided through national and regional branches, and on the basis of applications for comparatively small grants for local recipients. Proposed operational allocation of funds through rapid track and simplified procedures for evaluation of applications in case of emergencies is an innovation. It is combined with transparency principles for resource allocations, reporting and verification, avoiding excessive bureaucratic barriers in access to finance. Special institutional procedures are designed to ensure easier access to finance and implementation of aid-programs. National organ responsible for management and realization of actions supported by the Fund could be established in a recipient country. There is a choice of available options: (a) direct access via budget funding of national government, or partner organizations; (b) direct access via sub-national, national or regional organizations, or via partnerships with organs accredited with other international funds, for example, such as the Adaptation Fund, the Global Environmental

Facility (GEF), the Green Climate Fund; (c) international access through multilateral or bilateral agencies; (d) small grants for support of local adaptation projects, of indigenous communities, most vulnerable groups and settlements, including their rehabilitation after natural disaster

Sources of funding are among crucial issues. Resources of FLD are to be formed from a variety of sources, including donor states with their grants and preferential financing from governmental and private funders, as well as NGOs and different funds. Multilateral LD funding would be mobilized in addition to already functioning multilateral mechanisms of climate finance and international aid to sustainable development. Currently there is a variety of estimates of possibly mobilized adaptation funding. According to UNFCCC estimates by the end of 2023 at the start of FDL launch, several donor states announced their pledges on annual climate finance totaling to about $700 million (including, by the EU – €225 million, Italy – $200 million, Germany – $100 million, UAE – $100 million, with smaller funding from UK, USA, Japan). The effect of such financial mechanism for climate adaptation in developing countries would be tested in practice with the start of FDL performance. Among main concerns is how fast and effectively the operalization of its procedures and coordination of donors-recipients approaches would be undertaken. However, initial estimates indicate that expected funding might be quite modest versus possible annual costs of climate disasters mitigation in developing countries in mid-term perspective. The important question about methods and norms for assessment of actual LD in each recipient county-case, including economic and non-economic damage still remains open.

References

[1] WEF. The Global Risks Report 2024, 19th Edition, WEF, 2024.

[2] UNEP. Adaptation Gap Report 2023: Underfinanced. Underprepared, UNEP, 2023.

[3] CRED 2023. Disasters in Numbers, Brussels, CRED, 2023

[4] Kelman I. Disaster by Choice: How Our Actions Turn Natural Hazards into Catastrophe, Oxford University Press, 2020.

[5] Dixon-Woods, M. et al. (2006). How can systematic reviews incorporate qualitative research? A critical perspective. // *Qualitative research*, 6:27-44.

[6] Pahl-Wostl, C. et al. (2012). From applying panaceas to mastering complexity: Toward adaptive water governance in river basins. // *Environmental Science & Policy*, 23 (2012):24-34.

[7] Ostrom, E. (2010). Polycentric Systems for Coping with Collective Action and Global Environmental Change. // *Global Environmental Change*, 20:550–57.

[8] Carlisie K., Gruby R. (2017). Polycentric Systems of Governance: A Theoretical Model for the Commons. // *Policy Studies Journal*, 08.08.2017 https://doi.org/10.1111/psj.12212

[9] Baker, T. and McGuirk, P. (2017). Assemblage Thinking as Methodology: Commitments and Practices for Critical Policy Research. // *Territory, Politics, Governance,* 5 (4): pp.425–42.

[10] Fomenko G. A. Sustainable ecosystem design: prerequisites and approaches. ANO NIPI Cadaster, 2021.

[11] IPCC. Climate Change 2014: Syntehsis Report. IPCC, Geneva, Switzerland, 2014.

[12] Young O. R. Governing Complex Systems: Social Capital for the Anthropocene, The MIT Press Cambridge, 2017.

[13] UNEP. Adaptation Gap Report 2022: Too Little. Too Slow, UNEP, 2022.

[14] Baarsch F., Lissner, T., et al. Impacts of Low Aggregate INDCs Ambition: Research Commissioned by Oxfam. Climate Analytics, 2015.

[15] Nikitina, E. N., Pozhilova, N. A. (2023). International Mechanisms to Compensate for Loss and Damage: Innovations. // *World Economy & International Relations,* 67 (10): pp.62-70.

TOWARD RISK FORMALISM. THE SCORE MATCHING METHOD IN A GROUP CHOICE PROBLEM

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Abstract

The task of coordinating expert assessments inevitably arises in the expert construction of integral indicators of objective judging in sports, analysis of the state and risks of functioning of social, economic, environmental, transportation systems and for many other subject areas of human activity. A decision-maker, as a rule, sets a criterion by which an object is evaluated, and an expert defines a set of comparable objects according to this criterion and evaluates each object, ranking them in descending (ascending) order of one or another quality. It is assumed that the expert has his own opinion that does not diverge from the generally accepted one and is not built only on the basis of measurable data. This opinion is based on his/her personal experience and knowledge gained in the process of work. As a result, there is often a situation when the transitivity of expert evaluations is violated. The proposed procedures for finding an integral indicator can be used in the tasks of decision-making, harmonization of expert assessments of the state of objects, construction of environmental and social indicators, as well as quality indicators, such as the integral indicator of the quality of life, the index of the quality of the transport system, the index of human development, etc. The methods of matrix theory are applied. The methods of matrix theory, graph theory and combinatorics are applied. The presented algorithm differs from existing methods in that it measures the contribution of the total error of experts to the collective measure of their consistency. The method under discussion offers a solution for decision makers in the so-called group selection problem (which means the task of analyzing and aggregating heterogeneous information about the preferences of compared objects into a single "group" preference) of critical objects that require increased attention of the security service and expenditure of resources of the state and the owner of the system to ensure their safety, security and sustainability of operation.

Keywords: expert evaluations, consistency, integral evaluation, group choice problem, permutations

I. Introduction

The method of recovering a consistent solution in expert ranking of objects involves the use of various techniques and approaches. One approach is to extend the use of Kendall's concordance coefficient (W) to incomplete rankings, allowing for the inclusion of objects that are not easily compared with others [1]. Another approach is to reconstruct expert preference functions using available data and expert judgment, which can be achieved using machine learning and matching techniques [2]. Decision analysis techniques can also be used to systematically analyze complex problems and improve the objectivity of remediation decisions by quantifying expert opinions and prioritizing remediation activities based on several criteria [3]. In addition, the rank analysis method can be applied to calculate the ranking of managed objects by replacing ordinal rankings with effective rankings that take into account the degree of difference in the estimated values [4]. Finally, decision making using fuzzy and fuzzy preference relations can be improved by introducing the concepts of additive consistency and group consensus analysis [5].

The following method is designed to find the most consistent solution in the task of ranking objects by means of expert evaluations. Such tasks are not uncommon in various fields of activity, where it is necessary to analyze several available alternatives and decide on their relative importance. As a rule, each of the experts involved in the evaluation has its own evaluation scales (most often irregular, since the experts have different experience and knowledge). Linking disparate opinions into one is an extremely important task for the decision maker (LPR).

The main obstacle to combining different opinions into one is the need for consistent assessments. The requirement for consistency in expert judgment is that the experts involved in the evaluation process make consistent and coherent assessments of the issue or subject under study. This means that experts must adhere to the same evaluation criteria and methods to avoid contradictory or inconsistent results.

Consistency of expert assessments is important to ensure the objectivity and reliability of the assessment results. Inconsistent assessments can lead to distorted conclusions and incorrect decisions based on these assessments. This fact clearly reflects the so-called Condorcet paradox.

The Condorcet paradox is a situation in which uncertainty or contradiction in preference determination arises in group preference selection using a voting method. This paradox was discovered by the French mathematician and philosopher Marquis de Condorcet in the 18th century.

The essence of the paradox is that it is possible that, given three or more alternatives to choose from, there is no voting method that satisfies all the basic principles of democracy at the same time:

- transitivity (if A is preferable to B and B is preferable to C, then A is preferable to C),
- independence from alternatives (a change in preferences for alternatives should not affect the voting result),
- absence of a dictator (the decision is made collectively, not by one person).

Condorcet's paradox emphasizes the complexity of group choice and shows that even the most democratic voting methods can lead to imperfect or inconsistent results in certain situations.

Condorcet's paradox of preference conflict in social choice has been studied by scholars and scientists for more than 200 years [6]. Various mechanisms have been proposed to resolve this paradox, including the use of rules in coordination games [7]. To understand the solution to Condorcet's paradox, strategic models of majority bargaining have also been analyzed [8]. It was found that in these models, there exists a stationary perfect equilibrium in the subgame that ensures agreement within a finite expected time [9]. In addition, mixed and consistent perfect equilibria in subgames have been found in the simplest Condorcet cycle, leading to immediate agreement in some scenarios [10]. These studies provide insights to resolve the Condorcet paradox and shed light on the factors affecting collective decision making.

Various methods such as consistency analysis method, Delphi method, expert judgment aggregation method and others can be used to ensure consistency of expert judgments. These methods help to identify discrepancies between expert assessments and make adjustments to achieve consistency.

There are many methods for assessing the consistency of expert judgment. The most common ones are:

1. Kendall's W coefficient of concordance: This method is used to measure the degree of consistency between multiple experts when evaluating the same item. It takes into account not only the consistency between pairs of experts, but also the average consistency between all experts.
2. Pearson's correlation coefficient (Pearson's r): This method is used to measure the degree of linear relationship between the scores of different experts. The closer the correlation coefficient is to 1, the higher the level of consistency.
3. Fleiss' Kappa consistency index (Fleiss' Kappa): This method is used to assess the degree of consistency between multiple experts when classifying objects into categories. It takes into account the random agreement between experts.
4. Consistency Ratio (C.R. - Consistency Ratio) in Thomas Saaty's method of hierarchy

analysis. This indicator allows assessing the degree of consistency between pairs of compared alternatives and identifying possible errors or contradictions in the experts' assessments.

The choice of method depends on the problem to be solved. The methods allow identifying inconsistencies in the estimates, but they do not offer to correct these inconsistencies by asking experts to refine their estimates repeatedly. Sometimes such a process is looped and the LPR is forced to make a decision at his/her own risk.

In 1951, C. Arrow formulated [11] the theorem "On the Impossibility of Collective Choice within the Ordinalist Method", mathematically generalizing Condorcet's paradox [12]. The theorem states that within the framework of this approach there is no method of combining individual preferences for three or more alternatives that would satisfy some quite fair conditions (axioms of choice) and would always give a logically consistent result.

II. Problem statement

The proposed method not only states the existing inconsistency in the experts' assessments, but also allows obtaining an optimal solution for the available assessments and the alternatives under consideration, "restoring" their correct ordering. The original author's algorithm for processing expert preferences in a collective choice problem based on the concept of the total "error" of experts and measuring their contribution to the collective measure of their consistency is presented in [13]. The authors called it the Pit Finding Method (PF-Method).

Let us recall the problem formulation from [13].

Considered N comparison objects $0_1, \dots, 0_n, \dots, 0_N$ whose indices are the first N members of the natural series $\langle 1, \dots, n, \dots, N \rangle$ - correspond to the order of submission of objects for examination (initial order). The examination of objects involves M equal experts $\mathrm{E}_1, \dots, \mathrm{E}_m, \dots, \mathrm{E}_M$. Each of the experts E_m has its own idea about the order of objects placement $g_m = \langle g_{m,1}, \dots, g_{m,n}, \dots, g_{m,N} \rangle$. The indices of which increase as some quality of objects decreases from the point of view of this expert. That is, the value $g_{m,1}$ corresponds to the index of the object O_{k_1}participating in the examination with the maximum evaluated quality in the expert's opinion E_m, a $g_{m,N}$ - the worst object with the assessed quality with the index of 0_{k_N}:

$$g_{m,n} = \begin{pmatrix} g_{1,1} & \cdots & g_{1,N} \\ \cdots & \ddots & \cdots \\ g_{M,1} & \cdots & g_{M,N} \end{pmatrix}.$$

Thus g_m - is a permutation of object ratings whose argument is the initial order: $g_m = \begin{pmatrix} 1 & \dots & n & \dots & N \\ g_{m,1} & \cdots & g_{m,n} & \cdots & g_{m,N} \end{pmatrix}$. Places $p_m = \langle p_{m,1}, \dots, p_{m,k}, \dots, p_{m,N} \rangle$ by values inverse to permutations of object ratings $g_m (p_m = g_m^{-1})$ are permutations of object indices with argument $E_{\text{ПИО}}$:

$$p_{m,n} = \begin{pmatrix} p_{1,1} = g_{1,1}^{-1} & \cdots & p_{1,N} = g_{1,N}^{-1} \\ \cdots & \ddots & \cdots \\ p_{M,1} = g_{M,N}^{-1} & \cdots & p_{M,N} = g_{M,N}^{-1} \end{pmatrix}.$$

It is necessary to find the compression of all private ratings of permutations of object ratings $g_m (m = 1, \dots, M)$ in the form of permutation of object ratings $g_m^* = \langle g_1^*, \dots, g_N^* \rangle$which would minimize the total inconsistency of expert evaluations $g_{m,n} \to g_m^*$ (on the basis of equality of all participants of the expertise), measured in inversions of transitions from $g_{m,n}$ к g_m^*i.e.

$$K^* = \min K(g) = \min_{g_m} \left(\sum_{m=1}^{M} K_m(\langle g_1, \dots, g_N \rangle) \right),$$

where $K_m(\langle g_1, \dots, g_N \rangle)$ - is the sum of inversions in the estimations $m$of -th expert, K^*- is the marginal measure of disagreement between the experts' opinions.

III. Algorithm description

Finding an optimum in permutations of object ratings is equivalent to finding a permutation of an object index p^*: $p^* = \langle p_1^*, \dots, p_N^* \rangle$, since $K(g_m^*) = K(p_m^*)$where p^*=$(g^*)^{-1}$ (the lengths of the back paths ($E \rightarrow g$) coincide with the forward paths ($p = g^{-1} \rightarrow E$) at any g) (Table 1).

Table 1: *Solution search table $P(g)$ with inversion table $B(g,P)$*

	Arg E	1	...	n	...	N	*Arg E*	1	...	k	...	N	Criterion inconsistencies
	Func g	g_1	...	g_n	...	g_N	Func p	g_1^{-1}	...	g_k^{-1}	...	g_N^{-1}	
	Arg E	1	...	k	...	N	*Arg E*	1	...	k	...	N	
1	$p_1(g)$	p_{1,g_1}	...	p_{1,g_k}	...	p_{1,g_N}	$B_1(p_1(g))$	$B_{1,1}$	...	$B_{1,k}$	...	$B_{1,N}$	$K_1(g) = \sum_{k=1}^{N} B_{1,k}$
...	...	...	...	...	...	...		...	...	...	...	...	...
m	$p_m(g)$	p_{m,g_1}	...	p_{m,g_k}	...	p_{m,g_N}	$B_m(p_m(g))$	$B_{1,1}$	...	$B_{m,k}$	...	$B_{m,N}$	$K_m(g) = \sum_{k=1}^{N} B_{m,k}$
...	...	...	...	...	...	...		...	...	...	...	...	...
M	$p_M(g)$	p_{M,g_1}	...	p_{M,g_k}	...	p_{M,g_N}	$B_M(p_M(g))$	$B_{M,1}$	...	$B_{M,k}$	...	$B_{M,N}$	$K_M(g) = \sum_{k=1}^{N} B_{M,k}$
													$K(g) = \sum_{m=1}^{M} K_m(g)$

After the experts have expressed their opinions, we assume that the order of submitting objects for examination corresponds to their correct ranking. Then, when pairwise comparisons of all experts' evaluations are made, the evaluations for the i-th object should be "better" from the point of view of its quality than the assessments of the -th object. $i + 1$of the -th object. If this assumption is violated, a "penalty" is fixed for this compared pair and the total "experts' error" is increased by one. If the total "experts' error" turns out to be higher than some specified value (e.g., $\frac{N}{2}$), a contradiction arises, reflecting the inconsistency of experts' opinions when comparing this pair. Obviously, the lower is the set value of the total "error", the more stringent are the requirements to the consistency of experts' opinions.

For N for the objects, it is necessary to perform $N \cdot (N-1)$ pairwise comparisons. As a result of all comparisons, we obtain a square matrix of dimensionality $N \times N$in which the main diagonal consists of zeros (object's evaluations are compared in pairs with its own evaluations), and the matrix elements represent the corresponding total errors of experts, obtained as a result of the above described pairwise comparisons.

Then we rearrange the columns and rows of the obtained matrix in pairs, trying to move the maximum number of matrix elements, whose values are greater than the specified value of the total error, below the main diagonal. At such permutations the order of columns of the initial error matrix will change. The final order of columns will reflect the maximally consistent decision on the ranking of the compared objects. If such a solution is not the only one, it is necessary to calculate the value of the inconsistency criterion for all obtained solutions $K(g)$taking the obtained solution as the initial order of objects. The solution that has received the minimum value $K(g)$will be the final one.

Let us illustrate the work of the method on numerical examples.

IV. Case of study

Let seven experts $\mathrm{E}_m (m = 1,2,\ldots,7)$ compare 4 alternatives on some basis $\mathrm{O}_n (n = 1,\ldots,4)$. Let also let the initial order of the alternatives being compared be given by the mapping $\langle 1\ 2\ 3\ 4 \rangle \leftrightarrow \langle \mathrm{O}_1\ \mathrm{O}_2\ \mathrm{O}_3\ \mathrm{O}_4 \rangle$.

For a given set of evaluations of the alternatives being compared $\langle 1\ 2\ 3\ 4 \rangle$ it is necessary to find such a group $\langle k_1 \ldots k_4 \rangle$for which there is no possibility to improve the optimality criterion $K(g^*)$. The total number of consecutive inversions of each expert's evaluations is taken as the optimality criterion $K_m(g^*)$, restoring the current working order to the original one. In other words, it is necessary to find such a group for which $K(g^*) \rightarrow K_{\min}$.

	1	2	3	4
	O_1	O_2	O_3	O_4
E_1	1	4	2	3
E_2	2	3	1	4
E_3	3	2	1	4
E_4	4	2	3	1
E_5	1	4	3	2
E_6	2	4	1	3
E_7	2	1	4	3

	1	2	3	4	Inversions				$K_m(g^*)$
	O_1	O_2	O_3	O_4	1→1	2→2	3→3	4→4	
E_1	1	4	2	3	0	1	1	0	2
E_2	2	3	1	4	2	0	0	0	2
E_3	3	2	1	4	2	1	0	0	3
E_4	4	2	3	1	3	1	1	0	5
E_5	1	4	3	2	0	2	1	0	3
E_6	2	4	1	3	2	0	1	0	3
E_7	2	1	4	3	1	0	1	0	2
								Optimality criterion $K(g^*)$:	20

Fig. 1 shows all pairwise comparisons of object evaluations and the scheme of forming the matrix of "errors". Bringing the matrix of pairwise comparisons of evaluations assigned to alternatives by experts to the form in which the upper triangular matrix contains no contradictions, we obtain the desired solution ⟨3 1 4 2⟩ (Fig. 2).

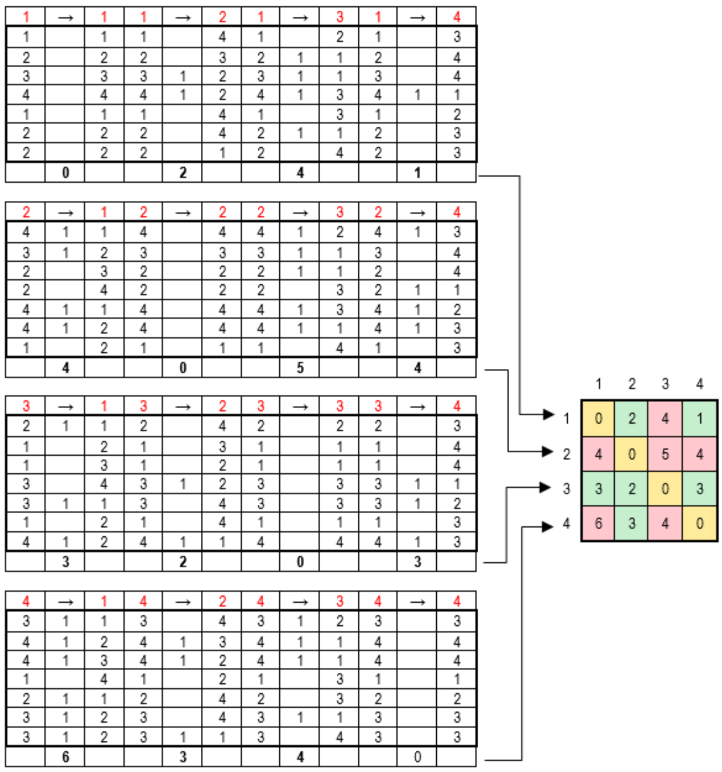

Figure 1: *Scheme of formation of the "errors" matrix*

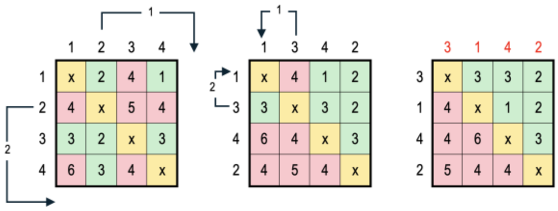

Figure 2: *Elementary transformations of the "error" matrix*

Since there are no contradictions in the upper triangular matrix, this solution is the only and non-improvable one. Let us check its compliance with the optimality criterion:

	3	1	4	2	Inversions				$K_m(g^*)$
	O_1	O_2	O_3	O_4	1→1	2→2	3→3	4→4	
E_1	2	1	3	4	1	0	0	0	1
E_2	1	2	4	3	0	0	1	0	2
E_3	1	3	4	2	0	2	0	0	2
E_4	3	4	1	2	2	2	0	0	4
E_5	3	1	2	4	1	1	0	0	2
E_6	1	2	3	4	0	0	0	0	0
E_7	4	2	3	1	3	1	1	0	5
							Optimality criterion $K'(g^*)$:		15

As can be seen from the table, the expert E_6 "guessed" the optimal solution, since. $K_6(g^*) = 0$. Experts E_1 и E_2 made only 1 error each, E_3 и E_5 - 2 errors each, and E_4 и E_7 - too many errors. The optimality criterion is *met* $K'(g^*) < K(g^*)$.

By reconstructing the $g^* = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 3 & 1 & 4 & 2 \end{pmatrix}$ the optimal sequence as $p^* = (g^*)^{-1}$ we obtain the desired locations $p^*(E) = \langle 2, 4, 1, 3 \rangle$.

V. Concluding remarks

The situation arising after permutations in the "errors" matrix will not always be as shown in the demo example. The problem of finding the optimal order of the evaluated objects may have several possible solutions. In this case, the best solution is determined by calculating the optimality criterion for all obtained solutions and selecting the solution that has the smallest value of this criterion. In most of the cases tested by the authors, the solution resulted in a global optimum, which favorably distinguishes the method from Schulze's method, for example. In addition, unlike the Schulze method, the PF-method is computationally much simpler and clearer.

Further development of this method implies its application in ranking definitions that allow equality of scores of the compared objects when determining the weight coefficients of the compared objects (similar to pairwise comparisons in the method of hierarchy analysis [14] and solving problems of fusion of heterogeneous scales [15, 16]).

References

[1] Fiorenzo, Franceschini., Domenico, Augusto, Francesco, Maisano. (2020). Decision concordance with incomplete expert rankings in manufacturing applications. Research in Engineering Design, doi: 10.1007/S00163-020-00340-X

[2] Leonid, Lyubchyk. and Galyna, Grinberg. (2014). Preference Function Reconstruction for Multiple Criteria Decision Making Based on Machine Learning Approach. doi: 10.1007/978-3-319-06323-2_4

[3] Kendra, Cipollini., Aimee, L., Maruyama., Christopher, L., Zimmerman. (2005). Planning for Restoration: A Decision Analysis Approach to Prioritization. Restoration Ecology, doi: 10.1111/J.1526-100X.2005.00057.X

[4] Natal'ya, E., Buletova. (2023). Solving the Issue of Managerial Decision Making in Terms of Ranking by the Effective Rank Method. doi: 10.1007/978-3-031-30926-7_9

[5] Jie, Tang., Qingxian, An., Qingxian, An., Fanyong, Meng., Xiaohong, Chen. (2017). A Natural Method for Ranking Objects from Hesitant Fuzzy Preference Relations. International Journal of Information Technology and Decision Making, doi: 10.1142/S0219622017500304

[6] Bernhardt, Lieberman. (1971). Resolving the Condorcet Paradox. American Journal of Sociology, doi: 10.1086/225163

[7] Luigi, Mittone. (2003). The Condorcet paradox: an experimental approach to a voting process. Research Papers in Economics,

[8] P., Jean-Jacques, Herings. and Harold, Houba. (2013). The Condorcet paradox revisited. Social Choice and Welfare, doi: 10.1007/S00355-016-0950-7

[9] William, V., Gehrlein. and Peter, C., Fishburn. (1976). Condorcet's paradox and anonymous preference profiles. Public Choice, doi: 10.1007/BF01725789

[10] Jean-Jacques P., Herings. and Harold, Houba. (2010). The Condorcet Paradox Revisited. Social Science Research Network, doi: 10.2139/SSRN.2265943

[11] Kenneth J. Arrow, 1951, 2nd ed., 1963. Social Choice and Individual Values, Yale University Press. ISBN 0-300-01364-7

[12] Condorcet J. Esquisse historique des progres de l'esprit humain = Esquisse d'un tableau historique des progres de l'esprit humain. - Librocom, 2011. - 280 c. - (From the Heritage of World Philosophical Thought. Social Philosophy). ISBN 978-5-397-01568-4.

[13] Bochkov A., Zhigirev N, Kuzminova A. Inversion Method of Consistency Measure Estimation Expert Opinions // RT&A. 2022. №3 (69). doi: 10.24412/1932-2321-2022-369-242-252

[14] Saati T. Decision making. Method of hierarchy analysis. M. Radio and communication. 1993. - 278 c. URL: http://rosculturexpertiza.ru/files/valuation/saati.pdf.

[15] Bochkov, A.V., Lesnykh, V.V., Zhigirev, N.N., Lavrukhin, Yu.N.. Some methodical aspects of critical infrastructure protection // Safety Science, V. 79, Nov. 2015. Pp. 229-242. URL: https://doi.org/10.1016/j.ssci.2015.06.008.

[16] Zhigirev, N.; Bochkov, A.; Kuzmina, N.; Ridley, A. Introducing a Novel Method for Smart Expansive Systems' Operation Risk Synthesis. // Mathematics 2022, 10, 427. URL: https://doi.org/10.3390/math10030427.

INVESTIGATION OF DIFFERENT SIMULATION METHODS FOR EXTRACTING RARE FAILURE EVENTS IN POWER SYSTEM RELIABILITY EVALUATION

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Abstract

In this paper, procedures for modeling rare events, which include power and energy shortages, are considered when analyzing the balance reliability of electric power systems using simulation methods. The primary goal is to investigate the use of iterative methods to form a sequence of nested probability subspaces with decreasing probability. Implementations of the subspace method are considered. A modification of the entropy method is proposed that involves a smooth adaptation of the indicator functions. The discussed procedures undergo a comparative analysis. The main disadvantage of the considered methods is their efficiency, which depends on the proper specification of parametric constants. The methods to improve the accuracy and convergence of iterative procedures are outlined.

Keywords: Monte Carlo simulation, power system reliability, simulation of rare events, cross-entropy method, probabilistic evaluation

I. Introduction

The main task of analyzing the reliability of an electric power system (EPS) is to assess the probabilistic indicators (probability, frequency, mathematical expectation, etc.) of power deficit (PD) in the EPS, the presence of which is considered a violation of the normal functioning of the EPS (failure) [1–3]. All technical systems, including EPS, exhibit a low probability of failure (a fraction of a percent) [4–5]. A technical system's reliability analysis is associated with the modeling and analysis of failure events. In this case, as a rule, failure occurs with an infinitely large combination of external events. Thus, in an EPS with two load nodes and a fixed maximum power of electric stations, a power deficit can manifest itself with an unacceptably large increase in the load of either the first, second, or both nodes. In this case, the excess of the total load over generation is continuous and hence has an infinitely uncertain value in implementation. The number of load and generation nodes in real EPS design circuits is measured in thousands. As a result, the probability of failure increases many times over, and identifying the most significant combinations of events leading to system failure becomes difficult.

The main mathematical apparatus for analyzing the reliability of EPS is currently the methods of statistical tests, and in particular the Monte Carlo method (MCM) [6–10]. These methods make it possible to model systems with complex functional relationships that cannot be described analytically, including taking into account the stochastic uncertainty associated with supply, demand, and the capacity of intersystem connections. The main drawback of the MCM is known: to ensure the required accuracy of the results, a sufficiently large number of tests is required, since N is inversely proportional to the probability of the simulated events. In particular, when modeling an event with a probability of 10-3 and a modeling error of 1%, at least 106 statistical tests are required [11]. When analyzing the balance reliability of real EPS, the most significant are multiple failures (simultaneous failure of two power transmission lines, simultaneous failure of a power line and a power unit, failure of a power unit during peak loads, etc.), since single failures of EPS electrical equipment, as a rule, do not lead to limitations on power consumption. EPS are designed and constructed taking into account criterion N-1, in which a single failure of any element of the EPS should not lead to failure of the power supply process to consumers [12–14]. The probability of multiple independent failures is equal to the product of the failure probabilities of the failed elements. As a result, the probability of multiple failures takes values of 10-5–10-7. At the same time, to identify, model, and analyze post-emergency states of EPS using the MCM method, the number of tests is required to be at least 107. With a smaller number of tests, the identification of such rare events becomes unlikely, which leads to a significant error in the resulting reliability indicators [14].

Given that each test necessitates the execution of optimization calculations (optimal flow distribution), the reliability analysis of EPS will require several hours of computer time. Note that most general problems, such as choosing the optimal configuration of the electrical network during its development, involve the calculation of reliability indicators. Hence, the duration of calculating the reliability of the EPS development option as a separate calculation block is limited in time. The modern power system requires increasingly complex detail and expansion of the factors taken into account, which non-linearly increases the complexity of the task of assessing the reliability of the EPS. Taken together, this leads to the inexpediency, and sometimes even impossibility, of using a standard MCM to assess the reliability indicators of a power system. Modifications of the MCM are required, aimed at increasing the computational efficiency of statistical methods.

One of the ways to solve the problem of performing a large number of relatively similar calculations associated with modeling rare (with a failure probability of less than 10-5) events in a multidimensional probabilistic space is the idea of parallel computing. The technology for simultaneous use of several computers (or processors) has been actively developing over the past 30 years [15–17]. Parallel calculations certainly reduce the computational load of the MCM. However, the relationship between the number of parallel computing resources and computation time is similar to a linear function [17]. Hence, when modeling rare events, the positive effect of parallelization of calculations becomes less obvious. Another direction is the use of pattern methods, metamodels, artificial immunity, artificial neural networks, least-squares support vector machines [18–21], etc. These methods have also demonstrated a reduction in the MCM method's computational load. However, as a rule, for reliability evaluation tasks, they have not been tested, are focused on a certain class of problems, are often ineffective, and do not provide the required accuracy and reliability of identifying events with a probability of less than 10-4, which is typical for real energy systems. Hence, the problem of identifying rare events remains relevant. Iterative methods associated with the transformation of analyzed spaces, functions of probability distributions of random variables, and criterion functions are more universal in nature. The most common methods in this class are subspace and significant sampling methods [22–25], as well as cross-entropy methods [26–28].

This paper proposes and analyzes new procedures for determining the probabilistic parameters of rare events based on nested set methods, including mono and polycenters for forming an intermediate sample of significant events, as well as a modification of the cross-entropy method. The models and methods used in this study are described in Section III and IV, after Section II, where the mathematical formulation of rare event simulation is highlighted. Section V presents an example case study, and the results are analyzed to address the objectives of the work. In Section VI, conclusions are drawn.

II. Mathematical formulation of Power Deficit as a rare event

Let $\boldsymbol{x} \in \mathbb{R}^{\boldsymbol{m}}$be a random vector that combines all probabilistic input variables, $L_i, G_i,$ etc. In the simplest case, when only available generation and load are taken into account and random states of system elements, ambient temperature, etc. are not taken into account, $\boldsymbol{x} = \{L_i, G_i,\ i = 1, \dots, n\}$, where i –where is the number of the electrical network node. In order to focus attention on the mechanisms for identifying rare events associated with failures of EPS operation, the set of random, probabilistically determined quantities in this work is limited only by the load and available generation.

The deficiency of the system is determined by the difference $D_\Sigma = L_\Sigma - G_\Sigma = \sum L_i - \sum G_i$, $L_\Sigma > G_\Sigma$. It can be estimated, for example, using the system power deficit (PD) function, $S = G_\Sigma - L_\Sigma$ or (taking into account the capacity of the electrical network) $S = \min(G_i - L_i, \forall i)$. When $\{L_i, G_i\}$ is independent, it often makes sense to consider a generalized random variable - the available generating capacity of a node, $r_i = G_i - L_i$. Its mean and variance: $\mu_{r_i} = \mu_{G_i} - \mu_{L_i}$; $\sigma_{r_i}^2 = \sigma_{G_i}^2 + \sigma_{L_i}^2$. As a result, the number of control stochastic variables is reduced to the number of nodes in the electrical network. In this case, $D_\Sigma = -r_\Sigma = -\sum r_i$, $r_\Sigma < 0$.

In general, when analyzing local PDs, it is necessary to take into account the laws of power distribution in the electrical network. In this case, each node is characterized by the export $u_i, i = 1, \dots, n$ or import (-u_i) of power, determined by the dispatch control of the EPS and depending on the available power of the nodes $u_i = u_i(\boldsymbol{r})$. In this case, the local PD $D_i = u_i - r_i = u_i - G_i + L_i$; $D_i > 0$. With local PD, the system PD is fixed if at least one of the nodes has a local PD $D_\Sigma = \sum D_i$. To more accurately account for the scarcity of EPS, it is necessary to take into account active power losses in the network, which are determined by the distribution of power flows $\boldsymbol{z} = \{z_j, j = 1, \dots, m\}$ in the elements of the electrical network and are nonlinear in nature. Taking into account power losses is associated with the appearance of an additional condition $\pi_\Sigma = \sum u_i$. In this case, $D_\Sigma = L_\Sigma - G_\Sigma + \pi_\Sigma$, $\mathcal{D}_\Sigma \geq 0$.

Vector $\boldsymbol{z}$ is determined by solving the problem of optimal distribution of load power between power sources. In the simplest case, acceptable in reliability assessment problems, we can consider $\boldsymbol{z} = C\boldsymbol{u}$ where C is the flow distribution matrix [7]. As a result, it can be noted that the PD in an EES represents a complex (often determined algorithmically) functional dependence on a set of control variables, usually of a random nature.

The system failure state is fixed if some criterion function $\psi(\boldsymbol{x})$ specified on the set of control variables exceeds its inherent threshold value, $\psi(\boldsymbol{x}) < \psi_{lim}$. In practice as shown in Fig. 1, to identify failures, a function with a zero threshold is more often used, $S(\boldsymbol{x}) = \psi(\boldsymbol{x}) - \psi_{lim}$, which takes a negative value when the system fails, $S(\boldsymbol{x}) < 0$. In this case, the region of system states characterized as "failure":

$$H := \{\boldsymbol{x} \in \mathbb{R}^{\boldsymbol{m}} : S(\boldsymbol{x}) < 0\}. \tag{1}$$

If we consider the presence of PD in the EPS as a failure, then the criterion function has the form:

$$S(\boldsymbol{r}) = \min\left(\sum r_i - \pi_\Sigma;\ r_i - u_i(\boldsymbol{r}), \forall i\right).$$

The criterion function corresponds to the indicator function:

$$J(\boldsymbol{x}) = \begin{cases} 1, & S(\boldsymbol{x}) < 0; \\ 0, & S(\boldsymbol{x}) \geq 0, \end{cases}$$

which allows you to express many logical constructions in analytical form. In particular, the probability $\mathbb{P}_H$ of a failure state (the presence of a power deficit in the EPS) can be defined as the mean of the indicator function $J(\boldsymbol{x})$, which in state $\boldsymbol{x}$ takes the value 1 in the presence of a failure in the EPS and 0 in its absence:

$$\mathbb{P}_H = \int J(\boldsymbol{x})\, f(\boldsymbol{x}) d\boldsymbol{x}, \tag{2}$$

where $f(\boldsymbol{x})$ – is the probability density function (PDF) of the multidimensional random variable $\boldsymbol{x}$ that determines the event under consideration. For a given PDF $f(\boldsymbol{x})$, the probability of a rare event occurring is determined by the region H, that satisfies the criterion $S(\boldsymbol{x}) < 0$.

$$\mathbb{P}_H = \int_{S(\boldsymbol{x})<0} f(\boldsymbol{x}) d\boldsymbol{x}.$$

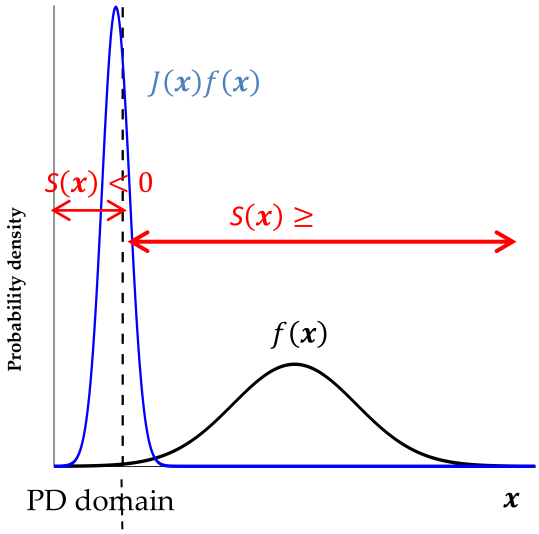

Figure 1: *Derivation of distorted probability distribution*

The PDF $f(\boldsymbol{x})$ of a random vector $\boldsymbol{x}$ of system states is almost impossible to represent in the form of an analytical expression, since it is the result of the convolution of a large number of system parameters of different types, with different parameters (loads, generations, binary variables that determine the state of system elements, solar radiation, wind speed, etc.). That is why the main method of analyzing the reliability of EPS at present is the simulation method (MCM), which allows, through repeated tests and their statistical processing, to obtain a fairly accurate estimate of the required values. In this case, as initial data, as a rule, the parameters of marginal distributions of initial RVs are set (for example, the load of node i of an EPS is described by a normal (Gaussian) distribution with a mathematical expectation μ_i and a standard deviation (STD) σ_i, $L_i \sim N(x, \mu_i, \sigma_i)$.

III. State subspace method

The performance of the MCM can be improved by applying variance reduction techniques such as significance sampling. The main idea of this group of methods is the formation of a sequence of subsets, $H_1 \supset H_2 \supset \cdots \supset H_m = H$ of the system state space, where each subsequent subspace increases the probability of identifying rare events and is determined on the basis of the previous one, forming a sequence of the Markov chain. In this case, the probability of the occurrence of a rare event can be written as follows:

$$\mathbb{P}_H = \Pr\left(H = \bigcap_{j=1}^{m} H_j \right) = \prod_{j=1}^{m} \Pr\left(H_j \middle| H_{j-1}\right).$$

Each subsequent subset is chosen so that the probability of the conditional event $\Pr\left(H_j \middle| H_{j-1}\right)$ would be large enough. As a result, a small probability is represented as a product of relatively large probabilities [23–25]. One of the ways to form $\left(H_j \middle| H_{j-1}\right)$ is to select a given share p_0 of the most significant events $X_b^j = \left(\boldsymbol{x}_1^j, \boldsymbol{x}_2^j, \dots, \boldsymbol{x}_k^j\right)$, where $k = p_0 N$; $N-$ is the sample size. The index b characterizes the maximum level of the criterion function $\psi(\boldsymbol{x})$ for the set X_b^{j-1}. The significance of events is determined by the value of $\psi(\boldsymbol{x})$ – the smaller $\psi(\boldsymbol{x})$, the greater the significance of $\boldsymbol{x}$ (for $\psi(\boldsymbol{x}_i, i = 1,\dots k) < 0$, the entire area X_b^j consists of "significant" (deficit states of the EPS)). Significance differentiation determines the mechanism of formation of the set X_b^j. The complete sample H_{j-1} obtained from the data of step $j-1$ is ordered in ascending order $\psi(\boldsymbol{x})$: $\psi(\boldsymbol{x}_1) \leq \cdots \leq \psi(\boldsymbol{x}_N)$. The first $p_0 N$ events ($p_0 \cdot 100$ percentile of the function ψ(x)) determine the set X_b^j and the maximum value of the criterion function corresponding to it, $b_j = max(\psi(\boldsymbol{x}), \boldsymbol{x} \in X_b^j)$, which, in turn, is the basis for the formation of a new set $H_j = \{\boldsymbol{x}: \psi(\boldsymbol{x}) < b_j\}$. In this case, the value p_0 can be considered as the probability of the conditional event $\Pr(H_j | H_{j-1}) = p_0$.

The presented stage-by-stage process of formation of a set of rare events is characterized by a positive value $b_j > 0$ at all intermediate stages. This means that the set X_b^j contains both failure events, $\psi(\boldsymbol{x}) < 0$, and non-failure events $\psi(\boldsymbol{x}) > 0$, that is, the principle of selecting events is to exclude less significant events and expand the region of more significant events , $b_j < b_{j-1}$. Initially, $b_0 = \infty$, which means that all system states generated on the basis of marginal PDF belong to the analysis zone. However, at subsequent stages, when generating the analyzed set of pseudo-random states of the system, a restriction is introduced: $\psi(\boldsymbol{x}) < b_{j-1}$. As a rule, this is realized by replacing the PDF parameters of random variables with some new calculated values.

At the last stage $b_j < 0$. This means that all events in the truncated set with p_0 are failures. But failures can also be events that do not fall into the region determined by the percentile, $b_j < \psi(\boldsymbol{x}) < 0$. Here, the conditional probability is determined according to the relation: $Pr(H_m | H_{m-1}) = N(\psi(\boldsymbol{x}) < 0)/N$, where $N(\psi(\boldsymbol{x}) < 0) -$ is the number of sample elements of size N satisfying the requirement $\psi(\boldsymbol{x}) < 0$.

Depending on the algorithm, the total sample size $N^{(j)}$ at intermediate stages may differ from the specified N, however, the selection principle is preserved - only the p_0 −part of the set of system states formed for analysis is accepted for further consideration.

A. Monocenter for the formation of an intermediate sample

A relatively small set of X_b^{j-1} is only the basis for the formation of H_j. Its elements are determined according to the type and parameters of the pseudo-random number generation distribution function in step $j-1$. At stage j , these should be different parameters, with a greater degree of identification of a rare event. One of the possible options for the formation of a new sample is proposed to generate pseudo-random numbers distributed according to a normal distribution with mean $\boldsymbol{\mu}^j = \mathbb{E}(\boldsymbol{x}_1^{j-1}, \boldsymbol{x}_2^{j-1}, \dots, \boldsymbol{x}_k^{j-1})$ and variance $\boldsymbol{D}^j = \mathbb{D}(\boldsymbol{x}_1^{j-1}, \boldsymbol{x}_2^{j-1}, \dots, \boldsymbol{x}_k^{j-1})$. At the first stage, as $\boldsymbol{\mu}^{(1)}, \boldsymbol{D}^{(1)}$ the mean and variances of the considered set of initial random variables are taken. Since the vector with parameters $(\boldsymbol{\mu}^j, \boldsymbol{D}^j)$ is the best representative of the region X^j, it is reasonable to consider this vector as the center of the region H_j.

The new set of pseudo-random vectors generated at stage j with center $(\boldsymbol{\mu}^j, \boldsymbol{D}^j)$, in the general case, contains points that do not belong to H_j according to the criterion $H_j \subset H_{j-1}$, that is, do not satisfy the condition $\psi(\boldsymbol{x}) < b_{j-1}$. The solution to this problem is either the addition of the resulting set to N elements that satisfy the condition $\psi(\boldsymbol{x}) < b_{j-1}$, or a simple removal of unsatisfactory system states. In the latter case, the sample is reduced from N to N_j elements, but all elements of the remaining set belong to H_j. It should be noted that the number of elements to be removed is, as a rule, relatively small, and the reduction of the analyzed set has little effect on the statistical estimates of the desired parameters (in particular, on the probability and mean of PD).

Calculations show that the choice of $(\boldsymbol{\mu}^j, \boldsymbol{D}^j)$ as the center of formation of the set F_j leads to some overestimation of the probability of a rare event in the region of very low probabilities (order: 10-6 in relation to 10-7). More accurate is the choice of the center at the point $\boldsymbol{x}^{*j}$, corresponding to the maximum value at stage $j-1$ criterion function, $\psi(\boldsymbol{x}^{*j}) = b_{j-1}$. Here, it is a priori assumed that at least half of the new generation of system states will not satisfy the condition $\psi(\boldsymbol{x}) < b_j$, but this increases the probability of taking into account those states that do not fall into the statistical sample with the center $(\boldsymbol{\mu}^j, \boldsymbol{D}^j)$. An increase in the proportion of deleted events is inextricably linked with the requirement to increase the sample size N. The shift of the center $(\boldsymbol{\mu}^{*j} = \boldsymbol{x}^{*j-1}, \boldsymbol{D}^{*j})$ of the sample relative to the MO leads to the need to correct the variance $\boldsymbol{D}^{*j} = \boldsymbol{D}^j + |\boldsymbol{x}^{*j-1} - \boldsymbol{\mu}^j|^2$.

B. Gaussian distribution- centered method

The monocentric approach assumes the concentration of the sample around some center, for example, according to a normal (Gaussian) distribution with mean at the center of the sample. However, the principle of selecting a peripheral region according to the probability p_0 and the asymmetry of the region of a rare event (the greater the load, the greater the PD) casts doubt on the validity of the Gaussian distribution at intermediate stages. Logically more justified here is a probability distribution, unknown in type, but represented by a set of (reference) points defined at the previous stage $C_{j-1} = (\boldsymbol{x}_1^{j-1}, \boldsymbol{x}_2^{j-1}, \ldots, \boldsymbol{x}_k^{j-1})$. Statistical modeling of this distribution is possible by representing the set H_j as a union of subsets centered at the reference points $H_j = \cup H_{js}(\boldsymbol{x}_s^{j-1})$. As the STD σ_j when forming the set H_{js} we can consider the maximum distance between the points of the set C_{j-1}: $\sigma_j = \max|\boldsymbol{x}_k^{j-1} - \boldsymbol{x}_l^{j-1}|, (\boldsymbol{x}_k^{j-1}, \boldsymbol{x}_l^{j-1}) \in C_{j-1}$. This makes it possible to ensure the intersection of sets of points formed in multidimensional spheres with centers at points $\boldsymbol{x}_k^{j-1} \in C_{j-1}$, and therefore more fully and uniformly take into account the region C_{j-1}.

C. Adaptive Sampling Algorithm

The main problem of methods of nested subspaces of states is the dependence of the resulting data on the mechanism of formation of intermediate sets. In this case, situations are possible when the subsequent subspace practically does not change the criterion threshold $b_k \approx b_{k-1}$, which leads to the lack of convergence of the computational process for a given number of iterations. In this case, the resulting probability of a rare event becomes arbitrarily small. Hence, the main directions of research in this area are aimed at increasing the robustness of the methods. There are a fairly large number of proposals for the formation of intermediate sets [22-25]. Along with the monocentric methods described above, we proposed and tested the adaptive sampling method, the essence of which is the multiple adaptive correction of the parameters (mean and variance) of the distribution of the intermediate sample. Its steps are as follows:

1. Initialization: $k = 1$; $N_c = p_0 N$; $N_s = 1/p_0$; $\lambda = 0.6$
2. Generation according to the standard normal (Gaussian) distribution of N pseudo-random numbers: $U = \{\boldsymbol{u_1}, \ldots, \boldsymbol{u_N}\}$.
3. Transformation of the set U into a matrix $X = \{\boldsymbol{x_1}, \ldots, \boldsymbol{x_N}\}$ of named random variables (load, generation, state of the system elements), according to their marginal distribution laws $\boldsymbol{x}_i = \varphi_i(\boldsymbol{u}_i)$.
4. Definition of the vector of criterion functions $\boldsymbol{\psi} = \{\psi_i(\boldsymbol{x_i})\}$ and its sorting in ascending order of the function: $\psi_i(\boldsymbol{x_i}) \geq \psi_{i-1}(\boldsymbol{x_{i-1}})$
5. Determination on the set $\boldsymbol{\psi}$ of the percentile $(p_0 \cdot 100)$, the parameter $b_k \geq 0$ corresponding to it, and the set of named significant states of the system $H_{xk} = \{\boldsymbol{x_i}: \psi_i(\boldsymbol{x_i}) < b_k\}$.
6. Generation of a new sample of N random states of the system based on the reference states of the system.
7. Items 4-6 are repeated until $b_k \geq 0$. In this case, the conditional probability $Pr(H_k|H_{k-1}) = p_0$. At the last step m, for $b_m < 0$ the number N_m of elements is determined that satisfy the condition $\psi_{N_m}(\boldsymbol{x}_{N_m}) \leq 0$, $\psi_{N_m+1}(\boldsymbol{x}_{N_m+1}) > 0$. The resulting probability of a rare event is $\Pr(H) = p_0^{m-1} N_m / N$.
8. Determination of other analyzed probabilistic indicators (mean of PD, etc.).

IV. Cross entropy method

The cross-entropy method (CEM) [26-28] is based on replacing the real function $f(\boldsymbol{x})$ of the distribution density of the analyzed multivariate random variable, according to which the MCM is sampled, by some auxiliary PDF $q(\boldsymbol{x})$, which shifts the scope of analysis into the region of interest of a rare event. This approach is widely known in the calculation of integrals of complex functions by statistical methods, where the integrand is multiplied and divided by some PDF, completely defined on the integration interval under consideration:

$$\int_a^b f(x)dx = \int_a^b \frac{f(x)}{q(x)} q(x)dx = \mathbb{E}_q\big(W(x)\big) \cong \frac{1}{N}\sum_{i=1}^{N} W(x_i),$$

where $W(x) = f(x)/q(x)$. In this case, the problem of choosing an auxiliary function arises - it is necessary that the calculation procedure based on it be not only adequate in direction (shift of the analyzed area towards a rare event), but also efficient in terms of speed and convergence. In the presence of CDF, the probability of power shortage (2) can be represented as the mathematical expectation of the weighted indicator function $J(\boldsymbol{x})W(\boldsymbol{x})$, defined in a multidimensional space of random variables with a density function $q(\boldsymbol{x})$:

$$\mathbb{P}_H = \int J(\boldsymbol{x})\frac{f(\boldsymbol{x})}{q(\boldsymbol{x})} q(\boldsymbol{x})d\boldsymbol{x} = \int J(\boldsymbol{x})W(\boldsymbol{x})q(\boldsymbol{x})dx = \mathbb{E}_q[J(\boldsymbol{x})W(\boldsymbol{x})], \tag{3}$$

where $W(\boldsymbol{x}) = f(\boldsymbol{x})/q(\boldsymbol{x})$ – is the weight function determined by the initial $f(\boldsymbol{x})$ and auxiliary $q(\boldsymbol{x})$ distribution densities. When choosing the most efficient function $q^*(\boldsymbol{x})$ in the class $\{q(\boldsymbol{x})\}$, the minimum of the variance $\mathbb{P}_H$ can serve as an optimization criterion:

$$\min_q \mathbb{V}_q\big[J(\boldsymbol{x})W\big(\boldsymbol{x}; q(\boldsymbol{x})\big)\big].$$

Theoretically, the best function leading to zero variance of the desired probability estimate $\mathbb{P}_H$ is the function [28]:

$$q^*(\boldsymbol{x}) = \frac{J(\boldsymbol{x})f(\boldsymbol{x})}{\int J(\boldsymbol{x})f(\boldsymbol{x})d\boldsymbol{x}} = \frac{J(\boldsymbol{x})f(\boldsymbol{x})}{\mathbb{P}_H}. \tag{4}$$

Since the optimal CDF depends on the unknown values $\mathbb{P}_H$ and $J(\boldsymbol{x})$, a direct analytical determination of $q^*(\boldsymbol{x})$ is impossible. A sufficiently good approximation makes it possible to obtain a FEM based on the successive refinement of the parameters $\boldsymbol{v}$ of the multidimensional distribution density $q(\boldsymbol{x}; \boldsymbol{v})$and the procedure for determining the resulting value is represented as a Markov chain with the choice of parameters at each step. To estimate the parameters $\boldsymbol{v}$, this method uses the results of intermediate statistical tests. The parameter vector $\boldsymbol{v}$ is determined by minimizing the cross entropy (KL divergence) [28]. KL-divergence determines the measure of proximity of two arbitrary PDFs: the optimal PDF $q^*(\boldsymbol{x})$ and its current estimate $q(\boldsymbol{x}; \boldsymbol{v})$. In the proposed work, the function $q(\boldsymbol{x}; \boldsymbol{v})$is represented by the density of a multidimensional normal distribution with the mathematical expectation $\boldsymbol{\mu}_q$ and the matrix of correlation moments Σ_q. In this setting, the degree of optimality, in essence, determines the vector of parameters $\boldsymbol{v} = [\boldsymbol{\mu}_q; \Sigma_q]$).

CEM solves the problem of optimization iteratively by determining a series of intermediate distribution densities $\{q(\boldsymbol{x}; \boldsymbol{v}_k),\ k = 1, \dots, NT\}$, which, as shown in Fig. 2, gradually approach the target density $q^*(\boldsymbol{x})$, representing region of existence of a rare event. At step k, the optimal PDF $q^*(\boldsymbol{x})$can be represented by the estimate $q(\boldsymbol{x}; \boldsymbol{v}_{k-1}^*)$ with the optimal parameters $\boldsymbol{v}_{k-1}^*$ obtained at the previous step. In this case, $W(\boldsymbol{x}; \boldsymbol{v}_{k-1}^*) = f(\boldsymbol{x})/q(\boldsymbol{x}; \boldsymbol{v}_{k-1}^*)$. The area H_k of the intermediate set of system states is determined by the threshold b_k:

$$H_k = \{\boldsymbol{x}: \psi_k(\boldsymbol{x}) < b_k\},$$
$$J_k(\boldsymbol{x}) = \begin{cases} 1, & \psi_k(\boldsymbol{x_k}) < b_k; \\ 0, & \psi_k(\boldsymbol{x_k}) \geq b_k. \end{cases} \tag{5}$$

The threshold b_k is calculated as a θ-quantile (for example, a decile obtained during statistical tests and sorted from the smallest to the largest values of the threshold function $\psi_i(\boldsymbol{x_i})$. In this case, the simulation is performed according to the distribution density $q(\boldsymbol{x}; \boldsymbol{v}_{k-1})$ with parameters

$\boldsymbol{v}_{k-1}$.

The vector $\boldsymbol{v}^*$ obtained as a result of solving the optimization problem at step $k-1$ is considered as a new value of the vector of parameters of the optimal PDF $q^*(\boldsymbol{x})$, $\boldsymbol{v}_k = \boldsymbol{v}^*$. Starting from the initial vector of parameters $\boldsymbol{v}_0$ that is assumed to be equal to the initial parameters of the probability distributions of the analyzed random variables, each subsequent vector $\boldsymbol{v}_k$ is determined by the solution of the optimization problem, approaching the optimal distribution density $q^*(\boldsymbol{x}) = \lim_{k\to\infty}(q(\boldsymbol{x};\boldsymbol{v}_k))$, which, in turn, is the best estimate of the auxiliary PDF optimal in the CEM. The procedure is repeated until b_k becomes negative, or at least $\theta \in [0.01, 0.1]$ trials are located in the desired region of rare events [28]. If the number of steps to reach the termination criterion of the iterative process is m, then the resulting probability of a rare event is:

$$\hat{\mathbb{P}}_F = \frac{1}{N}\sum_{i=1}^{N} J(\boldsymbol{x}_i)W(\boldsymbol{x}_i;\boldsymbol{v}_{m-1}). \tag{6}$$

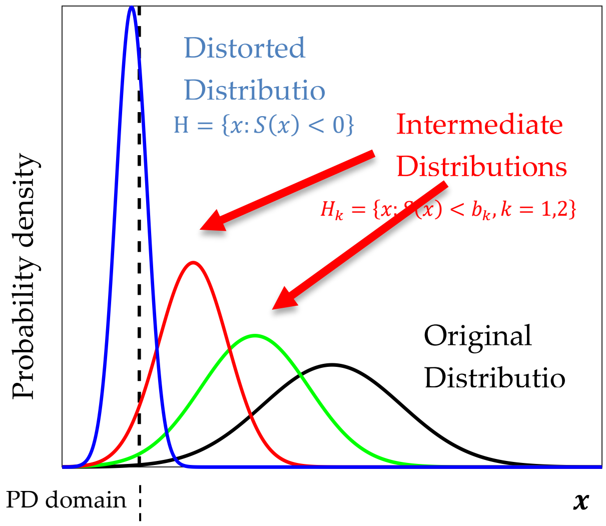

Figure 2: *Derivation of distorted probability distribution using CEM*

The classical CEM presented above requires an optimization procedure to be performed when determining the parameters $\boldsymbol{v}_k$ of the current PDF $q(\boldsymbol{x}, \boldsymbol{v}_k)$. In this case, $\boldsymbol{v}_k$ includes the mean $\boldsymbol{\mu}_k$ and the matrix of correlation moments Σ_k of those realizations x that belong to the area H_k, $\boldsymbol{x} \in H_k$. Expression (6) can be considered as the average value of the values $J_F(\boldsymbol{x}_i)$ with weights $W(\boldsymbol{x}_i)$. Since it refers to a probability, each component of the sum can be interpreted as the probability that the realization $\boldsymbol{x}_i$ belongs to the current region H_k of the rare event. Since the area $H_k$is defined by the indicator function $J_k(\boldsymbol{x}_i)$, then the mean of the available power of nodes in the area H_k is as follows:

$$\boldsymbol{\mu}_r^{(k)} = \left(\sum_{x_i \in H_k} \boldsymbol{x}_i W_i\right) / \left(\sum_{x_i \in H_k} W_i\right).$$

Matrix of correlation moments can be expressed as follows:

$$\Sigma_r^{(k)} = \left(\sum_{x_i \in H_k} W(\boldsymbol{x}_i)(\boldsymbol{x}_i - \boldsymbol{\mu}_r^{(k)})(\boldsymbol{x}_i - \boldsymbol{\mu}_r^{(k)})^T\right) / \left(\sum_{x_i \in H_k} W(\boldsymbol{x}_i)\right).$$

These parameters form the vector $\boldsymbol{v}_k$. With this approach, an optimization procedure is not required, which significantly reduces the duration of calculations without a significant decrease in the accuracy of the results.

V. Computational results

To compare the described procedures, calculations of the balance reliability indicators are performed for a five-node electrical circuit shown in Fig. 3, where in addition to the topology, load and generation expectations are presented. Standard deviations are taken equal to 10% of expectations. TLs, numbered in the order {1-5; 1-4; 4-5; 2-4; 2-3; 3-4}. TL have resistances respectively R = {10; 5; 5; 3; 1; 2}; X = {100; 50; 50; 50; 33; 10; 10}. The limiting capacity of all connections was taken equal to 500 MW.

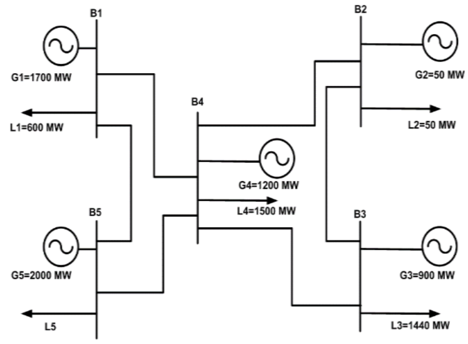

Figure 3: *Test circuit*

The calculation results are presented in Table I, where the methods are indicated: MCM – classical Monte Carlo method; Monocenter – subspace method with one point of formation of an intermediate subspace; Polycenter – the set H_{k-1}; is taken as reference points for the formation of the intermediate subspace H_k; SubSet– method of subspaces with changing parameters of probability distributions when forming an intermediate subspace; CEM– simplified cross-entropy method.

Table 1: *Computational results*

Methods	Pr, 10^{-5}	Pr, Cv	Pr_Eps, %	mD, 10^{-4}	mD, Cv	mD_Eps, %	t, sec
Convolution	2.23	0	0	1.21	0	0	0
MCM	2.23	0.07	0.1	1.21	0.10	0.1	19
Monocenter	2.24	0.6	0.5	1.48	0.90	22.1	0.44
Polycenter	2.29	0.65	2.9	1.52	0.92	25.7	0.19
SubSet	2.2	0.58	-1.4	1.41	0.92	16.7	3.21
CEM	2.3	0.54	3.3	1.24	0.03	2.5	0.12

The second column presents the calculated probability of the total power deficit of the EPS. It should be noted that all presented methods show an accuracy of a rare event acceptable for practical calculations - a maximum deviation of 3.3% (column Pr_Eps, %, CE method) with an exact probability value Pr = 2.23×10–5 can be considered insignificant for low probabilities. For comparison, it can be mentioned that with such probabilities, the widespread replacement of the binomial distribution with the Poisson distribution has a much larger error. The coefficient of variation presented in the Pr_Cv column shows that the spread of the resulting probabilities is relatively small for all methods.

The next 3 columns refer to the mean of PD. Here the spread (coefficient of variation (column mD, Cv)) of the resulting values is much greater. It should be noted that the relative error in calculating the mean of the PD exceeds 25%. Increasing accuracy is possible by increasing the volume of the intermediate sample. However, this leads to an increase in the duration of calculations (column t), which in the presented calculation procedures depends mainly on time-intensive transformations of probability distributions (uniform- Gaussian- individual (marginal)). If we assume that all random variables are described by the same normal distribution (with different parameters), then this allows us to reduce the duration of calculations several times.

The results obtained allow us to recommend cross-entropy methods for practical use that provide the smallest scatter of the resulting indicators.

VI. Conclusion

The described methods for identifying rare events in the electric power industry refer to those events for which it is possible to determine a criterion function that changes its value depending on the distance from the desired events. Such functions (and events) in the electric power industry include power shortages, positive when there is a shortage and negative when there is a reserve of generating capacity. The main technology for identifying rare events is the use of Markov chains, where each subsequent event is determined on a set of events identified at the previous stage according to some criterion. Of the existing approaches to identifying rare events, two can be identified that are most suitable for technical systems: those based on the use of nested subspace technology and the transformation of distribution functions of random variables (including entropy methods). It can be noted that all the procedures considered make it possible to identify rare events with an accuracy acceptable for practical use. According to the robustness criterion, preference can be given to the adaptive sampling algorithm from the class of nested subspaces and the modified cross-entropy method from the class of distribution function transformations. The accuracy of the calculations largely depends on the settings of the methods, including the size of the test sample at the intermediate stages of forming significant events. In this case, the duration of calculations is determined not only by the sample size, but also by the need for probabilistic transformations of distribution functions.

References

[1] Abunima, H.; The, J.; Lai, C.; Jabir, H. A Systematic Review of Reliability Studies on Composite Power Systems: A Coherent Taxonomy Motivations, Open Challenges, Recommendations, and New Research Directions. Energies. –2018. –vol.11, 2417.

[2] Mohsen Firouzi, Abouzar Samimi, Abolfazl Salami, Reliability evaluation of a composite power system in the presence of renewable generations, Reliability Engineering & System Safety, Volume 222,2022,108396, ISSN 0951-8320,

[3] Oboskalov, V.; Abdel Menaem, A.; Valiev, R.; Mahnitko, A.; Varfolomejeva, R. Mathematical methods for probabilistic estimation of power shortage in concentrated electric power systems. Proceedings of the 10th International Scientific Symposium on Electrical Power Engineering, Elektroenergetika. –2019. – P. 128–132.

[4] Song, J.; Wei, P.; Valdebenito, M.; Signal, M. Active learning line sampling for rare event analysis. Mech. Syst. Signal. Process. 2020. – vol.147. 107113.

[5] Rubino, G.; Tuffin, B. Rare Event Simulation using Monte Carlo Methods. John Wiley & Sons, Inc, Hoboken, New Jersey. – 2009. – ISBN:9780470772690.

[6] Kroese, D.P.; Taimre, T.; Botev, Z.I. Handbook of Monte Carlo Methods. John Wiley & Sons, Inc, Hoboken, New Jersey. – 2011. – ISBN 9781118014967.

[7] Zhang, F.; Lu, Z.; Cui, L.; Song, S. Reliability sensitivity algorithm based on stratified importance sampling method for multiple failure modes systems. Chin. J. Aeronaut. – 2010. – vol.23. – P.660-669.

[8] Abdel Menaem, A.; Valiev, R.; Oboskalov, V.; Hassan, T.; Rezk, H.; Ibrahim, M. An efficient framework for adequacy evaluation through extraction of rare load curtailment events in composite power systems. Mathematics. –2021. –vol.8. – P.1-21

[9] Abdel Menaem, A.; Oboskalov, V.P. Comparing Three Methods for Solving Probabilistic Multi-Area Load Shedding Distribution. International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM 2020). –19-22 May 2020.

[10] Wang, Y.; Guo, C.; Wu, Q.; Dong, S. Adaptive sequential importance sampling technique for short-term composite power system adequacy evaluation. IET Gener. Transm. Distrib.–2014.– vol.8. – P. 730–741.

[11] González-Fernández, R.A.; Leite, A.M.; Silva, Da.; Resende, L.C.; Schilling, M.T. Composite systems reliability evaluation based on Monte Carlo simulation and cross-entropy methods. IEEE Trans. Power Syst. – 2013. – vol.28. – P.4598–4606.

[12] Lucarelli, G.; Yan, C.; Bie, Z.; Wang, C.; Ding, T.; Xiong, F. Three approaches to use Cross-Entropy in reliability evaluation of composite system with high penetration wind energy. 2016 IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC) –2016.– P. 227-231.

[13] Gonz´alez-Fern´andez, R.; Silva, A. Reliability assessment of time-dependent systems via sequential cross-entropy Monte Carlo simulation. IEEE Trans. Power Syst. –2011.– vol. 26. – P. 2381–2389.

[14] Silva, A.; Castro, J.; Billinton, R. Probabilistic assessment of spinning reserve via cross-entropy method considering renewable sources and transmission restrictions. IEEE Transactions on Power Systems –2018.–vol. 33. – P. 4574-4582.

[15] Ge, H.; Asgarpoor, S. Parallel Monte Carlo simulation for reliability and cost evaluation of equipment and systems. Electr. Power Syst. Res. – 2011.– vol.81.– P.347–356.

[16] Giuntoli, M.; Pelacchi, P.; Poli, D. Parallel computing of sequential Monte Carlo techniques for reliable operation of Smart Grids. Proc. - EUROCON 2015, doi:10.1109/EUROCON.2015.7313707.

[17] Martinez, J.A.; Guerra, G. A parallel Monte Carlo method for optimum allocation of distributed generation. IEEE Trans. Power Syst. 2014, 29, 2926–2933.

[18] Leite da Silva, A.M.; de Resende, L.C.; da Fonseca Manso, L.A.; Miranda, V. Composite reliability assessment based on Monte Carlo simulation and artificial neural networks. IEEE Trans. Power Syst. 2007, doi:10.1109/TPWRS.2007.901302.

[19] Urgun, D.; Singh, C.A hybrid Monte Carlo Simulation and Multi Label Classification Method for Composite System Reliability Evaluation. IEEE Trans. Power Syst. –2019. –vol.287. – P.8535–8545.

[20] Pindoriya, N.M.; Jirutitijaroen, P.; Srinivasan, D.; Singh, C. Composite reliability evaluation using Monte Carlo simulation and least squares support vector classifier. IEEE Trans. Power Syst. 2011. – vol.211. –P.6048–6056.

[21] Dheybi Cervan, Alberto M. Coronado, Jaime E. Luyo, Cluster-based stratified sampling for fast reliability evaluation of composite power systems based on sequential Monte Carlo simulation, International Journal of Electrical Power & Energy Systems,Volume 147,2023,108813.

[22] Hua, B.; Bie, Z.; Au, S.K.; Li, W.; Wang, X. Extracting rare failure events in composite system reliability evaluation via subset simulation. IEEE Trans. Power Syst. – 2015. –vol.30. – P.753–762.

[23] Y. Zhao, Y. Han, Y. Liu, K. Xie, W. Li and J. Yu, "Cross-Entropy-Based Composite System Reliability Evaluation Using Subset Simulation and Minimum Computational Burden Criterion," in IEEE Transactions on Power Systems, vol. 36, no. 6, pp. 5198-5209, Nov. 2021, doi: 10.1109/TPWRS.2021.3073478.

[24] Zhao Y. Composite Power System Reliability Evaluation Based on Enhanced Sequential Cross-Entropy Monte Carlo Simulation/ Y. Zhao, Y. Tang, W. Li, J.Y. Power// Proceedings of the IEEE Transactions on Power Systems. –2019. –vol. 34. –P. 3891–3901.

[25] Cai J, Xu Q, Cao M, Yang B. A novel importance sampling method of power system reliability assessment considering multi-state units and correlation between wind speed and load. Int J Electr Power Energy Syst 2019; 109:217 – 26. https://doi.org/ 10.1016/j.ijepes.2019.02.019.

[26] Tomasson, E.; Soder, L. Improved importance sampling for reliability evaluation of composite power systems. IEEE Trans. Power Syst. – 2017. –vol. 32. – P. 2426–2434.

[27] Biondini G. An introduction to rare event simulation and importance sampling. Big data analytics. Handbook of statistics, vol. 33. Elsevier; 2015. p. 29–68.**Ошибка! Источник ссылки не найден.Ошибка! Источник ссылки не найден.Ошибка! Источник ссылки не найден.**

[28] Kroese DP, Rubinstein RY, Glynn PW. Chapter 2 – The cross-entropy method for estimation. Handbook of statistics: machine learning: theory and applications. Handbook of Statistics, vol. 31. Elsevier; 2013. p. 19–34.

AVALANCHE DANGER ON ROADS İN MOUNTAİNOUS REGİONS OF GEORGİA USİNG THE EXAMPLE OF RACHA-LECHKHUMİ KVEMO SVANETİ REGİON

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Abstract

Natural hazards, such as avalanches, are common in the mountainous regions of Georgia. They pose a great danger to the population, cause destruction, paralyze sections of roads, and often cause casualties.
Racha-Lechkhumi Kvemo Svaneti region of Georgia belongs to the high mountain region (400-4000 m. above sea level). The region is characterized by steep slopes and abundant snowfall. Therefore, avalanches are not a rare event in the region. Snow avalanches especially damage the road infrastructure that connects the municipalities of the region. In winter, the blocking of road sections by avalanches from the slopes threatens the surrounding populated areas, causes ecological problems and human casualties are frequent.
Meteorological elements: air temperature, snow cover, precipitation are studied on the research sections of the highways of the region. The data is processed according to the data of two weather stations in the region (Oni, Mamison Pass) and covers the last 60 years. Based on the results of the research. A geo-informational map of avalanche hazards of road sections of the Racha-Lechkhumi Kvemo Svaneti region has been compiled.
The conducted research will significantly contribute to the implementation of correct and effective anti-avalanche measures, reducing the economic losses of the country.

Keywords: natural disaster, avalanche, climate, road infrastructure, geoinformation map

I. Introduction

Snow avalanches are one of the most important natural disasters. The purpose of the study is to investigate the avalanche danger of the Racha-Lechkhumi and Kvemo Svaneti highways in the mountainous region of Georgia, the smooth operation of which is important for the sustainable development of the country.

Based on long-term (>60 years) data from meteorological stations and checkpoints in Georgia, regions with little snow, medium snow, no snow, and especially no snow are distinguished according to the amount of snow. The maximum height of the snow cover in the area with little snow varies from 30-50 cm to 140-160 cm in the area with average snow. The maximum height of the snow cover increases with the increase in the absolute altitude of the place and is from 60-100 cm to 450-500 cm in the area without snow the maximum height increases from 100–120 cm to 550–600 cm, and the maximum height of the snow cover changes from 100–120 cm to 700–750 cm in a particularly snowless area [1].

Therefore, it is logical that 56% of the territory of Georgia is covered with avalanche-prone slopes, catastrophic avalanches spread over 36% of the territory, avalanches occur annually on 20% of the territory, and sporadic, rare avalanches occur on 36% of the territory, which are possible to repeat once a year or several decades [2].

According to the data of the National Environmental Agency, there are more than 5,000 identified avalanche traps in Georgia [3].

Avalanche risk in mountainous regions of Georgia depends on topography (orography, hypsometry, and slope inclination), climate (air temperature, atmospheric precipitation, and snow cover), and vegetation cover. Evaluation of the above-mentioned elements allows for the determination of the origin, mode, and distribution characteristics of avalanches [4-6}.

Four main quantitative characteristics determine the degree of avalanche danger in the territory of Georgia:

- avalanche activity of the area (active area in terms of avalanche formation);
- Avalanche distribution frequency (number of avalanches per area unit);
- frequency of arrival of avalanches (the number of arrivals of avalanches from the avalanche reservoir in one winter);
- Duration of the avalanche period (number of avalanche days in one winter) [7,8]

On the territory of Georgia, especially strong, strong, medium, weak, and non-avalanche-prone areas are distinguished (Fig. 1) [9]. The percentage of their sea hazards is presented in Fig.2.

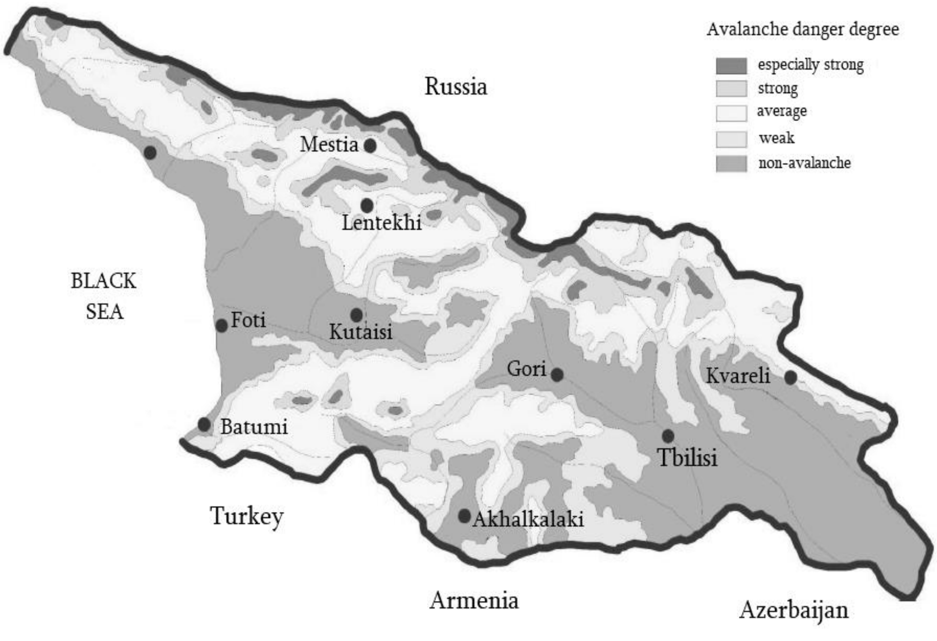

Figure 1: *Schematic map of Georgia's avalanche hazard quality. Source: Saluqvadze, M. (2018)*

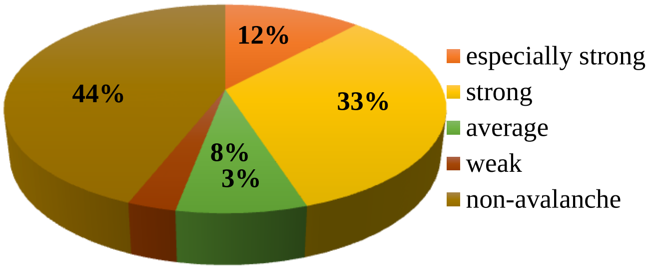

Figure 2: *The percentage of the degree of avalanche danger in Georgia.*

II. Methods

Area under study

The object of our research is one of the regions of Georgia, Racha-Lechkhumi and Kvemo Svaneti (Fig. 3). It is located on the southern slopes of the Central Caucasus and belongs to the high mountain zone (400–4000 m) [10].

Figure 3: *Racha-Lechkhumi and Kvemo Svaneti region. Source: http://rachalechkhumi.blogspot.com/2014/ [11]*

The region is rich in mountain resorts: Shovi, Usira, Lashichala, Veshwake, Muashi, Sortuan, Bugeuli, Khidikar. There are many types of healing mineral or sulphurous waters in the region. From the point of view of tourism, it is distinguished by the abundance of attractive objects.

On the territory of the region, we can find the oldest churches: Nikortsminda, Barakoni, Khonchiori, Mootdzali, Patara Oni, Ghe, Kviriketsminda, Laila, Chazhashi complex, Minda-tsikhe, Kvaratsikhe, the oldest complexes of castles - "Dakhdi", "Dahkari", "Arr Latsa", Oni Synagogue, Shaor and Lajan reservoirs, etc. [12]. All of the above emphasizes the need for proper functioning of the road infrastructure in the region.

Racha has humid weather up to 2000 m above sea level, winter is cold and long, summer is short and warm, absolute minimum temperature is -27 °, and the maximum is 36°. Precipitation ranges from 1000–1500 mm to 1600–1800 mm.

As for the maximum height of the snow cover, in general, it ranges from 127 cm to 535 cm in

Racha-Lechkhumi and Kvemo Svaneti (Table 1).

Table. 1: *The maximum height of the snow cover in Racha-Lechkhumi and Kvemo Svaneti*

Weather station	Altitude of weather station	Years of observation	Maximum height, cm	Recurrence of snow cover height of more than 50 cm, (cm/year)				
				>50-100	101-200	201-300	301-400	>400
Ambrolauri	544	1932-2021	165	25	6	-	-	-
Oni	788	1932-1998	127	21	3	-	-	-
Shaori	1145	1948-1988	255	21	19	4	-	-
Uravi	1150	1939-1990	230	19	6	1	-	-
Shovi	1507	1935-2021	365	24	30	4	1	-
Mamison Pass	2854	1935-1992	535	31	11	6	-	1

The Table 1., presents the height of meteorological stations and checkpoints, the years of observations, the maximum snow height, and the recurrence of the snow cover height of more than 50 cm by year [13].

As it can be seen from the presented material, in the territory of Racha-Lechkhumi and Kvemo Svaneti regions, according to the indicators of avalanche danger (Fig. 1.), especially strong, strong, and average avalanche-risk areas are separated.

The detection of avalanche-prone sections on the highways of the Racha-Lechkhumi and Kvemo Svaneti regions was based on the existing materials of many years of field studies, the databases of the National Environment Agency, information and publications published in literary sources, and the fundamental studies of the Shota Rustaveli National Science Foundation (grant FR 21-1677). Materials and data from field expeditions carried out in 2022 During the field work, the avalanche hazard of each research road section of Racha-Lechkhumi and Kvemo Svaneti region was studied. In particular, a drone (dji mavic 3) was used to describe the locations of avalanche arrivals on road sections, the location of avalanche collectors, and collect photo and video material in areas of avalanche danger where it is impossible to reach on foot.

III. Results

The morphometric (beginning and end height, length, focal area, surface slope) and dynamic characteristics of the avalanche (maximum speed and impact force, cone volume, and maximum height of the moving avalanche) of the area avalanche on the highways of Racha-Lechkhumi and Kvemo Svaneti region are presented in Table 2.

Table 2: *Morphometric and dynamic characteristics of dangerous avalanches of Racha-Lechkhumi and Kvemo Svaneti highways*

N	Altitude, m		Length, m		Total		Avalanche area, ha	Tilt angle, degree	Speed, m/s	Impact strength, t/m^2	Volume 1000 m^3	Avalanche height, m	Length, m	Suspension height
	Absolute	Relative	Horizontal	Factual	Horizontal	Factual								
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	Lentekhi municipality, village Nagomari. Right slope of river Tskhenistskali													
	550	35	80	85	2450	2695	4,8	24	0	0	92	24	2650	530
	The avalanche cross the road, pass by the buildings, cross the river and stop on the opposite slope													
2	Lentekhi municipality, village Nagomari. Left slope of river Tskhenistskali													
	545	5	140	140	600	720	0.2	2	0	0	3	17	680	544
	Crosses the road, passes by the buildings, stops in the river													
3	Lentekhi municipality, village Kvedrishi. Right slope of river Tskhenistskali													
	555	100	200	200	1040	1155	0.3	3	0	0	4	18	1060	560
	Cross the road, passes by the buildings, stops in the river													

4	Lentekhi municipality, village Mazashi. Right slope of river Tskhenistskali													
	620	15	120	120	830	980	0.2	7	11	6	3	18	930	615
	pass by the buildings, cross the road, the river and stop on the opposite slope													
5	Lentekhi municipality, village Tskhumaldi. Left slope of river Kheledula													
	1350	35	270	270	1470	1625	2.4	7	0	0	58	30	1500	1360
	Cross the road, pass by the buildings													
6	Lentekhi municipality, village Bavari. Left slope of river Kheledula													
	1220	150	1000	1010	3620	3880	12.0	8	0	0	331	35	2910	1360
	Pass by the buildings, cross the road, stop in the river													
7	Lentekhi municipality, village Bavari. Left slope of river Kheledula													
	1205	60	400	400	2490	2680	1.2	8	0	0	30	32	2570	1215
	Crosses the road, passes by the buildings, stops in the river													
N	Altitude, m		Length, m		Total		Avalanche area, ha	Tilt angle, degrees	Speed, m/s	Impact strength, t/m^2	Volume 1000 m^3	Avalanche height, m	Length, m	Suspension height
	Absolute	Relative	Horizontal	Factual	Horizontal	Factual								
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
8	Lentekhi municipality, village Bavari. Left slope of river Kheledula. The peak 1794 m. to the south-west													
	1190	30	200	200	1410	1525	0,4	8	0	0	9	27	1470	1200
	Crosses the road, passes by the buildings, stops in the river													
9	Lentekhi municipality, village Mananuri. Left slope of river Kheledula. The peak 1677 m. To the south-east													
	1110	20	200	200	530	595	0,1	6	0	0	2	22	540	1115
	Crosses the road, passes by the buildings, stops in the river													
10	Lentekhi municipality, village Khacheshi. Rght slope of river Kheledula. The peak Bachgeti 2272 m. to the north-east													
	1040	10	180	180	3510	3755	4.0	3	0	0	107	34	3670	1045
	Passes by the buildings and stops on the road													
11	Lentekhi municipality, village Khacheshi. Rght slope of river Kheledula. The peak 1902 m. to the north-east													
	1020	0	80	80	1410	1565	0.3	0	0	0	6	26	1530	1020
	Pass by the buildings, cross the road, stop in the river													
12	Lentekhi municipality, village Khacheshi. Left slope of river Kheledula. The peak 2379 m. to the south-west.													
	1005	5	190	190	2860	3130	9,8	2	0	0	247	32	3030	1008
	Pass by the buildings, cross the road, stop in the river													
13	Lentekhi municipality, village Khacheshi. Left slope of river Kheledula. The peak 1499 m. to the south-west.													
	1010	15	140	140	620	675	0,2	6	0	0	3	21	610	1015
	Passes by the buildings and stops on the road													
14	Lentekhi municipality, village Khacheshi. Left slope of river Kheledula. The peak 1499 m. to the south-west.													
	1001	3	180	180	1420	1520	3,0	1	0	0	56	24	1430	1004
	Passes by the buildings and stops on the road													
15	Lentekhi municipality, village Khacheshi. Left slope of river Kheledula. The peak 1499 m. to the south-west.													
	1005	15	150	150	850	950	0,2	6	0	0	4	23	890	1010
	Passes by the buildings and stops on the road													
16	Lentekhi municipality, village Kheledi. Left slope of river Kheledula. The peak 1365 m. to the south-west.													
	940	5	90	90	350	400	0.1	3	0	0	2	19	370	942
	Crosses the road and stops at the buildings													
17	Lentekhi municipality, village Tsinashi. Left slope of river Kheledula. The peak 1286 m. to the south.													
	815	15	300	300	1070	1150	0.2	3	0	0	3	20	1040	820
	Pass by the buildings, cross the road, the ravine and stop in the river bed													

18	Lentekhi municipality, village Tsinashi. Left slope of river Kheledula. The peak 1286 m. to the south.													
	815	15	300	300	990	1065	0,2	3	0	0	3	19	950	820
	Pass by the buildings, cross the road, the ravine and stop in the river													
19	Lentekhi municipality, village Faki. Left slope of river Kheledula. The peak 1848 m. to the Tsanashi													
	830	30	190	190	2560	2730	0.6	9	0	0	13	27	2620	850
	will pass the village near the buildings of Faki, crosses the road, ravine, stops at village in Nash													
20	Lentekhi municipality, village Faki. Left slope of river Kheledula. The peak 1848 m. to the south.													
	830	30	190	190	1860	1995	0.4	9	0	0	8	24	1900	845
	Pass the village near the buildings of Faki, crosses the road, ravine, stops at village in Tsanashi													
N	Altitude, m		Length, m		Total		Avalanche area, ha	Tilt angle, degree	Speed, m/s	Impact strength, t/m^2	Volume 1000 m^3	Avalanche height, m	Length, m	Suspension height
	Absolute	Relative	Horizontal	Factual	Horizontal	Factual								
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
21	Lentekhi municipality, village Lesema. Right slope of river Kheledula. The peak 1848 m. to the north-east.													
	800	35	60	70	1020	1170	0,6	30	0	0	10	22	1130	670
	Crosses the road, buildings, river and stops on the opposite slope.													
22	Lentekhi municipality, village Lesema. Right slope of river Kheledula. The peak 1590 m. to the north-east.													
	800	-35	60	70	1020	1170	0,6	30	0	0	10	22	1130	670
	Crosses the road, buildings, river and stops on the opposite slope.													
23	Lentekhi municipality, village Lesema. Left slope of river Kheledula. The peak 1917 m. to the South-west.													
	770	15	240	240	890	980	0,8	4	0	0	12	19	900	765
	Pass by the buildings, cross the river and rise to the road.													
24	Lentekhi municipality, town Lentekhi. Right slope of river Kheledula. The peak 1410 m. to the north-east													
	725	10	80	80	520	630	0.1	7	0	0	1	18	600	730
	Pass by the buildings, cross the road and stop in the river													
25	Lentekhi municipality, town Lentekhi. Right slope of river Kheledula. The peak 1410 m. to the north-east													
	750	20	20	30	960	1115	1.2	45	0	0	20	21	1110	740
	Pass by the buildings, cross the road, the river and stop on the opposite slope.													
26	Lentekhi Municipality, the right slope of the Lascadura River, The peak 971 m. to the east													
	755	10	50	50	340	425	0.1	-11	0	0	1	17	400	750
	Pass by the buildings, cross the river and stop on the road													
27	Lentekhi Municipality, the left slope of Lascadura River, Mt.1175 m. to the south-west.													
	745	10	130	130	590	680	0.6	4	0	0	9	19	630	750
	Crosses the road, passes the buildings, stops in the river													
28	Lentekhi Municipality, the right slope of Tskhenistskali River, Mt.1175 m. to the south.													
	725	10	130	130	410	460	0.2	4	0	0	3	17	400	730
	Cross the road, pass by the buildings													
29	Lentekhi Municipality, the left slope of the Tskhenistskali River, Mt.1299 m. to the north.													
	745	25	230	230	920	1015	0,3	6	0	0	5	19	960	750
	Crosses the road, passes the buildings, stops in the river													
30	Lentekhi Municipality, the left slope of Tskhenistskali River, village Babili, Mt.1177 m. to the north.													
	775	15	90	90	1810	1985	1.5	9	0	0	29	24	1955	770
	Pass near the village Babili buildings, crosses the road, the river and stops on the road													
31	Lentekhi Municipality, the left slope of the Tskhenistskali River, village Babili, Mt.2759 m. to the south-east.													
	880	-100	300	310	4040	4520	48.0	19	0	0	134	35	4300	810
	Pass the village near the Babil buildings, crosses the road, the river and stops on the opposite slope													
32	Lentekhi Municipality, the right slope of Tskhenistskali River, village Shtvili, Mt.1952 m. to the south-west.													

	1000	-35	140	145	1860	2105	6.0	14	0	0	134	28	2020	980
	Pass by the buildings of Shtvili village, cross the river and come up on the road													
33	Lentekhi Municipality, the right slope of Tskhenistskali River, village Buleshi, Mt.1952 m. to the south-east.													
	1030	-50	110	120	1190	1325	0.4	8	0	0	7	24	1260	1000
	Crosses the road, passes the buildings, crosses the river and stops opposite on the slope													
34	Lentekhi Municipality, the right slope of Tskhenistskali River, village Mami. Mt.2116 m. to the south													
	1025	-10	50	50	2970	3275	9.5	11	0	0	25	35	3250	1020
	Crosses the road, passes the buildings, crosses the river and stops oppositeon the slope road													
N	Altitude, m		Length, m		Total		Avalanche area, ha	Tilt angle, degree	Speed, m/s	Impact strength, t/m²	Volume 1000 m³	Avalanche height, m	Length, m	Suspension height
	Absolute	Relative	Horizontal	Factual	Horizontal	Factual								
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
35	Lentekhi Municipality, the right slope of the Tskhenistskali River, village Mami. The peak 1948 m. to the south-west													
	1050	-25	80	85	1100	1210	0.7	17	0	0	13	24	1170	1040
	Pass by the buildings, cross the river and stop on the opposite slope road													
36	Lentekhi Municipality, the right slope of Tskhenistskali River, village Makhashi. The peak Airashi 3189 m. to the south-east													
	1325	0	20	20	3880	4355	160.0	0	0	0	448	35	4350	1325
	Pass by the buildings, cross the road, stop in the river													
37	Lentekhi Municipality, the left slope of Koruldashi River, village Tsana. The peak 2302 m. to the south-east													
	1710	-20	100	100	540	615	0.1	-11	0	0	2	30	570	1700
	Pass by the buildings, cross the river and rise to the road of the second slope													
38	Lentekhi Municipality, the left slope of Koruldashi River, village Tsana. The peak 2339 m. to the west													
	1670	-15	90	90	800	900	0.2	-9	5	1	5	32	920	1665
	Crosses the road, crosses the river and stops at the buildings													
39	Lentekhi Municipality, the left slope of Koruldashi River, village Tsana. The peak 2339 m. to the west													
	1690	-20	60	65	560	670	0.1	18	0	0	2	30	640	1680
	Crosses the road, crosses the river and stops at the buildings													
40	Lentekhi Municipality, the left slope of the Tskhenistskali River, village Cvelieri. The peak 2936m. to the north													
	1000	-20	60	65	3470	3840	19.0	-18	0	0	53	35	382	995
	Pass by the buildings, cross the road, the river. Horseshoe and stops													
41	Lentekhi Municipality, the left slope of the Khopuri River, village Nanari. The peak 1373m. to the north-west													
	950	20	220	220	890	970	0.3	5	0	0	5	21	800	960
	Pass by the buildings, cross the road													
42	Lentekhi Municipality, the right slope of the Khopuri River, village Khofuri. The peak 1213m. to the south-west													
	660	15	170	170	415	475	0.1	5	0	0	1	16	405	667
	Crosses the road, passes by the buildings and stops at the river in Khopuri													
43	Lentekhi Municipality, the right slope of the Khopuri River, village Khofuri. The peak 1213m. to the south-west													
	700	-10	80	80	710	815	0.2	-7	0	0	3	18	775	695
	Cross the road, pass by the buildings, cross the river Khofuri. stops on the opposite slope													
44	Lentekhi Municipality, the left slope of Tskhenistskali River, village Khopuri. Mt.1351 m. to the wets													
	595	5	200	200	780	900	0.2	1	0	0	3	17	920	598
	Pass by the buildings, cross the road and stop at the river Tskhenistskali													
45	Lentekhi Municipality, the right slope of Gobishuri River, village Ghobi. The peak 1723 m. to the south-wets													
	1450	-35	110	115	880	965	1.7	-18	0	0	36	26	880	1425
	Pass by the buildings, cross the river Gobishuri and stops on the opposite slope													

46	Lentekhi Municipality, the left slope of Tskhenistskali River, village Sasashi. The peak 14531 m. to the north-east													
	1143	2	30	30	760	825	0.4	4	0	0	7	23	820	1144
	Passes by the buildings and stops on the road													
47	Lentekhi Municipality, the left slope of Tskhenistskali River, village Leusheri. The peak 2992 m. to the north													
	1035	25	110	110	5970	6325	350	13	0	0	980	35	6325	1025
	Pass by the buildings, cross the road and stop in the river													
N	Altitude, m		Length, m		Total		Avalanche area, ha	Tilt angle, degrees	Speed, m/s	Impact strength, t/m²	Volume 1000 m³	Avalanche height, m	Length, m	Suspension height
	Absolute	Relative	Horizontal	Factual	Horizontal	Factual								
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
48	Lentekhi Municipality, the left slope of Tskhenistskali River, village Tekali. The peak Tekali 3044 m. to the north													
	1050	-50	70	85	5050	5485	280.0	35	0	0	7840	35	5440	1025
	Pass by the buildings, cross the road, the river and stop on the slope													
49	Tsageri Municipality, the right slope of Lajanuri River, village Lesindi. Mt. 938 m. to the north-east													
	810	20	100	100	350	370	0.1	11	0	0	1	17	320	820
	Pass by the buildings, cross the road													
50	Tsageri Municipality, the left slope of Lajanuri River, village Lajana. Mt.1252m. to the north-east													
	590	10	100	100	1140	1265	1.4	6	0	0	21	19	1120	595
	Pass by the buildings, cross the road													
51	Ambrolauri Municipality, the right slope of Lekhuni River, village Uravi. The peak 2208m. to the south-east													
	900	-40	120	130	2120	2305	0.6	18	0	0	13	26	2260	880
	P0.6ass by the buildings, cross the road, the river and stop on the slope													
52	Ambrolauri Municipality, the right slope of Lekhuni River, ore of Lekhuni. The peak 2862m. to the south-east													
	1830	25	550	550	2350	1540	85.0	3	0	0	2380	35	2300	1840
	Pass by the buildings, cross the road, stop in the river bed													
53	Ambrolauri Municipality, the left slope of Lekhuni River, ore of Lekhuni. The peak 3076m. to the north-west													
	1855	35	310	310	2540	2875	205.0	6	0	0	5700	35	2260	1880
	Pass by the buildings, cross the road, the river and stop by the buildings													
54	Oni Municipality, the right slope of Chashuri River, village Gona. The peak 2680m. to the south-east													
	1720	30	200	200	690	790	0.1	8	0	0	2	31	700	1735
	Pass by the buildings, cross the road													
55	Oni Municipality, the right slope of Rioni River, village Chiora. The peak 1824m. to the south													
	1280	20	260	260	850	930	0.2	4	0	0	4	25	780	1290
	Pass by the buildings and cross the road													
56	Oni Municipality, the right slope of Chanchakhi River, village Glola. The peak 1926m. to the south													
	1245	5	220	220	1150	1280	0.3	1	0	0	7	27	117	1247
	Pass by the buildings, cross the road and stop in the river													
57	Oni Municipality, the left slope of Chanchakhi River, village Glola. Mt. 2347m. to the north													
	1315	5	80	80	530	600	0.1	4	0	0	2	25	550	1318
	Pass by the buildings and cross the road													

In the table of morphometric and dynamic characteristics of avalanches, columns 2–9 provide data on the absolute and relative height of the avalanche and its separate sections, horizontal and actual length, surface slope, and area of the avalanche center. Columns 10–15 present numerical data on the values of avalanche speed and impact force, avalanche cone volume, moving avalanche snow height, avalanche length, and the absolute height of the avalanche stop on a separate section of the avalanche collector. The last column of each avalanche description indicates the place where the avalanche will stop.

e.g. It will pass by the building, cross the river, cross the road, and stop on the opposite slope. In addition to these numerical data, the location of each avalanche is given (river valley, height of the mountain, or peak where the avalanche begins). The settlement and the main object of our research are indicated a road where an avalanche can cause damage. A minus sign in front of the number in the third column indicates that the avalanche crossed the road, ravine, or river and stopped on the opposite slope.

By combining the existing basic data and the data of our expeditionary works, we were able to create a modern, large-scale geo-informational maps of the avalanche danger of highways in the Racha-Lechkhumi and Kvemo Svaneti regions (Fig. 4; Fig. 5).

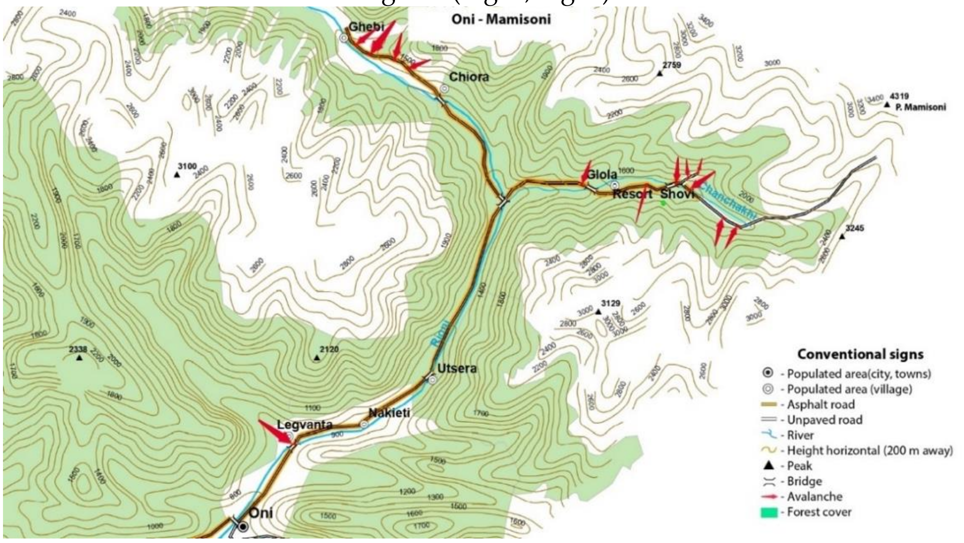

Figure 4: *Avalanche hazard map of Oni-Mamison section of the highway of Racha-Lechkhumi and Kvemo Svaneti region*

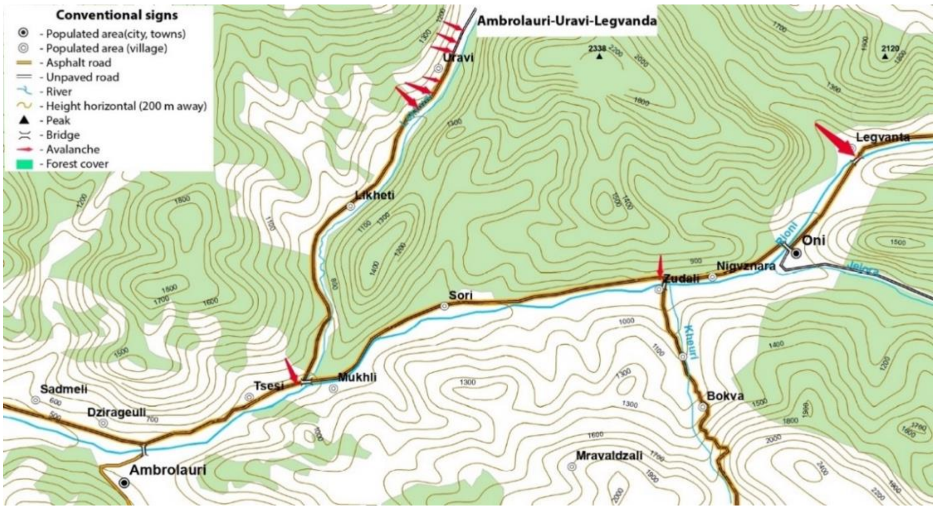

Figure 5: *Avalanche hazard map of Ambrolauri-Uravi-Legvanda section of the highway of Racha-Lechkhumi and Kvemo Svaneti region.*

IV. Discussion

Out of 76 avalanche collection points in the territory of Racha-Lechkhumi and Kvemo Svaneti region [14], 57 were identified, where in the event of an avalanche, a specific section of the highway is included in the area of avalanche arrival, that can cause damage to road infrastructure and, in some cases, human casualties.

The conducted research revealed that there are avalanche-prone areas on the highways of all four municipalities in Racha-Lechkhumi and Kvemo Svaneti region. Among them, Lentekhi municipality (48 sections), Oni municipality (4 sections), Ambrolauri municipality (3 sections), and Tsageri municipality (2 sections) are distinguished by the intensity of avalanche-prone areas. The slopes of 11 rivers and 31 rural areas of the region fall within the area of the highway's avalanche-prone area (Table 3.).

Table. 3: *Villages and Rivers with avalanche danger of highways section according to municipalities*

Villages with avalanche danger highways section according to municipalities				Rivers with avalanche slopes
Oni	Ambrolauri	Tsageri	Lentekhi	11
4	1	3	24	

V. Conclusions

Based on received data, processing

- Avalanche-risk highways of Racha-Lechkhumi and Kvemo Svaneti region were studied, and their climatic characterization will be done;
- Geo-informational maps were created - a schematic maps of each avalanche-prone road in the region;
- The morphometric and dynamic characteristics of each avalanche were calculated.
- The place of landing and stopping of the avalanche was indicated;
- The frequency of avalanches was determined according to the amount of snow.
- The obtained results will be the basis for the preparation and implementation of anti-avalanche works on the highways of the mountainous regions of Georgia.

Acknowledgement

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Note: The report on the mentioned study entitled “Snow avalanches on road sections of Racha-Lechkhumi Kvemo Svaneti region (Georgia))” was made at an international scientific conference held in 2023 in Rome (Italy). - 11th International Conference on Sustainable Development (ICSD) (https://ecsdev.org/books-proceedings/proceedings-2023)

References

[1] Saluqvadze, M. (2018) Cadastre of avalanches of Georgia. Institute of Hydrometeorlogy of Georgian Technical University, pp11.

[2] Saluqvadze, M. (2011) Avalanche hazard in Zemo (Upper) Svaneti. Institute of Hydrometeorology of Georgian Technical University.

[3] National environmental agency (2019). https://nea.gov.ge/En/popular/7

[4] Pipia M., Gorgijanidze S., Beglarashvili N., Kobakhidze N., Jintcharadze G. “Avalanche Danger on the Highways of the Samegrelo-Zemo Svaneti Region (Georgia)”, // European Journal of Sustainable Development,2023 / Vol. 12 (3), pp. 175-184

[5] Gorgidjanidze S., Beglarashvili N., Pipia M., Kobakhidze N., Jintcharadze G. “The Spread of Snow Avalanches at Transport Junctions in the Mountainous Regions of Georgia”, European Journal of Sustainable Development, 2023 / Vol. 12 (3), pp. 217-228

[6] Sophio Gorgidjanidze, Mikheil Pipia, Nazibrola Beglarashvili, Natela Kobakhidze,Gocha Jintcharadze, Lizi Ezieshvili. “Dangerous Natural Disasters (Avalanches, HeavySnow, Snowstorm) inAjara and Guria Region”, Proceedings of Niko Berdzenishvili Instituteof Batumi Shota Rustaveli State University Vol. XVI, 2023. p.1277-1289

[7] Salukvadze, M. (2018) Avalanche-prone regions of Georgia. Proceedings of the Geographical Society of Georgia. New Series I (XIX), pp. 177-128.

[8] Kaldani, L., Salukvadze, M. (2015) Snow avalanches in Georgia. (monograph), 169 p.

[9] Salukvadze, M. (2018) Cadastre of avalanches of Georgia. Institute of Hydrometeorology of Georgian Technical University, pp12.

[10] Saluqvadze, M. (2018) Cadastre of avalanches of Georgia. Institute of Hydrometeorology of Georgian Technical University, pp14.

[11] http://rachalechkhumi.blogspot.com/2014/.

[12] Saluqvadze, M. (2018) Cadastre of avalanches of Georgia. Institute of Hydrometeorology of Georgian Technical University, pp40-44.

[13] Salukvadze, M. Kobaxidze, N. (2015) Role of forest in formation of avalanches. Institute of Hydrometeorology, Georgian Technical University. V-121, pp.27-29.

[14] Saluqvadze, M., Lomidze, N. (2017) SOLID PRECIPITATION AND SNOW COVER ON THE TERRITORY OF GEORGIA Institute of Hydrometeorology of Georgian Technical University. vol.124, pp.7-11.

CURRENT CONCEPT OF RISK: THE HIGHER THE PROBABILITY OF AN EVENT, THE LOWER THE RISK

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Abstract

With the adoption of a new concept of risk in the economy (ISO 31000:2009), the main task of risk assessment is to justify the adoption of management decisions under conditions of uncertainty. Within the framework of the new concept, a new fundamental definition of risk (risk - the effect of uncertainty on objectives) was established. The most important practical consequence of the new concept of risk was introduction of concept "likelihood" instead of "probability". Another paradoxical conclusion follows from the current definition of risk, which is important for understanding the essence of risk and improving risk assessment methodologies in current conditions is: the higher the probability of occurrence of the assessed event, the lower the "actual risk" associated with this event.

Keywords: risk, probability, likelihood, uncertainty, OHSI method

I. Causes and consequences of the risk management revolution

In 2009 (ISO 31000 standard) the revolution in understanding of risk and tasks of risk management, which actually began at the end of the XX century, was completed. However, this event, its causes and consequences have not yet been sufficiently noticed and studied by both the scientific community and practitioners.

To assess the value of risk, the past conception used the following definition: risk is a combination of the severity of possible harm and the probability of occurrence of this harm. This is a particular variant of the modern fundamental definition, which leaves open the question of what we mean by "harm" (whose harm, what is harmed) and what "probability" we mean (objective or subjective).

Let us call this approach technocratic, because it is focused on risk assessment in the area of presumably known initial data, is based on precise mathematical methods, and its central element is the very process of obtaining values of risk elements (probability and harm) without taking into account the possibility of its further use of results in the interests of risk management.

Since in the previous (before 2009) assessment of risk value was associated with the term "probability" (probabilistic risk assessment, PRA), the methods of classical probability theory, statistical methods were used for its assessment.

It is not difficult to see that if we use these methods to estimate probability, then:

- we assume a high degree of confidence in the initial data, which are based either on reliable statistics of the flow of homogeneous random events, or knowledge of the actual state of all elements of the system at any point in time;
- as a result of such an assessment, we do not receive a risk value for decision-making purposes, but a reasonable forecast of the state of the system for a given period, assuming that the input data included in the risk assessment remain unchanged;
- management decision-making in such a model is based not on uncertainty and risk assessment, but on predetermination and confidence in the preservation of the established trend.

At the same time, obviously, we cannot use the classical approach to assessing probability when assessing the risk of rare or unique events, where we must use the term "likelihood" and apply fundamentally different methods of assessing likelihood rather than probability.

The modern definition of risk (risk - the effects of uncertainty on objectives) puts in the center of the risk management problem namely the uncertainty of the future and implicitly introduces the main actor of risk management - the owner of risk (decision maker, LPR), who is both the owner of the goal and responsible for the failure to achieve the goal as a result of risk realization.

Risk assessment within the framework of the modern concept is based on the following assumptions:

- the situation in economy, politics, technology, social relations is changing so fast these days that any past statistics loses its meaning (there are no statistics);
- events of interest to the risk manager (decision maker) are so rare and differing in essential features (not homogeneous) that it is impossible to form a representative sample of them (there are no frequency);
- development of technologies (innovations) requires risk assessment in the absence of information about similar activities and similar events (there were no similar events at all).
- the purpose of risk assessment is to assess the magnitude of the impact of an unfavorable event on the purpose of the activity (comparison of the purpose of the activity, probable damage and costs for the implementation of preventive measures).

Despite the fact that the objective needs to change the concept of risk arose at the end of the XX century, in economics the new concept of risk was formalized only in 2009 with the release of the international standard ISO 31000).

Nevertheless, until now among modern scientists and practitioners dealing with the problems of risk assessment, the followers of the previous concept of risk, based on objective probability, certainly prevail [1, 2, 3]. It is interesting to note that the PRA approach is also used to assess the risks of such rare events as earthquakes [4] or events that have not yet occurred [5].

The promoters of the subjective-probabilistic approach, to whom the author includes himself, are still underrepresented both in scientific publications and in practical developments.

A detailed analysis of these two views is given, for example, in [6].

II. The higher the probability of an unfavorable event occurring, the lower the risk. Paradox or obviousness?

The term "probability" is usually understood as either a frequency probability, somehow related to statistics (representative sample) of past similar cases, or to a homogeneous flow of events, or to the availability of reliable objective information (facts) about the possible occurrence of this or that event. From which we can conclude that a rating of "probably" means a high degree of confidence that the event is " very likely" to occur in the foreseeable period of time. A high degree of certainty that an event is "very likely" to occur means a low level of uncertainty about the decision to respond to that event.

Estimates of the probability of low-probability events can be obtained with a high degree of confidence on the basis of large-scale sampling (thousands of homogeneous events) or accurate knowledge of the actual characteristics of a system or process (based on objective research or monitoring). This case is characteristic of statistical methods used, for example, in quality management systems (QMS) in mass homogeneous production.

However, in risk management such a situation seems to be fundamentally impossible. For rare or unique events occurring in the sphere of economy, politics, global cataclysms (earthquakes, tsunamis), the estimation of probability (more precisely - likelihood) of occurrence of such events can be obtained only with a very low degree of reliability. This excludes the possibility of their use for decision-making purposes.

On the contrary, a low level of uncertainty means low effects of uncertainty on objectives and therefore low risk in decision making, regardless of the magnitude of the probability! Therefore, risk as effects of uncertainty on objectives (i.e., within the 2009 concept) decreases simultaneously with the reduction of uncertainty both in terms of estimating the magnitude of harm and in terms of estimating the probability of an event occurring.

This article deals with "risk" within the framework of the modern concept of 2009 (ISO 31000), which in the limit allows for the complete absence of information about past events. The degree of probability of occurrence in the future of an extremely rare in the past or unique event is negligible, but the occurrence of the event is not excluded, which determines the high level of uncertainty and its effect on the decision on the need to take measures to respond to the risk. Therefore, instead of the term "probability" in the framework of the modern concept of risk, the term "likelihood" is used, which initially implies a low degree of confidence both in the initial data and in the results of probability and risk assessment.

As is known, when designing the protection of the Fukushima NPP, it was assumed, based on previous observations, that earthquakes with a magnitude of more than 8.5 were "practically" impossible. Nevertheless, the main shock occurred with a magnitude of 9.1, which caused a tsunami wave whose height in the area of the plant exceeded the calculated height by almost 10 meters. It should be noted that according to some studies, earthquakes with a magnitude of more than 9 in this area were accepted as "extremely unlikely".

This is the seeming paradox: at high values of event probability, risk assessment for decision-making purposes does not require special knowledge or techniques, since taking measures to reduce risk is obviously necessary if the damage is assessed as unacceptable. This conclusion is valid in the area of evaluating the possibility of the event occurrence, where we can speak exactly about "the probability", i.e. the event is more expected than impossible.

At the same time, the maximum risks of decision-making are associated precisely with rare or unique events, the probability of occurrence of which is negligible, but not excluded (likelihood), and damages (harm) are assessed as critical or catastrophic. These events are characterized by low probabilities and extremely high degree of uncertainty.

Therefore, the statement "the higher the probability, the lower the risk" is true only within the framework of the modern concept of risk (2009), where the definition "risk - the effects of uncertainty on objectives" is used, and the concept of likelihood is used instead of probability.

Thus, the use of "likelihood" instead of "probability" in the modern concept of risk is not just a formal replacement of the term, but a fundamentally important distinction, reflecting a change in the focus of attention in risk assessment from statistically expected events, the possible effects of which on objectives have already been taken into account, to low-probability events that have critical effects of uncertainty on objectives, and their consideration in management is characterized by high cost and uncertainty.

III. The essence of uncertainty in risk management

The key concept of the modern concept of risk is uncertainty. Physics and computer science use the concept of uncertainty, similar to the concept of entropy, which reflects the measure of uncertainty in the state of any system. To estimate the amount of uncertainty (information entropy) Shannon's formula is used [7]

$$H_e(x) = -\sum_{i=1}^{n} P_i \; log_2 \, P_i. \tag{1}$$

It follows from the Shannon formula that the uncertainty value H_e is related to the probability of an event nonlinearly, $H_e \to 0$ if $P \to 1$ and $P \to 0$ and has a maximum near the point $P \approx 0.37$ (Fig.1).

Although the uncertainties of the credible (P=1) and the impossible (P=0) events are equal in the limit, however, it is just as obvious that the information entropy function behaves differently in areas close to 0 and close to 1.

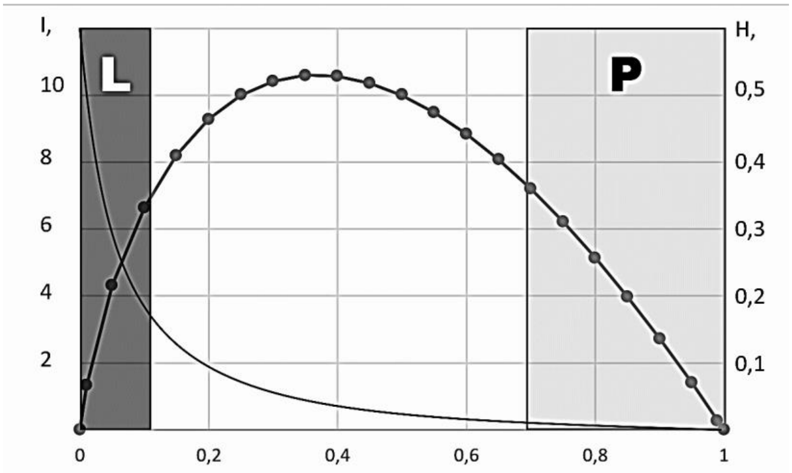

Figure 1: *Probability, likelihood and uncertainty*

The uncertainty of occurrence of extremely unlikely events (L, likelihood, q) is indeed substantially larger than that of their corresponding extremely likely (P, probability, P=1-q) events.

In general, formula (1) describes the uncertainty of the current state of the system, which is characterized by N possible states. That is, the entropy measure is the difference between the information contained in the new message and the part of information that is precisely known (or well predictable) in the message.

However, in the field of risk management, due to the lack (absence) of precisely known information, the general assessment of uncertainty (uncertainty) of the state of the system as a whole is not of practical importance. The decisive value is the assessment of certainty (certainty) of finding the system in a certain specific state from the set N or the possibility of transition of the system to such a state. Consequently, in the field of risk management it is necessary to consider uncertainty not in the form of information entropy, but in the form of self-information (2), which is a measure of uncertainty (unexpectedness) of occurrence of a certain event or being of the system in a certain state.

$$H_s\ (x) = -log_2\, P_x. \qquad (2)$$

That is why the ISO 31000 standard introduces the concept of uncertainty not in the form of information entropy, but in the form of self-information, i.e. complete or partial absence of information necessary to understand an unfavorable event, its consequences and their probabilities. In purposeful activity, the probability of a favorable outcome is much (by orders of magnitude) higher than a negative one, and its uncertainty is significantly lower. Therefore, in risk management, the probability of a negative outcome is usually considered, because a favorable outcome is expected (planned and ensured).

Passing in the uncertainty assessment from the information entropy formula to self-information, we will see even more significant difference in the values of uncertainties in the areas P and L (see the table below).

For example, if the values of uncertainty H at probability values $P_P = 10^{-1}$ and $P_L = 10^{-3}$ differ in times, then the values of uncertainties at the magnitude of the lack of self-information differ by four orders of magnitude.

Thus, a high probability of being a system in a critical (dangerous) state contains a low uncertainty and, accordingly, a low level of risk in making a management decision to prevent the

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dangerous situation: "unambiguously - to act!". Conversely, a low probability of the system being in a dangerous state contains a high level of uncertainty: whether to act (to bear, possibly, excessive costs) to prevent the development of the situation or to wait ("maybe this time it will not happen").

Table: *Significant difference in the values of uncertainties in the areas P and L*

Likelihood (L), q	Probability (P), P=1-q	H_L/H_P	I_L=-log$_2$ L, bit	I_P=-log$_2$ P, bit	I_L/ I_P
0,001	0,999	6,91	9,97	0,001	9970,0
0,01	0,99	4,63	6,64	0,014	474,3
0,05	0,95	3,07	4,32	0,074	58,4
0,1	0,9	2,43	3,32	0,152	21,8

In the framework of the ISO 31000 concept, this leads us to a seemingly paradoxical conclusion: **the higher the probability of a hazardous event (in the P zone), the lower the associated uncertainty in decision making, i.e. the lower the risk of the risk owner.**

At the same time, in the L (likelihood) zone for rare and unique events this rule does not work anymore, because the use of the term “probability” is excluded. And for events with expected catastrophic consequences, not only the assessment of the probability of occurrence of the event on the basis of the classical probability or "frequency", but also the assessment of risk on the basis of the formula "risk - the product of the probability of occurrence of the event by the amount of harm" loses its meaning.

V. The problem of estimating the probability and risk of rare events

As noted earlier, in the presence of a steady stream of events in the past, risk assessment is effectively a prolongation of past losses on the basis of deriving probability from the past frequency of events for future periods (Fig. 2). Generally speaking, this goes beyond the scope of risk management tasks for several reasons discussed in section 1.

When assessing risks caused by rare or unique events, the main task is to estimate the likelihood of their occurrence in the future in the absence of information about their frequency or, in general, about their occurrence in the past, that is, in the absence of any information about the value of probability. This leads to the task of determining the likelihood of occurrence of some event in the future on the basis of information about the current state of the analyzed system.

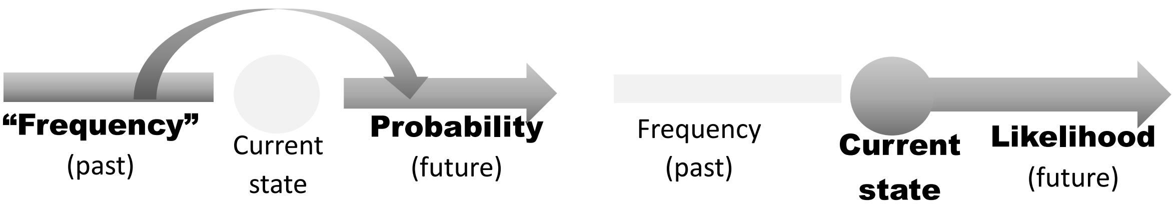

Figure 2: *The evolution of the concept of risk from statistical (on the left) to the concept based on uncertainty (on the right)*

On risk assessment in the L (likelihood) area, we usually do not have sufficient information about the probability of occurrence of events that are known to be rare, unique or assumed to be almost impossible.

In the traditional approach as a value of risk it is accepted to consider a combination of probability of occurrence of a dangerous event and severity of its consequences. In practice, as a combination is considered the product of

$$R = P \cdot W. \quad (3)$$

In the case of critical risks, this approach is not suitable, because the assessment of the probability of occurrence of an extremely unlikely hazardous event has no factual basis, and either does not give an idea of the actual value of the risk, or serves as a source of unfair manipulation. For example, if the estimated amount of harm is billions of dollars, then by simply manipulating the probability value (e.g., to 10^{-6}) the level of risk can be reduced to negligible (thousands of dollars).

In fact, estimates of extremely small probabilities (less than 10-3) are based, usually, on assumptions rather than on facts. Therefore, it is the economic (subjectivist) approach to probability estimation, outlined, for example, as early as in *de Finetti* [8] and developed in [9], that works in this range of probabilities.

De Finetti proposed to estimate the probability of occurrence of the event of interest related to economic consequences on the basis of game theory, weighing the possible benefits and losses from taking a particular decision regarding risk:

the probability of an event is the price *at which the person assigning the probability is neutral between buying and selling a ticket that is worth one unit of payment if the event occurs, and worthless if not.*

In relations to risk assessment, this statement should be understood in such a way that in the case of critical risks, it is advisable to consider a combination of the magnitude of the expected damage, the level of likelihood of causing such harm and the amount of costs for preventing the expected harm

$$(1-q) \cdot C \leftrightarrow q \cdot W,$$

from where it follows

$$q = \frac{C}{C+W} \approx \frac{C}{W} \ ,$$

where W is possible harm (cost); C is the allowable costs of avoiding harm ($C<<W$); q is the subjectively estimated probability of harm ($q<<1$).

That is, based on the de Finetti approach, the likelihood of a dangerous event in risk management is subjectively estimated as the ratio of the allowable costs of preventing harm to the magnitude of this harm. In the given example, it was assumed that protective measures are absolutely effective (E=1) and completely prevent (exclude) a dangerous event and the associated damage W. In fact, any preventive protective measures involve costs (this is, in fact, the essence of the risk problem), but have limited effectiveness E<1. In this case, the total losses W_Σ (the sum of the probable damage W and the cost of preventing it C) will be

$$W_\Sigma = q[EC+(1-E)(C+W)]+(1-q)C \approx C+qW(1-E).$$

If we exclude from consideration the subjective component of q (will happen or will not happen) and assume that the identified possibility of harm as a result of a possible adverse event is still realized (in an arbitrary period of time), then the formula of total losses (residual risk)

$$R_r \approx C+W_\Sigma(1-E),$$

and taking into account the assumptions C<<W, E→1

$$R_r \approx W(1-E),$$

where the expression in parentheses (1-E) represents the total estimated probability of an adverse event, provided protective measures are taken with the overall effectiveness of E.

Based on this approach, the author has developed a risk assessment method, which is called the OHSI Method (OHSI, Occupational Health & Safety Institute) [10], which is implemented in the Russian national standard GOST R 12.0.011-2017. This method was developed for the field of occupational safety, characterized precisely by rare heterogeneous events (frequency 10^{-2} ... 10^{-3} per year per 1000 employees) with significant damage (injuries and deaths of workers at work).

The method is based not on an analysis of the frequency of past allegedly similar events, which do not happen in the field of occupational safety, but on the use of objective information about the availability, protective properties (effectiveness) and the current state of protective measures. In the OHSI Method, the probability (likelihood) of the occurrence of an adverse event is assessed through the effectiveness of protective measures (barriers) that prevent the realization of the danger

$$P=1-E_{\Sigma},$$

where E_{Σ} is the total effectiveness of protective measures, defined in such a way that in the absence of protective measures the probability of occurrence of the event is equal to 1 (credible event), and when the source of danger is eliminated P=0 (impossible event). An example of calculation of E_{Σ} for several protective measures is also given in [10].

For practical application of the OHSI Method, a procedure (technology) has been developed, including two special ranking techniques for establishing the severity of consequences from identified hazards and establishing the effectiveness of protective measures. The registers formed in this way are the measuring tools of the OHSI Method. With the volume of registers more than 20 items, such registers provide quantitative nature of risk assessment and a high degree of objectivity of the risk assessment procedure, which is extremely necessary for the implementation of an effective risk management system of the organization.

The procedure based on the OHSI Method is automated and has been successfully applied in practice in the assessment of occupational injury risks, including as a methodological basis for OH&S management systems (OHSMS).

The disadvantage of the OHSI Method is only apparent when it is applied to critical events: extremely unlikely events (accidents) with catastrophic consequences. To significantly reduce the risk in these cases requires protective measures with a performance of 0.99...0.999, which cannot be confirmed on the basis of the ranking methodology. In this situation, the standard methodology for establishing the effectiveness of protective measures is not sufficiently convincing and requires uncertainty reduction.

As possible solutions to this problem, currently considered are:

- instrumental confirmation (monitoring) of preservation of design structural parameters of the object that affect safety (strength of the structure, condition of the foundation and soil);
- supplementing design structural solutions with special structural measures aimed at increasing the strength and stability of the structure under changed conditions;
- monitoring of availability, application and preservation of design parameters of special protective measures;
- application of statistical methods from the QMS field to identify trends in the change of protective properties (effectiveness of protective measures), etc.

References

[1] Taotao Zhou, Mohammad Modarres, Enrique López Droguett, Multi-unit nuclear power plant probabilistic risk assessment: A comprehensive survey, Reliability Engineering & System Safety, Volume 213, 2021.

[2] William Keller, Mohammad Modarres, A historical overview of probabilistic risk assessment development and its use in the nuclear power industry: a tribute to the late Professor

Norman Carl Rasmussen, Reliability Engineering & System Safety, Volume 89, Issue 3, 2005, Pages 271-285.

[3] Lee, J.; Tayfur, H.; Hamza, M.M.; Alzahrani, Y.A.; Diaconeasa, M.A. A Limited-Scope Probabilistic Risk Assessment Study to Risk-Inform the Design of a Fuel Storage System for Spent Pebble-Filled Dry Casks. Eng 2023, 4, 1655-1683.

[4] Kotaro KUBO, Yoichi TANAKA, Yuto HAKUTA, Daisuke ARAKE, Tomoaki UCHIYAMA, Ken MURAMATSU, Application of quasi-Monte Carlo and importance sampling to Monte Carlo-based fault tree quantification for seismic probabilistic risk assessment of nuclear power plants, Mechanical Engineering Journal, 2023, 10 巻, 4 号, p. 23.

[5] Polat, B, & Diaconeasa, MA. "On the Use of Probabilistic Risk Assessment for the Protection of Small Modular Reactors Against Terrorist Attacks." Proceedings of the ASME 2021 International Mechanical Engineering Congress and Exposition. Volume 13: Safety Engineering, Risk, and Reliability Analysis; Research Posters. Virtual, Online. November 1–5, 2021.

[6] Terje Aven, Genserik Reniers, How to define and interpret a probability in a risk and safety setting, Safety Science, Volume 51, Issue 1, 2013, Pages 223-231.

[7] C. E. Shannon, "A mathematical theory of communication,'' Bell System Technical Journal, vol. 27, pp. 379-423 and 623-656, July and October, 1948.

[8] de Finetti, B., 1930. Fondamenti logici del ragionamento probabilistico. Bollettino dell'Unione Matematica Italiana 5, 1–3.

[9] Singpurwalla, N., 2006. Reliability and Risk. A Bayesian Perspective. Wiley, NY.

[10] Alexander Fedorets, A new method of occupational risk assessment, based on uncertainty, RT&A, Special Issue № 3 (66), Volume 17, January 2022.

LİTHOFACİES MODEL AND OİL-GAS PROSPECTS OF MESO-CENOZOİC DEPOSİTS İN SHAMAKHİ-GOBUSTAN DEPRESSİON

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Abstract

Shamakhi-Gobustan oil-gas-bearing region is one of the most promising regions of Azerbaijan due to the hydrocarbon potential of Meso-Cenozoic deposits. Mesozoic, Paleogene-Miocene and Pliocene deposits are widespread in the area.
From north to south, the region divided into tectonic zones such as Northern Gobustan, Central Gobustan, Shamakhi, South-western Gobustan, South-eastern Gobustan and Alat.
In each tectonic element, regional anticlinal zones are separated, which are composed of stratigraphic sedimentary layers of a large range on the earth's surface.
Numerous core samples taken from the Meso-Cenozoic deposits in Shamakhi-Gobustan oil-gas-bearing region were analyzed and their reservoir properties were studied. The reservoir properties of the rocks were analyzed for separate zones and different stratigraphic units.
Carbonate content in the northern zone is relatively high, and the carbonation of the Cretaceous deposits varies in a wide range, from 24% to 93.4%. The average porosity of the rocks was more than 14%. However, these sediments are characterized by good reservoir properties, despite the low porosity in some areas. The highest porosity is typical for the Gizmeydan, Angikharan and Chikilchay areas. However, the areas of the northern zone are with low permeability. For this zone, there is an inverse relationship between carbonation and permeability.
In the northern zone, the carbonate content of Maykop deposits is less than that of the Cretaceous sediments and varies in a small interval, it is 17.5% only in the Garayazi area. In most cases, the porosity varies in the range of 20-26 5% in the studied areas, and with these values, the characteristics of the reservoir can be well characterized. Permeability was not very high, it is 20-70 $x10^{-15}$ m^2 only in Tuva area.
In the central zone, the deposits of the Upper Maykop and Chokrak horizons are characterized by low carbonate content and relatively high porosity and permeability.
Lower Pliocene deposits (PS) in South Gobustan are characterized by a high reservoir properties.
Based on the lithofacies analysis of the Shamakhi-Gobustan depression, the increase of the reservoir properties from the North zone to the South direction was determined.
The prospect of oil and gas in Shamakhi-Gobustan oil-gas-bearing region is related to Meso-Cenozoic deposits. Industrially important oil accumulations were identified in the sandy reservoirs of the PS, upper Maykop and Chokrak horizons, which were uncovered during drilling in separate areas in the southeastern and southwestern tectonic zones of the area.
Presence of oil and gas are noted in the Upper Cretaceous fractured limestone and marls, which are widespread in the northern zone. The density of these rocks varies in the range of 1.94-2.55 g/cm^3 along the northern zone. The Upper Cretaceous deposits are buried under the Paleogene deposits in a south-southwest direction.
Oil-filled formations and dolomites in the form of breccias lying in separate intervals along the section of the middle and upper Miocene in central Gobustan are of special interest. It should be

noted that the natural reservoirs for collecting oil and gas cummulatives in the section of the Meso-Cenozoic deposits are the terrigenous and carbonate reservoirs.
The sandy-siltstone reservoirs of Maykop suite and Chokrak horizon are oil-gas-bearing in Hajivalli, Umbaki, Maraza, Donguzlug areas. A short-duration oil flow was obtained in the upper Cretaceous fractured-carbonate reservoirs in Gizmeydan and Hilmilli areas.

Keywords: carbonation, porosity, permeability, reservoir, Maykop, Cretaceous, fractured-carbonate, core

I. İntroduction

The Shamakhi-Gobustan oil-gas-bearing region is a regional geostructural element. İt is located in the southwestern limb of the Greater Caucasus close to the crest part.

The region is surrounded by the following geotectonic elements from north to south: the southern part of Govdag depression (Northern Gobustan), Shamakhi, Central Gobustan, South-western, South-eastern Gobustan and Alat tectonic zone [1,2].

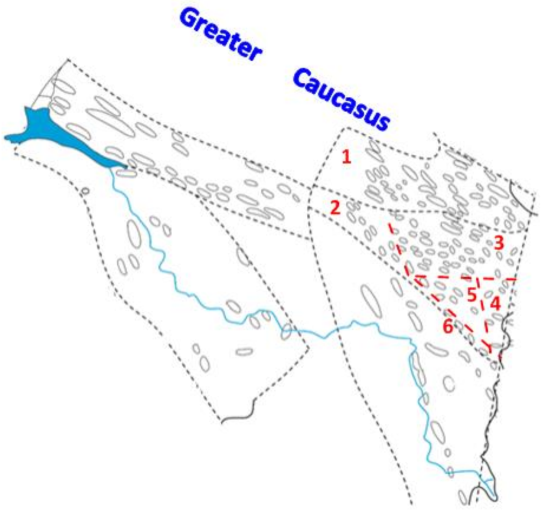

Figure 1: *Overview map of the tectonic zones of the Shamakhi-Gobustan oil-gas-bearing region*
Tectonic zones: 1- Northern Gobustan; 2- Shamakhi; 3 - Central Gobustan;
4 - South-eastern Gobustan; 5 - South-western Gobustan; 6 - Alat

In each geotectonic element, a number of regional anticlinal zones are separated, which are composed of a large range of stratigraphic sedimentary layers on the surface of the earth (from the lower Cretaceous in the north to the upper Pliocene in the south). The common characteristic of these zones is as follows. As a result of the ascent of the northern limbs and the descent of the southern limbs, the anticlines were bent to the south, the crests of the anticlines were complicated by longitudinal faults and mud volcanoes located on them. The dimensions of the folds depend on the lithological composition of the deposits that make them up. The widht of anticlines is 5-7 km made up by competent rocks and length is 13-15 km, while the anticlines made of soft rocks are 2 km widht and 10-5 km length [3].

Shamakhi-Gobustan oil-gas-bearing region is one of the most promising regions of Azerbaijan due to the hydrocarbon potential of Meso-Cenozoic deposits. Paleogene-Miocene deposits, which are widespread in the area, as well as Mesozoic and Pliocene deposits, are one of the main areas of exploration for discovering new oil and gas reserves [4].

The region has a complex geological structure and is relatively poorly studied. There are 79 local uplifts in this oil-gas-bearing region. In total, 5 oil and gas fields with a small reserves were discovered and put into operation in the Shamakhi-Gobustan oil-gas-bearing region, and oil and gas have been produced from these fields for a long time. These are East Hajiveli, Umbaki, Duvanni and Dashgil fields [5,6].

Only one structure- the Shikhigaya structure- was prepared for deep exploration drilling using the seismic exploration method.

Oil and gas occurrences and flows from Meso-Cenozoic deposits are optained. They are related with natural surface outcrops, as well as with fractured carbonate, sandy-siltstone reservoirs of drilled wells in the Shamakhi-Gobustan oil-gas-bearing region [7].

II. Metodology

The collected materials about of Meso-Cenozoic deposits show that these deposits are suffer of facies changes through the section vertically and areally along the horizontal in the Shamakhi-Gobustan oil-gas-bearing region. This is provide a basis for determining the distribution zones of reservoir rocks.

Reservoir properties of numerous core samples taken from Meso-Cenozoic deposits found in the research area were studied.

The oil-gas shows related to the Paleocene reservoirs in the separate uplifts of North Gobustan, formed from Mesozoic deposits, are mainly attributed to its southern part. Here, numerous thin (0.4-1.2 m) calcareous sandstone interlayers are found in the section of the Danian stage of Paleocene series (Ilkhidag suite).

Sand layers up to 10 m thick can be found in the section of the Sumgait suite (Paleocene) in the Garajuzlu and Nabur uplifts of the northern zone [8]. They are fine-grained and dense. Oil seeps are observed related with these sandstone layers in the Tuva area. The thickness of the sandy-clayey layer sometimes reaches 25 m, which is important as an oil object. The thickness of the Sumgait suite increases from the crest part of the folds towards its limbs and periclinals. An increase in the thickness of the sandstone layers is observed in this direction. This fact is also confirmed by the section of numerous structural wells drilled here. In the southern part of the northern zone, the thickness of medium- and coarse-grained sand and sandstone layers reaches 1.5-2 m in the section of the middle Govundag stage of the Eocene series. There is a sandy-clayey layer in the section of 25-30 m thick, which oil shows are found.

The lower and middle Eocene is 150-200 m thick in Central Gobustan and consists of irregular alternation of marly clays, marls, argillite and tuffaceous sandstones. The top of the Upper Eocene is 200 m thick in Cheyildag and is mainly composed of clays, while in Arzani-Kilij it consists of crushed clays [9,10].

In the southern part of the central zone of Gobustan, in the section of the Upper Eocene, intensive oil shows were noted in thin sandy layers (Boyanata, Baygustu, Boztepe).

All areas of Shamakhi-Gobustan are represented by clayey lithofacies of Lower Maykop.

The analysis of the prospecting-exploration works conducted in the South-West Gobustan area of Shamakhi-Gobustan depression shows that the oil and gas shows mentioned along the section are mainly observed in the Upper Maykop, Chokrak and Sarmatian reservoirs. As a result of drilling, intensive oil and gas flows were recorded in East Hajivalli and Gilij areas. Oil and gas deposits from the sandy-siltstone reservoirs of Upper Maykop and Chokrak were discovered in the Umbakı field. In South Gobustan, alongside the section of the Upper Maykop, numerous layers of sand and sandstone are found and their thickness increases toward south and southwest. In the Umbakı field, the horizon III of Maykop series is better studied by drilling and has more oil-gas-bearing [11].

III. Discussion and results

Analyzes of rock samples taken in Shamakhi-Gobustan oil-gas-bearing region were conducted to study the changes in reservoir properties of reservoirs of different ages.

In the Upper Cretaceous marl, sandy limestone rock samples in the Chikilchay area located in the northern zone, the carbonate content is 73-80%, the porosity is 14-26%, and the porosity is very low (2.5-3.0%) in the 2 samples with high carbonate content. The density of rocks is 2.3-2.44 g/cm^3.

In the Upper Cretaceous argillaceous marl samples in Eastern Agburun, carbonate content is 24-27%, porosity is 6.2-9.9%, permeability is 0.07x10^{-15} m^2, in Goradil area, marl samples of the same age have carbonate content of 60.5%, porosity is 6.3%, permeability 0.001x10^{-15} m^2, carbonate content in sandy-limestone samples is 57.6%, porosity is 8.1, permeability is 0.001x10^{-15} m^2, carbonate content in calcareous siltstone samples is 35%, porosity is 5.3%, permeability is 0.001x10^{-15} m^2, in the samples of limestone siltstone taken from Qizmeydan area, carbonate content varies from 27.3 to 93.4%, porosity from 2.9 to 17.8%, permeability from 0.001 to 1.5x10^{-15} m^2.

In the structure-mapping wells drilled in the Goradil area, gas and oil shows from the Upper Cretaceous deposits were observed. The Lower Cretaceous sandy carbonate reservoirs are considered to be more promising in this area. In separate wells (4, 5, 7) in the Garayazi area, active oil, gas, and water shows were recorded from the Upper Cretaceous deposits [12]. The oil and gas prospects of the area are mainly related to the Lower Cretaceous deposits. During the testing of structural-exploration well number of 36 in the Qizmeydan area, 3.5 t/day of light oil flow was obtained from sandstone and sandy limestone deposits of Upper Cretaceous series. Oil flow also was obtained from wells number of 15, 20, 29, 34 during the drilling process [13].

In Yunusdag area clayey limestone rock samples, carbonate content varies from 53.6 to 77.6%, porosity from 2.8 to 3.2%, permeability from 0.001x10^{-15} m^2 (Fıg.2). Weak gas-water shows were observed here in individual wells from Upper Cretaceous (Campanian, Maastrichtian) deposits. The main oil-gas object in the Yunusdag anticline is considered to be the Lower Cretaceous granular carbonate reservoirs.

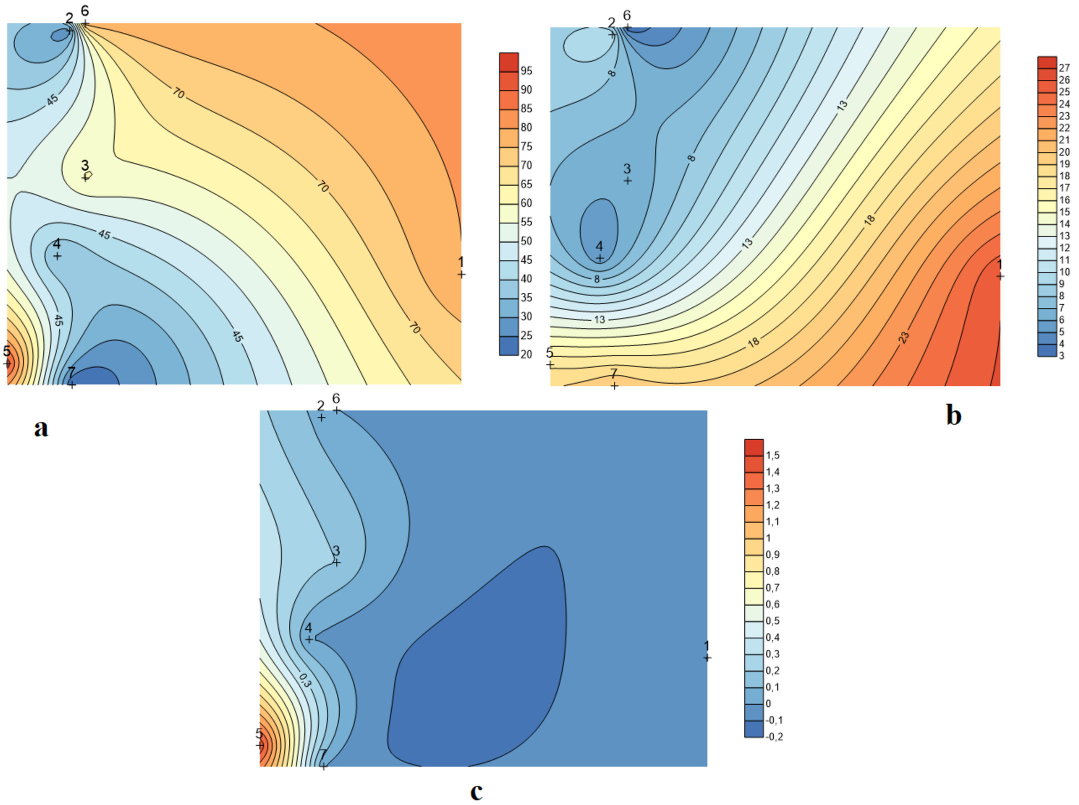

Figure 2: *Carbonate content (a), porosity (b), permeability (c) maps of Upper Cretaceous deposits in the northern zone of the Shamakhi-Gobustan depression*

Areas: 1 - Chigilchay; 2 - Shargi Agburun; 3 - Goradil; 4 - Garayazi; 5 - Gizmeydan; 6 - Yunusdag; 7 - Angikharan

In the Goradil area, located in the northern zone, the carbonate content of Eocene age silty limestone samples is 65.4%, porosity is 7.6%, permeability is 0.001x10^{-15} m^2, Calcareous siltstone samples of Miocene are characterized by the carbonate content of 37.4%, porosity is 15.3%, permeability is 0.001x10^{-15} m^2 , carbonate content in argillite samples of Maykop is 13.5%, porosity is 13.8%, permeability is 0.001x10^{-15} m^2, porosity is 20% in Maykop age clay samples in Agburun area, permeability is 0.001x10^{-15} m^2, porosity in Paleocene age clay samples in Yunusdag area is 13-28% , Eocene age limestone, marl samples have a porosity of 14%.

Carbonate content in siltstone limestones of Maykop agedeposits in Garayazi area is 17%, porosity is 12.7%, permeability is 0.001x10^{-15} m^2, carbonate (8.5-9.0%) in samples of Maykop-age limestone, marl, siltstone, clayey limestone in Gizmeydan area it varies in a small interval (1.7-3.5%).

In the Tuva area of Northern Gobustan (Fig.3), there are numerous oil and gas shows related to Upper Cretaceous deposits, some of which are related to faults. During drilling process of structure-mapping wells number of 2 and 5, oil and gas shows were obtained from deposits of the Paleocene and Danian stages. The drilling process of exploration well number of 1, gas shows was observed at a depth of 113 (Danian)-2219 m (Santonian) [14]. During the passing of the deposits of the Campanian stage in the exploratory well number of 2, gas shows was determined. Despite this, the prospect of industrially important oil and gas deposits is considered to be granular reservoirs of the Lower Cretaceous series. Study results of rock samples taken from well number of 1 show that Paleocene sandstones are light oil-saturated. Their porosity is 15.5-22%, effective porosity is 1.0-2.5%, and permeability is 20-70x10^{-15} m^2.

Oil and gas shows are noted along the section of fractured limestone and marls of Upper Cretaceous buried under Paleogene sediments toward south-southwest in the northern tectonic zone. Based on the analysis of rock samples, it should be noted that these deposits lithologically have favorable reservoir properties.

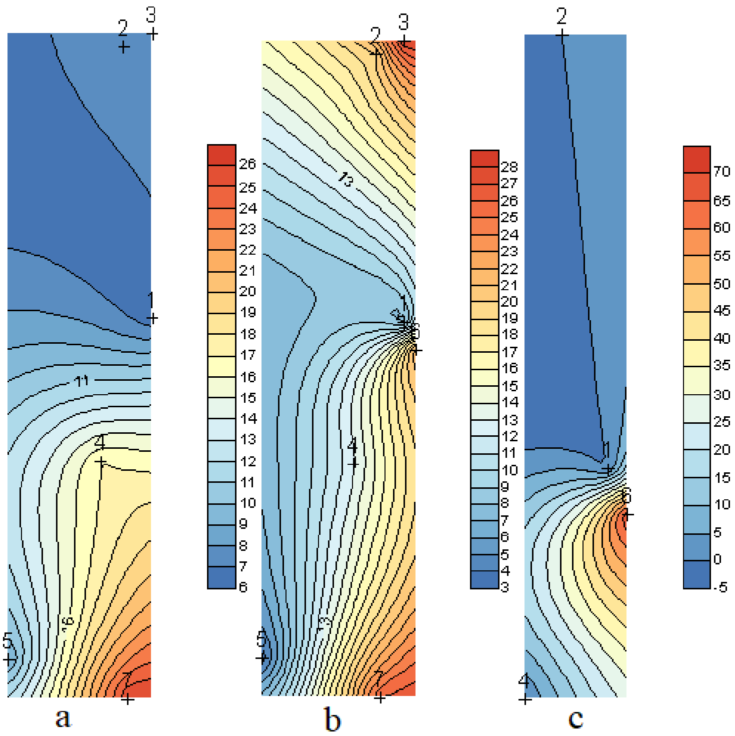

Figure 3: *Carbonate content (a), porosity (b), permeability (c) maps of Paleogene-Miocene deposits in the northern zone of the Shamakhi-Gobustan depression*

Areas: 1- Goradil ; 2-Shargi Agburun; 3- Yunusdag; 4-Garayazi; 5-Gizmeydan; 6-Tuva; 7-Angikharan

Sandy and sandstone layers of Middle Eocene series alongside the south part of the northern zone, represented by reservoir properties with porosity of 17-24%, effective porosity of 2.5-3.5% and permeability of 35-70.0x10^{-15} m^2.

The average carbonate content of the Lower Maykop deposits in the Cheyildag area is 8.0%, the total porosity is 20.5%, the effective porosity is 3.4%, and the permeability is $72.0x10^{-15}$ m^2. These indicators are 6.9%, 15.6% and $22.0x10^{-15}$ m^2 in the Umbaki area, respectively (Fig.4).

In the Maraza area located in the central zone of Gobustan, carbonate content of siltstone limestone, marl deposits of Upper Cretaceous is 23.2-65.3%, porosity is 3.9-17.6%, permeability is $0.001x10^{-15}$ m^2, the carbonate content of sandy limestones of Paleocene is 68-76.4 %, porosity 12.6%, permeability $0.3\text{-}0.6x10^{-15}$ m^2, carbonate content of clayey marls of Maykop series is 2.5-28%, porosity is 7.5-24.4%, and permeability is $0.001x10^{-15}$ m^2, limestone, silty limestone, and sandy limestones of Upper Miocene represented by carbonate content of 45.4-93.4%, porosity is 14.3-21.3%, permeability is $0.2\text{-}10.1x10^{-15}$ m^2. Here, the Upper Miocene deposits are characterized with high porosity and permeability.

The lithofacies characteristics of the Upper Eocene sediments show that these sediments in the Bayguştu area have a higher sand content. This suggests that the collector characteristic is higher in that area.

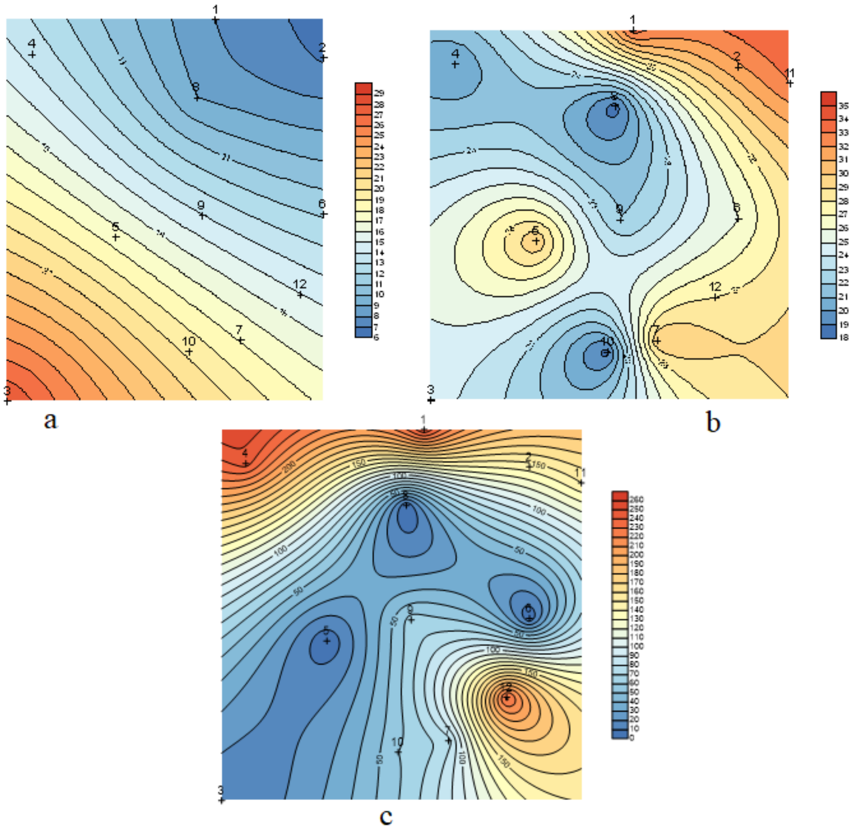

Figure 4: *Carbonate content (a), porosity (b), permeability (c) maps of Upper Maykop deposits in the central zone of the Shamakhi-Gobustan depression*

Areas: 1- Cheyildag ; 2-Umbaki; 3- Maraza; 4-Baygushtu; 5-Shaytanud; 6-Hajiveli; 7-Sundu; 8-Nardaran-Suleyman; 9-Nardaran-Akhtarma; 10-Gijakiakhtarma; 11-Arzani-Gilij; 12-Ilkhichi

The sandy layers forming the horizon are characterized by high collecting properties. The total porosity of the rocks is 20% on average, the effective porosity is 6% on average, and the permeability is 245x10-3 μm2.

The porosity of Upper Cretaceous sediments in the Angikharan area is 6-20%, the porosity of Paleocene sediments is 8-10%, the porosity of Eocene sediments is 10-26%, and the porosity of Miocene sediments varies from 6-10%. The density of the rocks of the mentioned stratigraphic units varies in the range of 2-2.6 g/cm3. In the Angikharan field, natural oil output is noted in the valleys intersecting with the southeastern pericline of the fold, and the oil-gas prospect is related to Upper Cretaceous carbonate and Lower Cretaceous terrigenous reservoirs, which increase in thickness from north to south, in the direction of regional subsidence of Mesozoic sediments.

The porosity of the rocks of Upper Maykop in Shaytanud area is 20-30%, permeability is 1.5x10^{-15} m^2, density is 2.1-2.18 g/cm^3. Here, the same name mud volcano is located. Around of Shaytabud mud volcano there are numerous mud gryphons and mud salsas. Gas, water, and water with an oil films are released from them. The Upper Maykop series represents with alternation of sand, sandstones and clays that along the section gas shows are observed. Thick sandy-clay bands saturated with oil were uncovered in the Maykop section. Slight oil and gas shows were noted along sandy-clay bands of Upper Maykop uncovered at different depths by structure-mapping wells [7,15]. The prospect in the lowered southern limb of the Shaytanud area is related to the Maykop suite. The Upper Cretaceous carbonate reservoirs are considered promising also.

In Hajiveli area, porosity of deposits is 21-26%, permeability is 1.5x10^{-15} m^2, density is 1.92-2.08 g/cm^3. Here, oil and gas shows were observed in the structure-mapping wells drilled into Upper Matkop and Chokrak horizons (middle Miocene) [16]. Oil and gas prospects are related with sandy deposits of Oligocene, Lower-Middle Miocene and carbonate reservoirs of Upper Cretaceous (Fig.5).

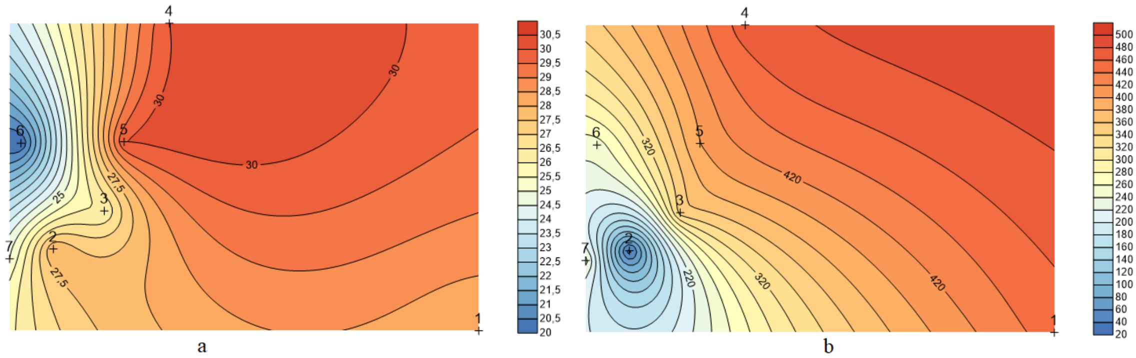

Figure 5: *Porosity (a), permeability (b) maps of Chokrak (Middle Miocene) deposits in the central zone of the Shamakhi-Gobustan depression*

Areas: 1-Cheyildag; 2-Sundu; 3-Ilkhichi; 4-Arzani-Gilij; 5-Shargi Hajiveli; 6-Nardaranakhtarma; 7-Gijaki.

The porosity is 18.0-30%, permeability varies in the range of 25-75x 10^{-15} m^2 in the Sundu area. In the structure-mapping wells in the Western Sundu area, oil flow related to the Upper Maykop, Chokrak, Karagan deposits was observed. In particular, a gas gush was obtained in well number of 10 from the sandy bands located in the upper part of the Chokrak horizon [7]. The oil and gas prospects of the area are related to the Maykop, Chokrak horizon, and the main object for the search of industrially important oil and gas deposits is the carbonate reservoirs of the Upper Cretaceous.

The argillites of Maykop series are represented by a carbonate content of 9%, porosity of 18.5%, permeability of 0.001x10^{-15} m^2 in the Nardaran-Süleyman area. In the process of drilling structure-mapping wells, intense oil and gas shows were noted from sandy reservoirs of the Upper Maykop, Chokrak horizon [9]. İn addition, Upper Cretaceous carbonate reservoirs are also considered the main object for the search of industrially important oil deposits.

Porosity of reservoirs in the Nardaran-Akhtarma area is 10.0-22%, permeability is 18-65x$10^{-15}$$m^2$, in the Gijakiakhtarma area porosity is 11.0-18.6%, permeability is 15-60x10^{-15} m^2, in Cheyildag porosity and permeability is 13.5-33.5% and 35-250x10^{-15} m^2, in Umbaki- is 11.5-31.8% and 10-145x10^{-15} m2, in Arzani-Gilij- is 12-33.0% and 30-150x10^{-15} m2, in Ilkhichi- is 9.7-28.0% and 25-235 x10^{-15} m^2, respectively.

Oil-gas shows in the Nardaranakhtarma area are related to the Nardaranakhtarma mud volcano, numerous mud gryphons, salsas, as well as the outcrops of sandy layers of the Upper Maykop at the crest and Chokrak horizon deposits along the south limb of the fold. Oil-gas shows related to the deposits of the Maykop suite and Chokrak horizon were also observed during the drilling of exploration and structure-mapping wells [9].

The Gijakiakhtarma area is differ by the presence of various oil and gas shows. İn addition, information about oil and gas content of Maykop, Chokrak deposits was obtained through structure-mapping wells. Also, during the opening of the deposits of the Karagan (Middle Miocene) horizon, Pontian (Upper Miocene) and Aghjagil (Upper Pliocene) stages near the tectonic fault, slight oil and gas shows were noted [5]. The presence of 1.5-2 m thick sandy layers in the section of the Upper Maykop and Chokrak horizons allows to consider it as the main object for the search of oil and gas induvidual deposits. The main object of exploration is the carbonate reservoirs of Upper Cretaceous.

Chokrak horizon is represented by sandy-clay facies in South Gobustan. Sandy layers reach their maximum in Cheyildag, Umbaki, and East Hajivalli areas. An industrially important oil deposit has been uncovered in the horizon I of the Çokrak stage of Umbaki field. Along the section of Chokrak with high porosity reservoir rocks oil and gas shows were recorded in exploration wells number of 9, 12, 29, 32 in Cheyildagh area. The production of the wells varies between 2.5 t/day. The layers are traced to the Zahirdag area and an oil gush was obtained from the section of Chokrak at a depth of 529 m in the exploration well number of 9. Oil-bearing layers of Chokrak stage belong to the southern limb of the Cheyildag uplift in the Cheyildara area. 6 oil-filled sandy layers are noted along the section [8]. The porosity of the rocks here is 26-28%, permeability is 100-450 $x10^{-15}$ m^2.

There is a sandy sandstone layer 45-55 m thick, 100 m below the top of the Chokrak horizon in the Sundu area. A gas gush was noted in well number of 10 from this layer [6]. The porosity of the rocks is 24-28%, and the permeability is 24-27 $x10^{-15}$ m^2.

Natural oil-gas shows in Ilkhichi and Arzani-Gilij areas are related to mud gryphons, and mud salsas of mud volcanoes. İnrush of gas and oil were observed from the sandy layers of Chokrak. Also, intense oil-gas shows were observed during the passing of individual sandy layers of Maykop, Miocene, Productive series (Lower Pliocene). The gush of gas obtained from Sarmatian, Konk and Karagan sandy bands has a special interest [14]. Apart from these deposits, carbonate reservoirs of Upper Cretaceous are also considered promising. The porosity of the rocks of the Chokrak horizon is 22-26%-24-30%, and the permeability is 30-350-50-470 $x10^{-15}$ m^2.

Oil-gas-bearing of the sand-sandstone layers of the Chokrak horizon in Eastern Hajivalli area has been confirmed. 5-7 t/day of heavy oil flow was obtained during the testing of sandy layers of the Chokrak horizon in 2 wells [9]. The porosity of the rocks is 25-30%, and the permeability is 100-400 $x10^{-15}$ m^2.

Fine-grained sands of Chokrak in the Nardaranakhtarma area are oil-gas-bearing. 2 oil-bearing layers are identified in the Chokrak stage along the northern limb. Layer I is located 115 m below the top of the horizon and is represented by fine- and medium-grained sands. Layer II is located 166 m below the top of the horizon. This is the main oil-bearing layer in the northeast limb and it is clearly traced. The porosity of the rocks is 13.8-20%, permeability is 25-250 $x10^{-15}$ m^2.

Oil leaks from the dolomites of the Çokrak horizon were noted in Gicaki area [10]. The porosity of the rocks is 21-25%, the permeability is 28-250 $x10^{-15}$ m^2.

Rock samples analyzes prevail taken from the Productive series (PS) in South Gobustan.

The porosity of the sandstones of the PS in Solakhay area is 11.4-26.5%, permeability is 90-664 $x10^{-15}$ m^2. In the southwestern limb of the structure, there are several small faults are found, which are associated with a large number of mud gryphons, mud salsas, which inrush of oil, gas, and water [7, 17, 18] (Fig.6). Intensive oil and gas shows were noted during the testing of almost all exploratory wells during the drilling process. There was an oil gush with production of 5-7 t/day in separate wells. 4 sandy horizons (I, II, III, IV) with a thickness of 900 m, three of which are oil-bearing, have been determined in the unopened part of the PS [9].

Carbonate content of sandy-clayey-limy deposits of PS in Dashgil area is 3.5-24.7%, porosity is 6-35.8%, permeability is 26-221 $x10^{-15}$ m^2.

There are numerous natural oil and gas shows in the Dashgil area relation to the activity mud gryphons of the Dashgil mud volcano. Oil and gas shows have also been recorded in numerous structure-mapping and exploratory wells related to the sandy-siltstone horizons of the PS. During the testing of the horizon VII of the PS in the southern limb of the fold, an industrial oil flow with an initial production of 75-100 t/day was obtained from well number of 15 [10].

The porosity of sandy deposits of PS in the Anart area is 20.2-30.6%, permeability is 32-326 $x10^{-15}$ m^2.

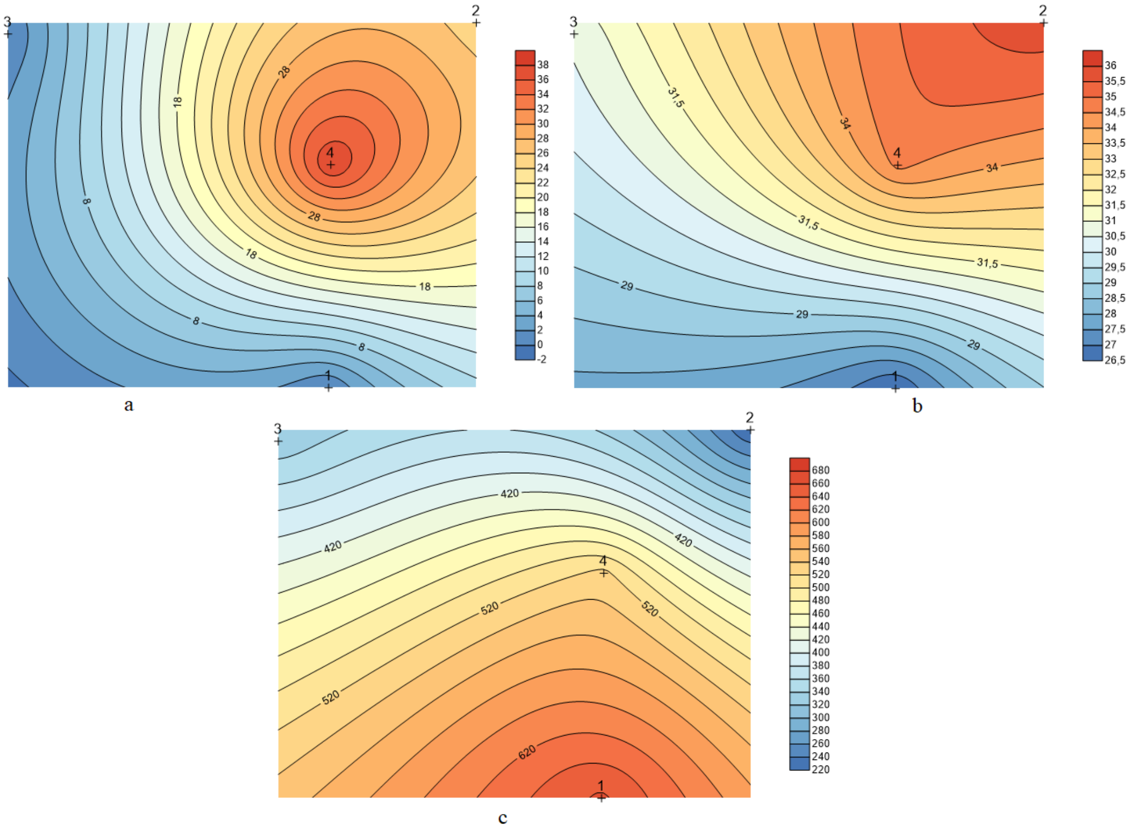

Figure 6: *Carbonate content (a), porosity (b), permeability (c) maps of PS (Lower Pliocene) deposits in the South Gobustan*

Areas: 1-Solakhay; 2-Dashgil; 3-Anart; 4-Duvvani.

İn addition, along the section of the PS 9 single sandy horizons were separated, from which 50,000-75,000 m^3/day of industrial gas flow was obtained. During the testing of one of the sandy horizons, a gas gush was obtained from well number of 6 with a flow of 110,000 m^3/day [6]. This is suggests that the Anart field is promising as a gas facility. By outlining the open gas field in the intersection of the PS, conducting exploration work in the unopened part of the PS, it is possible to open an analogue of the V horizon of the PS in the Garadag gas and oil field.

Carbonate of Miocene clayey-siltstones in Duvanni field is 2.7-44.1%, permeability is 11.3-36x$10^{-15}$$m^2$, carbonation of sandy-clayey-siltstone sediments of PS is 5.2-38%, porosity is 7.0-34.64 %, permeability varies in the range of 11.7-526 x10^{-15} m^2.

Industrially significant gas content of 2 sandy horizons was determined with the first exploratory well in the Duvanni field. The industrially important induvidual gas deposit related to the reservoirs of the horizon V covers the small northwestern part of the structure, and the large gas-condensate deposit related to the sandy-siltstone reservoirs of the horizon VII covers the southeastern half of the fold [6].

The prospecting for new oil and gas deposits in the Duvanni field may be related to the sandy-clayey sediments of the Maykop (Oligocene-Lower Miocene) suite, which was determined based on the analysis of eruption products of mud volcanoes.

As the Shamakhi-Gobustan depression is located in the area of the southwest limb of the Greater Caucasus, which is relatively close to the crest, the compressive stresses generated in this mountain folding system are intensely reflected here and have led to the development of thrusts, napps and mud volcanism in its structure. Due to the lithofacies composition of the rocks, this situation also affects the formation of derivative reservoir properties in them [11]. The northern tectonic zone of the Shamakhi-Gobustan depression is characterized by a wide spread of Cretaceous deposits (thickness 2000-2500 m), and mainly competent terrigenous-carbonate deposits were formed here. These rocks have a highly derived reservoir property.

Paleogene-Miocene-Pliocene deposits are widespread in the Central and South-West, South-East tectonic zones and have been relatively studied by drilling. It is noted that the number and thickness of the sandy-siltstone layers involved in their intersection increases from north to south-southeast.

It should be noted that the increase in the thickness of the deposits of Maykop, Chokrak and PS in the southern direction and the presence of sufficiently thick sandy reservoir horizons in their composition also played a role in the separation of South Gobustan as a highly prospective zone.

The prospect of oil-gas-bearing in Shamakhi-Gobustan region is related to Meso-Cenozoic deposits. Industrially important oil accumulations were identified in the sandy reservoirs of the PS, Upper Maykop and Chokrak horizons, which were uncovered during drilling in separate areas in the southeastern and southwestern tectonic zones of the area.

The oil and gas shows are noted in the Upper Cretaceous fractured limestone and marls, which are widespread in the Northern zone. The density of these rocks varies in the range of 1.94-2.55 g/cm^3 in the northern zone. The Upper Cretaceous sediments are buried under Paleogene sediments in the south-southwest direction [1].

Oil-filled layers and dolomites in the form of breccias lying in separate intervals at the section of the Middle and Upper Miocene in central Gobustan are of special interest. It should be noted that terrigenous and carbonate reservoirs are natural reservoirs for collecting oil and gas deposits in the Meso-Cenozoic deposits.

The sandy-siltstone reservoirs of Maykop suite and Chokrak horizon are oil-gas-bearing in Hajivalli, Umbaki, Maraza, Donguzlug areas. A short-duration oil flow was obtained in the upper Cretaceous fractured-carbonate reservoirs in Gizmeydan and Hilmilli areas.

IV. Conclusion

1. Due to incease the number and thickness of the sandy interlayers along the section of the Upper Cretaceous from the northern zone to the south, that is, in the direction of the regional dip, so they can be considered promising in the Central Gobustan zone in the Shamakhi-Gobustan depression.

2. In the northeastern part of South-Eastern Gobustan, the sediments of the Maykop suite and the Chokrak horizon have a high reservoir properties, and they are likely to contain industrially important oil and gas.

3. Based on the analysis of the reservoir properties of the rocks, it was determined that there are oil-gas sandy-siltstone reservoirs with high reservoir properties in the upper half-layer of the Maykop suite, the Chokrak horizon and the Sarmatian stage deposits in South-Western Gobustan.

4. The sandy horizons of the Upper Maykop series are considered most promising In the authochthones of the overthust that complicate the large folds in South-West Gobustan.

Reference

[1] Narimanov, N.R., Nasibova, G.D., Mansurova, S.I. Geodynamic regime of formation of the structural plan and oil and gas content of the Shemakha-Gobustan synclinorium. Geology, geophysics and development of oil and gas deposits. Moscow, 2017, 6, 17-23.
http://www.vniioeng.ru/_user_files/file/ants/ge/Geology_Geophysics_2017-05_rus.htm

[2] Nasibova, G.D, Ismayilzadeh, E.A., Ganbarova, Sh. A., Ismayilova, M.M. Oil and gas prospects of tectonic crashing zones of the Kura intermountain depression. "Reliability: Theory and Applications" RT&A, Special Issue No 5 (75) Volume 18, November 2023.
DOI: https://doi.org/10.24412/1932-2321-2023-575-313-322

[3] Nasibova, G.J. Paleotectonic conditions of Shamakhi-Gobustan oil and gas region based on study of litho-stratigraphic characteristics of Meso-Cenozoic deposits. International Scientific and Practical Conference International Trends in Science and Technology, 2019, Vol 1, Warsaw, Poland. https://conferences.rsglobal.pl/index.php/conf/catalog/view/18/25/388-1

[4] Nasibova, G.J. Oil and gas perspectives of the Umid structure in connection with its history of geological development, Journal "Reliability: Theory and Applications" (RT&A), Special Issue № 3 (66) Volume 17, January 2022c. 133-137.
http://www.gnedenko.net/Journal/2022_3%20SI.htm RT&A_SI 2022, # 3(66) Vol.17, ISSN 1932 2321. DOI: https://doi.org/10.24412/1932-2321-2022-366-186-192

[5] Yusifov, X.M., Efendiyev, A.A., Mammadov, S.B. - Complex analysis of the geological-geophysical study of Paleogene-Miocene sediments in the southeastern part of the Greater Caucasus and their prospective directions. Scientific works, 2006, 6, 25-35.

[6] Yusifov, X.M. Non-anticlinal traps and oil-gas content of Paleogene-Miocene sediments of Shamakhi-Gobusta. Baku, 2016.

[7] Yusifov, Kh., Suleymanov, A. Geological basis of oil and gas exploration in Mesozoic sediments in Azerbaijan. Baku, 2015.

[8] Maharramov, B.I. Geological basis of oil-gas content of Paleogene-Miocene sediments in Absheron and Shamakhi-Gobustan oil-gas regions. Scientific works, 2008, 10.

[9] Suleymanov, A.M., Zeynalov, R.L., Maharramov, B.I. Paleotectonic development of the Middle and Upper Miocene uplifts in the oil-gas regions of Western Absheron and Shamakhi-Gobustan and their oil-gas potential. ANE, 2006, 11.

[10] Yusifov, X.M., Rahmanov, R.R., Mammadov, S.B., Efendiyev, A.A. Geological basis of search for oil and gas deposits in Paleogene-Miocene sediments of Eastern Azerbaijan. Geologist of Azerbaijan, 2006, 11, 46-63.

[11] Narimanov, N.R., Nasibova, G.C., Ahmadov, M.G. The role of geodynamic regime and lithofacies in the formation of mud volcanoes and local uplifts in the Shamakhi-Gobustan basin. Azerbaijan Geologist, 2017, 21.

[12] Aliyev, Ad.A., Quliyev, I.S., Rahmanov, R.R. 2009. Catalogue of mud volcanoes eruptions of Azerbaijan . "Nafta-Press", 106.

[13] Feyzullayev, A.A., Quliyev, İ.S., Tağıyev, M.F. Source potensial of the Cenozoic rocks in South Caspian basin and their role in forming the oil accumlations in the Lower Pliosene. 2001.

[14] Ali-zadeh, A.A. Selected Works. Baku, 2011, Nafta-Press, 530.

[15] Aliyev, G.I., Aliyev, E.A. Oil and gas potential of great depths. Baku 2011, 419.

[16] Ismayilova, G.G., Azimov, M.A. Litofacies conditions of oil and gas accumulation within the Toragai-Khara-Zira-deniz anticlinal zone. AOE, 2008, 9.

[17] Bayraktutan, M. S., Ganbarova Sh. A. Analysis of geochemical properties of eruption products of mud volcano in the Lower Kura depression. Geolology, Geography and Geology, 33(2), 2024, 244-251. https://doi.org/10.15421/112422.

[18] Gultar J. Nasibova, Khuraman Z. Mukhtarova.Modelling of geochemical properties of mud volcano eruption products and relationship with oil and gas prospects within the South Caspian megadepression of Lower Kura region. Geolology, Geography and Geology, 33(2), 2024, 329-339. https://doi.org/10.15421/112431

DETERMINATION OF THE COEFFICIENT OF HYDRAULIC RESISTANCE WHEN USING ANTI-TURBULENCE ADDITIVES

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Abstract

The article discusses rheological models of non-Newtonian oils, and also analyzes existing theories on reducing hydraulic resistance when using anti-turbulence additives, the main methods and approaches to transporting high-viscosity oil. High-viscosity oil from the North Komsomolskoye field, as well as anti-turbulence additives from the Monomer company, were used as the object of study. As a result of processing the results of experimental studies, the rheological model of oil was determined, and the effectiveness of using anti-turbulence additives from the Monomer company for this oil was established. The work also carried out a comparative analysis of the existing dependencies of the hydraulic resistance coefficient, compared the main dependencies and found that the most accurate models are those based on the universal law of resistance and the Altschul logarithmic formula, taking into account the Deborah number and the model for calculating efficiency through the value.

Keywords: highly viscous oil; heavy oil; additives; transport; coefficient of hydraulic resistance; reserves of high-viscosity oil; Toms effect.

I. Introduction

Currently, reserves of light, low-viscosity oil are being depleted. This fact poses an urgent task for companies in the fuel and energy complex involved in drilling wells, field development and transportation, to study and resolve the issue of the economic feasibility of using heavy, highly viscous oils. In practice, this issue is fraught with enormous technical difficulties, ranging from the extraction of such oil to its refining [45].

Transportation of high-viscosity oil is one of the key challenges facing the modern oil industry. Due to its special rheological properties, such oil creates serious difficulties for engineers and technologists: its viscosity makes it difficult to move through pipelines, increases energy costs for pumping and contributes to equipment wear [1-3].

Currently, there are several main methods of transporting non-Newtonian oils: "hot" pumping, electric heating, hydropumping of high-viscosity oil, transporting oil with diluents, adding depressants and anti-turbulence additives to oil. Currently, one of the developing methods of oil transport is the transport of oil with anti-turbulence additives. This type of additives allows you to reduce hydraulic resistance during fluid movement; they can significantly change the physical and chemical properties of oil, improving its fluidity and reducing viscosity.

The principle of operation of anti-turbulence additives is based on the Toms effect. The Toms effect was discovered in the 1940s and has since been widely used in the oil industry. The essence of this phenomenon is that when a small amount of polymers is added to a liquid, its flow becomes more orderly, which reduces friction and facilitates the movement of liquid through the pipeline. This is especially true for highly viscous oil, which, without the use of additives, moves with high energy consumption. Additives that cause the Toms effect facilitate its movement through pipelines by changing the flow structure. As a result, the speed of oil movement increases and the energy consumption of the pumping process decreases.

The use of PTP also makes it possible to use the pipeline network more flexibly - to expand bottlenecks, replenish the volume of supplies after forced downtime, respond to changes in the viscosity of the pumped oil, to a shortage of electricity in a particular area, to changes in oil prices on the market.

The presence of turbulent flow is one of the necessary conditions for the operation of the PTP. Therefore, for heavy oils with high viscosity values, which are transported in laminar mode, the use of PTP will not lead to an increase in productivity. However, for oils with a viscosity of the order of several hundred centistokes, the use of PTP is possible; it is also possible to use PTP for heated oils or when pumping with a diluent, when a turbulent regime is realized.

Anti-turbulence additives can be divided into 3 types: polymers, fibers and surfactants.

The shares of drug consumption by region are distributed as follows: North America – 54.2%, Europe – 9.0%, Middle East – 13.1%, Southeast Asia – 4.4%, Africa – 11.7%, Countries CIS – 4.0%, China – 3.7%.

For the first time on an industrial scale, PTPs were tested in 1979 on the Trans-Alaska main oil pipeline with a diameter of 1219 mm by the company in order to increase the throughput of the oil pipeline. In 1978, TAPS conducted a very thorough laboratory study of the process of producing polymers in order to improve their characteristics. As a result, a polymer additive was developed, which was named CDR-101 and began to be used in the company’s pipelines. In 1980, a number of changes were made to the polymerization process, which led to the creation of a new high-performance polymer additive CDR-102. Within two years of using CDR-102 additives from Conoco Specialty Products Inc, the pipeline capacity was increased from 16 to 32 thousand m^3/day [4-5].

The world's leading manufacturers, as a rule, have a wide range of additive brands designed for various types of pumped products. The main producers on the global DTP market (80-90%) are foreign companies ConocoPhillips (USA) and Baker Hughes (USA).

Based on the results achieved, these companies have developed a line of PTP specifically for heavy oil based on polar polymers that have the ability to dissolve in the presence of a high content of asphaltenes.

There are also several small producers on the market, for example, FlowChem (USA), Propipe (Spain, USA), Champion (UK, Netherlands) and the Chinese company China National Petroleum Co., which, as a rule, have a local business.

II. Materials and Methods

2.1. Reological models

Rheological models are used to describe the behavior of non-Newtonian fluids, that is, fluids whose dynamic (or effective) viscosity depends on shear stress and is not a constant value. Some of the most common rheological models for non-Newtonian fluids are: The Shvedov-Bingham model is used to describe liquids that have an initial yield strength τ0, below which it does not flow and has the properties of a solid.

The Shvedov-Bing equation has the form:

$$\tau = \tau_0 + \eta \cdot \dot{\gamma} \quad (1)$$

where τ - shear stress, η - viscosity coefficient, γ - shear rate.

The Ostwald-de Waele model is a generalization of Newton's law of viscosity and describes, for example, the flow of polymer solutions. In this model, viscosity varies proportionally to the degree of strain rate:

$$\tau = K \cdot \dot{\gamma}^n \quad (2)$$

where K - model parameter, n is an index that determines the degree of nonlinearity.

The Herschel-Bulkley model is used to describe thixotropic liquids. In this model, shear stress is represented by the equation:

$$\tau = \tau_0 + K \cdot \dot{\gamma}^n \quad (3)$$

The Casson model is used to describe pseudoplastic fluids, in which the viscosity decreases with increasing shear stress, and has the form:

$$\tau^{\frac{1}{2}} = \tau_c^{\frac{1}{2}} + \eta_c^{\frac{1}{2}} \cdot \dot{\gamma}^{\frac{1}{2}} \quad (4)$$

where $\tau_c^{\frac{1}{2}}$ is Casson yield stress, η_c is Casson plastic viscosity.

The Prandtl model is used to describe the behavior of viscoelastic materials and has the following form:

$$\tau = arscin\left(\frac{\dot{\gamma}}{B}\right) \quad (5)$$

The Cisco model is used as a rheological model of pseudoplastic fluids and has the form:

$$\tau = \eta_\infty \cdot \dot{\gamma} + \eta \cdot \dot{\gamma}^n \quad (6)$$

To take into account the nonlinearity of changes in shear stress with increasing shear rate in non-Newtonian fluids, Williamson and Gillespie proposed introducing a special correction factor:

$$\eta = \frac{\tau_0}{\dot{\gamma} + \chi} + \eta_\infty \quad (7)$$

The Cross model is considered a transformation of the previous model and is quite universal for describing the behavior of viscous liquids:

$$\eta = \frac{(\eta_0 - \eta_\infty)}{\left(1 + \frac{\dot{\gamma}}{\chi}\right)} + \eta_\infty \quad (8)$$

The Carreau model is used to describe the behavior of nonlinear viscous media in isothermal and non-isothermal processes and takes into account the thixotropic properties of the liquid being studied:

$$\eta = (\eta_0 - \eta_\infty)(1 + (\lambda\dot{\gamma})^2)^{\frac{n-1}{2}} + \eta_\infty \quad (9)$$

There is also a modified Carreau-Yasuda model, which is used to describe dispersed and polymer systems and has the form:

$$\eta = \frac{\tau_0}{(\dot{\gamma}^n + \chi)^m} + \eta_\infty \quad (10)$$

To describe a viscous liquid containing dispersed particles, the Ree-Eyring model is used:

$$\eta = (\eta_0 - \eta_\infty)\frac{arcsh(\beta\dot{\gamma})}{\beta\dot{\gamma}} + \eta_\infty \quad (11)$$

The Rayner-Rivlin model is used to describe a rheologically complex viscous fluid:

$$\dot{\gamma} = \sum_{n=0} a_{2n} \cdot \tau^{2n+1} \quad (12)$$

There are a large number of rheological models that describe the behavior of non-Newtonian fluids. By transforming some of them, it is possible to obtain others, but analysis shows that there is no universal way to describe the behavior of a non-Newtonian fluid.

2.2. Hypotheses about the mechanism for reducing hydraulic resistance when using polymer additives

Polymer additives are one of the most effective means of reducing hydraulic resistance when transporting high-viscosity oil. Currently, there are several main hypotheses explaining the mechanism of their action.

The first hypothesis suggests that the polymers form a thin layer on the inner walls of the pipeline that acts as a kind of “lubricant” reducing friction between the pipe walls and the flow of oil.

The second hypothesis is related to changes in the structure of oil flow under the influence of polymers. It is assumed that polymers are able to “destroy” turbulence in a flow, turning it from turbulent to laminar or transitional. This also leads to a reduction in friction and, accordingly, hydraulic resistance.

The third hypothesis is the possibility of changing the physical and chemical properties of the oil itself under the influence of polymers, which can lead to a change in its viscosity and density.

These hypotheses are not mutually exclusive and may operate simultaneously. Table 1 summarizes the above, as well as other existing hypotheses about the nature of the reduction in hydraulic resistance when using polymer additives. The hypotheses are grouped according to the key features of the proposed mechanism of resistance reduction.

Table 1: *Hypotheses about the mechanism for reducing hydraulic resistance when using polymer additives*

Theory	Brief description
Molecular stretch	Turbulent flow, mixing with the polymer, deforms it. The influence of polymers on viscosity is significant, so the vortex is damped. This leads to excess local viscosity and energy dissipation [6-8]. These ideas were developed in work, where the stretching of macromolecules is accompanied by an increase in rigidity in the direction of stretching, which leads, in turn, to a significant increase in longitudinal viscosity. As the longitudinal viscosity increases, the formation of large-scale vortices and emissions in the near-wall region is inhibited.
Reduced turbulence generation	Some researchers [9-11] believe that polymer additives prevent the onset of turbulence and the effect of reducing drag is associated not with the dissipation of vortex energy, but with the suppression of their generation. However, it is possible that both mechanisms take place simultaneously.
Reduced turbulent dissipation	Some researchers [12-15] believe that polymer additives prevent the onset of turbulence and the effect of reducing drag is associated not with the dissipation of vortex energy, but with the suppression of their generation. However, it is possible that both mechanisms take place simultaneously.
Vortex stretching	It is postulated that the tensile resistance of the vortices reduces mixing and energy loss. Dilute polymer solutions can have longitudinal viscosities that are up to a thousand times higher than the steady-state viscosities, which can influence the drag reduction mechanism. The authors of the work [16-18] believe that the destruction of the vortex occurs as a result of the destruction of macromolecules due to energy absorption.
Anisotropic properties and turbulence	In a turbulent flow regime, the additive polymers are stretched in the direction of the flow. Uneven absorption of flow energy occurs and leads to anisotropy of turbulent transfer. Viscosity increases as turbulent

	movement occurs along the normal to the wall of the pipes, and as a result, the intensity of velocity pulsations normal to the wall decreases [19-21].
Laminarization of turbulent flow	Turbulence involves the waste of energy through the formation of tiny vortices, which leads to increased drag. Therefore, the reduction in resistance is a measure of flow laminarization.
Pseudoplasticity	It is assumed that the near-wall layer, due to pseudoplasticity (a decrease in viscosity under the influence of shear), may have a lower friction coefficient than that of a pure solvent. The theory was not developed, since a decrease in viscosity under the influence of shear, although it occurs, is by a smaller amount than the decrease in resistance [22-25].
Viscoelasticity and normal stresses	Polymer solutions exhibit viscoelasticity and normal stress differences, but at concentrations much higher than those required to reduce resistance. Very dilute solutions have no measurable elasticity and do not differ in viscosity from pure solvents. On the other hand, viscoelastic solutions of chemically cross-linked polyacrylic acid do not exhibit a resistance-reducing effect, although they exhibit pseudoplasticity. Thus, viscoelasticity is not a necessary condition for drag reduction.
Formation of supramolecular agglomerates	This theory implies a decrease in resistance when conditions are realized in a turbulent flow for intermolecular interaction, while in a static state, dilute mixtures of polymers remain molecularly dispersed.

The presence of several theories indicates the absence of a single mechanism for reducing hydraulic resistance using anti-turbulence additives.

The lack of a unified theory entails different approaches to applied calculations for determining the Toms effect and calculating the efficiency of reducing hydraulic resistance (calculating the coefficient of hydraulic resistance when using PTP) depending on different flow conditions.

2.3 Analysis of dependencies to determine the coefficient of hydraulic resistance using PTP

In world practice, there are many different models for calculating the coefficient of hydraulic resistance in a mixture with additives and criteria describing the effectiveness of the additive.

However, most of them were derived from studying the Toms effect in aqueous solutions.

One of the main and classic universal models is the model proposed by A.D. Altshul [26-28]:

$$\frac{1}{\sqrt{\lambda}} = 1{,}8 \cdot \lg\left[\frac{Re_0}{Re_0 \frac{0{,}1 \cdot k_э}{D} + 7}\right] \quad (13)$$

where λ – coefficient of hydraulic resistance for flow using an additive; Re_0 is the Reynolds number without adding an additive.

Another model for calculating the hydraulic resistance coefficient using anti-turbulence additives in an oil flow is a model that takes into account the Deborah number:

$$\lambda = \frac{\lambda_0}{(1 + De^2)^m} \quad (14)$$

where m – the Leibenzone coefficient.

The Deborah number is determined by the following equation:

$$De = \alpha_0 \theta^{\alpha_1} Re_0^{\alpha_2} \quad (15)$$

where θ – additive concentration, g/t; α_0, α_1, α_2– empirical coefficients.

The Reynolds number in this case is:

$$Re = Re_0(1 + De^2) \quad (16)$$

In the work of the authors [29-32], based on experiments with additives, the following model for calculating the hydraulic resistance coefficient is proposed:

$$\lambda = 0{,}11\left(\frac{Z + \varepsilon + X^{1{,}4}}{115X + Y + 1}\right)^{0{,}25} \quad (17)$$

where ε – elative roughness of the inner surface of the pipe; $Z = \frac{68}{Re}$ – (Reynolds number used for flow using additive).

$$Y = A \cdot C^p \cdot \varepsilon^b \quad (18)$$

$$X = (28 \cdot Z)^{10} \quad (19)$$

A, p, b – constant coefficients for a certain additive.

The authors of works [33-37], based on the semi-empirical theory of turbulence by T. Karman, derived a universal equation for hydraulic flow resistance together with the use of anti-turbulence additives:

$$\frac{1}{\sqrt{\lambda}} = 0{,}88 \cdot ln \ln\left[\frac{k_1(C)Re\sqrt{\lambda}}{1 + 0{,}35k_2(C) \cdot \varepsilon \cdot Re\sqrt{\lambda}}\right] - 3{,}745 \quad (20)$$

The values of the coefficients $k_1(C)$ and $k_2(C)$ are determined during experiments with additives. It is allowed to take $k_2(C) = 0.32$.

In [38-41], a model based on the power formula of A.D. Altshul was proposed:

$$\lambda_f = \left[0{,}11 \cdot \left(\frac{68}{Re} + \varepsilon\right)^{0{,}25}\right] \cdot (1 + C)^{-0{,}25} \quad (21)$$

where $\varepsilon = \frac{k}{D}$ – roughness of the inner wall of the pipe surface; D - pipeline diameter, m; Re – Reynolds number for liquid flow with anti-turbulence additives; C – concentration of antihypertensive drugs

In [42-43], the theory of T. Karman was also taken as a basis and the following equation was obtained for finding the value of the coefficient of hydraulic resistance in a flow using additives:

$$\frac{1}{\sqrt{\lambda}} = 0{,}88 \cdot ln \ln[\mathrm{A} \cdot Re \cdot \sqrt{\lambda}] - 3{,}745 \quad (22)$$

where A is a coefficient that takes into account the interaction of turbulent flow with the pipe wall, equal to A=A0=28 in the absence of additive.

One of the well-known models describing the coefficient of hydraulic resistance is the Colebrook-White model based on pipe roughness:

$$\frac{1}{\sqrt{\lambda}} = -2 \cdot log \log\left(\frac{k}{3{,}7 \cdot D} + \frac{2{,}51}{Re \cdot \sqrt{\lambda}}\right) \quad (23)$$

where k – pipe roughness.

2.3. Experimental apparatus and procedure

When developing methods for studying high-viscosity oils and choosing instruments for their implementation, it is necessary to take into account the features of the multicomponent systems under consideration. Firstly, when they flow over smooth surfaces, the effect of wall sliding occurs due to a change in their properties near the solid surface. Secondly, the presence of thixotropic properties complicates their experimental studies, since it is necessary to know and take into account the background of sample processing and the fact that the orientational thixotropic effect affects the rheological characteristics.

The essence of this effect is that, depending on the velocity field, one or another dynamically equilibrium state of the structure is created. The mutual orientation of particles ensures the predominance of a certain type of contact and interaction between them, which leads to a significant change in the properties of the original system. For experimental studies, oil from the North Komsomolskoye field was used.

Experimental studies were carried out using a rotational rheometer "Rheotest RN 4.1", widely used in the oil industry.

The general view of the rotational rheometer "Rheotest RN 4.1" is shown in Figure 1.

Figure 1. The general view of the rotational rheometer "Rheotest RN 4.1".

The main technical characteristics of the rotary viscometer "Rheotest RN 4.1" are given in Table 2.

Table 2: *The main technical characteristics of the rotary viscometer "Rheotest RN 4.1"*

Characteristics	Value
Dynamic viscosity measurement range, mPa·s	from 1 to 3.0·109
Limits of permissible relative error of the viscometer, %	±3
Number of measuring pairs, pcs.	17
Shear stress range, Pa	from 1.3 to 3.5·105
Range of shear rate gradients, s-1	from 0.04 to 20000
Temperature reading range, ℃	from -60 to +200
Smallest sample volume of the tested oil, ml	from 5 to 75 (depending on the measuring pair)

For experimental studies, oil from the Severo-Komsomolskoye oil field was used. The physical and chemical properties of oil are presented in Table 3.

Table 3: *The physical and chemical properties of oil*

Characteristics	Oil (20°C)
Density, kg/m3	945,5
Viscosity at 20°C, mm2/s	1216,2
Resin content, %	14,12
Paraffin content, %	0,62
Asphaltene content, %	1,02

At the beginning of the experiment, the oil sample is heated to the required temperature in a heating cabinet and then placed in a special cuvette of the device. After temperature control of the oil and parts of the device, the rotor is started, which begins to rotate with increasing angular velocity.

The friction force between the moving rotor and stationary oil causes the rotation of the rotor to accelerate or decelerate, which is monitored by the device's sensors. This change in rotation speed allows the dynamic viscosity of the sample to be determined.

It is important to note that measurements are carried out under strictly controlled conditions of temperature and pressure, as these parameters can significantly affect the results.

III. Results

During the experiment, graphs and values of shear stress and dynamic viscosity versus shear rate were obtained.

In Fig. 2-6 shows a graph of dynamic viscosity versus shear rate for pure oil from the North Komsomolskoye field.

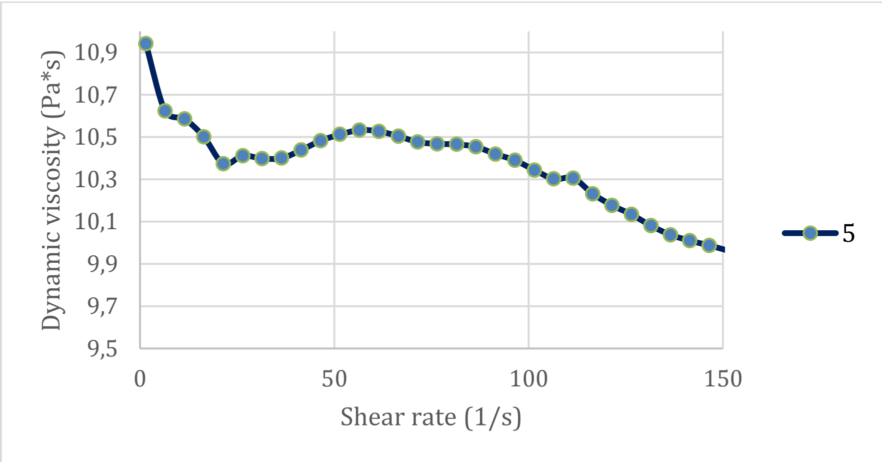

Figure 2: *Dynamic viscosity versus shear rate*

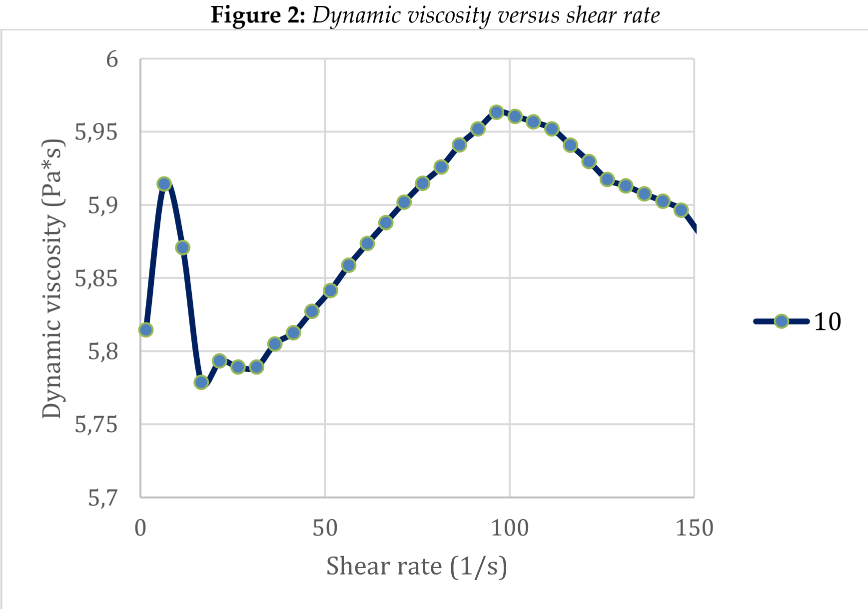

Figure 3: *Dynamic viscosity versus shear rate*

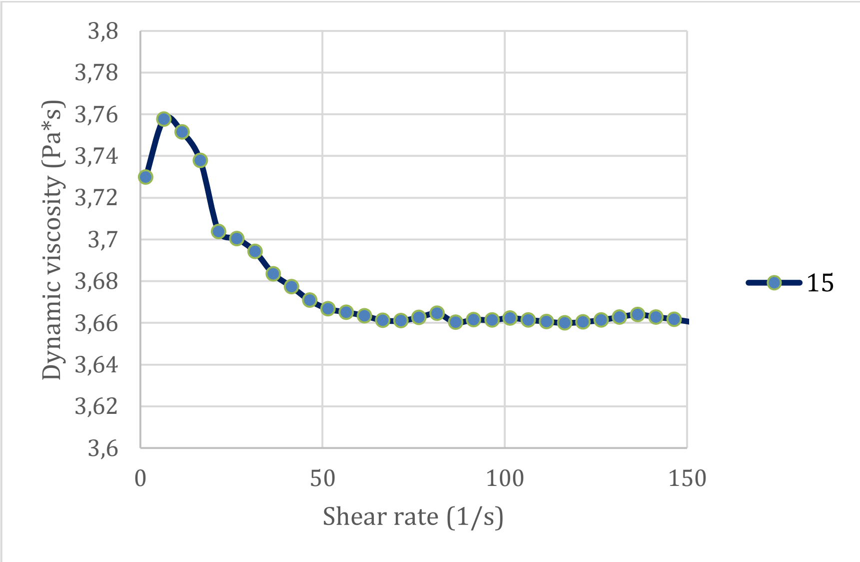

Figure 4: *Dynamic viscosity versus shear rate*

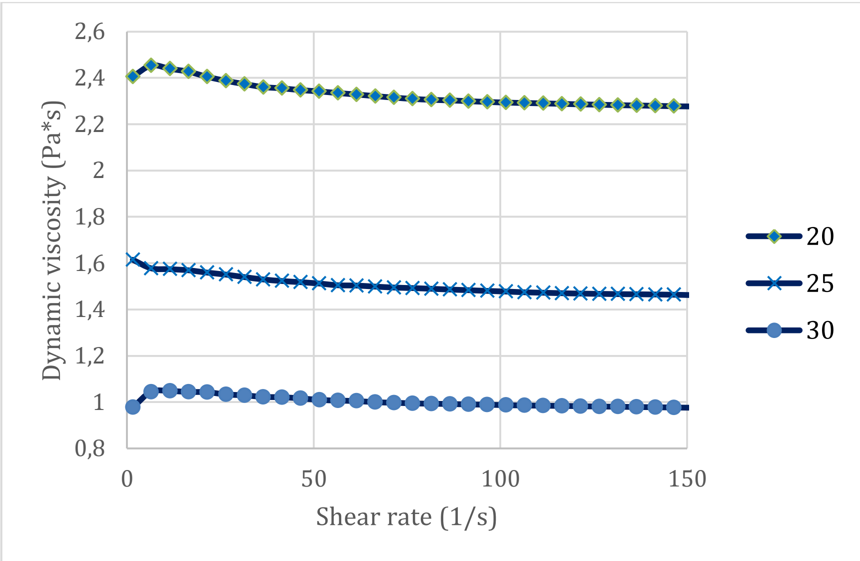

Figure 5: *Dynamic viscosity versus shear rate*

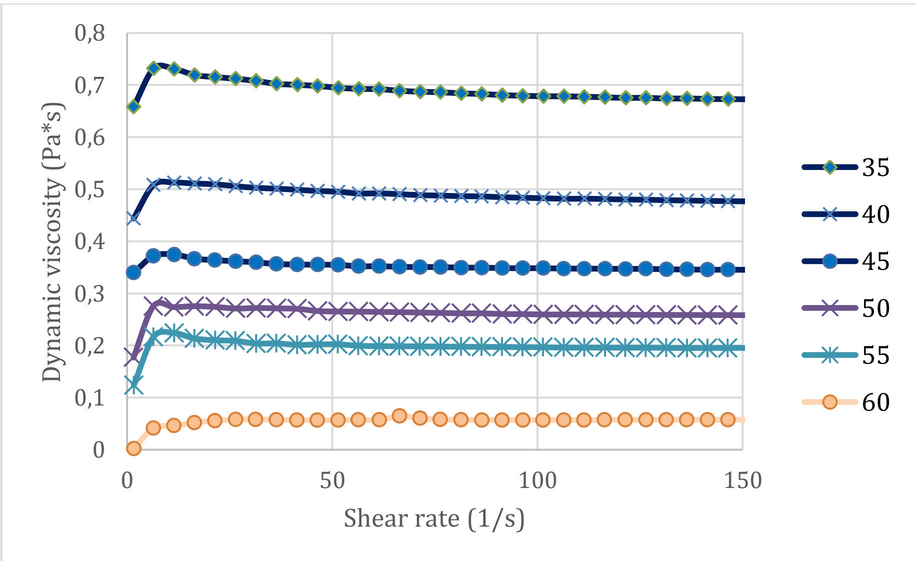

Figure 6: *Dynamic viscosity versus shear rate*

The graph shows that the oil begins to exhibit Newtonian properties in the temperature range from 40 to 45 °C (change in English version). The static shear stress at a temperature of 10 °C is 3.15 Pa (Remove).

The experimental results were processed using the least squares method. The resulting curves can be described by the nonlinear Bulkley-Herschel equation:

$$\tau = \tau_0 + k' \cdot \gamma^n \tag{24}$$

where τ_0 is the initial shear stress, k' is a coefficient depending on the consistency (the higher the viscosity, the greater k'), n is the index (depending on the shear rate).

Graphs describing the movement of liquid when adding an anti-turbulence additive at different temperatures are presented in Figure 7-10.

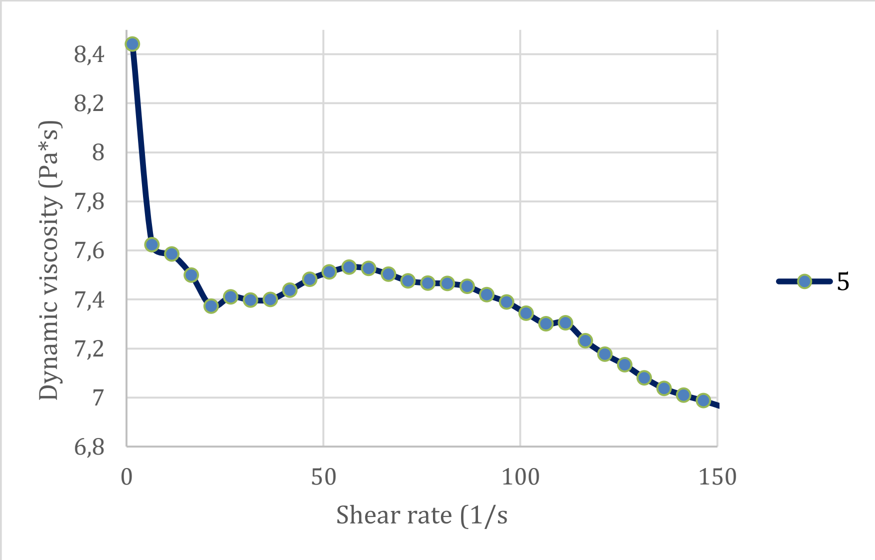

Figure 7: *Dynamic viscosity versus shear rate*

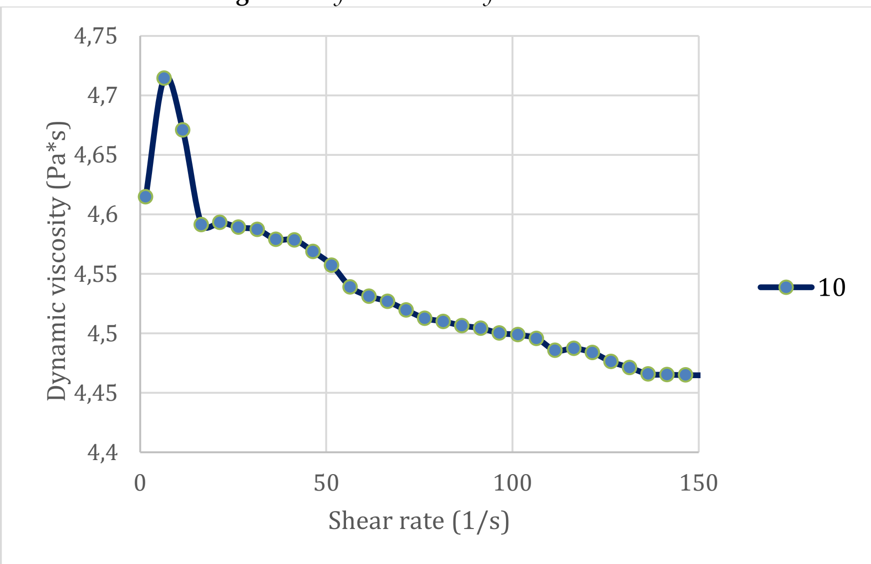

Figure 8: *Dynamic viscosity versus shear rate*

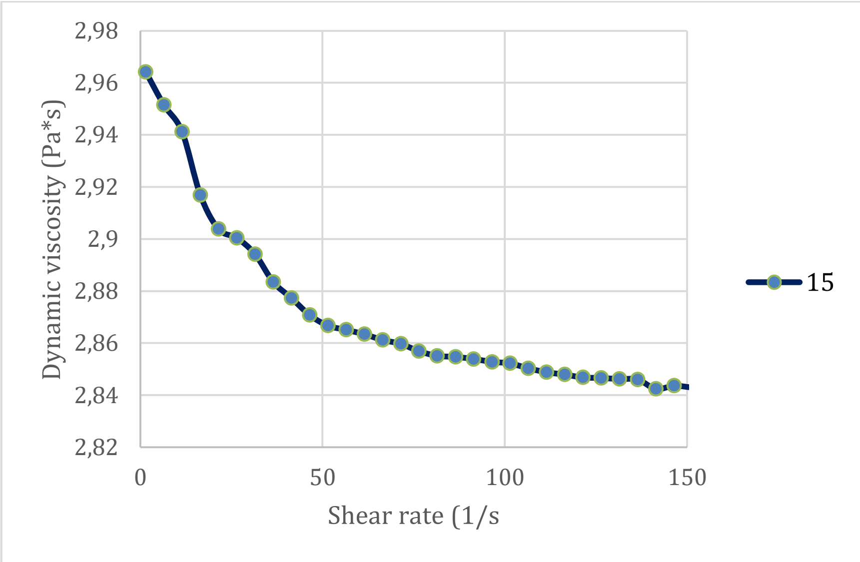

Figure 9: *Dynamic viscosity versus shear rate*

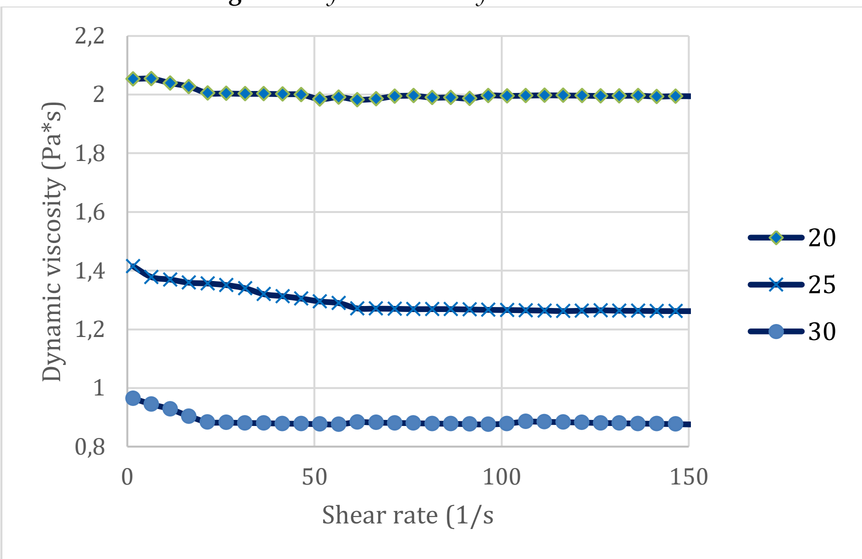

Figure 10: *Dynamic viscosity versus shear rate*

When transporting oil with an anti-turbulence additive, it is important to take into account the value of coefficient A1(0), which when transporting pure oil is a constant value, but when adding an additive changes its values and affects the value of the hydraulic resistance coefficient.

The results of determining the value of $A1(C)$ in modes using PTP are shown in Figure 12.

During the experiment, graphs and values of shear stress and dynamic viscosity from shear rate were obtained.

Figure 11 shows graph of the dependence of shear stress on shear rate.

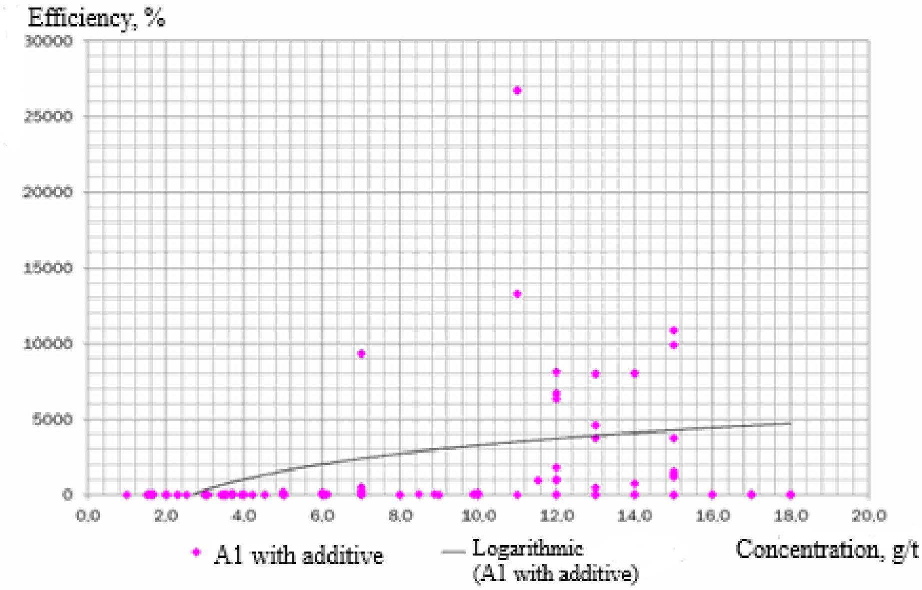

Figure 11: *Coefficient A1(C) in modes using PTP*

From Figure 11 it is clear that in modes with PTP the value of $A1$(C) varies in a wide range from 1 to several 1000. Moreover, in contrast to the literature data from Figure 3.2 it is clear that the construction of any analytical dependence of the value of $A1$(C) on concentration problematic. This indicates that the value of $A1$ is influenced not only by the concentration value, but also by a number of other factors.

To increase the accuracy of the calculation, the value of $A1$ was in the form $A1 = f\ (C,\ Re,\ \tau w)$. Based on the optimization results, a predictive calculation formula was constructed: $A1 = f\ (C,\ Re,\ \tau w)$, which gives the smallest error in determining the efficiency value ψQ. The results of comparison of actual efficiency values ψQ and calculated using the formula are presented:

$$\frac{1}{\sqrt{\lambda_f}} = 0{,}782 \cdot \ln\left(\left(1 + A_1(C, Re, \tau_w)\right) \cdot W_f\right) \tag{25}$$

From Figure 4 it can be seen that when applying the resulting formula, the convergence of the calculated data to the average efficiency values is quite good, however, some values related to high efficiencies above 60%, or low values obtained at high concentrations, differ from the calculated ones.

Based on the results of the analysis of actual and calculated values of efficiency ψQ when using the model under study, it was established that the average error is 10%.

The efficiency of PTP increases with increasing concentration of PTP in the pumped liquid; for the practical use of PTP on a specific pipeline, a curve of efficiency versus concentration ψ(C) is constructed, which is called the PTP efficiency curve. An example of this curve is shown in Figure 12.

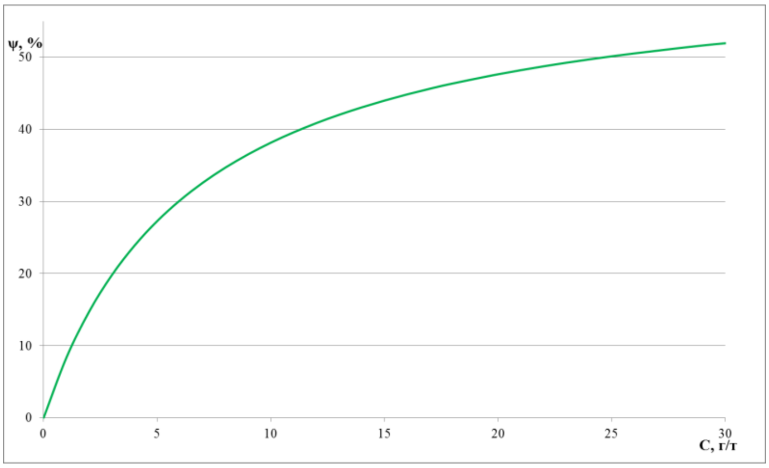

Figure 12: *DTP effectiveness curve*

The dependence of the effectiveness on the concentration of antipsychotic drugs, which quite accurately describes the behavior of antipsychotic drugs, can be presented in analytical form:

$$\frac{C}{\psi} = a + b \cdot C \quad (26)$$

Coefficients a, b are determined empirically, for example, as a result of pilot testing of PTP on a pipeline.

Based on the results of the research, a combined Q-H characteristic of pumping equipment and a section of the main pipeline with and without PTP was obtained, presented in Figure 13.

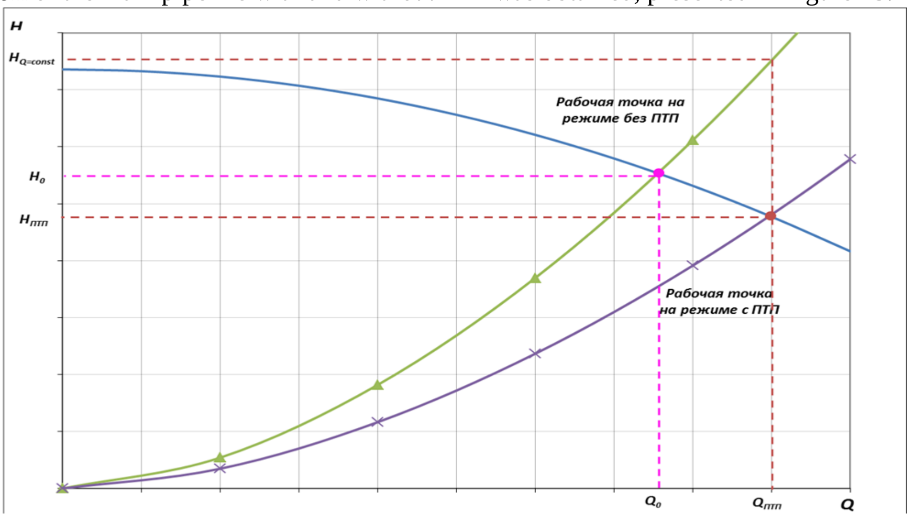

Figure 13: *Combined Q-H characteristics of pumping equipment and a section of the main pipeline with and without PTP*

In addition to the concentration of PRP, its effectiveness is influenced by a number of other factors: characteristics of the pipeline (pipeline length, its diameter, pipe wall roughness), properties of the pumped liquid (temperature, asphaltene content, solubility of PRP in the pumped liquid), flow regime (Reynolds number, shear stress on the wall of the pipeline), etc. [2].

Determination of hydraulic resistance based on the Colebrook-White equation for rough pipes:

$$\frac{1}{\sqrt{\lambda}} = 2 \cdot \log\left(\frac{Re \cdot \sqrt{\lambda}}{2{,}51} + N\right) \quad (27)$$

On the measuring line of the stand with diameter d1 and Reynolds number Re1, the value of $\frac{Re \cdot \sqrt{\lambda}}{2{,}51} + N$ is determined.

Next, the equation is solved for λ_1 for a pipeline with diameter d2:

$$\frac{1}{\sqrt{\lambda_2}} = 2 \cdot log \log\left(\frac{Re_1 \cdot \sqrt{\lambda_1}}{2{,}51} + N_1\right) \cdot \frac{d_2}{d_1}) \quad (28)$$

The Reynolds number corresponding to the found value of λ_2 is determined:

$$Re_2 = Re_1 \sqrt{\frac{\lambda_1}{\lambda_2} \cdot \frac{d_2}{d_1}} \qquad (29)$$

This method, based on experimental studies on an installation with a Re1 number, makes it possible to predict the effectiveness of the ATA for a pipeline with a diameter of d2 and the Re2 number, which depends on the ratio of diameters, the coefficient of hydraulic resistance and the Re1 number.

Table 4: *Calculation results using the Colebrook-White model*

D, mm	Consumption, m3/h	Temperature, oC	Negative roughness	Deviation of hydraulic resistance,%
50	10	20	366,8	9,2
	20			2,5
	30			-2,5
	50			-1,9

3.2. Calculation of the hydraulic resistance coefficient based on the model with the Deborah number (14):

$$\lambda\lambda_P = \frac{\lambda_0}{(1 + De^2)^m}$$

Table 5: *Results of calculations using the model with the Deborah number*

D, mm	Consumption, m3/h	Temperature, oC	α_0	α_1	De	Deviation of hydraulic resistance,%
50	10	20	121,5	-0,5134	1,9	1,6
	20		121,5	-0,5134	1,2	-1,5
	30		121,5	-0,5134	0,9	1,5
	50		121,5	-0,5134	0,7	-0,9

3.3. Calculation of the hydraulic resistance coefficient based on a model that takes into account mixture formation (19):

$$\frac{1}{\sqrt{\lambda}} = 0,88 \cdot ln \ln\left[\frac{k_1(C)Re\sqrt{\lambda}}{1 + 0,35k_2(C) \cdot \varepsilon \cdot Re\sqrt{\lambda}}\right] - 3,745$$

Results of calculation presented in Table 6.

Table 6: *Calculation results using a model that takes into account mixture formation*

D, mm	Consumption, m3/h	Temperature, oC	ε	k_1	k_2	Deviation of hydraulic resistance,%
50	10	20	0,00184	56	0,31	6,1
	20		0,00184	56	0,31	3,1
	30		0,00184	56	0,31	-2,9
	50		0,00184	56	0,31	-2,1

3.4. Calculation of the hydraulic resistance coefficient based on the T. Karman model using the transcendental equation (21):

$$\frac{1}{\sqrt{\lambda}} = 0,88 \cdot ln \ln\left[\mathrm{A} \cdot Re \cdot \sqrt{\lambda}\right] - 3,745$$

Results of calculation presented in table 7.

Table 7: *Results of calculations using the T. Karman model*

D, mm	Consumption, m3/h	Temperature, oC	A	Deviation of hydraulic resistance,%
50	10	20	41,2	9,9
	20		41,2	10,1
	30		41,2	-5,4
	50		41,2	-7,2

3.5. Calculation of the coefficient of hydraulic resistance based on the model of the universal law of resistance and Altschul's logarithmic formula:

$$\frac{1}{\sqrt{\lambda_f}} = 0{,}782 \cdot ln \ln\left[A_1 \cdot W_f\right] \tag{30}$$

where λ_f – coefficient of hydraulic resistance using ATA; $A_1(C)$ - coefficient depending on the concentration of the additive.

$$W_f = \frac{Re_f}{Re_f \cdot \frac{0{,}1 \cdot k_e}{D} + 7} \tag{31}$$

where k_e – roughness, Re_f – Reynolds number with ATA.

Table 8: *Results of calculations using the model based on the universal law of resistance and Altschul's logarithmic formula*

D, mm	Consumption, m3/h	Temperature, oC	A_1	W_f	Deviation of hydraulic resistance,%
50	10	20	1,1	406,8	6,1
	20		1,1	798,2	3,2
	30		1,1	1410,2	-2,5
	50		1,1	1850,2	-2,3

Models based on the universal law of resistance and the Altschul logarithmic formula, taking into account the Deborah number, and a model for calculating efficiency through the value of Re on the installation and the real pipeline turned out to be more accurate.

IV. Conclusions

As a result of the research, the following results were obtained:

1. Oil from the North Komsomolskoye field corresponds to the Bulkley-Herschel model and exhibits non-Newtonian properties in the temperature range from 10 to 20 degrees

2. A comparison of models of the hydraulic resistance coefficient showed that for a given type of oil the universal law of resistance and the Altschul logarithmic formula, taking into account the Deborah number and a model for calculating efficiency through the value of Re on the installation and the real pipeline.

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References

[1] Zakirova, G; Pshenin, V; Tashbulatov, R; Rozanova, L. Modern Bitumen Oil Mixture Models in Ashalchinsky Field with Low-Viscosity Solvent at Various Temperatures and Solvent Concentrations. Energies. 2023; 16(1):395. https://doi.org/10.3390/en16010395.

[2] Aleksander G., P., Yifan, T., & Fuming, Z. (2023). Predicting Service Life of Polyethylene Pipes under Crack Expansion using "Random Forest" Method. International Journal of Engineering, 36(12), 2243-2252. https://doi.org/10.5829/ije.2023.36.12c.14

[3] Nikolaev, A.; Plotnikova, K. Study of the Rheological Properties and Flow Process of High-Viscosity Oil Using Depressant Additives. Energies 2023, 16, 6296. https://doi.org/10.3390/en16176296.

[4] Palaev G., A., Fuming, Z., & Yifan, T. (2024). Method for Assessing Damage to Gas Distribution Network Pipelines based on Nonlinear Guided Wave. International Journal of Engineering, 37(5), 852-859. https://doi.org/10.5829/ije.2024.37.05b.04

[5] Shagiev, R.G.; Gumerov, A.G.; Khudyakova, L.P. The problem of degradation of anti-turbulent additives in pipelines of hydrocarbon raw materials. Sci. Technol. Pipeline Transp. Oil Oil Prod. 2017, 11, 41–47.

[6] Zhang, L.; Du, C.; Wang, H.; Zhao, J. Three-dimensional numerical simulation of heat transfer and flow of waxy crude oil in inclined pipe. Case Stud. Therm. Eng. 2022, 37 102237.

[7] Fetisov, V. Analysis of numerical modeling of steady-state modes of methane–hydrogen mixture transportation through a compressor station to reduce CO2 emissions. Sci Rep 14, 10605 (2024). https://doi.org/10.1038/s41598-024-61361-3

[8] Kumar, R.; Banerjee, S.; Mandal, A.; Naiya, T.K. Flow improvement of heavy crude oil through pipelines using surfactant extracted from soapnuts. J. Pet. Sci. Eng. 2017, 152, 353–360. https://doi.org/10.1016/j.petrol.2017.02.010.

[9] Ghoneim, N.I.; Megahed, A.M. Numerical Analysis of the Mixed Flow of a Non-Newtonian Fluid over a Stretching Sheet with Thermal Radiation. Fluid Dyn. Mater. Process. 2023, 19, 407–419.

[10] Shammazov I.A., Borisov A.V., Nikitina V.S. Modeling the Operation of Gravity Sections of an Oil Pipeline. Bezopasnost Truda v Promyshlennosti // Occupational Safety in Industry. 2024. № 1. pp. 74–80. (In Russ.). DOI: 10.24000/0409-2961-2024-1-74-808

[11] Mukhaimer, A.; Al-Sarkhi, A.; El Nakla, M.; Ahmed, W.; Al-Hadhrami, L. Pressure drop and flow pattern of oil–water flow for low viscosity oils: Role of mixture viscosity. Int. J. Multiph. Flow 2015, 73, 90–96. https://doi.org/10.1016/j.ijmultiphaseflow.2015.02.018.

[12] Mardashov, D.V.; Bondarenko, V.; Raupov, I.R. Technique for calculating technological parameters of non-Newtonian liquids injection into oil well during workover. J. Min. Inst. 2022, 254, 1–14.

[13] Wang, K.; Wang, Z.M.; Song, G.-L. Batch transportation of oil and water for reducing pipeline corrosion. J. Pet. Sci. Eng. 2020, 195, 107583. https://doi.org/10.1016/j.petrol.2020.107583.

[14] Bolobov, V.; Martynenko, Y.; Yurtaev, S. Experimental Determination of the Flow Coefficient for a Constrictor Nozzle with a Critical Outflow of Gas. Fluids 2023, 8, 169. https://doi.org/10.3390/fluids8060169

[15] X. Luo, G. Lü, W. Zhang, L. He, Y. Lü. Flow structure and pressure gradient of extra heavy crude oil-water two-phase flow. J. Exp. Therm. Fluid Sci., 82 (2017), pp. 174-181, doi.org/10.1016/j.expthermflusci.2016.11.015.

[16] Ulyasheva, N.; Leusheva, E.; Galishin, R. Development of the drilling mud composition for directional wellbore drilling considering rheological parameters of the fluid. J. Min. Inst. 2020, 244, 454–461. https://doi.org/10.31897/pmi.2020.4.8.

[17] J. Shi, M. Gourma, H. yeung. CFD simulation of horizontal oil-water flow with matched density and medium viscosity ratio in different flow regimes. J. J. Petrol. Sci. Eng., 151 (2017), pp. 373-383, doi.org/0.1016/j.petrol.2017.01.022.

[18] Perveitalov, O.G.; Nosov, V.V.; Schipachev, A.M.; Alekhin, A.I. Thermally Activated Crack Growth and Fracture Toughness Evaluation of Pipeline Steels Using Acoustic Emission. Metals 2023, 13, 1272. https://doi.org/10.3390/ met13071272

[19] Schipachev, A.; Aljadly, M.; Ganzulenko, O.; Chernikov, D.; Razzhivin, V.; Yusupov, R. Evaluating the Effectiveness of Magnetic-Pulse Treatment for Healing Continuity Defects in the Metal of Oil and Gas Pipelines. Metals 2023, 13, 1875. https://doi.org/10.3390/met13111875

[20] Lorena A. dos Santos, Danielda C. Ribeiro, Oldrich J.Romero. Heavy oil transportation through steam heating: An analytical and numerical approach. Journal of Petroleum Science and Engineering Volume 195, December 2020, 107932, doi.org/10.1016/j.petrol.2020.107932.

[21] Qian Huang, Hongying Li, Yu Zhuang, Yifei Ding, Chenbo Ma, Chaohui Chen, Yiwei Xie, Huaqing Liang, Shanpeng Han, Jinjun Zhang. Reducing viscosity of waxy crude oil with electric field perpendicular to oil's flow direction. Fuel Volume 283, 1 January 2021, 119345, doi.org/10.1016/j.fuel.2020.119345.

[22] Xiaoqing Li, Renqiang Liu, Hui Jiang, Peng Yu, Xiaoyan Liu. Numerical investigation on the melting characteristics of wax for the safe and energy-efficiency transportation of crude oil pipelines. Measurement: Sensors Volumes 10–12, 15 November 2020, 100022, doi.org/10.1016/j.measen.2020.100022.

[23] P. Babakhani, A. Azdarpour, E. Mohammadian. The hydrodynamic behavior of high viscous oil-water flow through horizontal pipe undergoing sudden expansion-CFD study and experimental validation. Chem. Eng. Res. Des., 139 (2018), pp. 144-161, doi.org/10.1016/j.cherd.2018.09.026.

[24] A. Archibong-Eso, J. Shi, Y.D. Baba, A.M. Aliyu, Y.O. Raji, H. Yeung. High viscous oil-water two-phase flow: experiments & numerical simulations. Heat Mass Tran., 55 (3) (2019), pp. 755-767, doi.org/10.1007/s00231-018-2461-9.

[25] J. Shi, M. Gourma, H. Yeung. CFD simulation of horizontal oil-water flow with matched density and medium viscosity ratio in different flow regimes. J. Petrol. Sci. Eng., 151 (2017), pp. 373-383, doi.org/10.1016/j.petrol.2017.01.022.

[26] Nikolaev, A., Lykov, Y.V., Duchnevich, L. (2018). Mathematical modeling of non-stationary gas flow in gas pipeline. IOP Conference Series: Materials Science and Engineering, 327. 327 (2), pp.1-6. https://doi.org/10.1088/1757-899X/327/2/022034

[27] Palaev A. G., Nosov V. V., Krasnikov A. A. Simulating distribution of temperature fields and stresses in welded joint using ANSYS. Science & Technologies: Oil and Oil Products Pipeline Transportation. 2022;12(5):461–469. https://doi.org/10.28999/2541-9595-2022-12-5-461-469

[28] Mingyan Shao, Palaev Aleksander, Yuhong Xia, Huiying Xu, Yifan Tian, Vadim Fetisov, A.M. Shipachev, Zhenqing Yang, Understanding the phase behavior during CO2 flooding by dissipative particle dynamics, Journal of Molecular Liquids, Volume 409, 2024, 125514, ISSN 0167-7322, https://doi.org/10.1016/j.molliq.2024.125514

[29] Xiaoqing Li, Renqiang Liu, Hui Jiang, Peng Yu, Xiaoyan Liu. Numerical investigation on the melting characteristics of wax for the safe and energy-efficiency transportation of crude oil pipelines. Measurement: Sensors Volumes 10–12, 15 November 2020, 100022, doi.org/10.1016/j.measen.2020.100022

[30] P.Babakhani, A. Azdarpour, E. Mohammadian. The hydrodynamic behavior of high viscous oil-water flow through horizontal pipe undergoing sudden expansion-CFD study and experimental validation. Chem. Eng. Res. Des., 139 (2018), pp. 144-161, doi.org/10.1016/j.cherd.2018.09.026

[31] A. Archibong-Eso, J. Shi, Y.D. Baba, A.M. Aliyu, Y.O. Raji, H. Yeung. High viscous oil-water two-phase flow: experiments & numerical simulations. Heat Mass Tran., 55 (3) (2019), pp. 755-767, doi.org/10.1007/s00231-018-2461-9

[32] Sultanbekov, R.R.; Schipachev, A.M. Manifestation of incompatibility of marine residual fuels: a method for determining compatibility, studying composition of fuels and sediment. J. Min. Inst. 2022, 257, 843–852.

[33] J. Shi, M. Gourma, H. Yeung. CFD simulation of horizontal oil-water flow with matched density and medium viscosity ratio in different flow regimes. J. Petrol. Sci. Eng., 151 (2017), pp. 373-383, doi.org/10.1016/j.petrol.2017.01.022

[34] Samigullin G H , Schipachev A. M., Samigullina L. G., Fetisov V. G. Assessment of damage of metallic elements in oil and gas facilities using small punch test International Journal of Applied Engineering Research. 2017. №12. pp. 11583-11587.

[35] Rafael Martínez-Palou, María de Lourdes Mosqueira, Beatriz Zapata-Rendón, Elizabeth Mar-Juárez, César Bernal-Huicochea, Juande la Cruz Clavel-López, Jorge Aburto. Transportation of heavy and extra-heavy crude oil by pipeline: A review. Journal of Petroleum Science and Engineering Volume 75, Issues 3–4, January 2011, pp. 274-282, doi.org/10.1016/j.petrol.2010.11.020

[36] Litvinenko, V.S.; Tsvetkov, P.S.; Dvoynikov, M.V.; Buslaev, G.V. Barriers to implementation of hydrogen initiatives in the context of global energy sustainable development. J. Min. Inst. 2020, 244, 428–438.

[37] N.H.Abdurahman, Y.M.Rosli, N.H.Azhar, B.A.Hayder. Pipeline transportation of viscous crudes as concentrated oil-in-water emulsions. Journal of Petroleum Science and Engineering Volumes 90–91, July 2012, pp. 139-144, doi.org/10.1016/j.petrol.2012.04.025

[38] Xintong Huang, Cuihong Zhou, Quanyu Suo, Lanting Zhang, Shihan Wang. Experimental study on viscosity reduction for residual oil by ultrasonic. Ultrasonics Sonochemistry Volume 41, March 2018, pp. 661-669, doi.org/10.1016/j.ultsonch.2017.09.021

[39] Wanqing Wang, Chenxi Yi, Wu. Xiaochuan, et al. Heavy oil viscosity reduction methods overview Sichuan Chem. Ind., 2 (2013), pp. 13-17, doi.org/10.4028/www.scientific.net/AMR.602-604.13

[40] Fetisov, V.G., Nikolaev, A., Lykov, Y.V. (2017). Experimental Studies for Determining Gas Flow Rate Accidental Release on Linear Part of Pipeline, 87 (6), pp.1-9. https://doi.org/10.1088/1755-1315/87/6/062003

[41] Korobov, G. Y., Vorontsov, A. A., Buslaev, G. V, and Nguyen, V. T. "Analysis of Nucleation Time of Gas Hydrates in Presence of Paraffin During Mechanized Oil Production." International Journal of Engineering, Vol. 37, No. 7, (2024), 1343–1356. https://doi.org/10.5829/ije.2024.37.07a.13

[42] C.A.M. Cavicchio, J.L. Biazussi, M.S. de Castro, A.C. Bannwart, O.M.H. Rodriguez, C.H.M. de Carvalho. Experimental study of viscosity effects on heavy crude oil-water core-annular flow pattern. J. Exp. Therm. Fluid Sci., 92 (2018), pp. 270-285, doi.org/10.1016/j.expthermflusci.2017.11.027

[43] X. Luo, G. Lü, W. Zhang, L. He, Y. Lü. Flow structure and pressure gradient of extra heavy crude oil-water two-phase flow. J. Exp. Therm. Fluid Sci., 82 (2017), pp. 174-181, doi.org/10.1016/j.expthermflusci.2016.11.015

[44] Mardashov, D.V. Development of blocking compositions with a bridging agent for oil well killing in conditions of abnormally low formation pressure and carbonate reservoir rocks. J. Min. Inst. 2021, 251, 617–626. https://doi.org/10.31897/PMI.2021

[45] Nasibova G. J. et. al., (2023). Oil and gas prospects of tectonic crashing zones of the Kura intermountain depression. "Reliability: Theory and Applications" RT&A, 5 (75), Volume 18, 313-322. https://doi.org/10.24412/1932-2321-2023-575-313-322.

STUDY OF VULNERABILITY AND PROTECTION OF BUILDINGS AND STRUCTURES ON STRUCTURALLY UNSTABLE CLAY SOILS

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Abstract

The study provides a clear definition of the vulnerability of buildings and structures designed and operated on structurally unstable clay soils. The condition of critical external negative impact on structurally unstable clay soil was considered as a random variable. Distribution functions were given for various degrees of damage or destruction of objects on structurally unstable clay soils. The methodology for study and construction of engineering protection schemes for objects designed and operated on structurally unstable clay soils was presented. An example of the energy balance of the object engineering protection with optimal loading of the building was given schematically. A scheme for protection of an object on structurally unstable clay soils with their optimal loading and a scheme for protection of an object on subsiding soils using a screen and drainage were also provided. A formula was given for determining the degree of implementation of the objectives of protecting objects on structurally unstable clay soils

Keywords: vulnerability, structurally unstable soil, building, structure, engineering protection, scheme

I. Introduction

The threat of damage to structures due to uneven deformations of structurally unstable clay soils (subsiding, swelling, populated and water-saturated) depends on the relative position of the source of soil moisture or drying and the action of various loads (primarily the weight of the structure itself) acting on the structurally unstable soil.

A threat of negative impact on structurally unstable soil causes occurrence of damage if this negative impact (a sharp change in the moisture content of structurally unstable clay soils) leads to critical uneven deformations of buildings and structures. Then the structures are damaged or, in extreme cases, go into an emergency state (complete destruction), leading to significant discomfort (material and psychological) for the owners and people operating the facilities. The possibility of damage and destruction of buildings and structures due to the impact of adverse factors on structurally unstable clay soil depends on the vulnerability of the building (structure) - structurally unstable (clay) soil system. The issues related to the study of the vulnerability of technical systems and territories to various adverse impacts are discussed in the monographs by V.A. Akimov, N.N. Radayev, V.D. Novikov, V.V. Lesnykh [1, 2], V.V. Bolotin [3], A.A. Rogozin [4], V.A. Vladimirov, Yu.L. Vorobyev, N.A. Makhutov and et al. [5], V.T. Alymov and N.P. Tarasova [6], N.N. Chura [7] et al.Vulnerability, by definition, depends both on the properties of the object itself and its ability to withstand adverse impacts, as well as on the intensity of these impacts [4].

II. Theoretical definition of vulnerability of engineering structures on structurally unstable clay soils

Let $\Delta_{cr.}$ critical action (moisture, leaching, evaporation, transpiration, and the pressure of water extrusion from the soil) at which damage or failure of a building or structure doesn't occur. Critical action characterizes the geotechnical stability of a building or structure against external adverse impacts. Geotechnical stability is the property of a construction object (building, structure) to maintain its geotechnical parameters within construction norms and rules and perform its functions during and after external adverse impacts on structurally unstable soil. The property of a building or structure opposite to geotechnical stability is geotechnical vulnerability (it can be called conditional geotechnical vulnerability). The characteristic of conditional geotechnical vulnerability of a geotechnical object coincides with the characteristic of the geotechnical ultimate stability of the object (building or structure). This critical external action (or actions) is the threshold beyond which damage occurs, leading to a geotechnical emergency situation.

$$\Delta'_{cr} \equiv \Delta_{cr}, \tag{1}$$

In geotechnical calculations and related engineering assessments of the consequences of hazardous influences on structurally unstable clay soils due to the effects of individual unstable factors (duration of exposure, quantity of negative agents affecting the unstable soil, influence of adjacent soils), the critical action can be treated as a random variable *Jcr.* The complete probabilistic characteristic of conditional geotechnical vulnerability of buildings and structures is the distribution function of critical action:

$$F_{cr}(\Delta_{cr}) = P(J_{cr} < \Delta_{cr}), \tag{2}$$

Distribution function $F_{cr}(\Delta_{cr})$ for geotechnical objects of a specific type can be considered as the physical laws governing the damage or failure of buildings or structures under consideration of the detrimental effect.

The random variable of critical action on known types of structurally unstable soils, interacting with typical buildings or structures, is typically distributed according to the normal law:

$$J_{cr} \in N(\mu_{cr}, \sigma^2_{cr}), \tag{3}$$

where μ_{cr} is the mean of the critical action on structurally unstable clay soils, and $\sigma^2_{\Delta_{cr}}$ - variance of the mean expectation Δ_{cr}.

Accordingly, the complete probabilistic stability of geotechnical objects under critical external actions is characterized by the function:

$$R_{cr}(\Delta_{cr}) = P(J_{cr} \geq \Delta_{cr}) = 1 \cdot F_{cr}(\Delta_{cr}) \tag{4}$$

representing the dependence of the probability of geotechnical objects stability on the considered structurally unstable clay soils on the level of adverse external impact.
Different distribution functions are distinguished

$$F_{cr}(\Delta_{cr} \geq |d) = P(J_{cr.d} < \Delta_{cr}) \tag{5}$$

for different degrees *d* of damage or destruction of objects on structurally unstable clay soils, or for degrees of damage or destruction not less than a specified D:

$$F_{cr}(\Delta_{cr}|D) = \sum_{d=1}^{D} F_{cr}(\Delta_{cr}|d). \tag{6}$$

These functions for each object situated on structurally unstable clay soils can be established on the basis of existing experience gained from analyzing the consequences of past damages and failures of buildings and structures on structurally unstable clay soils. This can also be derived from assessments of the resilience of buildings and structures under uneven deformations of structurally unstable clay soils. Critical external factors for specific geotechnical objects can be evaluated through the following methods:

- field-experimental methods: using data on the degree of damage and destruction of buildings or structures of similar construction on corresponding types of structurally unstable clay soils due to previous adverse external factors;
- computational-experimental methods: based on the results of studies on the response of buildings or structures to trial external impacts on structurally unstable clay soils with which these buildings or structures come into contact;
- computational-modeling methods: employing theoretical models and computer programs considering the structural features of buildings or structures to resist damages and emergencies both in normal conditions and with engineering protection against various adverse external impacts on structurally unstable clay soils.

$F_{cr}\left(\Delta_{cr}|d\right)$ for a fixed critical adverse external impact on structurally unstable clay soils, Δ_{cr} can be called "physical vulnerability" of buildings or structures interacting with structurally unstable soils referring to the proportion

$$\alpha_d\left(\Delta_{cr}\right) = N_d\left(\Delta_{cr}\right)/N \quad (7)$$

of damaged (destroyed) buildings or structures in the case of a specified intensity of Δ_{cr} . B (7) $N_d\left(\Delta_{cr}\right)$ of external negative impact *d*, representing the number of buildings (structures) that incurred damage (destruction) from the total number *N* of buildings (structures) interacting with structurally unstable clay soils in the area affected by the specific intensity of external negative impact Δ_{cr} . As is evident, mathematically, they coincide:

$$\alpha_d\left(\Delta_{cr}\right) \equiv F_{cr}\left(\Delta_{cr}|d\right). \quad (8)$$

III. Methodology for the study of the schemes for engineering protection and objects on structurally unstable clay soils

The stability of the considered geotechnical objects is established on the basis of everyday experience and experimental construction and operation of buildings or structures on structurally unstable clay soils. This stability is then codified in building codes, regulations, and guidelines at a level where the prevented damage from failures and accidents still outweighs the additional costs of engineering protective measures enhancing the stability of these objects constructed and operated on structurally unstable clay soils.

According to the modern standards, engineering protective measures against external negative impacts and the uneven deformations caused by them increase the cost of buildings and structures by 20-40%. Without these protective measures, repair costs for buildings and structures, depending on the type of unstable soils, range from at least 20-50% up to the complete demolition of the emergency structure, resulting in 100% loss of the object, plus costs for demolition and site remediation of the affected area.

The damage (destruction) possibility to considered geotechnical structures and the occurrence of emergency situations significantly depends on the protection of buildings or structures on structurally unstable clay soils, ensured through the implementation of preliminary protective engineering measures included in the construction project of buildings and structures on territories occupied by structurally unstable clay soils.

Methodological principles for engineering protection of buildings and structures operated on structurally unstable clay soils are proposed against various hazardous negative externalities on the basis of alteration of energy potentials.

The following components are identified for solving the problem of engineering protection of objects designed and operated on structurally unstable clay soils: the source of negative externality (Δ), the source of constant load (q) from the building or structure, the source of probabilistic short-term external (seismic) impact (S), the receiver (structurally unstable soil) of external impact (T), and the engineering protection which shields or reduces the intensity level of negative externality on structurally unstable clay soils to permissible values for safe construction and operation of objects (Z).

Let's consider from the total flow of negative energy E directed towards the receiver T and entering the engineering protection Z (Fig. 1), part E is reflected (shielded), part E_2 is absorbed by the receiver (soil) T, and part E_3 is dissipated into zones outside the receiver T. Thus, Z can be characterized by the following energetic coefficients:

– reflection coefficient $\xi = E_1 / E$,
– absorption coefficient $\beta = E_2 / E$,
– dissipation coefficient $\rho = E_3 / E$.

The overall equilibrium state of geotechnical object is represented as follows:

$$\xi + p + s = 1. \tag{9}$$

Sum

$$\beta + \rho = 1 - \xi - h, \tag{10}$$

where

$$h = E_h / E, \tag{11}$$

characterizing the unreflected energy flow E_h passed into the engineering protection Z.

If $\beta = 1$, then Z reflects all the energy of negative externality on the structurally unstable clay soil.

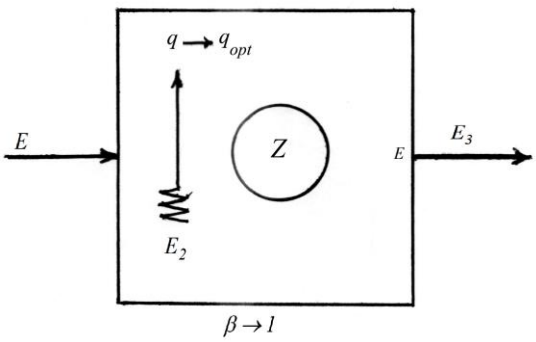

Figure 1: *Example of the energy balance of engineering protection for an object on structurally unstable clay soil (q_{opt} - optimal load)*

If $\rho = 1$, then Z reflects all negative energy from external impacts on the object associated with structurally unstable clay soil.

In practice, protective measures are often used in a combined form, for example $\xi + \rho = 1$. This means employing protective anti-filtration screens and draining water away from the protected area beyond its boundaries using specialized drainage systems.

The study [8] represents the examples of absorbing negative externalitys (soaking) on structurally unstable subsidence and swelling clay soils, with a protective measure involving maximizing water absorption by the soil. In these examples, techniques for optimizing the load from buildings or structures on the foundation soil were employed, specifically $q \rightarrow q_{opt}$. .

In the first example, the base area of the building foundation was maximally expanded (replacing strip foundation with a raft foundation). This approach achieved a specific pressure on the subsiding soil that was lower than the initial settling pressure. In the second case, the width of the strip foundation of a building on swelling clay soil was reduced to ensure that the specific pressure from the foundation on the soil base was less than the active pressure due to swelling of the clay soil [9]. The energy protection balance scheme for engineering protection of objects on structurally unstable soils during $\beta \rightarrow 1$ is shown in Fig. 1.

For the aforementioned examples, the protective engineering measure Z ensured achieving optimal loading of structurally unstable clay soils (subsiding and swelling) by buildings constructed on them, denoted as q_{opt} . This approach made structurally unstable soils fully transparent to negative externalities (soaking).

Fig. 2 illustrates the transparency scheme of structurally unstable clay soils to external negative moisture (W) under optimal loading conditions of structurally unstable soils (T).

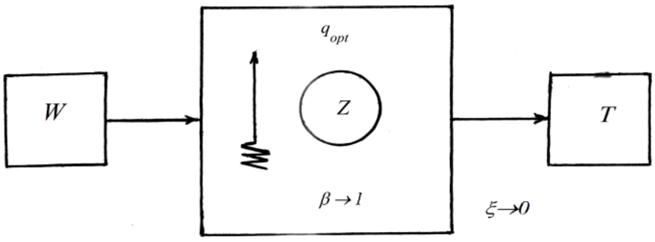

Figure 2: *Scheme of protection for geotechnical object on structurally unstable clay soils at their optimal loading*

Consider the case, when the building is located on subsidiary soil of a type II along the subsidence. In its natural state, the building retains its stability due to the structural strength of subsidiary soil. The building will go into a state of emergency under a negative externality (uneven soaking) due to uneven subsidence of the substrate. For the purpose of preventing an accident, a comprehensive protective film screen and drainage are provided.

Fig. 3 shows the scheme of reflection (screen) and removal (drainage) of negative externality (soaking) on subsidiary soil, loaded with the weight of the building, exceeding its structural strength in the moistened state.

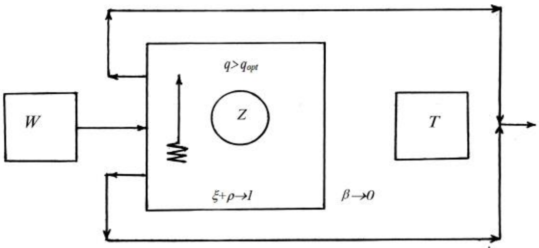

Figure 3: *Scheme of protection of an object on subsidiary soil in the case of using reflective anti-filtration screen and discharge drainage*

Realization degree of the objectives of protection of buildings or facilities (objects), erected and operated on structurally unstable clay soils can be expressed by:

$$K_s = \frac{M_z}{M_w} \tag{12}$$

where *K* is the protection coefficient of the object on structurally unstable clay soils; M_z – the cost of protective engineering measures; M_w – the cost of repairing a geotechnical object damaged or affected by the negative externality *W* (uneven soaking).

If $K_s \leq 0{,}3$ this is considered acceptable for the design and practical implementation of protective engineering measures. If $0.31 \geq K_s \geq 0.50$ this is considered a necessary condition for the design and practical implementation of protective engineering measures when there is no choice of construction site for critical buildings and structures. If $K_s > 0.50$, this is considered an unacceptable condition for the design and implementation of protective measures for geotechnical objects on structurally unstable clay soils.

IV. Conclusion

A threat of negative impact on structurally unstable soil causes occurrence of damage if this negative impact leads to critical uneven deformations of buildings and structures.

In geotechnical calculations and related engineering assessments of the consequences of hazardous influences on structurally unstable clay soils due to the effects of individual unstable factors, the critical action can be treated as a random variable.

The random variable of critical action on known types of structurally unstable soils, interacting with typical buildings or structures, is typically distributed according to the normal law. Critical external factors for specific geotechnical objects can be evaluated through the following methods: field-experimental methods; computational-experimental methods; computational-modeling methods.

Methodological principles for engineering protection of buildings and structures operated on structurally unstable clay soils are proposed against various hazardous negative externalities on the basis of alteration of energy potentials. The schemes are given of protection for geotechnical object on structurally unstable clay soils at their optimal loading and of an object on subsidiary soil in the case of using reflective anti-filtration screen and discharge drainage.

It is proposed to define realization degree of the objectives of protection of buildings or facilities (objects), erected and operated on structurally unstable clay soils through the object's protection factor.

References

[1] Akimov V.A., Novikov V.Yu., Radaev N.N. Natural and man-made emergencies: dangers, threats, risks. Moscow: ZAO FID Delovoy Express. 2001, 344 p.

[2] Akimov V.A., Lesnykh V.A., Radaev N.N. Fundamentals of risk analysis and management in the natural and man-made spheres. Moscow: Delovoy Express. 2004, 352 p.

[3] Bolotin V.V. Methods of probability theory and reliability theory in structure calculations. Moscow: Stroyizdat, 1981, 351 p.

[4] Assessment and management of natural risks. (Ragozin A.L., editor). Thematic volume. Moscow: Publishing form "KRUK", 2003, 320 p.

[5] Risk management: Risk. Sustainable development. Syneritika. Moscow: Nauka, 2000, 431 p.

[6] Alymov V.T., Tarasova N.P. Technogenic risk: Analysis and assessment. Moscow: ITC "Akadem-kniga", 2007, 118 p.

[8] Chura N.N. Technogenic risk. Moscow: KNORUS, 2011, 280 p.

[9] Gabibov F.G., Mamedov F.Sh., Amrakhov A.T., Makhmudov K.S. (2009). Vulnerability of structures designed and operated on structurally unstable soils of Azerbaijan. Proceedings of the International Scientific and Practical Conference. "Georisk-2009", Volume 1, "Problems of Reducing Natural Hazards and Risks", Moscow: Peoples' Friendship University of Russia, pp. 273-277.

[10] Gabibov F.G. Method for designing and constructing strip, rectangular and round foundations on swelling clay soils. Eurasian patent for invention No. 034709, 2020.

ON THE RELIABILITY AND EFFICIENCY OF OPERATION OF MULTIPHASE PIPELINES UNDER HYDRAULIC İMPACT

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Abstract

The issues of reliability and efficiency of operation of field and main oil and gas pipelines and control of energy characteristics during their operation are of no small importance. The efficiency of pipelines depends on the technical condition of facilities and equipment and the rationality of their use. The practice of operating pipelines shows that emergency and abnormal cases occur in them. Significant irregular pressure and flow pulsations are observed in pipelines. Waves of high and low shock pressure often occur and propagate along the pipeline.
Along with density, additional pressure in the system from hydrodynamic impacts also arises from the elasticity of the pumped liquid and the pipeline itself. This pressure is determined by the elastic compression of the transported system and the elastic expansion of the pipeline as the pressure in it increases. The pipeline through which the multiphase flow is pumped, and its structures and other components must withstand dynamic loads.
The work analyzes various modes of water impact. The volume of oil caused by its compression during hydraulic impact was calculated. The results of calculating the increase of an oil pipeline volume due to a dynamic impact are presented.

Keywords: Water impact, dynamic load, energy feature, elasticity, multiphase flow, flow structure.

I. Introduction

As it is known, any change in the parameters of pumping oils (petroleum products) through a pipeline can be called a hydraulic impact. Such a change can occur slowly or quickly; the cause of the shock can be the slow or fast closing or opening of shut-off valves, stopping or starting a pump, the destruction of a pressure pipeline with the release of the pumped product onto the relief, as well as various dynamic loads that arise during the operation of multiphase pipelines [1 ,2,3,4].

The pressure value during water impact according to Zhukovsky can be calculated using the following formula:

$$P = c \cdot \Delta \upsilon \cdot \rho \quad (1)$$

Where c is the speed of sound propagation in a fluid at rest;
$\Delta\upsilon$– reduction of flow velocity in the pipeline;
ρ– density of pumped oil.

The practice of operating field pipelines shows that significant irregular pulsations of pressure and flow are observed in pipelines transporting multiphase mixtures. The working environments of the oil field are characterized by the presence of liquid and gas phases, which coexist in almost all oil field pipelines [6-9].

Analysis of the parameters of water impact pressure distribution along the length of the pipeline allows to choose tactics and methods for protecting the system from impact. It was found that transient conditions during the transportation of gas-saturated oils through oil pipelines are a consequence of the same reasons as during the transportation of degassed oils. Waves of increased and decreased impact pressure, propagating along the pipeline also occur [2,10]. In this case, the wave of increased pressure has the greatest magnitude and, propagating towards the previous operating station, is superimposed on the existing pressure in the oil pipeline, summing up with it. A wave of low pressure, which moves at the speed of impact wave propagation in the liquid towards the subsequent pumping station, can cause the release of gas from gas-saturated oil and lead to the formation of gas accumulations in the oil pipeline and cavitation of pumps. As for transient regimes when pumping gas-saturated oils, they do not introduce significant changes and can be assessed using existing methods for calculating transient regimes in degassed oils. In this case, the relative change in the pressure increase in the disturbed gas-saturated flows will be determined by the relative change in the bulk elasticity modulus of gas-saturated oil.

In [6,9], taking into account changes in the structural forms of flow of multiphase systems based on an estimate of the critical flow velocity, the issues of distribution of dynamic loads were considered and it was found that when the gas phase dominates in the system, with increasing ratio of the density of liquid and gas, the dynamic load grows significantly.

II. Methods

As a rule, additional pressure during the operation of pipelines due to water impact arises from the density of the transported liquid, its elasticity and the elasticity of the pipeline itself. The practice of operating field and main pipelines shows that, due to impact pressures, the energy characteristics of pipeline systems can change significantly depending on the intensity of hydraulic pressure. Water impact pressure is determined by two factors: the elastic compression of the transported oil or petroleum product and the elastic expansion of the pipeline itself when the pressure in it changes. The change in the density of transported oil with changes in pressure can be assessed using the following relationship:

$$\rho(P) = \rho_{20}[1 + \beta_o(P - P_{atm})] \tag{2}$$

Where ρ_{20} is the density of oil at 20 ^{0}C, kg/m ^{3};
P– pressure, Pa;
P_{atm}– atmospheric pressure, Pa;
β_o– oil compressibility coefficient (β= 0.00078 MPa $^{-1}$)
The change in the volume of oil in the pipeline (ΔV_o) depends on its modulus of elasticity $E_o = 1/\beta_o$ and the level of hydraulic pressure (P):

$$\Delta V_o = P \cdot V_o / E_o \tag{3}$$

Where V_o *is* the volume of oil in the pipeline, m^3;

$$V_o = V_p = \frac{\text{ПД}^2}{4} \cdot l \tag{4}$$

D and l are the diameter and length of the oil pipeline, respectively, m
The change in pipeline volume during water impact can be calculated using the following formula [5]:

$$\Delta V_{т} = \frac{ПД^3 \cdot P \cdot l}{2E_{т} \cdot \delta} \qquad (5)$$

Here δ is the thickness of the pipeline wall;
E_p– modulus of elasticity of the pipe material ($E_p = 2{,}1 \cdot 10^{11}\ Pa$)

It should be noted that the duration of the change in liquid volume is equal to the duration of the impact phase, which is equal to the travel time of the pressure wave from the disturbance to the barrier and back

$$t = 2l/c$$

The speed of sound propagation in oil is determined by the well-known formula [3,5]:

$$c = \frac{\sqrt{E_o/\rho_o}}{\sqrt{(1 + E_o \cdot Д/(E_p \cdot \delta)}} \qquad (6)$$

Let's consider an example of calculating changes in the volume of oil and a pipeline during a hydraulic shock.

We take as initial data:

- Pipeline length l= 5000 m ;
- Pipeline diameter D = 500 mm;
- Wall thickness $\delta = 10\text{mm}$;
- Oil pipeline volume $V_p = \frac{ПД^2}{4} \cdot l = \frac{3{,}14 \cdot (0{,}5)^2}{4} \cdot 5000 = 981{,}25\ m^3$;
- Oil consumption Q_o=1500 m^3/hour= 0.4166 m^3/s ;
- Oil density $\rho_o = 860\ kg/m^3$

We can calculate the water hammer pressure for the full shock that occurs when the valves are instantly closed. The oil velocity in the pipeline was :

$$v = \frac{4Q}{ПД^2} = \frac{4 \cdot 0{,}4166}{3{,}14 \cdot (0{,}5)^2} = 2{,}12\ m/s$$

We calculate the speed of sound propagation in oil using formula (4):$C = 1074{,}2\ m/s$

Then from formula (1) the pressure from the water hammer will be:

$$P = 1074{,}2 \cdot 2{,}12 \cdot 860 = 1958481\ Pa = 1{,}96\ MPa$$

As it can be seen from the calculation of hydraulic pressure, such pressure can arise with a long pipeline length exceeding the value $l > 2 \cdot c \cdot t$; t– valve closing time.

Let's consider calculations of the volume of oil caused by its compression during a hydraulic shock. It is known that the elastic property of oil when it encounters a valve will continue until the compression wave reflected from the beginning of the oil pipeline meets a direct compression wave. The duration of the increase in pressure in the oil pipeline will be :

$$t = \frac{2l}{c} = \frac{2 \cdot 5000}{1074{,}2} = 9{,}31\ s$$

Then the compression of oil in the pipeline by additional pressure at the elastic modulus of oil $E_o = \frac{1}{\beta_o} = 1{,}3 \cdot 10^9$ Pa will be (according to formula (3)):

$$\Delta V_o = 1958481 \cdot \frac{981{,}25}{1{,}3} \cdot 10^9 = 1{,}4782\ \text{m}^3$$

At the end, we will determine the increase in the volume of the oil pipeline itself due to impact according to formula (5):

$$\Delta V_p = \frac{3{,}14 \cdot (0{,}5)^3 \cdot 1958481 \cdot 5000}{2 \cdot 2{,}1 \cdot 10^{11} \cdot 0{,}01} = 0{,}9151\ m^3$$

It is also possible to calculate changes in oil density when pressure changes as a result of impact. Using formula (2) we obtain:

$$\rho = \rho_{20}[1 + \beta_o(P - 1)] = 860[1 + 0{,}00078 \cdot 10^{-6}(1958481 - 10^5) = 861{,}29\ kg/m^3$$

Then the water impact pressure will have the following value:

$$P = 1074{,}2 \cdot 2{,}12 \cdot 861{,}29 = 1961419\ Pa$$

In this case, the effect of changes in density will be 1961419 – 1958481 = 2938 Pa

III. Results

1. Various dynamic loads arising during the operation of multiphase pipelines were analyzed.
2. In order to ensure the reliability of pipelines, in addition to single-phase movement, dynamic loads must also be taken into account for gas inclusions and multiphase flow with various structural forms of movement in field pipelines

References

[1] Vasiliev G.G., Korshak A.A., Lurie M.V. etc. vol.1. Pipeline transportation of oil. M.: Nedra, 2002, 341 p.

[2] Tugunov P.I., Brot R.A., Kutukov S.E. Determination of impact pressure in an oil pipeline with gas-saturated oil under transient conditions // Oil and Gas Business, Transport and Storage 2005, Volume 3, p. 199-205.

[3] Basniev K.S., Dmitriev N.M., Rosenbert G.D. Oil and gas hydromechanics. M.: 2005, 544 p.

[4] E.Kh.Iskenderov ., Improving the efficiency of the functioning of gas pipelines, taking into account the structural features of gas flows. // Izvestia NAS RK. Series of Geology and Technical Sciences No. 3 (447) May-June, 2021

[5] Lurie M.V. Problem book on pipeline transport of oil, petroleum products and gas. M.: Center "Litneftegaz", 2004, 351 p.

[6] Sitenkov V.T., Lebedeva E.V. Reducing dynamic loads on field pipelines // Oil Industry 6 / 1998, p. 67-69.

[7] Guzhov A.I. Joint collection and transportation of oil and gas. M.: Nedra, 1973, 280 p.

[8] Ismayilov G.G. Ismailov R.A., Akhundzade A.N. Diagnosing the presence of liquid inclusions in gas pipelines. // SOCAR PROCEEDINGS. Special issue №. 1 (2022), pp. 154-161.

[9] Ismayilova F.B., Cafarova X.T. Assessment of dynamic loads in multiphase pipelines. // ANT, 09, 2021, pp 29-31.

[10] Brot R.A., Kutukov S.E. Determination of rheophysical parameters of gas-saturated oils. Oil and gas business. 2005, http://www.ogbus.ru

THE SOLUTION ASPECT OF PROBLEMS IN THE OIL FIELDS THAT HAVE BEEN WORKING FOR A LONG TIME IN THE AZERBAIJAN REPUBLIC

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Abstract

In the article, the analysis of the factors affecting the reduction of oil production in the hydrocarbon fields of the republic, which are in the last period of development, and the analysis of the existing problems in the exploitation of those fields are given. At the same time, referring to the scientific researches and actual oil field products, the sources of attracting investment in the production of residual oil reserves that can be extracted from the deposits, the importance of the development and application of innovative techniques and technologies, the use of the research work of scientists and specialists of scientific institutions in solving problems related to the intensification of oil production. ways and solutions of the state's problems were explained.

Keywords: deposit, oil, natural resource, production, investment, innovation, progressive methods

I. Introduction

It is known that the oil industry is the most important structural component of the country's economy, and thanks to it more than 50% of the state budget is formed, which is one of the main factors in ensuring the vital activity of the country's population.

As of 01.01.2023, 81 oil and gas fields have been discovered in the territory of the Republic of Azerbaijan. At present, hydrocarbons are produced from 58 fields, while 23 fields are not included in the development or their operation has been stopped due to objective and subjective reasons. 39 beds under development are located on land and 19 beds are located in the sea area. In 2023, the development of 28 fields (including 15 onshore and 13 offshore fields) was continued by "Azneft" PU.

Evaluating the prospects of oil production in the world, it can be said that the era of cheap and easily produced oil is over. At the same time, in Azerbaijan, as in the whole world, the share of hard-to-renew resources is increasing year by year and has exceeded 65% so far. Forecasts of the dynamics of the reserve structure do not create optimism, and by 2025, the share of hard-to-renew reserves in Azerbaijan will exceed 70%, and active reserves will be produced by 80%.

The British BP company's report published in the World Energy 2022 annual statistical overview lists oil-producing countries, and the oil reserves of our country are 7 billion barrels. Despite the fact that the republic has large hydrocarbon reserves, for more than 10 years, oil production and export of oil products have been decreasing every year. According to official information, Azerbaijan's income from the export of crude oil and oil products in 2023 decreased to slightly more than 16 billion dollars compared to 19.5 billion dollars in 2022. The statistics of the State Customs Committee show that the share of crude oil and oil products in the total volume of

Azerbaijan's exports decreased to 47.91 percent compared to 51.08 percent in 2022. This is directly related to the decrease in oil production (Fig. 1).

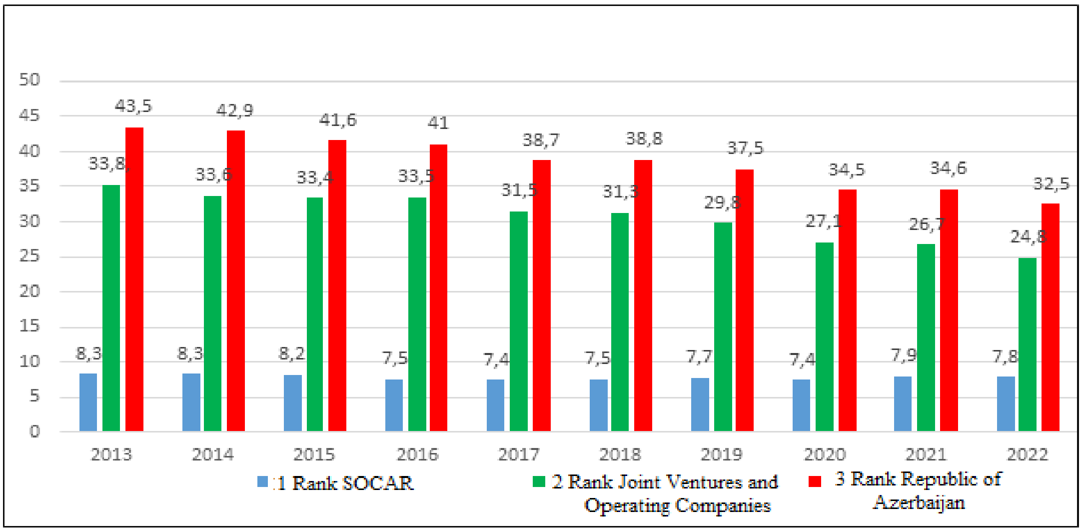


Figure 1: *Dynamics of oil production in the Republic of Azerbaijan in 2013-2022 (million tons)*

As can be seen from the picture, oil production has decreased by 11 million tons or 25.3% over the last ten years, along with the projects implemented together with foreign companies. Thus, oil production for the mentioned activity in 2013 is 43.5 million. 32.5 million tons in 2022. down to a ton.

It should be noted that along with foreign companies, Joint Ventures and Operating Companies of the republic, oil will be produced from fields located in long-term operating onshore and offshore fields. The reduction of production in these fields continues every year (Fig. 2).

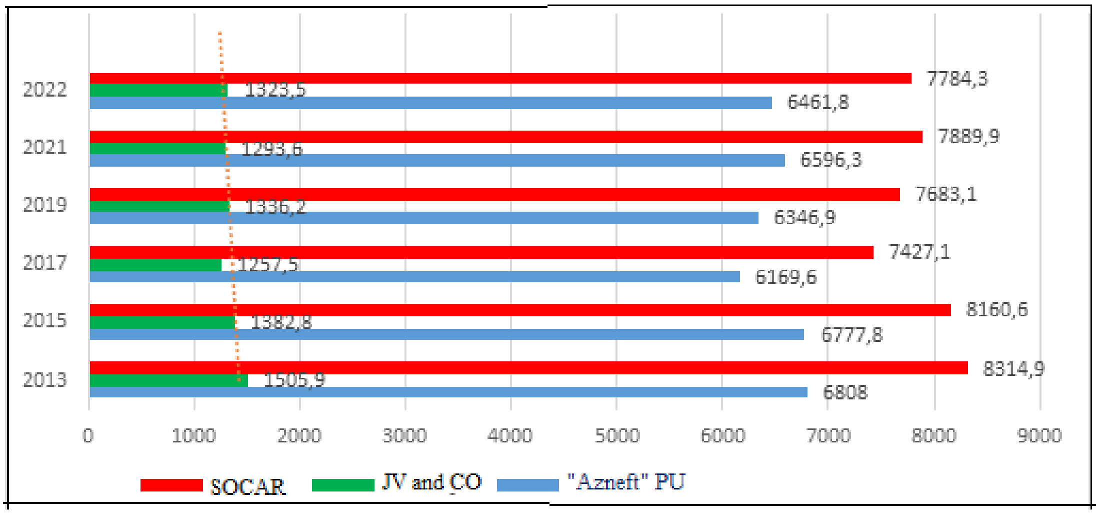


Figure 2: *Dynamics of oil production at SOCAR (2013-2022, million tons)*

According to SOCAR, oil production in the country's territories increased from 8,314.8 million tons in 2013 to 7,784.3 million tons in 2022, and the rate of decline in production in 10 years was 6.0%.

II. Methods

The problem of optimizing the development of oil fields involves a number of main problems, including the justification of the economic criterion of the efficiency of the exploitation of fields, the verification of the volume of natural resources by geological methods, the development and application of modern innovative technologies, the rationalization and application of effective methods, the acceleration of the application of scientifically based inventions and patents, etc. it is necessary to solve the issues. The issues of prevention and intensification of production decline in oil fields have been widely covered in the works and research works of many local and foreign scientists and experts.

Based on the results of our scientific research and actual oil fields, the following are the important factors that affect the reduction of production in the hydrocarbon fields located in the land and sea areas of our republic, which are in the final stage of development (the volume of reserves that can be extracted from these fields is close to 300 million tons). According to the assessment of the "De Golyer and MacNaughton" company, the total reserves of oil (proven, possible and probable) in the dry areas of the Republic of Azerbaijan are 2 billion barrels.

- As a result of over 100-150 years of working of the deposits, the percentage of wetted layers is 90-95%
- Lower formation pressure and temperature makes it difficult for oil to flow to the bottom of the well, allowing "dead" oil to remain in the formations.
- As a result of the increase in the viscosity of oil in the layers, the flow rate of oil decreases and the surface tension increases
- Failure to apply advanced methods for oil reserves that are difficult to extract;
- Formation of sand plug in wells
- The construction of well structures in oil and gas fields and the failure to take into account the geological and physical characteristics of the fields in the project materials related to the drilling of wells creates conditions for the occurrence of accidents in the processes of well drilling.
- Mistakes made in designing the development of oil and gas fields
- Non-intermittent operation of small production wells
- In the development of oil and gas fields, not investigating the issues of increasing the oil yield coefficient of the fields and not applying progressive methods in the production of oil and gas from the fields
- Non-involvement of scientists and non-specialists of scientific research and higher institutions in solving existing problems, etc.

III. Results

Determining the extent of residual oil and gas reserves in the fields based on 4D cartography technologies is one of the main aspects of solving the problems of hydrocarbon deposits. Resource assessment with geophysical methods plays a fundamental role. Thus, the volume of hydrocarbon reserves is one of the main components of the oil company's activity. Volume assessment In modern times, the importance of investments in the oil industry has increased to such an extent that they have already begun to have a political character. In this regard, it will allow the application of new advanced techniques and technologies in the stabilization of oil production in fields that are in the final stage of development. It is important to provide state support for investment in the development of the oil sector. The purpose of investment projects from this approach is to make the operation of the oil and gas extraction enterprise necessary to solve the following issues:

♦ identification of new resource sources;
♦ replacement of capital funds;

♦ reconstruction of capital funds;
♦ modernization of capital funds;
♦ commissioning of new construction facilities;
♦ purchase and installation of new advanced equipment, machinery and equipment.

The demand for oil in the industry is increasing day by day. For this reason, geophysical control in exploited oil and gas fields should be organized in such a way that it meets the requirements of the day. During the control of the deposits by geophysical methods, numerous petrophysical-geological operational issues should be studied to allow timely implementation of various measures in the wells. In addition to increasing the service life of the field, this should enable maximum hydrocarbon production from it. Analyzing the current state of development of Azerbaijan's oil and gas fields and monitoring them with well geophysical research methods, we will determine the following development directions:

* selection of optimal complexes for increasing the efficiency of control over the development of oil and gas fields with geophysical methods;

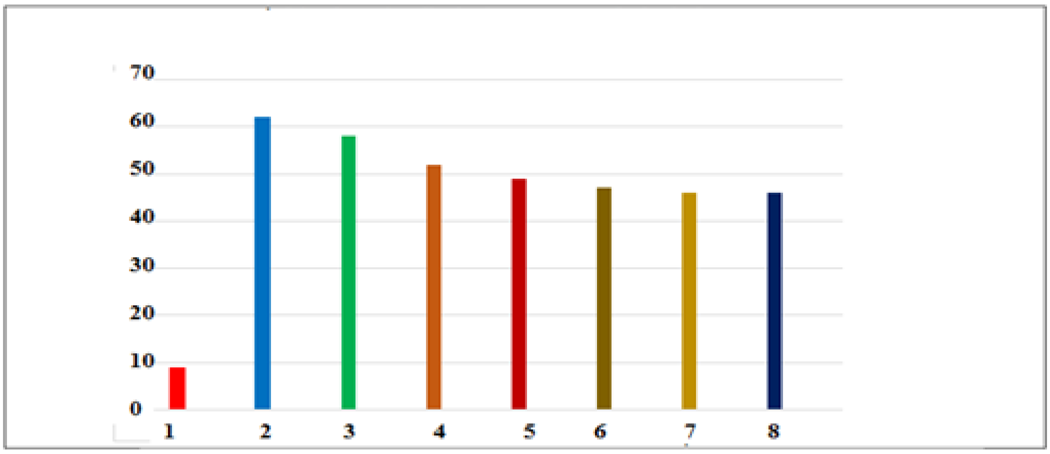
*development of more effective new interpretation methods for the assessment of the energy of oil and gas fields, the operating regimes applied to the formations that make up it, the collector properties of the formations and formation pressure;

*determining the technology and sequence of developing a satisfactory model of oil and gas field development control with QGT methods;

* selection of effective methods of influence to maximize productivity in oil and gas fields.

At present, solving the problems of the development of economic systems based on the methods of integrated assessment and management of the level of innovative development potential in the oil industry makes the development of new scientific approaches more and more urgent. In order to solve these issues, first of all, it is necessary to theoretically justify the essence and content of the structural components of the innovative potential in industries, and the methodological bases of the integral assessment of the interaction of their internal and external environmental factors. Thus, the analysis of scientific sources dedicated to the assessment and management of innovative technologies shows that there are practically very few theoretical and methodological provisions related to the development of models and methods for the integrated assessment and management of the level of innovative potential. In order to achieve the strategic goals of innovative development, the integral assessment of the development of economic systems at the micro and macro levels is a very urgent issue.

When determining the degree of efficiency of innovative activity in comparison with developed countries, it is clear that the overall level of innovative activity is only 4.3% according to the data of 2020. For comparison, let us show that the level of this indicator in Germany, Brazil, Canada, Israel and other countries is 30-35 times higher than ours (Figure 3).



1-Russiya, 2- Germany, 3 - Canada, 4 - Belgium, 5 - Switzerland, 6 - Finland, 7- Estonia, 8 – Israel

Figure 3: *The level of innovation in industrial sectors of developed countries,%*

From the analysis of the picture, it can be concluded that the following issues should be resolved in order to eliminate the low innovative activity of the republic's oil mining enterprises and the insufficient use of their innovative potential:

1. To support the involvement of small and medium businesses in oil production areas.
2. Solving issues related to classification criteria of enterprises according to the level of innovative activity.
3. To adapt the solution of problems of oil production of scientific research works.
4. Provision of concessional loans for the innovative development of enterprises.

Since the beginning of the 20th century, most US and Western oil companies have begun to pay attention to the extensive development of new information technologies. For this purpose, they mainly strengthened control over the development of the following areas:

- investment in digital technologies is not in expansion of the office equipment park, but in software;
- determining the impact of digital technologies on management processes in general;
- creation of unified information services for companies;
- development of new organizational forms of management;
- transfer of the automation management process almost from the level of operations to the level of tactical management;
- development of information systems mainly to support the decision-making process by company management.

It is clear from the experience of foreign oil companies that a special place in the digitization of management systems is related to the improvement of methods and forms of using digital technologies. In modern conditions, digitization and the development of "smart technology" guarantee, first of all, the creation and application of technical tools for personnel management, data analysis and transmission in enterprises, and the provision of economic infrastructure areas with new communication tools. Thus, the process of personnel management has a systemic nature, it involves the creation of an appropriate management mechanism, the determination of ways to solve this or that problem, the control of mutual relations between individual subdivisions, the comprehensive planning and organization of the activity of the entire system as a whole.

Scientific studies show that developed countries allocate significant financial resources to reveal the intellectual potential of the new generation and to create their world-class highly competitive technological industries and technological products. In these countries, economic "advancement" based on the end product strategy has become a tradition in higher institutions. In order to ensure the participation of students of higher schools in "unified technology" processes, companies and companies sign agreements with universities to solve the problems of innovative technologies before them and monitor their implementation. Due to the involvement of the new generation in these processes, they apply a preferential tax system to state financing companies. This experience is used in Japan, USA, Singapore, Norway, Germany, England, etc. widely distributed in countries. Thus, the main directions of the innovative development of the economy in foreign countries and the role of assessing the value of the right to a single technology are analyzed, directed and formed as a combined scientific and technical result of the interaction of identifiable and non-identifiable intangible assets of a scientific enterprise.

It should be noted that "Unit technology" is the result of scientific and technical activity of intellectual activity, which in one way or another includes inventions, useful models, industrial samples, computer programs or rules and can be the technological basis for a certain thing. In our country, in contrast to foreign higher institutions in this field, there are problems with the funding of scientific work contributions of students. Unfortunately, this field of activity remains problematic in the oil and gas sector of Azerbaijan. If the cost of scientific research, creation and application of innovative technologies in the world oil and gas sector is on average 1.5-2 dollars per ton of oil, it is 10-12 cents in Azerbaijan. Azerbaijan's oil companies lag far behind foreign oil companies in terms of the number and application of inventions and patents. For example, the Norwegian company Statoil's Patent portfolio includes about 800 inventions and 3.5 thousand patents. More than a third of these innovations are new solutions in the field of field development, and another third are solutions used in the production and sales chain. The American company Chevron, one of the world leaders in innovation, has 37,475 patents. Shell, another leader in innovation, has more than 14,000 patents.

Companies want not only to reduce costs and gain additional profits, but also to ensure the progressive development of their business in the future.

IV. Conclusion

It is especially important to create and develop new technologies and new technical means that allow to solve the existing problems in the oil industry of the Republic due to the increase of the resource base. Apparently, it is to create a whole system of pilot landfills in the extraction of "high viscosity" and "non-potential" hydrocarbons in oil fields. Such pilot projects should be planned in separate areas. It is not only a matter of separate program documents related to the creation of new technologies and the production of the technical means necessary for this, but also issues related to the process of field development and exploitation should be carried out with the sole participation of educated specialists and scientists. Thus, the issues of application of modern technologies in the development of oil and gas fields should be put in a timely manner and measures should be taken. However, in the above list of necessary solutions, the issues of who will do it and how, and from what sources of funding, should be resolved.

Famous oil industry scientists A.Kh. Mirzazanzade., V. N. Shelkachev., R. Kh. Muslumov and E. M. Khalimov, despite all the difficulties and limitations related to the operation and development characteristics of the oil industry, have repeatedly emphasized the importance of increasing attention to the issues of increasing the scientific and technical level and the efficiency of the industry in their research. The opinion of scientists that the application of methods of increasing oil production is not only a scientific and engineering task is gaining more and more understanding in the oil industry of many countries. However, it seems to us that the recommendations given in this regard are mainly based on the previously applied "linear" approach to solving scientific-technical, production, technical and organizational-economic problems. The approach of "innovative design of oil field development" proposed by R. Kh. Muslimov deserves serious attention. According to his definition, an innovative project is a scientific-research work in a certain field, which is carried out in the process of designing development. At this stage, the details of the geological structure of the object are studied, and on this basis, development technologies are selected that should fully take into account the features of the geological structure. It is to create and develop the environment that will help us to develop oil and gas potential based on a more fundamental and in some sense more realistic approach. The analysis based on the characteristics of the application of new technologies in Azerbaijan shows the following:

First priority:

- debates about what belongs to innovative technologies and what does not should not be ineffective and unnecessary in terms of evaluation for economic stimulus today.
- based on the natural dynamics of depletion of fields with large oil reserves, the transition to the organization of production from fields with more complex natural conditions should lead to changes in not only technological, but also economic norms and rules, including state regulatory methods.
- the evolution of the organizational structure of the oil industry in the direction of the gradual weakening of the monopoly role of large and integrated companies is, first of all, the selection of state policy priorities in the field of licensing, taxation, stimulation and crediting of oil companies and companies in Azerbaijan.
- the first and foremost priority for state politicians should be recognized as a comprehensive promotion of drilling new and inclined wells in all existing fields.

Second priority:

- the comprehensive promotion of the exploitation of small productive and high dilution wells is a new source of production. These wells are already a reality, they can provide the required oil production and their contribution to the total production will not be less than the contribution of all the latest technologies.

Third priority:

- compilation of national programs. These are innovative technologies programs based on individual feasibility studies and development programs for special field development projects, and programs for the development of heavy oil and bitumen resources.

The fourth priority, which is important for the implementation of the first three, is the improvement of the legal basis of oil production. First of all, it is necessary to create an open and affordable market for re-licensing and to allow the division of initial licenses both in terms of territory and object.

In order to ensure the active participation of the Azerbaijan National Academy of Sciences in the "science-education-production" chain, the High Technologies Park was established by the order of President Ilham Aliyev dated November 8, 2016. The purpose of creating the ANAS High Technology Park is the sustainable development of the economy, increasing competitiveness, innovation based on modern scientific and technological achievements, expansion of high technology areas, science, technology and innovation.

References

[1] Karimov, K.S., Ismayilov, B,V. and Nuraliyeva, R.N. Theoretical foundations of oil field development: Textbook, Baku, 2024.

[2] SOCAR. Annual reports: Baku, 2023.

[3] Karimov, K.S. and Beygulenko, I.V. Oil and its issues: Monograph, Mockva, 2016.

[4] Karimov, K.S. Investment and innovation activity in industry: Textbook, Baku, 2016.

[5] Karimov, K.S. Technical and economic justification of projects: monograph, Baku, 2015

[6] Karimov, K.S. and Zeynalova, S.C. Project management: Textbook, Baku, 2024

[7] Suleymanov, G.S., Karimov, K.S. and Isayev, K.H. Directions of innovative development of industrial enterprises: Monograph, Baku, 2020

[8] Karimov, K.S. and others. Methods of increasing the oil yield of formations: Invention N İ 2023 0088, Baku, 2023

[9] Mirzajanzadeh, A.X. And . Shirinzade, S.A. Improving the efficiency and quality of well drilling: Monograph, Moscow, 2016

[10] Petrovskaya, E.V. "Evaluation of intellectual property and intangible assets: Monograph, Elbrus, 2018

[11] Belyaev, O.G. and Kornilov D.A. Assessing the innovative potential of economic systems. Management of economic systems: electronic scientific journal. – 2012. No. 39. c. 16

AUTOMATED ENTROPY ANALYSIS OF THE SOCIAL CONSEQUENCES OF URBAN MAN-MADE ACCIDENTS AND NATURAL CATASTROPHES

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Abstract

The article describes the software package (SP) developed by the authors, which allows analyzing the social response to incidents and accidents of urban infrastructures in real time. The analysis is based on publications on the VKontakte social network. The SP performs filtering and categorization of textual information, storing data in a SQLite database, as well as quantitative and qualitative analysis of the reaction of citizens to a dangerous event. The SP automates the process of monitoring social response to emergencies, which makes it useful for the rapid response of government organizations and emergency services. The SP allows us to study, from an interdisciplinary perspective (combining the theory of technogenic safety and sociology), the interdependence of measurable damage caused by an accident of urban infrastructure and the intangible socio-cognitive damage to the community of citizens due to this accident.

Keywords: social networks, entropy, data analysis, safety.

I. Introduction

In [1, 2], the concept and approach to the entropy analysis of the social consequences of major accidents of urban infrastructures and systems are formulated based on the collection of necessary information published on social networks reflecting the details of accidents, moods, reactions and demands of society in connection with the occurrence of emergency situations. For the full-scale use of this approach, an algorithm is needed for automatic selection, collection and comprehensive socio-cognitive analysis of information purposefully extracted from social networks. This is the subject of this article.

The currently existing official methods and methods of informing the public about accidents related to the functioning of network systems and urban life support infrastructures are presented in Table 1.

There is also unofficial information, in the form of public reaction to the events, which is published on social networks. In this article, it is proposed to use social networks to monitor the state of critical infrastructures and obtain additional information about the reaction of urban society to man-made incidents and accidents [3].

II. Methods

Currently, the *VKontakte* social network is the most accessible, popular and, most importantly, legitimate platform. Therefore, it can be used as an effective tool for rapid response and understanding of public perception of incidents. *VKontakte* provides access to an extensive database, which is formed by various social groups and reflects various socio-cultural aspects of society. These multiple data are representative and can be used for a consistent analysis of public opinion and trends among different categories of the population.

Table 1: *Modern means and methods of informing society during and after natural and man-made accidents and catastrophes*

Title	Advantages	Disadvantages
Traditional media	Provide global coverage and have high credibility	Delay in the dissemination of information, limited coverage of points of view
Official reports and press releases	Information from primary sources, formal and accurate data	May be biased, delayed, do not include the public opinion
Polls and public opinion research	Allow getting structured data	May take time, limited coverage, depends on the wording of the questions
Expert assessments	High level of expertise	Can be subjective, due to a limited range of experts

VKontakte has a VK API that provides access to various data about users, communities, groups, posts, comments and other aspects of activity on the platform. Thanks to the VK API, researchers can collect statistics themselves and conduct in-depth analysis of user behavior data.

The disadvantage of *VKontakte* is data access restrictions due to user privacy settings, strict platform rules, and frequent API changes, which makes it difficult to collect data. This can lead to an incomplete analysis.

Nowadays, social networks (SN) are becoming an increasingly useful tool for improving public life. Many city administrations use SN (for example, *the Incident Management* system) as a channel through which citizens can promptly report their problem.

It seems that the SN can be used more effectively and in a multidimensional manner if regular monitoring of the SN is carried out in order to:

(1) promptly obtain information about incidents, accidents, natural disasters;

(2) monitor socio-cognitive changes in society during and after the occurrence of these incidents and accidents;

(3) promptly adopt measures to mitigate, prevent, protect and ensure the safety of citizens;

(4) carry out optimal governance in its territory, using the SN as a positive feedback in the management chain.

This work is aimed at quantitative, entropy-probabilistic analysis of social networks. The city of Kamyshlov, located in the Sverdlovsk region, was chosen to work out the methodology and algorithm for analyzing the reaction of the population to incidents in urban infrastructure. As of January 1, 2021, the city's population was 25,582. Data collection was carried out in the main community of the city in the SN *VKontakte*, where the number of participants exceeded 30,000 people.

A major accident at the central pumping station occurred on March 30, 2019. Meltwater flooded the pump's engine room, which led to the failure of two sewage pumps and the shutdown of the central water supply. As part of the study, a chronology of events was compiled:

30.03.2019	13:39 – Accident at the central pumping station
	15:00 – Shutdown of the central water supply
	16:33 – The first message about the accident (VKontakte publication)
04.01.2019	02:38 – The mayor of the city addressed the residents through a social network

	11:00 – The end of the liquidation of the accident
	23:05 – End of water chlorination
04.03.2019	22:07 – The last post about the accident
05.15.2019	7:19 – The last mention of the accident on social media.

The mayor of the city informed residents about the measures taken to restore water supply, but many citizens expressed dissatisfaction due to the lack of information about: a) the time of restoration of water supply, b) contact services, c) the causes of the incident.

Visualization of social activity after water shutdown is shown in Fig. 1. Along the abscissa axis the dates of the main events that occurred during the liquidation of the accident are posted. The ordinate axis shows the number of likes, views (in thousands) and comments under the post.

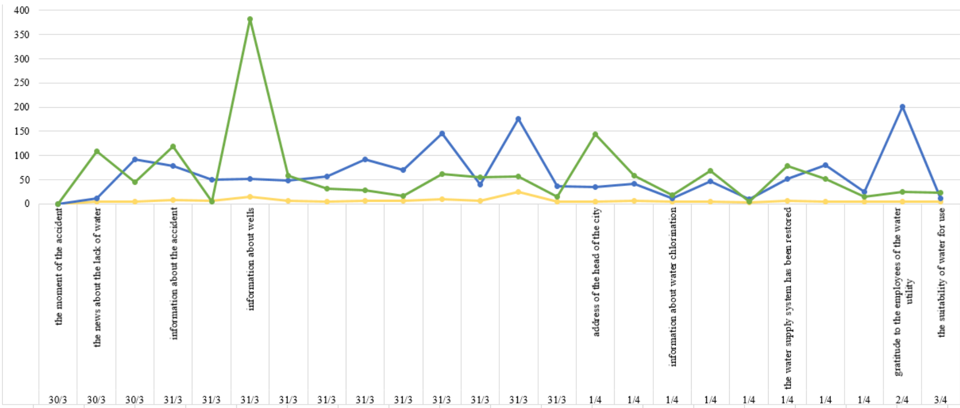

Figure 1: *User activity after the accident at the pumping station on 30.03.2019 (the number of views (in thousands) is given in yellow, the number of likes is given in blue, the number of comments is given in green)*

The greatest activity of citizens was observed on the second day after the water was turned off, when residents began to actively search for information about the possibilities of obtaining water and share information about available sources. The number of comments as a function of time is shown in Fig. 2.

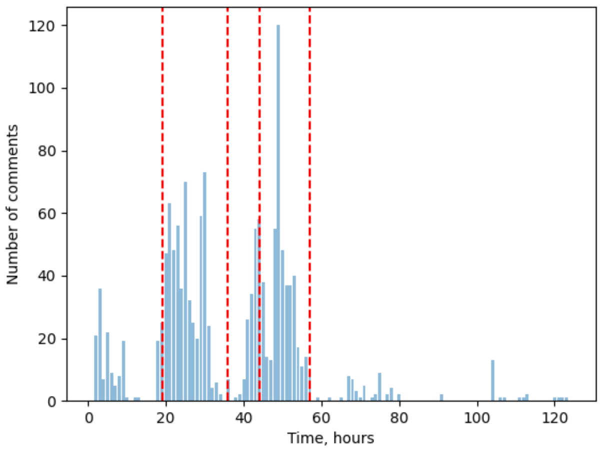

Figure 2: *The graph of the number of comments in time. The dashed lines indicate following events (from left to right): publication of information about available wells (19th hour), mayor addresses the citizens (6th hour), end of the accident liquidation (44th hour), end of water chlorination (57th hour).*

The graph shows a sharp increase in the number of comments, which peaked on the third day after the incident (April 1), when residents began to actively share their experiences, ask questions and support each other, after which the frequency of comments began to decrease, as the relevance of the topic decreases.

To improve the accuracy of the results, comments collected on social networks were classified according to their information value. The entries were divided into four groups, depending on the content of the comment, and visualized as shown in Fig. 3.

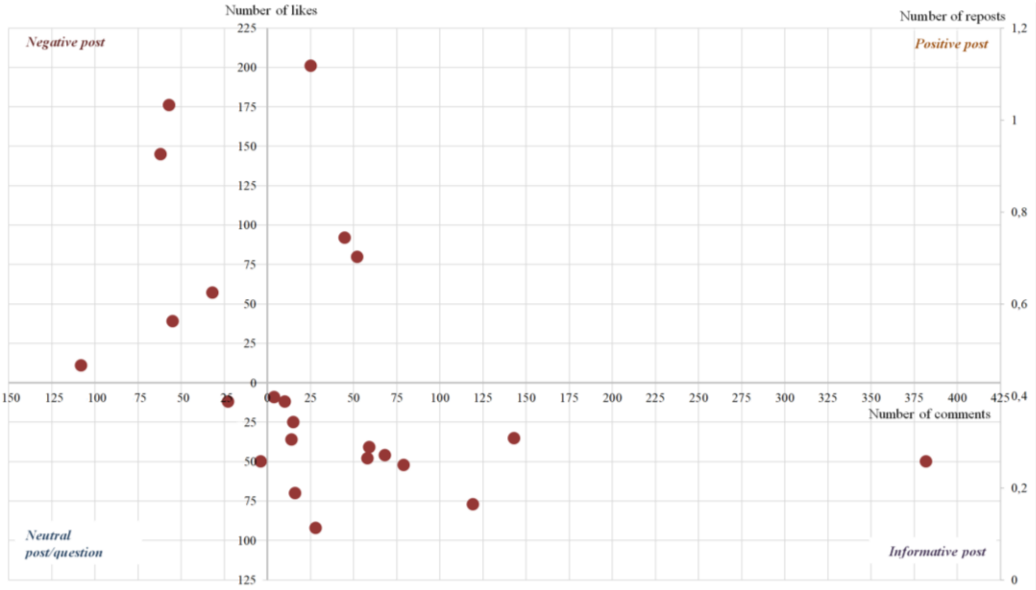

Figure 3: *A phase portrait of the accident*

Entries containing useful information are located in the lower right corner. Publications with a positive character and humorous messages are displayed in the upper right quadrant, and messages of a negative nature are displayed in the upper left quadrant. Neutral posts or messages containing a question are located in the lower left corner. The specific characteristic patterns in Fig.5 allow seeing at a glance what moods prevailed in the society during the crisis.

Fig. 4 shows the calculated entropy quanta (hourly entropy) (a) and its first derivative in time (b).

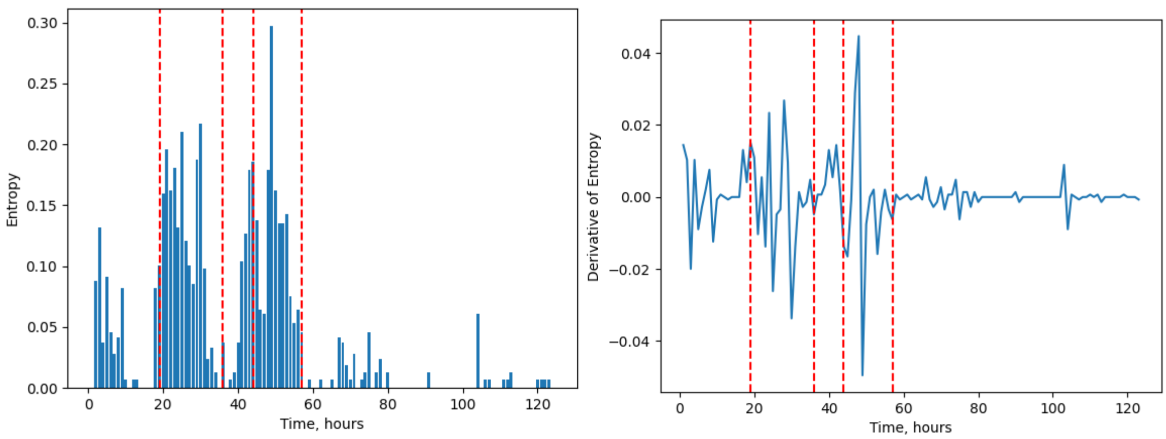

Figure 4: *Hourly values of entropy (a) and its derivative (b) in case of an accident at the central pumping station*

The initial stage of the study included: (1) manual selection of all messages related to the accident, which created a database for subsequent analysis; (2) chronological (hourly) systematization of comments about each message, and (3) their classification by content. Figure 5 shows the evolution of the probability density functions (PDF) and the entropy curve over time after an accident.

The analyzed real incident can be described as "standard", since it caused only one rapidly fading wave of social activity (five days). The main conclusions of this analysis are:

- The VKontakte social network plays an important role in the exchange of information and coordination of citizens' actions in times of crisis.

• The lack of information on the timing of the restoration of water supply and the causes of the accident contributed to an increase in social activity and discontent among the population.

• The short-term nature of the public reaction is due to the comparative speed of eliminating all the accident's consequences.

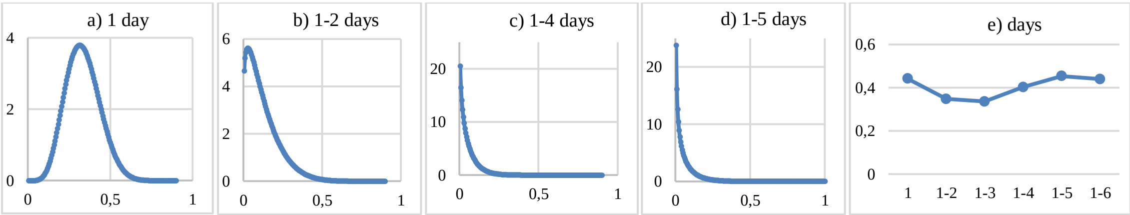

Figure 5: *a)-d) - Total PDF; e) - Change in entropy depending on the number of days that have passed since the accident*

The pilot study of the Kamyshlov population reaction has clearly shown that the use of modern technologies and communication platforms can significantly improve the quality of interaction between residents and local authorities, especially in times of crisis.

The main functions of the program for the automatic analysis of data on various incidents and events

The SP consists of the *following steps*:

1. Search in social networks for communities (public, groups, channels, etc.) by a given keyword (city name). The function is used to send a search request to the VKontakte API for groups by a given keyword. It returns a dictionary where the keys are the names of the groups and the values are their identifiers, which allows a quick find of groups of interest for further analysis

2. Filtering and analyzing publications (posts) according to a given *dictionary of keywords by category (such as "Fire", "Flood", "Terrorism", etc.)*. For this, the content of each group is parsed and checked for mentions of these words.

Additionally, it is possible to customize synonyms and variations of keywords. This makes the analysis more flexible, allowing to take into account different formulations and regional language peculiarities. For example, the expression "natural disaster" can be used instead of "catastrophe". This approach significantly increases the chances of finding important publications.

3. If a publication contains a keyword, information about it, including the text of the post, date, time, publication id, as well as the keyword mentioned in the text, is stored in the appropriate category. The program also collects and analyzes comments on these messages, which allows identifying the user reactions to specific events.

4. The program saves the result of the work to the SQLite database. Each category of data is stored in a separate table with an appropriate structure, which ensures organized storage of information. The SP contacts the SN daily and updates (replenishes) information about the incident, accident or catastrophe. SQLite provides compact storage and efficient access to data, which is critical for programs working with large amounts of information.

5. The quantitative analysis of the accumulated results includes the construction of graphs (Fig. 6) reflecting the dependence of the number of comments on time for each category of keywords. This function reads data from SQLite and visualizes the dynamics of discussions in VKontakte groups.

6. A qualitative analysis of texts is planned (identification of the mood of comments).

Each function of the program has a clearly defined task, which contributes to the modular structure of the code and facilitates the support and expansion of the program.

SP testing in the city of Yekaterinburg. ***Implementation***: a Python script using the requests, vk_api, matplotlib, numpy, pandas libraries to analyze messages from a social network.

Yekaterineburg, the capital of the Middle Urals, was chosen for SP ***testing.*** According to [4], 1,536,183 people lived in Yekaterinburg on January 1, 2024. Data collection was carried out in the groups of the city of the VKontakte social network. For the analysis, main types of incidents were selected - fire, flood, water outage, road accident, evacuation, pandemic, environmental crisis, terrorism, conflict, for each of which a dictionary of keywords was collected.

SP Advantages:

- Automation of the process of collecting and analyzing large amounts of textual information from social networks, which saves time and simplifies the real-time monitoring process.
- The ability to quickly identify and aggregate data on people's reactions to various emergency events.
- Creation of structured reports and analytics for subsequent use in making management decisions.
- Improving the efficiency and responsiveness of emergency response.
- Forecasting and prevention of emergencies.

The dynamics of user comments on the topic of incidents related to the "Fire" category from April 3, 2024 to July 31, 2024 is shown in Fig. 7. The vertical axis displays the number of comments left by users on each of the days related to the fire topic.

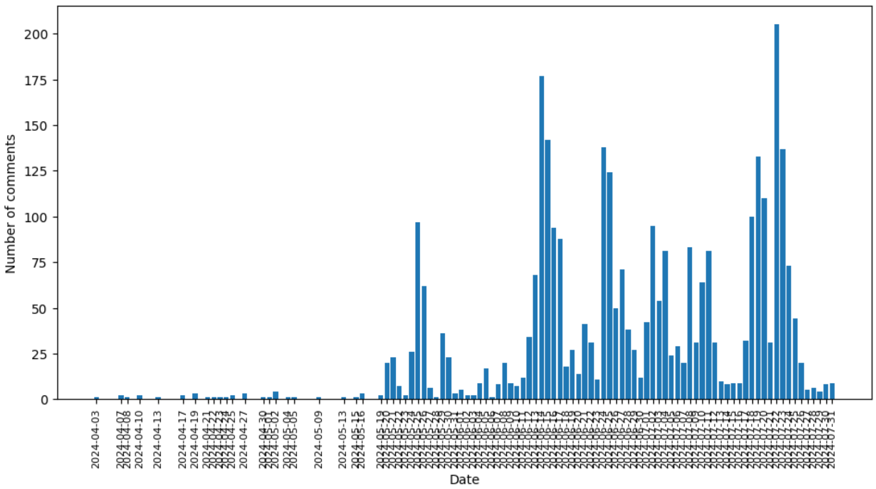

Figure 6: *A graph of the number of comments in time for incidents comments of the "Fire" category*

Judging by the graph (Fig. 6), bursts of discussion activity were observed on May 25, June 14, June 24 and July 22 (the highest peak) 2024, due to an increase in the frequency of fires. The latter is due to high air temperature, wind, dryness, active growth of grass and shrubs, and increased human activity in nature, which increases the likelihood of careless handling of fire.

The increase in user activity in the period from 11.06.24 to 17.06.24 is due to several large fires. At such moments, people tend to discuss what happened, express their feelings and get information about the situation. Peak days of activity are associated with the *size* of fires, *social unrest*; and *increased media coverage*, as users tend to follow the news and share their opinions.

User comments cover both informative and emotional aspects of the reaction to what happened. Analyzing these publications allows understanding which topics and content formats are causing an increased response from the audience that can be useful for further monitoring and analysis of incidents.

III. Results

Mathematical processing of the results

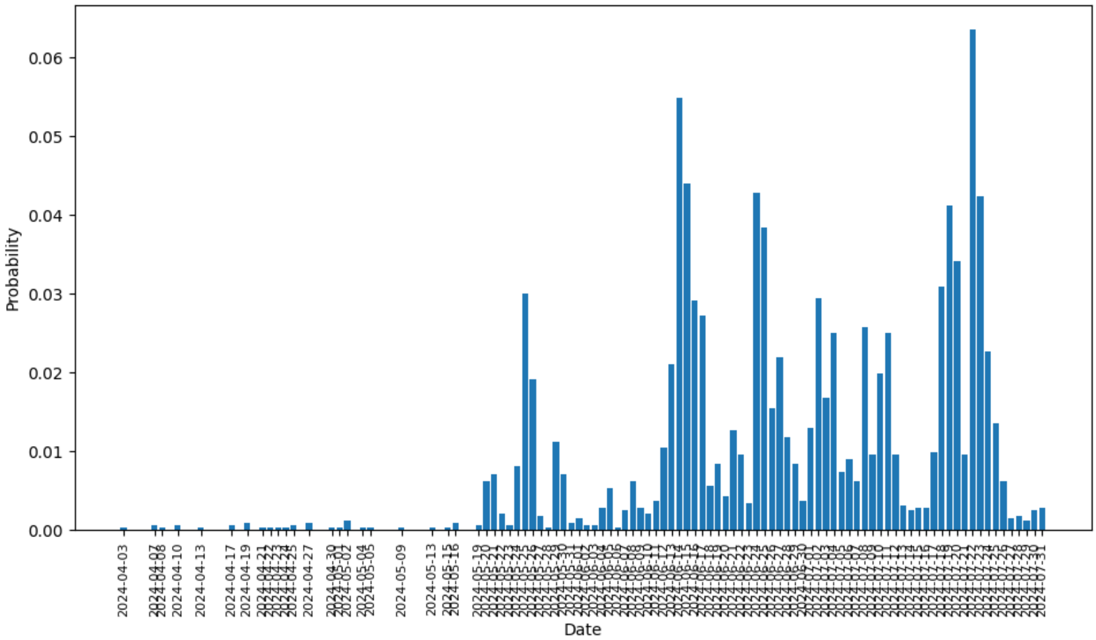

Figure 7: *A graph of the probability of comments for incidents of the "Fire" category*

The graph (Fig. 7) illustrates the probability of comments on fire publications depending on time, and shows peaks on the same dates as in Fig. 7, which indicates a direct relationship between the number of comments and public interest in incidents.

An increase in the likelihood of comments appearing at certain points confirms the importance of events taking place in a locality and their impact on social discussion.

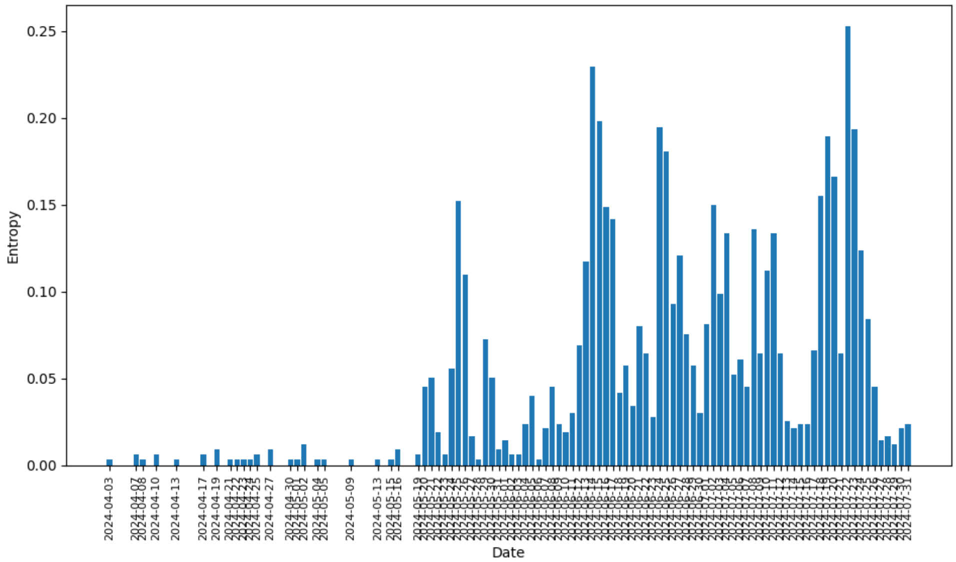

Figure 8: *A graph of the entropy of comments from time to time for the "Fire" category incidents*

The increased entropy during periods of maximum activity of citizens (Fig. 8) indicates a large number of unique and diverse opinions on the topic under discussion, which makes the audience's reaction more voluminous and saturated.

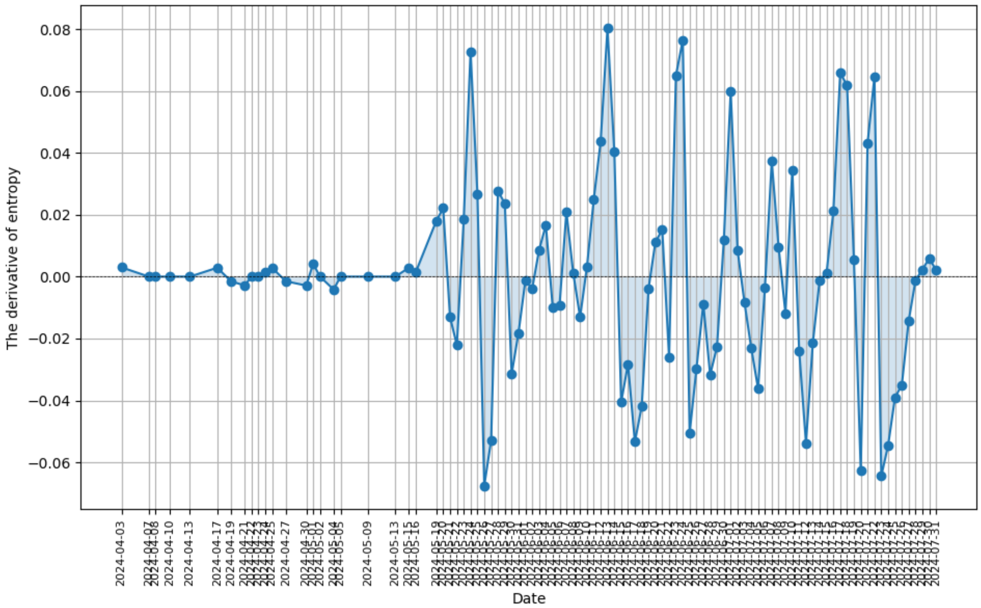

Figure 9: *Graph of the first derivative of the entropy of comments from time for the "Fire" category incidents*

The entropy derivative allows you to highlight the moments of abrupt changes in the volume and variety of comments. The points where abrupt changes in the derivative are observed may indicate significant events or changes in public opinion, which is important for crisis analysis and decision-making. These graphs provide a comprehensive understanding of the dynamics and reactions of users on social networks in response to incidents, allowing for more effective management of information flows in emergencies. The activity of users on social networks during crisis events has several important meanings:

A signal to the authorities: The high level of discussion indicates public concern, which may require government intervention.

Sentiment analysis: The number and tone of comments can help to understand the reaction of society to the incident, identify key problems and issues that need to be addressed.

Dissemination of information: Data analysis helps to track how information is disseminated among the population and which aspects of events are of the greatest interest.

The developed program is a multifunctional tool that significantly improves data processing in the context of big data flow, which makes it a valuable asset for all stakeholders. The results of testing the program showed that an automated approach to collecting, processing and analyzing data on events in the *VKontakte* SN allows:

(1) speeding up the process of monitoring incidents,

(2) better understanding the reaction of society to various emergencies,

(3) identifying key issues that concern the population, assess the emotional coloring of discussions,

(4) minimizing damage and save lives by ensuring more efficient use of resources,

(5) providing decision makers with the opportunity to make decisions that are more informed.

Combining the statistics accumulated by the SP with historical data on similar events will make it possible to create more competently a complete group of possible scenarios of incidents and accidents, which improves the quality of risk assessment of the operation of urban infrastructures.

In general, the use of this program can significantly improve the quality of real-time analysis of commercial, social and environmental information, which contributes to the creation of a more open dialogue between the authorities and society.

At this stage of SP development, the following stages of its upgrade are considered:

improving search accuracy by expanding the list of keywords; introducing machine-learning methods; expanding the functionality of the program by integrating with other social networks; improving data visualization; using sentiment analysis algorithms.

The increase in the volume of processed data leads to the problem of filtering information, and the use of data from social networks raises questions of confidentiality and ethics. It is important to find a balance between the need to respond quickly to emergencies and protecting the privacy of users. The establishment of transparent rules for working with data and compliance with ethical standards is an integral part of the effective use of SN monitoring technologies.

IV. Conclusion

The article describes the original principles and the approach to automated data analysis in social media to quantify the social consequences (unrest) that inevitably arise after each accident or natural disaster associated with the cessation/deterioration of the functioning of urban life support infrastructure. The article promotes (1) a more accurate assessment of the time of adaptation and recovery of a community at risk, (2) competent socio-economic elimination of the consequences of urban accidents by decision makers.

References

[1] Timashev S.A., Malyutina E.V. Entropic analysis of social activity during and after major accidents of urban infrastructure. — Yekaterinburg: Uralsky Rabochy, 2023.

[2] Timashev S., Malyutina E. Entropy Analysis of Social Unrest after Large Urban Infrastructure Accidents // ASCE INSPIRE. 2023. P. 631–639. DOI: 10.1061/9780784485163.074.

[3] Al-Quran M. W. M. Traditional media versus social media: challenges and opportunities. Technium: Romanian Journal of Applied Sciences and Technology, 4 (10), 145–160. – 2022.

[4] The number of permanent residents of the Russian Federation by municipality as of January 1, 2024 // Federal State Statistics Service: [Electronic resource]. URL: https://rosstat.gov.ru/compendium/document/13282

STUDY OF DECİSİON-MAKİNG MODELS BASED ON Z NUMBERS WHEN SOLVİNG DECİSİON-MAKİNG PROBLEMS UNDER CONDİTİONS OF İNCOMPLETE İNFORMATİON

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Abstract

In this article, decision-making models based on Z numbers were studied during the decision-making process under conditions of incomplete information, and a number of scientific and practical issues related to their application to solving the given problem were reviewed. As a result of the research, it became clear that it is not easy to form rational decision-making ability and make optimal decisions in conditions of uncertain, fuzzy or incomplete information based on existing approaches, and sometimes it is inaccurate. Thus, solving real decision-making problems, decision analysis, and systematic analysis in economics, ecology, and other fields are characterized by vagueness and partial reliability of certain data. In this regard, the Z numbers proposed by Professor Zade have a strong effect in expressing the uncertainty due to the unique structure.
This paper proposes a fuzzy approach for decision making based on Z-information based on exact computation on Z-numbers when solving decision-making problems under conditions of incomplete information. The approach is intended for hierarchical imprecise models. In the article, the models considered in relation to the research and application of decision-making models based on Z numbers are based on the processing of uncertain information and the use of word computing technology in decision-making.

Keywords: fuzzy information, fuzzy sets, Z numbers, probability distribution, decision making model

I. Introduction

Fuzzy logic theory deals with the processing of information that is vague, imprecise, fuzzy, partially true, or has no sharp boundaries arising from perception and intelligence. Fuzzy logic can be applied to linguistic evaluation, decision making, and information analysis with linguistic evaluation. Fuzzy logic, including fuzzy sets, linguistic variables, fuzzy rules, fuzzy mathematics, fuzzy database queries, computational theory of intelligence, and linguistic evaluations for computing with words, are very useful in determining the degree of uncertainty of variables.

In the researched problem, if the uncertainty arising during information processing is due to randomness, lack of information, the theory of probability, and if it is due to the inaccuracy of information, the theory of fuzzy logic is applied as a powerful tool.

The presence of uncertainty and inaccuracy in the vast majority of information in decision-making models requires greater caution and high intellectuality. Thus, it is difficult to form a rational decision-making ability based on imprecise, fuzzy or incomplete information [1].

Currently, one of the most effective and widely analyzed research problems is the problem of multi-criteria decision making. As uncertainty, impreciseness and complexity exist in the studied environment, fuzzy sets [2] will enter as one of the widely used key issues in the decision making process.

The purpose of the research in [2] is the study of representation models of uncertain information and its application to management. In this study, models of description and processing of fuzzy, imprecise information were analyzed. Issues of qualitative analysis of the researched information were considered. For this purpose, models based on objective and subjective probability theory, interval type, 1st, 2nd type and generalized fuzzy models, hybrid models were analyzed when solving decision-making problems under conditions of incomplete information, and the problems of processing uncertain information were considered.

Real decision-making problems in decision analysis, systematic analysis, economics, ecology and other fields are characterized by the vagueness and partial reliability of certain data. In recent times, the solution of a number of scientific and practical issues related to the research and application of decision-making models based on Z numbers has been considered. The considered models enable the processing of uncertain information and the use of word computing technology in decision-making. The concept proposed by Professor Zade - Z-numbers has become a center of research in fuzzy theory. Unlike previous fuzzy sets, Z numbers have a stronger ability to express uncertainty due to their unique structure [3,4].

The article [5] describes the methods of forming the uncertainty caused by the loss of information during the solution of a number of problems using Z numbers. To achieve this goal, the article examines how to convert real numbers and fuzzy numbers into Z numbers, and develops a new system of Z-linear equations.

Two processes of Z numbers ranking methods are presented in models that can efficiently use uncertain decision-making data [6]. Decision making is based on the proposed Z numbers. In this work, first Z numbers were converted into fuzzy numbers, and then ranking method using sigmoid function and sign method were used to record fuzzy numbers. In the next step, the method is extended to related Z numbers. This method was used to prioritize items and solve some patterns.

II. Models based on Z number theory

The Z number represents both the uncertain variable and its reliability. The Z number is used in decision-making, risk assessment, etc. A multi-criteria fuzzy decision-making method with stronger potential is proposed by its application in fields. Here, the assessment of each alternative by evaluators for each criterion, as well as the reliability of this assessment, is described as a Z number [3-6].

Decisions should be made based on accurate information. For decisions to be useful and effective, information must be reliable. Therefore, it is more appropriate to use the number Z. The Z number is a fuzzy number that describes the reliability of the information. The number Z is represented by the pair Z=(A,B) with two components. The first component A is the admissible constraint on the acceptance of the real-valued variable X into the fuzzy set. The second component, B, is a measure of the reliability (certainty) of the first component. Typically, A and B are described in natural language. Calculation with Z numbers is considered more important [5-7]. For example, "İnci is excellent" (Very High, Probable). The first part, "Very High" is the assessment limit of Pearl's knowledge, that is, the value of A, and the second part, "Probable" is R, which is a measure of probability that tells how true this information is.

Counting with Z numbers belongs to the field of counting with words (CW or CWW). This article introduces the concept of Z number and methods of calculation with Z numbers. The Z-number concept has great potential in many applications, economics, decision analysis, risk assessment, and predictive problems based on characteristic rules of inexact functions and relationships.

Zade introduced the concept of Z-numbers to describe vague information in a generalized form. A Z-number is a pair of fuzzy numbers $(\widetilde{A}, \widetilde{B})$. Here, $\widetilde{A}$ is the value of a variable, and $\widetilde{B}$ represents an idea closely related to a certain concept, such as certainty, confidence, reliability, degree of accuracy, and probability. Let's look at an example: Which number is more accurate for the highest age limit among people in the country: (about 100, true) or (about 90, very true). The main field of application of the proposed number theory Z will be word computing technology.

In modern activity models, for example, socio-economic, technical-medical models, it is very difficult to solve decision-making problems without taking into account the intuitions of the decision-maker. It is known that in classical decision-making models, probability values are required to be accurately described. In most real-world cases, this is impossible to achieve. In reality, especially in economics, information is subjective and imprecise. There are many approaches that describe the imprecision of relevant probabilistic information: classical numbers (level 0, for example, 1.9-17); interval numbers (level 1, for example, temperature from 20 to 25); random number (level 2, for example, male height is normally distributed around 1m 85cm); fuzzy number (level 2, eg its moral weight is "too great"); finally, Z-numbers (level 3, for example, the price of crude oil on the world market will be "high", the belief is "great"). One of these approaches is used for hierarchical imprecise models [3-7]. These models are used to account for second-order uncertainty that describes real problems. According to this approach, the opinion of the expert about the imprecise probabilities is estimated imprecisely.

III. Methods of solving the decision-making problem based on Z-numbers

It should be noted that in recent decision-making models, optimal decisions are made based on Z-numbers. Because Z is a fuzzy number that describes the reliability of information. Therefore, it is considered more appropriate to use the Z number. Lutfi Zade proposed some operations using the expansion principle for computation with Z-numbers.Diskret ədədlər üzrə arifmetik əməliyyatların ümumi strukturu.

For example, $Z_1 = (\tilde{A}_1, \tilde{B}_1)$ and $Z_2 = (\tilde{A}_2, \tilde{B}_2)$ are discrete Z-numbers that describe information about the characteristics of the random and variable. It is possible to perform various analytical calculations on Z-numbers as well as on fuzzy numbers [9-11].

$$Z_{12} = Z_1 * Z_2, \; * \in \{+, -, \cdot, /\} \tag{1}$$

First, $Z_{12}^+ = Z_1^+ * Z_2^+$ is calculated:

$$Z_1^+ * Z_2^+ = (\tilde{A}_1 * \tilde{A}_2, R_1 * R_2) \tag{2}$$

Here we describe the discrete probability distributions with R1 and R2:

$$\begin{aligned} p_{R_1} &= p_{R_1}(x_{11}) \setminus x_{11} + p_{R_1}(x_{12}) \setminus x_{12} + \ldots + p_{R_1}(x_{1n}) \setminus x_{1n}, \\ p_{R_2} &= p_{R_2}(x_{21}) \setminus x_{21} + p_{R_2}(x_{22}) \setminus x_{22} + \ldots + p_{R_2}(x_{2n}) \setminus x_{2n} \end{aligned} \tag{3}$$

Restrictions on probability distributions (4):

$$\sum_{k=1}^{n} p_{R_1}(x_{1k}) = 1, \quad \sum_{k=1}^{n} p_{R_2}(x_{2k}) = 1 \tag{4}$$

and (5) eligibility conditions

$$\sum_{k=1}^{n} x_{1k}\, p_{R_1}(x_{1k}) = \frac{\sum_{k=1}^{n} x_{1k}\, \mu_{\tilde{A}_1}(x_{1k})}{\sum_{k=1}^{n} \mu_{\tilde{A}_1}(x_{1k})}, \quad \sum_{k=1}^{n} x_{2k}\, p_{R_2}(x_{2k}) = \frac{\sum_{k=1}^{n} x_{2k}\, \mu_{\tilde{A}_2}(x_{2k})}{\sum_{k=1}^{n} \mu_{\tilde{A}_2}(x_{2k})} \tag{5}$$

is given. Here, the composition $p_{12} = p_1 \circ p_2$ is the convolution of $R_1 * R_2$, $* \in \{+,-,\cdot,/\}$.

The 'true' probability distributions p_{R_1} and p_{R_2} for $Z_1 = (\tilde{A}_1, \tilde{B}_1)$ və $Z_2 = (\tilde{A}_2, \tilde{B}_2)$ are not precisely known. Known information is given in the form of fuzzy constraints. That is,

$$\sum_{k=1}^{n} \mu_{\tilde{A}_1}(x_{1k}) p_{R_1}(x_{1k}) \ \tilde{B}_1 - dir, \qquad \sum_{k=1}^{n} \mu_{\tilde{A}_2}(x_{2k}) p_{R_2}(x_{2k}) \ \tilde{B}_2 - dir$$

This is described in terms of membership functions:

$$\mu_{\tilde{B}_1}\left(\sum_{k=1}^{n} \mu_{\tilde{A}_1}(x_{1k}) p_{R_1}(x_{1k})\right), \mu_{\tilde{B}_2}\left(\sum_{k=1}^{n} \mu_{\tilde{A}_2}(x_{2k}) p_{R_2}(x_{2k})\right) \tag{6}$$

It means that there are fuzzy sets of probability distributions p_{R_1} and p_{R_2} with membership functions.

$$\mu_{p_{R_1}}(p_{R_1}) = \mu_{\tilde{B}_1}\left(\sum_{k=1}^{n} \mu_{\tilde{A}_1}(x_{1k}) p_{R_1}(x_{1k})\right),$$
$$\mu_{p_{R_2}}(p_{R_2}) = \mu_{\tilde{B}_2}\left(\sum_{k=1}^{n} \mu_{\tilde{A}_2}(x_{2k}) p_{R_2}(x_{2k})\right) \tag{7}$$

Then, since $\tilde{B}_1$ and $\tilde{B}_2$ are discrete, the values of

$$\mu_{\tilde{B}_j}(b_{jl}),$$
$$b_{jl} \in \operatorname{supp} \tilde{B}_j, \quad j = 1,2; l = 1,\ldots,n \tag{8}$$

μ can be found by solving a series of linear programming problems:

$$\sum_{k=1}^{n} \mu_{\tilde{A}_j}(x_k) p_j(x_k) \to b_{jl}$$
$$\left.\begin{array}{l} \sum_{k=1}^{n_j} p_j(x_{jk}) = 1 \\ p_j(x_{jk}) \geq 0 \end{array}\right\} \tag{9}$$

We recognize that the "true" probability distributions p_1 and p_2 are not exact. There are fuzzy constraints μ_{p1} and μ_{p2} of p_1 and p_2 generated only by B_1 and B_2.

During the solution of the linear programming problem, we calculate the membership degrees μ_{pj} (x_j), j=1,2. Consider finding the membership degrees μ_{p1} and μ_{p2} of the distributions p_1 and p_2. It is calculated according to the formula

$$\mu_{p1}(p_1) = \mu_{B1}\left(\sum_{k=1}^{n1} \mu_{A1}(x_{1k}) p_1(x_{1k})\right)$$

using the known values of A_1 and p_1.

For the solution of the p_j th problem, each $l = 1,\ldots,n$ index is denoted by $p_{jl} = p_j$. The membership degree of p is calculated as (10):

$$\mu_{p_j}(p_j) = \mu_{\tilde{B}_j}\left(\sum_{k=1}^{n} \mu_{\tilde{A}_j}(u_k) p_j(u_k)\right), \ j = 1,2. \tag{10}$$

The probability distributions p_{1l} and p_{2l} bring the fuzzy set to the fuzzy set p_{12s}, $s = 1,...,l^2$, and their membership functions are described as (11):

$$\mu_{p_{12}}(p_{12}) = \max_{p_1, p_2}[\mu_{p_1}(p_1) \wedge \mu_{p_2}(p_2)],\ p_{12} = p_1 \circ p_2 \tag{11}$$

Here the sign "$\wedge$" is a *min* operator.

According to (12) in the next step

$$A_{12} = A_1 * A_2 \tag{12}$$

the fuzzy price is calculated:

$$P(\tilde{A}_{12}) = \sum_w p_{12}(w)\mu_{\tilde{A}_{12}}(w) \tag{13}$$

In the last step,

$$P(\tilde{A}_{12})\ P(\tilde{A}_{12}) = b_{12} \tag{14}$$

we calculate the probability measure b_{12}, where p_{12} is known. However, we only know the fuzzy constraint described by the probability function.

Thus, $P(\tilde{A}_{12})$ is a B12 fuzzy set with $\mu_{\tilde{B}_{12}}$ membership function:

$$\mu_{\tilde{B}_{12}}(b_{12s}) = \sup(\mu_{p_{12s}}(p_{12s}))\ ,\ b_{12s} = \sum_k p_{12s}(x_k)\mu_{\tilde{A}_{12}}(x_k) \tag{15}$$

Consequently, Z_{12} is calculated as:

$$Z_{12} = Z_1 * Z_2,\ * \in \{+,-,\cdot,/\}\ \ Z_{12} = (\tilde{A}_{12}, \tilde{B}_{12})$$

Figure 1. shows the probability measure indicating that the knowledge assessment threshold is correct on a 10-point scale (A).

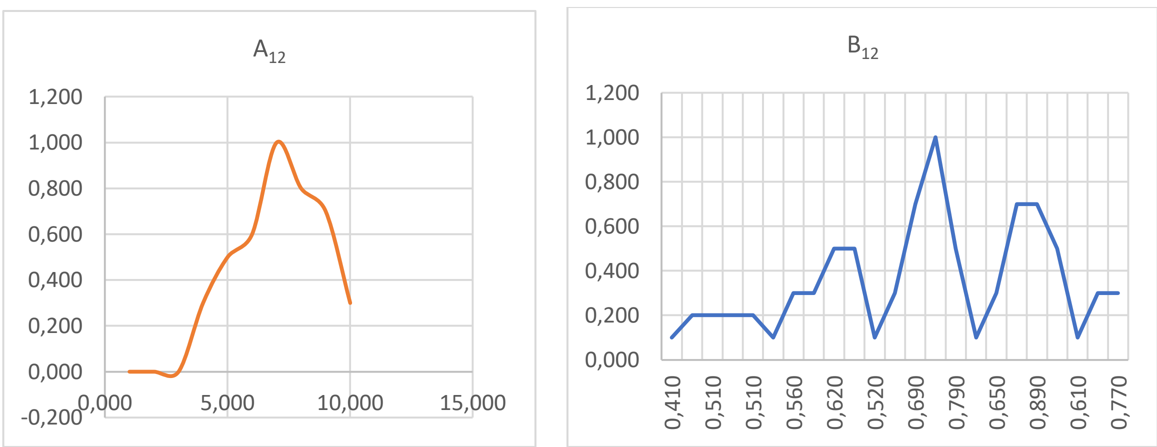

Figure 1: *Results of summing discrete Z-numbers*

IV. Result

This article presents an approach for Z-information based decision making based on exact computation on Z-numbers under conditions of incomplete information. This approach is based on finding a probability measure by applying arithmetic operations on discrete Z-numbers that describe information about the properties of random variables X_1 and X_2. This approach is widely used in solving management issues in the field of economics.

References

[1] Qardaşova L.A. Decision making in the fuzzy environment in oil refinery management systems.Baku, 2012, 327 p.

[2] Mammadova K.A. Determining the risk level for food safety in a fuzzy environment using Z-numbers. // News of Azerbaijan Engineering Academy/International scientific and technical journal. 2022, vol 14, № 1, s. 117-124.

[3] Zadeh L.A. From computing with numbers to computing with words - from manipulation of measurements to manipulation of perceptions. // IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications, 1999, 45(1):105–119

[4] Zadeh L.A. A Note on Z-numbers // Information Sciences, 2010, v.181, pp. 2923–2932

[5] Motamedi Z.P., Allahviranloo T. Z-Numbers for Uncertainty Formulation. Progress in Intelligent Decision Science. January 2021, pp.975-985

[6] Somayeh E., Allahviranloo T. Two new methods for ranking of Z-numbers based on sigmoid function and sign method. // International Journal of Intelligent Systems 33(7). March 2018. DOI: 10.1002/int.21987

[7] Aliev R.A., Alizadeh A.V., Huseynov O.H. The arithmetic of discrete z-numbers // Information Sciences, 2015, v.290, no 1, pp. 134-155

[8] Aliev R.A., Alizadeh A.V., Huseynov O.H., Jabbarova K.I. Z-number based Linear Programming // International Journal Of Intelligent Systems, 2015, v.30, pp. 563–589

[9] Aliev R.A., Akif V.A., Shirinova U.K. Fuzzy Chaos Approach to fuzzy linear programming problem / Proceedings of the 2nd International Conference on Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control, Turkey, Antalya, 2003, pp.287-295

[10] Mammadova K.A., Sultanova A.B., Aliyeva Y.N., Huseynova A.N. Problem solving based on z-numbers. 14th International Conference on Applications of Fuzzy Systems, Soft Computing, and Artificial Intelligence Tools – ICAFS-2020, pp.555-564

[11] Mammadova K.A., Aliyeva Y. N., Huseynova A. N. Determining the Level of Risk for Food Safety in a Fuzzy Environment with the Help of Z Numbers. Aerosol Science and Engineering. https://doi.org/10.1007/s41810-022-00136-7 . Springer

ASSESSMENT OF THE TRANSMITTANCE OF MODERN PERSONAL RESPIRATORY PROTECTION EQUIMENT FOR WELDING AND GALVANIC FUMES

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Abstract

The article focuses on the study of the filtration performance of modern respirator models when exposed to welding and electroplating fumes containing ambient particles smaller than 10 microns (PM_{10}). The low filtration capacity of most modern respirators with respect to nano- and microparticles was revealed. Respirator filtration performance can be affected by a number of factors including: different filtration mechanisms, environmental parameters, filter material properties, number of respirator layers used, packing density, fiber loading density, fiber diameter, aerosol particle type and size, aerosol flow rate and concentration values, and additional factors from different human activities. Modern filtration materials and respirators are not able to provide 100% protection against the penetration of the smallest particles of industrial aerosols into the body. Respirators with multi-layer protection, fitted with carbon filters, have the highest capture capacity.

Keywords: industrial aerosols, particulate matter, filtration capacity, electroplating, welding, nano- and microparticles, respirators

I. Introduction

Ambient air pollution by particulate matter has become a serious public health hazard in many regions [1]. Some of the main sources of pollution are exhaust gases from motor vehicles, welding, and electroplating.

According to the standard definition of nanoparticles by the U.S. National Nanotechnology Initiative (NNI) [2] and ASTM E2456-06 [3], particles smaller than <100 nm should be considered ultrafine particles. These particles are highly permeable, capable of penetrating deep into the alveoli, beyond the natural airways of bodies and settling in the lower respiratory tract [4]. These particles can trigger serious diseases such as respiratory symptoms, lung cancer, and silicosis depending on the components of particles [5]. Ultrafine particles of industrial aerosols pose toxicological hazards depending on their surface characteristics [6].

Therefore, there is a high demand for respiratory protective devices. Variants of respiratory protective devices are a face mask and a respirator.

A face mask is a loose-fitting, disposable device that creates a physical barrier between the user's mouth and nose and potential pollutants near an air pollution source. A respirator is a personal air cleaner equipped with a filter that provides a tight fit to a person's face [7]. There are several key factors that affect respirator performance: (a) filtration, (b) flow resistance (i.e., air permeability), (c) ergonomics, and (d) continuous operation in a given environment. Additionally, it is important to note that using respirators does not prevent oxygen from entering the human body. And there is no significant difference in the oxygen saturation of human lungs when using respiratory protective devices (P> 0.05) [8].

The filtering and separation of submicron-sized contaminants is a major challenge today. The development of modern respirator filter materials that would effectively capture suspended nano- and microscale particles requires an innovative approach. Nanofibers [9], 3D printers [10], and additive technologies [11] for manufacturing filter materials can significantly advance the technological development of respiratory protective devices.

Filter efficiency depends on several factors. It improves as the size of the filter material fibers decreases due to the high mechanical ability to trap the smallest particles suspended in the ambient air. However, it is the shape of the fibers, rather than their calculated average aerodynamic diameter, that is the dominant factor in the deposition mechanisms in the tested respirators [12].

The present study is focused on the research of the trapping characteristics of respirators exposed to aerosols of electroplating origin. Electroplating is a source of emission of heavy metal oxides into the air. It is known that exposure to aluminum, arsenic, lead, cadmium, and manganese in the workplace can increase the risk of numerous neurophysiological changes in workers and can trigger the development of Parkinson's and Alzheimer's diseases [13].

Among the technological processes of modern industrial production that have been studied so far, those that pose the most significant hygienic risks are the following:

- In electroplating it is the electrochemical process of nonferrous metals etching [14]. Used daily, this is one of the main technological processes in electroplating workshops for manufacturing parts from nonferrous metals.

- In welding production, it is manual arc welding of metal plates (construction steel, S = 8 mm) using electrodes with rutile covering, diameter 3 mm [15]. Emissions from manual welding are almost equivalent to the air emissions from the underwater welding [16].

For the listed technological processes, it was decided to perform a comparative analysis of the trapping characteristics of filters in 10 modern respirators in real production conditions.

It is important to understand that different types of respirators and masks have their advantages, disadvantages, capabilities, and limitations. However, for each specific type of industrial production, the most suitable and versatile masks can be developed that can provide a high level of industrial safety for workers.

In addition to the safety requirements for viral aerosol filtration tests, one of the major problems that researchers currently face is the inability to simulate or simulate true aerosol filtration scenarios through laboratory experiments, field tests, and in vitro / in vivo studies [17]. There are few studies on the effectiveness of respirators in capturing suspended particles of industrial aerosols in real production conditions [18].

For this reason, a full-scale experiment was conducted in real production conditions of electroplating and welding shops. This work is aimed at investigating the penetration ability of welding and electroplating fume particles through the filter material of modern models of respirators. For this purpose, we selected the most popular models of respirators for welding production and compared the trapping characteristics of their filter elements in real production conditions. In contrast to the works of other researchers [19], in this experimental work, only samples of filter materials were used to assess the penetration ability, not the whole respirators.

II. Experimental

Measurement of the quantitative composition of PM

The quantity of airborne PM was measured using the AeroTrak Handheld Particle Counter 9306 (TSI Incorporated, USA). This sampler meets all the requirements set out in ISO 21501-4.

Continuing the previous research of air pollution by electrochemical processes from the hygienic point of view (depending on the levels of $PM_{0.3}$ and PM_{10} in the air) [20, 21], we chose to further study the influence of the nonferrous metals etching and manual arc welding using electrodes with rutile covering on the trapping characteristics of filters in modern respirators (Table 1, Figure 1).

Filtering facepiece respirators (FFP) are commonly used in workplaces due to their low cost, comfort, ease of use, and sufficient effectiveness.

Table 1: *The list of personal respiratory protective equipment used in the experiment*

No.	Respirator/mask model	Technical specifications
1	Filtering facepiece respirator with breathing valve “Stayer Master 11118”	Protection class: FFP1 Material: textured polypropylene Manufacturer: Kraftool I/E GmbH, Germany
2	Filtering facepiece respirator with breathing valve “Zubr Expert 11160”	Protection class: FFP1 Material: textured polypropylene Manufacturer: Zubr OVK, Russian Federation
3	Filtering facepiece respirator “DEXX 11103”	Protection class: FFP1 Material: polypropylene Manufacturer: Zubr OVK, Russian Federation
4	Filtering facepiece respirator with breathing valve “Zubr Master 11163-2”	Protection class: FFP2 Material: textured polypropylene Manufacturer: Zubr OVK, Russian Federation
5	Filtering facepiece respirator with breathing valve “Rutex F1101”	Protection class: FFP1 Material: electret filtering material Manufacturer: Rutex, China
6	Filtering facepiece respirator “KN95”	Protection class: FFP2 Material: non-woven fabric and meltblown filter fabric Manufacturer: Jinhua Han Ye Daily, China
7	Filtering facepiece respirator with breathing valve “Istok”	Protection class: FFP2 Material: polyethylene foam Manufacturer: Istok, Russian Federation
8	Filtering facepiece respirator with breathing valve “Briz-1102(Y-2K)”	Protection class: FFP1 Material: polyurethane foam Manufacturer: Briz-Kama, Russian Federation
9	Facepiece elastomeric air-purifying respirator “RPG-67” with filter type A1B1	Protection class: FFP1 Material: woven fabric, charcoal filter Manufacturer: GK Rim, Russian Federation
10	Medical face mask	Material: nonwoven three-layer SMS (spunbond, meltblown, spunbond)

Air samples were taken at a distance of 1 m from the source of air pollution (Figure 1) at a constant height of 1.5 m corresponding to human breathing level.

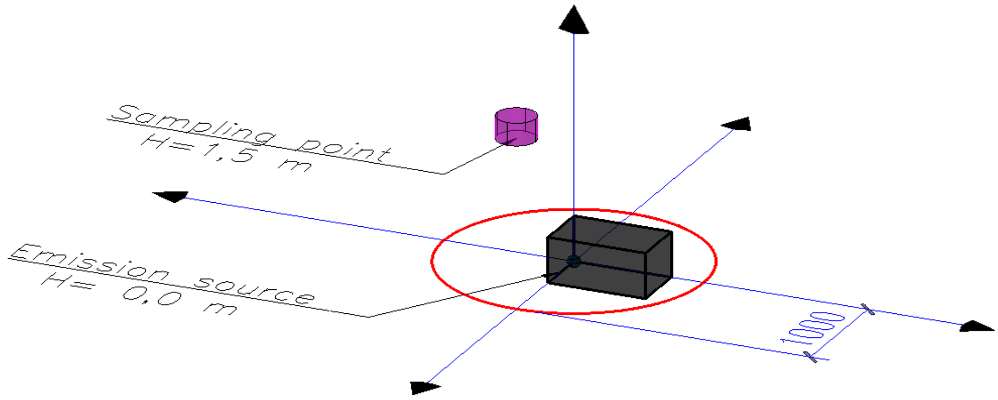


Figure 1: *Location of the sampling point in the production shops*

Two series of sampling were performed: using filters of 10 models of respirators for welding and electroplating.

Mass concentration of airborne PM

To determine the content of fine particles of industrial aerosol in ambient air, a series of air samples were taken using the aspirator-type sampler "Aspirator PU" (JSC Khimko, Russia) with filters from 10 modern respirators.

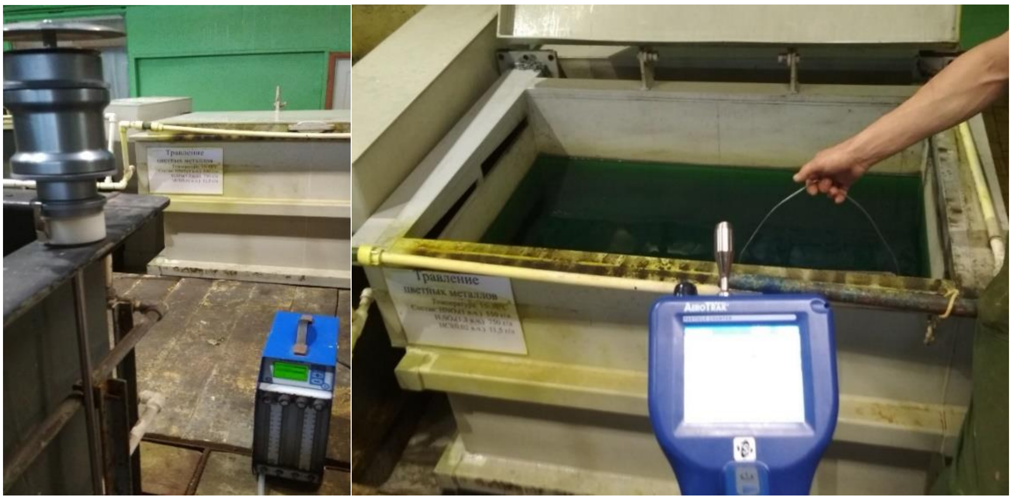
In this sampler, instead of normally used aerosol filters based on a Petryanov filtering cloth made of fibrous perchlorvinyl fabric (Gorky Kimry Factory, Russia), we used filter material taken from modern models of respirators and cut to the size fitting the sampler (Table 1).

During the experiment, this sampler was equipped with an additional attachment for sampling particles of the PM_{10} fraction, taken from a similar aspirator LVS 3.1 (Ingeniero Nobert Derenda, Germany). The range of particles for filters in this attachment is from 0.45 μm to 10 μm. The upper limit (PM_{10}) was chosen because it poses the greatest danger to human health, being the cause of respiratory diseases [22]. This reflects the current trend in the field of control of substances suspended in ambient air [23].

Before sampling, the filters were pre-dried in a TC-1/20 thermostat (Russia) for 24 hours at 40 °C (Fig. 2), then each filter was weighed three times on electronic balance CAS CAUY-120. Arithmetic mean weight was determined for each filter.

Figure 2: *Preparation of filter materials in the thermostat*

The samples were taken at the sampling points shown in Fig. 1, 3 and 4 at 1 m from the pollution source (electroplating bath or welding operator).



A) B)

Fig. 3: *Sampling air probes in the electroplating shop. A) air sampling, B) PM sampling.*

The installation height of the sampler corresponded to the level of human respiration – 1.5 m. The sampling time was 1 min for each filter. The air temperature during the experiment was 18 °C, the wind speed was 0 mps (samples were taken inside the workshop). The volume of air pumped through the sampler was 2.8 m^3/h. Filters with samples of particulate matter were transported to the laboratory of REC "Nanotechnology" of the Polytechnic Institute FEFU for further determination of the concentration of PM_{10} particles.

A) B)

Figure 4: *Taking air and PM samples during welding. A) Measuring instruments, B) Welding process*

Dust content in the air was measured by weighing the filters on electronic balance CAS CAUY-120 before and after sampling. Each filter was weighed three times and arithmetic mean was determined. The resulting difference in the weight of filters before and after the air sampling procedure corresponded to the settled mass of particulate matter, including the PM_{10} fraction.

Electron microscopy of PM

To visualize airborne particles deposited on respirator filter material, a state-of-the-art stereo microscope Zeiss Stemi DV4 (Germany) was used. The microscope's features include 30x image magnification with viewing angle up to 60°.

This microscope is equipped with a high-intensity illuminator that offers three illumination modes to produce a clear image of the sample. The Zeiss dual-lens zoom system ensures excellent sharpness and high-resolution images.

Two 50x50 mm samples were cut out from each filter of 10 respirator models, corresponding to "before" and "after" the experiment on measuring the concentration of deposited industrial aerosol particles. The fibers of each filter were photographed using electron microscopy.

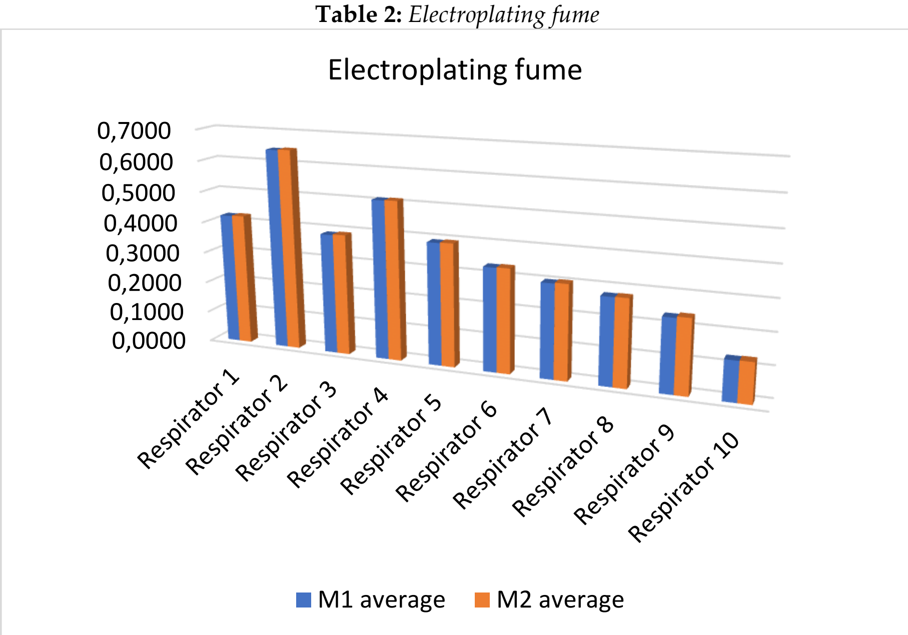
III. Results and discussion

It is known that penetration of industrial aerosol particles through the filters of respirators increases with the flow rate regardless of the type of particles, and the particle size is a significant factor influencing the penetration of combustion aerosol particles [24]. For this reason, the experiment was focused on measuring particles up to 10 μm in size, which have the greatest penetrating ability [25] and ability to settle deep into the lungs of welders and workers of related professions. Tables 2—5 summarize data on mass concentration and quantity of welding fume and electroplating fume particles.

The issue of identifying ineffective personal respiratory protective equipment is particularly relevant in the context of the pandemic [26] and the shortage of masks and respirators on sale, as well as appearance on commercial market of uncertified products with low effectiveness or even fake models [27—29].

Mass concentration of airborne particles of electroplating fume deposited on filters

Table 2: *Electroplating fume*



According to the data obtained (Table 4), the trapping capacity of filters in respirators varies depending on the PM fraction. Table 2 shows the weight data of respirator filter samples before and after the series of experiments. M1 values describe the weight of the filter sample before the experiment and M2 values – after pumping 2.8 liters of air through the respirator filter.

To obtain the values of the mass of deposited solid particles originating from electroplating aerosol, their content was recalculated to the level of 1 m^3 of air pumped through the filter.

The highest mass of deposited particles was found in respirator No. 9 (RPG-67 with filter type A1B1). This respirator can trap up to 1.6 mg when pumping 1 m^3 of air through its filter.

The second place in terms of the mass of industrial aerosol particles deposited on the filter is respirator No. 3.

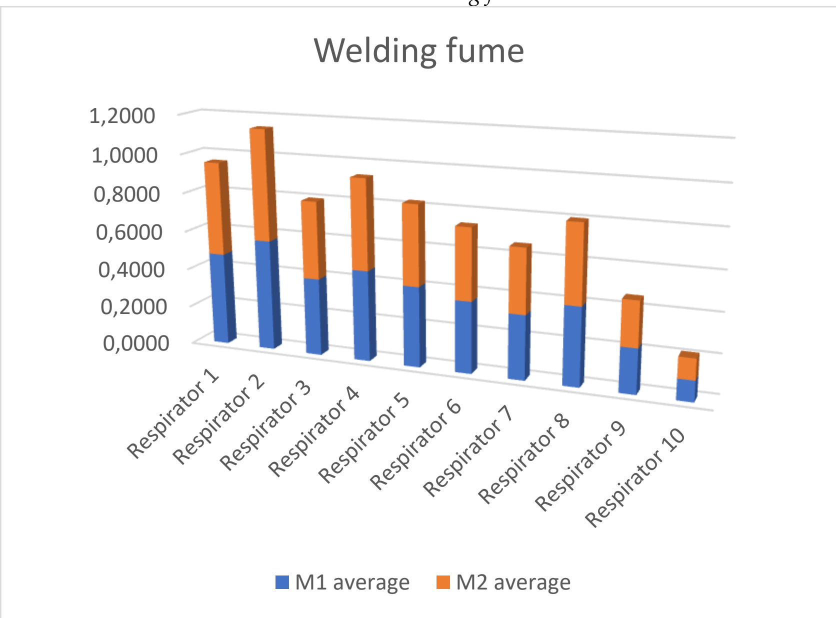
Respirators No. 2 and No. 5 show average values of deposition of industrial aerosol particles. The values for these samples range from 0.8 to 0.9 mg/m^3. Respirator No. 4 demonstrates the best trapping ability for PM_1 and PM_3 fractions. Respirator No. 5 (closely followed by respirators No. 3-7), has the highest mass of deposited PM_5 and PM_{10} particles.

Respirators No. 8, 10, 6, 4, and 1 are ineffective in trapping airborne particles of electroplating aerosol and practically do not prevent particles from freely penetrating the filtering material of respirators. The values of deposited particles on filters of these respirators range from 0.5 to 0.7 mg/m^3.

As can be seen from the data presented in Tables 2, 3, the mass concentration of airborne PM deposited on the filter elements of respirators in the electroplating shop is several times higher than the concentration of particles in the air of the work zone in the welding shop. This fact may be due to the finer size of solid particles of the welding fume, which easily overcome the filtering barrier of respirators.

Mass concentration of airborne particles of welding fume deposited on filters

Table 3: *Welding fume*

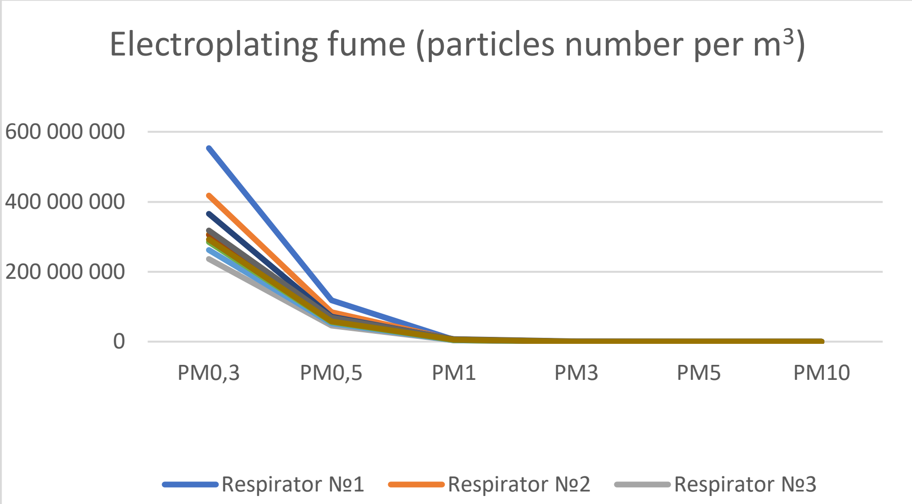


The obtained data indicate that the majority of respirators used in the experiment had low particle trapping efficiency. Respirators No. 2—6 (group 1) are barely effective in capturing solid particles of welding fume. Additionally, other 2 models of respirators: No. 8 and No. 1 (Group 2) have average efficiency against other tested respirators.

The highest mass of deposited particles was found in respirator No. 9 (RPG-67 with filter type A1B1). This respirator has several protective layers – woven fabric and charcoal filter. The filter material of this respirator trapped from 2 to 10 times more particles compared to samples from the first and second groups, correspondingly.

Quantity of airborne PM

Table 4: *Electroplating fume (particles number per m³)*



Filters do not degrade or recover after the exposure to industrial aerosols stops. Therefore, the aerosol penetration measured at any time after exposure should be equal to the maximum obtained using the respirator [30]. It should be noted that since the filter material samples were used as filters in the aspirator, they demonstrated 100% efficiency, and there was no air leakage through the end seal in different head positions when the respirator was placed against the worker's face.

The filtering efficiency of respirators depends largely on the size of solid particles, and the penetration of any dust through the mask will be critically influenced by its fractional composition.

Considering that 30-100 nm particles have the maximum penetrating ability [31], respirator No. 3 should be selected as having a clear advantage. Respirator No. 3 is most effective in trapping particles of the smallest fractions: $PM_{0.3}$ and $PM_{0.5}$. This respirator has a higher particle trapping capacity for these particle sizes compared to other respirators ranging from 20% to 234%, depending on the model.

The maximum content of aiborne PM was registered at the beginning of the experiment, with values being an order of magnitude higher than those for other repetitions. The content of particles of the smallest fraction ($PM_{0.3}$ and $PM_{0.5}$) exceeds similar indicators of other models of respirators.

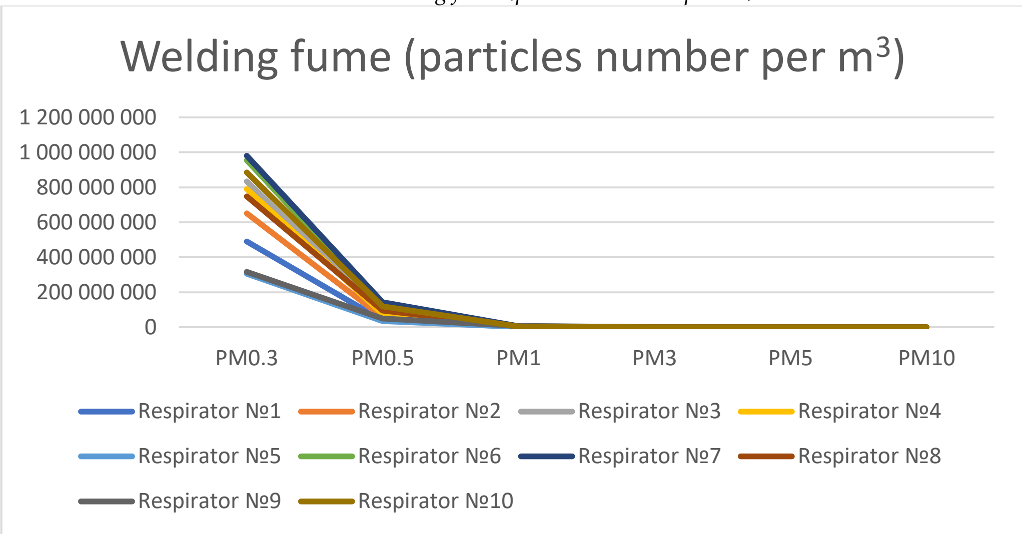
Table 5 below summarizes the measurement values for the experiments performed in the welding shop.

It is known that unlike the ultrafine fraction, larger particles (e.g., 800 nm) are almost completely trapped by the filter material in respirators with medium and high protection class [32]. That is why the numbers of nano- and micro-size particles were counted before they were deposited on the filter material inside the aspirator. The number of fine particles in welding fume ($PM_{0.3}$ fraction) reached hundreds of millions particles per 1 m³ (from 316 to 980 mln particles), which exceeded the number of PM_{10} particles several hundred-fold (from 19 to 42 thousand/m³). Nano-range particles are the most hazardous for human health as they can easily bypass alveolar protection of lungs, deeply penetrating into human internal organs and causing chronic diseases of the upper respiratory tract [33].

Compared to electroplating, a greater number of airborne particles were formed in the second half of the sampling experiment series rather than at the beginning.

As expected, the lower mass fraction of particles deposited on respirator filter elements during welding is due to their smaller size. The cells of the filter elements significantly exceed the dimensions of particles that easily penetrate the protection of respirators and penetrate into the respiratory organs. This is evidenced by the higher number of suspended particles of the $PM_{0.3}$ and $PM_{0.5}$ fractions during welding in comparison with the electrochemical process (Table 5). The average values of PM during welding are on average 1.5÷2 times higher in comparison with the electroplating process.

Table 5: *Welding fume (particles number per m³)*



Electron microscopy of ambient particles on filters

Figures 6-24 show a comparative analysis of the surface of filters from respirators before and after the experiments in the electroplating and welding shops. In the lower right corner, there is a scale bar to show the dimensions of deposited particles.

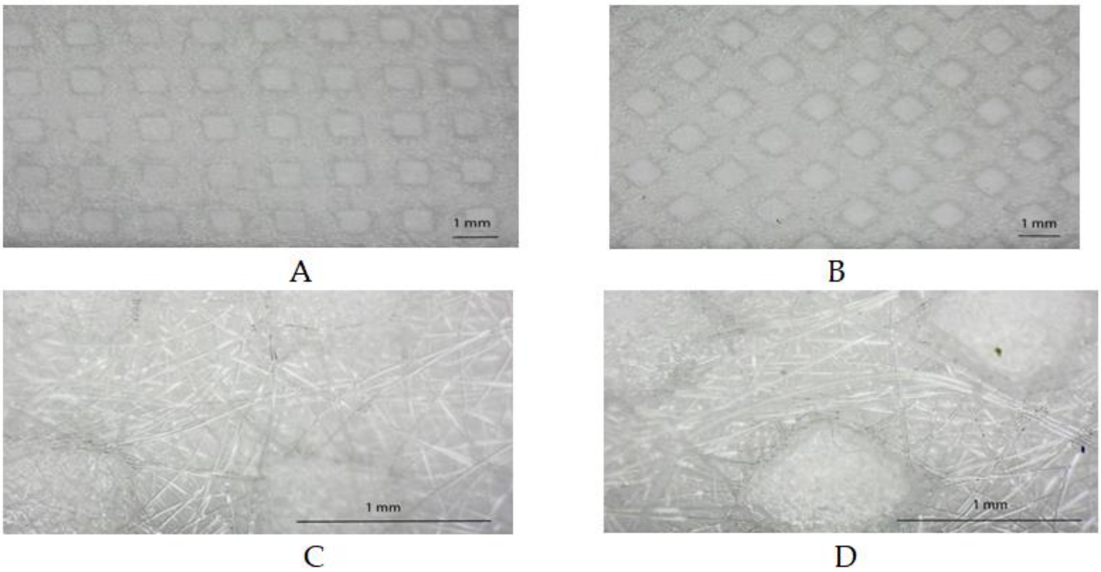


Figure 5: *Electroplating fume. Respirator 1.*
A), C) Before sampling; B), D) After sampling

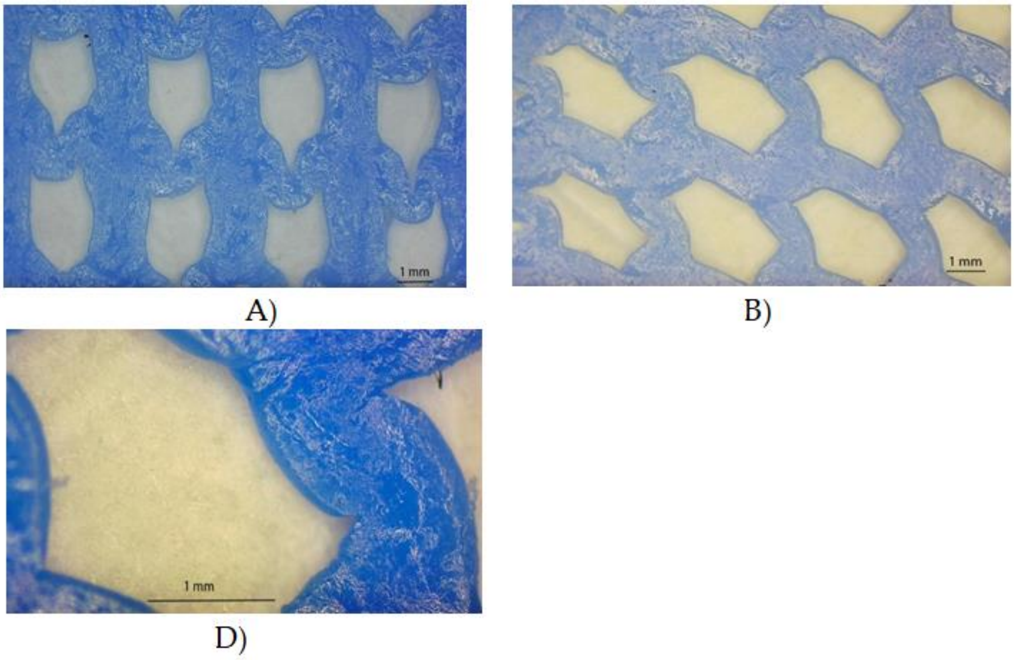


Figure 6: *Electroplating fume. Respirator 2. A) Before sampling; B), D) After sampling*

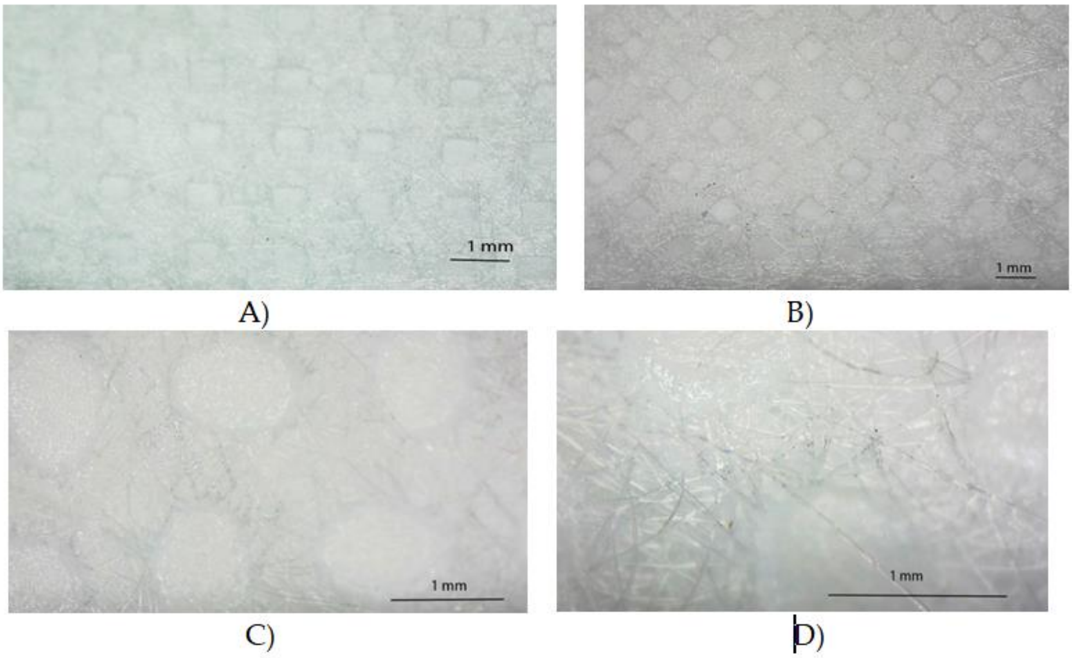


Figure 7: *Electroplating fume. Respirator 3. A), C) Before sampling; B), D) After sampling*

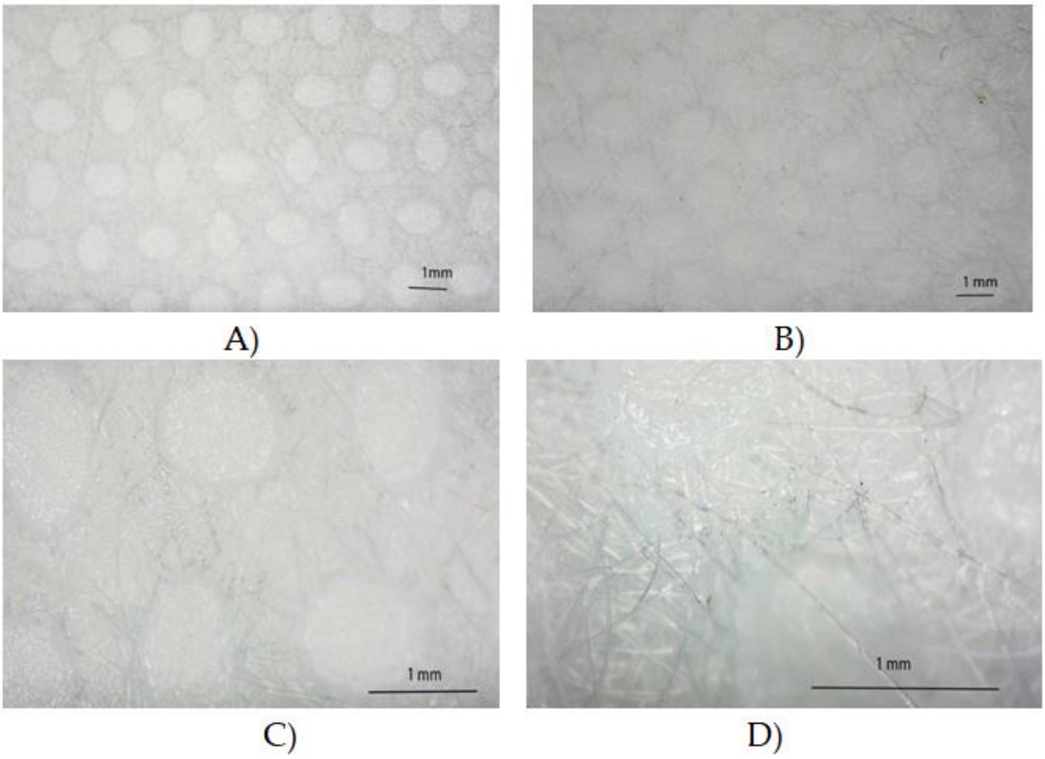


Figure 8: *Electroplating fume. Respirator 4. A), C) Before sampling; B), D) After sampling*

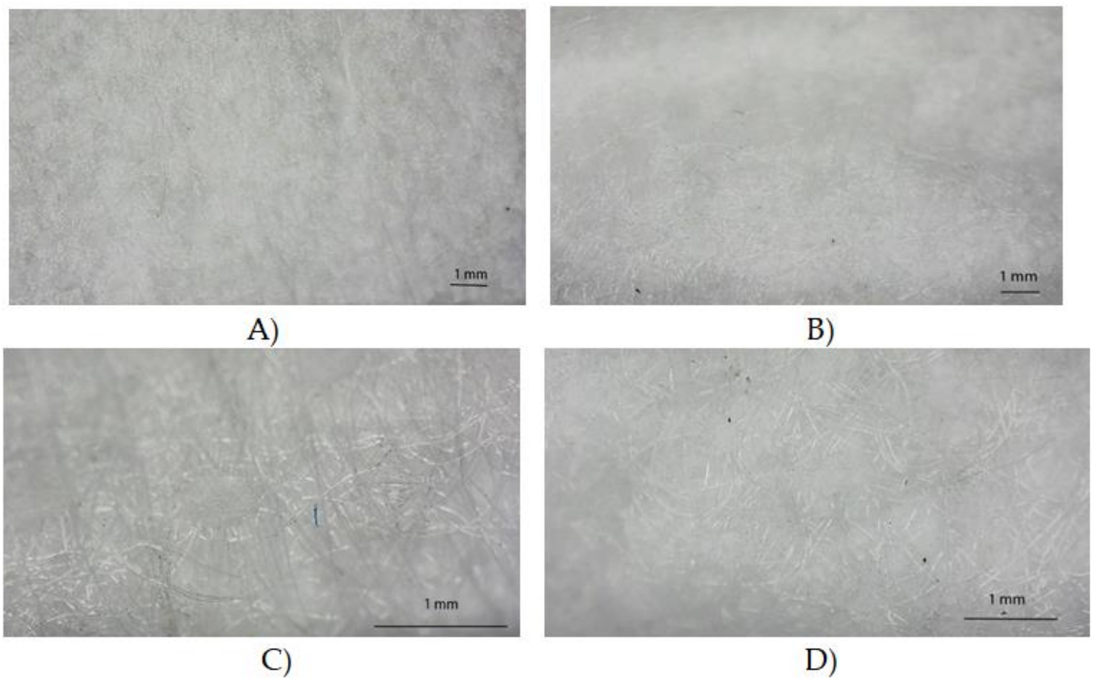


Figure 9: *Electroplating fume. Respirator 5. A), C) Before sampling; B), D) After sampling*

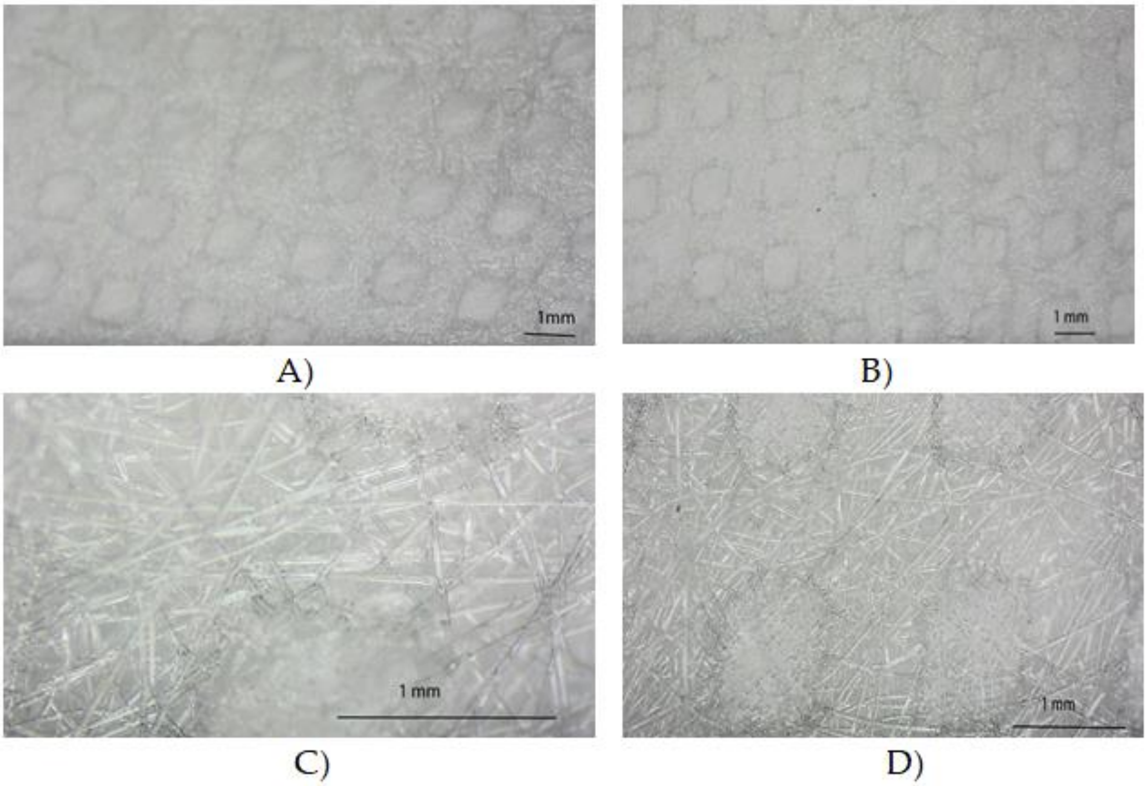


Figure 10: *Electroplating fume. Respirator 6. A), C) Before sampling; B), D) After sampling*

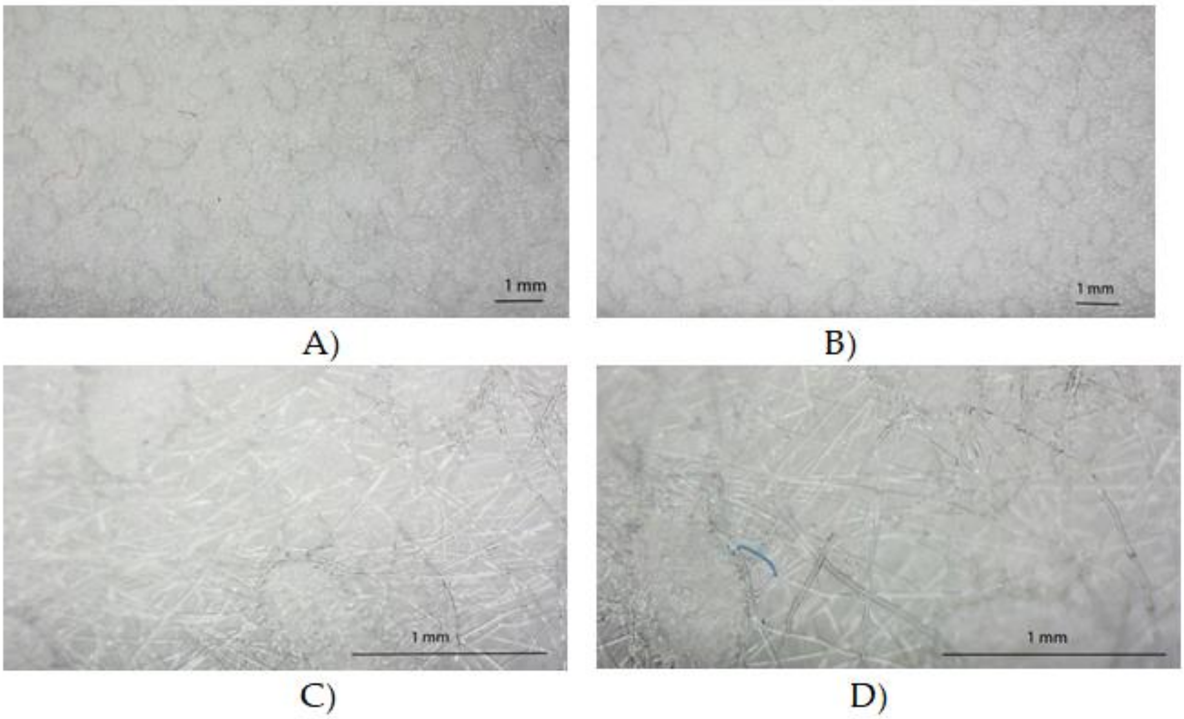


Figure 11: *Electroplating fume. Respirator 7. A), C) Before sampling; B), D) After sampling*

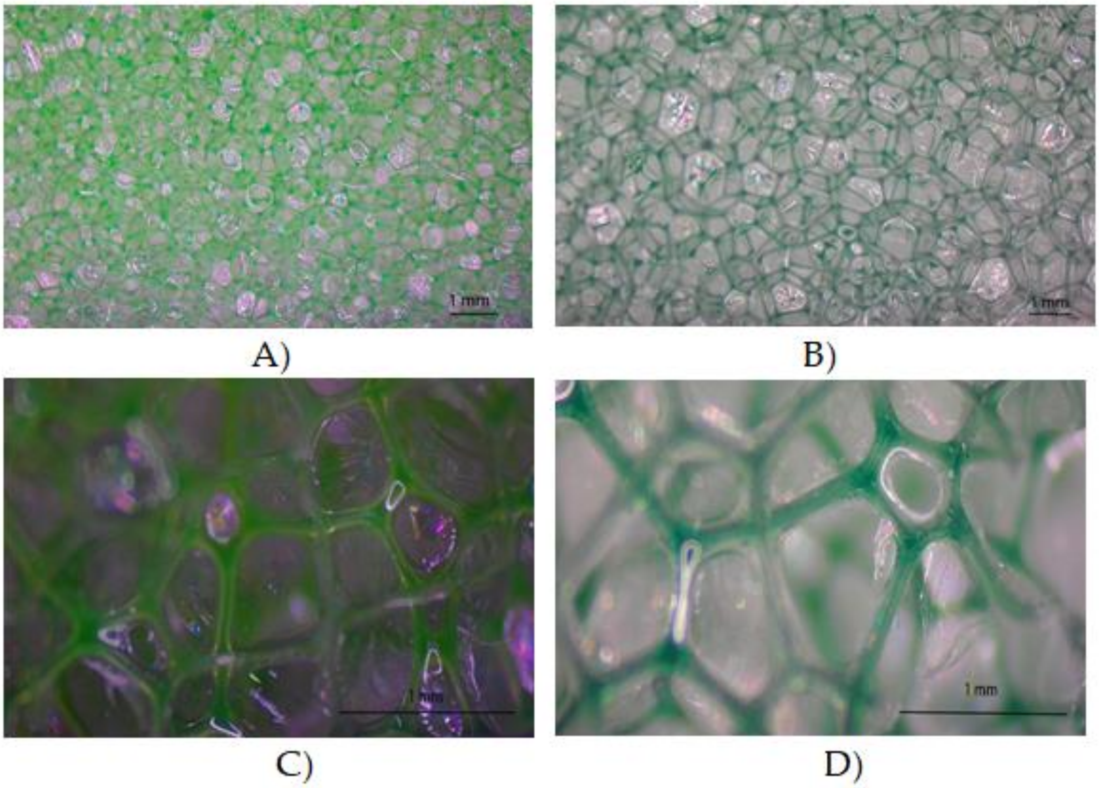


Figure 12: *Electroplating fume. Respirator 8. A), C) Before sampling; B), D) After sampling*

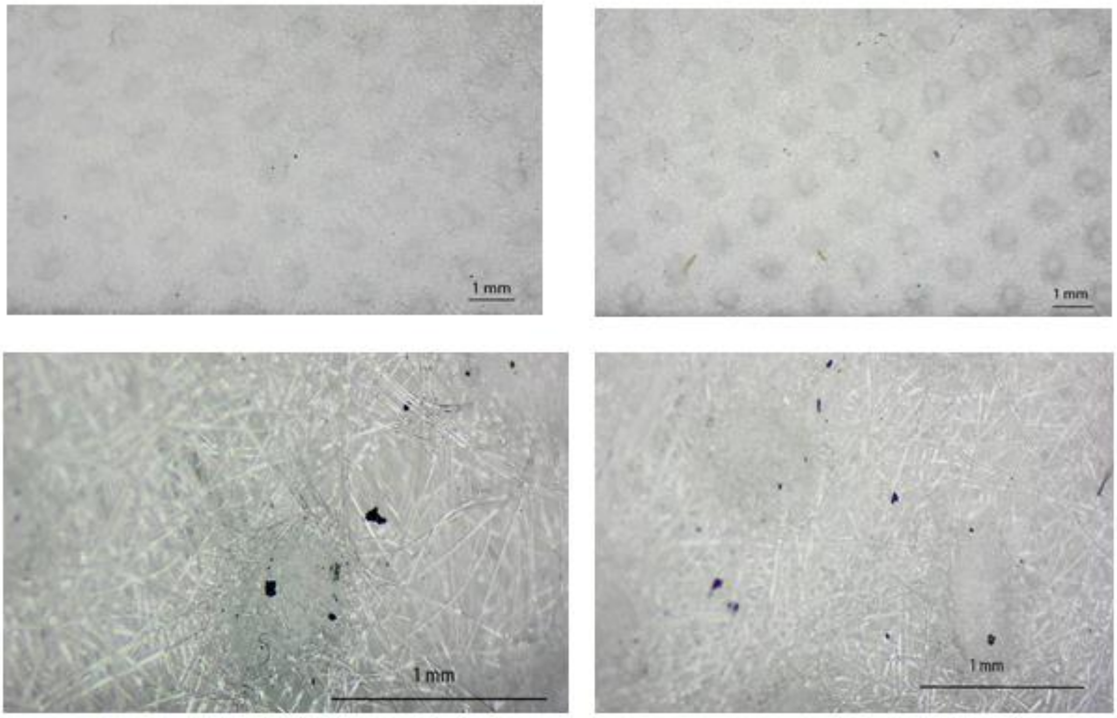


Figure 13: *Electroplating fume. Respirator 9. A), C) Before sampling; B), D) After sampling*

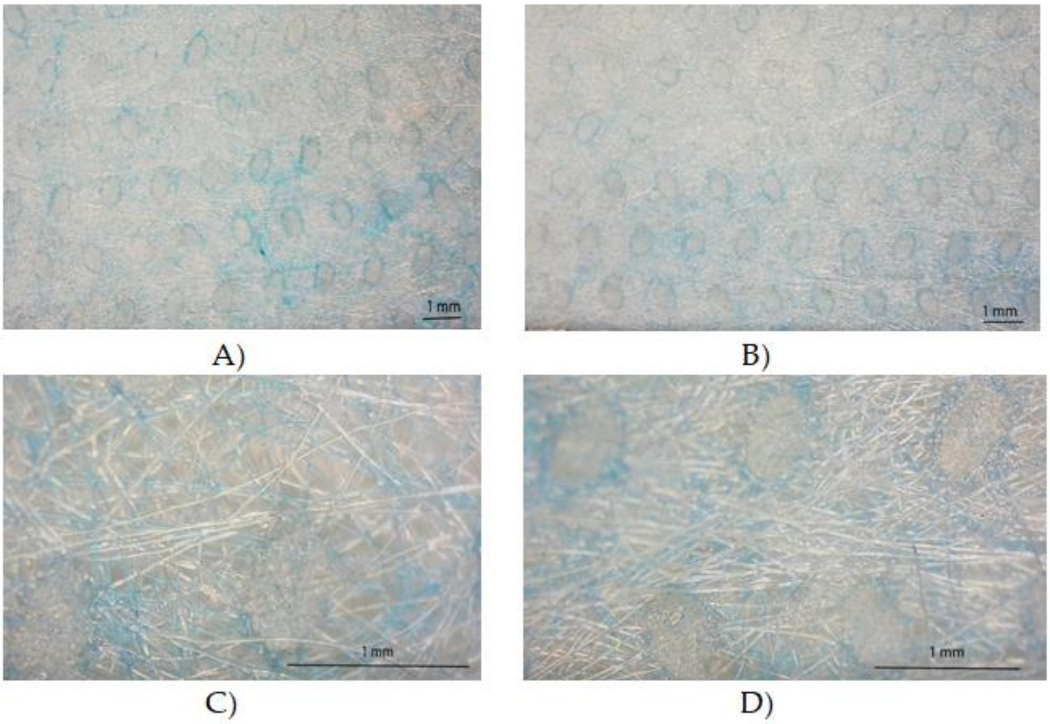


Figure 14: *Electroplating fume. Respirator 10. A), C) Before sampling; B), D) After sampling. Comparison of the surface of filter material of the respirators before and after the experiment. Carl Zeiss Stemi DV4 stereomicroscope, magnif. 30x*

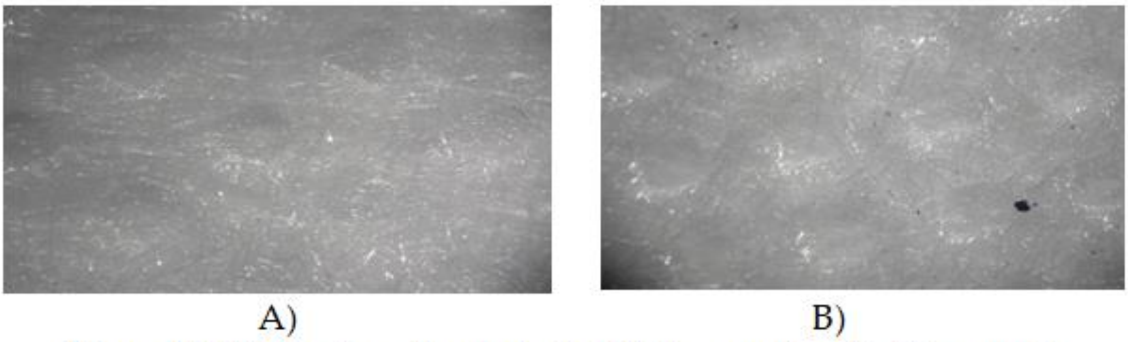


Figure 15: *Welding fume. Respirator 1. A) Before sampling; B) After sampling*

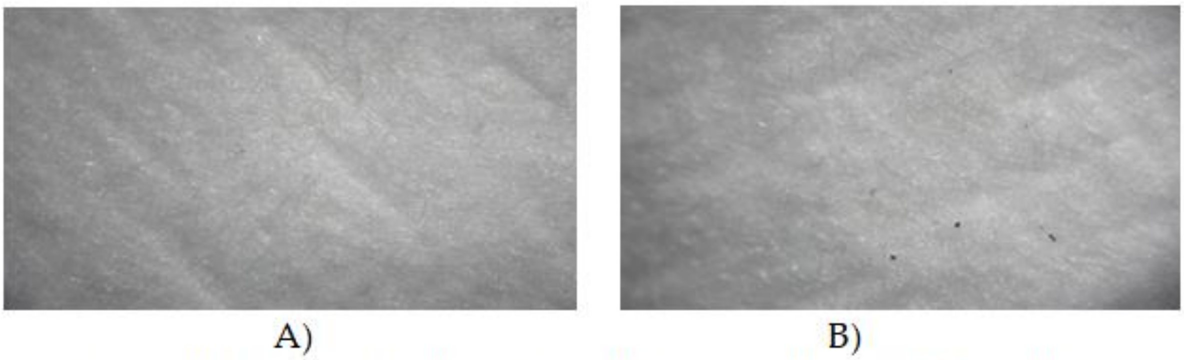
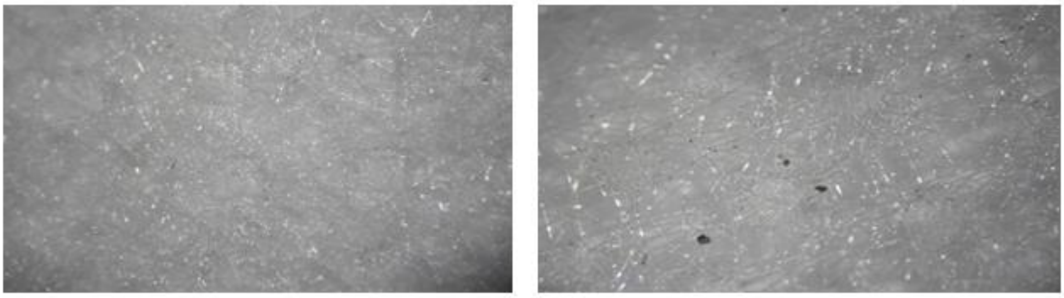
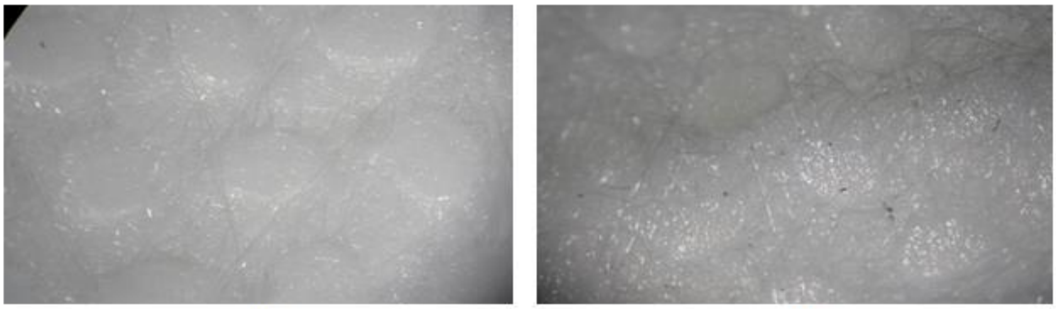


Figure 16: *Welding fume. Respirator 1. A) Before sampling; B) After sampling*



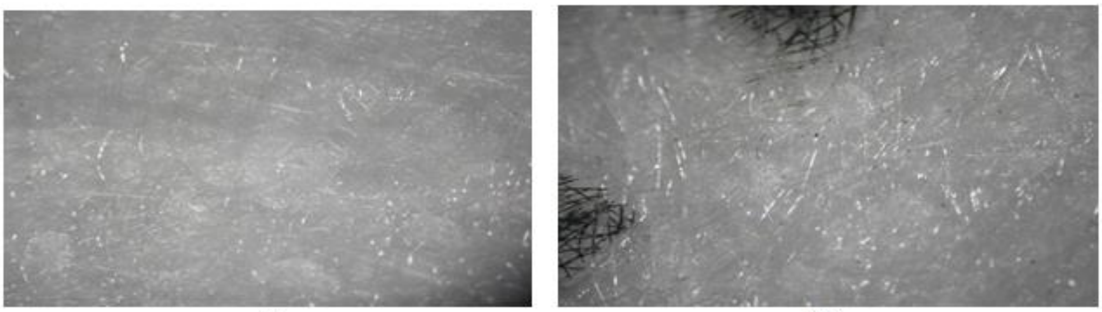
A) B)

Figure 17: *Welding fume. Respirator 3. A) Before sampling; B) After sampling*



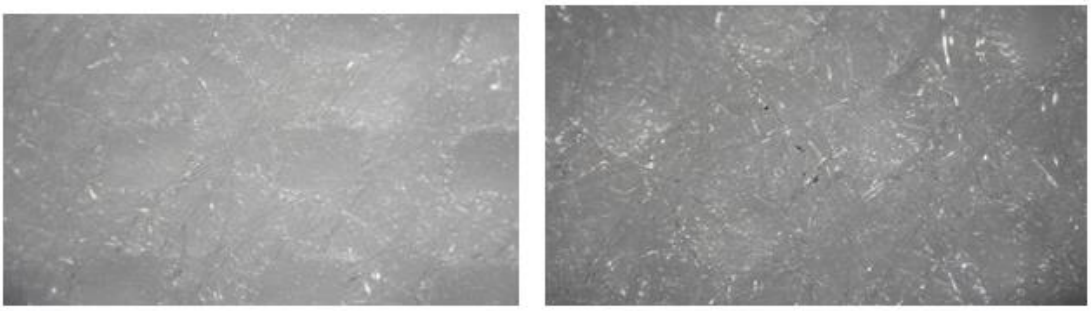
A) B)

Figure 18: *Welding fume. Respirator 4. A) Before sampling; B) After sampling*



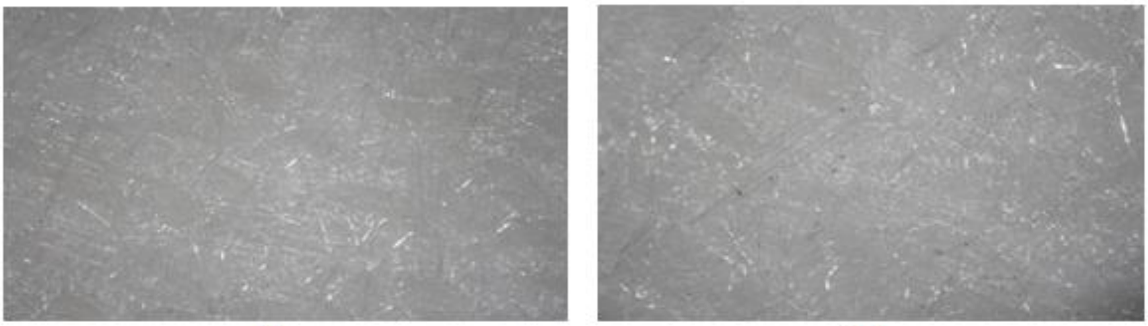
A) B)

Figure 19: *Welding fume. Respirator 5. A) Before sampling; B) After sampling*



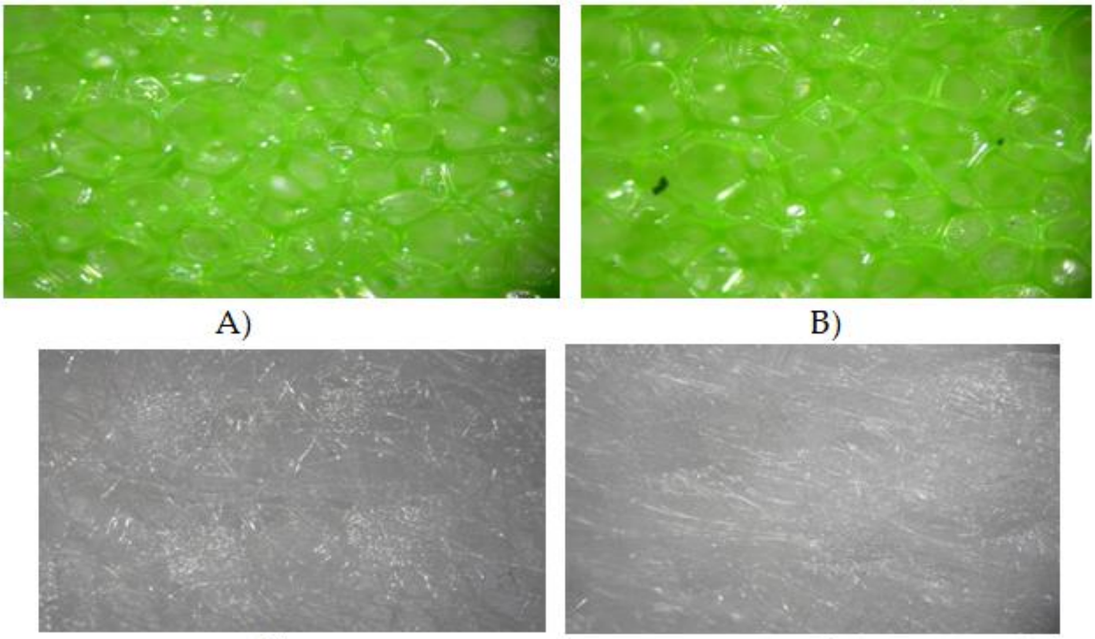
A) B)

Figure 20: *Welding fume. Respirator 6. A) Before sampling; B) After sampling*



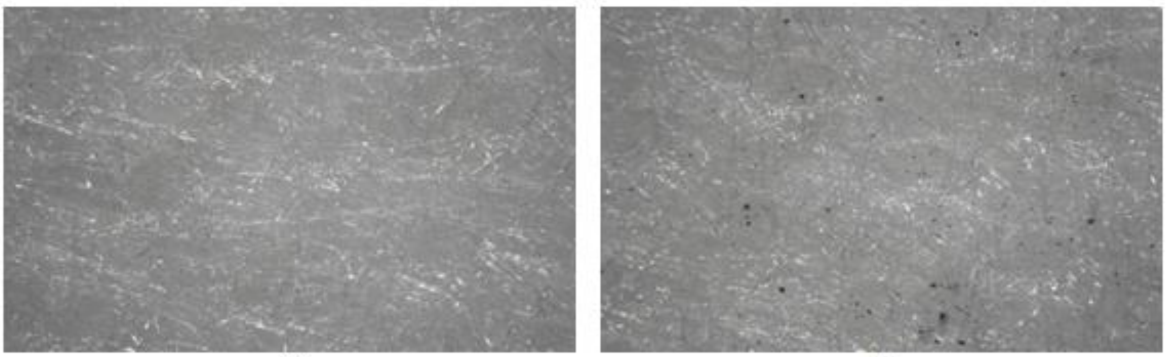
A) B)

Figure 21: *Welding fume. Respirator 7. A) Before sampling; B) After sampling*



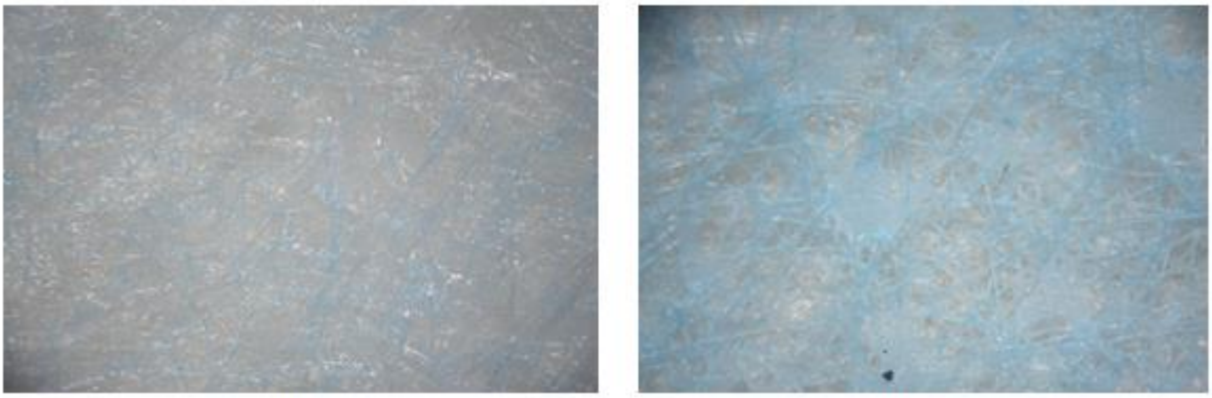
A) B) C) D)

Figure 22: *Welding fume. Respirator 8. A), C) Before sampling; B) D) After sampling*



A) B)

Figure 23: *Welding fume. Respirator 9. A) Before sampling; B) After sampling*



A) B)

Figure 24: *Welding fume. Respirator 10. A) Before sampling; B) After sampling*

According to the results of electron microscopy, the samples of filter material from respirators No. 3 and 9 demonstrate the best trapping properties. Solid particles of industrial aerosols deposited on the filter are clearly visible (they have a dark color). The electron microscopy results correlate with the number concentration of airborne PM confirming the mechanical trapping ability of the respirator filtering material (Table 2).

The photographs of filters from respirators No. 8, 10, 6, 4, and 1 before and after the experiment are very similar because no deposited particles of industrial aerosol can be observed. These photographs and the data in Table 2 confirm the low sorption and filtration capacity of these respirators. Therefore, these respirator models are ineffective in trapping airborne PM originating from electrochemical processes in electroplating production.

The results obtained indicate the possibility of penetration of the smallest particles of industrial aerosols through the protective filtration barriers of personal respiratory protective equipment. It is known that prolonged inhalation exposure to industrial aerosols contributes to the emergence and development of occupational respiratory diseases in welders, electroplaters and workers of related professions. Prolonged exposure to industrial aerosols provokes the development of fibrogenic processes, mainly silicosis, dust bronchitis, pleurisy, pneumonia and asthma [34]. The risk of occupational diseases increases with each year of work experience, and at the age of 12-15 years the maximum rates of development of chronic diseases are reached in welders, electroplaters and workers of related professions [35].

The solution to this problem may be the introduction of new materials as filtration elements in personal respiratory protective equipment, such as composites, nonwovens, or with physical properties of magnetic fields to improve trapping characteristics.

IV. Conclusions

The results obtained indicate that there is a significant variation in the filtration efficiency of the filter elements in different respirator models.

Respirator filtration performance can be affected by a number of factors including: different filtration mechanisms, environmental parameters, filter material properties, number of respirator layers used, packing density, fiber loading density, fiber diameter, aerosol particle type and size, aerosol flow rate and concentration values, and additional factors from different human activities [17] and the fit of the respirator to the human face [36, 37].

According to the data obtained, the trapping capacity of filtering material in respirators varies depending on the fraction of airborne PM. The maximum efficiency is demonstrated by respirator No. 9 with a multilayer filter element which traps particles of the smallest fraction much better than other models used in the experiment. It should be noted that in experimental conditions, the maximum trapping characteristics of the filtering material of respirators were considered, without any leakage on edges where respirators fit to the worker's face. For models with the low trapping capacity of the filtering material (respirators No. 8, 10, 6, 4, and 1), it may be a factor that compensates for the disadvantages through better ergonomics and tight fit of the respirator to the face of the worker in real production conditions.

It should be noted that choosing the most effective respirator model that captures the maximum amount of airborne particles, thereby preventing their penetration into the human body, which can lead to occupational diseases with prolonged exposure, can solve the problem of reducing the incidence of disease among electroplaters, welders and workers in related professions. However, polymer materials used in the production of respirators and masks are usually not biodegradable which can cause serious environmental problems in most countries where waste disposal systems are ineffective. Therefore, respirator models with non-woven and non-synthetic materials have great prospects for the future if they achieve a high trapping capacity and low airflow resistance.

The results obtained for the filtration efficiency of the filter materials allow us to conclude that respirators with combined multi-layer filter elements are the most effective. Since we did not take into account a number of respirator factors, such as the tightness of the mask to the face, long-term preservation of working characteristics, and based only on the filtration capacity, it is possible that other respirator models will be more effective in real production conditions due to unaccounted for advantages.

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References

1. Polymer/MOF-derived multilayer fibrous membranes for moisture-wicking and efficient capturing both fine and ultrafine airborne particles. Wang, Zhe; Zhang, Youfang; Ma, Xiu Yun Daphne; Ang, Jiaming; Zeng, Zhihui; Ng, Bing Feng; Wan, Man Pun; Wong, Shing-Chung; Lu, Xuehong. 2020. Separation and Purification Technology, 235(), 116183.

2. National Nanotechnology Initiative. Standards for Nanotechnology. Available online: https://www.nano. gov/you/standards (accessed on 31 August 2018).

3. ASTM 2456-06 Standard Terminology Relating to Nanotechnology. Available online: http://www.astm.org/ Standard/index.shtml (accessed on 30 August 2018).

4. Nanomaterials and nanoparticles: Sources and toxicity. Buzea, C.; Pacheco, I.I.; Robbie, K. Biointerphases 2007, 2, MR17-71. [CrossRef] [PubMed].

5. Nanoparticles—Known and unknown health risks. Hoet, P.H.; Brüske-Hohlfeld, I.; Salata, O.V. J. Nanobiotechnol. 2004, 2, 12. [CrossRef] [PubMed]

6. Park, H.J.; Sohn, J.H.; Kim, Y.J.; Park, Y.H.; Han, H.; Park, K.H.; Lee, K.; Choi, H.; Um, K.; Choi, I.H.; et al. Acute exposure to silica nanoparticles aggravate airway inflammation: Different effects according to surface characteristics. Exp. Mol. Med. 2015, 47, e173. [CrossRef] [PubMed]

7. Akduman, C.; Akçakoca Kumbasar, E. P. Nanofibers in face masks and respirators to provide better protection. IOP Conference Series: Materials Science and Engineering. 2018. 460(), 012013. doi:10.1088/1757-899X/460/1/012013.

8. Kim, Jung-Hyun; Benson, Stacey M.; Roberge, Raymond J. Pulmonary and heart rate responses to wearing N95 filtering facepiece respirators. American Journal of Infection Control. 2013. 41(1), 24–27. doi: 10.1016/j.ajic.2012.02.037

9. Song, Yufeng; Chau, John; Sirkar, Kamalesh K.; Peterson, Gregory W.; Beuscher, Uwe. Membrane-Supported Metal Organic Framework Based Nanopacked Bed for Protection against Toxic Vapors and Gases. Separation and Purification Technology. 2020. 117406–. doi: 10.1016/j.seppur.2020.117406

10. Foresti, R., Ghezzi, B., Vettori, M., Bergonzi, L., Attolino, S., Rossi, S. et.al. 3D Printed Masks for Powders and Viruses Safety Protection Using Food Grade Polymers: Empirical Tests. Polymers. 2021.13(4), 617. doi:10.3390/polym13040617.

11. Bezek, L. B., Pan, J., Harb, C., Zawaski, C. E., Molla, B., Kubalak, J. R. et.al. Additively manufactured respirators: quantifying particle transmission and identifying system-level challenges for improving filtration efficiency. Journal of Manufacturing Systems. 2021. 60, 762–773. doi: 10.1016/j.jmsy.2021.01.002

12. Cho, Kyungmin Jacob; Turkevich, Leonid; Miller, Matthew; McKay, Roy; Grinshpun, Sergey A.; Ha, KwonChul; Reponen, Tiina. Penetration of Fiber Versus Spherical Particles Through Filter Media and Faceseal Leakage of N95 Filtering Facepiece Respirators with Cyclic Flow. Journal of Occupational and Environmental Hygiene. 2013. 10(3), 109–115. doi:10.1080/15459624.2012.752321

13. Jumpponen, M.; Rönkkömäki, H.; Pasanen, P.; Laitinen, J. Occupational exposure to solid chemical agents in biomass-fired power plants and associated health effects. Chemosphere 2014. 104(), 25–31. doi: 10.1016/j.chemosphere.2013.10.025

14. Complex study of air pollution in electroplating workshop. Kirichenko, K.Y., Vakhniuk, I.A., Ivanov, V.V., Kholodov, A.S., Golokhvast, K.S. Scientific Reports, 2020, 10(1), 11282.

15. Kirichenko, K.Y., Kholodov, A.S., Golokhvast, K.S. et al. Characterization of fume particles generated during arc welding with various covered electrodes. Scientific Reports Volume 8, Article number: 17169 (2018).

16. The Impact of Metal-Based Nanoparticles Produced by Different Types of Underwater Welding on Marine Microalgae. Pikula, K.S., Kirichenko, K. Yu., Chernousov, V.A., Tsatsakis, A.A., Golokhvast, K.S. et.all. Toxics, 2023, 11(2), 105

17. Advanced research and development of face masks and respirators pre and post the coronavirus disease 2019 (Covid-19) pandemic: A critical review. Ogbuoji, E.A., Zaky, A.M., Escobar, I.C. 2021. Polymers. 13(12),1998

18. Field Evaluation of N95 Filtering Facepiece Respirators on Construction Jobsites for Protection against Airborne Ultrafine Particles. Adhikari, Atin; Mitra, Aniruddha; Rashidi, Abbas; Ekpo, Imaobong; Schwartz, Jacob; Doehling, Jefferson. 2018. Int. J. Environ. Res. Public Health 2018, 15, 1958; doi:10.3390/ijerph15091958.

19. Holton, P.M., Tackett, D.L., Willeke, K. Particle Size-Dependent Leakage and Losses of Aerosols in Respirators (1987) American Industrial Hygiene Association Journal, 48 (10), 2010. pp. 848-854.

20. Characteristics of fume sedimentation in the working zone during arc welding with covered electrodes. Kirichenko, K.Y., Vakhniuk, I.A. Golokhvast, K.S. et al. Toxicological & Environmental Chemistry (GTEC). https://doi.org/10.1080/02772248.2020.1747465.

21. Modeling the Process of the Distribution of Suspended Particles of Nano- and Microparticles of Industrial Aerosols in Electroplating Workshop. IOP Conference Series: Earth and Environmental Science, Volume 459, Chapter 3. Kirichenko, K.Y., Vakhniuk, I.A. Golokhvast, K.S. et al.

22. Penttinen P. Ultrafine particles in urban air and respiratory health among adult asthmatics / P. Penttinen, K.L. Timonen , P. Tiittanen, A. Mirme , J. Ruuskanen, J. Pekkanen // European Respiratory Journal Volume 17, Issue 3, 2001, Pages 428-435.

23. Simonova I.N., Antonyuk M.V., Vitkina T.I. The Influence of nanoparticles from the air on the state of brochopulmonary system. Bull. Physiol. Pathol. Respir. 2013. 49, pp. 115–120.

24. Gao, S., Kim, J., Yermakov, M., Elmashae, Y., He, X., Reponen, T., Grinshpun, S.A. Penetration of combustion aerosol particles through filters of NIOSH-certified filtering facepiece respirators (FFRs). (2015) Journal of Occupational and Environmental Hygiene, 12 (10), pp. 678-685.

25. Popova S.Y. The results of using a device to reduce dust levels at the welder's workplace. Agro-industrial Complex of Russia. 2010. 56, pp. 71-74.

26. Schilling, K., Gentner, D.R., Wilen, L.

27. , Medina, A., Buehler, C., Perez-Lorenzo, L.J., Pollitt, K.J.G.,Bergemann, R., Bernardo, N., Peccia, J., Wilczynski, V., Lattanza, L. An accessible method for screening aerosol filtration identifies poor-performing commercial masks and respirators. (2020) Journal of Exposure Science and Environmental Epidemiology.

28. Lam SC, Suen LK, Cheung T.C. Global risk to the community and clinical setting: flocking of fake masks and protective gears during the COVID-19 pandemic. Am J Infect Control. 2020; 48:964–5.

29. Broadhurst R, Ball M, Jiang C. Availability of COVID-19 related products on Tor darknet markets. Statistical Bulletin no. 24. Canberra: Australian Institute of Criminology; 2020. p. 12

30. Ippolito M, Iozzo P, Gregoretti C, Cortegiani A. Counterfeit filtering facepiece respirators are posing an additional risk to healthcare workers during COVID-19 pandemic. Am J Infect Control. 2020; 48:853–8.

31. N.P. Vaughan; R.C. Brown; P.G. Evans. The effects of asbestos wet-stripping agents on filters used in powered respirators. 1996. Annals of Occupational Hygiene 40(5), c. 539-543

32. Ronald E. Shaffer; Samy Rengasamy (2009). Respiratory protection against airborne nanoparticles: a review., 11(7), 1661–1672. doi:10.1007/s11051-009-9649-3.

33. Zaripov, S.K., Mukhametzanov, I.T., Grinshpun, S.A. Numerical studies on the performance of an aerosol respirator with faceseal leakage. (2016) IOP Conference Series: Materials Science and Engineering, 158 (1), № 012100.

34. Kuznecov D.A., Ignatov M.N., Ignatova A.M. Physics-chemical methods of studies of solid part welding fumes. Bull. Perm National Research Polytechnic University. 2014. 16(4). Pp. 140-150.

35. Grishagin V.M. Welding aerosol as the main source of the ecological hazard of the welding production. Ecology of the industrial production. 2008. No. 2. P. 27-35.

36. Voznesenskiy N.K., Tsenekov A.S. Clinical and epidemiological approaches to analysis of effects of welding spray and industrial wood dust on target-organs in low-alloyed steel electric welders and woodworkers. Vyatka Medical Bulletin. 2003. No. 2. P. 12-16.

37. Liu, Y., Corey, J., Yermakov, M.V., Wu, B., Grinshpun, S.A. Preliminary Development of a Real-Time Respirator Seal Integrity Monitor with Low-Cost Particle Sensor. 2018. IEEE Transactions on Industry Applications. 54(4), c. 3928-3933

38. Development of a real-time respirator seal integrity monitor with low-cost particle sensor. Liu, Y., Corey, J., Yermakov, M., Wu, B., Grinshpun, S. 2017. 2017 IEEE Industry Applications Society Annual Meeting, IAS 2017. 2017-January, c. 1-5

PREDICTING AND MINIMIZING THE RISK OF RAIL TRANSPORTATION OF DANGEROUS GOODS IN THE CONDITIONS OF CLIMATE CHANGE

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Abstract

The article is devoted to the study of the natural risk impact on the operation of railway industry facilities using a Bayesian network model in the GeNIe Modeler software package. Statistics of railway accidents from floods over the past few years have allowed to identify the main parameters of the model, the network structure is based on the experience and expert opinion of railway industry workers and foreign researchers. The results show that natural and climatic factors can cause serious disruptions in the operation of railway transport, and in the case of dangerous goods, create conditions for developing cascading accidents. The developed Bayesian model can be used in integrated planning and railway system management during floods.

Keywords: railway transportation risk, Bayesian network, climate change, flood

I. Introduction

According to the estimates of the United Nations Intergovernmental Panel on Climate Change extreme climate events (fires, floods, intense rainfall) are a serious threat and will occur more often, leading to disruption of various infrastructures. Nowadays, the scale of natural disasters far exceeds the human capacity to cope with them.

Rail transport is a critical infrastructure. The railway failure leads to economic damage from the displacement of the delivery time of goods, the cost of restoring equipment, potential loss of life and environmental damage. When moving dangerous goods through the territory of urban agglomerations, there is a high risk of accidents, especially in combination with weather anomalies.

Thus, the flooding in Armenia caused by intense rains in May 2024 led to the death of 4 people, the evacuation of 300 people and the wash away of more than 2.5 km of railway tracks. In August 2023, 1000 m of the Baikal-Amur mainline and 10 power transmission towers were destroyed in Buryatia as a result of cloudbursts, more than 300 people were evacuated. In 2018, due to the heat at the Pskov-Tovarny railway station, sulfuric acid leaked from the tank, by chance no one was injured.

Natural risks cannot be managed; they can only be analyzed and quantified. Railway transport is more susceptible to natural risks compared to other modes of transport, because it is less flexible in spatial terms [3]. Measures to combat climate impacts are being developed on a global scale and may be useless at the regional and local levels, as they do not take into account socio-economic opportunities, limited resources, geographical and climatic features of a particular territory. The situation is aggravated by the negligence of the staff, and wear and tear of the equipment.

Many studies have been devoted to the problem of the nature influence on the engineering system functioning. Ostankovich I. et al. [15] conducted an analysis of the extreme temperatures and snowfall risks to assess the state of the Dutch railway network. Alabbad et al. [5] performed a spatial analysis of railway infrastructure facilities (marshalling yards, bridges and crossings) during seasonal floods in Iowa. Struzhkova et al. [17] investigated the influence of permafrost on the railway network functioning. The dependence of the working capacity of the Serbian railway personnel on weather conditions was studied in [1].These studies show that the assessment of natural risks in regions exposed to extreme weather conditions is of great importance for maintaining the operability of the railway network.

In this work, a prediction and detailed analysis of a railway accident as a result of the impact of a natural factor (flooding) was performed based on the previously developed hybrid Bayes network in the GeNIe Modeler software package for a railway accident (159 variables) [4] (Figure 1). The model was tested using the example of the spring leash of the Ural River in 2024 in Orsk, the city where the last flood occurred almost 70 years ago.

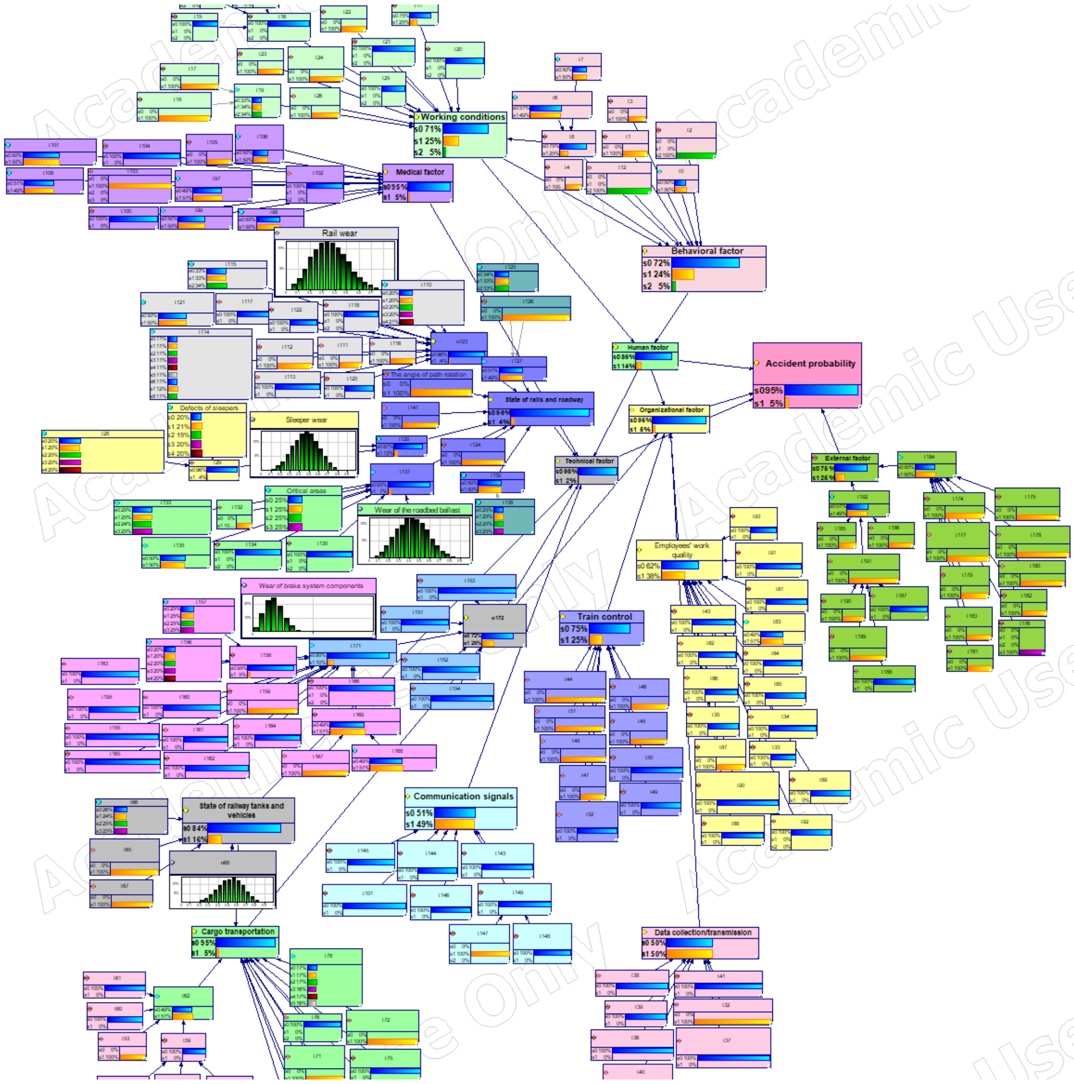

Figure 1: *The Bayesian model of a railway accident*
(the parameter names are hidden in order to preserve intellectual property)

II. Research methodology

2.1 Climate influence on the operation of railway infrastructure

The railway track is the most vulnerable element of the railway, because it is most affected by external factors. The most common meteorological factors are temperature and precipitation (snowfall, heavy rains, ice, etc.). Table 1 contains a list of possible impacts.

Table 1: *Natural phenomena and possible consequences for railway facilities [13]*

Natural hazards	Negative consequences
Geological Mudslides, landslides, flushing, subsidence, dust storms, avalanches, frost upheaval, waterlogging of territories, erosion (destruction of rocks by water, wind, man), abrasion (destruction of shores by waves)	Damage/destruction of railway tracks, embankments and slopes, falling power lines/trees, etc., blocking of railway stations
Geophysical Earthquakes, volcanic eruptions, karsts	Damage/destruction of railway tracks
Meteorological Storms, hurricanes, tornadoes, squally wind, whirlwinds, large hail, snowfall, showers, blizzard, fog, sleet, frost, drought, abnormal heat/frost, frequent change of warm/cold days, melting permafrost, lightning	Deformation and warping of railway tracks, sagging of power lines, overheating/electronic failures, fires on slopes, equipment failure, speed limitation, shortening of equipment life, the need for cooling equipment, damage to contact networks, power surges, breakdowns of alarm devices, centralization, blocking, falling of power lines/ trees, etc., freezing, icing, increased fragility of rails, freezing of switches, blocking of railway stations, accumulation of snow along railway tracks
Hydrological Flooding, high water, congestion, wind surges, rising groundwater levels, earthquake flood, typhoons, storms, changes in the strength and direction of waves	Inundation, damage to railway embankment and slope, erosion of bridge supports, railway tracks, contact networks, water penetration into underground structures, tunnels, flooding of coastal infrastructure
Wildfires Forest, peat, steppe, underground fires of combustible minerals	Thermal effects on all metal, combustible elements of railway equipment

Table 2: *Possible flood factors*

Natural and climatic	Non-climatic (organizational)
The amount of the winter precipitation, the water supply in the snow cover, the temperature condition before the start of spring melting, soil moisture in autumn, the snowmelt intensity, the terrain of the riverbed, the slope of rivers, the landscape of the area (forest belts, steppe or wooded soil with underlays), the presence of constrictions in the riverbed, the presence of obstacles to the flow, the earthquake impact, landslides, landslides, rising groundwater levels, deep freezing of the soil, snow reserves and its rapid melting, terrain.	The water level in the dam site, the technical condition of hydraulic structures, the distance from the dam, insufficient water discharges, design errors, poor-quality construction and maintenance, reduction of river capacity in the area of bridges, narrows, buildings in the floodplain, losses as a result of business activities, economic development, urban planning.

In this study, the focus is on floods, since the railway is the most vulnerable mode of transport to external influences [11]. In addition, floods occupy the first place among natural disasters in Russia in terms of frequency, area of distribution and total material damage [14]. The scale of floods depends on many natural and organizational factors (see table 2). It is necessary to take into account their synergistic effect, because in combination with each other, these factors increase the risk of an accident.

2.2 Data availability

The Bayesian approach makes it possible to combine frequency data with domain knowledge. Numerical values of probabilities can be extracted from databases, based on expert opinion, or determined by a combination of the above. Experts point out serious problems in collecting statistical information on the railway state due to climate impacts [5, 9, 11, 14]. This is due to the following factors:

- Complexity of meteorological observations, poor knowledge of the water regime of rivers, lack of hydrological observation posts, especially at the regional and local levels
- Lack of a clear algorithm for reporting railway accidents
- Deliberate misrepresentation of information by responsible persons in order to get away with it
- Inconsistency or inaccuracy of the data

Beyond that, the railway accident registration as a result of the effects of floods is not conducted anywhere. Therefore, this paper combines two sets of statistical data on floods and railway accidents [8] when creating two interconnected Bayesian networks. The first network is designed to calculate the probability of an accident as a result of flooding. The results of its calculates are partially used as input data for the launch of the second network, which determines the type of possible railway accident and the amount of possible damage.

2.3 Construction of model

The first data set contains more than 200,000 records on 50 features of past floods. The second data set includes more than 100,000 records of railway accidents abroad in 160 parameters from 1975 to 2022. These initial data were processed in the Python programming environment: cleared of omissions, invalid character and zero values, duplicates; all quantitative characteristics were given in the International System of Units, some of them are categorized for the convenience of building Bayesian models. After performing an Exploratory Data Analysis, only a few of the recorded data parameters were identified.

Flood data includes the following 19 features out of 50: relief drainage, drainage systems, river management, deforestation, urbanization, climate change, dam quality, siltation, incursions, effective disaster preparedness, vulnerability of coastal areas, landslides, deterioration of infrastructure, loss of wetlands, inadequate planning, political factors, probability of an accident.

Data on railway accidents include the following 18 features out of 160: month of accident, type of accident, dangerous cars, evacuated people, visibility, weather conditions, type of track, total tonnage, derailed loaded freight cars, derailed loaded passenger cars, cost of track damage (Figure 2).

The formatted data was imported into the GeNIe software package [10]. The columns in the data files correspond to variables (future nodes of the network), and the rows (records) correspond to various values of these variables. Continuous variables have been discretized. Based on the knowledge of the subject area [1, 2, 16, 17], the basic structures of Bayesian networks have been created. The Greedy thinning algorithm was used as the main algorithm for structural learning.

Report Year	Accident Month	Time	Accident Type	Hazmat Cars	Persons Evacuated	Temperature	Visibility	Weather Condition	Track Type	Maximum Speed
2017.0	6.0	2:14 PM	Derailment	0.0	149	65.0	Day	Clear	Yard	10.0
2017.0	6.0	2:14 PM	Derailment	0.0	0	65.0	Day	Clear	Yard	10.0
1981.0	4.0	7:20 AM	Side collision	0.0	0	28.0	Day	Snow	Yard	4.0
2007.0	1.0	7:10 AM	Derailment	0.0	0	56.0	Day	Cloudy	Industry	4.0
2017.0	10.0	3:55 AM	Hwy-rail crossing	7.0	0	66.0	Dark	Clear	Siding	0.0
2017.0	10.0	6:00 AM	Derailment	0.0	0	60.0	Dawn	Rain	Yard	3.0
2017.0	12.0	7:57 PM	Obstruction	0.0	0	62.0	Dark	Cloudy	Main	80.0
2016.0	12.0	6:30 AM	Other (describe in narrative)	0.0	0	16.0	Dark	Clear	Main	60.0
2017.0	3.0	8:45 AM	Derailment	23.0	0	44.0	Day	Rain	Industry	10.0
2017.0	4.0	10:40 AM	Derailment	0.0	0	38.0	Day	Clear	Yard	10.0
2006.0	10.0	5:10 PM	Derailment	0.0	0	70.0	Day	Clear	Yard	5.0
2010.0	6.0	10:00 PM	Derailment	1.0	0	55.0	Dark	Cloudy	Yard	6.0
2013.0	5.0	6:15 PM	Derailment	0.0	0	48.0	Day	Cloudy	Yard	7.0
2013.0	11.0	1:20 AM	Raking collision	0.0	0	0.0	Dark	Clear	Yard	3.0
2006.0	3.0	3:30 AM	Derailment	22.0	0	31.0	Dark	Clear	Yard	5.0
2006.0	3.0	9:55 AM	Derailment	3.0	0	45.0	Day	Cloudy	Yard	10.0
2014.0	3.0	6:00 PM	Derailment	0.0	0	40.0	Dusk	Cloudy	Industry	4.0
2011.0	4.0	6:15 AM	Derailment	0.0	0	42.0	Dawn	Rain	Yard	5.0
2007.0	7.0	10:25 AM	Derailment	0.0	0	75.0	Day	Clear	Siding	1.0
2006.0	10.0	4:50 AM	Derailment	4.0	0	40.0	Dark	Rain	Yard	10.0
2010.0	7.0	6:05 PM	Side collision	0.0	0	85.0	Day	Clear	Yard	6.0
2010.0	5.0	11:22 AM	Hwy-rail crossing	0.0	0	82.0	Day	Cloudy	Main	38.0
2010.0	5.0	5:45 AM	Other impacts	0.0	0	65.0	Dark	Clear	Yard	7.0
2012.0	5.0	6:00 AM	Other impacts	0.0	0	42.0	Dawn	Clear	Yard	6.0
2006.0	11.0	11:18 AM	Hwy-rail crossing	1.0	0	75.0	Day	Clear	Main	58.0
2016.0	8.0	5:30 AM	Other impacts	0.0	0	70.0	Dawn	Clear	Yard	16.0
2016.0	8.0	5:30 AM	Other impacts	1.0	0	70.0	Dawn	Clear	Yard	16.0

Figure 2: *Fragment of the data set on railway accidents*

As a result, two Bayesian models were obtained, including a number of factors described in Table 2. Figure 3 shows that climate changes do not directly affect the probability of an accident, but are significant with a low organization of services in case of an accident (see Figures 3 and 4).

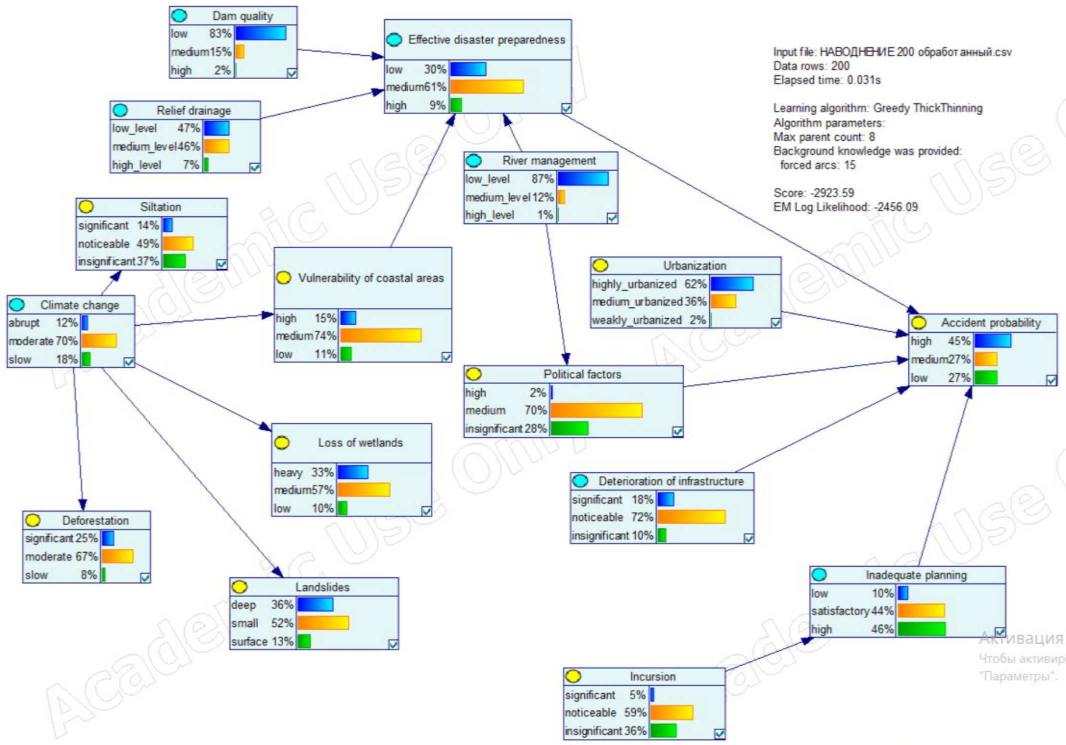

Figure 3: *Bayes network for calculating the probability of an accident*

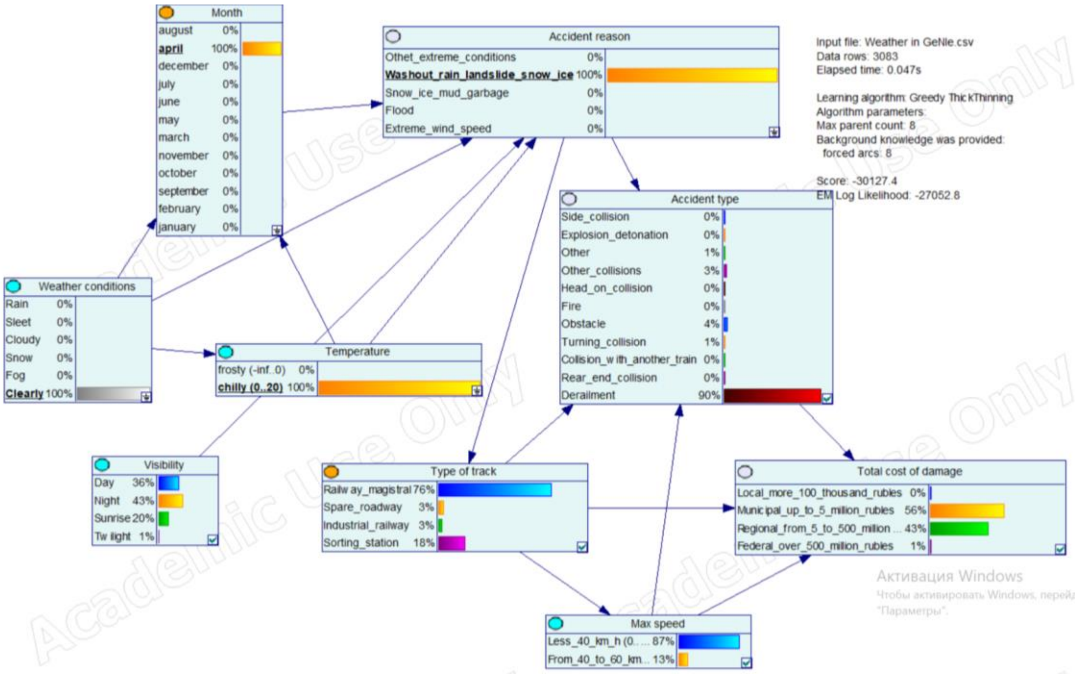

Figure 4: *Bayes network for determining the consequences of a railway accident*

2.4 Evaluation of model accuracy

The model accuracy was evaluated in two ways. Based on the first set of flood data, a new data file was generated to verify the accuracy of the first model with 200 records. The second model was evaluated by 10-fold cross validation. In this case, the original set of data on railway accidents was divided into 10 equal parts. The first nine parts participated in the training of the model, the last 10th part was used as a test sample. A graphical representation of the model accuracy is presented in the form of ROC curves with an overall accuracy of 89 and 75% for the main nodes of the network, respectively (Figure 5). Curves located above the diagonal and tending to the upper left corner represent good forecast results.

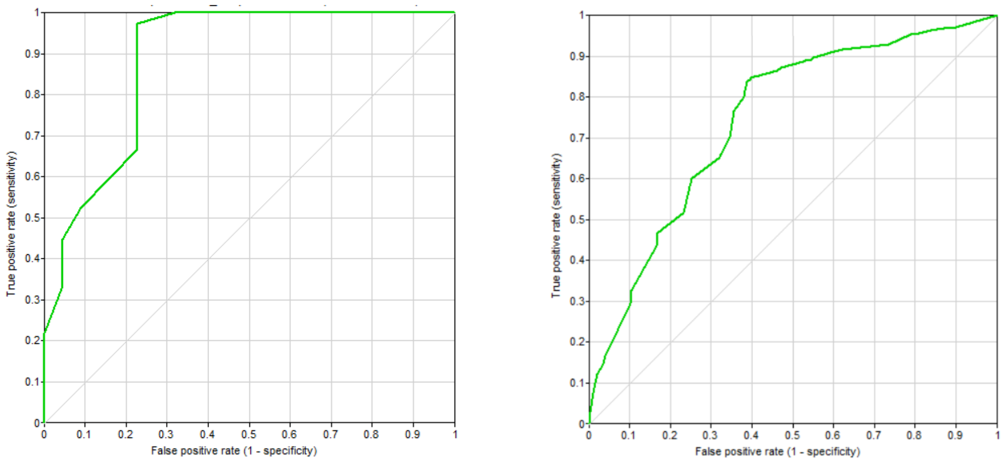

Figure 5: *ROC-curves for nodes ''Accident probability = high'' and '' Total cost of damage = Regional''*

II. Results

3.1 Case study

In April 2024, a number of Russian regions were exposed to catastrophic flooding caused by the spring flood on the Ural River. The city of Orsk in the Orenburg region suffered the most, for which flooding is a rather rare phenomenon. The last ones happened in 1922, 1942 and 1957. In Orsk, as a result of the destruction of the dam, about 6.6 thousand residential buildings, summer cottages and vegetable gardens were flooded (Figure 6). The total damage is estimated at more than 21 billion rubles. The flood led to the destruction of buildings and communications, the cattle death, the erosion of sewers, urban landfills, cemeteries and animal burial grounds, which created a threat of contamination of drinking water and human diseases. This real flood case was chosen to demonstrate the calculations of the resulting Bayesian networks.

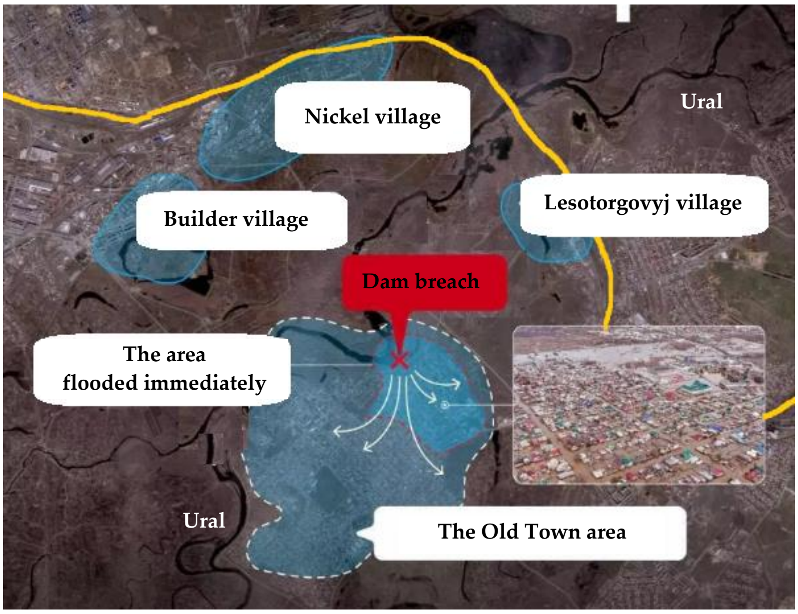

Figure 6: *Scheme of flooding in Orsk (the railway location is indicated in orange) [18]*

3.2 Analysis of calculation results

The probabilistic models have been edited for the case under consideration. The calculation of the networks showed updated posteriori probability distributions in the nodes of the networks. Further, the mutual influence of network parameters was analyzed.

Sensitivity analysis showed that the critical factors in flooding are "Disaster preparedness", "Level of urbanization", "Deterioration of infrastructure", which significantly affect the main target variable "Accident probability". This means that even minor changes in the colored nodes have a significant impact on the risk of an accident (Figure 7).

The ranking of flood factors showed that the most critical of them were "River management at zero level", "Poor quality of hydraulic structures", "Deterioration of infrastructure" (Figure 8). If the city's leadership had taken these factors into account, it would have been possible to prevent the developing of the spring flood up to a federal emergency.

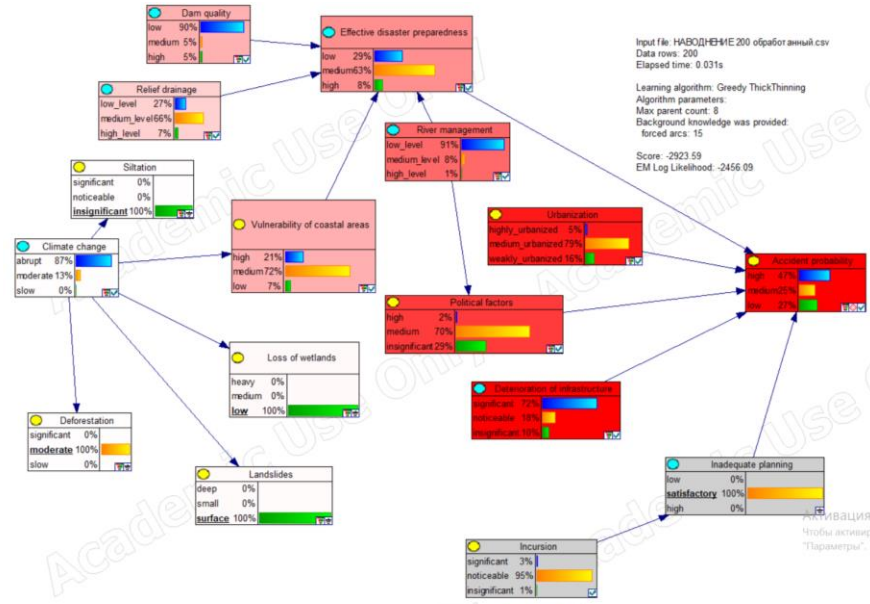

Figure 7: *Sensitivity analysis of the main node*

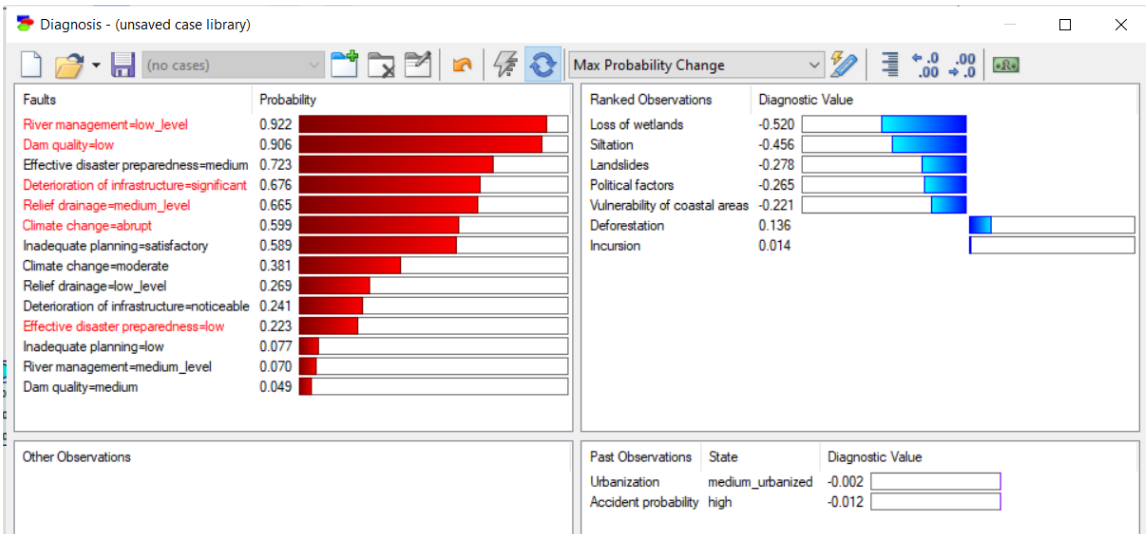

Figure 8: *Ranking of flood causes*

The developed networks are only an approximate model for predicting flood risk, since they are based on foreign statistics without taking into account the location of the area. At the moment, the accumulated scientific material is not enough to create a more complex and realistic flood model in the region under consideration. The study should be continued in the direction of collecting data covering a wider range of climatic factors and creating a database on accidents on domestic railways.

In the qualitative assessment of flood factors in Orsk, it is worth noting the following:

1. Features of the Ural River. The river has the largest water content among European rivers due to the uneven flow. The difference in river flow between high-water and low-water years can be 10 times. The depth of the river is small, but due to elevation differences in the source and mouth of the river, its speed can reach up to 10 km/h. [6]

2. High rate of urbanization. The massive construction of residential and commercial buildings, roads in the floodplain led to a 4-fold reduction in the natural floodplain.

IV. Conclusion

The article discusses the features of natural accidents on the railway due to floods in the context of climate change. The use of two thematic data sets (on floods and on railway accidents) is proposed. As a result, two Bayesian networks have been created to predict railway accidents in flood conditions. Using the example of a real flood in Orsk, the effectiveness of using the Bayesian approach for a comprehensive analysis of a railway accident as a result of a flood, including sensitivity analysis and ranking of flood causes with color visualization, is demonstrated.

The proposed probabilistic models can help in creating strategies for managing the consequences of natural risks on the railway, especially in cases of dangerous goods transportation. This will increase the reliability of the railway infrastructure in the face of climate change.

Among the preventive measures, the following should be highlighted:

- A ban on the construction and management of economic activities in floodplain areas and lowlands, which represent a permanent potentially dangerous area for urbanism
- Creation of a continuous monitoring system in vulnerable regions to collect climate data and take into account the impact of climate change in the design and operation of railway infrastructure

Acknowledgment

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References

[1] Aleksic, D., Markovic, M., Vasiljevic, M., Stojic, G., Pavlovic, N., Tanackov, I. (2017). Analysis of impact of meteorological conditions on human factors in estimating the risk of railway accidents. *Transport*, 33(5), 1-14. doi: 10.3846/16484142.2017.1332684

[2] Antonioni, G., Landucci, G., Necci, A., Gheorghiu, D., Cozzani, V. (2015). Quantitative assessment of risk due to NaTech scenarios caused by floods. *Reliability Engineering and System Safety*, 142, 334–345. doi: 10.1016/j.ress.2015.05.020

[3] Changnon, S. A. (2009). Impacts of the 2008 Floods on Railroads in Illinois and Adjacent States. *Transactions of the Illinois State Academy of Science*, 102, 181-190. URL: https://ilacadofsci.com/wp-content/uploads/2013/03/102-17MS2819-print.pdf. Accessed 30 Jan 2024

[4] Chikir, M.V., Poluyan, L. V. (2023). Bayesian Network Modeling for Analysis and Prediction of Accidents in Railway Transportation of Dangerous Goods. *Proceedings of the 6th International Conference on Construction, Architecture and Technosphere Safety ICCATS 2022*, 554-563. doi: 10.1007/978-3-031-21120-1_53

[5] Cikmaz, A.B., Alabbad, Y., Yildirim, E., Demir, I. A. (2024). Comprehensive Flood Risk Assessment for Railroad Network: Case Study for Iowa. Available via URL: https://www.research square.com/article/rs-4171938/v1. Accessed 21 Jun 2024

[6] Climate and waters, orensteppe.org. Available via URL: http://orensteppe.org/content/rek a-ural. Accessed 3 Mar 2024

[7] Cozzani, V., Antonioni, G., Landucci, G., Tugnoli, A., Bonvicini, S., Spadoni, G. (2014). Quantitative assessment of domino and NaTech scenarios in complex industrial areas. *Journal of Loss Prevention in the Process Industries*, 28, 10-22. doi:10.1016/j.jlp.2013.07.009

[8] Datasets, www.kaggle.com. Available via URL: https://www.kaggle.com/datasets. Accessed 1 Jun 2024

[9] Gang, Y., Dinghao, L., Jiayi, X., Ye. Ken, W. (2023). A Novel Approach for Modeling and

Evaluating Road Operational Resilience Based on Pressure-State-Response Theory and Dynamic Bayesian Networks. *Applied Sciences*, 13(7481), 1-33. doi: 10.3390/app13137481

[10] GeNIe 4.1, bayesfusion.com. Available via URL: https://www.bayesfusion.com/2023/09/15/genie-4-1/ Accessed 10 Jun 2024

[11] Gonzva, M., Barroca, B., Gautier, P. E. (2015). A modeling of disruptions cascade effect within a rail transport system facing a flood hazard. *Journal of Polish Safety and Reliability Association Summer Safety and Reliability Seminars*, 6(3), 53-60.

[12] Khakzad, N. (2018). Impact of wildfires on Canada's oil sands facilities. Natural Hazards and Earth System Sciences, 18(11), 3153-3166. doi: 10.5194/nhess-18-3153-2018

[13] List of possible effects of climate change for transport infrastructure facilities. Available via URL: https://mintrans.org/docs/Публикации/перечень%20повреждений%20ОТИ%202023.pdf. Accessed 10 Jun 2024

[14] Makhinov, A.N., Kim, V.I., Voronov, B.A. (2014). The 2013 *Amur Basin flood: causes and consequences. Vestnik* of Far Eastern Branch of Russian Academy of Sciences, 2, 5-14.

[15] Oslakovic, I.S., Maat, H., Hartmann, A., Dewulf, G. (2013). Risk assessment of climate change impacts on railway infrastructure. *Proceedings – EPOC 2013 Conference*, 1–16.

[16] Simonov, V., Osadchy, O. (2014). The nature of the occurrence of floods, inundations and the characteristics of their damaging factors. *Scientific and educational tasks of civil defence*, 1, 9-19.

[17] Struchkova, G.P., Kapitonova, T.A., Levin, A.I. (2019). Safety of Railway Transport Facilities Operating in Extreme Climatic Conditions. *Advances in Engineering Research*, 188, 328–332. doi: 10.2991/aviaent-19.2019.61

[18] Ural Flood 2024, commons.wikimedia.org. Available via URL: https://commons.wikimedia.org/wiki/File:Ural_Flood2024.jpg?uselang=ru. Accessed 10 Jun 2024

MODELING OF EMERGENCY OIL SPILL IN FREE MODE OF FLOW

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Abstract

In the paper, based on the analysis of accidental oil spills from pipelines, a grapho-analytical method was proposed for the correct determination of the amount of hydrocarbons spilled into the environment in different modes. During the accident, it was proved that the opinion about the free flow of oil into the environment is not correct due to the fact that the atmospheric pressure was not created at the maximum point of the track profile, but at the accident site (hole).
Currently, there are almost no correct methods for multiphase flows, unlike single-phase flows, in normative documents and literature sources.
Taking into account that the determination of which part of the oil flows from the pipeline during real accidents is very important for risk analysis, studies were carried out on the basis of the compressed profile of the oil pipeline.
In the paper, accident-oil spills, as well as the conditions under which it is possible to make 3-5% of the volume of the pipeline in the free flow mode, and the complete emptying of the pipeline are defined.

Keywords: oil spill, free flow, hydrostatic pressure, vapor elasticity, condensed profile, grapho-analytical method

I. Introduction

Although oil spills during the operation of oil and gas pipelines that do not result in explosions, fires and pollution of water sources are not considered very serious accidents, it is important to determine the amount of oil spilled in order to assess the losses and environmental impact. Explosion and fire monitoring and assessment of such accidents must be done. In this regard, the development and application of methods for correct determination of the volume of oil or gas spilled into the environment due to any impact from pipelines in different regimes deserves special attention.

If we are talking about short pipelines, then the simplest method for determining the volume of liquid and gas is the method based on the average flow rates of the phases, taking into account the speed of movement of the mixture. The results of such a calculation result in a significant reduction of the volume of the liquid phase in the pipeline, and an increase of the volume of the gas, on the contrary. However, experience shows that during multiphase flows in relief pipelines, there is always a ballast volume that is not displaced by gas. This ballast volume can be small at high speed of movement of multiphase mixture, and much more at low speed values.

According to the current methodology [1, 2], the volume of oil spilled into the environment during accidents in oil pipelines is determined according to the following expression:

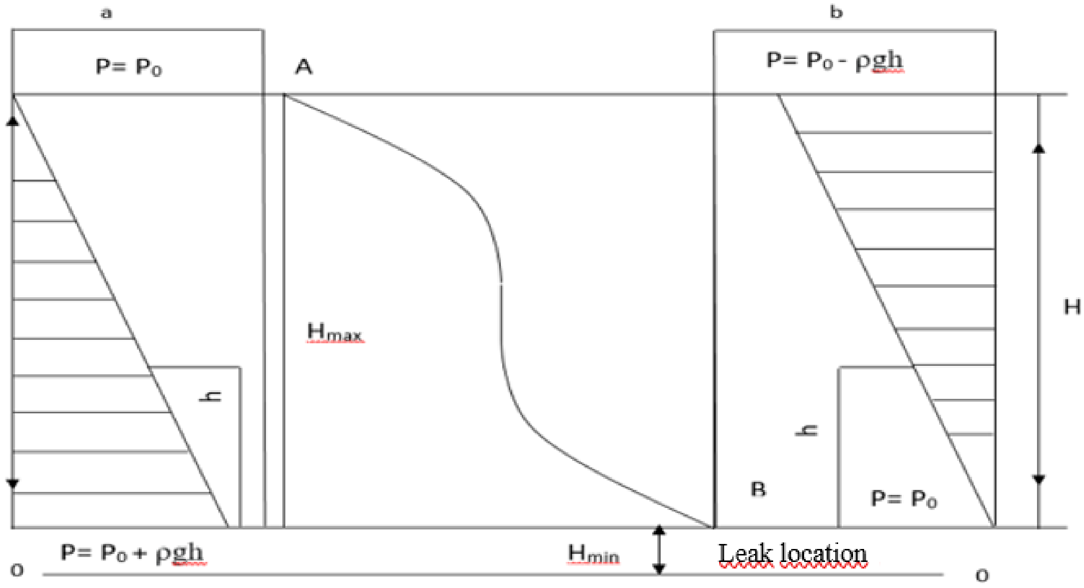
$V = V_1 + V_2 + V_3$

Here: V_1- the volume of oil discharged (dispersed) in pressurized mode. This volume is the volume of oil flowing during an accident until the pumps stop working (within 2 minutes); V_2- is the volume created due to unpressurized (free) flow, it is the volume of oil spilled during the time between stopping the pumps and closing the valve in the pipeline; V_3-is the volume of oil flowing through the emergency hole in free flow mode.

It should be noted that the main oil or oil product pipelines are equipped with an automatic system, so the flow time in the pressurized mode does not exceed 2 minutes (the pump and outlet drawer are closed at the same time and within 2 minutes). After the pumps are stopped, the oil flow time in the free-flow mode is assumed to be almost zero, since the valve is closed at the same time. The most interesting problems are observed during the determination of the volume of oil flowing in the free-flow mode after the valve is closed. This volume depends very much on the detection and localization of the place of damage and collapse of the pipeline.

II. Methods

In order to solve the mentioned problem, 2 points (A and B) are marked as the maximum and minimum on the profile of the pipeline. Then the graph of pressure distribution in the intended part is constructed. At this time, the crash site (hole) is considered as the minimum point of the profile. The pressure distribution graph constructed in this way is shown in figure 1.



a and b – on the false and true model, respectively

Figure 1: *Distribution of hydrostatic pressure in the leaking part of the oil pipeline*

Then it is assumed that the pressure varies along the profile of the AB part of the oil pipeline according to the graph (a) in figure 1. At this time, it is considered that the atmospheric pressure in the pipeline corresponds to its maximum point (A). Then, accepting the distribution of pressure along the height according to the law P = $P_0 + \rho g h$, the oil flow rate from the emergency hole is determined by the following formula known from hydraulics:

$$v = \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2(P_0 + \rho g h)}{\rho}} \quad (1)$$

Here: ρ- density of oil, kq /m^3 ;P_0 –atmospheric pressure, Pa; g- free acceleration, m/s^2; h- current height, m.

From Fig. 1, it can be seen that, the atmospheric pressure in the accident oil pipeline is not created at the maximum point of the profile as in option (a), but at the minimum point of the profile, i.e. at the accident hole (B). The pressure of the liquid column below the crash hole increases because the pressure of the liquid column is added to the atmospheric pressure. On the other hand, going up from the hole, the pressure in the pipeline decreases to the pressure of the liquid column at the height h (Fig. 1, b). Thus, it is found that in non-pressurized flow, since the intra-pipe pressure is equal to the atmospheric pressure in the cross-section of the crash hole, it will not be possible for the oil to flow freely to the environment. The free flow of oil from the accident hole will be possible when the hole is not located under water. When this hole is dry, only a part of the pipeline between the near crossing point and the emergency hole will slowly and gradually loosen. The rest of the oil in the pipeline will not be able to flow freely (without pressure). In this case, the relief is usually provided by compression with a piston or by opening holes in the pipeline at all crossing points (to allow air to freely enter the pipeline).

In general, the currently existing mathematical models for calculating the amount of oil and gas spilled as a result of accidents are adopted according to the hydraulics of single-phase flow of liquids and gases through holes and pipes [2÷4]. Appropriate assessment and calculation methods for multiphase flows are almost non-existent in normative documents and literature sources.

Let's examine the possibility of complete discharge of the pipeline section when the valves are closed at the beginning and end. Using the principle of continuity of flow, it can be confirmed that, in principle, it is impossible to completely empty the pipeline. This also goes against the laws of physics. So, the place of the oil removed from the pipeline must be filled with another cold medium (for example, atmospheric air or oil vapors).

It should be noted that oil evaporation is possible due to the difference between the atmospheric pressure and the pressure inside the pipeline when the heights are different along the pipeline route. That is, the pressure drop in any section of the pipeline leads to the following equation:

$$P_0 - \rho g h = P_{v.e} \quad (2)$$

Here, $P_{v.e}$- oil vapor elasticity pressure, Pa; h - is the height of the oil column from the accident hole, m.

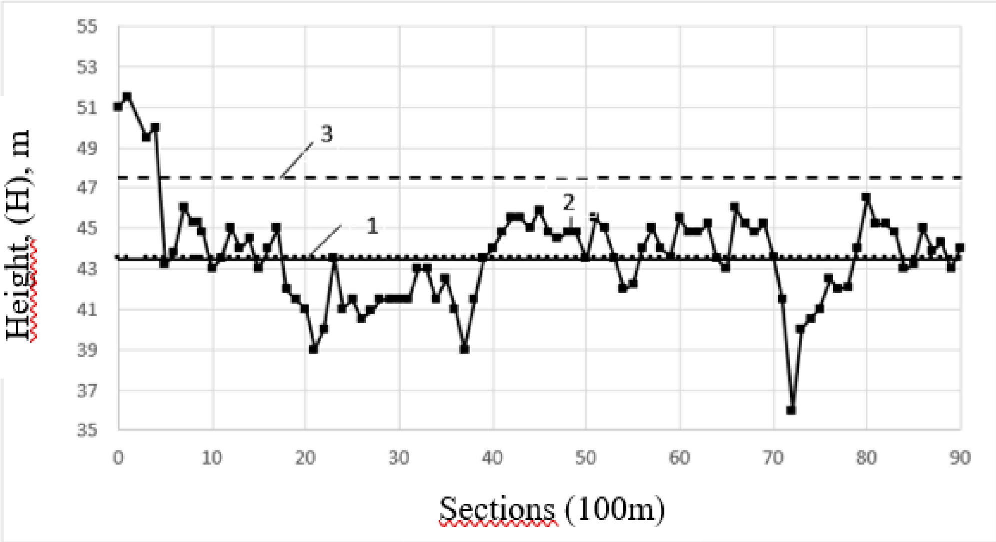
Where condition (1) is met, the oil begins to "boil" and the vapor phase separates from it, which replaces the liquid phase flowing through the pipeline.

Taking into account that determining which part of the oil flows from the pipeline during real accidents in practice is also very important for risk analysis, let's examine the issue based on the condensed profile of the oil pipeline (Figure 2). The parameters of the considered oil pipeline are as follows:

- pipeline length L=8.5 km;
-pipeline diameter D=0.7 m;
- pipeline volume V_P=3103 m^3;
- the minimum point of the profile - 36 m;
- the maximum point of the profile - 51.2 m;
- the middle point of the profile - 43.6 m;
- temperature of transported oil - 40°C;
- temperature at the depth where the ipeline is buried - 5°C.

The investigation of the flow of oil through the pipeline was considered according to 2 options:

- It is assumed that the accident hole is at the level of the average height of the pipeline route. For the considered pipeline, this value is H_{ave}= 43.6 m as mentioned.
- In order to estimate the maximum spillage of oil, it is assumed that the accident hole occurs at the minimum point of the pipeline. As can be seen from picture 2, the 72nd section of the pipeline corresponds to the mentioned condition. In this case, the length of the pipeline between two crossing points is considered as the part under accident. That section is 1.1 km long and is located between section- 69 and 80.



1÷3- is the average height of profile (H_{ave}), pipeline (H_{pipe}) and oil discharge (H_{empty}) respectively

Figure 2: *Compressed profile of the pipeline route*

Considering that there are 17 intersection points at the average height (H_{ave}= 43.6) for the studied oil pipeline profile, and if the leakage point is located at the minimum point of the profile H_{min}= 39 m, then oil will flow into the accident hole from both sides. Since the intersection point divides the profile section into two parts, the oil flow area is located above the intersection point. At this time, the 2nd part will not be free of oil. The average length of the pipe section free of oil can be determined according to the following expression:

$$l_{ave} = 0{,}427 \cdot \frac{L}{n}, m \tag{3}$$

Here: L- the length of the pipeline, m; n- is the number of intersection points of the profile with the average height of the pipeline. If we consider the values of L and n in (3), we get:

$$l_{ave} = 0{,}427 \cdot \frac{8500}{17} = 213{,}5\ m$$

Fig. 3 shows the distribution of pressure during oil discharge in the oil pipeline section from the accident hole formed at the middle height of the profile in a non-pressurized mode. The discharge level corresponds to the vapor elasticity pressure of the oil.

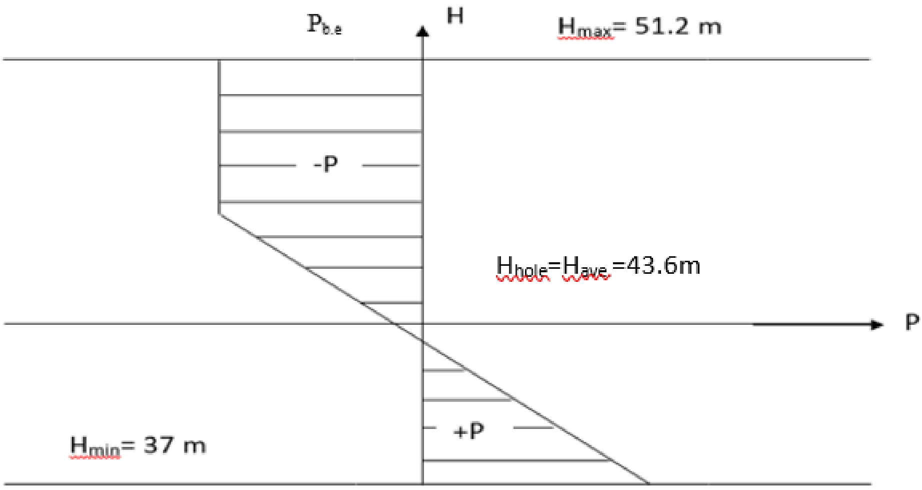


Figure 3: *Pressure distribution diagram in the damaged part of the oil pipeline*

According to the currently existing and above-mentioned methodical guidance, the volume of oil spilled during pipeline accidents is always assumed to be equal to the volume of the pipeline, regardless of the location of the damage. But as it turns out, even in the worst case, it is almost impossible to completely empty the pipeline. These are listed in table 1 in a comparative manner. As can be seen from Table 1, according to the existing methodical guidelines, the volume of accidental oil spills is increased by 39.8 and 7.6 times according to the mentioned scenarios (options).

It was also confirmed by analyzing the data of the Internet HSE AgensyLtd, Labor Protection, Industrial and Fire Safety, Warning of Emergency Events - Chronicle of Events and Accidents (2007-2008 years) [5] that the opinion about free flow of oil during the accident is not valid.

Table 1: *Assessment of accidental oil spills in pipelines under different scenarios*

Scenarios	The volume of oil pipeline, m^3	Pipeline discharge volume, m^3	Reconciliation of part share
According to methodological guidance [2].			
Probable Hypothetically	3103 3103	3103 3103	1 1
According to the proposed grapho-analytical method			
Probable Hypothetically	3103 3103	78 408	0,025 0,13

In those data, accidents related to oil spills from 8 different pipelines were investigated and systematized. Preliminary data characterizing oil spills occurring in oil pipelines of different diameters and systematized results are given in table 2.

Table 2: *Calculated results of the part of oil spilled from pipelines in free flow mode (based on accident statistics)*

D, m	V_o^s, m^3	L_p^v, km	V_p^v, m^3	$Q_o^{b.a}$, m^3/hour	v, m/s	V_o^p, m^3 (within 2 min)	V_o^f, m^3	$\frac{V_o^s}{V_p^v}$	$\frac{V_o^f}{V_p^v}$	$\frac{V_o^f}{V_p^v}$, %
0,15	9,1	10	176,6	64	1,0	2,1	7,0	0,0012	0,0396	3,96
1	12,8	10	7850	367	0,13	12,2	0,6	0,001	0,0001	0,01
1,2	26,0	10	11304	732	0,18	24,4	1,6	0,002	0,0001	0,01
0,7	43,0	10	3846,5	1246	0,90	41,5	1,5	0,004	0,0004	0,04
0,8	49,0	10	5024,0	1429	0,80	47,5	1,4	0,009	0,0003	0,03
0,6	51,5	10	1962,5	707	1,0	23,5	28,0	0,012	0,0143	1,43
1,2	126,0	10	11304	3744	0,91	124,7	1,3	0,011	0,0001	0,01
0,7	272,0	10	3846,5	2769	2,0	92,2	179,8	0,024	0,0467	4,67

Here,

D – Diameter of the oil pipeline, m;

V_o^s – the volume of oil spilled from the pipeline, m^3;

L_p^v – length of pipeline between valves ($L_p^v = 10km$) ;

V_p^v – volume of pipeline between valves, m^3 ;

$Q_o^{b.a}$- volumetric flow rate of oil before accident, m^3/hour;

v – flow velocity, m/s ;

V_o^p - volume of oil spilled under pressure (within 2 min)., m^3;

V_o^f – volume of oil spilled in free flow mode, m^3.

The volume of oil discharged in pressurized mode is determined based on the flow rate of oil flowing through the pipeline in 2 minutes, and the volume of oil flowing in free flow mode is determined based on the expression $V_o^f = V_o^s - V_o^p$.

As can be seen from the calculation results shown in Table 2, the volume of oil spilled in free flow mode does not exceed 3-5% of the volume of oil in the pipeline. The experience of long-term operation of main oil pipelines confirms the above.

III. Results

A grapho-analytical method was proposed for the evaluation of oil spills with free flow in pipelines. It was determined that even in the worst case, it is not possible to completely empty the oil pipeline. In the case of accidental spills, complete emptying of the pipeline in the free-flow mode is possible when holes are formed at all extreme points of the pipeline (at the maximum and minimum points of the profile) during the accident.

References

[1] Mazur I.I and Ivanov O.M. Safety of pipeline systems, Moscow, 2004.

[2] Methodological guidelines for assessing accidents on main oil pipelines, Moscow, 2002.

[3] Zavyalov V.V. Problems of operational reliability of pipelines at a late stage of field development, Moscow, 2005.

[4] Loytinskiy L.G. Mechanics of liquid and gas, Moscow, 1973.

[5] Internet HSE Agency LTD (2007-2008)

PROBABILITY OF EMERGENCY RELEASE DURING DEPRESSURIZATION

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Abstract

"The idea of the proposed work is that the volume of an emergency discharge should be calculated based on the characteristics of the discharge event itself." There are some tools for this that are not used by developers of analysis methods. This refers to an automatic method of monitoring emissions using sensors up to an explosive gas concentration (EGC), automatic control of flow rates, pressure, visual control methods, by the sound of gas emissions, by the smell of a hazardous substance, etc. These methods, which can be calculated, are especially effective for partial depressurization of the block.

Keywords: emergency release, reliability, probability of depressurization, frequency, risk, technological equipment

I. Introduction

The level of reliability of oil field process equipment can also be seen in the forecast of the probability of complete depressurization of dangerous blocks, estimated by document [1] as the frequency of complete depressurization equal to 10^{-5} units/year. Let's consider the physics of the designated phenomenon and how it affects the reliability of equipment over time. Fig. 1 shows a graph characterizing the probability of failure of a technological unit due to its physical aging or wear. This graph is presented in LogP - LogT coordinates, where T is the operating time of the equipment, years, P is the probability of equipment failure.

II. Methods

To understand the essence of the analysis being performed, we note that the probability of failure (degree of wear) and the equipment reliability indicator add up to one. The higher the wear, the lower the reliability of the equipment. If we take as a boundary condition corresponding to the moment of block destruction the frequency of complete depressurization equal to 10^{-5} units/year. This means that complete depressurization of the block will occur once every 100,000 years. When analyzing the graph, you can find a variable value for the reliability indicator. If we take the probability of equipment failure at the level of 10^{-6} as an acceptable value, then it is found that at the initial stage and after 100 years of operation, the probability of failure is higher than the acceptable value. At the initial stage, the low reliability of equipment is explained by the presence of defects during its production at the manufacturing plant, the appearance of additional defects during its transportation to the construction site and during installation as part of the construction project. During operation, equipment wears out, accompanied by a decrease in residual life. Wear is expressed by a change in the thickness of power elements due to corrosion, the appearance of microcracks in critical equipment components caused by cyclic loads, changes in the structure of the metal as a result of aging, etc. The ability of equipment to completely depressurize is determined by the degree of its wear. The standard operating life of machines and devices does not exceed 10–15 years. As follows from the analysis of the reliability graph, the probability of complete depressurization of equipment within the established resource is negligible, therefore we consider it unacceptable to use complete depressurization as the main scenario for the development of an accident.

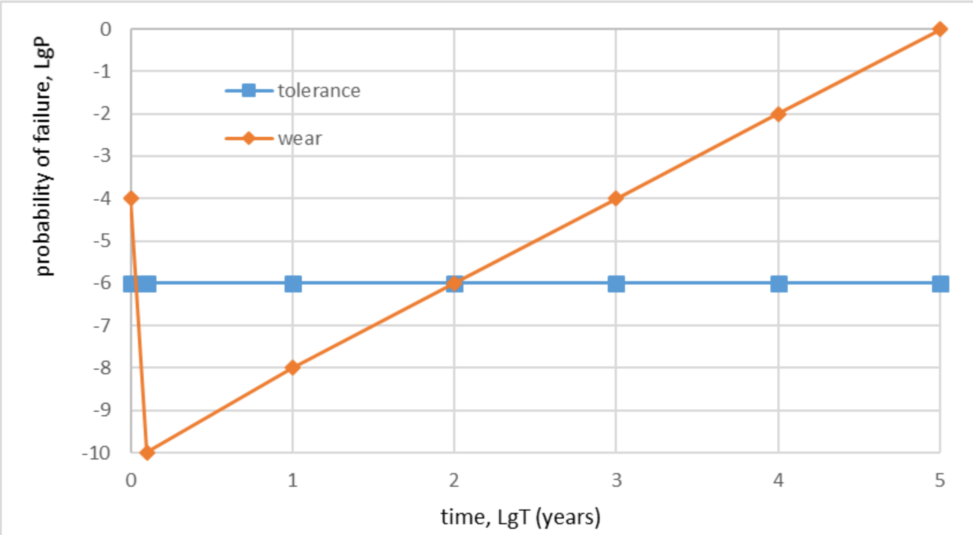

Fig.1: *Depenedence of equipment wear on time*

Accident statistics were most fully presented in RD 03-357-00 [1], where the following indicators can be found in Table 1: probability of depressurization of a process pipeline with a length of no more than 30 m $5x10^{-3}$ per 1 km of pipeline per year; probability of depressurization of the main pipeline (1-3) x 10^{-4} per 1 km of pipeline per year; probability of failure of machinery (pump or compressor) 3 x 10^{-3} per 1 km per year; the probability of complete destruction of the reservoir is 10^{-5} per year; the probability of partial depressurization of the tank is 10^{-4} per year.

Table 1: *Probability of depressurization of process equipment*

The probability of depressurization of a process pipeline with a length of no more than 30 m.	$5x10^{-3}$ per 1 km of pipeline per year
Probability of depressurization of the main pipeline	(1-3) x 10^{-4} per 1 km of pipelines per year
Possibility of failure of machinery (pump or compressor)	$3x10^{-3}$ per 1 km per year
Probability of complete tank destruction	10^{-5} per year
Probability of partial depressurization of the tank	10^{-4} per year
Possibility of rupture of connecting hoses during draining/filling of railway and road tanks	10^{-3} per refill or 10^{-2} per hose

As a base, we have to use the data presented in the table, which in the original source is called "Generalized statistical data for assessing the frequency of equipment failures." In particular, the value of partial block failure is presented here as the "probability of failure (incident)" with the dimension "per year". From the theory of probability, from the instructions of GOST R 50779.10-

2000 [2], it follows that the probability of a random event is a dimensionless quantity. The "frequency" or "probability" of partial block failure is 10^{-4}. With the release of the Methodology [3], a database on depressurization of process equipment, tanks and pipelines appeared. In appendix 1 to the specified Methodology, tables appeared indicating the frequency of complete and partial depressurization for certain types of equipment and process pipelines. The frequency of partial depressurization is presented in tables for different sizes of emergency opening in the range from 5 to 100 mm for equipment and from 12.5 to 100 mm for pipelines. In this case, each size of the emergency hole is assigned a certain frequency of system depressurization. According to the idea of this document, the volume of release should be determined depending on the size of the emergency opening. What to do next with the resulting emission volumes? The volume of release is determined not by the size of the emergency opening during partial depressurization of the system, but by the method of monitoring the tightness of the system. Partial depressurization is a dynamic process. It starts with a small omission of product and only in the absence of control will it progress over time. For partial depressurization of devices operating under pressure, 5 depressurization stages have been installed with emergency opening sizes of 5, 12.5, 25, 50 and 100 mm. As a result of lengthy calculations, it is possible to determine the volume of oil or gas release for each hole size[4]. Then, for all emission volumes, perform calculations of affected areas. What to do next with this data array? Our approach to solving this problem is as follows: The volume of emergency release in the event of partial depressurization of an apparatus or pipeline is determined not by the size of the emergency hole, but by the method of monitoring the tightness of the system. The volume of emergency release at on-site facilities equipped with an automatic gas control system is determined by the sensitivity of the control system. At linear structures and well pads, where there are no maintenance personnel, control of the system tightness is carried out by personnel on duty (inspectors of linear structures, mobile crew at well pads) at established intervals. The size of the oil slick formed on the surface of the earth is taken as an indicator of depressurization. In this regard, as a database on the frequency of partial depressurization (FPD), we take the total frequency presented in the tables of the Methodology [3,5,6]. As a result of summing the frequencies of partial depressurization, accident statistics are presented in Tables 2 and 3.

Table 2: *Frequency of depressurization of equipment and tanks*

Name of technical device	Dimension	Depressurization frequency	
		Partial	Complete
Devices under excess pressure > 0.07 MPa	pcs/year	$6{,}2 \times 10^{-5}$	3×10^{-7}
Pumps	pcs/year	$5{,}62 \times 10^{-3}$	1×10^{-4}
Compressors	pcs/year	$1{,}28 \times 10^{-2}$	1×10^{-4}
Tanks and reservoirs under pressure < 0.07 MPa	pcs/year	1×10^{-4}	5×10^{-6}

Table 3: *Frequency of depressurization of process pipelines*

Pipeline diameter, mm	Specific failure rate, pcs/km/year	
	Partial depressurization (PD)	Complete depressurization (CD)
50	8×10^{-3}	$1{,}6 \times 10^{-3}$
80	6×10^{-3}	4×10^{-4}
100	$4{,}5 \times 10^{-3}$	$1{,}6 \times 10^{-4}$
150	3×10^{-3}	$2{,}6 \times 10^{-5}$
200	$2{,}4 \times 10^{-3}$	$1{,}8 \times 10^{-5}$
250	$1{,}9 \times 10^{-3}$	$1{,}6 \times 10^{-5}$
300	$1{,}7 \times 10^{-3}$	$1{,}4 \times 10^{-5}$
400	$1{,}4 \times 10^{-3}$	1×10^{-5}

500	$1x10^{-3}$	$8x10^{-6}$
600	$8x10^{-4}$	$6,5x10^{-6}$
700	$7x10^{-4}$	$5,5x10^{-6}$
800	$6x10^{-4}$	$4,8x10^{-6}$
900	$5x10^{-4}$	$4,1x10^{-6}$
1000	$4,7x10^{-4}$	$3,8x10^{-6}$
1200	$4x10^{-4}$	$3,2x10^{-6}$

Calculation of the probability of leakage of flammable substances P1

Assuming that the start of a typical most probable accident is the partial destruction of a dangerous unit, the probability of a leak is determined by the product of the frequency of leaks of this element and the duration of the leak. $P_i = Nt$, where P_i is the probability of leakage of a hazardous substance; N – leakage frequency of the i-th element; t is the duration of the leak.

Calculation of emergency depressurization frequency N

The frequency of emergency depressurization is determined based on statistical data on the frequency of depressurization of individual units of the installation. The frequency of emergency depressurization can be determined for one unit (as a statistical indicator of the failure rate), for a group of units included in 1 technological installation (as the sum of the depressurization frequencies of the units included in the installation), for a complex of installations (as the sum of the depressurization frequencies of technological installations) and etc.

Determining the amount of hazardous substance involved in the accident

Data on the amount of hazardous substances released into the environment are necessary to solve the following problems:

- To determine the damage associated with the loss of valuable hydrocarbon raw materials;
- To determine the amount of compensation for damage to the environment;
- To determine the areas affected by personnel and the population during fires of flammable liquid spills;
- To determine the cost of restoring an object after an accident;
- To generate risk indicators, the frequency and probability of explosions and fires, the probability of injury to personnel and the population, and determine the locations of possible injury;
- To develop recommendations to reduce risk

III. Results

1. The use of the term "probability" with the dimension of frequency is unacceptable, since this follows from the theory of probability, which has no dimension.
2. The volume of emergency release in the event of partial depressurization of the system is determined not by the size of the emergency hole, but by the method of monitoring its tightness.

IV. Discussion

Emission potential

The consequences of accidents associated with the release of a hazardous substance into the environment determined by the energy potential, which can be realized in an unfavorable scenario. For fire and explosion hazardous industries that use flammable substances (liquids and gases), the main scenario of the emergency process is the oxidation of these substances with atmospheric oxygen, which leads to a fire or explosion. The consequences of such an accident determined by the magnitude of the energy potential of the flammable substance that can take part in the oxidation reaction. Let's consider an algorithm for calculating the amount of substances released for oil field facilities. Based on the nature of production, fisheries can be divided into the following groups:

- On-site facilities with the constant presence of maintenance personnel;
- On-site facilities with staff visits once a day;
- Linear structures controlled by a lineman once a day.

At the location of the release, hazardous objects can be above-ground or underground. This indicator has a significant impact on the volume of flammable substances involved in creating hazards. Based on the volume of release, accidents are divided into 2 groups: with partial depressurization of the unit and with complete destruction of the unit. Combustible substances can be in liquid or gaseous state. Liquid substances can accumulate for a long time on the surface of the earth. Gaseous substances create a cloud of gas-air mixture of certain sizes. Taking into account dispersion in the atmosphere, the size of the cloud depends on the consumption of flammable substances in the emission. With a long-term release, the potential stabilizes at a certain level, after which all additionally released gas is dissipated in the atmosphere. Methods for monitoring the tightness of a technological system can be divided into automatic and visual. Automatic methods include methods for monitoring technological parameters (pressure, level, flow), by changing which one can indirectly determine the degree of depressurization of the technological unit. The specified parameters make it possible to determine the possibility and degree of depressurization of a dangerous unit. In addition, automatic methods include direct methods for monitoring the presence of flammable substances in the environment, carried out using flammable gas detection systems using sensors up to explosive concentration (EVC), a sensor cable that reacts to the presence of oil and its products. The volume of methane emission that initiates the sensors, with their average distance from the emission site of 11.2 m, is 22 m^3.

References

[1] Methodological recommendations for drawing up an industrial safety declaration for a hazardous production facility. Moscow, State Scientific and Technical Center for Safety in Industry of the State Mining and Technical Supervision of Russia. 2000 (in Russian)

[2] GOST R 50779.10-2000. Statistical methods. Probability and basic statistics. Terms and Definitions. Gosstandart of Russia, Moscow, 2002, 42 p. (in Russian)

[3] Methodology for determining the magnitude of fire risk at production facilities. Approved by order of the Ministry of Emergency Situations No. 404, Article 10.07.2009. (in Russian)

[4] Ismayilov G.G, Ismayilova H.G, Babirov H.N, Jabrayilov R.A. Assesment of environmental oil spills and economic-environmental risks. RT&A, Special Issue № 4 (70) Volume 17, November 2022, p 212-217. DOI: https://doi.org/10.24412/1932-2321-2022-470-212-217

[5] Zavyalov V.V. Problems of operational reliability of pipelines at the late stage of field development, Publishing House OJSC "VNIIOENG", Moscow, 2005, 332 p. (in Russian)

[6] GOST R51901.1 – 2002. Risk management. Risk analysis of technological systems. Gosstandart of Russia. Moscow, 2002, 23 p. (in Russian)

ABOUT A RISK OF STUCK PİPE WHILE DRILLING

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Abstract

The experience of drilling oil and gas wells shows that one of the most common complications that occur in the drilling process is the stuck pipe. Scientists and drilling experts explain and prove the occurrence of such cases for various reasons. Indeed, these reasons are very different. Taking into account the new physical model of multiphase flow and rheological properties, the issue of evaluation of the mechanical particles (debris) as a result of the dislocation (movement) along the axis of the cylindrical flow because of the interaction of the phases in the drilling fluid as a factor causing compression and stuck pipe was considered in the article.

Keywords: drilling fluids, pressure gradient, visco-plastic, shear stress, stuck pipe

I. Introduction

As it is known, oil and gas extraction, gathering, transportation to processing sites, separation, as well as oil, gas, formation water and mechanical particle cleaning processes are based on multiphase technologies.

It is known that the process of drilling oil and gas wells is carried out with the participation of drilling fluid, and this fluid performs several important functions. Thus, during drilling, it constantly circulates and brings the drilled rock fragments to the surface, which is one of its main functions. At this time, there are horizontal, up-bottom and bottom-up movements of the drilling fluid in laminar mode. Based on a large number of rheological studies, it was determined that drilling fluids are mainly described by a viscoplastic (pseudoplastic) rheological model [1÷4].

The movement of the drilling fluid, which has visco-plastic properties, settled in the pipe was studied by us.

It is known that the following dependence is used for the rheological description of visco-plastic fluids (Shvedov-Bingham model):

$$\tau = \tau_0 + \mu \frac{dv}{dr} \tag{1}$$

μ- plastic viscosity;

v- flow velocity.

It is typical for visco-plastic flows that they have the initial shear stress τ_0 [4, 5, 6]. At values greater than this tension, the structure of the liquid begins to disintegrate. After a certain critical velocity, the dependence $\tau = f(\gamma')$ turns into a linear dependence, and the motion of the fluid is characterized by plastic viscosity, being the motion of a Newtonian fluid ($\mu = tg\beta$). The dynamic shear stress – yield point (τ_d) is determined by extending the linear part of the dependence until it intersects the ordinate axis. It should also be noted that yield point cannot be determined experimentally.Unlike the dynamic viscosity coefficient, the plastic (structural) viscosity coefficient (μ) does not have a constant value for most fluids. As a rule, for non-Newtonian fluids, the concept of effective viscosity at a certain shear rate is used. This viscosity is calculated based on the tangent of the slope angle as a function of the shear rate ($\mu = tg\alpha$). The analysis shows that most of the fluids with visco-plastic properties show a decrease in viscosity with increasing shear rate.

The shear stress distribution along the cross-section and the yield point can be determined according to the following known expressions:

$$\tau = \frac{\Delta P * r}{2l}; \qquad \tau_0 = \frac{\Delta P * r_0}{2l} \qquad (2)$$

ΔP is the pressure difference.

The tangential stress on the pipe wall (when r=R) takes a maximum value..

$$\tau = \tau_{max} = \frac{\Delta P * R}{2l}$$

τ = 0 when r = 0 on the pipe axis. $\tau = \tau_0$ and $dv/dr = 0$ on a cylindrical surface with radius $r = r_0$ from the pipe axis. In the interval $0 \le r \le r_0$, the velocity of the flow remains constant, in other words, the cylindrical part with the radius r_0 moves like a solid body and is considered the core of this flow. The radius of the core is found from the following equation based on the condition $\tau = \tau_0$:

$$r_0 = \frac{2l * \tau_0}{\Delta P}$$

According to the last condition, $\tau > \tau_0$ should be on the inner surface of the tube for the fluid to move. When $r = R$, the initial pressure difference (ΔP_0) corresponding to the stationary state of the fluid ($\tau = \tau_0$) will be as follows:

$$\Delta P_0 = \frac{2l * \tau_0}{R}$$

That is, it is important to have the condition $\Delta P > \Delta P_0$ for the fluid to move in the pipe.

Let's examine how the gradient-velocity field changes during laminar flow of non-Newtonian drilling fluid. For this purpose, let's examine how the velocity and pressure gradient change along the cross-section of the pipe.

It is known that the change of the pressure gradient along the cross-section can be determined by the following mathematical equation [5,6]:

$$\frac{dP}{dr} = \rho v \frac{dv}{dr} \qquad (3)$$

Here ρ- density of drilling fluid.

Let's assume that the change in velocity (v) during the flow of the drilling fluid in the pipe occurs with the following expression:

$$v = Ar^2 + Br + C \qquad (4)$$

Let us use the following boundary conditions to determine the coefficients A, B and C included in the trinomial (4):

1. When $r = R$, velocity $v = 0$ at the pipe wall is assumed .

$$Ar^2 + Br + C = 0$$

2. $\frac{dv}{dr} = 0$ when $r = r_0$,

$$\frac{dv}{dr}_{r=r_0} = 2Ar_0 + B$$

3.

$$\tau_{max} = \mu \frac{dv}{dr}_{r=R} + \tau_0$$

$$\tau_{max} = \frac{\Delta P * r}{2l}; \qquad \tau_0 = \frac{\Delta P * r_0}{2l}$$

Using the mentioned conditions above, we get the following expressions for determining the coefficients A, B, C included in equation (4):

$$\left.\begin{aligned} A &= -\frac{\Delta P}{4\mu l} \\ B &= \frac{\Delta P r_0}{4\mu l} \\ C &= \frac{\Delta P R^2}{4\mu} - \frac{\Delta P r_0}{2\mu l} \end{aligned}\right\} \qquad (5)$$

From the last expressions, taking into account the coefficients A, B, C, the following expression can be written for the determination of the distribution of the velocity along the cross-section of the pipe:

$$v = \frac{\Delta P}{4\mu l}(R^2 - r^2) - \frac{\tau_0}{\mu}(R - r) \tag{6}$$

According to expression (6), the change of the velocity gradient along the cross-section is as follows:

$$\frac{dv}{dr} = \frac{\Delta P(r_0 - r)}{2\mu l} \tag{7}$$

If we consider the expressions characterizing the distribution of velocity and velocity gradient (6) and (7) and the expression of τ_0 in equation (3), we get the following expression reflecting the distribution of the pressure gradient along the cross-section:

$$\frac{dP}{dr} = \frac{\rho \Delta P^2}{4\mu^2 l^2}(r - r_0)[2r_0(R - r) - (R^2 - r^2)] \tag{8}$$

Considering that the expression (6) reflecting the cross-sectional velocity distribution of visco-plastic fluids during laminar flow is true only in the interval $r_0 \le r \le R$, then when $r = r_c$, as can be seen from the expression (8), the pressure gradient becomes 0 $\frac{\Delta P}{\Delta r} = 0$. By the same rule, when r = R, that is, the pressure gradient on the pipe wall is equal to 0 ($\frac{\Delta P}{\Delta r} = 0$) and in the center of the tube (when r = 0) $\frac{dP}{dr} = \frac{\rho(R-2r_0)\tau_{max}\tau_0}{\mu^2}$.

The maximum value of the pressure gradient along the cross-section can be determined by deriving the expression (8). So, if we take the derivative of that expression with respect to r and make it equal to zero, we get the following quadratic equation:

$$3r^2 - 6r_0 r + (2r_0 R - R^2 + 2{r_0}^2) = 0$$

Following roots are obtained from the solution of the last equation with respect to r:

$$r_1 = r_0 + \frac{\sqrt{3}}{3}(R - r_0)$$

$$r_2 = r_0 - \frac{\sqrt{3}}{3}(R - r_0)$$

As you can see, although the second root satisfies the equation because $r_2 < r_0$ is obtained, it contradicts the condition $r \ge r_0$ mentioned above. Therefore, the pressure gradient dP/dr will have a maximum value at $r^* = r_0 + \frac{\sqrt{3}}{3}(R - r_0)$. This value will be as follows:

$$\frac{dP}{dr}_{max} = \frac{\sqrt{3}\rho(R - r_0)(\tau_{max} - \tau_0)^2}{3\mu^2}$$

The variation of flow parameters (velocity, tangential stress, velocity gradient and pressure gradient) for visco-plastic fluids is shown in Fig. 1.

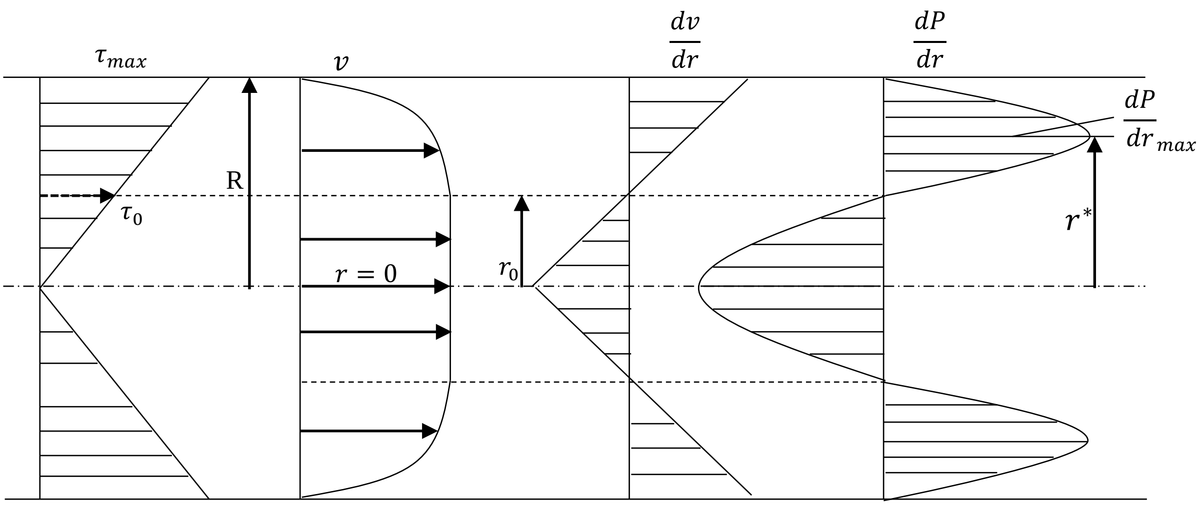
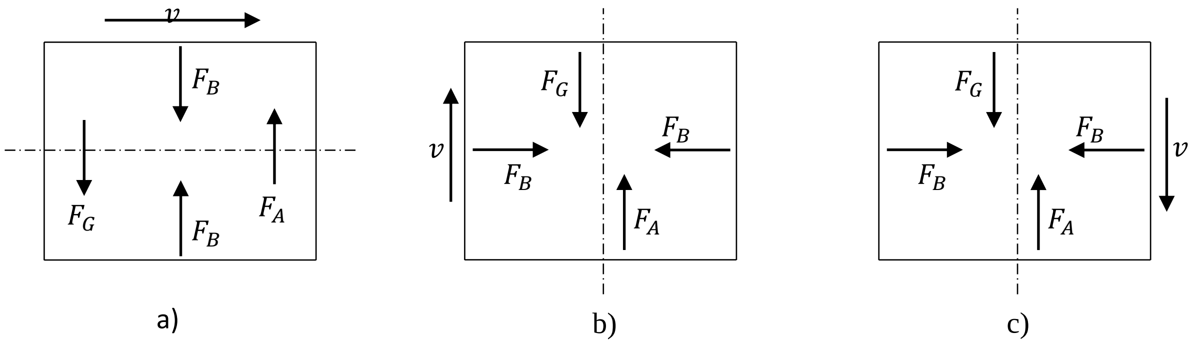


Figure 1: *Cross-sectional distribution of flow parameters of visco-plastic drilling fluid*

Studies show that the structure of multiphase flows (gas-liquid, oil-water-gas, oil-gas-mechanical particles, drilling fluids, etc.) is highly dependent on the orientation and direction of movement of the channel (pipe). So, during the movement of these flows in the vertical pipe from top to bottom and vice versa from bottom to top, as well as in horizontal direction, their characteristics differ significantly from each other. Although there is currently a considerable amount of scientific research work on horizontal and bottom-top vertical flows, top-bottom flow forms have been limited studied .

The results of scientific research conducted in recent years have shown that there is mutual influence of phases in multiphase cylindrical flows regardless of the direction [5÷8]. As the gradient-velocity field is formed not only along the length but also along the cross-section of the flow according to the law of conservation of energy, the continious phase is able to transport dispersed phase particles along the axis of the flow, in its center. Due to the Bernoulli force, which is directed from the edges of the cylindrical flow towards the center, those particles (mechanical, gas, water, etc.) very easily move in the core of the continious phase, being directed to the axis of the flow.

It is known that during such flows mainly gravity, Archimedes, and Bernoulli forces (if we do not consider friction and inertia forces) are active forces, which cause sedimentation and migration phenomena. It is clear that although the direction of these forces is known, their effect will be different depending on the direction of the multiphase flow. So, in vertical downward and upward flows, Archimedean and gravitational forces will be opposite to each other, and Bernoulli's force will be perpendicular to them. In the case of horizontal flows, although the direction of all three forces is perpendicular to the flow, the Bernoulli force will be perpendicular to the axis of the flow from the edges, and the Archimedean and gravitational forces will be opposite to each other. Schematically, the directions of these forces in different directional flows are shown in figure 2.



a-horizontal, b- bottom to top, c-top to bottom

Figure 2: *Direction of active forces in multiphase flows with different directions*

F_B – Bernoulli force, F_A – Archimedes force, F_G – Gravitational force

Thus, the cross-sectional transfer of matter and energy in multiphase flows does not occur only due to turbulent diffusion. This process is also caused by the directed movement of the medium itself. Such transfer phenomena, which are characteristic of multiphase flows and multicomponent drilling fluid, occur due to the Bernoulli force, which causes the interaction of phases in both horizontal and gravity flows[4, 7]:

$$F_B = 0.167\pi d^3 \frac{dP}{dr} \quad (9)$$

Here d - the diameter of the dispersed phase particle, the volume of the particle (gas bubble, mechanical particle, scrap, etc.) with a diameter d of $0.167\pi d^3$;

dP/dr - is the pressure gradient across the flow cross-section.

The transfer movement of the flow along the cross-section occurs under the influence of the pressure gradient along the length (height), against the background of the movement of the medium. Turbulence of the flow also increases with the increase of the average flow rate, because the pressure gradient along the cross-section increases more intensively with the increase of the velocity.

If we consider the expression that reflects the change of expressions of pressure gradient, v and dv/dr, in equation (9) we get;

$$F_B = 0.167\pi d^3(\rho_{m.h} - \rho_m)g \tag{10}$$

As can be seen from the last statement, the Bernoulli force directed from the pipe wall to the center of the flow in the cylindrical flow increases significantly as the density difference of the mechanical particles and fluid (drilling fluid) and the diameter of the mechanical cuttings increase.

As can be seen from the last expression, the migration of the dispersed phase to the center of the flow is inevitable despite the high degree of dispersion even in the small diameters of the rock fragments. Therefore, due to intensive migration (transportation) of drilled rock particles to the center of the flow due to the effect of the Bernoulli force caused by the variable pressure gradient, it can greatly increase the local resistance caused by friction and cause the stuck pipe.

II. Conclusions

– Based on the physical model of multiphase cylindrical flows, the regularity of the formation of the velocity-gradient field during its movement in the pipe, taking into account the visco-plastic properties of the drilling fluid, has been shown.

– It has been shown that one of the possible causes of stuck pipe during drilling of oil and gas wells is due to the compression of the tool as a result of the dislocation of mechanical particles and rock fragments in the direction of the flow axis due to the Bernoulli force formed by the velocity-gradient field.

References

[1] Ogibalov P.M. Mirzacanzade A.Kh. Unsteady movements of visco-plastic fluids. M.: MGU, 1977, 372

[2] Klimov D.M., Petrov A.G. Georgievsky D.V. Viscoplastic flows, dynamic chaos, stability, mixing M.: Nauka, 2005, 394 p.

[3] Gnosvoy A.V., Klimov D.M., Chesnokov V.M. Fundamentals of the theory of flow of Bingham media. M. Fizmatlit, 2004, 272s

[4] Sattarov R.M. Unsteady movement of rheologically complex liquids in pipes. Baku: Ely-1999, 412 p..

[5] Sitenkov V. T. Theory of gradient-velocity field. M.: OJSC "VNIIOENG", 2004, 308c

[6] Sitenkov V.T. Determination of the critical speed of disc molded site in horizontal pipelines // Chemistry and technology of fuels and oils, 1963, No. 9, p. 51-54.

[7] Ismayilova F.B. On the role of Bernoulli force in the functioning of multiphase pipelines. (Rassokhsinsky reading. Materials of the international conference (February 4-5, 2021) part 2, UKhTA, USTU, 2021, pp. 68-71.

[8] Khasanov M.M., Bulgakova G.T. Nonlinear and nonequilibrium effects in rheologically complex media. M.: Izhevsk Institute of Computer Research, 2003, 388c

[9] Shulman Z.P. Convective heat transfer of logical tracking liquids M. Energia, 1975, 352c

[10] Kelbaliev G. I., Tagiev D.B., Rasulov S.R. Rheology of non-Newtonian oils. Monograph. M.. Mask, 2022, 601 p.

MULTIMEDIA SUPPORT SYSTEM FOR AEROSPACE MONITORING OF EMERGENCY SITUATION BASED ON AI TECHNOLOGIES

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Abstract

Technological development, digitalization, cybersecurity, the use of artificial intelligence, all these areas are becoming part of the everyday life of society. Along with the task related to renewable energy, the republic is making its contribution to solving climate change issues. This year, the international conference COP29 will be held in Azerbaijan under the auspices of the UN Framework Convention on Climate Change. In this regard, the attention of the international community will be directed to our country, namely to activities in the field of environmental protection and climate change. Based on this, it is necessary to introduce new solutions and innovations that will help reduce the negative consequences of climate change. One of the important problems is global warming. It leads to disruption of the natural ecosystem, including the occurrence of hazardous natural phenomena and destructive natural disasters. Forecasting the occurrence and development of natural and man-made phenomena on Earth is of great relevance. Direct damage from all types of emergency events amounts to a huge amount. Preventing emergency situations (ES) based on monitoring their precursors is more economically profitable than responding to the consequences of emergencies. Thus, one of the main tasks of disaster risk management is monitoring and forecasting emergencies. The noted consists in constant monitoring of processes occurring in nature and the technosphere with the aim of scientific prediction of possible dangerous phenomena. The forecasting system includes information about the forecast object, which reveals its behavior in the past and present, as well as the patterns of this behavior. Information about these precursors should be sent to the monitoring and forecasting center using monitoring systems. Here, appropriate predictions are made based on heuristic and mathematical methods. According to the area of occurrence, emergencies are divided into natural and man-made ones. On the base of the above-mentioned facts, this paper is aimed of discussing several important features of multimedia support system for aerospace monitoring of emergency situation on the Caspian Sea using technologies AI.

Keywords: multimedia, support system, aerospace monitoring, emergency situation, AI technologies

I. Introduction

The major environmental issues in the 21st century include: climate change, freshwater scarcity, deforestation and desertification, freshwater and marine pollution, loss of biodiversity, air pollution, soil and natural resource depletion [2]. The environment is considered favorable if its condition meets the criteria and standards established by environmental legislation regarding its cleanliness (non-pollution), resource intensity, environmental sustainability, species diversity and aesthetic richness. The Republic of Azerbaijan is a party to a number of international conventions in the field of environmental protection, including the Convention on Environmental Impact Assessment (EIA) in a Transboundary Context (Espoo Convention) [1,4]. At its core, the Espoo Convention is a means to help Parties (states) cooperate, jointly discuss problems, exchange opinions and experiences. This Convention represents a set of opportunities for countries in the Economic Commission for Europe region, but at the same time the way they implement them needs to be improved. The most important task at the present stage is to know the boundaries of

HOMEOSTASIS, that is, those critical values of the parameters of the biosphere, beyond which the unpredictable development and destruction of the biosphere begins. Information in the field of environmental protection includes the state of the environment, impacts on the environment, and regulation of environmental quality. An ecosystem of a certain type is preserved only with certain combinations of ecological components. Otherwise, if the balance of eco-components is disturbed, irreversible processes will be observed (classic example: degradation of the Aral Sea) [5]. The most significant changes in ecosystems are caused by significant reasons (accidents on oil pipelines, fires, soil degradation, deforestation, emissions of pollutants into the atmosphere, water bodies and seas, etc.). Within the framework of the scientific and technical work "Development of a multimedia model for aerospace monitoring of emergency situations based on expert systems technology", carried out at the Institute for Space Research of Natural Resources ANASA, three groups of issues are considered: characteristics of the Caspian Sea, oil production and transportation, aspects of emergency situations at sea. Remote research is carried out with the aim of confirming or rejecting a particular scientific hypothesis. Monitoring as a system includes a subsystem for collecting, accumulating and transmitting information, as well as a subsystem for processing, modeling, analyzing and forecasting data. At the monitoring and forecasting center, appropriate predictions are made based on heuristic and mathematical methods [6,9].

Promptly obtaining information about the coverage area, level and quality of the event in each geographic point of the emergency area is one of the main factors that can reduce the tension of the situation in the region. In this regard, the features of multimedia technologies are: the transformation of traditional maps into multimedia ones. Here, along with maps and texts for them, audiovisual information is important: pictures, animation, sound, 3d graphics; a visual representation of the process under study (its phase), for example, in the form of an animated film. Based on this, the "revival" of the components of the IF - THEN heuristics, in the form of static snapshots (pictures), was demonstrated for the first time. The objects of monitoring in this work are aspects of emergency situations. The purpose of monitoring is not a passive statement of facts. It should also include modeling of the processes under study, generalization of accumulated world experience in assessing and forecasting natural and man-made hazards, development of multimedia data banks on various aspects of emergency situations, etc.

II. Methods

A cognitive multimedia monitoring model (CMMM) is proposed in the form of a set of interconnected elements

$$B=B_k, \qquad B_k=R_1^k \cup R_2^k \cup R_3^k \cup \ldots \cup R_{l-1}^k \cup R_l^k = \bigcup_{j=1}^{l} R_j^k$$

The model characterizes the various phases of the study, where: R_j is the set of elements of the j-th group model; here $K=m,n,p$: m – number of elements, $m=\overline{1,M}$; l - number of groups, $l=\overline{1,L}$; n – form of representation of semantic information, $n=\overline{1,N}$ (with $N=4$ we have t, S, g *and* C – forms, where t – text form, S – audio form, g – dynamic (dynamic video images) form, C – graphic (static images: maps, aerospace images, graphs, diagrams, etc.) form; p – type of observations (*2d or 3d*).

CMMM from the position of a researcher represents a certain task, which has conditions, a goal and means of achieving it. Solving a problem is a process of dialogue interaction between a researcher and a complex that has access to the Internet according to a pre-formed strategy. During the dialogue, the current state of the object model is displayed. The course of the process is assessed according to an established criterion (for example, extremes: signal/noise ratio, time to reach the goal, etc.).

The CMMM identifies three functional components: a multimedia model of the subject area (technological process), phases of the technological process, interactive interaction of the researcher with the complex and dialogue with experts on the Internet.

CMMM elements are associated with specific indicators of technical means (for example, on-board sensor systems) [7] ; data from simulation modeling, mobile environmental laboratories.

A multimedia model of a subject area is a set of audiovisual forms of the phases of a technological process and the laws of change in their content. Process phases, i.e. multimedia images of source data are relationships and conditions that define the task for studying a given situation [8]. The multimedia model is designed to display the parameters and states of various research objects, i.e. information models (IM).

III Results

Thus, the developed cognitive multimedia monitoring model is a set of interconnected static and dynamic information models of objects (processes, phenomena) and background images.

Forms of representation of semantic information. Based on the theory of semantic networks, homogeneous and complex forms of representation of semantic information are distinguished. The set of homogeneous forms is determined by the expression

$$N_1 = \{t, S, g, C\}$$

The complex form of representation of semantic information consists of several homogeneous forms, namely: text and auditory, text and graphic, graphic and visual, etc. In the general case, many options for complex forms of representing semantic information are determined analytically. To do this, using the operation of direct product of sets, from the elements of set N1 they form set N2, which contain double elements

$$N_2 = N_1 \cdot N_1 = \{(t,t), (t,S), (t,g), (t,C), (S,t), (S,S), (S,g), (S,C), \\ (g,t), (g,S), (g,g), (g,C), (C,t), (C,S), (C,g), (C,C)\}.$$

As a result, the resulting expression defines a list of complex forms of representation of semantic information that simultaneously combine two homogeneous forms (16 double elements). These complex forms are binary forms of expressing semantic information.

In order to obtain further diversity, ternary forms are used, which simultaneously combine three homogeneous forms

$$N_3 = N_1 \cdot N_1 \cdot N_1 = \{(t,t,t), (t,S,t), (t,g,t), (t,C,t), \ldots, (S,S,S), \ldots, (S,C,t), \ldots, (g,g,g), \ldots,\}$$

As a result, 64 ternary elements are obtained. Thus, it is possible to obtain complexes containing four, five, six or more simultaneously combined forms of representation of semantic information.

IV Discussion

Current emergency issues [3] are important for both scientific and practical activities. As part of our research, we have identified and selected the main aspects of emergency situations in the Caspian Sea.

The Fig.1: shows a general scheme of emergency situation at sea.

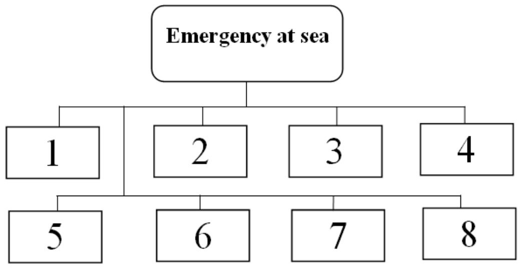

Figure 1: *General scheme of emergency situation at sea*
Legend: 1 - Oil spills; 2 – Fire on a fixed platform; 3 – Volcanic activity; 4 – Ice; 5 – Storm; 6 – Oil transportation problem; 7 – Sea level change; 8 - Earthquake

The selected material is the basis for the subsequent creation of multimedia data banks for a multimedia support system for aerospace monitoring.

The use of complex forms to express semantic information is of great practical importance in solving various remote sensing problems, since the degree of knowledge of an object increases with the simultaneous (complementary) representation of its aspects by multiple forms.

Azerbaijan is both an oil-producing country and a transit territory for the transportation of petroleum products, which creates an additional burden on ecosystems. The main stages of oil use are considered: 1. Exploration of oil fields. 2. Oil production. 3. Oil transport. 4. Refining and petrochemicals. 5. Use of petroleum products. 6. Waste disposal. All of these stages are associated with environmental pollution. In particular, when transporting oil, dangers are associated with transportation (by sea, land) and with pipeline rupture.

At the same time, the anthropogenic load on the marine ecosystem, coastal zone ecosystems, and ecosystems along the pipeline route increases. As a result, an extensive set of possible problematic situations and contradictions between human intentions and the capabilities of nature emerges. The Caspian region can be represented as a set of interconnected ecosystems.

Knowledge of the patterns of ecosystem behavior and factors that influence ecological balance is important.

Characteristics of the Caspian Sea.

Sea coordinates:
1. North latitude: $36^0 33^/ – 47^0\ 07^/$ N
East longitude: $45^0\ 43^/ – 54^0\ 03^/$ E
2. Its length ---------- 1200 km
3. Width -------------------310 km (average)
435 km (max)
4. Depth --------- ----208 m (average)
1025 m (max)
5. Division of the Caspian
1. -- north
2. – average
3. – south
6. The area of the Caspian Sea --------------- 3.5 million km^2
7. The area of the sea water area ----- 386.4 thousand km^2

The Fig.2: shows the general scheme of oil transportation.

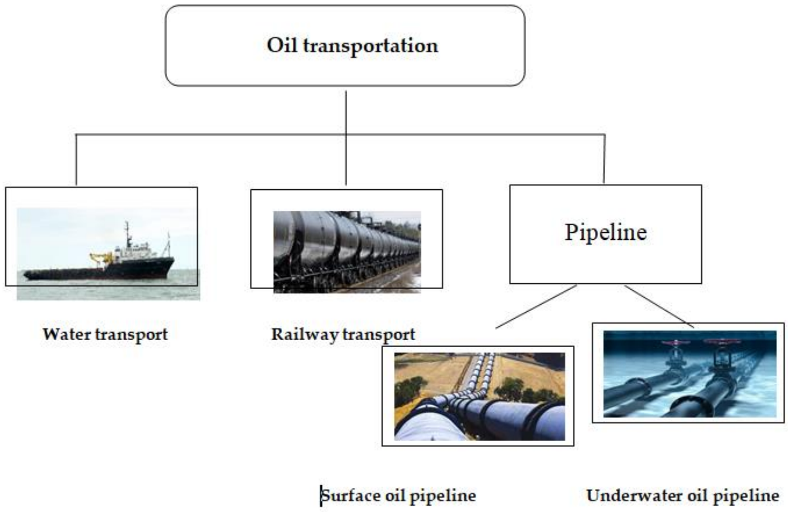

Figure 2: *General scheme of oil transportation*

We analyzed incidents of aspects of emergency situations in the Caspian Sea: 1. Mercury tanker accident; 2. Freezing (covering with ice) of the northern part of the sea. A broken block of ice in the area of the Neft Dashlari field; 3. Fire on the Guneshli oil platform; 4. Storm at sea in the area of stationary platforms; 5. Volcano activity at sea; 6. The problem of oil transport at sea; 7. Fluctuations in sea level and the Kura River; 8. Oil stains on the surface of the sea.

Along with incidents of aspects of emergency situations in the Caspian Sea, we separately examined incidents in other regions of the world:

1. The problem of a Japanese oil tanker that ran aground near the island of Mauritius;
2. Fire on the fixed oil platform "Deepwater" in the Gulf of Mexico.

Development of informative heuristics based on IF-THEN constructions. Visual forms of heuristics.

Heuristics 1.

1. IF a fire breaks out on a large oil platform and the platform collapses,
2. THEN there is a high probability that an oil spill will spread to the surface of the sea.

Figure 3: *A visual form of heuristics 1(IF component)*

Heuristics 2.

1. IF an oil pipeline accident occurs,
2. THEN the probability of an oil spill spreading is high.

Figure 4: *A visual form of heuristics 2 (THEN component)*

Let's consider a fragment of a visual database for generating heuristics for the problem under study.

The Fig.5: shows a block diagram of the animation algorithm for an oil slick leaking from an underwater oil pipeline (phase 1) and the formation of an oil slick on the sea surface (Phase 2).

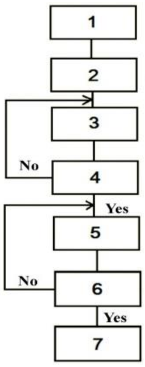

Figure 5: *Block - diagram of the animation algorithm for an oil slick leaking from an underwater oil pipeline (phase 1) and the formation of an oil slick on the sea surface (phase 2)*
Legend: 1. beginning; 2. animation; 3,4. phase 1; 5,6. phase 2; 7. end

The Fig.6 shows an animation diagram of an oil leak from an undersea pipeline.

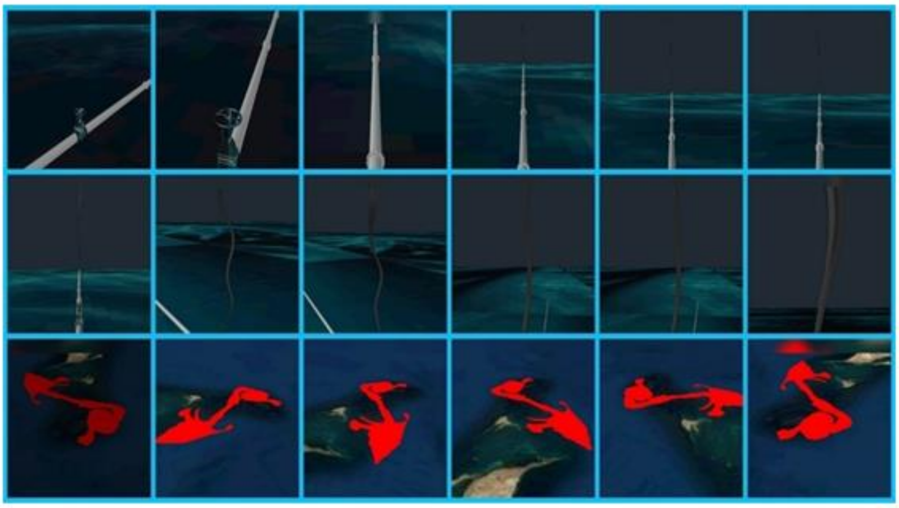

Figure 6: *An animated diagram of an oil spill from an undersea oil pipeline*

References

[1] Espoo convention (25.02.1991). https://www.un.org>env_assessment

[2]Global Environment Outlook (GEO 2000). Review. UNEP, 1999, 16 p.

[3] Mamedova G.G., Odzhagov G.O. Actual problems of emergency situation // International scientific-practical conference on modern problems of emergencies related to globalization. Baku, May 30-31, 2012, pp.3-7 (in Russian).

[4]Mehdiev A.Sh., Kajar C.O., Sattarov N.A. Priorities of the Azerbaijani space program and the practice of international cooperation //*Scientific Notes of NAA,*Baku,vol. 11, no. 3, 2009, pp. 39-46 (in Russian).

[5]Sadev A.V. Dynamics of ecosystems of the Aral basin based on space photography materials // IZiK, No. 4, 1981, pp. 18 – 26 (in Russian).

[6] Sattarov , N. (2023) Aerospace Monitoring of Sea Oil Pollution Based on Technologies of Cognitive and Expert Systems // Reliability : Theory and Applications, v.18. N5 (75), pp.483 – 488.https : //doi.org/10.24412/1932-2321-2023-575-483-488.

[7] Sattarov N.A., Hummetov R.M. Features of the correct use of radar and optical satellite data in the problem of improving the modern ecosystem of Azerbaijan // Materials of conf. " Solutions for improving the modern ecosystem of Azerbaijan". BSU, Baku, May 2024.

[8] Sattarov N.A., Odzhagov G.O., Kengerlinskaya T.K. Study of anthropogenic chemical sources of danger to public health with the aim of developing a multimedia data bank //Proceedings of the International. scientific-practical conf. Baku, 2012, pp. 285-288 (in Russian).

[9] Sattarov N.A., Vladimirsky E.I. Mathematical aspects of problems of aerospace monitoring of oil and gas complex objects // Materials of International scientific - practical conf."Estimation of the Accidents' Risks and Problems of Security in Oil and Chemistry Industry" 4-5 Dec. 2014. Baku. p.41-43 (in Russian).

THE ROLE OF ARTIFICIAL INTELLIGENCE IN FORECASTING AND MANAGING TECHNICAL RISKS

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Abstract

Artificial Intelligence (AI) has emerged as a transformative tool in forecasting and managing technical risks across various industries. By leveraging machine learning algorithms, data analytics, and predictive modeling, AI enables the identification, assessment, and mitigation of potential technical failures with unprecedented accuracy and efficiency. This paper explores the role of AI in enhancing risk management practices, particularly in sectors such as finance, manufacturing, energy, and cybersecurity. AI's ability to process vast amounts of data in real-time allows for early detection of anomalies, prediction of equipment malfunctions, and optimization of maintenance schedules. Additionally, AI-driven risk management systems can adapt to evolving risk landscapes, improving decision-making and reducing operational costs. Despite its potential, challenges such as data quality, algorithmic bias, and integration with existing risk management frameworks remain. The study concludes that while AI offers substantial benefits in technical risk forecasting and management, it must be deployed with careful consideration of these challenges to maximize its effectiveness.

Keywords: anomaly detection, equipment failure prediction, real-time data processing, risk mitigation, operational efficiency

I. Introduction

In today's rapidly evolving technological landscape, managing technical risks has become a critical concern for organizations across various industries. The increasing complexity of systems, coupled with the growing reliance on digital infrastructure, has heightened the potential for failures that can lead to significant operational disruptions, financial losses, and reputational damage. Traditional methods of risk management, while effective to an extent, often struggle to keep pace with the dynamic nature of these challenges. This has created a demand for more advanced, data-driven approaches capable of predicting and mitigating risks before they materialize.

Artificial Intelligence (AI) has emerged as a powerful solution to these challenges, offering innovative tools for forecasting and managing technical risks. By utilizing machine learning algorithms, data analytics, and sophisticated modeling techniques, AI can analyze vast quantities of data, identify patterns, and predict potential issues with greater accuracy and speed than traditional methods. AI is now being applied in a wide range of industries, including finance, manufacturing, energy, healthcare, and cybersecurity, where its ability to process real-time data and learn from past events enables organizations to take proactive measures against potential risks.

This paper examines the growing role of AI in technical risk management, highlighting its key contributions and benefits. It explores how AI-driven systems can enhance predictive maintenance, improve decision-making processes, and reduce operational costs. Additionally, the paper addresses the challenges associated with AI implementation, such as data quality, algorithmic biases, and the need for integration with existing risk management frameworks. Through this analysis, the paper aims to demonstrate the transformative impact of AI on risk management practices and its potential to revolutionize how organizations approach technical risk forecasting and mitigation.

Recent research on business continuity and risk assessment highlights the potential of new technologies, particularly artificial intelligence (AI), to improve the effectiveness of risk management. Although some studies have explored AI's role in risk assessment, more research is needed to understand how specific AI technologies can significantly enhance risk prediction for business continuity. While many studies underscore AI's potential, there has been limited in-depth analysis of the various AI techniques and tools most beneficial in different corporate contexts. For instance, machine learning algorithms, natural language processing (NLP), data analytics, and predictive maintenance systems are some of the technologies categorized under AI. However, the relative effectiveness of these tools in addressing different types of risks and ensuring business continuity has not been thoroughly examined. Additionally, while the benefits of AI in risk assessment are becoming more recognized, there is still a lack of empirical evidence quantifying improvements in accuracy, efficiency, and overall business continuity due to AI adoption. Organizations need concrete data to inform their investments in AI-driven risk management solutions.

Organizations are increasingly focused on identifying, assessing, and mitigating risks that threaten their continuity. Jackson et al. (2023) argue that AI has become a transformative tool for addressing these challenges. AI capabilities, such as machine learning, NLP, data analytics, and predictive maintenance, play a critical role in improving risk prediction for business continuity. Each of these AI technologies offers unique advantages in enhancing preparedness and resilience. According to Brintrup et al. (2023) and Raza (2023), AI-driven predictive maintenance is particularly effective at ensuring operational continuity. By analyzing sensor data and equipment performance, AI can predict when machinery or infrastructure is likely to fail, enabling preventive action to minimize unplanned downtime—a key aspect of business continuity, especially in industrial and critical infrastructure sectors.

II. Methods

AI has the capability to process vast amounts of data at remarkable speeds, uncovering patterns and insights that would be difficult for humans to detect. This technology is being applied to transform business forecasting by integrating advanced AI techniques with traditional financial practices, resulting in higher levels of accuracy and efficiency.

Historically, forecasting, budgeting, and variance analysis have relied on manual processes and historical data. However, with the increasing complexity and volatility of markets, there is a growing demand for more agile, data-driven approaches. AI leverages sophisticated algorithms and machine learning to process information from diverse sources, identifying hidden patterns and providing predictions that surpass human abilities.

Traditional financial forecasting methods, such as time series analysis, involve tracking data points at regular intervals and often use techniques like moving averages or exponential smoothing to filter out noise and reveal trends. AI enhances these methods by using deep learning and neural networks, which can detect more intricate patterns in the data. This leads to more accurate predictions of market behavior, revenue, profit margins, and other financial metrics. Additionally, AI continually refines its models, adjusting its calculations in real-time to improve forecast precision.

These tools are becoming easier for all parts of the business to deploy; now finance has the ability to see further into the future by joining with these efforts in partnership with the business and within the office of the CFO. Here are some brief examples:

Demand Forecasting:

- E-commerce Business: An e-commerce giant heavily relies on AI for demand forecasting. Their sophisticated AI models analyze historical sales data, customer behavior, seasonality and external factors to predict future demand accurately. This allows them to optimize inventory levels, minimize stockouts and reduce excess inventory costs, resulting in improved customer satisfaction and operational efficiency.
- Healthcare: Hospitals and healthcare providers use AI to predict patient admission rates and optimize resource allocation. AI models can help hospitals adjust staffing levels, manage bed availability, etc., by considering factors like historical patient data, seasonality and disease outbreaks.
- Content Strategy: Streaming companies are utilizing AI algorithms to forecast viewer preferences and predict the success of potential content offerings. They gain insights by analyzing viewer behavior, including viewers watching habits, search history and ratings. Companies can tailor their content creation and acquisition strategies. This data-driven approach has contributed to the reputation for producing highly engaging and successful original shows and movies.

Supply Chain: Retail Inventory Management: Retail chains leverage AI to optimize inventory levels across their stores. It analyzes sales data, foot traffic, and external factors like weather. AI systems can also provide recommendations on replenishment quantities and timing. This minimizes overstocking and understocking issues that lead to improved profitability and customer satisfaction.

Operations: Energy Consumption Prediction: Utility companies employ AI to forecast energy consumption patterns. By considering historical usage, weather forecasts and economic indicators, AI models can predict peak demand periods and engage users to optimize their energy consumption. This helps prevent power shortages during high-demand periods and enhances overall grid stability.

These real-world examples underscore the transformative impact of AI-driven approaches in financial processes. By leveraging AI's analytical capability, businesses gain a competitive edge by making data-informed decisions and staying ahead of market dynamics. However, it's important to note that while AI offers tremendous potential, its success depends on high-quality data, robust model training and ongoing validation to ensure accurate and reliable results.

III. Results

AI-driven financial analysis offers significant potential for improving decision-making, but it also faces several challenges and limitations, as you’ve outlined. Here’s a closer look at each:

1. Data Quality and Quantity:

- Challenges: Financial analysis depends heavily on accurate, comprehensive data. Poor data quality (incomplete, outdated, or erroneous data) can lead to incorrect predictions and analyses. Additionally, many businesses may not have access to the vast amount of historical data required to train AI models effectively.

- Mitigation: Businesses need robust data governance frameworks to ensure data integrity, and techniques like data augmentation can help alleviate some issues with limited datasets.

2. Model Overfitting:

- Challenges: Overfitting occurs when a model learns the noise and specific patterns in training data, resulting in poor performance on new, unseen data. In financial analysis, market anomalies and time-specific events can cause a model to overfit if not properly controlled.

- Mitigation: Regularization techniques, cross-validation, and robust testing on diverse datasets can help minimize overfitting, ensuring models are better suited for generalization across different market conditions.

3. Volatility and Uncertainty:

- Challenges: Financial markets are volatile and prone to unpredictable events like black swan events, market crashes, or geopolitical upheavals. AI models, trained on historical data, often struggle to predict such sudden, extreme events due to their reliance on past patterns.

- Mitigation: Combining AI models with scenario analysis, stress testing, and human oversight can improve preparedness for unexpected market shifts. AI models can also be complemented with alternative data sources, such as real-time news sentiment analysis, to capture emerging risks.

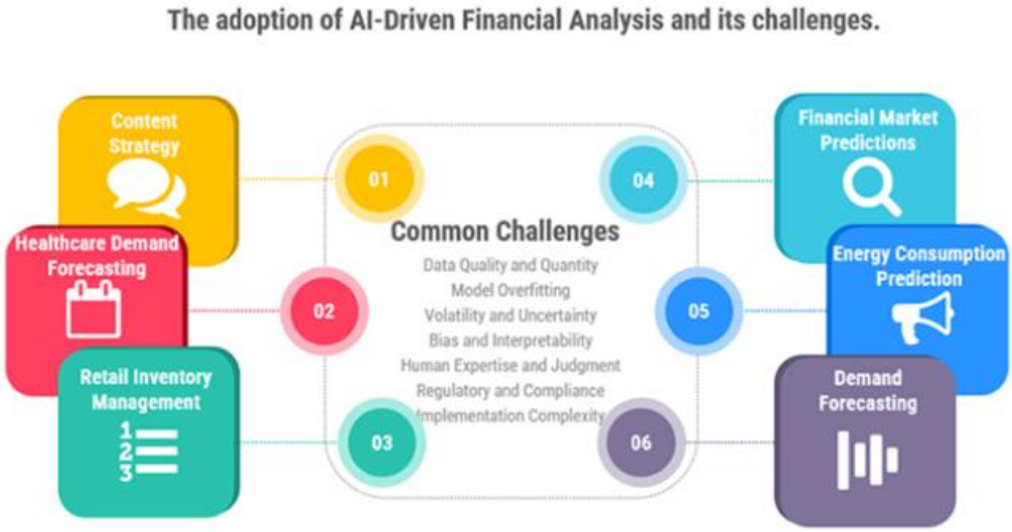

Figure 1: *AI-driven approaches in financial processes*

4. Bias and Interpretability:

- Challenges: AI models can inherit biases from the historical data they're trained on, potentially reinforcing existing disparities in predictions. Furthermore, many complex AI models (like deep learning) act as "black boxes," making it difficult to understand or explain the reasoning behind their decisions, which can hinder trust and regulatory compliance.

- Mitigation: Explainable AI (XAI) techniques are being developed to make models more transparent. Auditing AI predictions for biases and implementing fairness checks can help ensure the model's outputs are reliable and compliant with ethical standards.

5. Human Expertise and Judgment:

- Challenges: Despite AI's computational power, human expertise is still required to interpret nuanced situations and make strategic decisions. AI may struggle to handle highly context-dependent decisions where qualitative factors or unique market insights are involved.

- Mitigation: AI should be seen as a decision-support tool, augmenting human judgment rather than replacing it. Human oversight and collaboration between domain experts and data scientists are crucial for making well-rounded decisions.

6. Regulatory and Compliance Challenges:

- Challenges: Financial institutions must adhere to strict regulations, which can change frequently. AI models must be agile enough to adapt to new regulations while ensuring compliance. Failure to do so can lead to legal and reputational risks.

- Mitigation: A regulatory-aware AI framework can be developed to track and incorporate changes in regulations. Additionally, strong collaboration with legal teams and the integration of compliance checks into the AI model development lifecycle are essential.

7. Cost and Implementation Complexity:

- Challenges: Developing and maintaining AI models in financial analysis is resource-intensive, requiring substantial investments in infrastructure, skilled personnel, and ongoing updates. Smaller businesses may find these costs prohibitive.

- Mitigation: Cloud-based AI services and off-the-shelf AI tools can lower the barrier to entry. Additionally, firms can focus on modular implementations, starting small and expanding their AI capabilities as their resources allow.

These challenges reflect the complexity of integrating AI into financial analysis but also highlight areas where careful planning, regulation, and human involvement can enhance its effectiveness.

IV. Discussion

While AI offers tremendous potential in financial analysis, it's essential to approach its implementation with a clear understanding of its limitations and potential risks. The above real-world examples underscore the transformative impact of AI-driven approaches in financial processes, and addressing the mentioned challenges requires rigorous data preprocessing, model validation, ongoing monitoring and expert human oversight in each area of operations.

It is interesting to refer to Gartner 2023 - Hype Cycle for Artificial Intelligence, which shows the high adoption of AI innovations and techniques and how they are going towards the peak of inflated expectations. We may be at "peak AI" hype now and we may see headlines receding. Don't be fooled; this market is already taking off and people are hard at work finding ways to infuse AI into all parts of industry and our lives. Our role today is to acknowledge AI's potential, work to overcome challenges, and create an AI-driven culture with a holistic adoption into day-to-day finance operations.

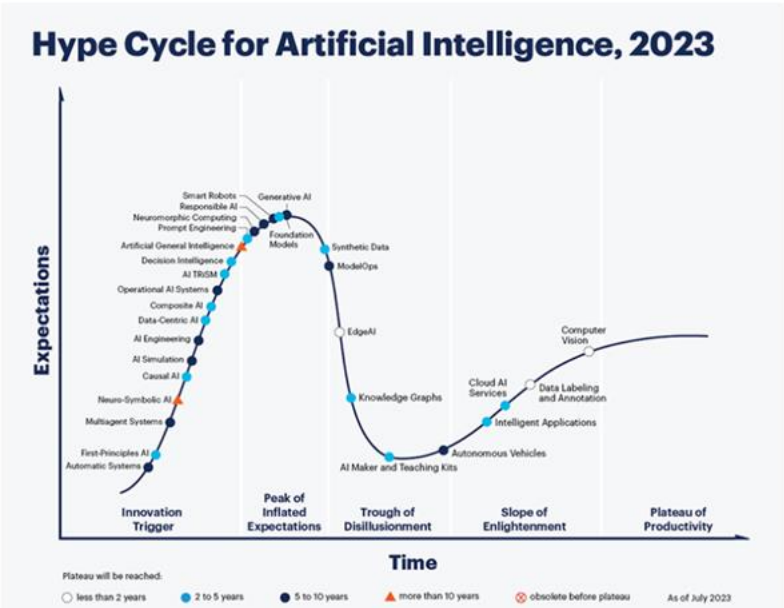

Figure 2: *Hype Cycle for Artificial Intelligence*

Based on the results of this study, several practical recommendations can be made for the financial industry to implement and use artificial intelligence (AI) to improve financial forecasting and reduce risks in the context of a global crisis.

First, financial institutions need to significantly invest in the technological infrastructure to support the implementation of AI. This includes purchasing the necessary hardware and software, as well as increasing the volume of data storage and processing power. A reliable infrastructure will ensure the optimal operation of AI-based forecasting systems and will allow for the efficient processing of large volumes of data for real-time analysis.

Second, it is important for financial institutions to train staff in the skills of working with AI and interpreting its results. The training should cover an understanding of AI algorithms, data analysis and forecasting methods. With sufficient skills, employees will be able to make better and faster decisions using AI technologies.

Third, financial institutions should develop adaptive and flexible AI models that can quickly respond to changing market conditions. Models that can adapt to changing data and the market environment will be more effective in forecasting accuracy during times of crisis. It is important to implement machine learning techniques that automatically update models based on new data.

Fourth, the integration of AI technologies with existing risk management systems must be done carefully to ensure that both systems function smoothly. Financial institutions need to develop processes that ensure that the results of AI models are effectively integrated into risk management strategies and applied in practice.

Fifth, a key factor in the success of AI models is good data governance. Financial institutions need to implement best practices for collecting, storing, and processing data to ensure its quality and integrity. This includes ensuring that the data is clean, relevant, and free from bias that could affect the accuracy of forecasts.

Sixth, financial institutions need to consider applicable ethical standards and legal requirements when implementing AI. Transparency of AI algorithms and the decisions made based on them, as well as data protection, should be a priority to prevent ethical and legal violations. It is important that the use of AI is compliant with all applicable regulations and that all decisions based on AI results are justified.

Finally, financial institutions should regularly evaluate the performance of AI models and make adjustments as necessary to improve their accuracy and effectiveness. Regularly evaluating and updating models ensures that AI technologies remain relevant and effective in addressing new challenges that arise during a crisis.

By following these recommendations, financial institutions will be able to effectively use AI to improve forecasting and risk management, allowing them to better manage uncertainty and increase the resilience of financial systems to unexpected risks.

References

[1 Perri, L. (2023, August 17). What's New in Artificial Intelligence from the 2023 Gartner Hype Cycle. https://www.gartner.com/en/articles/what-s-new-in-artificial-intelligence-from-the-2023-gartner-hype-cycle.

[2] Flammer, Caroline, Michaela W. Toffel, and Kala Viswanathan. 2021. "Shareholder Activism and Firms' Voluntary Disclosure of Climate Change Risks." Strategic Management Journal 1–30.

[3] Krueger, Philipp, Zacharias Sautner, and Laura T. Starks. 2020. "The Importance of Climate Risks for Institutional Investors." Review of Financial Studies 33 (3): 1067–111.

[4] Lange, F. & Dewitte, S. Measuring pro-environmental behavior: Review and recommendations. J. Environ. Psychol. 63, 92–100. https://doi.org/10.1016/j.jenvp.2019.04.009 (2019).

[5] Rastogi, R. (2018, June 27). Machine Learning @ Amazon. *The 41st International ACM SIGIR Conference on Research & Development in Information Retrieval*. SIGIR '18: The 41st International

ACM SIGIR conference on research and development in Information Retrieval, Ann Arbor MI USA. https://doi.org/10.1145/3209978.3210211.

[6] Gerrig, R. J., & Zimbardo, P. G. (2009). Psychology and Life. London: Pearson Education.

[7] Verganti, R., Vendraminelli, L., & Iansiti, M. (2020). Innovation and design in the age of artificial intelligence. The Journal of Product Innovation Management, 37 (3), 212–227. https://doi.org/10.1111/jpim.12523.

[8] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[9] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[10] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[11] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[12] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[13] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[14] Podkolzina I., Tenishchev A., Gornostaeva Zh., Tekeeva H., Tandelova O. Ecological and food security in the conditions of the geopolitical situation in the worldglobal digital transformation trends in real sectors of the economy // SHS Web of Conferences. 2023. T. 172. C. 02041.

METHODOLOGY OF ASSESSING TERRITORIAL RISKS OF THE ARCTIC ZONE OF KRASNOYARSK REGION IN THE IMPLEMENTATION OF INVESTMENT PROJECTS

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Abstract

The work is aimed at developing effective methods and models for solving problems in the field of analyzing the safety and security of Northern and Arctic territories in the context of multifactorial impacts (intensified development, implementation of investment projects, climate change), including identification of hazard factors, assessment of current and future man-made risks and security. To establish cause-and-effect relationships of the hazard factor's impact on the safety and sustainability of territories, it is proposed to use probabilistic graphical models based on Bayesian networks. The work was tested using the example of the Arctic territories of the Krasnoyarsk Region.

Keywords: climate change, technogenic hazards, territorial risks, safety

I. Introduction

One of the key problems of our time is adaptation to climate change. The international community is making attempts to solve this problem at the global level (Kyoto Protocol, Paris Agreement on Climate), but no significant results have been achieved. The problem is especially acute in the Arctic Zone (AZ), which is the most vulnerable territory to climate change.

According to the forecasts of the Intergovernmental Panel on Climate Change (IPCC), in the foreseeable future the Arctic territories may face the following problems [1-3]:

– - reduction in the extent of sea ice in the Arctic Ocean;
– - degradation of permafrost;
– - melting of the Greenland ice shield;
– - northward shift of the boundaries of natural zones and habitats of biological species.

One of the key problems of socio-economic development of the Arctic territories is associated with the melting of permafrost [3]. In the Strategies for the Development of the Arctic Zone and the Siberian Federal District of the Russian Federation for the Period up to 2035 [4, 5], from the standpoint of ensuring national security, one of the key factors influencing socio-economic development is changing climatic conditions, which contribute to the emergence of both new economic opportunities and risks for economic activity and the environment. Climate change leads to a decrease in the load-bearing capacity of buildings and structures, the integrity of industrial facilities and critical infrastructure is disrupted, which leads to the emergence of additional natural and man-made hazards, as well as significant economic losses associated with a reduction in service life, costs for maintenance, repair and reconstruction, and replacement of equipment earlier than planned. Accidents that occur in the networks of telephone, water or electricity supply can lead to serious consequences, up to and including the decision to evacuate the population [6, 7]. In these conditions, issues of technogenic safety acquire primary importance, since they determine the prospects for the development of territories, which makes research absolutely relevant.

The purpose of this work is to analyze technogenic safety in the implementation of investment projects taking into account natural and climatic factors based on a risk-oriented approach with subsequent testing on the example of the Arctic territories of the Krasnoyarsk Region.

The Arctic zone of Krasnoyarsk Region has a number of features:

- the climate of the territory belongs to the absolutely uncomfortable zone (the average annual temperature in January is -50°C);
- the landscape of the territory is represented by the Arctic desert, tundra and forest-tundra;
- a significant part of the territory is glaciers and permafrost (up to 46.2% of the total area of the Krasnoyarsk Region);
- active industrial development: mining, fuel (oil and gas), metallurgy, food industries, production and distribution of electricity, gas and water.
- high frequency of dangerous natural phenomena (storms, hurricanes, squalls, snowfalls, heavy ice, frost, blizzards, fog, frost, avalanches, heavy waves, coastal ice breakaway, floods, low water levels, early freeze-up, wildfires, etc.).
- high man-made load (occurrence of accidents in transport systems, industrial facilities, life support systems).

The Arctic zone of Krasnoyarsk Region includes 4 municipalities: Norilsk, Taimyrsky Dolgano-Nenetsky, Turukhansky and Evenkiysky districts. The total area of the AZ is 1854.5 thousand km^2, where more than 230 thousand people live.

Most of the Arctic territories are only subject to development, the main economic activity is concentrated in populated areas and along linear objects of transport infrastructure, thus climatic features and man-made load lead to destabilization of the natural system, to the emergence of environmental problems and a decrease in the quality of human life in extreme living conditions. In this situation, ensuring natural and man-made sustainability, increasing the security of the population and territories is possible only with an integrated approach to planning and managing development risks [8].

II. Methods

For sustainable development and functioning of territorial systems in conditions of multifactorial impact (intensified development, implementation of investment projects, climate change, etc.), it is necessary to analyze and assess both current risks and possible new threats.

Figure 1 shows a step-by-step scheme for analyzing the safety of a territory during the implementation of investment projects.

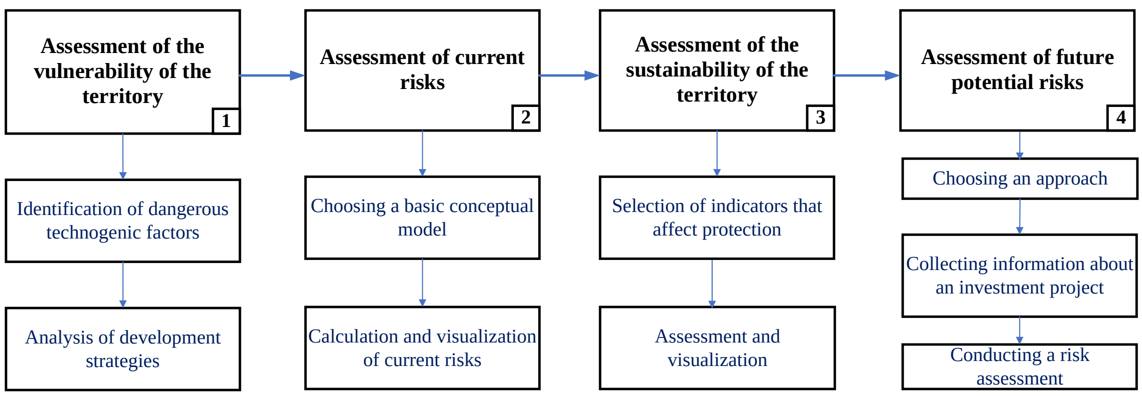

Figure 1: *Area Security Analysis Scheme*

At the first stage, when assessing the vulnerability of the territory, it is necessary to identify existing hazardous factors and analyze development strategies (activities) aimed at attracting new investors and stimulating industrial production.

At the second stage, when assessing current risks, it is necessary to select a mathematical model. In the work, to establish cause-and-effect relationships of the influence of hazard factors on the safety and sustainability of territories, it is proposed to use probabilistic-graphical models based on Bayesian networks. Bayesian networks combine the mathematical apparatus of probability theory and graph theory [9-11]. The basic idea of constructing a graphical model is related to the concept of modularity, i.e. decomposition of a complex system into simple elements. The probability of an event for each graph is determined by the formula for total probability. If event A can only occur when one of the events B_1, B_2… B_n, which form a complete group of incompatible events, is executed, then the probability of event A is calculated using formula (1):

$$P(A) = P(B_1) \cdot P(A \mid B_1) + P(B_2) \cdot P(A \mid B_2) + \cdots + P(B_n) \cdot P(A \mid B_n) \qquad (1)$$

To calculate the conditional probabilities of a given event, the Bayes formula (2) is introduced:

$$P(A \mid B_i) = \frac{P(B_i) \cdot P(A \mid B_i)}{P(B_1) \cdot P(A \mid B_1) + P(B_2) \cdot P(A \mid B_2) + \ldots P(B_n) \cdot P(A \mid B_n)} \qquad (2)$$

The assessment of the current risk for each hazardous factor is determined on the basis of the obtained values of probability and damage (3):

$$R_t = P_i \cdot U_i \qquad (3)$$

where P_i is the probability of occurrence of a certain risk factor; U_i is the damage from a certain risk factor, million rubles (data obtained from the official database of the Russian Emergencies Ministry).

At the third stage, we determined the sustainability (protection) of the territory. Technogenic protection of the territory is understood as a set of factors and measures that ensure the safety of the technosphere in the event of emergencies and disasters. Table 1 presents a list of indicators that affect the sustainability of the territory to occurrence of hazards.

Table 1: *Sustainability (protection) indicators*

List	Normative values	Normative documents
Fire departments	Estimated ratio of the dependence of the rescuers number on the population density	Organizational and methodological recommendations for determining the number of firefighting services of a constituent entity of the Russian Federation and its technical equipment
Emergency rescue teams	Calculated ratio of the dependence of the number of formations on the number of hazardous industrial facilities	Order of the Ministry of Health of the Russian Federation dated 27.02.2016 No. 132n "On the requirements for the placement of medical organizations of the state healthcare system and the municipal healthcare system based on the needs of the population"
Medical organizations	Depending on the population size	Orders and Decisions of the subjects of the Siberian Federal District "On approval of the list of potentially dangerous objects".

Quantitative values of protection are determined on the basis of the proposed formula (4):

$$Z_{(\tau)} = \frac{1}{3}\left(\frac{N^{A}_{\text{FD}}}{N^{S}_{\text{FD}}} + \frac{N^{A}_{MO}}{N^{S}_{MO}} + \frac{N^{A}_{ER}}{N^{A}_{HIF}}\right) \cdot 100 \geq 100\% \quad (4)$$

где N^{A}_{FD}/ N^{S}_{FD} – actual/standard number of fire stations in the territory under consideration; N^{A}_{MO}/ N^{S}_{MO} – actual/standard number of medical institutions in the territory under consideration; $N^{\Phi}_{\text{АСФ}}$ - the actual number of emergency rescue teams in the territory under consideration; N^{A}_{HIF} - the actual number of hazardous industrial facilities in the territory under consideration..

At the fourth stage, it is necessary to assess the possible risks from the implementation of investment projects in the territory under consideration. It is recommended to analyze possible hazardous events using probabilistic-graphical models, which allows assessing the combined impact of current and future risks.

III. Results

For the Arctic zone of Krasnoyarsk Region, the main dangerous man-made factors were identified, presented in Figure 2. Based on this graphical model, the probabilities of occurrence of events and risk values for each factor are determined. According to the proposed algorithm, state programs and plans for the development of the Arctic zone of Krasnoyarsk Region were further analyzed, which are aimed at creating a regional transport and energy infrastructure, and forming high-tech and competitive territorial clusters.

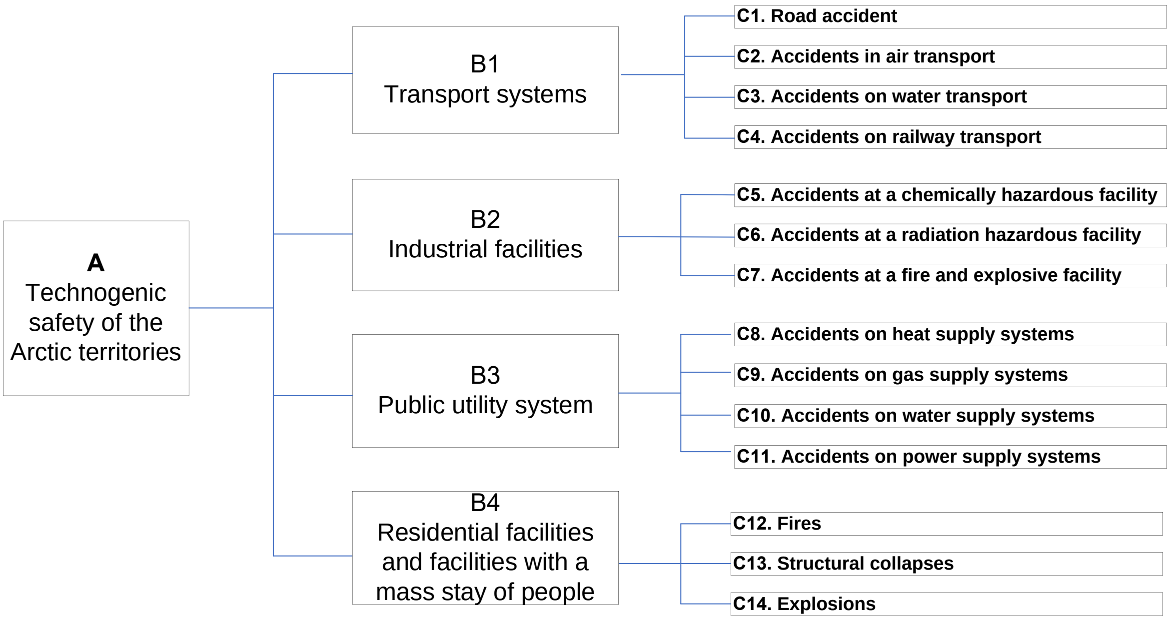

Figure 2: *List of man-made hazards*

Key investment projects for the development of the Arctic zone of Krasnoyarsk Region include [4]:

- creation of a network of latitudinal and meridional railways;
- development of the infrastructure of the Northern Sea Route;
- creation of a new large mining and metallurgical complex in the Norilsk industrial region - the "Southern Cluster" Project;
- development of oil and gas fields;
- gasification of the Krasnoyarsk agglomeration based on the associated gas resources of Evenkiysky district;

- renovation of the housing and communal services of the Norilsk agglomeration;
- development of Arctic and northern tourism.

To assess the current territorial man-made risk, it is necessary to determine the probability of a hazardous event. Figure 3 shows probability distribution diagrams for event groups.

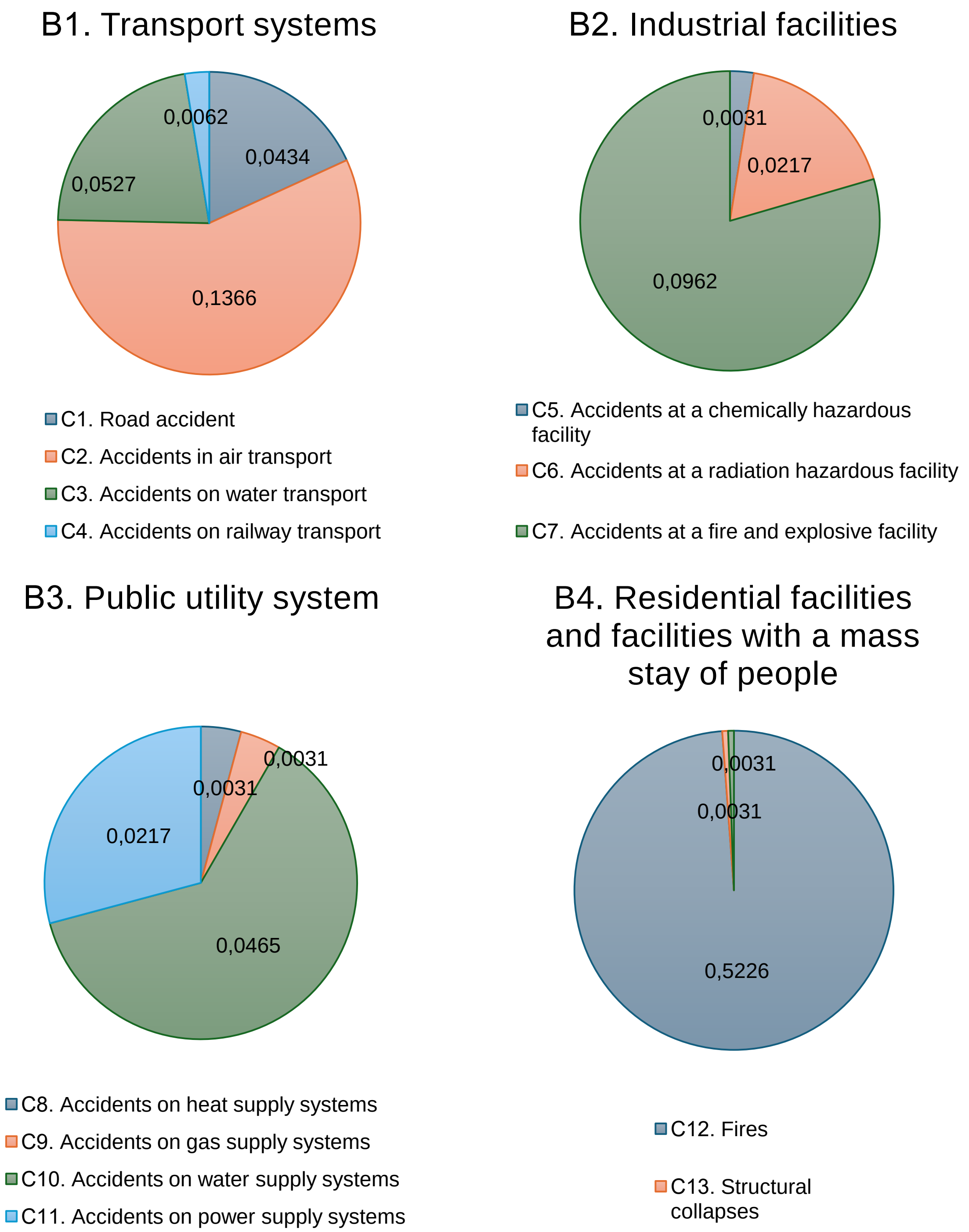

Figure 3: *Probability distribution across event groups*

Based on the obtained results of probability calculation, it can be concluded that the most frequent occurrences are fires, accidents on air transport, at fire-explosion hazardous facilities and on power grids.

Table 2 presents the results of the assessment of territorial man-made risks for each municipality of the Arctic zone and the level of protection.

Table 2: *Territorial man-made risk of the Arctic zone of Krasnoyarsk Region*

The name of the main factors	**The risk of a dangerous factor**			
	Taimyrsky Dolgano-Nenetsky district	Evenkiysky district	Turukhansky district	Norilsk city
Transport systems	$4{,}8 \cdot 10^{-2}$	$5{,}2 \cdot 10^{-2}$	$3{,}6 \cdot 10^{-2}$	$8{,}1 \cdot 10^{-2}$
Industrial facilities	$6{,}1 \cdot 10^{-3}$	$3{,}7 \cdot 10^{-2}$	$1{,}2 \cdot 10^{-2}$	$6{,}4 \cdot 10^{-2}$
Public utility system	$1{,}2 \cdot 10^{-2}$	$1{,}5 \cdot 10^{-2}$	-	$4{,}3 \cdot 10^{-2}$
Residential facilities and facilities with a mass stay of people	$3{,}9 \cdot 10^{-2}$	$1{,}4 \cdot 10^{-1}$	$6{,}5 \cdot 10^{-2}$	$3{,}03 \cdot 10^{-1}$
	The level of protection of territories			
	17%	37%	34%	39%

The Taimyr Dolgano-Nenets and Turukhansky districts are at risk of air transport accidents. The Evenki district has the highest risk of household fires. The greatest man-made hazard is concentrated in Norilsk, which is due to the high population (in comparison with municipal districts), the number of potentially dangerous objects and the intensive traffic of the Norilsk airport. Having identified the dangers arising in the territory, it is necessary to analyze its ability to withstand threats. Municipalities of the Arctic zone have a low level of protection. For the city of Norilsk, Taimyrsky Dolgano-Nenets and Turukhansky districts there are not enough emergency rescue teams, fire departments and medical institutions. For the Evenki district there are not enough fire departments and emergency rescue teams.

When assessing possible future man-made risks, we will consider the emergence of additional threats associated with the creation of a large mining and metallurgical complex in the Norilsk industrial region. We will consider a common scenario of a fire and explosion associated with blasting operations. Fig. 4 shows a probabilistic graphical model for analyzing this scenario.

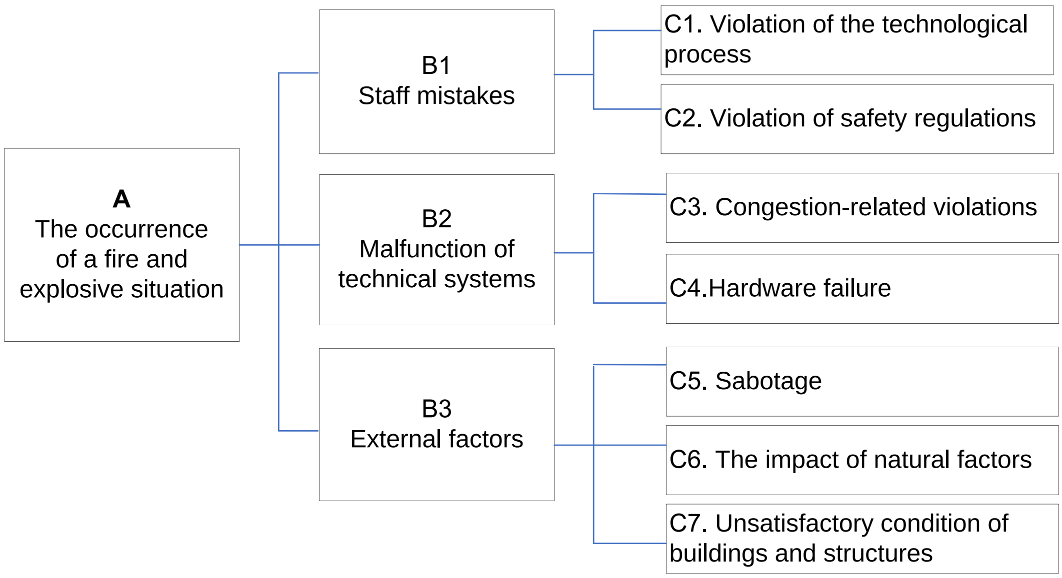

Figure 4: *Cause-and-effect patterns of occurrence of a fire-explosion hazardous situation*

The probability of occurrence of a fire and explosion hazardous situation is 5.6·10-6, the damage from the implementation of this scenario is about 200 million rubles. Thus, the territorial man-made risk from the occurrence of industrial accidents for the city of Norilsk increases from 6.4·10-2 to 6.51·10-2 and this is taking into account one possible accident scenario. Thus, with an insufficient level of protection, high current man-made territorial risks, the implementation of investment projects should be carried out with increased control by the state. Development and exploration of territories should be without damage to future generations.

IV. Discussion

Active industrial development of northern and arctic territories, the development of infrastructure projects and clusters, taking into account special natural and climatic conditions leads to a dilemma between economic growth and an increase in the number of potential dangers associated with the growth in the number of industrial facilities.

Thus, the management of territorial entities should be based on the methodology of risk and security assessment within the framework of the concept of sustainable development and the leading priority of the socio-economic and scientific-technical development of Russia - the security of society and the state. Prevention of hazards can be effective only with the development of a methodological complex of territorial analysis based on a risk-oriented approach.

Man-made systems, natural processes, and territorial formations are subject to the impact of characteristic types of risk that must be specifically identified and necessary measures taken to protect and mitigate the consequences in the event of a hazard, which is especially important for Arctic territories with unique natural complexes, the impact on which can lead to catastrophic consequences.

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References

[1] Zhilina I.YU.. Warming in the arctic: opportunities and risks // Economic and Social Problems of Russia, № 1, 2021. P 66-87. https://doi.org/10.31249/espr/2021.01.04

[2] The global climate threat and the Russian economy: in search of a special path / Energy Center of the Moscow School of Management Skolkovo. - 2020. – 69 p.

[3] Biskaborn, B.K., Smith, S.L., Noetzli, J. et al. Permafrost is warming at a global scale. // Nat Commun 10, 264 (2019). https://doi.org/10.1038/s41467-018-08240-4

[4] The Strategy for the development of the Arctic zone of the Russian Federation and ensuring national security for the period up to 2035 (Approved by Decree of the President of the Russian Federation No. 645 dated October 26, 2020). https://docs.cntd.ru/document/566091182

[5] The Strategy of socio-economic development of the Siberian Federal District until 2035 (Decree of the Government of the Russian Federation No. 129-r dated 01/26/2023). http://government.ru/docs/all/145780/

[6] Berman M., Schmidt J.I. Economic effects of climate change in Alaska // Weather, climate, and society. – 2019. – Vol. 11. P. 245–258

[7] Moskvichev V.V., Postnikova U.S., Taseiko O.V., Efremova I.S. Analysis of the stability of the technosphere of the arctic territories of the Krasnoyarsk territory using probabilistic and graphical models // Computational Technologies. – 2023. – T. 28, № 4. – C. 45-56. https://doi.org/10.25743/ICT.2023.28.4.005

[8] Postnikova U., Taseiko O., Anikin M. Territorial risks assessment of natural hazards // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 111-117.

https://doi.org/10.24412/1932-2321-2023-575-111-117.

[9] Heckerman, D. Dependency Networks for Inference Collaborative Filtering and Data Visualization // Journal of Machine Learning Research. – 2000 – №1. – p. 49–75.

[10] Probabilistic Networks and Expert Systems: tutorial / R. G. Cowell, P. Dawid, S. L. Lauritzen, D. J. Spiegelhalter.– New York: Springer-Verlag, 1999. – 205 p.

[11] Citation: Pan, L.; Zheng, Y.; Zheng, J.; Xu, B.; Liu, G.; Wang, M.; Yang, D. Characteristics of Chemical Accidents and Risk Assessment Method for Petrochemical Enterprises Based on Improved FBN. Sustainability 2022, 14, 12072.

THEORETICAL AND METHODOLOGICAL APPROACHES AND TOOLS FOR THE STUDY OF ENTREPRENEURIAL ECOSYSTEMS: SYSTEM AND NETWORK ANALYSIS

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Abstract

The following paper looks into the development of a comprehensive toolkit for analyzing entrepreneurial ecosystems. The work is examines in the context of the modern digital economy, based on a theoretical and methodological approach.
The dynamic conditions of digital transformation, against the backdrop of global economic instability, have sparked both scientific and practical interest in studying entrepreneurial ecosystems (EEs).
The authors critically examine approaches to defining the essence of entrepreneurial ecosystems, as well as the directions of applied and fundamental research that shape the core areas of related scientific interests. Systematizing the spheres of academic focus within the context of EE research, the authors conclude that, in Russia, particular attention is paid to regional entrepreneurial system development, sustainable development principles, and the assessment of the impact of the digital environment.
The following work studies key ideas underlying ecosystem concepts such as evolutionary theory, organizational ecology, neo-institutional theory, dynamic capabilities theory, and as well as the modular structure. The authors of this paper conclude that an entrepreneurial ecosystem is a complex interaction system, carried out through the creation of network effects and a special connection between cooperation, competition, innovation etc.
It is also essential to mention that by examining the key components of EEs and the fundamental principles of their functioning, the authors of the work outlined major research tracks related to core aspects of entrepreneurship ecosystems:
Access to resources and startup support,
The role of government influence on EE development,
Innovation issues and the commercialization potential of innovative products.
The authors were able to develop a theoretical and methodological approach to studying entrepreneurial ecosystems and classify EEs based on key characteristics.

Keywords: entrepreneurial ecosystems, theoretical and methodological approach, ecosystem actors, classification features of PES, ecosystem concepts

I. Introduction

The current conditions of digital transformation and global economic instability have fueled interest in studying the concept of entrepreneurial ecosystems as one of the mechanisms for business and innovation development. Modern research on entrepreneurial ecosystems progresses in various directions, reflecting a wide spectrum of scientific interests. The main areas can be grouped by themes, as presented in Fig. 1.

1. General Concept of Entrepreneurial Ecosystems

- Application of ecosystem concepts in economic and management research (Ramenskaya L.A.): This work offers theoretical foundations and methodological approaches for analyzing ecosystems in management, including the role of interactions between participants.
- Meaningful analysis of innovation, business, and entrepreneurial ecosystem concepts (Burda Ye.D. et al.): This study covers a conceptual analysis of innovation and entrepreneurial ecosystems, emphasizing innovation and entrepreneurship within ecosystems

2. Entrepreneurial Ecosystems in the Post-Crisis Economy

- A New Entrepreneurial Policy for Russia After the 2020 Crisis (Zemtsov S.P. et al.): The authors examine the opportunities and challenges for the development of entrepreneurial ecosystems in Russia following the COVID-19 pandemic.
- The Role of Entrepreneurship in the Sustainable Development of Rural Areas in Russia (Polbitsyn S.N.): This study focuses on the development of rural areas through entrepreneurship, emphasizing the importance of ecosystems in ensuring sustainable growth.

3. Regional Features and Ecosystem Development in Russia

- Rural Entrepreneurial Ecosystems of Russia (Polbitsyn S.N.): The paper analyzes regional aspects of ecosystem development in rural areas.
- Assessing the Links Between Entrepreneurial Ecosystems and Economic Development Levels in Russian Regions (Ovchinnikova A.V., Zimin S.D.): This study focuses on analyzing the relationship between entrepreneurial ecosystems and the economic development of regions.

4. Technological Entrepreneurship

- Technological Entrepreneurship as a Factor in Russia's Development (Zemtsov S.P.): The research highlights the importance of technological entrepreneurship for long-term economic growth and innovation in Russia.

5. Post-Socialist Economies

- *Entrepreneurial Ecosystems in Post-Socialist Economies* (Chepurenko A.): This work focuses on the specifics of ecosystem development in post-socialist countries, where the institutional environment differs from Western models.

6. Digital Environment Factors

- *The Influence of Digital Environment Factors on the Development of Entrepreneurial Ecosystems in Russia's Regions* (Yakimova V.A., Pankova S.V.): This study addresses the impact of digitalization on the development of entrepreneurial ecosystems, with a focus on regional characteristics

7. International Cooperation and Investments

- *Stimulating Local Entrepreneurship Through Foreign Investments* (Machtama A., Sauka A.): This research analyzes the role of foreign investments in developing entrepreneurial ecosystems in various countries.

8. Innovation and Business Incubators

- *Business Incubators in Russia: A 2020 Survey in International Comparative Perspective* (Slesarev M.A.): This study examines the role of business incubators in Russia and their effectiveness in an international context.

Figure 1: *Systematization of scientific interests in the context of EE research*

Scholarly consensus on the essence of entrepreneurial ecosystems reveals that they are complex systems of interaction between various actors: entrepreneurs, government institutions, investors, and even educational institutions. Together, these entities create the conditions for the emergence and sustainable development of new business structures. The systemic approach applied to studying EEs allows for the identification of key factors influencing the dynamics and stability of such business structures and defines the roles of various participants in creating a favorable environment for entrepreneurial activity.

The relevance of the study is driven by the need to develop a comprehensive toolkit for analyzing entrepreneurial ecosystems in the modern digital economy. Integrating various methodological approaches, including systems analysis, network methods, and institutional theory, offers a deeper understanding of the relationship between actors and the conditions of their interaction. This article proposes a theoretical and methodological framework for researching entrepreneurial ecosystems, with a focus on identifying key structural elements and factors contributing to the development of entrepreneurship.

Thus, research on entrepreneurial ecosystems covers a wide range of aspects, from theoretical and methodological foundations to practical cases of ecosystem development in regions and specific industries. In Russia, particular attention is given to regional development, sustainable entrepreneurship in rural areas, and the impact of the digital environment. Innovation and technological entrepreneurship play a crucial role, particularly in post-crisis economies and post-socialist markets.

II. Methods

Several key methods were applied in the study, including bibliographic analysis, network analysis, and case study methods. The bibliographic analysis allowed for identifying the main scientific discourses and approaches to studying entrepreneurial ecosystems, based on publications from the last two decades. Network analysis was used to map interactions between ecosystem participants, revealing central actors and determining the structure of connections. The case study method, based on the study of specific ecosystems, such as Silicon Valley and Russian technoparks, allowed for a deeper examination of their functioning and the identification of critical success factors.

III. Results

The concept of an entrepreneurial ecosystem involves the creation of a network of autonomous organizations that jointly create value through cooperation and some degree of interdependence. Ecosystems can include various types of participants (commercial organizations, government agencies, NGOs, startups, and other entities) united by the idea that they interact for mutual benefit. However, competition remains, though it is governed by cooperative principles.

Let us examine the key ideas underlying the ecosystem concept:

1. Evolutionary theory and organizational ecology traditionally view ecosystems as biological analogs where participants compete and cooperate, adapting to changes. By applying concepts like "natural selection" and "ecological niches" to the life cycle of EEs, one can explain how these systems are created, survive, and evolve.

2. Neo-institutional theory distinguishes entrepreneurial ecosystems from other forms of systemic interaction, such as markets or entrepreneurial hierarchies. Applying this theory to EEs leads to an understanding of the role of institutions in coordinating system elements and reducing transaction costs through inter-institutional cooperation.

3. Dynamic capabilities theory emphasizes the ability of companies within ecosystems to adapt and transform their development strategies in response to ecosystem changes. This adaptability is key to achieving long-term competitiveness.

4. Modular structure suggests that while ecosystems consist of independent modules, they nonetheless exhibit a degree of interdependence a symbiosis that allows EE participants to create value together, even while maintaining their economic and legal autonomy. This trait is

particularly important for platform ecosystems, where large companies are embedded in a unique interaction architecture filled by its participants as individual modules.

Thus, an entrepreneurial ecosystem is a complex interaction system, where cooperation, competition, and innovation create network effects. The ecosystem enables the participating organizations (the system's modules) to jointly create products and services, discover new business models and solutions, reduce costs, and adapt their activities to external changes.

Let us consider and characterize the main components of the PES (Figure 2).

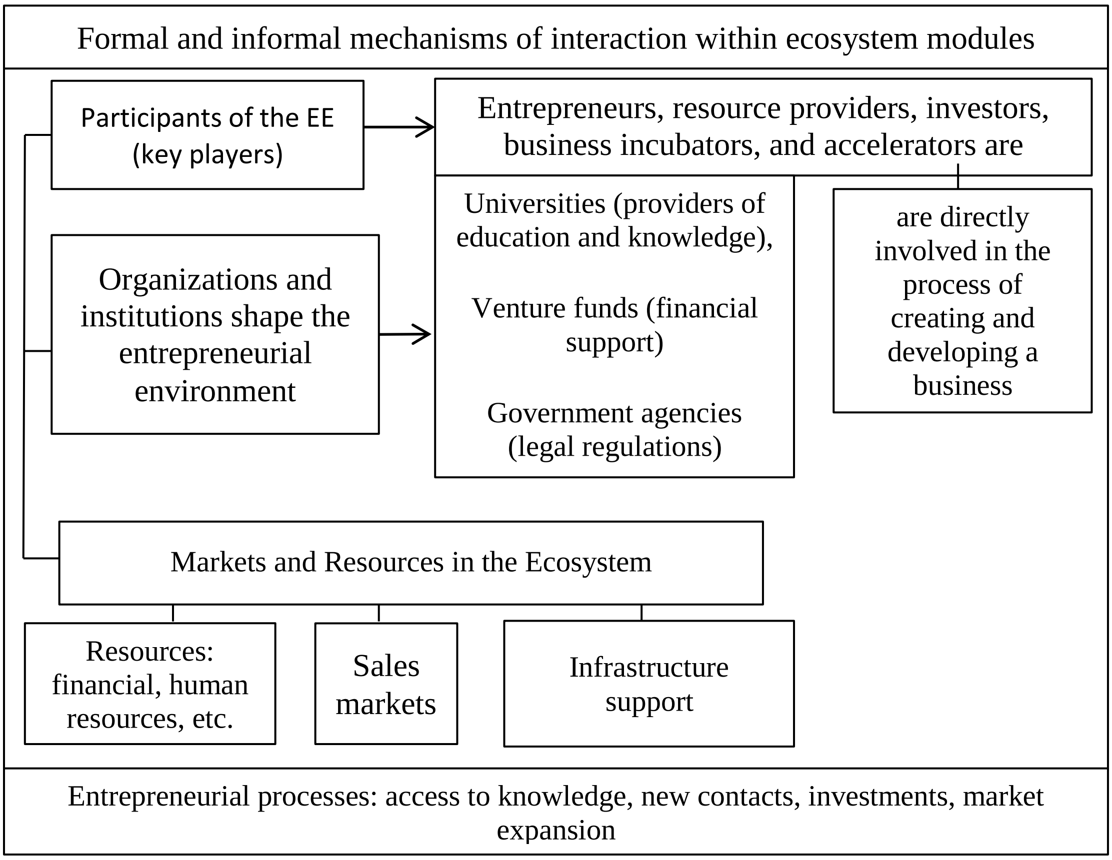

Figure 2: *Key Components of EEs*

The components of an EE, presented in Figure 2, interact based on several principles:

Interconnectedness and Interdependence;

Leadership;

Value Creation;

Flexibility and Adaptability

A classic example of an entrepreneurial ecosystem, which can serve as an academic model, is Silicon Valley. This ecosystem includes system modules such as entrepreneurs, investors, universities, technology companies, and startup creators. Through interaction, these components work together to create a favorable environment for innovation and technological entrepreneurship.

In Russia, analogous structures can be found in technoparks and innovation clusters, where the government provides funding through grants and other support programs.

IV. Discussion

Research into EEs develops along several lines, driven by regional context and the scientific interests of the authors. We have identified three main tracks, which systematize the body of research regarding the fundamental aspects of entrepreneurial ecosystems:

1. Research on access to resources and startup support as the main driver of innovation and project development. This track examines the availability of resources such as finances, knowledge, and connections.

2. Research on the role of government in the development of EEs and the possible or necessary degree of state control over EEs. In this context, the government is viewed as an actor that either facilitates or hinders the creation of conditions for the development of the ecosystem through a system of restrictions, regulations, and support.

3. Innovation and commercialization of innovative products: This track focuses on the innovative entrepreneurial activity of all ecosystem components. The reason for emphasizing this group of studies is that, through synergy, such structures create a collaborative effect that promotes the generation and implementation of new ideas, enhancing their chances of commercialization.

Based on the components of EEs and the principles by which these systems are created, operate, and evolve, as well as the basic research tracks, it is proposed that when creating a theoretical and methodological foundation for the study of these systems, the complex and multi-component nature of the ecosystem approach should be considered. This approach systematically links the connections between ecosystem participants, institutionalizing them and taking into account the processes the system undergoes throughout its lifecycle.

The proposed theoretical and methodological approach to EE research incorporates both theoretical and empirical methods, which will allow for the study of the dynamics, structure, and factors of successful ecosystem functioning.

1. Theoretical and Methodological Foundation of EE Research

1.1 Key Theories (Foundation of Research):

- Ecosystem Theory (Iansiti, Levien, 2004): This theory suggests that ecosystem participants are interdependent, develop together dynamically, and that their co-evolution contributes to value creation;
- Network Approach Theory (Granovetter, 1985): This theory emphasizes the importance of network connections between participants, forming channels for the exchange of resources, knowledge, and technologies;
- Innovation Systems Theory (Lundvall, 1992): This theory primarily considers innovation ecosystems as a key part of the entrepreneurial environment. It highlights the importance of creating such systems for startups and small companies, leveraging networks of partners and their resources to drive innovation;
- Institutional Theory (North, 1990): This theory underscores the role of institutional conditions (through the establishment and enforcement of legal, regulatory, cultural, and other norms) in entrepreneurial ecosystems. Established institutions support the entrepreneurial environment by providing access to resources and reducing transaction costs;

1.2 Research Principles:

- cystematicity: The ecosystem is viewed as a holistic system that includes interdependent elements (entrepreneurs, institutions, resources, infrastructure);
- multilevel Approach: This principle calls for conducting research on the ecosystem at different levels: micro (enterprises, entrepreneurs, startups), meso (local and regional systems), and macro (national ecosystem);
- interactivity: This principle is crucial due to the dynamic nature of EEs, which requires an analysis of the interactions between actors in the exchange of resources, knowledge, and support;
- adaptability: This principle reflects the constant variability of EEs, necessitating the application of flexible approaches to their study and management.

2. Research Methods and Tools

The research methods include both qualitative (descriptive) and quantitative methods.

2.1 Qualitative Methods may include:

- case Studies: The method of studying successful EE examples helps identify key success factors and lessons for other ecosystems;
- surveys of Key Actors: This allows for an understanding of their roles, motivations, and participation in the ecosystem, revealing the dynamics of interactions;
- content Analysis: The study of data presented in reports, results of strategy implementations by large companies and holdings, and evaluation of the effectiveness of government programs help determine key measures that support the development of EEs.

2.2 Quantitative Methods may include:

- social Network Analysis: This method allows for measuring and visualizing connections between various ecosystem participants. It helps identify key participants (leaders), those on the periphery, support modules, and other system elements. This analysis aids in assessing the density of connections, identifying cluster elements, and outlining the overall network architecture;
- statistical Analysis and Econometrics: Using regression models, this method evaluates the correlation between various factors (e.g., access to venture capital and startup success);
- benchmarking: Aimed at comparing different ecosystems, or one's case with a benchmark system, this helps identify factors that contribute to entrepreneurship growth and sustainability, as well as obstacles to it;
- entrepreneurial Ecosystem Development Indices: These indices allow for the evaluation of ecosystem development based on various criteria (access to financing, institutional support, level of innovation, etc.);

2.3 Data Collection Tools: In this case, traditional tools are used, such as secondary data analysis (official reports, statistics, analytical reviews, etc.) and surveys of entrepreneurs and representatives of key ecosystem actors.

3 Research Stages are shown in Figure 3

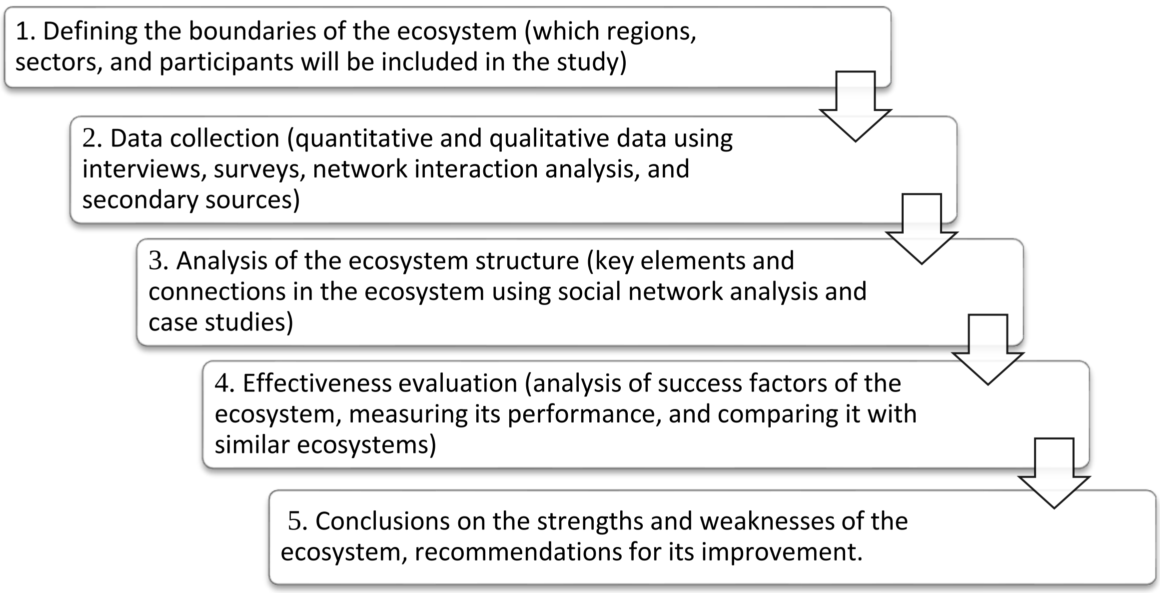

Figure 3: *Stages of Research on Entrepreneurial Ecosystems*

Thus, the proposed theoretical and methodological approach to the study of entrepreneurial ecosystems (EEs) meets the criteria of systematicity and multilevel analysis, combining theoretical and empirical methods for a joint analysis of the dynamics, structure, and factors that influence the functioning and development of ecosystems.

An essential condition for the scientific study of EEs is the systematization of characteristics that define their essence. The classification of EEs by their key features, as proposed by us, is presented in Table 1.

Table 1: *Classification of Entrepreneurial Ecosystems by Key Features*

Classification features	Subtypes	Description
1. Territorial Affiliation	Global Ecosystems:	Interactions and processes at the level of international business and global economies.
	National Ecosystems:	Characteristics of entrepreneurship within a single country.
	Regional Ecosystems:	Local business ecosystems in specific regions (cities, regions, rural areas).
2. Sectoral Focus	Technological Ecosystems:	Related to innovative and high-tech industries (IT, biotechnology, fintech, etc.).
	Agro-industrial Ecosystems:	Ecosystems in agriculture and agro-industry.
	Traditional Industries:	Include entrepreneurship in traditional economic sectors (trade, manufacturing, services).
3. Maturity Level	Nascent Ecosystems:	Ecosystems in the early stages, where infrastructure and connections between participants are still developing.
	Developing Ecosystems:	Ecosystems with basic infrastructure, actively growing through the adoption of technologies.
	Mature Ecosystems:	Stable ecosystems with well-established connections and a solid infrastructure.
4. Target Audience	Small and Medium-sized Enterprises (SMEs):	Ecosystems that support the development of small and medium-sized businesses.
	Large Companies:	Ecosystems interacting with large corporations and international players.
	Startups and Incubators:	Ecosystems aimed at supporting startups and business incubators.
5. Institutional Structure	University-based Ecosystems:	Include educational and research institutions as key elements.
	Corporate Ecosystems:	Ecosystems where large corporations play a leading role.
	Public-Private Partnerships:	Ecosystems developing with strong government support.
6. Technological Focus	Digital Ecosystems:	Structures based on digital technologies (blockchain, AI, Big Data, etc.).

	Analog Ecosystems:	Ecosystems with traditional business methods not related to digitalization.
7. Economic Model	Innovation-driven Ecosystems:	Focused on developing new products and services through innovation.
	Sustainability-oriented Ecosystems:	Include principles of ecological and sustainable growth.
	Investor-oriented Ecosystems:	Ecosystems focused on venture funding and investments.
8. Type of Interactions	Horizontal Ecosystems:	Interaction between participants of equal status.
	Vertical Ecosystems:	Interaction between participants at different levels, including startups and large companies.
9. Ecosystem Resources	Infrastructure-based Ecosystems:	Ecosystems where key roles are played by business incubators, coworking spaces, and technology parks.
	Financial Ecosystems:	Ecosystems focused on financial support (venture funds, grants, etc.).
	Cultural and Social Ecosystems:	Ecosystems that influence entrepreneurship through cultural and social factors.

In conclusion, the theoretical and methodological basis for the study of entrepreneurial ecosystems involves the integration of several theoretical approaches and the use of a wide range of methods and tools. To comprehensively study the ecosystem, a combination of qualitative and quantitative methods is necessary, such as social network analysis, case studies, interviews, and statistical analysis. This approach enables a deeper understanding of the structure and dynamics of the ecosystem and the development of measures to support and enhance it.

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References

[1] Раменская, Л. А. Применение концепции экосистем в экономико-управленческих исследованиях / Л. А. Раменская // Управленец. – 2020. – Т. 11, № 4. – С. 16-28.
[2] Овчинникова, А. В. Оценка связей предпринимательских экосистем с уровнем экономического развития регионов России / А. В. Овчинникова, С. Д. Зимин // Journal of Applied Economic Research. – 2021. – Т. 20, № 3. – С. 362-382.
[3] Шаститко, А. Е. Мезоинституты для цифровых экосистем / А. Е. Шаститко, А. А. Курдин, И. Н. Филиппова // Вопросы экономики. – 2023. – № 2. – С. 61-82.
[4] Природопользование и устойчивое развитие регионов России : Сборник статей Международной научно-практической конференции, Пенза, 26–27 июня 2018 года / Под редакцией И.А. Байракова, И.А. Лушкина. – Пенза: Пензенский государственный аграрный университет, 2018. – 116 с.
[5] Gakaev, R. Functional classification of forests: Study of carbon sequestration / R. Gakaev // BIO Web of Conferences. – 2023. – Vol. 76. – P. 06004. – DOI 10.1051/bioconf/20237606004. – EDN IMHMOD.
[6] R.A. Gakaev, I.A. Bayrakov, M.I. Bagasheva, Ecological foundations of the optimal structure of forest landscapes in the Chechen Republic. In the collection: Environmental problems.

A look into the future. Proceedings of the III scientific-practical conference. Executive editor Yu.A. Fedorov. 2006.pp. 50-52.

[7] R.A. Gakaev, Comprehensive assessment of the current state of the mountain-forest landscapes of the Chechen Republic and measures for their optimization. In the collection: Modern problems of the geoecology of mountain areas, 2008.pp. 189-194.

[8] A.S. Salamova, Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] A.S. Salamova, Global networked economy as a factor for sustainable development, 2020, p. 03053.

[10] Kantyukov R R., Kolybanov K. Yu, Ravikovich V I Information technologies for preparing control decisions in automated systems of environmental monitoring, 2019.

[11] Kampschreur MJ, Temmink H, Kleerebezem R, Jettena MSM, van Loosdrecht MCM. Nitrous oxide emission during wastewater treatment. Water Res. 2019, pp.4093–4103

PROBABILISTIC ANALYSIS IN THE RELEASE OF LIQUEFIED PETROLEUM GASES

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Abstract

In this paper we analyzed the probabilities of accident development in case of liquefied hydrocarbon gas emission taking into account the logistic scheme of accident development. It was found that the probability of ignition of the release is determined by the probability of combustible substance coincidence with the ignition source. It should be borne in mind that the probability of ignition source manifestation depends on the area of the affected object (cloud of gas-air mixture or gas liquid).

Keywords: liquefied gas, risk, probability, accident, logistics scheme, spill combustion, gas-air mixture

I. Introduction

For risk analysis RD 03-48-01 [1] offers 6 methods of analysis. If the theory of risk corresponded to the probability theory, the best method of analysis would be quantitative analysis. Unfortunately, risk theory almost completely ignores the existing probability theory.

To demonstrate the dubiousness of the examination requirements, let us consider a method of analysis that uses an event tree logic diagram.

The logical scheme of the accident development associated with the release of combustible substances at an outdoor facility is presented in Fig. 1.

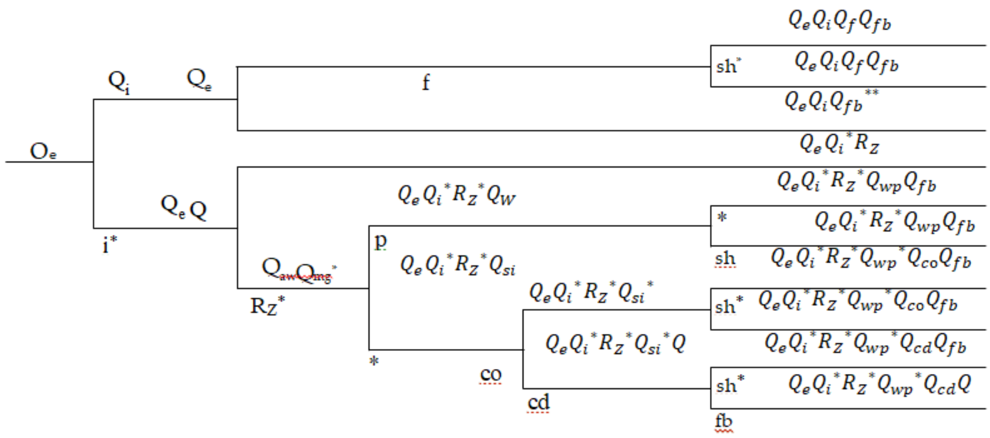

Figure 1: *Logic diagram of an accident involving the release of flammable substances at an outdoor facility*

Decoding of designations on the diagram:

A1 - instantaneous ignition of the flowing product followed by flaring combustion;

A2 - flare combustion, thermal effect of the flare leads to destruction of the nearby tank and formation of a fireball;

A3 - instantaneous release of product with formation of a fireball;

A4 - no instantaneous ignition, the accident is localized due to effective fire prevention measures or due to vapor cloud dissipation;

A5 - instantaneous flashover did not occur, fire prevention measures were not successful, spill ignition;

A6 - destruction of a nearby tank under the influence of excessive pressure or heat during burning of the spill or formation of a fireball;

A7 - combustion of a vapor-air mixture cloud;

A8 - destruction of a nearby tank under the influence of excessive pressure or heat during burning of a spill or formation of a fireball;

A9 - combustion of a cloud with development of overpressure in open space;

A10 - destruction of a nearby tank under the influence of excessive pressure or heat during burning of a spill or fireball formation;

Calculation of the probability Q(Ai) of each of the variants of realization of the logic circuit. For this purpose the following relations are used:

$$Q(Ai)= Q_e Q_i Q_f Q_{fb} Q_{fb}^{*}, \quad (1)$$

Qe - probability of emergency release of a combustible substance;

Qi - probability of instantaneous ignition of the flowing product;

Qf - probability of flare combustion of the jet of the expiring product;

Qfb - probability of destruction of a nearby tank under the influence of a fireball;

Qfb* - probability of preservation of the nearby tank under the influence of the fireball;

$$Q_{fb}^{*}= 1- Q_{fbh}. \quad (2)$$

$$Q(A2)= Q_e Q_i Q_f Q_{fb}, \quad (3)$$

$$Q(A3) = Q_e Q_i Q_{fb}^{**}, \quad (4)$$

Q_{fb}^{**} - is the probability of tank collapse with fireball formation.

$$Q(A4) = Q_e Q_i^{*} R_Z, \quad (5)$$

Qi is the probability that instantaneous ignition of the expiring product will not occur;

P3 - probability that the fire prevention means have fulfilled the task or there was a dispersion of the vapor-air mixture cloud.

$$Q(A5)= Q_e Q_i^{*} R_Z^{*} Q_{wp} Q_{fb}^{*}, \quad (6)$$

P3*=1-P3 probability of failure to fulfill the task by fire prevention means;

Qsi - probability of spill ignition;

$$Q(A6)= Qe\, Q_i^{*}\, R_Z^{*}\, Q_{si} Q_{fb}^{*}\ , \quad (7)$$

$$Q(A7)= Qe\, Q_i^{*}\, R_Z^{*}\ \ Q_{si} Q_{fb}^{*}\, Qco, \quad (8)$$

Q_{si}^{*}=1-Qsi;

Qco – probability of ignition of the vapor-air mixture cloud.

$$Q(A8)= Qe^{*}\ Qi^{*}\ R_Z^{*}\ \ Qsi\ Qfb^{*}\ Qco \quad (9)$$

$$Q(A9)= Qe^{*}Qi^{*}R_Z^{*}\ \ Qsi\ Qfb^{*}\ Qcd^{*}, \quad (10)$$

Qcd = 1 Qco – probability of combustion of vapor-air mixture cloud, with overpressure development.

$$Q(A10) =Qe^{*}Qi^{*}R_Z^{*}\ \ Qsi\ Qfb^{*}\ Qcd^{*} \quad (11)$$

The probability of depressurization of the installation Qe is determined by the equation Qe=Ne/(N installation T), here Ne is the total number of accidental releases of flammable product at installations of this type (the result of static studies), Nst is the number of observed units of installations, T-period of observation, year.

Analysis of the structure of the formula determining the probability of depressurization of the unit indicates that the result of the analysis has the dimension of 1/year.

All subsequent parameters called "probability" (instantaneous ignition, flaring, dispersion, etc.) have no dimensionality.

Probability of instantaneous ignition of the flowing product Qi=0.05

Probability of flare combustion Of=0.0574.

Probability of fireball Qfb at destruction of the nearby tank under the influence of fire (overpressure) depends on the properties of the product and the possibility of its overheating.

II. Methods

According to the data of Taubkin S.I. [2] and Marshall W. [3], a fireball is formed by instantaneous release of a large mass (at least 10 tons) of liquefied gas or superheated liquid. The degree of liquid superheating should be such that at least 35% of the mass of the combustible substance passes into the vapor state.

Overheating of liquid is possible in a tank, e.g. in case of fire inside the bund only if the tanks are hermetically sealed and have no communication with the atmosphere. If the tanks in the project facility are communicating with the atmosphere, a fire inside the bund will cause the product in the tank to heat up. The temperature of the product rises to boiling point at atmospheric pressure. Further temperature rise of the liquid is not possible because the liquid vaporizes at atmospheric pressure. All heat supplied from outside to the product is spent on vaporization of the liquid. For this case Qfb=0.

Probability R3 of fire prevention due to effective fire prevention measures or weather conditions.

$$R3=Nna/(Ne-Ni), \quad (12)$$

Nna - number of accidents in which no ignition of combustible substances occurred.

Ni - number of cases of instantaneous ignition of the expiring product during its accidental release.

Probability Qsi of ignition of flammable liquid spillage

$$Qsi=Nsi/(Ne-Ni-Nna), \quad (13)$$

Here Nsi is the number of spill ignition events in accidents.

Probability Qco of combustion of a mixture cloud formed as a result of release and subsequent vaporization of combustible substances.

$$Qco=Nco/(Ne-Ni-Nna-Nsi), \quad (14)$$

Here Nco - number of cases of cloud combustion in accidents at the plants of this type. Probability Qcd of combustion of vapor-air mixture with development of overpressure is determined by the formula

$$Qcd=Ncd/(Ne-Ni-Nna-Nsi), \quad (15)$$

Here Ncd is the number of cases of combustion of vapor-air mixture with overpressure development.

If statistical data necessary for calculation of probabilistic parameters included in the formulas are not available, the probability of realization of different accident scenarios is calculated by the formula Q(Ai)=Qe Q(Ai)st, where Q(Ai)st-statistical probability of accident development on the i-th branch of the logical scheme. These data for a release of liquefied petroleum gas (LPG) are determined from Table 1.

Statistical probability of different scenarios of accident development with LPG release (data from GOST R 12.3047-98).

Table 1: *The liquefied petroleum gas data*

Scenario	Probability	Scenario	Probability
Torch	0.0574	Cloud explosion	0.0119
Fireball	0.7039	Hot water dispersion	0.0292
Spill burning	0.0287		
Cloud combustion	0.1689	Total	1

Analysis of the statistical probability distribution of LPG release accident scenarios reveals interesting points:

1. The share of scenarios related to ignition of the combustible substance is too high. Out of all emissions only 3% are dispersed and the remaining 97% are ignited. This situation does not correspond to the actual state of affairs. Analyzing the presented statistics, one comes to the conclusion that it is inexpedient to fight against the possibility of ignition of combustible substances. Why to use explosion-proof equipment, install lightning arresters, install grounding systems, if anyway 97% of cases of release ends up with ignition. Let's imagine a situation when to the frequency of 10-41/year of ignitions will be added another 3%. The result will not change.

2. The proportion of hot water dispersion scenarios assumed at 3% does not correspond to the probability of fire source visibility.

3. GOST gives statistical information on the probability of realization of different scenarios for LPG, but where can we find similar information for flammable liquids and gases?

4. The GOST table assigns a statistical probability of 0.0574 to the flaming accident scenario. This data should be used in the calculation of individual risk depending on the value of the conditional probability of harm to humans from flaring hazards. Where is the method for determining the conditional probability of people being hit by a flare? This technique can only be found in journal articles, but it cannot be used because it does not claim to be "timely".

5. GOST provides 2 scenarios of hot water cloud combustion: simple combustion and combustion with overpressure development. From literature sources we learn that a mixture of methane gas with air cannot explode [4], [5]. What is combustion with pressure development can be understood from FSS 105-03, but what is simple cloud combustion, what are its affecting factors, how does it differ from the fire of a flammable liquid spill? It is known that flammable liquids do not burn, burning vapors above its surface. Perhaps by cloud burning we mean the burning of liquid vapors in a spill fire?

Calculation of individual risk, performed in strict accordance with the methodology of GOST, gives its value with the dimension "1/year". In paragraph 6.7 GOST requires that the calculated risk values comply with the requirements of paragraph 6.2. Clause 6.2 - quote: "Fire safety of technological processes is considered unconditionally fulfilled if:

- Individual risk is less than 10^{-8};
- Social risk is less than 10^{-7};

(Note: The permissible values of individual and social risks are given in dimensionless format!)

The operation of technological processes is unacceptable if the individual risk is greater than 10^{-6} or the social risk is greater than 10^{-5}

What does GOST mean by "individual risk?"

Quote: "individual risk: Probability (frequency) of occurrence of fire and explosion hazards arising from an accident at a certain point in space. Characterizes the distribution of risk"

Clause 6.7 of GOST

1. Requires fulfillment of the conditions of paragraph 6.2, in which they forgot to specify in which point of space the value of individual risk should be determined.

2. It sets the permissible level of individual risk in an uncertain point of space as a dimensionless value, and the calculation method presented in this GOST gives the result with the dimension "1/year". The question arises, how can we compare quantities with different

dimensionality?

3. For comparison, we give the definition of "individual risk" presented in the "Methodological Guidelines for Risk Analysis of Hazardous Production Facilities", quote: "individual risk is the frequency of an individual person being affected as a result of exposure to the studied accident hazard factors". If GOST under the individual risk takes into account the probability (frequency) of occurrence of hazardous factors, then the "Methodological Guidelines" take into account the frequency of human injury. But these are completely different concepts.

The methodology presented in GOST is very similar to a house that forgot to make a roof. It is impossible to live in it!

What should be done when it is necessary to address such materials, because there is no statistical data. Our proposal is that the probability of ignition of an emission is determined by the probability of combustion of a combustible substance with an ignition source. It should be borne in mind that the probability of occurrence of the ignition source depends on the area of the affected object (hot water clouds or liquid liquid spills).

III. Result

Based on a logical partitioning scheme for an accident involving the release of combustibles, it is found that the probability of ignition of a release is determined by the probability of combustible combining with an ignition source.

References

[1] RD 03-418-01. Methodological guidelines for risk analysis of hazardous production facilities.

[2] Taubkin S.N. Fire and explosion, peculiarities of their expertise. VNIIPO M., 1999, 600 p.

[3] Marshall V. Basic Hazards of Chemical Production Facilities. M., Mir, 1987

[4] Vodyanik V.I. Burning and explosion of gases. // Journal of Labor Safety in Industry. №1, 2005, p.57-59

[5] Mishuev A.V., Komarov A.A., Khusnutdinov D.Z. General regularities of emergency emissions development and methods of explosive loads reduction to a safe level. // Journal Pozharovzryvzryvo bezopasnost No. 6, 2001, pp. 8-19.p.

INNOVATIVE TECHNOLOGIES AND THEIR IMPACT ON REDUCING TECHNICAL RISKS

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Abstract

In this article, we will talk about technical risks, their nature of occurrence and their impact on the workflow. Modern technologies are constantly evolving, new devices and equipment are appearing, and the range of influence of computer technology is expanding. Scientific innovations make a huge contribution to the development in all spheres of society, old technical devices are being updated with new, more modern and multifunctional ones. The trend in the development of society, the desire to improve qualitative and quantitative indicators and minimize marriage allow us to speak about the relevance of the chosen topic. The use of modern devices makes it possible to use them more effectively in any field, increasing the parameters that favorably affect the growth of the economy, on which the development of both private companies and the state as a whole depends.

Keywords: technical risks, innovative technologies, computer technologies, digitalization, innovative risks

Innovative technologies play a big role in the modern world. The use of machine labor and computers can replace human labor in many industries, both physical and mental. The desire to improve performance and minimize risks forces manufacturers to purchase new equipment capable of performing a much larger list of functions than the previous one. Many different scientific papers have been carried out on this topic, thousands of studies have been conducted taking into account the effectiveness of the introduction of innovative technologies, which allows us to talk about the right approach in this direction.

So, technical risk is the probability of an event causing system malfunctions related to equipment malfunction, failures in technical infrastructure, reduced productivity, etc. Technical risks negatively affect the economic development of the company, its image, the quality of products, and also cause delays in the timing of orders.

There are many types of technical risks in the production and sale of products, we will discuss the most likely of them:

- Engineering errors. When planning a project, it is necessary to take into account many significant factors that affect both the performance of equipment and its high-quality performance. All these responsibilities fall on the shoulders of engineers, whose mistakes can significantly reduce the overall performance of the entire company.
- Defects in raw materials. This factor does not depend on the company that manufactures and sells products, but on the delivery company. The delivery of low–quality goods, the presence of defects in blanks, delays for various reasons - all this affects the number of products produced, compliance with deadlines and the image of the company as a whole.
- Manufacturing errors. When manufacturing goods, it is necessary to strictly follow the instructions, comply with safety requirements when working with hazardous production facilities and use the equipment for its intended purpose. To do this, it is necessary to competently

hire staff and train them to work with new devices that have not previously been used in the course of their activities.

• Sales of products. Most companies that produce products offer services for delivering goods to the buyer. There are two ways to hire employees yourself or use the delivery services of transport companies. For the first option, it is necessary to consider the terms of delivery so that during transportation the products are not damaged and spoiled, delivered to the buyer ready-made. The second option involves cooperation with other entrepreneurs or companies, when concluding a contract with which it is necessary to take into account the experience of its representatives, transportation conditions, well-chosen personnel and many other factors affecting the delivery of manufactured goods to the consumer.

There are many factors that negatively affect technical risks, let's talk about the main ones:

- Low level of scientific research. This type belongs to the criteria of production safety. The scientific technologies used do not meet the proper level of safety, which leads to negative consequences.
- Low level of development work. The choice of potentially dangerous design schemes and principles of operation of technical systems, errors in determining operational loads, incorrect choice of structural materials, insufficient margin of safety, lack of technical safety equipment in projects – all this increases the level of technical risks of production.
- Pilot production of new equipment. The use of outdated equipment or low-quality devices that have not been properly tested. Maintaining documentation of safety criteria and compliance with all requirements is also an important aspect of maintaining production.
- Serial production of unsafe equipment. A violation in the chemical composition of the products produced, inaccuracy in the proportions of the components used, inconsistency of the specified dimensions of the finished product, errors in choosing the temperature during production, violation of the instructions in the sequence of actions performed – all this leads to increased technical risks and reduced work efficiency.
- Violation of the rules of safe operation of technical systems. When using the equipment, it is necessary to observe all prescribed precautions – use the devices only in cases specified by the manufacturer, observe operating modes, do not overload or overheat the equipment, carry out professional repairs of damaged equipment and check its operability in a timely manner, adhere to safety measures during transportation and use of equipment, etc.
- Staff mistakes. Perhaps one of the most important reasons for the occurrence of technical risks is the incompetence of the people working behind the entrusted equipment. It is necessary to constantly improve the skills of personnel, conduct discourses and educational programs, and train them to work with new devices. Important are the personal qualities of workers – discipline, responsibility, stress tolerance, the ability to make quick right decisions in case of emergency situations, etc. It is necessary to pay due attention when applying for a position, take into account previous experience and characteristics from previous work.

In the context of digitalization of society, these problems can be solved using computer technologies used in the development and modeling of projects, improving and optimizing equipment, training personnel through video lectures, signing cooperation agreements and purchasing goods with other companies, placing orders through online resources and much more.

However, with the introduction of scientific technologies, a new problem appears – innovative risks, indicating the likelihood of losses when introducing innovative technologies. In other words, innovation risk is the consequences that an enterprise may face when introducing innovative technologies.

There are several types of innovative risks that can lead to a deterioration in the quality and quantity of manufactured products, here are some of them:

- Lack of financial resources. Lack of financing to achieve the company's goals – purchase of new raw materials, purchase of new modern equipment, maintenance and repair of damaged devices, and many other factors that cause lag and contribute to downtime in production.

- Underestimating marketing when planning a project. This type of risk may arise due to improper use of the budget, in which there will not be enough funds for good advertising of goods, which will lead to a large difference between the products produced and sold, will entail stagnation in production, and, as a result, losses to the company.
- Changing consumer needs and demands. The changing structure of the modern market significantly complicates the choice of manufactured products from the manufacturer, because the demand for the supplied goods can significantly decrease. The solution to this problem can be a constant analysis of supply and demand in the market, and in case of its decline, the opportunity to change the direction of production to other, more relevant and purchased goods.
- Lack of raw materials and materials used. With the introduction of new technologies, the production process changes significantly, especially in cases where completely new products are produced. To do this, it is necessary to correctly assess the available budget and use it to the maximum benefit. The manufacturer should think in advance about the suppliers from whom he will purchase materials, calculate how much and what kind of raw materials are needed for this type of product in order to avoid a shortage of one raw material and an excess of another.
- Data leakage within the company. The production of new products, especially new ones for the existing market, should always remain secret until the moment of product sale. In order to avoid disclosure of information, it is necessary to clearly identify the circle of people who may know about the planned deliveries. Otherwise, competitors are able to steal the idea and launch this industry into mass consumption faster, which can significantly reduce projected sales revenues and lead to losses for the company.
- Copyright of scientific technologies. When using new directions, it is necessary to make sure that these innovations do not have copyright. Otherwise, the owner may demand a percentage of the profit received, which will bring huge losses to the company.
- Delays in production dates. In fact, this species combines the first and fourth species mentioned above. All these factors negatively affect the entire production process, from the purchase of goods and creation to the delivery of the finished product to consumers. This can lead to delays and downtime, loss of clientele and investors, and loan arrears if creditors' money was used during the sale.

There are innovative risks at each stage of production – at the stage of project planning, purchasing new equipment and updating old equipment, using purchased equipment.

Consider the sources of innovation risk:

– financial (arise as a result of improper management of financial flows). They are divided into portfolio (the impact of macroeconomic indicators on the assets of enterprises), currency (changes in the exchange rate) and interest (changes in interest rates in the case of borrowing funds);

– insurance (related to the possibility of insured events);

– marketing (low-quality marketing research);

– commercial (losses arising in the process of selling goods or services, or in case of loss of profit);

– industrial (disruption of production from equipment failure to destruction of buildings);

– investment (the possibility of non-repayment of invested funds);

– political (the possibility of changing the socio-political situation);

– environmental (the likely onset of environmental degradation, which led to a deterioration in the quality of forest, water, land, air conditions, as well as a change in the life and health of third parties).

Based on the opinion of the author, E.G.Zakharenko identified such risks as:

1) external, risk-related effects of direct (suppliers, competitors, consumers, investors) and indirect (politics, economics, social sphere, ecology, force majeure) impacts on project performance;

2) internal, including resource and organizational-production (management and risks of interaction within project teams).

Innovation risks are closely related to economic risks. The main economic risks in the Russian Federation today include:

– the federal budget deficit;

– decrease in the volume of the reserve fund;

– a noticeable increase in the unemployment rate;

– decrease in the inflow of foreign investments into the Russian economy and the outflow of Russian investments abroad;

– a sharp drop in the exchange rate of the Russian ruble and the stock market caused by external factors.

Project risk analysis is an important part of the innovation planning process. It occupies one of the leading places along with goal setting, budget development, and approval of the project plan.

Of course, in order to avoid financial losses, it is necessary to try to reduce innovation risks. Here are some of the ways to minimize them:

– avoidance – rejection of projects with a high level of risk (this is typical for risk-averse investors who do not expect a high level of income from financial investments);

– localization – concentration of high-risk activities within one structural unit or territory (such a policy will protect other units from the consequences of the occurrence of a risky event);

– dissipation – distribution of risk in time and space;

– diversification – working in several markets, in different fields of activity, with different partners;

– reservation (formation of a reserve fund in case of failures in financing or losses during the implementation of an innovation);

– insurance (using the services of third–party insurance companies and choosing the most optimal insurance system) - risk distribution between performers and projects;

– diversification (dispersion) of risks for unrelated projects;

– hedging (reducing the risk of adverse (as a result of market factors) changes in the price or expected cash flow of one instrument by using another instrument associated with it as part of the project);

– limitation (introduction of a limit on expected project costs);

– transfer of risk to another person in case of exceeding the maximum acceptable value for the enterprise.

In order to avoid significant financial losses, insurance is used that can compensate for part of the losses incurred as a result of production. With the help of insurance, it becomes possible:

- To compensate for losses or lost profits. With an increase in the number of negative risk factors, the insurance company can return to the entrepreneur part of the funds spent on compensation for losses, which will help the production to survive the crisis more easily.
- Coverage of damage from possible negative events. This aspect refers to events that can lead to damage to property, equipment, finished products and other forms of ownership, compensation for the loss of which the insurance company is able to reimburse.
- Compensation for damage caused by a third party. In cases where the actions of other persons, both individuals and legal entities, have led to losses of the company, the insurance company can reimburse all losses of the organization.
- Compensation for investment losses. In the case when new technologies not only did not benefit, but also led to losses of the organization, the insurance company will help to recover the costs.

As we have already understood, insurance companies help entrepreneurs to use innovative technologies more safely when doing business, covering part of the costs in case of unsuccessful attempts at reorganization. This leads to an increase in the number of new developments in this area, increasing the economic development not only of an individual enterprise, but also of the state economy as a whole. It is necessary to develop this institution, help firms use all available resources to achieve new goals, develop in the chosen direction and develop the state economy through trade both within one country and on the world market.

It is necessary to mention one more concept – competitiveness – the ability of an enterprise to compete adequately with other similar firms and develop effectively in a market economy. This quality expresses the ability of an organization to change the direction of its activities depending on customer demand, anticipate possible risks and avoid them with minimal consequences for its budget. There are many factors – the field of activity, consumer demand and opportunities, mainly financial, the willingness of managers to global changes, etc.

Obviously, manufacturers are not able to see the future in order to know at what point production may come to a standstill. However, it is necessary to have a backup plan, especially typical for unstable market relations, with which you can not only avoid a production crisis, but also reach a new level of company development, deferred funds that can be used to change the course of business without drastic losses.

The state is interested in supporting private business and protecting it from potential risks, so there are various programs to identify the most vulnerable places in production planning. For example, the St. Petersburg University of Information Technologies of Mechanics and Optics has created a risk register that allows you to record and track all factors affecting innovation risks. This mechanism is used at all stages – project development, organization of supplies and purchases of raw materials and equipment, manufacture of goods, etc., contains all the basic data about risks, their changes, possible consequences, people responsible for working in different directions, as well as ways to prevent and minimize consequences.

In particular, this educational institution has developed an Information Management Decision-Making System that allows you to keep a risk register and assess its importance, conduct test activities for new employees who want to get a job at the enterprise, take into account their professional qualities and much more. As mentioned earlier, well–chosen staff is a reliable way to protect against many factors of existing risks.

Based on the conducted research, it can be noted that most innovation risks are associated with limited financial resources. In the course of activity, the costs for each stage of production formation often exceed the expected ones, new areas appear for which funds need to be allocated, prices rise due to inflation, etc. Recently, the number of companies aimed at creating and selling products has increased, but the quality of the goods produced is not always the best.

Everything is complicated by the budget of the organization – miscalculations in the purchase of goods lead to the purchase of cheap but lower–quality raw materials, lack of funds for equipment - the use of old, less efficient devices and many others. All this leads to the appearance of cheaper, but less high-quality products.

Summing up the above, I would like to remind you once again about the existing technical risks. As mentioned earlier, it is impossible to predict at what stage of the company's development losses will appear, but they can be prevented and minimized.

In this article, we discussed the most possible factors that negatively affect the development of production facilities, which can cause significant losses to the efficiency and image of the company. In addition, we have studied the nature of their occurrence, the main causes of their occurrence and ways to eliminate them.

The use of information technologies, on the one hand, makes it possible to avoid technical risks by optimizing production, improving equipment, replacing human labor, using risk registers, etc., but on the other hand, they carry new problems, the use of which does not guarantee an absolute result.

Another important factor that I would like to mention again is the search for qualified and responsible employees who are able not only to do their job competently, but also to be prepared for emergency situations. It is necessary to constantly improve the level of knowledge of the team – to conduct educational courses on working with equipment, to remind them about compliance with safety regulations at work, to send them to study courses, to apply mentoring, etc.

By observing all the above rules and hiring competent analysts who are able to constantly monitor changes in market demand, an entrepreneur will be able to protect himself and his company from many factors that negatively affect the improvement of his company, effectively develop his company and the economy of the state as a whole.

References

[1] Zakharenko E.G. Risks of carrying out experimental design work in 2017 // Naukovedenie. 2017. Vol. 9. №.4.

[2] Chernikova A.E. Features of innovative project management // Young Scientist. 2016. № 24 (128).

[3] Dubinyak T.S., Olekhnovich S.A. Risks of an innovative project // The online journal "Science Studies". 2016. Vol. 8. №. 5.

[4] Zinchenko L.A. Improving the risk management system in the process of development of entrepreneurial structures / Diss. for the academic degree. Candidate of Economics.Sciences, St. Petersburg State University, 2019.

[5] Audretsch D.B., Mahmood T., 1995. ‘New Firm Survival: New Results Using a Hazard Function’, Review of Economics and Statistics, 77, 97-103.

[6] Cefis E., Marsili O., 2011. Born to flip. Exit decisions of entrepreneurial firms in high-tech and low-tech industries. Journal of Evolutionary Economics 21, 473-498.

[7] Dockner J.E., Siyahhan B., 2015. Value and risk dynamics over the innovation cycle. Journal of Economic Dynamics & Control, 61, 1-16.

[8] Ericson, R., Pakes A., 1995. Markov-Perfect Industry Dynamics: A Framework for Empirical Work, Review of Economic Studies, 62, 53-82.

[9] Fernandes A.M., Paunov C., 2014. The risks of innovation: are innovating firms less likely to die? The Review of Economics and Statistics, 1-58.

[10] Hagedoorn J., Cloodt M., 2003. Measuring innovative performance: is there an advantage in using multiple indicators? Research Policy, Vol.32. № 8. P.1365-1379.

CALCULATING THE COLLISION RISK OF A MOBILE ROBOT WITH A FUZZY CONTROLLER IN AN ENVIRONMENT WITH DYNAMIC OBSTACLES

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Abstract

Research on navigation of mobile robots in uncertain dynamic environments is of great importance. This article is focused on solving existing problems such as planning, optimization, failure in difficult situations, and error rate vector prediction under constantly changing uncertain conditions. The aim of the conducted research is to propose a multilayer fuzzy logic model based on decision making for robots to find safe path navigation by overcoming any kind of obstacles and to understand collision-free movement of mobile robots in an uncertain dynamic environment. In this study, fuzzy logic control prediction and multilayer solution priority rules are used to improve the quality of the next position based on the path length, safety and realization time. For this purpose, the article considers the topic of calculating the risk of collision with obstacles for planning the trajectory of a mobile robot with a fuzzy controller in an environment with dynamic obstacles.

Keywords: dynamic mobile robot, fuzzy approach, dynamic obstacle, membership function, risk assessment, fuzzy inference.

I. Introduction

In modern times, there is a great interest in robotic devices in all fields of industry, computer systems, scientific research centers, service works, household and agriculture. That is, they are considered necessary and an important factor in all fields. The replacement of humans in dangerous and military operations by robots has led to an increase in researchers' interest in mobile intelligent robots [1]. It is very important for mobile robots to plan the trajectory of an optimal free path by overcoming obstacles from their starting point to the final target point based on indicators such as time, distance and energy [2]. The goal of mobile robot is to understand the environment, interpret received data, improve knowledge about its position, overcome obstacles by controlling the turning angle and linear speed of the mobile robot, and to plan the route from the starting point to the final position [3]. Path planning in static environments is a well-studied and efficiently solved problem. However, the problem of robot trajectory planning in an environment presence several dynamic obstacles is still has not been solved. This is due to the need to add time dimension in trajectory planning [4].

Classical approaches to planning mobile robots are inadequate. Such approaches cannot overcome the challenges of dynamic environments or inadequate information about the environment [5,6]. Therefore, some reactive (i.e., taking action after the occurrence of events not taken into account in advance) approaches are presented. The application of these approaches allows to learn, justify the main task and use artificial intelligence methods in solving problems. In this work, artificial intelligence methods, including fuzzy logic and neural networks are form the basis of navigation systems in mobile robots [7-9]. Fuzzy logic (FL) is a type of artificial intelligence that describes human thoughts and decision-making. Fuzzy logic allows interpretation of intermediate values between traditional values, such as yes/no, true/false, high/low and etc.. Fuzzy logic approaches have been used in many studies on mobile robot navigation [10].

A number of approaches have been proposed in various research studies related to the pre-planning and analysis of the robot's motion trajectory. Comparing the approaches proposed in this study with other intellectual and heuristic methods is an effective way to solve the previously mentioned problems and make effective decisions in complex situations. Especially, the combination of our approach with fuzzy logic is one of the most important types of intelligent hybrid systems. In the fuzzy logic control system, the priority and prediction rules of the multilayer decision-making approach are used to improve the quality of the next position related to the working time, the safety conditions in risky situations, and the trajectory. Fuzzy systems are still used because planning is still difficult when there are some dynamic obstacles. This is because planning is included as an additional dimension to the search space explored by the planner. Moving obstacles and their velocity vectors are not known in advance. Other approaches to planning mobile robots are not powerful enough and cannot overcome the challenges of mixed complex situations where the environment is dynamic and unknown.

In this research work, a multilayer decision-based fuzzy logic approach is proposed for obstacle avoidance based on velocity vector of dynamic obstacle and priority behavior. Planning the navigation of a mobile robot in a complex dynamic environment and performing sensor-based planning tasks are the essence of this approach. To make the proposed approach more efficient and intelligent, it is considered appropriate to use fuzzy logic controllers. These controllers evaluate the robot's next-state prediction procedure in the action area and enable optimal decision-making. The best next step of a mobile robot is selected based on several proposed criteria for solving sensor-based planning problems in both risky and complex dynamic uncertain environments. These criteria are prepared by the rules of the proposed approach and transformed into fuzzy variables to create a fuzzy reasoning system.

II. Mathematical modeling and kinematics of a mobile robot

Mathematical modeling of a mobile robot in a environment with dynamic obstacle includes a risk calculation based on finding the distance between the robot's platform and the nearest obstacle to the left, front, or right at each program iteration. The distance to the nearest obstacle is determined by a measuring sensor placed on the platform of the mobile robot.

Figure 1 provides a graphical representation of the distances between the platform of the mobile robot and the obstacles.

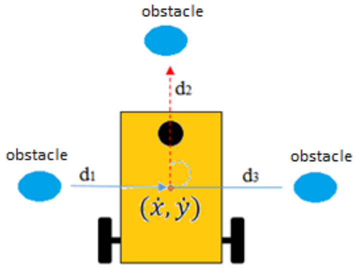

Figure 1: *Distances between the platform of the mobile robot and the obstacles*

In the computer modeling of the mobile robot, dynamic moving obstacles whose position in its working zone is unknown were considered. The result of the measurements performed by distance measuring sensors in their Cartesian coordinate system is known at each program iteration. The modeling involves the problem of measuring the distance between all transmitters of the mobile robot and dynamic obstacles with unknown position during each program iteration. The distance between the mobile robot and obstacles is determined by the formula (1) [1,2]:

$$d_{Si} = \sqrt{(x_m - x_{Si})^2 + (y_m - y_{Si})^2} \quad (1)$$

there are (x_m,y_m) – coordinates of the obstacle; (x_{Si},y_{Si}) - are the coordinates of the i^{th} measuring sensor. If the obstacle is the left dynamic obstacle (or right , or front dynamic obstacle), (figure 2), the distance between the measurement sensor and the obstacle is calculated as follows:

$$d_{Si} = \sqrt{(x_{ci} - x_{Si})^2 + (y_{ci} - y_{Si})^2} \text{ , } i = \overline{1,3} \quad (2)$$

There is (x_{ci}, y_{ci}) – are presented as the coordinates of the nearest point indicating the distance from the i^{th} measurement sensor to the obstacle (Fig. 2).

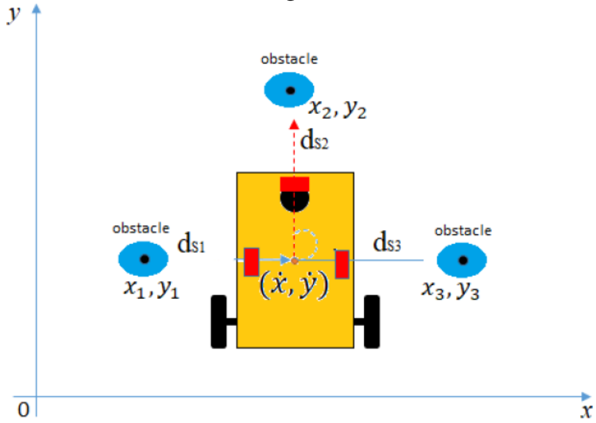

Figure 2: *Graphical representation of the distance between a mobile robot and a dynamic obstacle*

In practical terms, employing geometric techniques for distance measurement via sensors is not deemed significant. Currently, dynamic obstacles with unspecified positions may have varied shapes and placements. The sensor covering mounted on the mobile robot's working body is positioned to establish contact with obstacles.

The placement density of the measurement sensors should be arranged in such a way that the invariable (i.e., static state) zones of the sensor cover are not taken into account [7].

During the calculation of the distance between the mobile robot's platform and nearby obstacles, any objects within the sensing range of the distance sensors on the platform are considered obstacles. In computer modeling, the information (input data) received from all sensors represents the input parameters of the function. Based on the input data, the distance between each sensor and the nearest dynamic obstacle is determined.

In the process of developing the intelligent planning system of real-time displacement of a mobile robot in an uncertain environment, it is necessary to take into account a number of its characteristics, for example, the size and maximum speed of the platform of the mobile robot, the discretization period, the type of mechanical connection between the motor and the wheels.

There are two typical configurations of a mobile robot: a differential and a classic three-wheeled mobile robot (Figure 3) [8].

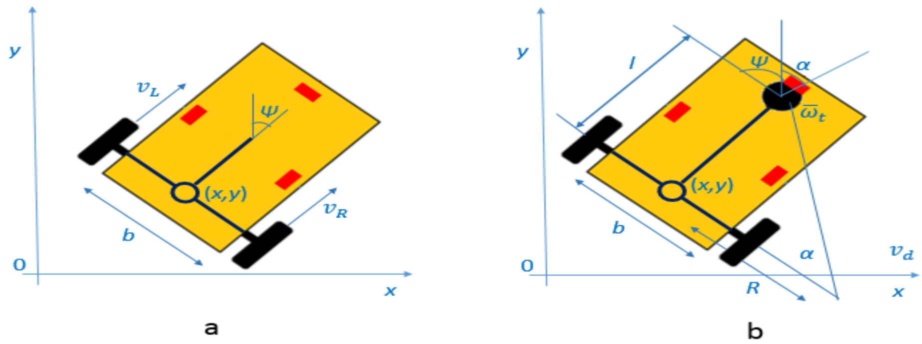

Figure 3: *a) differential və b) a classic three-wheeled mobile robot configurations*

The differential configuration of the mobile robot uses independent velocities on both wheels (left and right wheels, VL and VR) to move it to a specific point (x, y) in a two-dimensional plane and in a specific direction Ψ.

The displacement of the three-wheeled mobile robot towards a target point and its direction are determined by utilizing a single controlled speed and angle applied to one wheel. The research focuses on a differential mobile robot as the subject of investigation.

In the differential mobile robot model, ωL and ωR represent the angular velocities of the left and right wheels. The radius of the driven wheels is denoted by r, and the distance between the two wheels is denoted by b. Assume that solid objects placed on the platform of a mobile robot move on a non-deformable horizontal surface. At any moment, the current coordinate (x, y) and rotation angle (ψ) of the mobile robot in the Cartesian system are known (Fig. 3).

The movement parameters of the mobile robot in the working area are calculated by the following formulas [1,5]:

$$q = [x \;\; y \;\; \psi \;\; \Phi_L \;\; \Phi_R\,]^T \tag{3}$$

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} \text{-}sin\,\psi & 0 \\ \text{-}cos\,\psi & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V \\ \omega \end{bmatrix} \tag{4}$$

Here: x, y – the current coordinates of the mobile robot.φ_L- rotation angle of left wheel;

φ_R- rotation angle of right wheel;

ψ – turn angle of the mobile robot.

The corresponding linear and angular velocities of the mobile robot are defined as:

If we replace statements (5), (6), (7) with (4):

The current coordinate and rotation angle of the mobile robot – (x, y) and Φ are determined from the following equation [9]:

$$V = \frac{V_R+V_L}{2} = \frac{\omega_R+\omega_L}{2} r \tag{5}$$

$$\omega_L = \frac{d\Phi_L}{dt} = \frac{V-(b/2)\omega}{r} \tag{6}$$

$$\omega_R = \frac{d\Phi_R}{dt} = \frac{V+(b/2)\omega}{r} \tag{7}$$

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} \text{-}rsin\,\psi/2 & \text{-}rsin\,\psi/2 \\ \text{-}rcos\,\psi/2 & \text{-}rcos\,\psi/2 \\ \text{-}r/b & r/b \end{bmatrix} \begin{bmatrix} \omega_L \\ \omega_R \end{bmatrix} \tag{8}$$

Based on the obtained equation (9), the current coordinate and direction of the mobile robot over time is calculated as follows [9,10]:

$$\dot{x} = \frac{r\cos\Psi(\omega_R+\omega_L)}{2}$$
$$\dot{y} = \frac{r\sin\Psi(\omega_R+\omega_L)}{2} \qquad (9)$$
$$\dot{\Psi} = \frac{\omega_R-\omega_L}{b}r$$

here, Ψ_{Li} – relative rotation angle of the left wheel;

Ψ_{Ri} – relative rotation angle of the right wheel.

By determining the displacement of the wheels of the mobile robot, the calculation of its current coordinate is performed taking into account the already known position of the robot. The relative rotation angle of each wheel is measured by means of position sensors placed on the axles of the electric motors.

$$\begin{cases} x_i = x_{i-1} + \frac{r\cos\Phi(\Delta\Phi_{Ri}+\Delta\Phi_{Li})}{2} \\ y_i = y_{i-1} + \frac{r\sin\Phi(\Delta\Phi_{Ri}+\Delta\Phi_{Li})}{2} \\ \Phi_i = \Phi_{i-1} + \frac{r(\Delta\Phi_{Ri}+\Delta\Phi_{Li})}{b} \end{cases} \qquad (10)$$

Equation (10) shows that the movement coordinates and direction of the mobile robot depend on the measurement accuracy and geometrical parameters (the radius of the wheel–r, distance between the two wheels –b) of the rotation angle of the wheels.

Table 1 lists the values of the parameters of the studied robot model.

Table 1: *Mobile robot parametrs*

Parameters	Values
The mobile robot's platform size, m	0.50
Distance between drive wheels -b, m	0.40
The radius of the wheel -r, m	0.042
Engine type	12V DC
Maximum engine speed, dövr/dəq	120
Discretization period, s	0.028

Based on the data in Table 1, the values of the following parameters of the mobile robot can be calculated:

- number of iterations per second: $\frac{1}{0{,}028} = 36$
- the maximum displacement step of a wheel in each iteration:

$$\frac{100*2\pi*0{,}042}{60*36} = 0{,}0122 \text{ m.}$$

Finding a suitable collision-free path connecting the initial position p0 at the initial time t0 of the mobile robot with the final position pend at the time tend can be considered as a navigation problem (task). In the environment with dynamic obstacles, it is important to determine the velocity vector of each obstacle, especially the displacement of obstacles in different directions towards the moving robot, the number of iterations in one second and the maximum displacement step of one wheel in each iteration.

The main problem here occurs when the robot decides to move inside the dangerous area where 3 obstacles moving in an unknown direction move towards each other and collide with the next position. Since the robot has a different solution to avoid obstacles in each movement, it cannot choose how to avoid them. For example, the decision made by the robot to avoid an obstacle moving to the right is to move to the left, but the decision made by the robot against obstacles moving to the left and forward direction is different from this decision [11]. Therefore, a collision will occur as long as the robot cannot predict the dangerous area, i.e. predict and change its state to another state with a lower risk of collision and obstruction. In order to solve the problem, the development and realization of the intelligent planning system of the predicted navigation of the mobile robot in an unknown dynamic environment was considered.

The main goal in this section is to guide a robot moving under uncertainty to choose the most optimal next step between positions without collision with dynamic obstacles. A fuzzy control system is developed to verify the forecasting process and decisions about the next position and to choose the best positions in terms of minimum risk. This control is activated after the next step finds a position away from the collision. The values of three fuzzy variables, including left dynamic (LeftD), front dynamic (FD), and right dynamic (RightD), are calculated by the control for each iteration.

The first fuzzy variable (FV) is the distance to the left (right or front) dynamic obstacle, defined as intersection points (IP) between the sensor range and the obstacle. The robot learns to determine the safe distance to the left (right or front) dynamic obstacle when detected through this part of the control. The control measures the intersection points between the sensor layers and the obstacle. If the obstacle intersects the top layer of the sensor, it means that the obstacle is far from the robot. At the same time, if the obstacle crosses the middle layer of the sensor, it indicates that the distance between the obstacle and the robot is safe. However, if the intersection occurs with a lower layer, the robot is close to the obstacle. By extracting these values, we obtain the values (FV) to be used in future fuzzy control. This variable can be formulated as follows [11]:

$$Sensor\ layers\ (R_i = 0.2, 0.4, 0.6, 0.8), Range\ quarters\ (q_j = 1, 2, 3, 4^{th}) \quad (11)$$

$$IP = (n, R_x(q_j, :), R_Y(q_j, :), x_{polygon}, y_{polygon}) \quad (12)$$

Function [distance] = to obtain the obstacle distance from the interval (cross-interval, first layer radius, second layer radius, third layer radius, fourth layer radius) (13)

$$Function\ (distance) = Determining\ the\ direction\ of\ the\ obstacle\ from\ q_j$$

$$(1^{st} q_j,\ 2^{nd}\ q_j) \quad (14)$$

$$LeftD\ (R_i, q_j) = (distance, direction) \quad (15)$$

$$LeftD \in [-1, 1] \quad (16)$$

When the minimum distance of LeftD is placed at the new position Ri(min), its maximum distance occurs at R_i(max). All values of LeftD are between these maximum and minimum levels. A zero value of IP indicates that the obstacle is outside the range of the sensor, and a positive value indicates that the obstacle is within the range of the sensor. Three ranging sensors are used to determine the exact position and direction of obstacles. For example, if the robot detects that the obstacle is in the first and second quarters, it means that the obstacle is in front of the robot. The second and third quadrants show the left side of the robot, and the third and fourth quadrants show the obstacles behind the robot. Finally, the fourth and first quadrants belong to the right side of the robot. Sometimes the obstacle is in the first quarter of the navigation. In this case, the sensor informs for all other quarters that the obstacle is in the right corner of the robot, and so on. Four linguistic variables were identified for LeftD, including Close, Medium, Far, and Very Far. Analogously, these linguistic variables were used for the right and front dynamic barriers.

Input parameters Left, FD, and Right, entered as control parameters, represent the distance to the left, right, and front dynamic obstacles, respectively. These elements are determined using the same equations applied for dynamic barriers.

The constituent functions of the left dynamic (LeftD), front dynamic (FD) and right dynamic (RightD) input variables are the same, and their structure is shown in Figure 4. Fuzzy subsets for the input and output variables of the mobile robot are defined as trapezoidal membership functions.

Upon detecting the obstacle's distance to the next position and its location, the controller organizes these obstacles into a matrix. dynamic obstacles. If the controller detects that the next position faces two or more dynamic obstacles, it determines the position of the three nearest dynamic obstacles.

The output fuzzy variable of this process is the risk for the next trajectory. Fuzzy rules are formulated to evaluate the efficiency of the next trajectory. An intelligent system has been developed with five linguistic grades for this speech, including Very High (VH), High (H), Normal (N), Low (L) and Very Low (VL). The output variable of the proposed fuzzy control can be expressed as:

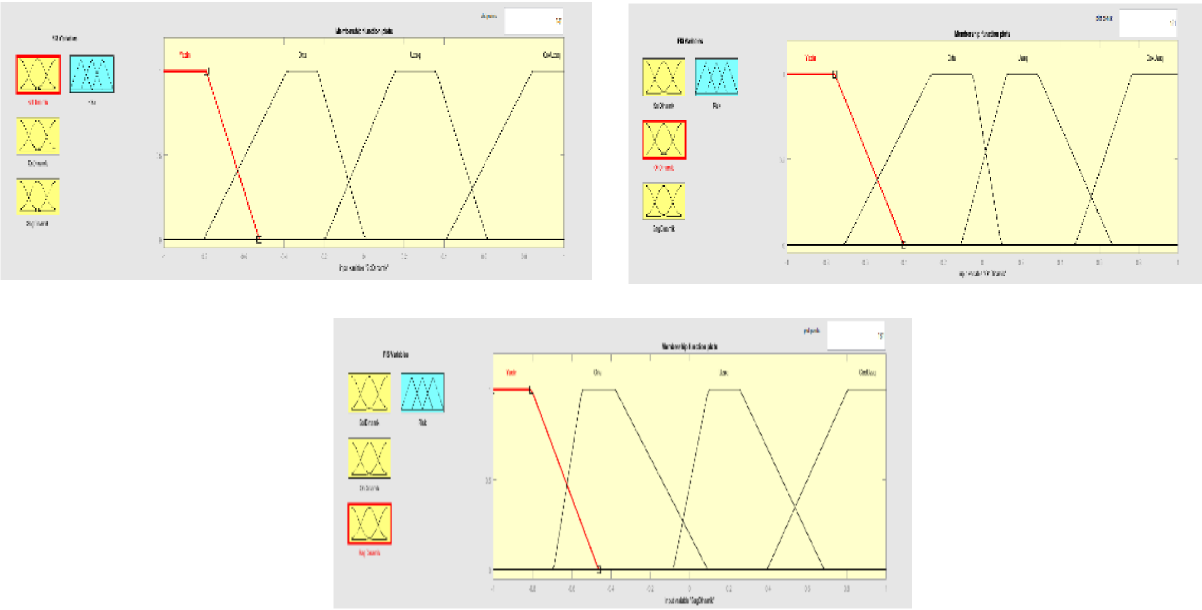

Figure 4: *Obstacle function curves using the trapezoidal method*

$$Risk = Function\ (LeftD, FrontD, RightD),\ \ Risk \in [0, 1] \tag{17}$$

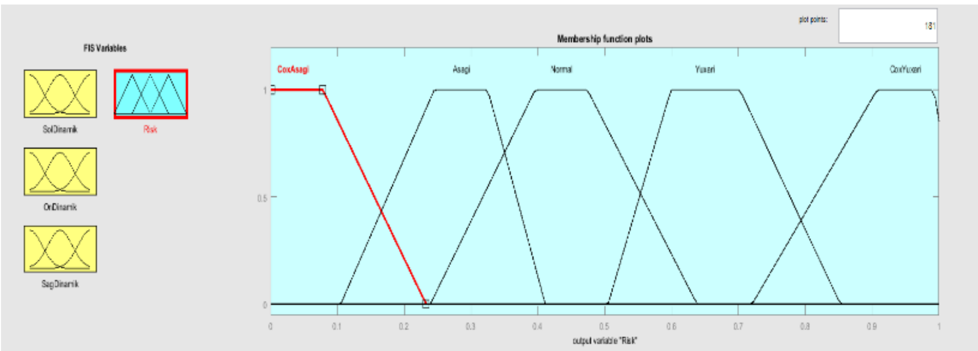

Figure 5: *Trapezoidal membership function curves of risk*

III. Structure of the issue

Trapezoidal membership functions (MF) are chosen in fuzzy logic depending on the structure of the issue:

1. Have simpler analytical structures.
2. Preserves the adaptability.
3. It gives the user more freedom in MF construction.
4. Preserves the novelty.

Also, 5 intervals are selected to evaluate the efficiency of the next trajectory by accurately identifying dangerous situations and to formulate fuzzy rules.

Determining the input and output values of the mobile robot. Designed fuzzy logic elements.

İnput variables:

Left dynamic = relationship between the robot and the left dynamic obstacle in the interval -1÷ 1.

Front dynamic = -1÷ 1 relationship between the robot and the front dynamic obstacle in the interval -1÷ 1.

Right dynamic = relationship between the robot and the right dynamic obstacle in the interval -1÷ 1.

Output variable:

Risk = Probability of collision risk of robot with obstacles in interval 0÷1.

The goal is to guide the robot to choose the most optimal next step between positions, avoiding collisions. Fuzzy management is developed to verify the forecasting process and next position decisions and select better positions with minimum risk. This control is activated after the next step finds a position away from the collision. The values of three fuzzy variables, including left speaker, front speaker, and right speaker, are calculated by the control for each iteration. Tables 2 and 3 describe the normalized universe values of the input and output parameters.

Table 2: *Normalization table of universes of input parameters*

İnput parameters	Range	Normalized piece	Linguistic variable
Left, front, right dynamic obstacles	[-∞ ÷ -1.00]	[0 ÷ 0.25]	Close
	[-0.99÷0.00]	[0.25÷0.5]	Medium
	[0.01÷0.50]	[0.5÷0.75]	Far
	[0.51÷1.00]	[0.75÷ 1.0]	Very far

Table 3: *Normalized universium table of the output parameter*

Output parameters	Range	Normalized piece	Linguistic variable
Risk	[0÷0.20]	[0÷0.20]	Very low
	[0.21÷0.40]	[0.21÷0.40]	Low
	[0.41÷0.60]	[0.41÷0.60]	Normal
	[0.61÷0.80]	[0.61÷0.80]	High
	[0.81÷1.00]	[0.81÷1.00]	Very high

Defining fuzzy rules. The knowledge base consists of a set of fuzzy control rules expressed as a fuzzy conditional proposition. The knowledge base constitutes the rule set of the fuzzy controller. When building a knowledge base, it is important to define input variables, output variables, types of fuzzy regulation rules etc. Fuzzy rules must be based on one of four basic conditions to obtain. For example, 1) if the fuzzy control rules are given in the form of a fuzzy conditional sentence, then there is a connection between the state variables included in the condition part and the control variables included in the sentence part; 2) in the case of fuzzy rules, the management activity of a person is observed and created by revealing the input-output connection; c) in the linguistic approach, the fuzzy model of the controlled process can be viewed as a linguistic description of its dynamic characteristics. d) the knowledge base of the fuzzy controller is formed through self-learning.

The fuzzy IF-THEN implication proposed by Mamdani was used in the research work. Each fuzzy control rule is given in the form of a fuzzy conditional sentence. These rules describe the relationship between the state variables included in the condition part and the control variables given in the judgment part. 64 fuzzy rules indicating the positions of the left, front and right dynamic obstacles and the dependence of the risk on these positions have been defined. (Figure 6).

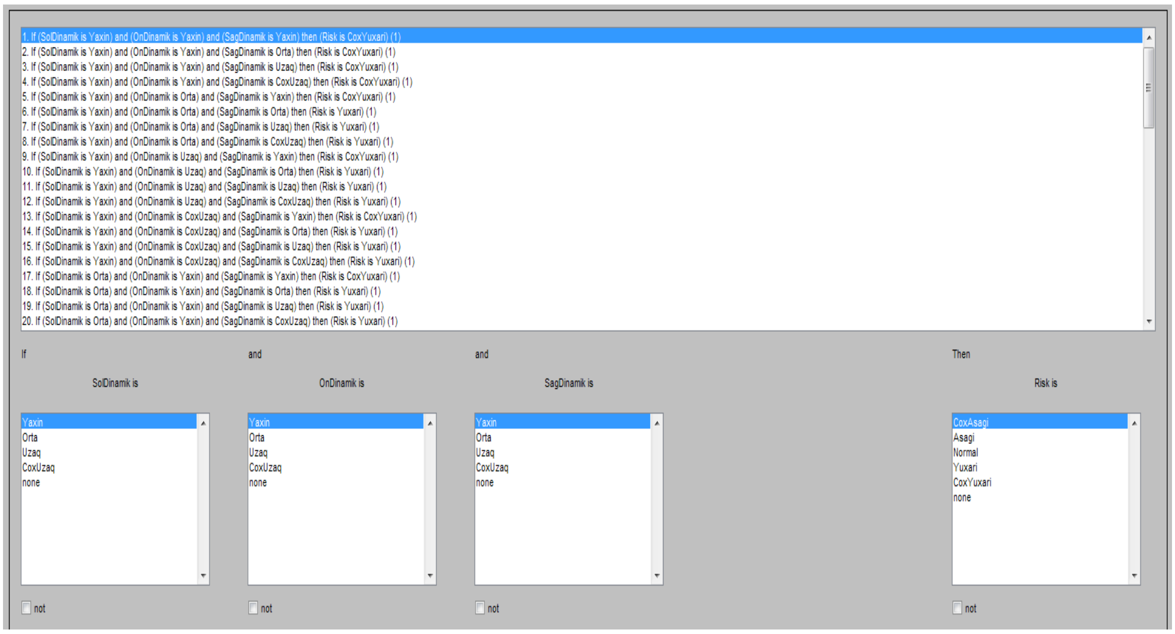

Figure 6: *Fuzzy-logic rules*

There is some examples:

Rule 1.

If (LeftDynamic is Close) and (FrontDynamic is Close) and (RightDynamic is Medium) then (Risk is VeryHigh)

If (LeftDynamic = -0.83) and (FrontDynamic = -0.77) and (RightDynamic = -0.26) then (Risk = 0.89)

Rule 2.

If (LeftDynamic is Close) and (FrontDynamic is Medium) and (RightDynamic is Far) then (Risk is High

If (LeftDynamic = -0.81) and (FrontDynamic = -0.32) and (RightDynamic = 0.07) then (Risk = 0.67)

Rule 3.

If (LeftDynamic is Medium) and (FrontDynamic is Medium) and (RightDynamic is Far) then (Risk is Normal)

If (LeftDynamic = -0.30) and (FrontDynamic = -0.32) and (RightDynamic = 0.25) then (Risk = 0.44)

Rule 4.

If (LeftDynamic is Far) and (FrontDynamic is VeryFar) and (RightDynamic is Far) then (Risk is Low)
If (LeftDynamic =0.44) and (FrontDynamic = 0.94) and (RightDynamic =0.24) then (Risk = 0.26)
Rule 5.
If (LeftDynamic is Medium) and (FrontDynamic is VeryFar) and (RightDynamic is VeryFar) then (Risk is VeryLow)
If (LeftDynamic = -0.28) and (FrontDynamic = 0.82) and (RightDynamic = 0.95) then (Risk = 0.082)

Figure 7 illustrates the logic inference system.

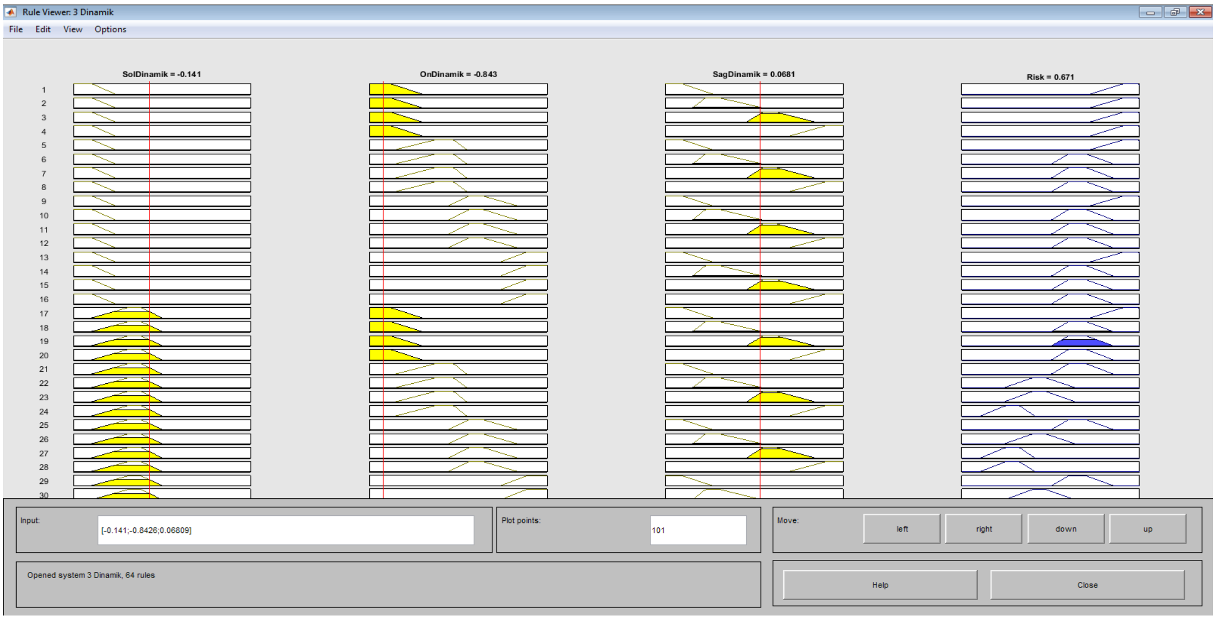

Figure 7: *Logic inference system.*

Figure 8 depicts the fuzzy spatial clusters of the mobile robot's left, front and right dynamic obstacles.

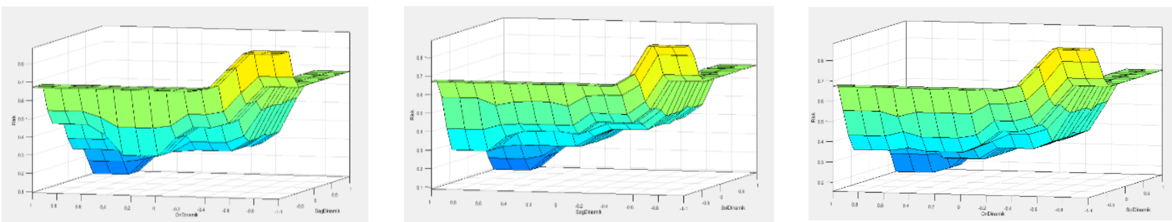

Figure 8: *Fuzzy spatial clusters of the mobile robot's risk due to dynamic obstacles: a) Front dynamic-Right dynamic b) Front dynamic -Left dynamic c) Right dynamic -Left dynamic.*

IV. Conclusion

A sensor-based algorithm is proposed for robot trajectory planning in various dynamic environments. A fuzzy system was used to evaluate the positions generated by the planner and select better steps that reduce the total path length with the help of an algorithm. In addition, it keeps the robot away from possible local minima. This system uses priority rules and prediction of a multilayer approach to improve the quality of the next position by taking into account risky situations to develop three fuzzy control variables. Fuzzy variables will be calculated every time the planner creates a new collision configuration. They will serve as input to a fuzzy reasoning system to decide the overall risk of the next step. When the prediction shows that the risk of collision with many obstacles is too high, the mobile robot finds a new way from alternative solutions to avoid the risky regions through priority behavior. This algorithm makes the multilayer decision making process more efficient and effective by using the advantages of fuzzy logic.

References

[1] Dunwei G, Na G. Local robot path planning with predicting band trajectories of obstacles / Natural 2.Computation (ICNC), 2011 Seventh International Conference on; IEEE; 2011.

[2] Zeng Z, Sammut K, Lian L, et al. A comparison of optimization techniques for AUV path planning in environments with ocean currents. Rob Auton Syst. 2016; Aug 1;82:61–72.

[3] Dongshu W, Yusheng Z, Wenjie S. Behavior-based hierarchical fuzzy control for mobile robot navigation in dynamic environment / Control and Decision Conference (CCDC), 2011 Chinese; IEEE; 2011.

[4] Phillips M, Likhachev M. Sipp: Safe interval path planning for dynamic environments/ Robotics and Automation (ICRA), 2011 IEEE International Conference on; IEEE; 2011.

[5] Mingxin Y, Sun'an W, Canyang W, et al. Hybrid ant colony and immune network algorithm based on improved APF for optimal motion planning. Robotica. 2010;28(06), pp.833–846.

[6] Li G, Yamashita A, Asama H, et al. An efficient improved artificial potential field based regression search method for robot path planning. Mechatronics and Automation (ICMA), 2012 Interna- tional Conference on; IEEE; 2012.

[7] Faisal M, Al-Mutib K, Hedjar R, et al. Multi modules fuzzy logic for mobile robots navigation and obstacle avoidance in unknown indoor dynamic environment /Proceedings of the 2013 International Conference on Systems, Control and Informatics; 2013.

[8] Masehian E, Sedighizadeh D. Classic and heuristic approaches in robot motion planning – a chronological review. World Acad Sci Eng Technol. 2007;23:101–106.

[9] Mammadova K.A. , Aliyeva A.A. Intelligent control system of multi-motion mobile robot/ The Caucasus Economic & Social Analysis journal of Southern Caucasus multidisciplinary journal refereed & reviewed journal. volume 58 (12), issue 01, Georgia, Tbilisi 2024. pp.83-96. ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online); DOI PREFIX:10.36962/CESAJSC

[10] Mammadova K.A. Mathematical Modeling and Simulation of Robotic Dynamic Systems/ News of Azerbaijan Engineering Academy/ International scientific and technical journal. 2022, volume 14, no. 4. pp. 98-111. http://www.ama.com.az/wp-content/uploads/2022/12/N14-N14-N14-4.pdf

[11] Farah Kamil & Mohammed Yasser Moghrabiah (2022) Multilayer DecisionBased Fuzzy Logic Model to Navigate Mobile Robot in Unknown Dynamic Environments // Fuzzy Information and Engineering, 2022. Vol14 №1. DOI: 10.1080/16168658.2021.2019432. pp.51-73

RESEARCH ON THE ROLE OF THE CLUSTER APPROACH IN RISK MANAGEMENT AT INDUSTRIAL ENTERPRISES

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Abstract

The article studies the features of managing various types of risks. The main elements of risk management relevant for managing economic clusters are identified. The article studies the features of managing various types of risks. The main elements of risk management relevant for controlling of economic clusters are identified. Clusters are systems consisting of economic entities demonstrating development in a similar sector, formed by the location of related, complementary spheres of development in a certain geographical region, having a common infrastructure, technology, a single market, labour, opportunities for mutual establishment of trade relations, communication, mutual dialogue through the sharing of services. At the same time, it is assumed that competition and cooperation between small and medium-sized business entities in the clusters will be simultaneously ensured. Their demonstration of development within such a system gives a competitive advantage to small and medium-sized entrepreneurs. Consequently, with the introduction of the system, the costs of economic entities are reduced, marketing opportunities are expanded, productivity indicators are increased, their exports are increased, research and development opportunities are strengthened. At the same time, the promotion of new products, the creation of new industries, employment growth, leads to the development of regions, the improvement of infrastructure services. Clusters contribute to improving the material well-being of the population in the region by exporting goods and services in the form of groups of interrelated industries that serve to increase this location. Clusters cover the entire ring of the supply chain, support the provision of services, as well as dedicated infrastructure, which distinguishes it from traditional manufacturing industries.
Clusters have certain similarities, connections, and other trade among themselves, as companies and organizations with production ties demonstrate development in the same geographical area, they are formed.

Keywords: management of various types of risks, basic elements risk, innovation cluster, industrial cluster, competitiveness, economic efficiency

I. Introduction

With the cluster approach, it is important to take into account the self-development and self-organization of cluster structures. Clusters are not formed by chance; they are subjected to the requirements of the system. Clusters are subject to self-organization to a greater extent than other elements of economic entities. Synergy is a consequence of the joint use of specialized production facilities, scientific equipment, buildings, and engineering structures among groups of companies. It should be taken into account that in addition to the positive synergistic effect, a negative synergistic effect, which leads to an increase in risks for cluster participants may appear. Due to the synergistic effect, the authors of the article identified the risk of synergy (positive and negative synergy). To manage risks, an enterprise that is part of a cluster can be restructured to adapt to changes in the external and internal environment of the enterprise.

Restructuring of an enterprise, which does not affect the rights and obligations of a legal entity, is the creation of a new structural unit, the liquidation of a division, the merger of structural units, the creation of a subsidiary or affiliated company [2]. Reorganization of an enterprise that is part of a cluster, in the form of creating a cluster of an auxiliary legal entity together with other enterprises, in order to manage the risks of cluster operation.

Among the main goals of clustering, one can highlight: increasing the risk resistance of cluster participants through the introduction of new technologies. The formation and support of a cluster economic model is a promising way to increase the risk resistance of enterprises. In the process of interaction of enterprises with each other within the same cluster, it is necessary to reduce the production time of products in compliance with the necessary requirements for it from a technological point of view. The effectiveness of cooperation between enterprises can also be manifested in the distribution of risk and responsibility in the event of adopting an effective (losing) version of the development strategy. The lower the probability of new potential competitors entering the industry, the higher the synergistic effect from the interaction of enterprises with each other. The closer enterprises are dispersed within one cluster to the leading raw materials center, the lower the costs of transportation and storage of products, and the higher the possibility of finding additional reserves and attracting resources for the development of activities. The cluster approach assumes that the competitiveness and risk resistance of each individual enterprise is largely related to the competitiveness and risk resistance of other enterprises that are part of the same value chain or provide the external environment of the value creation process itself.

In a market economy, producers and consumers are always faced with possible dangers, risks and fear of losses. Risk in business is not only a possible threat, but also an absolute reality. Risks reduce tactical and strategic expectations regarding the future development of the enterprise and organization. At the same time, it creates a feeling of uncertainty and hopelessness in achieving set up goals.

In a market economy, most risk management must be carried out by entrepreneurs themselves. An entrepreneur must logically and thoughtfully accept the risk and evaluate its impact on business development. An entrepreneur always faces certain risks in the process of entrepreneurial activity. Those who want to earn a lot of money, of course, often have to take risks. This is the basic rule of business.

There are objective reasons for the occurrence of risks when doing business. Because it is impossible to calculate the influence of all factors on the activity of an enterprise in the first place. Therefore, some important points in the implementation of planned activities may change unexpectedly. That is why an entrepreneur can always face a loss during the operation of the company.

World economic science considers cluster associations as an effective tool for improving the performance and sustainability of individual enterprises. Formation clusters with the purpose of distribution of risks between participants in a cluster association seem to be an effective risk management tool. At the same time, the effectiveness of combining enterprises into a cluster is also associated with high uncertainty and risks. Incomplete grades, as how consequence, ineffective risk- management lead to the failure of cluster projects and large financial loss of participants. Thus, the development of theoretical approaches and methodological tools for effective risk management of enterprises in the context of cluster association is an urgent scientific task.[9]

One of the effective methods of risk prevention is diversification. The purpose of diversification is usually to improve the performance of enterprises and gain their positions in the market (Table 1).

Table 1: *Basic advantages use diversification onenterprise [9]*

Advantages	Characteristic benefits
1. Effective control of the risks	Losses in one area of activity are compensated by obtaining greater profits from the sale of other products, while at the same time losses in one area of diversification activity - the enterprise will no longer significantly influence its financial and economic condition. So how will its share in income spirit cease to be dominant?
2. More complete usage resources	Allows you to mitigate the seasonality of production, increase worker employment, receive additional income from the timely and thoughtful maneuverability of the industry, and increase volumes faster. The production of those types of products for which there is demand and form entails the required price.
3. Receipt enterprises synergistic effect	Defined as a type of cooperation, interconnected and cooperatively deployed actions that can manifest themselves in the form of strategic partnerships, mutually beneficial cooperation, mergers and cooperative interactions and those very same, in one and other conditions, that increase the efficiency of activities.

It seems that to identify and conduct a detailed study of the essence of risks affecting the functioning of cluster structures, it is advisable to distribute them into general risks of enterprises and specific cluster risks. Of course, the formation and functioning of clusters are associated with many common enterprise risks that are characteristic of any organizational and legal form of the companies. Analysis of the conditions of formation and the functioning of industrial clusters allows us to identify two traditional areas of risk occurrence: the external and internal environments of the cluster, which determine the stability and efficiency of the cluster formation. [9].

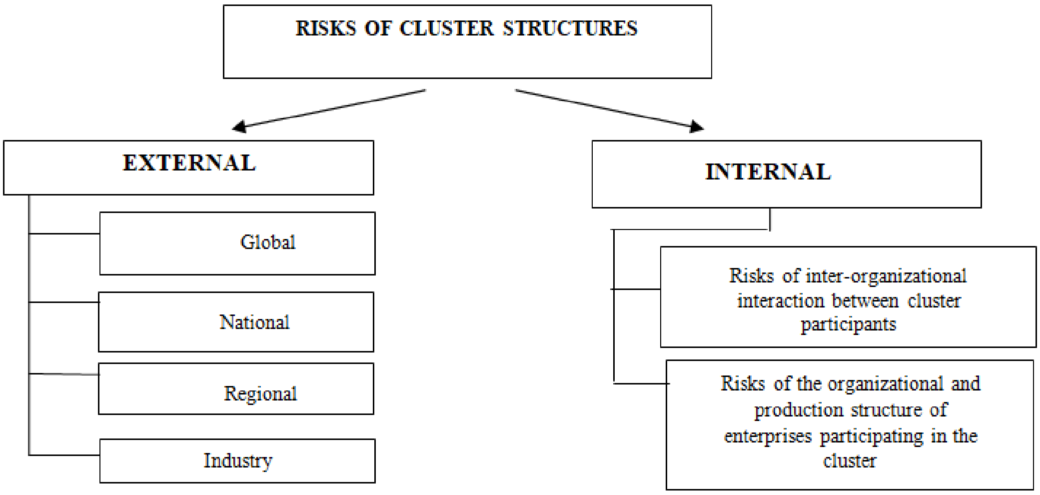

Figure 1: *General classification risks cluster structures.*

In modern economic science, innovative clusters are viewed as locomotives of economic progress due to their ability to enhance the competitiveness and innovation of businesses, and address issues related to employment, industry, and regional imbalances.

As regional entities, innovation clusters have an impact on the economy of the entire nation, given the intrinsic relationship between regional and national economic development. Innovation clusters that promote regional growth are integral to advancing the country's overall development. Furthermore, paradoxically, in the context of globalization, the significance of innovation clusters and their growth intensifies, as they have the potential to generate international and even global repercussions.

Globalization enables companies to allocate their resources and operations to the most suitable locations. Therefore, the wider the reach of globalization in markets, the greater the likelihood of resource flows being directed towards regions that offer the most favourable business environments, thereby enhancing the significance of clusters and regional specialization. Further specialization within clusters promotes relationships with other clusters that deal with complementary values, fostering economic cooperation among neighbouring states instead of territorial disputes, resulting in mutual benefits for each state's economic development and stability in regional and domestic politics.

The interpretation of the "cluster" concept is shaped by the scientific approaches adopted by researchers studying the economic clustering process from various academic disciplines. It is worth noting the distinctive theoretical perspectives of different scientific schools. For example, scholars of the "America" ("California") school emphasized the significance of geographic proximity and shared specialization among enterprises, highlighting the interplay between competitive and collaborative mechanisms.

Representatives of the "Scandinavia" school highlights the central role of knowledge and innovation-driven interactions among enterprises in the development of regional and industrial clusters.

Muro M., Katz B. (Harvard Business School) noted the Four "Critical" characteristics of the cluster: proximity of enterprises and organizations included in it; connectivity factor of clusters; active forms of interaction between firms; The existence of a critical mass of participants in the cluster can affect the activities of the companies. [6]

It should be noted that the differences in the approach to defining the concept of "cluster" and the mechanisms of its formation led to the differentiation of the concepts of "industry" and "innovation" cluster.

An "innovation cluster" refers to a network of interdependent enterprises and affiliated organizations that complement each other and contribute to the advancement of innovation potential among each element of the cluster and the region as a whole. Some scholars perceive regional clustering as a gradual shift from innovative industrialization. Universities, engineering centres, and technological or innovation hubs serve as the nuclei of innovation clusters established through competence management, which entails acquiring new knowledge and sustaining innovation growth. The geographical scope of the technological chain underpinning the cluster may span across borders. Government support is an essential prerequisite for nurturing such clusters.

The main formation process for "industrial clusters" is technological chain (production process management) optimization and process management. State bodies may act as part of the cluster, but are not a mandatory component of it. The core of such clusters are companies that determine their technological and production integrity. The systematization of all of the above based on the analysis and generalization of leading scientific schools allowed the authors to distinguish 6 leading signs of territorial clusters:

1. Geographical proximity;
2. Critical mass of cluster participants;
3. General specialization of enterprises;
4. Competition;
5. Collaboration through knowledge-based relationships;
6. Innovativeness of production.

The term refers to the physical proximity, shared specialization of economic entities, dynamic competition and collaboration among all stakeholders, promotion of knowledge-based relationships, and active integration of all types of innovation into economic endeavours. [2]

Economic entities and participants of clusters encompass a wide spectrum, ranging from large corporations to small and medium-sized enterprises, scientific research organizations, and municipal and state authorities advocating for the advancement of regions and territories.

The disparity in defining clusters in foreign and local literature is contingent on the specific regional traits that shape their development. Most of the clusters are the result of the natural development process of the world economy and the territorial structure of its regions.

1. The research conducted unmistakably indicates that the concept of "cluster" has fortified its standing in contemporary economic science, and the tendency of fostering related legislation is discernible. Nonetheless, since there is no definitive scientific and legal clarification of the essence and features of clusters, there is a lack of consensus regarding their normative regulation.

2. The allocation of considerable financial resources of different levels of budgets for the creation and development of clusters gives special urgency to this problem. Therefore, the need for greater clarity in the understanding of the recognized category is not only derived from theoretical interests, but also aims to prevent inefficient spending of budget funds;

3. The notion of "cluster" was scrutinized, and a categorization of clusters in the economy was provided.

4. The research indicates that the economic clustering facilitates the formation of a comprehensive outlook on regional development policy, enhances the productivity, efficacy, and competitiveness of enterprises, widens the scope of innovation development, and optimizes interaction among diverse economic actors in the region, including the state, large and small enterprises, academic and research associations, and the public. Additionally, it leads to an improvement in the population's quality of life.

5. Cluster initiatives of regional economic development were explained. In addition, classification of the cluster development of economically developed countries and regions and analysis of the cluster structure of their economies and the obtained results are provided.

6. Institutions and tools for supporting and developing cluster initiatives in developed countries are reviewed.

II. Methods

Future research directions include analysing and proposing strategies for forming organizational structures for cluster management and determining their legal forms to ensure clusters' effective functioning. This includes considering internal factors as well as external challenges posed by globalization.

Research indicates that the term "cluster" was coined only three decades ago, during the final years of the 20th century. Nevertheless, governments of developed nations view the creation of innovative clusters at a regional level as a key driver for economic growth and recovery, despite its relatively recent emergence as a concept.

As the concept of cluster has various interpretations, it is more significant to examine it as a factor of economic growth and competitiveness from a political-economic standpoint. Therefore, in this context, a cluster can be described as:

1. Clusters are defined by some authors (implicitly or explicitly) as geographically close groups of firms that mainly produce the same product or service;

2. Clusters are a group of interconnected industrial enterprises located in a close geographical area;

3. Clusters are networks of firms, especially small and medium-sized enterprises and related institutions, within geographical boundaries, and organizations that cooperate with other enterprises that use the same basic technology.

The global search for ways to enhance the competitiveness of national economies has shown that the creation and advancement of clusters are worthwhile. The acceleration of globalization necessitates effective solutions for the issue of economic clustering at both the national and regional levels.

Michael Porter, a professor at Harvard Business School, is a prominent figure in the field of competition and competitiveness research in the United States. He is the founder and advocate of the cluster theory in economics and the author of the theory of competitive advantage. Porter suggests that competitive firms in a particular industry can be found concentrated in a specific region or country. In his book "The Competitive Advantage of Nations" (1990), he proposed a theory of national, state, and local competitiveness within the global economy. This theory highlights the significance of clusters and underscores the importance of understanding the role of geographical location in shaping the competitive advantage of clusters, rather than individual firms and industries in isolation [1].

M. Porter has developed multiple definitions of the cluster phenomenon, and each of them is characterized by its own unique features and particularities. One of the most common definitions is as follows: "a cluster is a group of companies and related organizations operating in a certain area, characterized by joint activity and complementing each other, geographically close to each other." The scientist also defined the cluster as "a system of interconnected firms and organizations whose value as a whole exceeds the simple sum of its constituent parts", thus emphasizing its synergistic effect. In Porter's definitions, attention is paid to the main features such as geographical concentration (localization) of cluster members, close ties between cluster members, and the combination of competition and cooperation in the cluster.

M. Porter suggests that clusters are more effective than individual industries in achieving a balance between competition and competitive advantage. Clusters can leverage linkages, complementary industries, technology diffusion, expertise, information, marketing, and awareness of consumer needs. He further argues that the competitive advantages in the global economy are largely connected to the location of clusters, which benefit from the concentration of specialized skills and knowledge, institutions, interconnected economic activities, and consumers in a specific geographic area [3].

Clusters can be called local interconnected groups of small, medium and large enterprises and various research institutes that produce complementary products, compete and at the same time cooperate.

In this regard, M. Porter called for the funds earned in the commodity sector to be directed to the diversification of the economy and the development of clusters.

The classical clusters proposed by M. Porter in 1990 are distinct from the innovative clusters that are currently being studied and formed. While Porter's original approach to clusters was innovative, aiming to improve professionalism, specialization, customer relationships, and complementary products and services, the goal of innovative clusters is to establish more sustainable production and service facilities, associations, and start-ups by introducing new techniques and technologies. This includes constant development, enrichment of new ideas and analytical tools, and maintaining the dynamism of developing clusters.

The clustering of the economy of individual territories determines their most efficient integration into the world economic system, allows for the collection and optimal use of resources in terms of global trends, and helps to increase the efficiency of the state's industrial policy. Clusters have become one of the main driving forces and determinants of the competitiveness of geographical regions, their effectiveness is confirmed by world experience. Clusters allow to increase the competitiveness not only of their enterprises, but also of specific areas of activity within the region, including expanding the application of innovations, reducing transaction costs, developing and strengthening relations between business, science and the state.

Cluster policy is traditionally understood as a set of measures aimed at increasing the competitiveness of the national economy by stimulating the development of clusters.

Synergistic and synergistic benefits obtained from the organization of a cluster consist not only of increasing the efficiency of its work as a whole compared to the efficiency of individual participants, but also of mutual strengthening of the competitive positions of both industrial production and the territory it covers.

As previously noted, the use of regional economic clustering is increasingly being utilized to enhance the effectiveness of the entire economic system of countries worldwide. The growing number of cluster initiatives in numerous countries, including both developed and developing nations, have demonstrated their feasibility and efficacy. Cluster policy is now integrated into the innovative and regional development strategies of various countries globally, and clusters have become crucial to their economies.

The most important factor for increasing the efficiency of industrial production in cluster enterprises is the improvement of management within the framework of the creation of an information system for the management of industrial clusters.

The possibility of evaluating the efficiency of the presence of clusters through the assessment of its organizational cost and competitiveness can be considered. In this approach, the evaluation of competitiveness of clusters is carried out from three positions. The assessment of the dynamics of market positions is carried out through the analysis of the change in the share of cluster enterprises in the industrial volume of production in the world market; increase in export volumes for the cluster; the number of new markets in which firms - cluster participants participate.

Another methodology for evaluating the efficiency of the newly created cluster consists of 5 integral characteristics. Each of them consists of several assessment criteria that have different weights during the analysis:

1) Availability of competitive enterprises;
2) Implementation of innovative projects;
3) Increasing the economic indicators of the field;
4) Existence of mutual relations between cluster participants;
5) Geographic proximity of cluster participants, correct choice of cluster participants and their number.

The analysis examines various indicators to evaluate the success of cluster enterprises. These include the growth of economic indicators in the industry, the increase in the share of work and services provided by cluster enterprises, the percentage of employees working in cluster enterprises compared to the total number of employees in the industry, and the updating of main assets through increased investments in the region. The effectiveness of relationships between cluster participants is evaluated based on their ability to cooperate, create necessary infrastructure, and the managerial skills of the heads of the cluster enterprises. The selection of cluster participants, including their number and geographical proximity, is assessed by considering the territorial location of participants and the selection of the minimum number of enterprises with the maximum share of their participation in the internal market [7]

When evaluating the economic efficiency of industrial enterprises in the conditions of clustering, the following must be taken into account:

1. Cluster life cycle,
2. The interests of each economic entity included in the cluster,
3. Evaluation of efficiency at three levels: enterprise, region, territory.

III. Results

Six key characteristics can be identified for cluster derivatives of industrial enterprises formed in different regions of the world. Some of these characteristics describe the participants of the cluster, such as the leading enterprise that connects all the other participants in the value chain and smaller enterprises with a higher level of innovation in their production processes. Others determine the direction of development for the enterprises, such as a focus on internationalization through direct foreign investments and export of the final product. The formation of clusters cannot occur without direct or indirect support from the state. State cluster policies stimulate the development and improvement of relationships and competition in both domestic and foreign markets. In a free market environment, competition between companies plays a decisive role in the cluster. The more producers there are of the same product, the more efficiently the cluster market mechanism works, leading to lower production costs for the final product. [4]

Innovative cluster enterprises also have the following positive effects:

1. Effects of production scale (provides a multiplicative effect of cluster operation due to the interaction of companies);
2. Covering effect (occurs when the production factor is used in the production process of not one, but several types of products);

3. Synergy effect (an effect resulting from the movement of coordinated mechanisms in time and space, which is essentially different, but causes fundamental qualitative changes in the entire system under consideration);

The presence of these effects enables cluster enterprises that experience losses in the short term to overcome difficulties and achieve significant competitive advantages in the long term. The nature of innovation clusters gives them the ability to provide substantial benefits to their participants by combining cooperation and competition within the cluster, resulting in a synergistic effect that enhances the competitiveness of the entire system. In comparison to industrial clusters, innovative clusters are comprised of organizations that generate new knowledge, such as research centers or universities. This allows for the coordination of efforts and funding to create new products and technologies, as well as the formation of a complete technological chain, beginning with the conception of an idea and ending with the introduction of new products to the market.

The economic effect created by innovative clusters is the object of analysis of many scientific articles and studies, the results of which have been published in the last decade. In modern economic science, innovative clusters are considered locomotives of economic development.

Based on all this, in general, assistance (support) to the formation and development of innovative clusters by regional authorities should be implemented in the following directions:

• Creation of conditions for constructive dialogue between business and government, alignment of interests of cluster members and strengthening of cooperation between them;

• Stimulation of demand, formation of consumer preferences in the region, development of related and supporting areas of the economy, state orders;

• Development of the vocational education system in order to form the necessary competencies in the region;

• Development of foreign relations, elimination of trade barriers, protection of intellectual property rights, implementation of joint infrastructure and investment projects;

• Creation of favorable economic, institutional and other conditions in the region;

Innovation clusters, which operate at a regional level, have a significant impact on the national economy due to the direct link between regional and national development. Nevertheless, their importance extends beyond the national level as they can have international and even global impacts, especially in the context of globalization.

In addition to the above, in the organization and management of clusters, not only in the public sector, but also in the private sector, the attitude towards this field should be strengthened and a sufficiently efficient environment for entrepreneurs should be created.

One of the advantages of cluster management of an industrial enterprise is the ability to concentrate management influences on the most promising areas of activity and their support. The cluster is a sustainable territorial-industry partnership of enterprises and entities united by an innovative program for the introduction of advanced technologies to increase the sustainability of cluster participants in the market of manufactured goods, works, and services. The cluster includes independent enterprises, the cooperation of which is beneficial to each of the participants and generally increases their sustainability and profit.

IV. Discussion

The cluster development stages are as follows: at the formation stage, cluster members collaborate around the main activity and explore common opportunities, making it impossible to assess effectiveness. Thus, only economic activity indicators such as the dynamics of Foreign Direct Investments, production volumes, state support, and the number of jobs created can reflect the actual situation. Since performance indicators are not considered at this stage, the efficiency weight index value will be 0, while the performance will be 1.

During the "development" stage of the cluster, the area of interaction between the cluster members expands, new participants are involved in the work, and new formal and informal institutions are formed. At this stage, it is possible to evaluate the activity of enterprises in terms of both efficiency and productivity on all the proposed indicators.

The stage of "maturity" is determined by the degree of reaching a certain critical mass of participants, which allows forming and permanently maintaining constantly updated relations between cluster members. At this stage, it is possible to use all the recommended indicators (except for the number of jobs created).

In the "decline" stage, some indicators can no longer show positive dynamics (for example, the growth rate of the production volume, the company's market share, the number of highly productive workplaces, the volume of shipped innovative products and scientific-research works).

To put it differently, the approach suggested for evaluating economic efficiency allows for a range of values between 0 and 1 for the economic efficiency index.

$$0 < I_{EE} < 1$$

The lower the value of the index, the lower the economic efficiency of the enterprises in the cluster.

Our opinion is that contemporary approaches to assessing the effectiveness of clusters should consider the various stages and factors involved in their development, along with the concerns and objectives of all involved parties. It's important to note that the methodology we propose is only applicable for evaluating clusters that are of the same type and can be compared.

In clusters, higher labor productivity is achieved, as well as higher employment opportunities. At the same time, the role of regional authorities is as follows: using information opportunities to attract new participants to clusters; tax policy stimulating the development of clusters; simplification of establishment procedures; facilitating access to start-up and venture capital.

Constant improvement of worker qualifications is a crucial requirement for successful economic clustering in the rapidly evolving technological landscape. However, US companies are currently falling behind their counterparts in Europe and Asia in terms of investing in their employees' training, both in production and otherwise. Compared to regions like Europe, Japan, and Southeast and Southwest Asia, US employers allocate fewer resources per employee towards training.

The evaluation of the economic efficiency of the clusters consists of 6 main stages:

Stage I: The assessment of cluster formation involves examining various factors such as proximity of the businesses, common areas of specialization, number of participants, collaboration on scientific research and innovation, competition and cooperation. It's important to note that the absence of any of these factors would make it inappropriate to evaluate the performance of the cluster.

Stage II: The selection criteria can be evaluated by determining the nature of the clustering action factor, such as forming pairs of factors like foreign direct investment, executive directions, the primary consumer, and market competition and innovation for small and medium businesses.

In order to develop the cluster on the basis of "direct foreign investment-export directions", it is absolutely necessary to analyse the indicators of the volume of foreign direct investment and export.

If the cluster is formed and develops on the basis of the main consumer - market/competition, then the price indicator is the organization of the number of workplaces, the volume of production, tax and profit of the enterprise in the market. If the enterprise cluster works on the basis of "innovation - small and medium-sized business", then the issues of evaluating the volume of scientific research and construction works, the volume of innovative products and the organization of workplaces must be analysed.

Stage III: Efficiency and result indicators are employed to assess the performance of industrial companies within the cluster, and these are referred to as selection indicators.

The level of achieving the planned result characterizes the final result. For example: the organization of the number of jobs, innovation products, exports, taxes, etc.

Taxes allocated to the population, growth rate of production volume, export level; the rate of growth of the enterprise in the market and the volume of state aid characterize the efficiency indicators.

For an objective assessment of the result, the cumulative index of efficiency can be used. Which is calculated as the sum of the achieved indicators of the planned results:

$$I_{ef} = \sum_{n=1}^{k} \alpha_n R_{fh}/R_{ph}$$

Here, I_{ef} - integrated productivity index;
R_{fh} – the actual indicator of productivity;
R_{ph} - planned indicator of productivity;
K is the sum of indicators, $0 < \alpha_n > 1$, if the indicators are equal, then $a_n = 1/K$
We propose to calculate efficiency as a cumulative index. This is calculated as the sum of quality indicators of the achievement of results:

$$I_{ec} = \sum_{n=1}^{k} b_n E_{fn}/E_{pn}$$

Here I_{ec} is the integrated efficiency index,
E_{fn} – the actual indicator of efficiency
E_{pn} – planned indicator of efficiency,
K' is the sum of indicators, $0 < \beta_n > 1$, if the indicators are equal, then $\beta_n = 1/K'$
Thus, the economic efficiency can be calculated as the subtotal of the total efficiency index and the efficiency index:

$$I_{EE} = {}^1/_2\, I_{ec} + {}^1/_2\, I_{ef}$$

Here:
I_{EE} – economic efficiency,
I_{ec} – efficiency index,
I_{ef} – general index of results (integral index).

Stage IV: Selection of signs characterizing the efficiency of the work of different types of economic subjects. It is proposed to distinguish:

1. Large business enterprises (main manufacturers),
2. Enterprises belonging to medium and small businesses,
3. Research and educational institutions.

At this stage, it is necessary to evaluate the activity of each enterprise in terms of its characteristics and possible participation in the cluster work.

Finally, the calculation of efficiency or effectiveness indices is carried out on the basis of specific indicators. For example: the efficiency index for large business enterprises is calculated by the following formula (number of indicators K=3).

$$I_{efbb} = 1/3\Delta V_{prf}/\Delta V_{prp} + 1/3\Delta V_{exf}/\Delta V_{exp} + 1/3\Delta WP_f/\Delta WP_p$$

Here:
I_{bb} – efficiency index of large business enterprises,
ΔV_{prf} – dynamics of actual production volumes,
ΔV_{prp} – dynamics of planned production volumes,
ΔV_{exf} – dynamics of actual export volumes,
ΔV_{exp} – dynamics of planned export volumes,
ΔWP_f – the dynamics of the number of actual workplaces,
ΔWP_p – the dynamics of the number of planned workplaces.

Stage V: Determining the efficiency of cluster work and its criteria, taking into account the development interests of enterprises, the region as a whole or a separate field.

To assess the development of individual businesses, it is crucial to analyze changes in production volumes, adoption of innovative products, market share, and employment rates. Indicators of sustainable growth in both domestic and foreign markets can be determined by evaluating export volumes and the share of industry enterprises in the market. The indicators of socio-economic progress in the regions include the number of new jobs (including high-productivity roles) and the trend of taxes per capita. The selection of indicators at this stage is based on a similar approach to the previous stage.

Stage VI: Consideration of the possibility of realistic evaluation of activity indicators at different stages of the development of cluster enterprises. For the correct assessment of economic efficiency, it is necessary to take into account the weight of each of the indices:

$$I_{EE} = j_{ec}I_{ec} + j_{ef}I_{ef}$$

Here:
I_{EE} – Economic efficiency,
I_{ec} – Efficiency index,
I_{ef} – Consequentiality index,
j_{ec} – Efficiency weighting factor,
j_{ef} – is the activity measurement factor.

The significance of the weighting coefficients varies in all four stages of production and is directly proportional to the number of indicators considered in calculating the integral productivity indices.

The weighting coefficients are assigned greater importance as more indicators are included in calculating the integral productivity indices, and this varies across the four production stages. The efficiency weighting factor is determined by dividing the efficiency or effectiveness indicators considered during the analysis by the total number of such indicators evaluated for that particular stage of cluster development.

$$j_{ec} = N_{ec}/(N_{ec} + N_{ef}); \quad j_{ef} = N_{ef}/(N_{ec} + N_{ef})$$

Here,
j_{ec} – the efficiency weighting factor,
j_{ef} – activity measurement factor,
N_{ec} – the number of analyzed indicators of economic activity and
N_{ef} – the number of analyzed indicators of economic activity.

References

[1] Porter, M.E. The Competitive Advantage of Nations, Free Press, New York, 1990.

[2] Michael E. Porter. Clusters and the New Economics of Competition, Harvard Business Review. November-December 1998. Retrieved 3 August 2018

[3] Porter Michael E. Location, competition, and economic development: local clusters in a global economy // Economic Development Quarterly, Vol. 14. - № 1, February 2000, 15-34 s

[4] Rosenfeld S.A. Industrial-strength strategies: regional business clusters and public policy. Washington, The Aspen Institute Community Strategies Group. – 1995, 150 s.

[5] Enright, M. J. Survey on the Characterization of Regional Clusters: Initial Results. Working Paper, Institute of Economic Policy and Business Strategy: Competitiveness Program, University of Hong Kong, Sun Hung Kai, 2000, 21 s

[6] Muro M., Katz B. «The New Cluster Moment: How Regional Innovation Clusters Can Foster the Next Economy» // Brookings Institution Metropolitan Policy Program, September 2010. (in Russian)

[7] United Nations Industrial Development Organization. Available at: http://www.unido.org 165. Van der Linde C. The Demography of Clusters, Findings from the Clusters Meta-Study // Innovations Clusters and Interregional Competition. Berlin, 2003. pp.130-149.;

[8] World Economic Forum «The Global Competitiveness Report 2009-2010». Available at: http://www.weforum.org/en/index.htm

[9] Izmalkova, I.V. Risks of the formation and functioning of a cluster model of development of organizations. articles of the 8th All-Russian scientific and practical conference with international participation / Southwestern State University. 2018. (in Russian)

THE IMPACT OF CLIMATE CHANGE ON THE FUNCTIONAL RELIABILITY OF ROAD TRANSPORT NETWORKS

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Abstract

The article considers the problem of taking into account the impact of climate change on the functional reliability (FR) of regional road networks. An algorithm and methodology for assessing the FR of a road are proposed, which are based on assessing the durability and residual life of the road surface structure according to deformation criteria: (1) the maximum permissible residual deflection of the road surface, (2) the maximum permissible reduction of the road surface material elasticity modulus as a result of multiple elastic-plastic deformation of the road surface under the action of traffic, (3) the appearance of unacceptable longitudinal track(s) and/or potholes in the road surface.

Keywords: functional reliability, transport network, climate change, durability, residual resource

I. Introduction

The problem of assessing the reliability of a developed road network is very relevant, especially in light of the increasing complexity of transport and logistics chains, the constant growth of transport traffic, the degradation of the road surface from the impact of transport, temperature changes, adverse weather conditions, climate change, frost upheaval, earthquakes, mudflows, landslides, avalanches, destruction and demolition of bridges due to floods, insufficient funds for repairs, etc. The criterion for the road network failure is road surface deformation.

The functional reliability (FR) of a regional road network is understood as the reliability of the main route for which this network is intended. The main route FR is equal to the product of the reliabilities of the network sections that form it.

In the case where the main route consists of several equivalent routes, its reliability is calculated using the formula:

$$R_n = 1 - Q_1 \cdot Q_2 \cdot \ldots \cdot Q_n, \tag{1}$$

Where $Q_1 \cdot Q_2 \cdot \ldots \cdot Q_n$ are the probabilities of failure (POF) of paths n in number that make up the main route.

Calculation of network reliability shows that the more equivalent paths the selected route is organized by, the higher its reliability and, accordingly, the higher is the entire transport network the reliability.

II. Mathematical model of the road network

When assessing the functionality of a transport network, its mathematical model is used, with the help of which each driver of a vehicle selects a route, calculates the travel time and the traffic flow on each road. The stationary distribution of traffic is found as the solution of the optimization problem of the transportation network functioning [7]:

$$min\ Z(x) = \sum_i \int_0^{x_i} t_i(w)dw\ , \qquad (2)$$

Where x_i is the volume of traffic on the road i; t_i is the travel time on the road i:

$$t_i(x_i) = t_0(1+\alpha\left[\frac{x_i}{C_0 \cdot N_L}\right]^\beta), \qquad (3)$$

where t_0 is the time of unimpeded passage on the *i-th* road; C_0 is the capacity of one traffic lane; N_L is the number of lanes of the *i-th* road; α and β is the variable parameters defined as 3.0 and 4.0 respectively for design speeds of 20 km/h and 30 km/h and 4.5 for design speeds of 40 km/h and above [7].

The total travel time of the road is determined as follows:

$$C_i = \sum_i t_i(x_i)\delta_i\ , \qquad (4)$$

Where δ_i is a logical function that indicates whether the selected route passes along the *i-th* road.

III. Simulation of real-time traffic flow after an accident using an agent-based model

Agent-based modeling is a powerful method for analyzing distributed complex systems, suitable for modeling systems under three conditions: the problem domain is spatially distributed; subsystems exist in a dynamic environment; subsystems must interact with each other with greater flexibility [7].

IV. Initialization of the agent-based model [7]

With continuous monitoring of road traffic (including with the help of video cameras and drones), information is accumulated about the travel time of each vehicle and the volume of traffic flow on each road of the transport network. In this case, the number of cars on each road I_i, is:

$$I_i = x_i \cdot t_i \qquad (5)$$

The probability that a particular car on the *i-th* road will take a particular route k between an origin r and a destination s is [7]:

$$\Pi_{i,rs} = \frac{\sum_{k\in\Psi_{rs}} f_k^{rs}\delta_i}{x_i}, \qquad (6)$$

where f_k^{rs} is the traffic volume of the *k-th* route between the source point r and the destination point s; Ψ_{rs} is the set of all routes between r and s.

Using equation (6), each car on the *i-th* road is randomly assigned a direction of travel. The probability that an individual car assigned a particular direction of travel *r-s* will travel a particular route *r-t* is [7]:

$$\Pi^{rs}_{i,rt} = \frac{f^{rs}_{rt}\,\delta_{i,rt}}{\sum_{k\in\Psi_{rs}} f^{rs}_{k}\,\delta_{i}} \quad (7)$$

Using equation (7), each vehicle on the *i-th* road is randomly assigned a route. Assuming that the vehicles are uniformly distributed across the roads (links in the transport network), the time it takes for the *j-th* vehicle in the queue to reach the intersection between the links is [7]:

$$t_{j,a} = t_i(x_i)\cdot\frac{j}{I_i} \quad (8)$$

V. Algorithm for assessing the durability of road surfaces

The durability of a road surface is usually understood as the time during which it retains its basic properties at a level that satisfies operational requirements.

Currently, to assess the durability of the road surface of a specific section of the road network, the initial reliability is set (the probability of failure-free operation at standard average values of the strength and rigidity parameters of the road surface).

From the standpoint of reliability theory, a highway is a recoverable system. Since analytical calculation of recoverable network systems reliability as yet has not been developed, the highway during the time between repairs is considered as a non-recoverable system [4].

Elements of non-repairable systems have the following durability indicators [4]:

$P(t)$ is the probability of failure-free operation of an element during time t (lifetime function);

$f(t)$ is the density of distribution of time between failures;

$\lambda(t)$ is the failure rate at time t;

T_0 mean time between failures;

P_0 is the initial reliability of an element (the probability of failure-free operation at standard average values of the strength and rigidity parameters of a road).

The following relationships exist between durability indicators [4]:

$$P(t) = P_0 e^{-\int_0^1 \lambda(t)dt} \quad (9)$$

$$T_0 = \int_0^{\infty} P(t)dt \quad (10)$$

These expressions show that the initial function in the durability calculation is the failure rate. To determine the durability (mean time between failures) of a road surface, the Weibull distribution law is used:

$$\lambda(t) = \alpha\lambda t^{(\alpha-1)} \rightarrow P(t) = P_0 e^{-\lambda t^{\alpha}} \rightarrow T_0 = P_0\int_0^{\infty} e^{-\lambda t^{\alpha}}dt \quad (11)$$

The existing method of determining durability is not objective, since the initial reliability of the road surface is specified from regulatory documents during the calculation. For an objective assessment of durability, it is necessary to calculate the probability of failure-free operation of the road surface on each section of the road network.

The elastic moduli E_{total} and E_{min} are taken as random variables for assessing the durability of the road surface [5].

The reliability of asphalt concrete road surfaces as flexible road surfaces is determined by the permissible elastic deflection:

$$E_t \geq E_{min}\cdot K_{cr} \quad (12)$$

where E_t is the total calculated modulus of elasticity of the road surface structure, MPa,

E_{min} is the minimum required overall modulus of elasticity of the road surface, MPa,

K_{cr} is the required coefficient of road surface strength according to the elastic deflection criterion K_{cr} = 1,17 [2].

The value of the minimum required overall modulus of elasticity of the road surface structure is calculated using the empirical formula [5]:

$$E_{min} = 98,65 \cdot [\, lg(\sum N_p) - c], \ \ Mpa, \tag{13}$$

Where $\sum N_p$ is the total estimated number of load applications over the service life of the road surface;

c - empirical parameter adopted for different axle loads of a vehicle. For the maximum calculated axle load of 100 kN (with a lightweight type of road surface) c = 3.55.

To determine the durability for each section of the road network, it is necessary to determine the value of the minimum required overall modulus of elasticity of the structure E_{min}. To do this, it is necessary to calculate the total estimated number of load applications over the service life of the road surface on each section of the network according to [3], in the following sequence:

First, the prospective traffic intensity at the end of the inter-repair period N_{ps} is determined using the formula [3]:

$$N_{ps} = \ N_{in}(1+\frac{p}{100})^t, \tag{14}$$

Where N_{in} is the initial traffic intensity, vehicles/day;

p is the annual increase in traffic intensity, %;

t is the prospective period, years.

Then the traffic intensity N_p [3] reduced to the calculated two-axle vehicle is determined:

$$N_p = f_{st} \sum_{m=1}^{n} N_m \cdot S_{mt}, \ cargo\ units/day, \tag{15}$$

where f_{st} is a coefficient that takes into account the number of traffic lanes and the distribution of traffic across them;

n is the total number of different brands of vehicles in the traffic flow;

N_m is the traffic intensity of vehicles of the m-th brand (number of trips per day in both directions of vehicles of the *m-th* brand);

S_{mt}, is the total coefficient of reduction of the impact of the *m-th* brand vehicle on the road surface [3].

The multi-lane coefficient f_{st} is assigned according to Table 3.2 [3]. The roadway lane number is counted from the right in each direction of vehicle traffic. For two-lane roads f_{st} = 0.55.

Next, the total calculated number of applications of the calculated load to a point on the road surface during the service life is found using the formula [3]:

$$\sum N_p = 0,7 \cdot N_p \frac{K_c}{q^{(T_{lt}-1)}} \cdot T_d \cdot K_n \ , \tag{16}$$

Where q is the indicator of change in traffic intensity over the years;

T_{lt} is the estimated service life;

K_c is the summation coefficient;

T_d is the estimated number of days per year corresponding to a certain state of deformability of the road surface;

K_n is a coefficient that takes into account the probability of deviation of the total movement from the expected average.

The estimated service life T_{lt} is set according to table P6.2 [3].

The summation coefficient K_c is determined by the formula [3]:

$$K_c = \frac{q^{T_{lt}}-1}{q-1} \qquad (17)$$

For Eastern and Western Siberia, the calculated number of days per year corresponding to a certain state of deformability of the road surface is taken as T_d = 130 days [3].

The coefficient K_n, which takes into account the probability of deviation of the total movement from the expected average, is found from Table 3.3 [3].

Having data on the minimum and total calculated modulus of elasticity of the road surface of each section of the road, it is possible to determine [4,5]:

The average value of the bearing capacity reserve:

$$[g] = [E_t] - [E_{min}] , \qquad (18)$$

where $[E_t]$ – average value of the total calculated modulus of elasticity of the road surface structure;

$[E_{min}]$ - average value of the minimum required overall modulus of elasticity of the road surface structure.

The dispersion of the reserve of bearing capacity:

$$S_g^2 = S_{E_t}^2 + S_{E_{min}}^2 , \qquad (19)$$

Where $S_{E_t}^2$ is the dispersion of the total calculated modulus of elasticity of the road surface structure;

$S_{E_{min}}^2$ is the dispersion of the minimum required overall modulus of elasticity of the road surface structure.

Standard deviation of the bearing capacity reserve:

$$S_g = \sqrt{S_g^2} \qquad (20)$$

Where S_g^2 is the dispersion of the reserve capacity.

Reliability index:

$$\beta = \frac{\bar{g}}{S_g}, \qquad (21)$$

Where $\bar{g}$ is the average value of the bearing capacity reserve;

S_g is the standard deviation of the bearing capacity reserve.

And finally, the probability of failure-free operation, i.e. the reliability indicator of the road surface structure:

$$P(\bar{g} \geq 0) = 0{,}5 + F(\beta), \qquad (22)$$

Where $F(\beta)$ is the value of the Laplace function.

To determine the average values of elastic moduli, the variation coefficients are used:

$$[E_t] = \frac{E_t}{(1\text{-}C_{E_t})};\ [E_{min}] = \frac{E_{min}}{(1\text{+}C_{E_{min}})} \tag{23}$$

Where C_{E_t} is the coefficient of variation of the total calculated modulus of elasticity of the road surface structure, $C_{E_t} \le 0{,}2$;

$C_{E_{min}}$ is the coefficient of variation of the minimum required modulus of elasticity of the road surface structure, $C_{E_{min}} \le 0{,}2$.

The dispersions of elastic moduli are also determined using the coefficients of variation [5]:

$$S_{E_t}^2 = (C_{E_t} \cdot [E_t])^2;\ S_{E_{min}}^2 = (C_{E_{min}} \cdot [E_{min}])^2 \tag{24}$$

VI. Example of application of the methodology to the Ural Federal District road networks

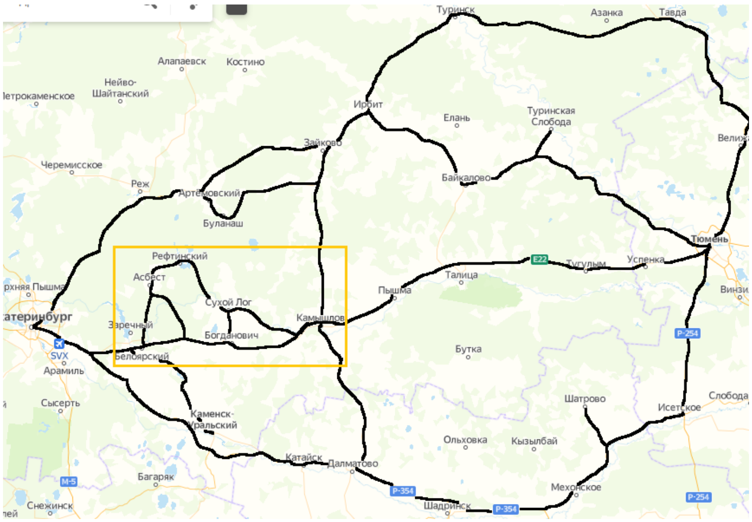

Figure 1: *The main road network with a highlighted area of the secondary road network in the Urals Federal District*

To assess the road surface reliability and durability, a network of highways (Figure 1) was selected, located in the Sverdlovsk, Tyumen and Kurgan regions of the Ural Federal District, which provides ground communication to two regional capitals: Yekaterinburg (with a population of over 1,5 million) and Tyumen.

According to the road-climatic zoning, the entire selected automobile network is located in the second road-climatic zone, II subzone, and is divided into following sections:

1) The main highway R-351 in the direction of Yekaterinburg-Tyumen through the intermediate settlements: Beloyarsky - Bogdanovich - Kamyshlov - Pyshma - Talitsa - Tugulym - Uspenka (length 330 km). Traffic intensity - 7980 vehicles/day.

2) Northern secondary direction Yekaterinburg-Tyumen through intermediate settlements: Artemovsky - Zaikovo - Irbit - Turinsk - Tavda - Velizhany (length 500 km). Traffic intensity - 5100 vehicles/day.

3) The southern secondary direction Yekaterinburg-Tyumen through the intermediate settlements: Kamensk-Uralsky - Kataysk - Dalmatovo - Mekhonskoye - Isetskoye (length 432 km). Traffic intensity - 6520 vehicles/day.

4) Direction Reftinsky – Asbest – Beloyarsky (length 57 km). Traffic intensity - 450

vehicles/day.

5) Direction Reftinsky – Sukhoi Log – Bogdanovich (length 61 km). Traffic intensity – 690 vehicles/day.

6) Direction Zaikovo - Kamyshlov (length 81 km). Traffic intensity - 750 vehicles/day.

7) Direction Irbit – Baikalovo – Talitsa (length 110 km). Traffic intensity – 800 vehicles/day.

8) Direction Turinskaya Sloboda – Tyumen (length 110 km). Traffic intensity – 2100 vehicles/day.

9) Direction Baikalovo – Turinskaya Sloboda (length 49 km). Traffic intensity - 1000 vehicles/day.

10) Direction Artemovsky - Bulanash - Zaikovo-Kamyshlov highway (length 73 km). Traffic intensity - 400 vehicles/day.

11) Direction Beloyarsky – Kamensk-Uralsky (length 72 km). Traffic intensity - 600 vehicles/day.

12) Direction Kamyshlov – Dalmatovo (length 80 km). Traffic intensity – 550 vehicles/day.

13) Direction Shatrovo – southern highway Yekaterinburg – Tyumen (length 22 km). Traffic intensity – 300 vehicles/day.

Using the above methodology, all necessary parameters of road surface wear for each section of the road network were calculated, the results of which are shown in [13].

Based on the obtained results, the initial reliability P (the probability of failure-free operation of the road surface structure at the beginning of road operation after the next repair) of each section of the road network was calculated, which is necessary for calculating the durability of the road surface.

A 100x50 km rectangle is selected from the main road network, in which all secondary roads adjacent to the main network are displayed (Fig. 1). The secondary road network has 30 nodes and 37 links.

To assess the maximum possible impact of a traffic accident on the capacity of the main route of the road network under study, a traffic accident was simulated. The accident was set at 9:00 (when the entire transport network is maximally loaded with vehicles) on the main highway R-351 in the direction of Yekaterinburg-Tyumen in the settlement of Gryaznovskoye, involving a fuel tanker, which led to a fire and explosion, with the subsequent destruction of a bridge structure. This made it impossible for vehicles to continue moving along this road until the bridge was completely restored [13].

The use of an agent-based model to analyze the consequences of the accident showed that the road accident led to a significant decrease in the speed of movement of vehicles and their accumulation, which directly depends on the speed of movement of cars. The average speed of the flow during normal functioning of the transport network is 57.5 km/h [11].

The destruction of the bridge as a result of the accident and the impossibility of driving along this section of the road led to the extension of the route along the main highway R-351 by 85 km (taking into account detours). The maximum time to bypass the destroyed section of the road using detours is $t_1=S/V=85/30=2{,}8$ hours, where S is the length of the detour, km; V is the average speed of movement along the detour, km / h.

The length of the bypass section of the road is 39 km. Provided that this section of the road is fully operational, the travel time along it t_2 at an average speed of 57.5 km/h is 0.7 hours. Time loss when bypassing the destroyed section of the road $\Delta t = t_1 - t_2 = 2{,}8 - 0{,}7 = 2{,}1$ hours. Thus, the travel time along the R-351 highway in the direction of Yekaterinburg-Tyumen in the event of the destruction of the bridge in the Gryaznovskoye settlement increases by 2.1 hours.

For a more accurate calculation of the probability of road pavement failure and the time tothe next repair, it is necessary to take into account all factors affecting the wear of the road pavement. In this regard, it is necessary to analyze the impact of each event on the probability of failure (POF) of the road pavement structure. One promising method for assessing and predicting the failure of any system with a large number of cause--effect relationships between events is Bayesian networks. BNs are graphical models that describe probabilistic relationships between a set of variables. Formally, they are directed acyclic graphs (DAGs), the nodes of which represent variables related to the system, and the arcs of directed action represent probabilistic dependencies between the variables [12]. Modeling a system with cause--effect relationships allows for a deeper understanding of the main mechanisms of its degradation and allowing studying how external interventions affect the system. The GeNIeModeler software package (hereinafter referred to as GeNIe) is used for this purpose. In this work, impacts, external influences, mechanical damage and the human factor are taken as factors influencing the probability of road surface failure.

When constructing a Bayesian network model to determine the probability of road surface structure failure, it is necessary to understand the circumstances leading to the object's failure. Due to the poorly developed system of monitoring road networks, the necessary statistics on road surface destruction are absent, therefore the conditional probabilities of failure of the road surface structure are specified by experts.

The probabilities of failure of the road surface structure on each section of the road network before the next major repair using the "GeNIe" software package are presented in [13].

According to the obtained results, the highest POF of the road surface structure is found in section № 9 (Q = 0.3176) in the direction of Baikalovo - Turinskaya Sloboda of the road network.

Communication between Yekaterinburg and Tyumen is provided by six routes with corresponding failure probabilities Q:

1) The main highway R-351 (Q = 0.2818);
2) The northern direction Yekaterinburg-Tyumen (Q = 0.2875);
3) The southern direction Yekaterinburg-Tyumen (Q = 0.2943);
4) The northern direction through the settlements of Baikalovo and Turinskaya Sloboda (Q = 0.4813);
5) The northern direction through the settlements of Zaykovo and Kamyshlov with an exit to the main highway R-351 (Q = 0.6397);
6) The main highway R-351 through the settlements of Kamyshlov and Dalmatovo with an exit to the southern road (Q = 0.613).

The reliability of the transport network under consideration in this case is equal to:

$$R_n = 1- 0,2818 \cdot 0,2875 \cdot 0,2943 \cdot 0,4813 \cdot 0,6397 \cdot 0,613 = 0,9955 \quad (25)$$

It should be noted that not all six routes could ensure the smooth movement of heavy-duty vehicles with a carrying capacity of over 20 tons. This is due to the fact that some routes have insufficient roadway width and weak points (bridges with reduced carrying capacity), which don't allow passing heavy-duty vehicles. For these reasons, routes No. 4 and 6 cannot ensure the movement of vehicles with a carrying capacity of over 20 tons. Hence, the reliability of the transport network along the Yekaterinburg-Tyumen route in this case will be determined only by: Main highway R-351 (Q = 0.2818); **N**orthern direction Yekaterinburg-Tyumen (Q = 0.2875); **S**outhern direction Yekaterinburg-Tyumen (Q = 0.2943); Northern direction through the settlements of Zaikovo and Kamyshlov with an exit to the main highway R-351 (Q = 0.6397).

So,the reliability of the network with respect to heavy-duty vehicles is:

$$R_n = 1- 0,2818 \cdot 0,2875 \cdot 0,2943 \cdot 0,6397 = 0,9847 \quad (26)$$

Calculation of network reliability shows that the more paths the selected route has, the higher its reliability, and, accordingly, the higher is the reliability of the entire transportation network. The results of calculating the residual resource (in years) of each section of the road network under consideration based on the elastic modulus of the road surface structure reduction criterion (formation of potholes on the roadway) are presented in [13]. The maximum permissible (critical) dimensions of a pothole are: length - 60 cm, width - 15 cm, depth - 5 cm.

One of the types of failure of the road surface structure is the formation of a rut on the roadway, as a consequence of decrease in the elastic modulus of the road surface structure during operation. The work [13] presents a calculation of the residual life of each section of the transport network based on the criterion of the formation of a longitudinal rut, the depth of which exceeds the maximum permissible value of 35 mm.

VII. Conclusion

The paper proposes a method for calculating durability and residual lifetime based on: the criteria of pothole and longitudinal rut formation, and the regional road network reliability based on the permissible residual deflection caused by multiple elastic-plastic deformation of the road surface under the influence of traffic.es

To determine the POF of each section of the road network, a method for assessing the initial reliability has been developed taking into account traffic and atmospheric) impacts and the human factor (violation of the asphalt concrete laying method), using Bayesian networks in the format of the GeNie software package.

The application of the developed methodology to the assessment of the FR of the Yekaterinburg-Tyumen route, showed that its reliability for conventional transport is 0.9955, and for vehicles with a carrying capacity of over 20 tons is 0.9847.

The use of an agent-based model of driver behavior for assessing and analyzing the vulnerability of the Yekaterinburg-Tyumen UFD transport network in the event of a main road failure due to a bridge collapse showed that the more developed the transport network is, the more robust it is.

The most vulnerable sections of the Yekaterinburg-Tyumen transport network in terms of road surface wear are**:** section No. 9 of the Baikalovo-Turinskaya Sloboda direction (with POF= 0.6824 and minimum failure-free service life of 4.5 years according to the pothole formation criterion), and section No. 10 of the Artemovsky-Bulanash direction (failure-free service life 4.39 years, with POF= 0.6842).

References

[1] Assessment and forecasting of durability of asphalt concrete road surfaces: Textbook. Manual / E.N.Barinov; St. Petersburg Civil Engineering Institute, 1993. – 66 p.

[2] ODN 218.1.052-2002 Industry road standards. Strength assessment of flexible road surfaces. – M, 2002. – 60 p.

[3] ODN 218.046-01 Industry road standards. Design of flexible road surfaces. – M, 2001. – 99p.

[4] Moiseenko R.P., Efimenko V.N. On the assessment of the durability of highways // Bulletin of Tomsk State University of Architecture and Civil Engineering - 2019. Vol. 21 - No. 3. P. 207–213.

[5] Moiseenko R.P., Pushkareva G.V., Akimov B.G. Calculation of reliability of flexible road surfaces using the method of moments based on the criterion of permissible deflection // Bulletin of Tomsk State University of Architecture and Civil Engineering – 2017 - No. 6. P. 220-226.

[6] Transport and operational qualities of highways and city streets: textbook for students of higher educational institutions / V.V. Silyanov, E.R. Domke. - 2nd ed., reprinted - M .: Publishing center "Academy", 2008. - 352 pp.

[7] Kairui Feng, Quanwang Li & Bruce R. Ellingwood (2020): Post-earthquakemodelling of transportation networks using an agent-based model, Structure and Infrastructure Engineering, DOI: 10.1080/15732479.2020.1713170

[8] S.A. Timashev, A.V. Bushinskaya, M.G. Malyukova, L.V. Poluyan Integrity and safety of pipeline systems. – Ekaterinburg: Ural Branch of the Russian Academy of Sciences, 2013. – 590 p.

[9] Description of the construction area [Electronic resource] – URL: https://studbooks.net/2441945/tehnika/opisanie_rayona_stroitelstva (Accessed 04/30/2021).

[10] Road pavement reliability criteria [Electronic resource] – URL: https://road-project.okis.ru/files/8/3/6/836/DO/5_DO_Nadezjnost.pdf (Accessed 02/07/2021).

[11] ODM 218.2.020-2012 Industry road methodological document. Methodological recommendations for assessing the capacity of highways. – M, 2012. – 148 p.

[12] Tulupyev A.L. Bayesian networks: Logical-probabilistic approach. – St. Petersburg: Science, 2006. – 607 p.

[13] Ponomarev V.A. Maintenance of the regional road network according to the risk criterion based on digital monitoring of their load and wear: Master Diss. 08.04.01 / Ponomarev V.A. - Ekaterinburg, 2021. - 123 p.

INCREASING THE EFFICIENCY OF ELECTRIC MOBILITY

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Abstract

In recent years, important steps have been taken in the direction of expanding the use of electric cars in our country. Electric cars are considered environmentally friendly as they do not run on fuel. Electric cars are quiet and comfortable. There are three types of electric cars. Fully electric, hybrid and plug-in. Fully electric forms of hybrid electric cars are designed for short distances. Because their energy decreases on a long journey and it is necessary to re-accumulate energy. Some cars use solar energy to provide part of their electricity needs. Solar panels are used to power electric motors and charge batteries. They only get energy from the sun during the day. In this paper, another construction for long-distance electric vehicles is proposed. By installing piezoelectric materials in the wheels of electric cars, their long-distance movement is ensured. Unlike electric cars, where solar panels are installed, piezoelectric materials will provide additional electricity at any time when the cars are moving, not just during the day. In electric cars, since piezoelectric materials are installed on the tires, they will not need additional structural changes.

Keywords: electric car, solar panel, piezoelectric material, electric batteries, electric vehicles, wheels

I. Introduction

Electric cars are safer not only for nature, but also for passengers. Their maneuverability is higher than that of cars powered by conventional energy sources. Currently, climate change is one of the global problems that concern the world. Azerbaijan has not been left out of the influence of global climate changes. In the last 100 years, average annual temperatures in the territory of Azerbaijan have increased by 0.4-1.3^{0}C. Against the background of climate changes, Azerbaijan is experiencing floods, avalanches, storms, hurricanes, surges, strong winds, heat, droughts, melting of glaciers, salinization, land degradation, desertification, reduction of precipitation and water resources, etc. exposed to the effects of such extreme climate events. One of the main factors in environmental pollution is the transport sector [1]. The increase in vehicles is rapidly increasing the risks to the environment. One way to reduce these risks is to increase the share of electric vehicles in the transport sector. There are difficulties in the matter of power supply of electric vehicles. Works aimed at eliminating these problems will directly create conditions for reducing environmental risks. The 29th session of the Conference of the Parties to the UN Framework Convention on Climate Change - COP29, which is hosted by a different country every year, in Baku this year also means global support for Azerbaijan's green energy policy. At present, light material is mainly used in the production of electric vehicles. Thanks to the use of environmentally friendly fuels such as electricity, most urban vehicles (taxis, company and service vehicles, etc.) have no exhaust gases, which makes them promising for use in urban environments.

Currently, many well-known car manufacturing companies have started producing their own electric cars. The power of German-made electric cars has been increased to 544 horsepower. US-made electric cars have four electric motors. There are 105, 135 and 180 kWh batteries. It has a range of 370 to 660 km. These cars can accelerate from 0 to 100 km/h in about 4.4 seconds, just like internal combustion engine cars.

"National Program on Electromobility" is being prepared in our country. There is an order of the Minister of Energy of the Republic of Azerbaijan on the creation of a working group on "Preparation of the National Program on Electromobility". The working group will prepare and implement measures for the development of electromobility.

In recent years, important steps have been taken in the direction of expanding the use of electric cars in our country. From 2022, the import and sale of electric cars and level 2 and 3 electric chargers for them are exempted from VAT. More than 100 electric car charging stations have been installed in the last year. Since last year, the application of the customs duty on the import of electric motor vehicles that have passed the factory release date up to 3 years has been suspended. Statistics show that after these measures, the import of electric cars to the country has increased significantly. So, last year, 3,102 vehicles powered by an electric motor were imported to Azerbaijan worth 125 million 268 thousand US dollars, which is 7.1 times and 6.4 times compared to 2022, respectively, compared to 2021 in comparison, it is 36.2 times and 19.4 times more.

However, in order to promote the use of electric cars, it is not only the reduction of import and sales prices, but also the creation of favorable infrastructure that is important. In other words, electric cars should have a sufficient number of charging points, spare parts warehouses, and quality service should be provided to them. A lot of work has been done in Azerbaijan in the direction of creating such infrastructure.

Usually, some companies that sell electric cars say that the car can travel about 400 kilometers after charging. Experience shows that this car cannot travel even 250 kilometers with an electric engine. Solving these issues requires special attention and control in the area in question.

Electric cars are considered environmentally friendly as they do not run on fuel. Electric cars are quiet and comfortable. There are three types of electric cars. All-electric forms of electric cars in all-electric, hybrid and plug-in hybrid forms are designed for short distances. Because their energy decreases on a long journey and it is necessary to re-accumulate energy. Hybrid cars work with both gasoline and electric engines. Such cars use the electric motor when driving and driving at low speeds, and as the speed increases, the gasoline engine starts to work. The battery of a hybrid car is technically designed for long journeys, as it can collect energy by itself while driving, while the gasoline engine is running, and when it is stopped. Plug-in Hybrid cars, unlike normal hybrids, have batteries with external electrical storage capacity. Such cars can be used on long roads thanks to their powerful batteries.

Taking into account the demand for electric cars, projects related to the production and export of this type of cars are expected in Azerbaijan in the coming years. In total, 8,000 cars are planned to be produced in Azerbaijan in 2024, of which 6,000 are passenger cars, and 2,000 are trucks and buses. The price of cars starts from 17,800 manats and this figure varies up to 160,000 manats.

Due to the lgots for the use of electric cars, their importation to our country, low operating costs, and their environmental friendliness, they replace those working with traditional energy sources more and more every year.

Over the years, energy prices are rising, and it is becoming more difficult to obtain it. Clean energy is being used all over the world. The electric car market is one of the best solutions to these problems. This market has great potential for long-term growth: as expected, the vast majority of cars in the world will be electrified in the near future.

Silent operation, comfort, modern design, simple management and maneuverability of electric cars allow for their wider application.

The developers of their electric cars are working to cover longer distances with a smaller battery. In this regard, everything is simpler with regular buses - the route is known, the distance is also known. Taking all this into account, the American AEM presented to the public the latest version of the 18-seater electric bus E-Shuttle.

II. Methods

The transition to electric vehicles has not always been straightforward. One day, John Mountey, a resident of the United States, decided to completely stop burning fuel. He took the 1994 "Geo Prism" sedan, the Toyota Corolla car produced jointly with "General Motors" under his own brand, and threw the internal combustion engine into the landfill. Many components were sent for recycling: engine cooling system, exhaust pipes, catalytic converter, fuel tank, clutch basket, etc. There was a lot of free space under the hood. But it didn't take long for the new electric motor to occupy a significant part of the space. It is mated to a standard manual transmission locked in second gear. The entire bottom is covered with a large battery. More precisely, there are 50 of them: two sections of 25 12-volt lead-acid batteries.

Additional details: power steering, brake master cylinder and air conditioning system are connected to the electric motor. These are the standard items available. But the water tank with a small heater is new. Of course, heating does not always mean "free" in cars with an internal combustion engine. The gearbox has been changed to make it easier to switch between forward and reverse. A socket is installed instead of the fuel tank mouth. Charging can be done from 120 or 240 V networks. And of course the fuel sensor has been changed to a voltmeter. John Mountey left all other systems unchanged.

Let's say that the standard Geo Prism sedan consumes no more than 10 liters of fuel per 100 km. It turns out that the internal combustion engine will burn 8 liters in 80 km. While the average price of gasoline is 1 AZN/liter, it turns out that a trip of 80 km costs 8 AZN. According to John Mountey, only 12 kW of power is needed to fully charge the batteries of his electric car. The tariff in Baku is AZN 0.08 per 1 kW. If you charge the car during the day, this procedure costs AZN 0.96! In the latter case, each kilometer traveled by car is 8 times cheaper than a standard car. Such savings can only be dreamed of. The disadvantage of operating electric cars is quite obvious: the need for constant recharging. And the maximum mileage is not important here: whether you travel 50 km or 300 km from your home, it is very difficult to find a free outlet. Moreover, the charging procedure requires an average of about 8 hours! You can completely forget about traveling on such transport. It turns out that the destiny of electric vehicles is purely urban use. Here we can add that hydrogen fuel cars are exactly the same as electric cars. The only difference is in the way the electric motor is powered. In the first case, this is the charge of the batteries, and in the second, the energy of the chemical reaction of hydrogen decomposition. But filling a full tank of liquid hydrogen takes no longer than a regular tank of gasoline. The only question is infrastructure.

Solar electric buses (solar cars) are a type of electric buses that move using solar energy. It uses solar panels to power electric motors and recharge batteries. Like an ordinary electric bus, the sunmobile moves at night, and during the day it has enough energy from the sun [2].

The drawback of electric cars is quite simple: the need for constant charging. And here the maximum mileage is not important: it is very difficult to find an electric charger, whether you travel 50 km or 300 km from your home. Moreover, the charging procedure takes about 8 hours on average (15 minutes at special stations)! You can completely forget about traveling in such transport. It turns out that the fate of electric cars is purely urban use. We can add here that hydrogen fueled cars are exactly the same as electric cars. The only difference is in the way the electric motor works. In the first case, it is the charge of the batteries, and in the second case, it is the energy of the chemical reaction of hydrogen decomposition. But filling a tank full of liquid hydrogen doesn't take much longer than a regular tank of gasoline. The only question is the infrastructure.

III. Results

Some cars use solar energy to provide part of their electricity needs. Solar panels are used to power electric motors and charge batteries [3]. They only get energy from the sun during the day.

The following calculation is used when calculating the engine power of an electric car:

Required power:

$N_e = g\eta m\vartheta + C_v F\vartheta^3$, Watt

Where: $g = 9{,}8$ m/сек² - acceleration of free fall;

- η- average rolling coefficient on asphalt;
- m- full mass of the car;
- υ- speed in meters in seconds;
- C_υ- body flow coefficient;
- F- frontal area of the car.

For electric vehicles weighing 2000kg, at a speed of 30 km/h. or 8.3m/sec;

N_e=4072 Watt.

with motor efficiency 0.7, transmission 0.9 (total 0.63), then

$N_{бат}$=N_e / Efficiency=4072 / 0.63=6,4 kW.

Discharge current:

I = N: U = 6400: 100 = 64 amperes; With a battery capacity of 150 Ah, the permissible discharge is 100 A/H, the permissible discharge time is 100: 64 = 1.56 hours or 94 minutes.

The distance from here will be 47 km. By changing the parameters of the battery, we can get the range we want, and the electric car should be as light and small as possible.

Like any technical device, the solar battery has its operational and technical characteristics, which differ for different models and different manufacturers, but with a fairly small discrepancy.

With a solar cell area of about 1.5 m2, the power of the module is about 250 W. A typical solar cell has an efficiency of 16-21%. The service life of such a solar battery is at least 25 years.

IV. Discussion

Apart from the solar panels mentioned above, electric vehicles can be energy efficient by using piezoelectric materials [4]. Piezoelectric materials are materials that generate an electric current when they are mechanically affected, even when raindrops fall on them (Kalbiyev and Jamalova, 2020).

Piezoelectric materials are used to generate electricity using the kinetic energy of raindrops [5]. The physical properties of piezoelectric materials allow them to generate electricity. This feature is known as the piezoelectric effect. When compressive or tensile stress occurs in these materials, an electric field is created in the material and a voltage difference occurs, causing current to flow. The occurrence of this stress difference is due to the asymmetry of the shape of the crystals (cells) of these materials. As can be seen from the figure, a small part of the crystalline form (cell) is positively located as a particle in the center. As shown in Fig. 2, when a certain compressive force is applied, this particle slides in a certain direction, distributing the charge and then creating an electric field. These materials come in different forms. Crystals are the most common, but substances such as plastic and ceramics are also found [6].

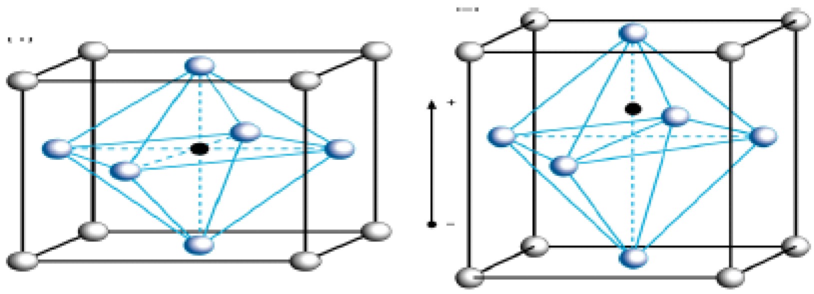

Figure 2: *Structure of the crystal lattice of piezoelectric materials*

The energy obtained by this method is stored in electric batteries and can be used in the electric batteries of electric vehicles.

As shown in Fig. 3, the electrical energy obtained during the use of piezoelectric materials [7] will be directly supplied to the electric battery.

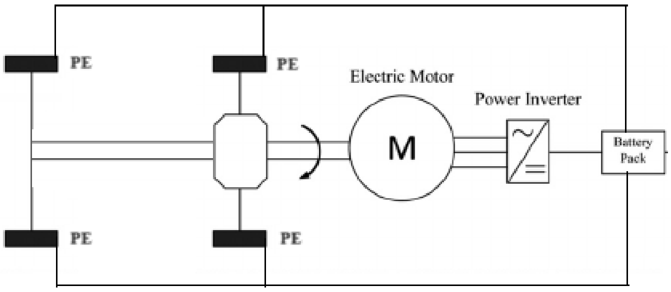

Figure 3: *Power supply and power management of electric vehicles with piezoelectric materials*

The piezoelectric material will be placed on the tires, which can be installed on the wheels, rather than directly on the wheels of the electric vehicle. It is similar to anti-skid pads on car tires. Depending on the amount of electricity consumption of electric machines, the surface area of the piezoelectric material will be determined. During the movement of the electric car, as the piezoelectric materials on the wheels are affected by the car's gravity, as a result, electric energy will be generated, and this electric energy [8] will be transferred to the battery of the electric car.

Figure 4: *Placement of piezo electric material parts on car wheel*

There is experience in using piezo electric materials in cars. There, the piezoelectric material is installed inside the wheel disc. The implementation of this proposal is quite complicated. It interferes with the structure of the disks and changes them. Our proposal does not interfere with the wheel and its other parts. Piezoelectric material parts are installed in a removable cover that is simply attached to the wheel (Fig. 4). One advantage of this offer is that the tire can be fitted to different tire sizes (wheel rims are made for specific tires).

V. Conclusion

One of the main parts of electric cars is its power supply element. Their ability to travel long distances depends on this element. Various methods are proposed to increase this period, for example, installing solar panels. In this paper, another construction for long-distance electric vehicles is proposed. By installing piezoelectric materials in the wheels of electric cars, their long-distance movement is ensured. Unlike electric cars, where solar panels are installed, piezoelectric materials will provide additional electricity at any time when the cars are moving, not just during the day. In electric cars, since piezoelectric materials are installed on the tires, they will not need additional structural changes.

References

[1] Badalov A.B., Kalbiyev R.K., Dzhafarov T.D., Barkhalov R.R. Energy and resource conservation – XXI century: Collection of materials of the X international scientific and practical Internet conference, March 1 – June 30, 2012 – Orel: FGBOU VPO State University-UNPK, 2012.

[2] Yusifbeyli N, Kalbiyev R, Hamidova R, Sadiqov A (2023) Reducing pollution losses in solar panels. *International scientific journal // Endless Light in Science - December 2023 in Russian DOI.* https://cyberleninka.ru/journal/n/endless-light-in-science?i=1131288

[3] Use of solar energy. Ed. L.E. Rybakova. Ashgabat: Science, 1985

[4] Ramiz Kalbiyev, Rana Hamidova, Murad Rzayev. Increasing the energy efficiency of UAVs. / İSUDEF 24. NAA. 2024. May 22-24. Baku. Azerbaijan.

[5] Kalbiyev R**,** Jamalova R **(**2022**)** Yağış generatoru rainergy-nin hazırlanması və yağışlı ölkələrdə sınaqdan keçirilməsi. / The XXVI International Scientific Symposium, Şuşa: Triumph of victory. / The 29th of May 2022, Eskishehir / Turkey. https://www.scribd.com/document/686845096/The-XXVI-International-Scientific-Sympos

[6] Kalbiyev R**,** Jamalova R **(**2022**)** Technical and economic calculations of rain equipment (rainergy). XVI International scientific and technical conference "Improvement of energy systems and heat power complexes". October 11-13, 2022 Russian Federation, Saratov. https://leader-id.ru/events/330498

[9] Dahiya, R.S., Valle, M.: Fundamentals of piezoelectricity. In: Robotic Tactile Sensing. Springer, Newyork. https://doi.org/10.1007/978-94-007-0579-14

[7] Whatmore, R.W.: Piezoelectric and pyroelectric materials and their applications. In: Miller, L.S., Mullin, J.B. (eds.) Electronic Materials. Springer, Boston, MA (1991). *(12) (PDF) Piezoelectric Materials*. Available from: https://www.researchgate.net/publication/356440415_Piezoelectric_Materials [accessed Jul 17 2024] . https://link.springer.com/chapter/10.1007/978-1-4615-3818-9_19

[8] Uchino, K.: 1 - The development of piezoelectric materials and thenew perspective. In: Uchino, K. (ed.) Woodhead Publishing Seriesin Electronic and Optical Materials, Advanced PiezoelectricMaterials, pp. 1–85., ISBN. Woodhead Publishing, Sawston (2010). *(12) (PDF) Piezoelectric Materials*. Available from: https://www.researchgate.net/publication/356440415_Piezoelectric_Materials [accessed Jul 17 2024] . https://www.sciencedirect.com/science/article/abs/pii/B9781845695347500017?via%3Dihub

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TECHNICAL RISKS IN MODERN LOGISTICS

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Abstract

The article discusses the issues of the emergence of risks of logistics activities, the nature of their occurrence and the features of technical risks in modern logistics. The classification of risks according to certain signs and the cause of their occurrence is given. The stages of risk management of logistics activities at enterprises of various industries and types of activity are determined. It is determined that one of the main reasons that have increased the possibility of risks in logistics activities is economic instability in the global environment. All this had a negative impact on all areas of business activity, in particular, an increase in the level of uncertainty in the relations of enterprises with counterparties involved in the logistics chain. Possible ways and methods of minimizing the risks of logistics activities are considered, strategies for minimizing risks in the logistics activities of enterprises are recommended.

Keywords: risks, logistics activities, risk management, transport, risk minimization

I. Introduction

The unstable economic situation in the country, caused by sanctions pressure, has had a negative impact on all areas of business activity. Added to this were fluctuations in the foreign exchange market, which contributed to the receivables of many enterprises, which, in turn, led to a reduction in budgets and expenses, and some companies ceased operations altogether.

These changes in the economy have led to an increase in the risks of logistics activities, that is, an increase in deviations from the expected results due to the disruption of the stability of the logistics system of enterprises. Therefore, the issue of reducing risks in the logistics activities of enterprises, taking into account modern economic conditions, is relevant.

The issue of the emergence of risks and the reduction of their impact on entrepreneurial activity is very relevant, especially in the conditions of uncertainty of the external environment, therefore domestic and foreign scientists devote their works to the study of such concepts as "risk", "uncertainty", "methods of assessing the degree of risk", "risk management", etc. S.G. Kholmovsky [6], A.S. Svezhintseva [6], M.I. Raskatova [3], V.I. Sergeev [4] and others.

Various aspects and approaches to the identification and management of risks related to various types of activities are presented in scientific works. However, changes in the external environment, the state of the national economy, changes in the impact of technical risks on logistics activities cause the need for additional research on the issue of reducing the risks of logistics activities in modern economic conditions.

The purpose of the article is to study the technical risks of logistics activities and determine the ways and methods to reduce their impact in modern economic conditions.

II. Methods

In the logistics system, risks occur at almost all stages of the logistics chain, from the supply of raw materials and goods to production and ending with the delivery of finished products to the consumer. The main reasons for the emergence of risks are the uncertainty of external conditions and the instability of the logistics system, including economic, political, currency instability, violation of product delivery times, changes in consumer demand, etc.

There are many definitions of the category of "risk" [1; 5], since this science is quite young. In particular, examples of these definitions are given in the paper [5], but one can agree with the authors regarding their interpretation of the definition: risk can be defined as the possibility of an event that can lead to a disruption of the normal functioning of the logistics system in a constantly changing external environment. This work provides the following reasons for the emergence of uncertainty that causes risks in the logistics system and a decrease in the level of its reliability:

\u2012 randomness, that is, an event that may occur differently in the future;

\u2012 information gap as vagueness and unreliability of information about the environment;

\u2012 a gap in competence, that is, the influence of subjective factors on the result of the analysis of a risk situation;

\u2012 divergence of interests of the parties that are participants in the logistics process;

\u2012 the influence of the internal and external environment on the effectiveness of the logistics system.

Particular attention should be paid to the subjective factors that play a decisive role in the process of risk management in any business activity. It is clear that the functioning of complex systems in a competitive environment, which are logistics systems, is impossible without reliable organizational and managerial elements. Therefore, the priority task of the logistics system is to ensure its reliability by creating a risk management system. Logistics risks are the risks of carrying out logistics operations of transportation, warehousing, cargo handling and inventory management and the risks of logistics management at all levels, including managerial risks arising from the performance of logistics functions and operations [6].

Determining the place of each risk and creating opportunities for the effective application of risk management methods makes it possible to scientifically substantiate the classification of risks, since each type of risk corresponds to a certain method of management.

III. Results

The main reasons for the emergence of logistics risks are limited or lack of information, instability of the external environment, a decrease in the volume of product sales, the likelihood of breaking the contract with the supplier and the carrier, an increase in the level of the customs rate, non-compliance of the selected transport with the requirements of transportation, low quality of carriers' work, imbalance of the main elements of the logistics chain. A detailed analysis of risks according to certain classification features is given in Fig. 1.

To develop effective ways to manage risks in logistics activities, we will consider the risks that may arise in the procurement, production, sales, transport and storage activities of the enterprise.

The following risks are possible within the framework of procurement logistics:

– the risk of delay in the delivery of raw materials or materials to the warehouse due to non-fulfillment of the terms of the contract by the supplier or carrier;

– the risk of damage to raw materials or materials due to non-compliance with the necessary conditions for the transportation and storage of products;

– the risk of an increase in the price of raw materials due to price fluctuations, exchange rate differences or price increases by the supplier;

– the risk of cargo detention at the customs border due to violation of the conditions for certification of goods;

– risk of customs clearance by violation of documentary support of goods.

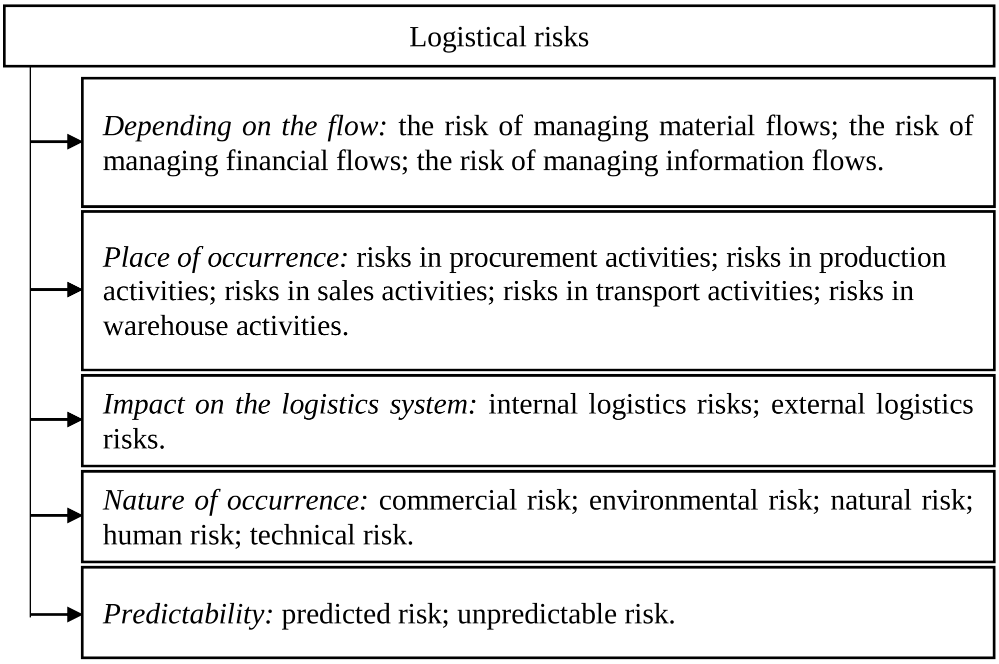

Figure 1: *Classification of risks of logistics activities*

Within the framework of production activities, the following risks are distinguished:

– the risk of a shortage of the required amount of raw materials or materials due to incorrect calculation of the necessary amount of stocks to ensure the uninterrupted operation of the enterprise;

– the risk of an increase in the cost of storing raw materials by raising prices for utilities and renting warehouse space.

Within the framework of sales activities, the following risks are possible associated with the movement and storage of finished products:

– the risk of violation of the deadline for the delivery of products to the customer due to untimely shipment of goods or delay in delivery by the carrier;

– the risk of damage to products during storage and transportation;

– the risk of a surplus or shortage of goods due to an error in determining the optimal amount of demand.

Within the framework of transport activities, we highlight the following risks:

– the risk of severing ties with logistics partners;

– the risk of non-fulfillment of obligations for the transportation of goods by logistics partners;

– the risk of an increase in transportation costs;

– the risk associated with partial damage or complete loss of the goods during their transportation;

– the risk of breakdown of vehicles, which leads to untimely delivery of goods to the consumer.

The following risks may occur within the framework of warehouse activities:

– the risk of an excessive amount of inventory in the warehouse;

– the risk of an expiration date, which will lead to the liquidation of a batch of stock or goods;

– the risk of growth of fixed costs.

Risks in logistics arise in the process of movement of material, financial and information flows, that is, they combine various types of risks of all components of the logistics system. There are the following types of risks of the logistics system:

\u2012 commercial, directly related to the economic aspect of the enterprise's activities;

\u2012 technical, related to the operation of technical means;

\u2012 economic and legal, related to the civil liability of individuals and legal entities in the process of logistics activities;

\u2012 force majeure, which are completely unpredictable.

To reduce the impact of risks on the result of the logistics activities of enterprises, it is important to take into account all aspects of the modern conditions of the logistics activities of enterprises and consider them separately and in interconnection and interdependence.

The following types of risks are considered the most typical in logistics activities:

\u2012 loss of cargo due to theft, false shipment to third parties, damage due to natural and man-made disasters or negative social phenomena;

\u2012 untimely delivery due to delays, changes in routes, etc.;

\u2012 damage to goods, when the use value of goods is lost in whole or in part due to the movement of goods for a long time in long chains of transportation, transshipment, sorting, etc.

\u2012 improper execution of accompanying documents, as a result of which problems arise during customs clearance of goods;

\u2012 disclosure of confidential information, which may lead to a violation of equality in competition;

\u2012 environmental risks may arise as a result of violation of the rules for the transportation and storage of goods, they may harm the life and health of people or the environment;

\u2012 risks of loss of reputation as a result of choosing an unscrupulous partner who may have a negative reputation;

\u2012 risks of civil liability for causing losses to third parties in the process of carrying out logistics operations.

Due to the occurrence of risks, the following types are distinguished:

\u2012 internal risks – organizational, technical and technological, depend mainly on the company's employees. They can be reduced by the correct organization of logistics processes at the enterprise;

\u2012 external risks are those that do not depend on the company at all. These include natural disasters, international conflicts, epidemics. To minimize them, it is necessary to calculate possible scenarios of events on the way of cargo movement;

\u2012 mixed risks - associated with both external factors and the behavior of the company's employees. These include theft, violation of the rules for the transportation and storage of goods, legal and legal risks, financial risks.

In order to reduce risks to a minimum level, to ensure the development of the logistics system and its functioning, it is necessary to manage risks by using appropriate methods. Risk management of the logistics system is a set of methods, functions and stages of the logistics cycle process, the successful application of which allows you to prevent risks or reduce them, ensure the sustainable functioning and development of the logistics system of the enterprise. The risk management process is carried out in stages.

At the first stage, it is necessary to identify the external and internal risks of the logistics system under study. At this stage, risks specific to each specific enterprise are identified and identified.

At the second stage, a qualitative and quantitative assessment of risks is carried out, that is, the amount of losses in the event of a risk event and the probability of its occurrence are identified. At this stage, the statistical method, the method of the stage of expert assessments, the method of analogies are used.

At the third stage, the analysis of the impact of risk factors, its magnitude and frequency on the indicators of logistics activities is carried out using correlation and regression analysis, simulation modeling and analytical methods.

At the fourth stage, it is necessary to carry out forecasting, modeling decisions made to prevent logistics risk;

At the fifth stage, the acceptability of the logistics risk is assessed and the management method that can ensure its minimization is selected.

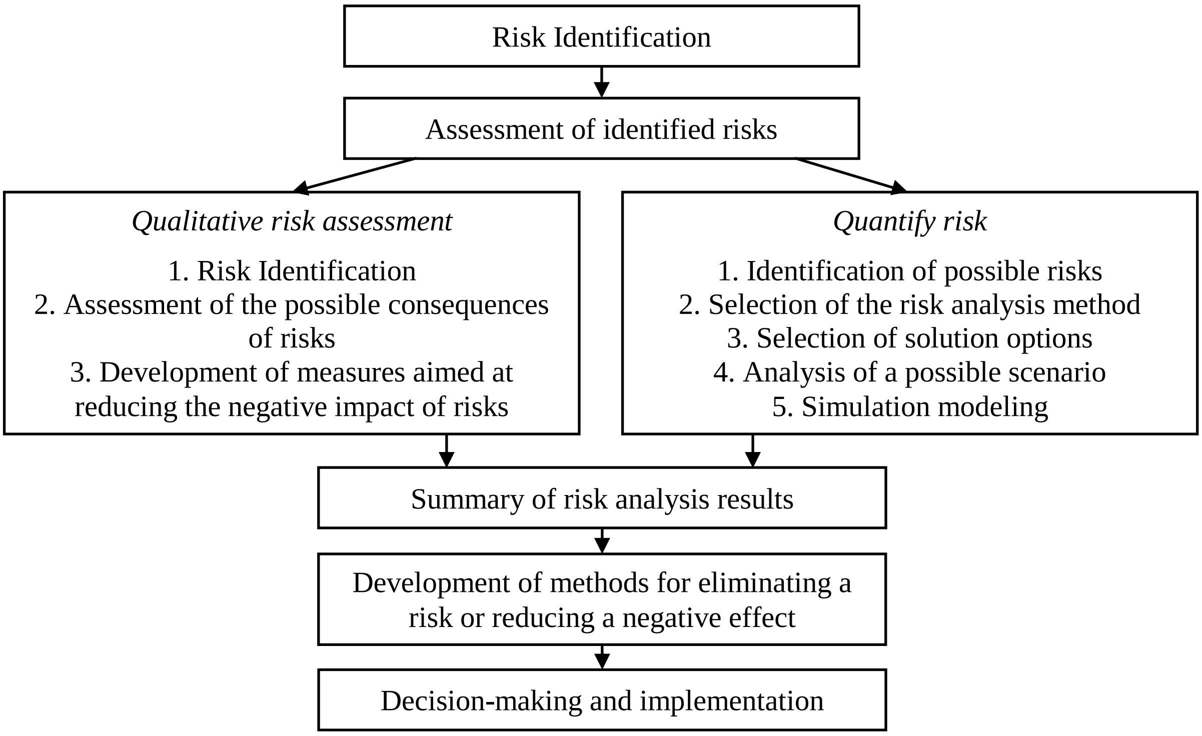

Figure 2: *Algorithm for managing the logistics risks of the enterprise's activities*

Usually, the methods of minimizing risks are: risk avoidance; localization of risks; risk diversification; risk compensation; risk transfer; limitation; insurance [3].

If risk avoidance involves rejection of the services of unknown or dubious partners, rejection of dubious offers, then integration or association with reliable partners allows you to distribute risks between them and reduce the impact of a certain type of risk on each of the parties to the transaction.

To reduce the impact of risks on logistics activities, it is possible to use risk localization methods that provide for local interest - the link in the supply chain that is the most risky.

IV. Discussion

Reducing the degree of risk is also possible through the use of differentiation of activities and/or markets for products with an expansion of the range of products, orientation to various groups of consumers, etc.

Risk compensation provides for the use of strategic planning of enterprises, forecasting the external environment, monitoring the socio-economic and legal environment and creating a system of reserves.

Risk transfer is carried out through the conclusion of lease, supply, storage, transportation, maintenance, etc. agreements.

To reduce the expected risks, it is possible to carry out limitation, that is, to establish maximum costs when selling goods on credit.

At the same time, it is advisable to include the method of risk management, which is relevant in modern economic conditions both for the logistics system and for enterprises of all types of activity, since the instability and uncertainty of both external and internal conditions for the functioning of the economy contribute to an increase in risks at all stages of logistics activities. Such a method is the method of risk acceptance, that is, readiness for risk and the formation of measures that can prevent foreseeable losses. In this case, management decisions should be aimed at forming readiness for their occurrence through the creation of self-insurance and external insurance funds.

Insurance is the main and more widespread way of minimizing risks, which is used by both manufacturers and carriers on domestic flights and international carriers. One of the ways to manage logistics risks is the Incoterms 2020 rules, which are eleven unified rules applied in the practice of world trade. These rules set out the rights and obligations of the parties to a foreign trade contract in terms of the supply of products from the seller to the buyer [2]. These rules regulate both the distribution of transportation costs between the seller and the buyer, and the transfer of transport risks (damage to goods, loss or unexpected destruction of cargo) and insurance.

Risk management in the logistics system is closely related to the chosen corporate strategy, which ensures its stability and effective operation. The work [4] reflects the influence of the enterprise strategy on the choice of risk management methods in the logistics systems of the enterprise:

When choosing a "cautious" strategy, the company can abandon logistics risks or transfer it to another participant in the logistics process. A "balanced" strategy involves, depending on the current situation, the assumption of risk and the creation of insurance funds or the provision of guarantees, the transfer or rejection of logistics risks. A "risky" strategy may involve accepting or transferring risks depending on the specific situation.

In modern conditions of economic development, enterprises are faced with the need to search for methods to expand the sales market by entering international markets. In these conditions, risk becomes an integral condition for the functioning of the enterprise due to the effect of economic, financial, legal and political factors, which often generate various threats of material losses in the implementation of foreign economic activity. In addition, enterprises are increasingly making management decisions in conditions of uncertainty, so the issue of logistics risk management at enterprises focused on foreign markets requires special attention.

All components of the risk management process are closely interrelated, and each has not only a determining, but also a subordinate nature in relation to the other component. The multi-stage nature of the logistics system implies a high level of potential risk. Therefore, the logistics system should provide for a set of measures aimed at maintaining a high level of reliability of the system, which should minimize the probability of adverse events, from the point of view of risk management.

Thus, for the effective functioning of the logistics system in conditions of uncertainty, it is necessary to assess and analyze the risks of logistics activities. The use of the proposed methodological approaches to logistics risk management will make it possible to identify reserves for improving the efficiency of managing individual business processes of the logistics system and develop measures aimed at optimizing costs, using the resources of logistics system participants in the most rational way and meeting the requirements for the quality of logistics services in the supply chain.

References

[1] Nikolaenko V.S. Risk, risk-management and uncertainty: clarification of concepts // Electronic Bulletin. – 2020. – № 81. – P. 91-119.

[2] Incoterms Rules. Quattro Logistics - Customs broker. – URL: https://4logs.ru/blog/pravila-inkoterms/

[3] Raskatova M.I. Theoretical Foundations of Risk Management: A Textbook. – Chelyabinsk: SUSU, 2019. – 46 p.

[4] Sergeev V.I. Logistics in Business: Textbook // V.I. Sergeev. Moscow, INFRA-M Publ., 2011. – 608 p.

[5] Fateeva O.V., Kononko V.A. Risks and Uncertainty in Enterprise Management: Definition, Approaches to Assessment // Bulletin of the Altai Academy of Economics and Law. – 2020. – № 4-2. – P. 262-269.

[6] Kholmovsky S.G., Svezhintseva A.S. // Baikal Research Journal. – 2021. – T. 12, – No 3.

THE IMPACT OF DIGITAL TECHNOLOGIES ON SUSTAINABLE CONSUMPTION AND PRODUCTION

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Abstract

The article explores the transformative role of digital innovations in advancing sustainability across industries. It focuses on how technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics are reshaping the way businesses and consumers interact with resources, leading to more sustainable consumption and production models. These technologies help optimize resource use by improving the efficiency of supply chains, enhancing waste management systems, and enabling real-time monitoring of environmental impacts. For instance, AI and machine learning algorithms allow companies to forecast demand more accurately, reducing overproduction and minimizing waste. IoT devices provide valuable data on energy and resource consumption, enabling more efficient production processes, while blockchain ensures transparency and traceability in supply chains, helping consumers make informed, sustainable choices. The article also examines the growing influence of digital platforms that promote sustainable consumption, such as apps encouraging eco-friendly purchasing decisions or online marketplaces for sharing and reusing goods. By leveraging data-driven insights, these platforms encourage consumers to adopt sustainable lifestyles, while businesses can better align their operations with sustainability goals. Additionally, the article delves into the potential for digital technologies to accelerate the transition to a circular economy, where products and materials are reused, repaired, and recycled instead of following a linear lifecycle. However, the article also addresses the challenges and limitations of adopting digital technologies for sustainability. These include concerns over data privacy, the energy consumption of digital infrastructures, the need for standardized regulations, and the widening digital divide that could limit the accessibility of these technologies in certain regions. Despite these hurdles, the potential of digital technologies to revolutionize sustainable consumption and production is immense, offering new pathways to achieve global sustainability targets and reduce environmental degradation.

Keywords: circular economy, resource optimization, waste management, real-time monitoring

I. Introduction

In the modern era, digital technologies are playing an increasingly pivotal role in transforming industries and reshaping how societies consume and produce goods. As the global community faces growing environmental challenges—such as climate change, resource depletion, and waste accumulation—there is an urgent need to shift towards more sustainable models of consumption and production. Sustainable Development Goal 12 (SDG 12), established by the United Nations, emphasizes the importance of responsible consumption and production patterns to ensure the long-term well-being of both people and the planet.

In this context, digital technologies like artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics are emerging as powerful tools for fostering sustainable practices. These technologies offer unprecedented opportunities to enhance efficiency, reduce waste, and create transparency across supply chains, which are critical in promoting sustainability across various sectors.

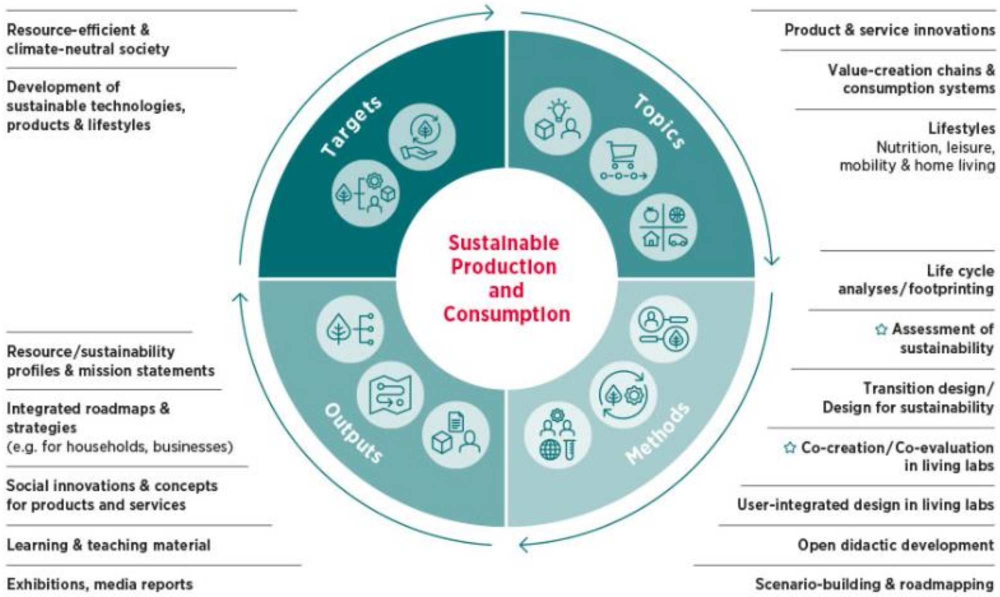

Figure 1: *Sustainable Production and Consumption Division analyses*

To create a climate-neutral and resource-efficient society in the medium to long term, it is essential to undertake a fundamental "dematerialization" of production and consumption. This involves implementing strategies focused on efficiency, consistency, and sufficiency, which ensure that products are designed to be "lighter on resources" and can be utilized for longer periods and in more effective ways. The process of achieving this is inherently tied to thoughtful design.

The Sustainable Production and Consumption Division is dedicated to analyzing, evaluating, and developing technological and social innovations through the use of real-world laboratories and living labs. These environments actively involve users in the development process, both before and during innovation implementation. Researchers assess the resource efficiency and social impacts of production and consumption along value chains, creating transformative approaches and scenarios that aim for climate neutrality, resource efficiency, and sustainability. Their focus areas include nutrition, leisure, mobility, and housing.

For meaningful changes in production and consumption patterns to take place, it is crucial to have companies that create and provide these innovative products and services. Additionally, empowered consumers who actively utilize these offerings are necessary, along with a supportive political framework that facilitates the transformation process.

The research undertaken by the Sustainable Production and Consumption Division encompasses several key areas:

- Sustainability and Resource Assessment: Evaluating the sustainability of materials and processes.
- Product and Service Innovations: Developing new offerings in real-world laboratories and living labs that prioritize sustainability.
- Education: Fostering knowledge and awareness around sustainable practices among consumers and businesses.
- Science-Based Innovation, Enterprise, and Consumer Policy Approaches: Informing policies that support sustainable production and consumption.

This research is characterized by its inter- and transdisciplinary nature, leveraging collaborations across numerous national and international networks. The Division draws upon extensive experience from various third-party funded projects, enhancing its ability to drive forward the agenda of sustainable production and consumption.

The integration of these digital innovations is not just limited to businesses optimizing their production processes but also extends to consumers who are becoming more empowered to make eco-friendly choices. Digital platforms are facilitating access to information, enabling consumers to adopt sustainable lifestyles, while businesses are using real-time data to reduce their environmental footprint.

However, while digital technologies present immense potential for advancing sustainability, their implementation comes with challenges. Issues such as the energy consumption of digital infrastructures, data security, and the need for comprehensive regulations to govern digital ecosystems must be addressed to ensure that these technologies contribute meaningfully to sustainable development.

This paper aims to explore how digital technologies are impacting sustainable consumption and production, highlighting both the opportunities they offer and the obstacles that must be overcome to harness their full potential.

Demographic shifts, including population growth and rapid urbanization, are intensifying pressure on existing food systems and agricultural resources. As global food demand rises, there is an urgent need for sustainable practices to ensure food security while safeguarding the environment. Additionally, the ongoing effects of climate change further strain the availability and quality of essential resources for agriculture, underscoring the importance of adaptation and innovation in food production. These complex challenges demand integrated, forward-thinking approaches to achieve sustainability in food systems, requiring transformative changes across agricultural practices.

A key aspect of this transformation involves the evaluation and adoption of advanced production technologies, which can help drive sustainable productivity growth. These technologies also hold potential for influencing broader trends, such as sustainable consumption patterns and reductions in greenhouse gas (GHG) emissions.

Digital technologies, including artificial intelligence (AI), big data (BD), the Internet of Things (IoT), and cloud computing (CC), are increasingly recognized as vital tools for addressing sustainability challenges in food systems. These technologies can enhance supply chain transparency and efficiency, reduce food loss and waste, and optimize resource use. For example, automation can streamline production processes, while biotechnologies can improve crop resilience and quality, essential for maintaining sustainable production in the face of climate change. Furthermore, digital innovations can optimize transportation and logistics, lowering carbon footprints and minimizing environmental impacts across the food supply chain.

Investment in research and development of digital technologies could yield significant benefits, particularly in promoting sustainable food systems globally. However, fully realizing the potential of these technologies requires not only technical innovation but also increased awareness, understanding, and adoption by all stakeholders in the food supply chain.

This paper seeks to explore the broader impact of digital technologies on sustainable food production and consumption. Specifically, it aims to assess how these innovations affect municipal waste, primarily stemming from food consumption, and agricultural emissions of nitrogen and methane, which are key contributors to GHG emissions. Additionally, the study aligns with the objectives of Sustainable Development Goal 12 (SDG12), which focuses on promoting responsible consumption and production patterns.

Despite the growing importance of digital solutions in agriculture, research gaps remain, particularly in the form of detailed longitudinal analyses that track the long-term impact of digital technologies on food sustainability. There is also a need for a more comprehensive understanding of the intricate relationships between food production, consumption, and critical variables tied to sustainability.

The originality of this study lies in its application of Structural Equation Modeling (SEM) to assess correlations between the adoption of digital technologies and key sustainability metrics, particularly in relation to food production and consumption. By offering valuable insights into how these technologies can mitigate food waste and agricultural emissions, this research aims to contribute to the development of policies and practices that foster long-term food sustainability.

The structure of this paper includes six sections: an introduction outlining the research purpose and objectives, a literature review and hypothesis development, a description of the research methodology, presentation of the findings, discussion of the results, and conclusions summarizing the key contributions of the study.

II. Methods

This section outlines the research design, data collection, and analysis methods used to assess the impact of digital technologies on sustainable food production, consumption, and related sustainability metrics. The study primarily focuses on exploring the correlations between digital technology adoption and key variables such as municipal waste, greenhouse gas (GHG) emissions from food production (specifically nitrogen and methane emissions), and overall progress towards Sustainable Development Goal 12 (SDG12), which promotes responsible consumption and production.

1. Research Design

This study employs a mixed-methods approach, combining quantitative data analysis with qualitative insights to understand the multifaceted impact of digital technologies on food sustainability. The research was designed to capture both the breadth and depth of technological influences across the food supply chain, from production to consumption.

Structural Equation Modeling (SEM) was chosen as the primary analytical tool to assess the relationships between digital technology adoption and sustainability outcomes. SEM allows for the testing of complex relationships between observed and latent variables, making it well-suited for evaluating the multi-dimensional effects of digital technologies on food systems.

2. Data Collection

The study utilized secondary data sources for quantitative analysis, including data from international organizations, government reports, and industry publications. These data sources provided information on the following variables:

- Adoption of digital technologies: Data on the implementation of AI, Big Data, IoT, and cloud computing in agricultural and food supply chain processes were gathered from industry reports and technology adoption studies.
- Municipal waste: Data on food waste at the municipal level, particularly in urban areas, were sourced from reports by the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization (FAO).
- Agricultural GHG emissions: Data on nitrogen and methane emissions from agriculture were obtained from reports by the Intergovernmental Panel on Climate Change (IPCC) and national greenhouse gas inventories.
- Sustainable Development Goal 12: Indicators related to SDG12 were collected from the United Nations' Sustainable Development Goals (SDG) database, focusing on responsible consumption and production patterns, particularly those tied to food systems.

In addition, qualitative data were collected through interviews with industry experts, technology providers, and stakeholders in the food supply chain, including farmers, food processors, retailers, and policymakers. These interviews provided insights into the practical challenges and opportunities of implementing digital technologies in real-world settings.

III. Data Analysis

The analysis followed a two-step process:

A. Quantitative Analysis using Structural Equation Modeling (SEM)

SEM was used to test the hypotheses on the impact of digital technologies on sustainable food production, consumption, and waste reduction. This method allowed for the examination of both direct and indirect effects of technology adoption on food sustainability metrics. Key steps in the SEM analysis included:

1. Model Specification: A conceptual model was developed to represent the hypothesized relationships between digital technology adoption, food waste reduction, GHG emissions, and SDG12 indicators.
2. Model Estimation: Maximum likelihood estimation (MLE) was used to estimate the parameters of the SEM model.
3. Model Fit Assessment: Goodness-of-fit indices, such as the Chi-square test, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA), were used to evaluate the model fit.
4. Hypothesis Testing: The relationships between variables were tested for significance using standard error estimates and p-values.

B. Qualitative Analysis

A thematic analysis of interview data was conducted to complement the quantitative findings. Key themes included:

- Barriers to technology adoption: Challenges faced by stakeholders in integrating digital solutions into their operations.
- Opportunities for sustainability: Insights into how digital technologies can contribute to improved resource efficiency, waste reduction, and sustainable practices.
- Policy and regulatory support: The role of governments and international organizations in facilitating or hindering the adoption of sustainable technologies.

4. Hypotheses Development

Based on the literature review and theoretical foundations, several hypotheses were developed to guide the research. These hypotheses included:

- H1: The adoption of digital technologies (AI, Big Data, IoT, CC) in the food supply chain positively correlates with a reduction in municipal food waste.
- H2: Digital technologies in agriculture contribute to the reduction of nitrogen and methane emissions, improving agricultural sustainability.
- H3: Digital technologies in food systems positively impact the achievement of Sustainable Development Goal 12 by enhancing sustainable consumption and production patterns.
- H4: The effect of digital technologies on food sustainability is mediated by improved supply chain transparency and collaboration among stakeholders.

5. Limitations

Several limitations should be acknowledged in this study. First, reliance on secondary data may present challenges regarding the consistency and accuracy of the data, as reporting practices vary across sources. Second, the cross-sectional nature of the quantitative data limits the ability to draw conclusions about long-term trends. Future research could benefit from longitudinal studies that track the impact of digital technologies over time.

In summary, the methods employed in this study, including SEM and qualitative interviews, provide a comprehensive framework for assessing the impact of digital technologies on food sustainability, focusing on critical variables such as municipal waste, GHG emissions, and progress towards SDG12. The combination of quantitative and qualitative data ensures a robust understanding of the challenges and opportunities presented by digital innovations in the food sector.

IV. Results

The use of digital technologies in agriculture can have a significant impact on the efficiency and sustainability of food systems. However, for these technologies to achieve a truly transformative effect, their implementation must consider the social, economic, and cultural contexts of the communities in which they are used. Improving access to food and reducing the carbon footprint of global agri-food systems are critical priorities for achieving Sustainable Development Goals (SDGs) and ensuring global food security.

The primary objective of this study was to explore the impact of digital technologies on food production and consumption, with a particular focus on their influence on municipal waste, largely originating from food consumption, nitrogen and methane emissions from agriculture, and sustainable consumption and production in alignment with SDG12. The study utilized longitudinal data to track trends over time, offering insights into how these technologies affect sustainability in the food sector. Additionally, it examined the relationships between agricultural production, waste generation, and greenhouse gas (GHG) emissions to better understand the complex interactions in the food supply chain.

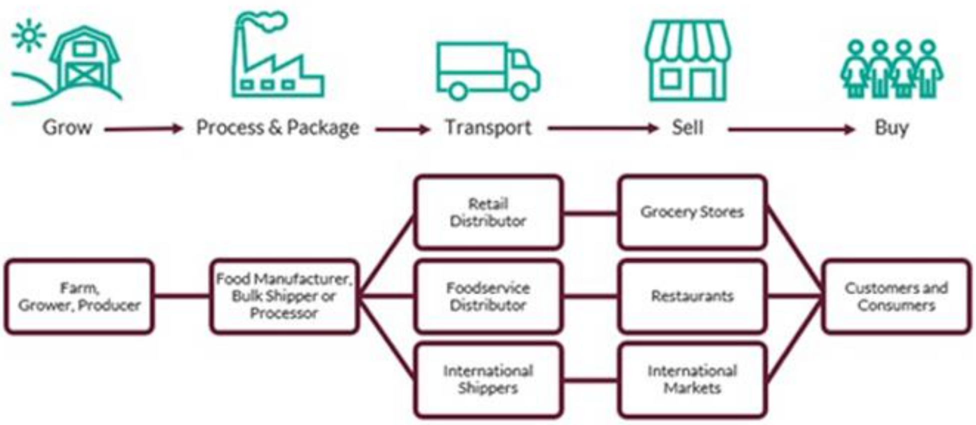

Figure 2: *The Global food supply chain*

Food supply chains represent one of the most significant yet underappreciated areas for investment and business innovation. This industry impacts every individual globally and stands at the precipice of disruption.

In the medium term, the future of food supply chains will revolve around assembling a network of resilient suppliers capable of providing year-round harvests, with inputs sourced from around the globe. The long-term outlook is even more promising, especially with emerging technologies guiding us toward a post-carbon future. For instance, "touchless agriculture" is one of the transformative technologies on the horizon, utilizing extensive data analytics to help farmers select optimal seeds without the need for physical planting, potentially revolutionizing agricultural practices.

The global food supply chain plays a critical role in transporting, processing, and marketing food worldwide. Globalization has facilitated this process, enabling food chains to deliver substantial quantities of quality products to nourish approximately one in nine people on Earth. However, globalization should not be viewed solely from an economic standpoint; its social and environmental implications are equally important.

While globalization enhances the availability of quality foods and fosters advancements in agricultural techniques and transportation, it also poses sustainability challenges. The environmental and cultural impacts of global food chains cannot be overlooked. For example, the globalization of food production can lead to job losses in specific regions due to outsourcing and shifts in transportation practices. It has contributed to enhanced food security but simultaneously raised concerns regarding food safety.

Moreover, global food chains have induced considerable ecological disturbances at local, regional, and even international levels. Although globalization brings numerous advantages, it also carries side effects that often go unnoticed or unaddressed.

Given that globalization is a persistent reality, food supply chains must take proactive measures to ensure their long-term sustainability. This requires a holistic approach that balances economic growth with environmental stewardship and social responsibility, ensuring that food systems remain resilient and equitable for future generations. Embracing sustainable practices within global food chains will be essential for mitigating adverse effects while maximizing the benefits of globalization.

The key findings of the study revealed several important points. First, there is a negative relationship between digital technologies and SDG12, indicating that while these technologies can have a positive effect on sustainability, their overall impact on consumption and production is moderate but significant. This supports the H2 hypothesis, suggesting that the application of digital technologies may have unintended consequences for sustainable development. The study also found that increasing efficiency through digital tools can paradoxically lead to higher resource consumption.

The study also highlighted the challenges posed by digitalization in agriculture. As Kamble et al. pointed out, these include ensuring equal access to technology and data for all stakeholders, particularly smaller producers, as well as addressing concerns around data protection and cybersecurity in increasingly complex and interconnected food supply chains. Despite these challenges, the research confirmed a positive relationship between agricultural production and both sustainable consumption and the generation of municipal solid waste, validating the H1 and H3 hypotheses. This finding emphasizes the close connection between agricultural productivity and sustainability, as increased production brings both benefits and challenges for waste management.

Moreover, the study demonstrated that digital technologies can play a crucial role in reducing municipal solid waste by optimizing various processes such as production, distribution, and inventory management. This finding, which aligns with the research of Bahn et al., validates the H4 hypothesis, showing that digital tools can contribute to more effective waste management and, in turn, support the sustainability of food systems. However, the study also stressed the importance of considering the indirect environmental impacts of digital technologies, such as increased energy consumption and the generation of electronic waste. These factors must be managed carefully to ensure that the sustainability benefits of digitalization in agriculture are not undermined.

In conclusion, the study highlights the dual nature of digital technologies in the agricultural sector. While they offer significant potential to reduce waste, improve supply chain efficiency, and contribute to sustainable food production, they also present risks related to increased energy consumption and unequal access. As a result, a balanced and cautious approach to the implementation of these technologies is essential to ensure they contribute positively to the long-term sustainability of food systems.

IV. Discussion

I. Subsection One

The findings of this study indicate that sustainable consumption and production practices, in alignment with Sustainable Development Goal 12 (SDG12), have a negative influence on greenhouse gas (GHG) emissions from agriculture, supporting the H5 hypothesis (fig.3). This result highlights the critical role that sustainable practices can play in reducing agricultural emissions and mitigating environmental impact. These findings are consistent with the research of Dong et al., Agrawal et al., and Sharma et al., who emphasize that companies can enhance their operational efficiency using digital technologies while contributing to sustainability efforts, particularly in achieving SDG12. By improving efficiency and reducing GHG emissions, digital technologies can strengthen the sustainability of supply chains, making them more transparent and accountable. Furthermore, these technologies facilitate the monitoring and reporting of sustainable practices, thereby reinforcing sustainability goals across industries.

The study also confirmed the H6 hypothesis, revealing a positive relationship between agricultural production levels and GHG emissions. This suggests that as agricultural production increases, so too do emissions, underscoring the urgent need for more sustainable agricultural practices to reduce environmental degradation. Research by Kabange, Xu, Wang, and Ouyang supports these findings, showing that agriculture is a significant source of global GHG emissions due to activities like livestock fermentation and fertilizer use. However, modern agricultural practices, coupled with the adoption of digital technologies, can help mitigate these emissions by enhancing efficiency and sustainability.

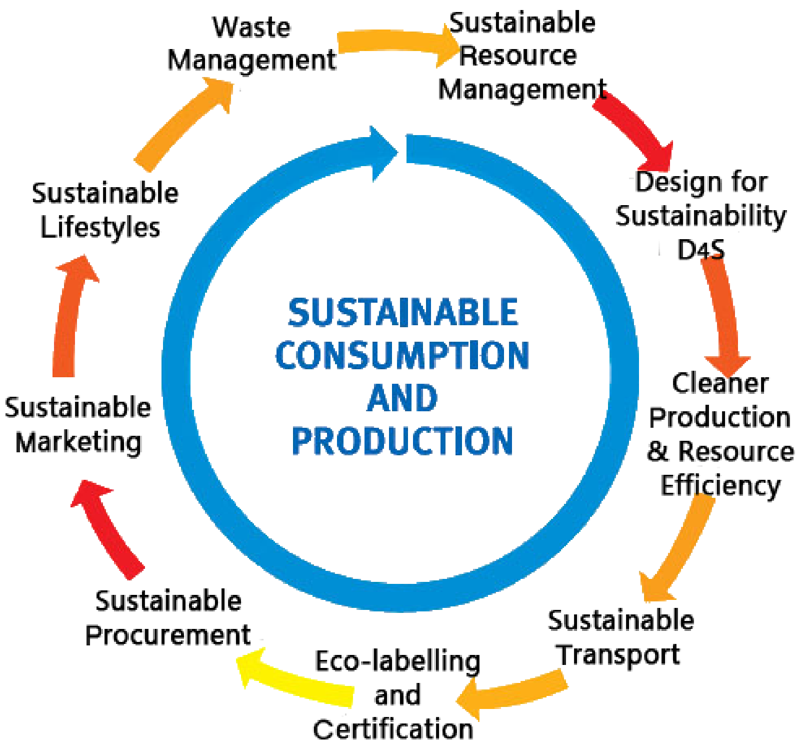

Figure 3. Sustainable consumption & production

Digital technologies, when implemented in agriculture, can provide significant advantages, including better resource management, real-time decision-making tools, and more sustainable farming practices. The results highlight the importance of promoting the adoption of these technologies across the food supply chain to meet sustainability goals. However, challenges remain, particularly regarding the equitable access to these technologies, especially for small- and medium-sized primary producers. Investments in digital infrastructure and education are necessary to support the transition to more efficient and sustainable agri-food systems.

The European Union (EU) is taking a proactive stance in promoting the digitalization of agriculture as part of its efforts to transition to more sustainable farming practices. The concept of the "fourth agricultural revolution" emphasizes the potential for digital technologies to transform agriculture radically. By integrating these technologies, production processes and resource management can be optimized, enhancing sustainability and resilience in the face of current and future challenges.

Digital technologies offer numerous benefits to agriculture, such as increased efficiency, reduced environmental impact, improved food quality, and higher incomes for producers. These tools also support more sustainable farming practices by reducing reliance on external inputs like pesticides and chemical fertilizers, while promoting the efficient use of natural resources. Additionally, they enhance access to agricultural information and services, particularly for rural producers, fostering greater transparency and efficiency across the entire food supply chain.

However, despite the advantages of digitalization, there are significant barriers to its widespread adoption. The high cost of advanced agricultural technologies can be prohibitive for primary producers, particularly in developing countries. Furthermore, a lack of training and resources to support the adoption of these technologies may exacerbate existing inequalities, creating a digital divide within the agricultural sector. Therefore, efforts to promote digitalization must address these challenges to ensure that the benefits of technology reach all stakeholders and contribute to the broader goal of sustainable development.

II. Subsection Two

The challenges facing food systems are multifaceted and interconnected, reflecting the complexity and fragility of the global food chain. Issues such as population growth, competition for resources, climate change, dietary shifts, limited food access, unsustainable agricultural practices, and significant food waste contribute to the precariousness of food security. Rapid urbanization and population expansion place immense pressure on natural and agricultural resources, increasing the risks of food insecurity and environmental degradation. Climate change exacerbates these problems by directly impacting agricultural productivity and food accessibility for millions worldwide. Unsustainable farming methods further highlight the urgent need for reforms in agricultural and food supply chains to promote more equitable and sustainable production and consumption practices.

Reducing food waste and improving access to nutritious, sustainable food are essential to achieving future food security and sustainability. A sustainable food system benefits not only human health by ensuring access to safe, healthy food but also the environment and economies by protecting natural resources and supporting agricultural communities. As agriculture is a fundamental part of global economies and livelihoods, efficient and sustainable agricultural practices are critical to minimizing the sector's environmental footprint. The current production and consumption patterns exacerbate climate change through increased greenhouse gas (GHG) emissions, highlighting the need for more environmentally friendly agricultural practices that protect future generations.

This paper emphasizes the role of digital technologies in optimizing resource use and reducing environmental impacts, fostering more sustainable consumption and production patterns. Additionally, these technologies can mitigate municipal waste by improving resource management. However, without appropriate regulations and sustainable resource management strategies, the use of these technologies could lead to resource overuse, necessitating a balanced approach to their implementation. To fully harness the benefits of digital technologies, legislative and policy frameworks must evolve in tandem with technological advancements, facilitating widespread adoption in agriculture beyond the food industry.

Understanding the needs and perspectives of primary producers is also essential to developing digital solutions that support a more efficient and inclusive transformation in agriculture. Despite the paper's efforts to explore the relationships between digital technologies, sustainable food production, GHG emissions, and municipal waste, certain limitations exist. The longitudinal nature of the study, while tracking trends over time, may have been influenced by contextual factors or unforeseen events. Additionally, the study focused primarily on the relationship between digital technologies and key aspects of food sustainability, such as crop and animal output, municipal waste, nitrogen and methane emissions, and Sustainable Development Goal 12 (SDG12). Future studies should consider broader aspects of food sustainability, including the social and economic impacts of technological shifts, such as employment in agricultural labor, market access for small producers, or the equitable distribution of technological benefits.

Another important area for future research is the unintended consequences of digitalization in agriculture. While the benefits of digital technologies are substantial, their potential negative impacts, such as the risk of digital exclusion or the concentration of economic power among large corporations, must also be examined. Future studies could investigate the specific effects of emerging digital technologies, including the Internet of Things (IoT), data analytics, and artificial intelligence (AI), on the sustainability of food systems. Such research would provide a more comprehensive understanding of how these technologies can be leveraged to enhance food system resilience while avoiding potential drawbacks.

References

[1] Dobrynina M.V., Kovalenko D.G. Youth social entrepreneurship: problems and prospects//Economic and social-humanitarian research. 2023. No. 3 (39). P. 53-61.

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] Zheng, Q., Wang, M., & Yang, F. (2021). Optimal channel strategy for a fresh produce e-commerce supply chain. Sustainability, 13, 6057. Retrieved July 2022, from https://www.mdpi.com/2071-1050/13/11/6057

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Cep. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. C. 239-245.

[7] European Commission (2022a) Communication from the Commission. Guidelines on the application of the Regulation (EU, EURATOM) 2020/2092 on a general regime of conditionality for the protection of the Union budget. Brussels, 2.3.2022 C (2022) 1382 final.

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144.

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

THE INFLUENCE OF CLIMATIC FACTORS ON THE PROCESSES OF NATURAL AND ARTIFICIAL AGING OF DOCUMENTS

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Abstract

A distorted date of a document is a factor of strong social and public risks, leading to erroneous court decisions and undermining confidence in the judicial system as a whole. Document forgeries are common in the public relations sphere. Often, at the workplace, employees may encounter so-called "black accounting". If the employer provides them with a date issued "retroactively", then there is a possibility of evading criminal liability. The most popular category are bankruptcy cases (about 40% in total). The next are cases on collection of penalties, debt (8%), followed by cases with share of 5% on invalidation of tax authority decisions; on collection of unjust enrichment, etc. Chromatographic methods, most often used in methods for determining the age of a document. Almost all researchers, by default, assume that the components of the writing materials evaporate, and the main factors limiting this process are temperature and illumination.
In spite, the authors suggested that during the storage of documents, not pure components, but their diluted aqueous solutions evaporate. Water is a volatile liquid. The source of this water is the surrounding atmosphere and its good absorbent in the form of paper sheet cellulose.
Another factor of natural aging is the natural drop in atmospheric pressure. In the case of a decrease in atmospheric pressure, the evaporation of aqueous solutions of the components of writing materials should also accelerate.
The number of humidity and pressure cycles was determined based on a decrease in the level of the chromatographic signal of the studied samples. The results presented in our work show that frequent and deep changes in natural humidity and pressure accelerate the evaporation of volatile and soluble components of ink, leading to accelerated aging of the document. Overcoming this problem will help to significantly improve the quality and validity of court decisions in all types of cases under consideration and reduce the risks of obtaining erroneous court decisions.

Keywords: climatic factors, aging of documents, atmospheric pressure, humidity

I. Introduction

Document forgeries are common in the public relations sphere. Often, at the workplace, employees may encounter so-called "black accounting", when the director suggests signing documents "retroactively". When investigating accidents with a fatal outcome or causing serious harm to health, investigative bodies require the issuance of protocols on knowledge testing. If the employer provides them with a date issued "retroactively", then there is a possibility of evading criminal liability. Therefore, it is very common to make a document or make an addition, correction "retroactively".

A distorted date of a document is a factor of strong social and public risks, leading to erroneous court decisions and undermining confidence in the judicial system as a whole.

To compile the most complete picture of the categories of cases, in the resolution of which an examination of the limitation period of the application of document details is carried out, a small table can be shown.

Table 1: *Categories of cases, in which an examination of the limitation period of a document is most often required.*

Court cases	number of cases	%
on bankruptcy of an individual	9	24%
on bankruptcy of a legal entity	6	16%
on collection of penalties, debt for undelivered goods	3	8%
on invalidation of a tax authority decision	2	5%
on collection of unjust enrichment, interest for the use of other people's money	2	5%
on invalidation of transactions	2	5%
on invalidation of a contract for work	2	5%
on invalidation of a pledge agreement	1	3%
on termination of a purchase and sale agreement	1	3%
on invalidation of a surety agreement transaction	1	3%
on recognition of ownership of real estate	1	3%
on bankruptcy of an individual entrepreneur	1	3%
on invalidation of an interest-free loan agreement	1	3%
on invalidation of a purchase and sale transaction for non-residential premises	1	3%
on exclusion from the composition of participants in a limited liability company	1	3%
on collection of debt, penalties under a purchase and sale agreement	1	3%
TOTAL	**37**	**100%**

The most popular category are bankruptcy cases (about 40% in total). The next most popular category are cases on collection of penalties, debt for undelivered goods (8%), followed by cases with the same share of 5% on invalidation of tax authority decisions; on collection of unjust enrichment, interest for the use of other people's money; on invalidation of transactions; on invalidation of a contract for work. Chromatographic methods, most often used in methods for determining the age of a document, demonstrate high dispersion of results and not always satisfactory convergence. Almost all researchers, by default, assume that the components of the writing materials evaporate as a result of evaporation, and the main factors limiting this process are temperature and illumination. Some works compare the influence of abstract factors of natural and artificial aging on the measurement results [1-5]. The authors of [6] were the first to suggest that such an opinion is erroneous. The temperature factor, of course, affects the rate of degradation of the writing composition, although in natural conditions of room storage its fluctuations usually do not exceed several degrees. Light exposure, as a rule, is also limited by the dark conditions of storing documents in folders and cabinets. However, in some cases, the amount of 2-phenoxyethanol in the process of chromatographic analysis begins to increase over time according to chromato-mass spectrometry data [7]. This phenomenon is difficult to explain by temperature or light fluctuations. An alternative hypothesis explaining this fact is the underestimation of such an important factor of natural aging, which, according to the authors, should be changes in atmospheric humidity [6]. This reasoning arose in connection with the fact that, having compared data on the volatility of glycerin and 2-phenoxyethanol, the authors [6] drew attention to the fact that both components are absolutely non-volatile substances, have very high boiling points (240-290 C), very low equilibrium vapor pressures, especially glycerin, which is one of the most non-volatile liquids in nature, and 2-phenoxyethanol at room temperature, according to some data from open sources, is a crystalline substance at 26 C, according to others - at 13 C. [8]

In [6] it was suggested that during the storage of documents, not pure components, but their diluted aqueous solutions evaporate [9]. Unlike 2-phenoxyethanol and glycerol, water is a volatile liquid. The source of this water is the surrounding atmosphere and its good absorbent in the form of paper sheet cellulose [10]. In this case, the natural aging period of the ink will be determined not so much by the duration and temperature of storage, but by the frequency and depth of changes in natural atmospheric humidity. This assumption explains the non-monotonic behavior of the time dependence of 2-phenoxyethanol [7]. During periods of high humidity, a larger amount of easily evaporating 2-phenoxyethanol aqueous solution is formed.

Another factor of natural aging that has not been covered by systematic research is the natural drop in atmospheric pressure. In the case of a decrease in atmospheric pressure, the evaporation of aqueous solutions of the components of writing materials should also accelerate. Considering the above assumption that the components of the writing composition evaporate as part of diluted aqueous solutions, the factor of pressure drops can seriously affect the rate of ink degradation. Pressure and humidity, in contrast to elevated temperature and intense light radiation, represent a separate group of natural climatic factors that do not have a destructive effect on the paper base of the document and on the ink dyes. In this regard, the authors [6] propose to introduce the concept of "accelerated" aging along with the concepts of "artificial" and "natural" aging. This is aging caused by increased exposure to climatic factors during the storage of the document and does not cause the destruction of paper and writing materials.

II. Experimental procedure

Randomly selected writing compositions of both certain brands and unknown brands were used for the study.

Chromatographic and chromatograph mass spectrometric studies were performed on a Crystal-5000 GCMS complex with a flame ionization detector (FID) and a mass detector (MS). Samples were introduced using a pyrolytic attachment (in the case of MS) and a solid sample dispenser in the case of FID. The MS channel is equipped with a device for cryofocusing of gas mixture components. The study was conducted using CR-5 chromatographic columns 30 m x 0.32 mm x 0.5 μm for FID and CR-5 ms 30 m x 0.32 mm x 0.25 μm for MS. Components were identified based on the results of GCMS measurements in the Chromatec Analytic and NIST libraries. The modeling of humidity processes was carried out in a climatic chamber "heat-humidity" M 0/100-1000 KTV in the range of maintaining humidity from 40% to 80%, at a temperature of +25 °C (accuracy of humidity control: 3%. , temperature ± 5 C). The choice of the humidity range was determined by typical differences for the city of St. Petersburg.

During one cycle of studies, samples of strokes applied to office paper were kept for 3 hours in a climatic chamber at a relative humidity of 80%, then 3 hours at a humidity of 40% or natural drying in the air for 24 hours.

The number of humidity cycles was determined based on a decrease in the level of the chromatographic signal of the studied samples to background values or until reaching a horizontal plateau.

Detection of signs of accelerated aging of documents was carried out using GCMS measurements, and optical microscopy using a MIKMED-6 microscope with a built-in web camera. The calculation of the correlation coefficients (Pearson coefficients) of the intensity of the chromatographic response and the number of cycles of humidity changes was calculated using the formula:

$$Rxy = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sqrt{\left(n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right) \times \left(n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} Yi\right)^2\right)}} \quad (1)$$

where Xi are the serial numbers of the humidity change cycles, Yi are the corresponding values of the chromatographic peak intensity. The relative dispersion (σ%) of the chromatographic response intensity was calculated using the formula

$$\sigma\% = \frac{\sigma_{a\delta c}}{\bar{y}} \times 100\% \quad (2)$$

where

$$\sigma_{abs} = \sqrt{\frac{\sum(\bar{y}-y_i)^2}{n(n-1)}} \qquad \bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$$

The pressure drop processes were simulated in a sealed chamber with a volume of 2 liters. The vacuum was created using a diffusion pump H-250/2500 with a depth of up to 0.133 Pa. The duration of one cycle is 24 hours. The number of pressures drop cycles was determined based on the decrease in the chromatographic signal level of the studied samples to background values or until reaching a horizontal plateau. Detection of signs of accelerated aging of documents was performed using GCMS measurements and a MIKMED-6 microscope with a built-in web camera. The dynamics of individual components was studied.

III. Research results

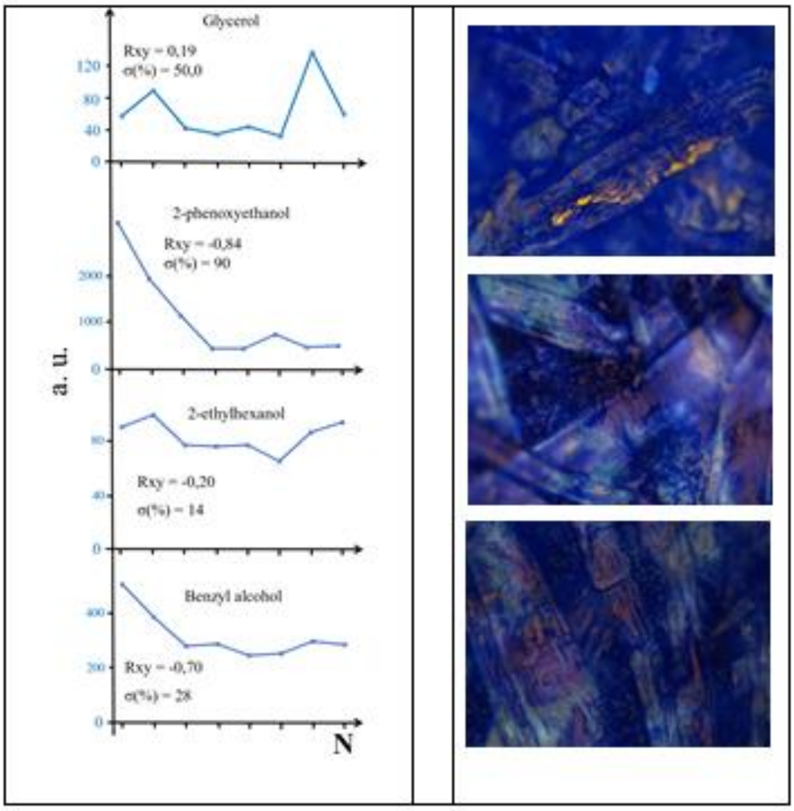
The average results of measuring the GC dynamics of individual components of the writing composition under the influence of humidity changes are given in Table 2. On the right are microscopic images of the surface of the ballpoint ink stroke obtained at the beginning of the process, in the middle and at the end.

The results presented in Table 2 show that periodic exposure of a document to humid air results in strong dispersion of the chromatographic signal. For various ink components and mathematical processing methods, the relative signal dispersion can vary from 18 to 1000 percent or more. The Pearson coefficients of signal intensity change with increasing number of humidity cycles can also be in a wide range from values close to +0.7 to -0.8 or more.

Most of the studied samples demonstrate a consistent decrease in the content of soluble ink components in a stroke with increasing number of humidity change cycles. 2-phenoxyethanol and benzyl alcohol demonstrate a stable dynamics of content decrease in a stroke with increasing number of humidity – drying change cycles. 2-ethylhexanol can react to humidity changes in different directions. Glycerol, in all cases, exhibits strong dispersion of chromatographic peak intensity values and low Pearson coefficient values. In approximately half of the studied cases, for most components, the first wet aging cycle leads to a significant increase in the content of the volatile component in the chromatographic response. Then this content decreases systematically as the number of cycles of drops increases. This behavior of the components strongly resembles the effect noted in [7].

It is evident that artificial modeling of humidity fluctuations in the range of 40-80% leads, in some cases, to accelerated aging of ink according to the criterion of the content of volatile components in it. In other cases, it leads to the appearance of uncontrolled strong fluctuations in the values of chromatographic peaks.

Table 2: *Research of the GC dynamics of individual components of the writing composition under the influence of humidity changes*



The results of the microscopic study show that signs of wet accelerated aging appear on the materials of documents in an implicit form, which does not allow the document to be clearly identified as "artificially aged". There are no areas of melting, bleeding and chipping of the dye, yellowing and uneven fluorescence. This explains some of the anomalies previously discovered by researchers during chromatographic studies of the age of ink [7]. And refutes the opinion about the insignificant influence of the humidity factor on the evaporation rate of high-boiling components of ink [11]. The porous nature of the ink stroke and the paper base on which it is applied results in the penetration of components that are fluid at the time the stroke is applied into the volume of the paper sheet, creating a diffuse region at the paper-stroke boundary. It is obvious that the action of capillary forces causes processes similar to the separation of components of an extract on a thin-layer chromatography plate [12].

The amount and rate of evaporation of poorly soluble and low-volatile components depend on the ratio of their solubility in water and the equilibrium vapor pressure. One can see the relationship between the average values of the correlation coefficients Rxy and T, S\P and N (the number of humidity cycles, Table 3). Glycerol, which has unlimited solubility in water and virtually zero volatility at room temperature, probably falls out of this relationship. Both factors act in opposite directions, which creates uncertainty in the result.

Changes in atmospheric pressure, similar to changes in humidity, can accelerate the process of evaporation of volatile components. When the pressure decreases, the evaporation rate of all substances included in the composition of paper materials and writing compositions increases. It is logical to expect that the dynamics of the content of volatile components of writing materials will have a picture similar to changes in humidity.

The test results are given in Table 4.

Table 3: *Relationship between the dispersion indices of the chromatographic signal and the physicochemical properties of the solvent [8,13,14,15].*

	S - solubility in water, g/l	T boiling point, C	P- equilibrium vapor pressure at 20C (kPa)	S/P	Pearson's coefficient r_{xy}	Dispersion % σ
2-phenoxyetanol (PE)	26	244	5,2*	5,0	-0,52÷-0,84	45÷303
Glucerol (G)	unlimited	290	0,4 (at 50C)	∞	-0,14÷-0,39	29÷63
Ethylhexanol (EH)	0,7	185	7,33	≈0,1	-0,2 ÷+0,7	14÷64
benzyl alcohol (BA)	40	205	12,7	3,1	-0,08÷-0,7	18÷67

Table 4: *Results of studies of the dynamics of the content of volatile components due to pressure changes using the chromatograph mass spectrometry method.*

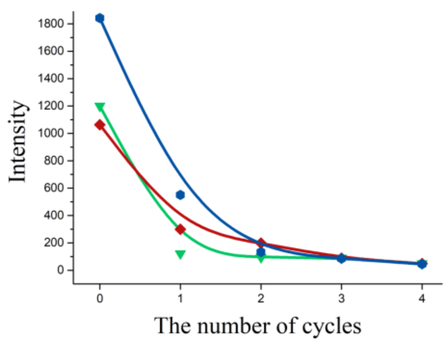
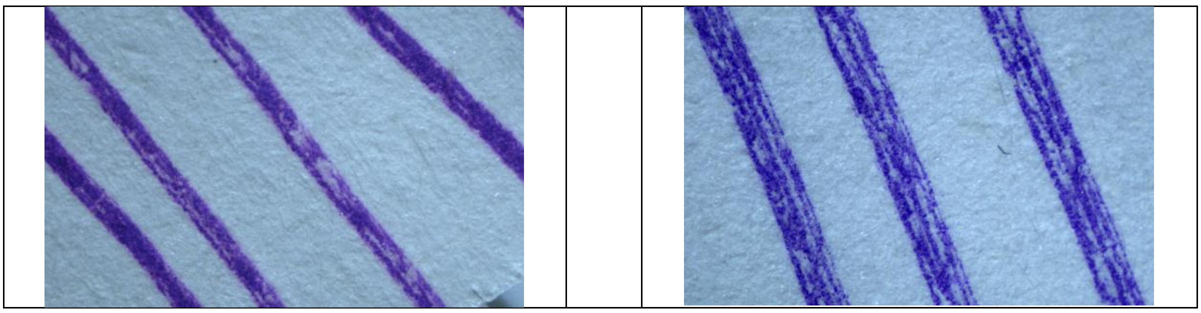
Number of cycles	Time, min	Component	Area	Height	Graph
0	3,513	ethylene glycol	7121,913	1199,834	
	8,370	glycerin	51857,774	1063,293	
	13,873	triethanolamine	6169,034	1841,471	
1	3,503	ethylene glycol	931,818	121,735	
	7,352	glycerin	3935,379	298,879	
	13,784	triethanolamine	1489,906	550,339	
2	3,508	ethylene glycol	671,905	93,477	
	7,023	glycerin	2114,581	198,140	
	13,764	triethanolamine	334,942	133,854	
3	3,511	ethylene glycol	599,203	90,422	
	7,028	glycerin	1105,776	88,140	
	13,760	triethanolamine	234,972	85,834	
4	3,511	ethylene glycol	259,211	48,615	
	7,028	glycerin	874,223	48,434	
	13,760	triethanolamine	134,234	45,616	

Fig. 1 (a, b) shows micrographs of the blue streak before and after the end of the process.



a в

Figure 1: *Micrographs of writing ink strokes before the process of artificial aging by pressure (a) and after the end of the aging process (b)*

The results presented in Tables 2 and 4 show a close analogy of the effects of humidity changes and pressure changes on the dynamics of the volatile components of writing materials. Frequent and deep changes in natural humidity and pressure accelerate the evaporation of volatile and soluble components of ink, introducing a large dispersion into chromatographic measurements.

IV. Conclusion

In world practice, there is a significant gap in understanding the fundamental processes of aging of props. It is meant that it is necessary to expand the list of factors influencing the dispersion of the results of determining the age of a stroke, namely, to fundamentally study humidity, atmospheric pressure, structure and composition of paper, as well as various processes occurring during aging [6].

Thus, currently the applied methods require revision and improvement in connection with new results.

Determination of the absolute and relative age of a document and its details is in great demand among courts and parties in the framework of pre-trial investigation, but it encounters the impossibility of ensuring the quality of examinations due to the imperfection of existing physical and chemical models of aging, ignoring natural climatic factors. These are not random phenomena, but a consequence arising from a misunderstanding that a document is the most important material evidence, especially in civil and arbitration proceedings.

Overcoming this problem will help to significantly improve the quality and validity of court decisions in all types of cases under consideration and reduce the risks of obtaining erroneous court decisions.

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References

[1]. Koenig, A., Magnolon, S., & Weyermann, C. (2015b). b. A comparative study of ballpoint ink ageing parameters using GC/MS. Journal of Forensic Sciences, 252, 93–106.

[2]. Ortiz-Herrero, L., & de Almeida, A. A. C. (2020). A novel, non-invasive, multi-purpose and comprehensive method to date inks in real handwritten documents based on the monitoring of the dye ageing processes. Chemometrics and Intelligent Laboratory Systems, 207, Article 104187.

[3]. Islek, D. S., Isat, E., & Cengiz, S. (2017). Determining malpractice by ink aging method. Medicine Science, 6(1), 136–138.

[4]. Islek, D. S., Isat, E., & Cengiz, S. (2018). The structure and age determination of the writings written with ballpoint pen. Medicine Science, 7(1), 166–169.

[5]. Sauzier, G., Gann, J. M. C., & Lewis, S. W. (2018). A study into the ageing and dating of blue ball tip inks on paper using in situ visible spectroscopy with chemometrics. Analytical Methods, 10, 5613–5621].

[6]. Physicochemical analysis of the age of handwritten inscriptions on vdocuments: Trends and prospects. Ksenia Olegovna Ershova a, Svetlana Valerievna Kochemirovskaia a, Rafal Ciesla b, Natalia Pavlovna Kirillova c, Dmitry Anatolyevich Mokhorov a, Vladimir Alekseevich Kochemirovsky. Expert Systems With Applications 205 (2022) 117683

[7]. Díaz-Santana, O., Conde-Hardisson, F., & Vega-Moreno, D. (2018). Comparison of the main dating methods for six ball-point pen inks. Microchemical Journal, 138, 550–561.

[8]. David, C., & Lide, R. (2010). CRC handbook of chemistry and physics (90th ed.). CRC Press

[9]. Vapor pressure and evaporation coefficient of glycerol Heiko K. Cammenga, Friedrich W. Schulze, and Wilhelm Theuerl J. Chem. Eng. Data 1977, 22, 2, 131–134https://doi.org/10.1021/je60073a004

[10]. Mohammadzadeh, A., Barletta, M., & Gisario, A. (2020). Manufacturing of cellulose based paper: Dynamic water absorption before and after fiber modifications with hydrophobic agents. Applied Physics A, 126, 383.

[11]. Lociciro, S., Mazzella, W., Dujourdy, L., & Lock, E. (2004). Dynamic of the ageing of ballpoint pen inks: Quantification of phenoxyethanol by GC-MS Margot P. Science & Justice, 44(3), 165–171

[12]. Journal of the Society of Dyers and Colourists. Thin-layer Chromatography and its Application to Dyes G. H. Rettie, C. G. Haynes Volume80, Issue12 December 1964 Pages 629-640.

[13]. Bahrmann H., Hahn H.-D., Mayer D., Frey G. D. 2-Ethylhexanol (англ.) // Ullmann's Encyclopedia of Industrial Chemistry. — 2013.

[14]. Yalkowsky S.H., Yan H. Handbook of aqueous solubility data. - CRC Press, 2003 2 phenoxyethanol

[15]. Chemical Encyclopedia / Ed. team: Knunyants I.L. et al. - M.: Soviet Encyclopedia, 1988. - T. 1 benzyl alcohol

PROBABILITY OF IGNITION SOURCE OCCURRENCE AT HAZARDOUS OIL AND GAS PRODUCTION FACILITIES

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Abstract

It is known that the final result of risk analysis is the determination of the consequences of explosions and fires at a hazardous facility. One of the most important indicators used in performing a risk analysis is the probability of occurrence of an ignition source.
The presented work proposes a method for taking into account the probability of mixture ignition. It is indicated that such an assessment is more plausible and consistent with observations and does not contradict the need for personnel participation in localizing an emergency release.

Keywords: emergency release, risk, ignition source, probability, oil spill, gas-air mixture

Introduction

The final stage of risk analysis is to determine the consequences of explosions and fires at a hazardous production facility (HPF). The final result of a risk analysis can be obtained if there is a reliable base of initial data, reference (statistical) data, a meaningful physical model of the processes of explosions and fires, and a completed mathematical model of analysis.

The input data includes the following:

- List of blocks included in the HPF;
- Technological diagram of connecting blocks;
- Performance of installations consisting of analyzed blocks;
- Characteristics of the blocks, including their volume, operating pressure, degree of filling, name of the products filling the block;
- Distribution of personnel on the territory of the hazardous production facility (HPF).

Reference data includes:

- Physico-chemical properties of the products filling the blocks, including properties characterizing their explosion and fire hazard;
- Statistical data on partial and complete depressurization of blocks;
- Data on lightning activity in the area where hazardous production facilities are located (HPF).

One of the most important indicators used in performing a risk analysis is the "probability of occurrence of an ignition source" indicator.

Table 1, based on data from [1], presents the distribution of fires and explosions by ignition sources.

Distribution by ignition sources.

The share of explosions and fires initiated by lightning discharges is 9.7%.

To determine the probability of an ignition source, we use the methodology of Appendix 3 GOST 12.1.004–91 [2] for calculating the probability of a direct lightning strike on an object, taking into account other ignition sources.

For a stationary object, the probability of a direct impact is determined by the relationship

$$P_{is} = 1\text{-}e^{-N_{ls}\, t} \tag{1}$$

where, N_{ls} is the number of direct lightning strikes into an object in 1 year; t-duration of the observation period equal to 1 year.

Table 1: *The distribution of fires and explosions by ignition sources*

İgnition source	Total quantity, pcs.	%
Hot work:	10	32.3
Mechanical sparks	5	16,1
Fire technological installations;	3	9,7
Lightning strike;	3	9,7
Electric sparks;	4	12,5
External ignition sources;	2	6,5
Static electricity discharge;	1	3,2
Vehicle;	1	3,2
Careless handling of fire;	1	3,2
Other.	1	3,2
Total	**31**	**100**

For round objects

$$N_{ls} = (2R+6H)^2 \cdot n_{ls} \cdot 10^{-6} \tag{2}$$

Here R - is the radius of the cloud within the boundaries of the lower concentration flammable limit (LCFL) or the radius of the flammable liquid spill, m; H - is the height of the cloud, equal to R_{LCFL} for a hemisphere with a ground-based gas release, m; during a spill FL-N=0. n_{ls} is the average number of lightning strikes per 1 km^2 of the earth's surface [3, 4].

Let's perform a control calculation to determine the number of direct lightning strikes into an object occupying an area of territory that accounts for 1 lightning strike per year. This area is equal to f1=1000000/3=333000 m^2. Base radius R= $(333000/3.14)^{0.5}$=325.6 m. For control calculation we take H=R. Then N_{ls} = $(2\cdot325.6+6\cdot325.6)^2 \cdot 3\cdot10^{-6}$ =20.35 1/year. The number of strikes of a discharge into an object occupying an area with the number of lightning strikes equal to 1 per year turns out to be 20.35 times greater than the number of lightning strikes.

To determine the probability of lightning strikes from a cloud of gas-air mixture, it is necessary to adjust the N_{ls} dependence taking into account the lack of electrical conductivity of the gas-air mixture. To do this, we eliminate the height part by equating the H term of the equation to zero. Then the equation for an object that does not generate electricity is transformed to the form:

$$N_{ls} = (2R)^2 \cdot n_{ls} \cdot 10^{-6}$$

When studying the possibility of igniting a cloud of a gas-air mixture (GAM), we take R = R_{LCFL}, and when studying the possibility of a liquid spill, R = D/2, where D - is the diameter of its spill.

To check the obtained dependence, we perform a control calculation. Let's find the number of lightning strikes into a hot water cloud with a radius of the lower concentration limit of ignition (LCFL) equal to 325.6 m.

$$N_{ls} = (2\cdot325.6)^2 \cdot 3\cdot10^{-6} = 1.27 \text{ 1/year}$$

The non-convergence of the result reaches 27%. The source of calculation error is the incorrect representation of the object area in the form of a square of twice the radius of the

LCFL. A more accurate value of N_{Is} can be obtained after specifying the area of projection of the GAM cloud onto the Earth's surface in the form

$$N_{Is} = \pi \cdot R^2 \cdot n_{Is} \cdot 10^{-6}$$

Check: N_{Is}=3.14·325.6^2 ·3·10^{-6} =0.9992 1/year.

To take into account other ignition sources, we introduce an additional factor k=10 into the N_{Is} equations. Then it is converted to mean

$$N_{Is} = 10\pi \cdot R^2 \cdot n_{Is} \cdot 10^{-6}$$

After substituting the obtained value of N_{Is} into the original equation, we finally obtain a formula for calculating the probability of the appearance of an ignition source affecting a cloud of hot water or a spill of flammable liquid within the boundaries of the possible ignition of an object:

$$P_{is} = 1 - e^{-x}$$

where,

$$x = 10\pi \cdot R^2 \cdot n_{Is} \cdot \tau \cdot 10^{-6}, \quad (4)$$

Let's plot the dependence $P_{is} = f \cdot (R_{LCFL})$ at $x = 10\pi \cdot R^2_{LSFL} \cdot n_{Is} \cdot \tau \cdot 10^{-6}$.

Analysis of the graph presented in Figure 1 allows us to draw the following conclusions:

1. The larger the affected object (GAM clouds of hot water or a spill of hot liquid), the more realistic the completion of an emergency release by ignition of a flammable substance.
2. Small targets are characterized by a low probability of ignition of the emission.
3. The dependence of the probability of the appearance of an ignition source Reese on the size of the affected object allows us to establish the probability of distribution of the consequences of the release according to accident scenarios. The release may result in combustion or dispersion. Possibility of ignition or dispersion. The probability of ignition is equal to the probability of the appearance of an ignition source, that is, $P_{ignit} = R_{is}$. The probability of release dissipation is equal to the difference $P_{disp} = 1 - P_{is}$.

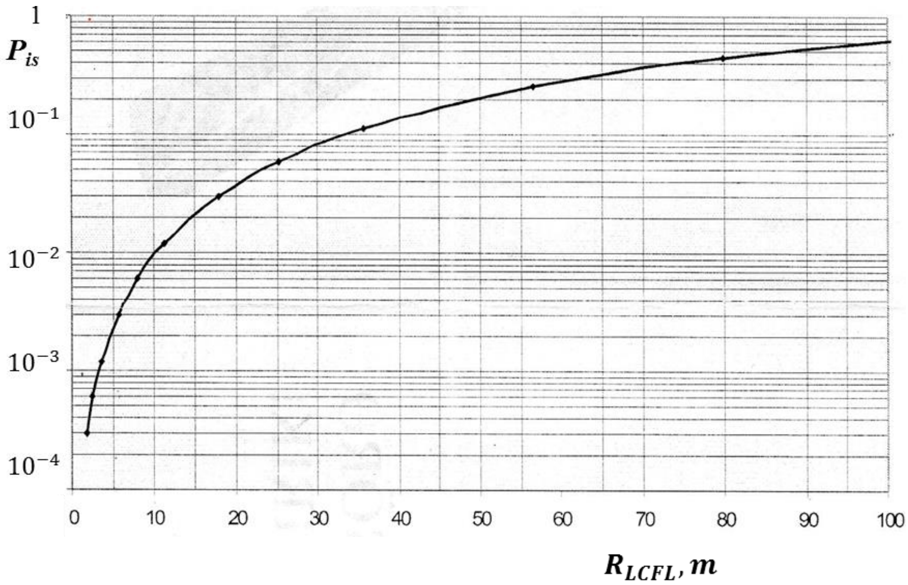

Figure 1: *Probability of the appearance of an ignition source*

4. The probability distribution of accident scenarios, adopted in GOST R 12.3.047–98, is incorrect in that this distribution does not depend on the size of the affected object.

Let us find the dependence of the frequency of implementation of the scenario with ignition of the emission on the size of the hot water cloud or the diameter of the gas liquid spill (GAM):

$$N_{ignit} = N_{depr} \cdot P_{is} \quad (5)$$

where

N_{ignit} is the ignition frequency of hazardous product emissions, 1/year;

N_{depr} - frequency of unit depressurization, 1/year;

R_{is} - is the probability of manifestation of the ignition source, fraction.

The release frequency in accordance with the database [5] is: with partial depressurization - $1 \cdot 10^{-4}$ 1/year, with complete depressurization - $1 \cdot 10^{-5}$ 1/year. When using the Methodology database [6], the specified values must be adjusted.

The probability of a fire scenario occurring depends on the size of the target. With partial depressurization, the emission volume is less than with complete depressurization. In accordance with this, the probability of ignition of the emission during partial depressurization is less than during complete depressurization. Let us assume that with partial depressurization the volume of gas in the release is 10 m^3, and with complete depressurization it is 1000 m^3.

Let us find R_{LCFL} for each case of depressurization.

For partial depressurization $R_{LCFL} = 1.633(10/5)^{0.333} = 2.06$ m. This value corresponds to the probability of the appearance of an ignition source

$$P_{is}=1-2.73^{-x}$$

where, $x=R^2_{LCFL} \cdot n_{Is} \cdot \tau \cdot 10^{-5}$. $x=3.14 \cdot 2.06^2 \cdot 3 \cdot 1 \cdot 10^{-6} = 4 \cdot 10^{-4}$. $R_{LCFL}=1-2.73^{-0.0004}=4 \cdot 10^{-4}$

In case of partial depressurization of a block with the release of 10 m^3 of gas, the probability of the scenario with the ignition of a hot water cloud being realized is (GAM) 0.0004.

If the block is completely depressurized, $R_{LCFL}=1.633(1000/5)^{0.333} = 9.53$ m.

For this case, $x = 3.14 \cdot 9.53^2 \cdot 1 \cdot 10^{-5} = 8.56 \cdot 10^{-3}$. The probability of the scenario with the ignition of a hot water cloud being realized will be (GAM)

$P_{disp} = 1-2.73^{-0.000856} = 8.59 \cdot 10^{-3}$. The probability of cloud dispersal without its ignition during partial depressurization will be $P_{disp} = 1-0.0004 = 0.9996$. If the unit is completely depressurized, the probability of the release dissipating without igniting the cloud will be $P_{disp} = 1-0.00856 = 0.991$.

Example:

Determine the parameters of an oil spill fire and explosion of a gas-air mixture cloud at an oil separation installation.

Initial data:

The installation refers to on-site structures where there is service staff. The oil production capacity of the installation is 1000 m^3/hour, the gas factor of reservoir oil is 70 m^3/m^3, the pressure at the beginning of degassing is 8.5 MPa. The possibility of depressurization of the pipeline located in the circuit before the separator (first calculation option), the oil pipeline after the separator (second calculation option) and the gas pipeline (third option) is being considered.

Solution:

Determination of the volumes of gas and oil in the release. This problem is solved by the volume of gas capable of activating DVK sensors installed at a distance of 11.2 m from the possible release site. $V_k = (0.01 \cdot 11.2/0.041)^3 \cdot V_k = 20.38$ m^3. The results of the determination are presented in Table 2.

With an average release duration of 1 hour, the share of oil and gas extraction does not exceed 0.06% of the nominal value. The release may go unnoticed until the next operator walks through the installation.

The radius of the explosion affected area, determined using the TNT equivalent method, is overestimated by 10 times. In this regard, the greatest danger is the release of oil. If we take into account the dynamics of the development of an accident associated with an oil release, then a catastrophic release should be considered impossible, since the oil slick will be detected by personnel when walking around the installation before the gas control system is activated. The scenario of an accident with massive flooding of the installation with oil should be classified as hypothetical. The likelihood of such an accident occurring is negligible.

Table 2: *The determination of the volumes of gas and oil in the release*

	First option		Second option		Third option	
	Gas	oil	Gas	oil	Gas	oil
Volume of gas in the cloud, m^3	20,38		20,38		20,38	
Residual gas factor, % vol.		70		35,16		
Volume of oil and release, m^3		0,29		0,58		0
R_{LCFL}, m	2,24		2,24		2,24	0
Spill diameter, m		3,03		4,3		
Release frequency, 1/year	$1{,}0 \cdot 10^{-4}$	$1{,}0 \cdot 10^{-4}$	$1{,}0 \cdot 10^{-4}$	$1{,}0 \cdot 10^{-4}$	$1{,}0 \cdot 10^{-4}$	
Probability of an ignition source	$5 \cdot 10^{-4}$	$1 \cdot 10^{-3}$	$5 \cdot 10^{-4}$	$1{,}8 \cdot 10^{-3}$	$5 \cdot 10^{-4}$	
Radius from the affected area on an outdoor installation, R_0, m	0	1,5	0	2,15	0	0
Frequency of explosions (fires), 1/year	$5 \cdot 10^{-8}$	$1 \cdot 10^{-7}$	$5 \cdot 10^{-8}$	$1{,}8 \cdot 10^{-7}$	$5 \cdot 10^{-8}$	0

Conclusions

1. The probability of the appearance of an ignition source depends on the size of the hot water cloud within (GAM) the boundaries of the LCFL or the size of the flammable liquid spill.

2. The probability of ignition of an emission, established in the Methodology [6] and GOST as a constant value independent of the size of the flammable object, does not correspond to probability theory and cannot be used in risk analysis calculations.

3. Calculation of the probability of the occurrence of an ignition source connects the risk research procedures into a continuous chain, allowing to achieve the result of the analysis.

References

[1] RD 34.21.122–87. Instructions for the installation of lightning protection of buildings and structures. M., 2000, 65 p.

[2] GOST 12.1.004–91 "Fire safety".

[3] REI Rules for electrical installations.

[4] GOST 14249–89. Vessels and devices. Norms and methods of strength calculations. USSR State Committee for Standards. M., 1989, 82 p.

[5] RD 03-357-00. Methodological recommendations for drawing up an industrial safety declaration for a hazardous production facility. M., State Scientific and Technical Center for Safety in Industry Gosgortekhnadzor of Russia, 2000.

[6] Methodology for determining fire risk values at production facilities. Approved by order of the Ministry of Emergency Situations No. 404 dated July 10, 2009.

EFFECT OF TEMPERATURE AND IONS CONCENTRATION ON THE DENSITY AND SPEED OF SOUND OF NATURAL MINERAL WATERS FROM THE REGION OF SOUTH RUSSIA

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Abstract

Density (ρ), and speed of sound (W) of natural mineral waters from the region of south Russia (North Caucasus, Essentuki wells ES№1, ES№2, ES№4, and ES№17) have been measured as a function of temperature. The measurements were made over the temperature range from (278 to 343) K at atmospheric pressure. Anton Paar DSA 5000 M sound-speed analyzer has been employed to the simultaneously measurements of the density and speed of sound of the mineral water samples. The combined expanded uncertainty of the density, speed of sound, atmospheric pressure (P_0), and temperature (T) measurements at the 95 % confidence level with a coverage factor of k = 2 is estimated to be ± 0.005 kg·m^{-3} (or 0.01 %), 0.1 %, and 15 mK, respectively. The measured temperature behavior of density, and speed of sound for natural mineral waters were compared with the values for pure water (IAPW formulation) and for various binary aqueous salt (NaCl, Na_2CO_3, Na_2SO_4, etc.) solutions. The measured values of density, and speed of sound were used to develop correlation models for the temperature and ion species concentration dependences (Riedel's characteristic constants of the ions determination). The measured properties as a function temperature at atmospheric pressure have been used as a reference data for prediction of the high-pressure thermodynamic behavior.

Keywords: mineral water, geochemistry, density, chemical composition

I. Introduction

Multicomponent aqueous salt solutions play a major role in both natural and industrial processes. Most of Earth surface is covered by water. Natural mineral water is a multicomponent aqueous solution containing varying amounts of dissolved solids and gases. According to the European Legislation (2009/54/EC Directive), physical and chemical characterization is used to make a classification of the different mineral waters [1]. The exploitation of thermal and mineral water resources requires availability of reliable thermodynamic and transport property data at high temperatures and high pressures. For example, these data are needed for estimate the likehood of scaling and corrosion developing within the wells and surface equipment, and to predict the commercial lifetime of the exploitation project. The temperature dependence of the density of geothermal and mineral waters has also to be considered when defining the dimensions of the pumping systems because buoyancy effect decreases pumping requirements. Use of pure water or geothermal brine models (synthetic brines like binary or ternary aqueous salt solutions) properties instead of their natural mineral water values, in practical application (engineering calculations), leads to inaccuracy and incorrect estimation of the practical calculations, for example, pumping requirements. This work is a part of our long-term continuing program of experimental study and modeling of the thermodynamic (*PVT*, heat capacity, vapor-pressure), acoustic (speed of sound) and transport (viscosity and thermal conductivity) properties of natural thermal and mineral waters at high-temperature and high-pressure [2-5]. In our recent publications [2-5] we have experimentally studied density, speed of sound, and viscosity of natural geothermal and mineral waters from various regions over the world (Azerbaijan, Turkey, and Germany) with different chemical compositions. The present results are considerably expanding the available data base on density of natural geothermal and mineral waters from various regions of the South Russia and around the world with various chemical compositions.

II. Methods

The chemical composition was obtained with the ionic chromatograph Dionex 100 + ICS 100. The pH, was determined at 293.15 K using the standard NF T 90-008.

The density and speed of sound of the natural mineral water samples at atmospheric pressure at elevated temperatures have been simultaneously measured with a sound-speed analyzer DSA 5000 M (Anton Paar Instrument, Austria). The method (experimental details, the physical basis and theory of the method, procedure of measurements, uncertainty assessment, etc.) and apparatus have been described in our several previous publications [2,4,5]. Only a brief review and essential information will be given here. The two-in-one instrument is equipped with a density and a sound velocity cell thus combining the proven Anton Paar oscillating U-tube method with a highly accurate measurement of sound velocity. Both cells are temperature-controlled by a built-in Peltier thermostat. The temperature, where located the U-tube, was controlled with a solid-state thermostat, working via Peltier effect with a precision of ±0.005 K. The temperature of the experimental cell was measured using the (ITS-90) PRT100 thermometer with an uncertainty of 0.03 K. The sample is introduced into the sound velocity-measuring cell that is bordered by an ultrasonic transmitter on the one side, by a receiver on the other side. The transmitter sends sound waves of a known period through the sample. The speed of sound can be calculated by determining of the period of received sound waves and by considering the distance between the transmitter and receiver. The digital density analyzer in these instruments uses a U-shaped vibrating tube (VTD). The working principle of an oscillation-type densimeter is based on the law of harmonic oscillation, in which a U-tube is completely filled with the sample under study and subjected to an electromagnetic force. Density measurements with a VTD are based on the dependence of the period of oscillation of a unilaterally fixed U-tube on its mass. Due to complexity of the geometry of the vibrating tube it requires very carefully calibration with a reference fluid of well-known density. The accuracy of the method is limited by the calibration procedure. The calibration of the VTD is very important step of the measurements and should be performed very carefully and frequently to keep the high accuracy using a few (minimum 2) references fluids (such as water, benzene, nitrogen, air, and toluene) whose *PVT* properties are well known. In the present study the calibration was performed using a few reference fluids such as air, double distilled, deionized and degassed water, benzene, and toluene with well-known *PVT* properties [6]. The reference data Lemmon et al. [6] were used to determine the temperature dependence of the calibration parameters in the working equation of the method [2,4,5]. Further information about the details of the experimental technique for density and speed of sound measurements has been provided in our previous works [2,4,5]. The density and speed of sound measuring ranges for DMA 5000 instrument are from (0 to 3000) $kg \cdot m^{-3}$ and from (1000 to 2000) $m \cdot s^{-1}$, respectively in the temperature range from (278.15 to 343.15) K. The uncertainties of the density and speed of sound measurements are 0.01 % and 0.10 %, with repeatability of 0.001 $kg \cdot m^{-3}$ and 0.10 $m \cdot s^{-1}$, respectively.

III. Results and Discussion

I. Chemical Composition

Thermal and mineral water samples was distributed directly from Essentuki springs. Chemical composition and pH of the mineral water samples taken from the EMW (ES№1, ES№2, ES№4, and ES№17) are presented in Table 1. The pH of the mineral water samples under study ranges from (6.2 to 7.5).

Table 1. Chemical composition (mg/L) of natural mineral waters from Essentuki wells

Species	Sample: ES№1 pH=6.9-7.2	Sample:ES№2 pH=7.2	Sample: ES№4 pH=6.2-6.9	Sample: ES№17 pH=7.0-7.5
	mg/L	mg/L	mg/L	mg/L
		Cations		
Al^+	<0.1	<0.1	<0.1	<0.1
As^+	<0.1	<0.1	<0.1	<0.1
B^{++}	**1.4**	**1.6**	**5.7**	**10.3**
Ba^+	**7.0**	**<0.1**	**1.9**	**1.6**
Ca^{2+}	**86**	**407**	**124**	**101**
Cd^+	<0.1	<0.1	<0.1	<0.1
Co^+	<0.1	<0.1	<0.1	<0.1
Cr^+	<0.1	<0.1	<0.1	<0.1
Cu^+	<0.1	<0.1	<0.1	<0.1
Fe^{2+}	<0.1	<0.1	<0.1	<0.1
Hg^+	<0.1	<0.1	<0.1	<0.1
K^+	**6.7**	**63.3**	**15.8**	**11.7**
Li^+	**0.2**	**1.7**	**0.7**	**1.2**
Mg^{2+}	**15**	**53.8**	**52.8**	**66.5**
Mn^+	<0.1	0.2	<0.1	<0.1
Mo^+	<0.1	<0.1	<0.1	<0.1
Na^{2+} (Max)	**539**	**948**	**2020**	**6620**
Ni^+	<0.1	<0.1	<0.1	<0.1
P^+	<0.1	<0.1	<0.1	<0.1
Pb^+	<0.1	<0.1	<0.1	<0.1
S^+	**7.1**	**275**	**0.4**	**0.3**
Sb	<0.1	<0.1	<0.1	<0.1
Se^+	<0.1	<0.1	<0.1	<0.1
Si^+	**7.1**	**22.7**	**5.6**	**3.5**
Sr^+	**2.6**	**8.8**	**4.9**	**7.1**
Ti^+	<0.1	<0.1	<0.1	<0.1
Tl^+	<0.1	<0.1	<0.1	<0.1
V^+	<0.1	<0.1	<0.1	<0.1
Zn^+	<0.1	<0.1	<0.1	<0.1
Total:	**674**	**1784**	**2233.7**	**6825.1**
		Anions		
Cl^-	**400**	**1009**	**1660**	**2268**
Nitrate	<0.1	<0.1	<0.1	<0.1
Sulfate	**31.5**	**849**	**1.3**	**0.8**
Total:	431.6	1849.1	1661.4	2268.9
Total Dissolved Salt (TDS	**1105.6**	**3633.1**	**3895.1**	**9094.0**

Due to pressure difference between underground and the near surface conditions (0.101 MPa), degassing (no stable components like dissolved gases such as CO_2, CH_4, H_2S, N_2, H_2 and O_2) occurs during production. Thus, in general, the mineral water samples are chlorine rich with Na and Ca, *i.e.*, the Na^+, Ca^{2+}, and Cl^- are dominant ions.

II. Density

Density measurements were performed at atmospheric pressure as a function of temperature from (278.15 to 343.15) K. The measured density data are presented in Table 2 and depicted in Figs. 1 to 3 in the $\rho-T$, $\rho-S$ (where S is the TDS concentration), and and $\rho-x_{NaCl}$ projections together with the values for pure water calculated from IAPWS fundamental equation of state (IAPWS, Wagner and Pruß) [7]. As can be noted from Fig. 1, the thermodynamic behavior of the mineral and thermal waters (also, for all aqueous salt solutions) governs by the properties of pure water (see Fig. 1), *i.e.*, the temperature dependence of the measured properties (density, and speed of sound) of mineral waters is determined through the pure water properties. Figure 1 also includes the values of density for the same mineral water samples measured using SVM 3000 visco-densimeter. As one can see from Fig. 1, the agreement between the both set of measurements is good enough, the average absolute deviations (AAD) are 0.008 % (ES№1), 0.014 % (ES№2), 0.009 % (ES№4), and 0.015% (ES№17). This confirms the accuracy and the reliability of the measured density data for the mineral water samples under study.

A major source of measuring uncertainties when using a density are the effect of bubbles of dissolved gases in the measuring cell. The bubbles can be formed during the filling procedure. However, the present instrument (DSA 5000 M) allows detect automatically the filling errors or bubbles forming in the sample during the cell heating.

Table 2: *Experimental values of density (ρ), and speed of sound (W) as a function of temperature for mineral waters at atmospheric pressure*

	ES№1			**ES№2**	
T (K)	ρ (kg·m⁻³)	W (m·s⁻¹)	T (K)	ρ (kg·m⁻³)	W (m·s⁻¹)
278.15	1001.90	1429.99	278.15	1004.68	1433.35
283.15	1001.60	1450.52	283.14	1004.30	1453.29
293.14	1000.00	1485.00	293.13	1002.70	1487.62
303.13	997.40	1511.57	303.12	1000.10	1514.03
313.12	993.96	1531.13	313.12	996.70	1533.45
323.13	989.80	1544.63	323.12	992.30	1546.77
333.13	985.13	1552.92	333.11	987.80	1554.92
343.13	979.20	1556.94	343.12	983.10	1558.83
	ES№4			**ES№17**	
T (K)	ρ (kg·m⁻³)	W (m·s⁻¹)	T (K)	ρ (kg·m⁻³)	W (m·s⁻¹)
278.17	1007.70	1438.23	278.17	1011.10	1442.67
283.16	1007.30	1458.28	283.16	1010.70	1462.48
293.15	1005.60	1492.02	293.15	1008.90	1495.86
303.14	1002.90	1518.00	303.13	1006.20	1521.56
313.12	999.20	1537.08	313.13	1002.60	1540.51
323.12	993.20	1550.23	323.12	997.72	1553.50
333.12	987.06	1558.30	333.12	992.20	1561.43
343.15	979.67	1562.20	343.13	984.31	1565.15

Standard uncertainties u are: (DMA4500) $u(T)$=7.5 mK; $u_r(\rho)$=0.005 %; $u_r(W)$ =0.05 %; and $u_r(P)$=0.05 %.

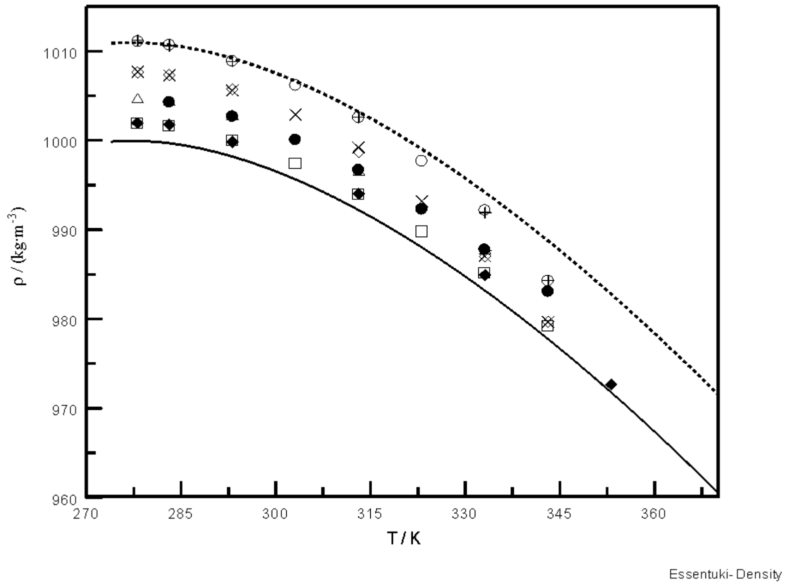

Figure 1: *Measured values of density of the mineral water samples using VTD (DSA 5000 M) together with the values measured with visco-densimeter (SVM 3000) and for pure water calculated from IAPWS formulation. Solid line is pure water values calculated from the IAPWS fundamental equation of state state (IAPWS, Wagner and Pruß, 2002). Dashed lines are calculated from the correlation model for the samples ES№17. From DSA 5000 M measurements: □ – ES№1; ● – ES№2; ✕ – ES№4; and ○ – ES№17. From SVM 3000 visco-densimeter measurements: ◆ – ES№1; △ – ES№2; ◇✕ – ES№4; and + – ES№17.*

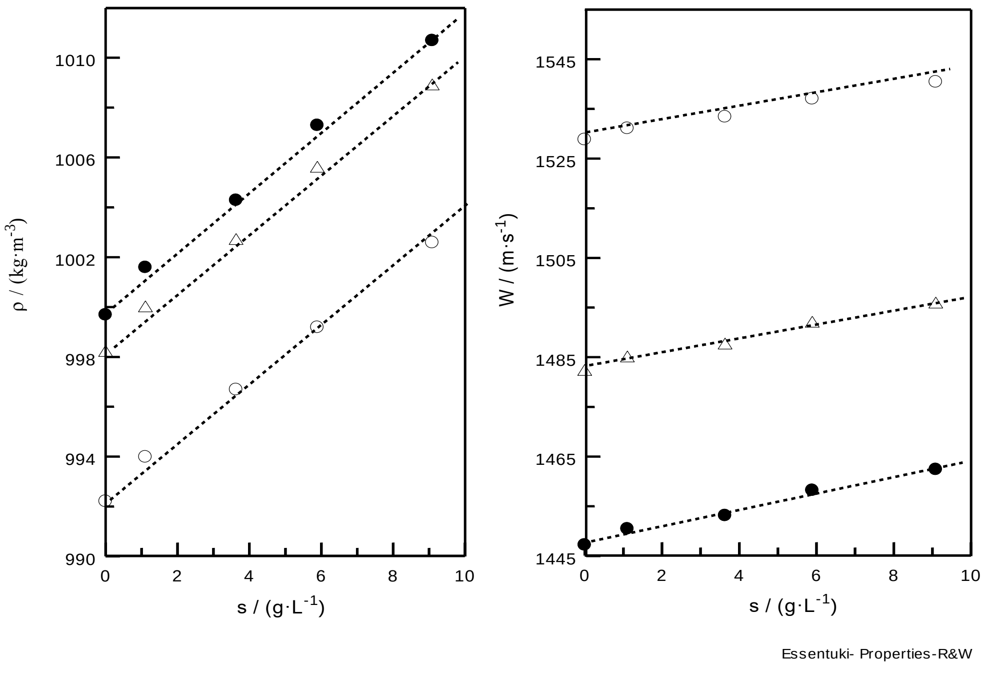

Figure 2: *Measured values of density and speed of sound for various mineral waters as a functions of mineralization (TDS, S) along the selected isotherms together with the values for pure water (S=0, IAPWS, Wagner and Pruß, 2002). Dashed lines are linear interpolations. ●-283.15 K; △-293.15 K; ○-313.15 K.*

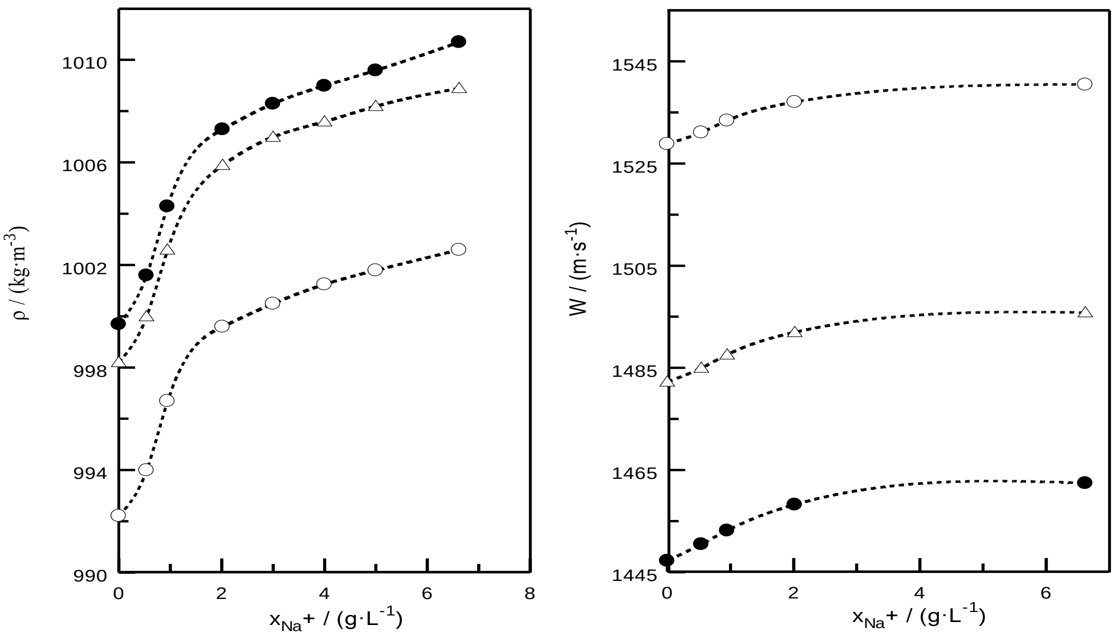

Figure 3: *Measured values of density (left) and speed of sound (right) for various mineral waters as a functions of Na^+ ion concentrations (sensitivity to Na^+ concentrations) along the selected isotherms together with the values for pure water (x_{Na+} =0, IAPWS, Wagner and Pruß, 2002). Dashed lines are interpolated values. ●-283.15 K; △-293.15 K; ○-313.15 K.*

Also, the measuring instrument (DSA 5000 M) allows to follow the sample filling process live on screen or recall stored images later. Therefore, the instrument allows verifying the correct sample filling and measurements later, *i.e.*, alert us of potential filling or bubble forming problems. At temperatures above 323 K, we found that heating of the samples (especially high concentrated samples ES№4 and ES№17) during the measurements causes the release of the dissolved gases. Therefore, the measured data at temperatures above 323 K are affected by dissolved gases. Above the 323 K the intensity of the gas release increases. At low temperatures (below 323 K) the effect of gas release to the measured properties can be neglected. The instrument automatically detects inhomogeneity and gas bubbles forming in the whole density measuring cell by an advanced analysis of its oscillation pattern and generates a warning message in real time for any single measurement, *i.e.*, the bubbles (gas release) in the sample are detected automatically during the experiment (instrument alert us of potential gas release problems). At temperatures below 323 K we did not observed any gas release problem in our experiment (no warning messages from the instrument were observed). To study of the effect of dissolved gases in the mineral water samples at high temperatures, the measurements at high pressures are required because the solubility of gases in liquids increases with pressure increasing.

Figure 2 shows the salinity (TDS) dependence of the density (left) along the fixed temperatures. As one can see, ρ–*S* dependence is almost linear function. In the limit, $S \to 0$, the measured density data becomes equal to the pure water values (IAPWS, Wagner and Pruß, 2002) at each fixed temperature. The present extrapolated to zero salinity $(S \to 0)$ density data and the values for pure water calculated from IAPWS formulation (Wagner and Pruß, 2002) are in good (discrepancy is AAD=0.003 %) agreement (see Fig. 4). This excellent agreement between the present extrapolated data and IAPWS (Wagner and Pruß, 2002) calculations for pure water confirms the reliability and high accuracy of the present measurements for the mineral water sample and correct operation of the measuring instrument and the procedure of measurements. The measured values of density for various mineral waters as a function of Na^+ ion concentrations (sensitivity of the measured densities to Na^+ concentrations) along the selected isotherms together with the values for pure water (*S*=0, IAPWS Wagner and Pruß,

2002) are depicted in Fig. 3 (left). As this figure shows, in the low concentration range ◎⤙⤙◎x_{Na^+} <2 g/*L*, rapid increase of the density along the isotherms is observing. At high concentration of Na^+, above >2 g/*L* gradually increases of the measured density with almost constant slopes is observing.

III. Speed of Sound

Measurements of the speed of sound for the same natural mineral water samples were performed at atmospheric pressure as a function of temperature in the same temperature range as in density experiment, namely, from (278.15 to 343.15) K. The measured speed of sound data is presented in Table 2 and depicted in Figs. 2,3 (right), 4, and 5 in the *W*◎⤙◎◎ *W*◎⤙⤙◎◎*W*◎◎*S*,, and *W*◎◎x_{Na^+} projections. As one can see from Figs. 4 and 5, the temperature and density behavior of the speed of sound, as a density and other properties, similar pure water behavior (Wagner and Pruß, 2002) . However, speed of sound, in contrast to density, is less sensitivity to the effect of gas releases. The measured speed of sound (Fig. 2 right) of the mineral water is almost linear function of the TDS concentration like density. The sensitivity of the speed of sound data to concentration of the sodium ions (main component of the mineral waters) shown in Fig. 3 (right). As one can see, a speed of sound is smoothly increasing with x_{Na^+}. The present measured speed of sound data for mineral water samples deviates from those for pure water (IAPWS standard data, Wagner and Pruß, 2002) within (0.13 to 0.27) % for ES№1, from (0.28 to 0.42) % for ES№2, from (0.53 to 0.83) % for ES №4, and from (0.75 to 1.13) % for ES№17. At high temperatures the deviations are lower than at low temperatures.

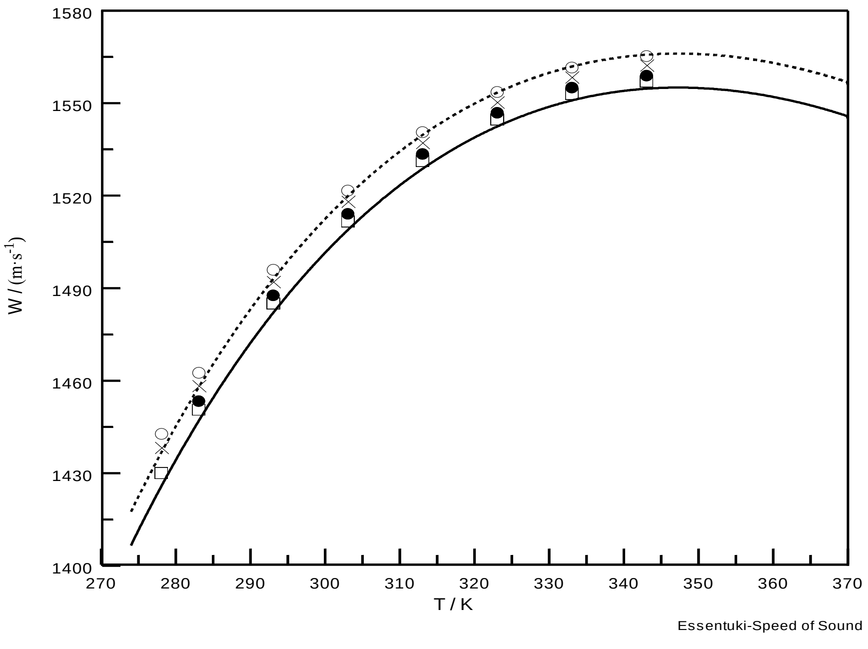

Figure 4: *Measured speed of sound for various mineral waters as a function of temperature together with the values for pure water calculated from IAPWS formulation. Solid line is pure water values calculated from the IAPWS fundamental equation of state (Wagner and Pruß, 2002) . Dashed lines are values calculated from the predictive correlation model for the sample ES№17. The symbols are the same as in Fig. 1.*

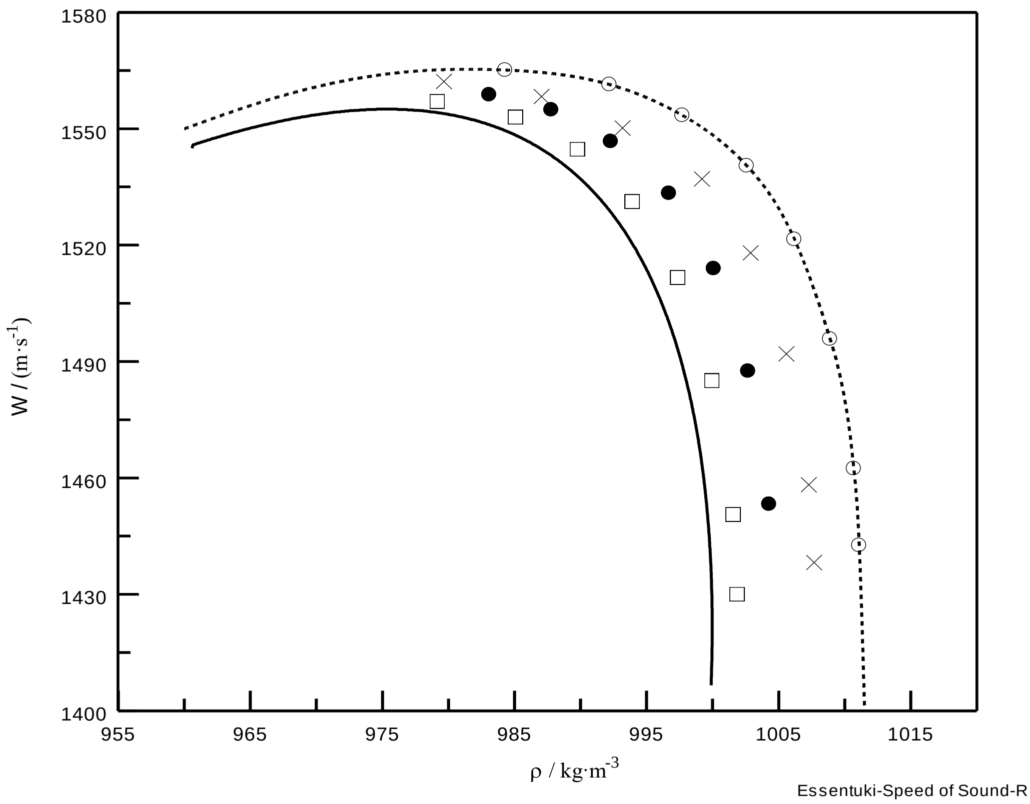

Figure 5: *Measured speed of sound for various mineral waters as a function of density together with the values for pure water calculated from IAPWS formulation. Solid line is pure water values calculated from the IAPWS correlation (Wagner and Pruß, 2002). Dashed line is calculated from the prediction model. The symbols are the same as in Fig. 1.*

IV. Correlation Models for Density, and Speed of Sound

Since there is no theory available for the thermodynamic (equation of state) and transport properties (temperature and concentration dependence correlation models) of multicomponent aqueous solutions, its evaluation is empirical and based solely on experimentally obtained data. Therefore, the present measured density data as a function of temperature were represented by polynomial type temperature function

$$\rho(T) = a_0 + a_1 T + a_2 T^2 . \tag{1}$$

The derived optimal values of fitting parameters are given in Table 3. As one can see from Table 1, the AAD between measured and calculated from Eq. (1) values of density for samples ES№1, ES№2, ES №4, and ES №17 are 0.009, 0.020, 0.015, and 0.017 %, respectively.

Measured speed of sound data was fitted to the same quadratic function of temperature

$$W(T) = b_0 + b_1 T + b_2 T^2 . \tag{2}$$

The values of derived adjustable coefficients of Eq. (2) are presented in Table 5 together with deviation statistics. As can be seen, AAD between the measured and calculated values of speed of sound data for ES№1, ES№2, ES №4, and ES №17 is 0.062, 0.052, 0.061, and 0.058 %, respectively.

Table 3: *Values of fitting parameters (a_i) of the correlation Eqs. (1), for the density of mineral water samples together with the deviation statistics*

Sample	a_0	a_1	a_2	AAD, (%)	Bias, (%)	St.Dev, (%)	St.Err, (%)	Max.Dev, (%)
ES№1	705.823	2.2129	-0.004127	0.01	-0.00	0.01	0.00	0.02
ES№2	795.181	1.6478	-0.003208	0.02	-0.00	0.03	0.00	0.04
ES№4	558.613	3.2746	-0.005968	0.01	-0.00	0.02	0.01	0.04
ES№17	597.450	3.0213	-0.005517	0.02	0.00	0.02	0.01	0.05
Sample	b_0	b_1	b_2	AAD, (%)	Bias, (%)	St.Dev, (%)	St.Err (%)	Max.Dev, (%)
ES№1	-2123.8361	21.5876	-0.03166	0.06	0.00	0.07	0.03	0.09
ES№2	-1996.4817	20.8167	-0.03048	0.05	-0.00	0.06	0.02	0.06
ES№4	-2040.7540	21.1368	-0.03101	0.06	0.00	0.07	0.02	0.09
ES№17	-2008.0588	20.9698	-0.03077	0.06	-0.00	0.07	0.02	0.08

V. Concentration dependence of the density, and speed of sound

As was mentioned above, thermodynamic properties of all aqueous salt solutions, thermal and mineral waters can be represented based on pure water properties (IAPWS formulations, Wagner and Pruß, 2002), because pure water is the dominant constituent and governs aqueous systems properties, see above Figs. 3, 6, and 8. The present experimental density, and speed of sound data for the mineral waters were fitted to the Riedel's correlation equations [8].

$$\rho(T, x_i) = \rho_{H_20}(T)\left(1 + \sum_{i=1}^{n} a_i x_i\right), \tag{3}$$

$$W(T, x_i) = W_{H_20}(T)\left(1 + \sum_{i=1}^{n} b_i x_i\right), \tag{4}$$

where $\rho_{H_20}(T)$, and $W_{H_20}(T)$ are the density, speed of sound (IAPWS formulation, Wagner and Pruß, 2002) of pure water respectively at a temperature of T and at atmospheric pressure; x_i is the concentration of ions (g/*l*); n is the number of main components of the mineral water ; a_i , b_i are the density, and speed of sound fitting coefficients (Riedel's characteristic constants of the ions) for each ion species *i*, which are defining the contribution of each single ion species to total measured properties. For the present mineral water samples, we have selected 8 main components (ions): Na^+, Ca^{+2}, Mg^{+2}, K^+, S^+, Si^+, SO_4^{-2}, and Cl^{-1} which contributions to the measured properties of the mineral waters are significant. The effect of other ions to the measured properties is negligible small. As can be note, from Eq. (3), (4) the temperature dependence of the $\rho(T, x_i)$, and $W(T, x_i)$ of mineral waters is determined through the temperature behavior of pure water properties, $\rho_{H_20}(T)$, and $W_{H_20}(T)$, see Figs. 1, and 4. All measured $\rho(T, x_i)$, and $W(T, x_i)$ data for various temperatures and concentrations (ES№1, ES№2, ES№4, and ES№17) together were fitted to Eqs. (3) and (4). The derived values of the Riedel's characteristic constants (a_i , b_i) for 8 selected ions of Na^+, Ca^{+2}, Mg^{+2}, K^+, S^+, Si^+, SO_4^{-2}, and Cl^{-1} are presented in Table 4.

Table 4: *Characteristic constant (Riedel's characteristic constant of the ions) a_i, b_i, and c_i for density, and speed of sound correlation models Eqs. (3)and (4) for basic ions in the mineral water samples*

Ions	a_i (density) (l/g)	b_i (speed of sound) (l/g)
Ca^{+2}	-0.1345	-0.1345
K^{+}	-0.0945	-0.0945
Mg^{+2}	-0.1435	-0.1435
Na^{+}	-0.0545	-0.0545
S^{+}	0.1555	0.1555
Si^{+}	-0.1245	-0.1245
Cl^{-1}	0.3555	0.3555
SO_4^{-2}	0.0555	0.0555

As one can see, the values of the Riedel's characteristic constants (a_i , b_i , c_i) for density and speed of sound are the same. This means that the contribution of the same ion specie to the density and speed of sound is the same. Also, the Riedel's characteristic constants for all cations are negative (except for S^+), while for anions are positive. Thus, using the present measured density, and speed of sound data for the mineral water samples we can separate the contribution of different ion species to the total measured properties. and natural geothermal waters.

As can be note from Eqs. (3) and (4), the Riedel's model is the linear function of the concentration of ions. However, to improve the accuracy of the experimental data representations of the Riedel's model, the next terms ($x_i^{0.5}$, $x_i^{1.5}$, x_i^{2}) in expansion (Eqs. 3 and 4) should be used. More experimental thermophysical property data of thermal and mineral waters from various regions over the world with various compositions are needed to improve the accuracy of prediction of the models for any natural waters over the wide range of temperature and compositions of salt ions.

IV. Conclusions

The density, and speed of sound of four natural mineral water samples from the region of south Russia (CMW filed, ES№1, ES№2, ES №4, and ES №17) have been measured over a temperature range from (278 to 345) K at atmospheric pressure. Qualitative the measured temperature dependence of the density, and speed of sound of mineral water samples is similar to pure water behavior. Quantitatively the average differences between the measured mineral waters density, and speed of sound and pure water values (IAPWS standards) are within (0.2 to 1.1) %, and (0.15 to 1.13) %, respectively, which are much higher than their experimental uncertainties. At temperatures above 323 K, we found that heating of the samples (especially high concentrated samples ES №4 and ES №17) during the measurements, causes the release of the dissolved gases, which effects on temperature behavior of the density and speed of sound. We have demonstrated that the measured (ρ,W) data at atmospheric pressure can be used to predict high-pressure and high-temperature behavior of density ($P\rho T$) and speed of sound (WPT). If the thermophysical properties of mineral water are known at reference pressure (for example, P_0 =0.101 MPa) and any temperature, then their properties at high pressures at which this properties of pure water are known (IAPWS standards) maybe calculated by multiplying the properties of the mineral water at reference state, P_0 , and given temperature, T, by the ratio of the this property of pure water at the desired pressure to that at a known reference pressure, P_0 =0.101 MPa. Riedel's characteristic constants of the 8 selected ions of Na^+, Ca^{+2}, Mg^{+2}, K^+, S^+, Si^+, SO_4^{-2}, and Cl^{-1} for density, and speed of sound were estimated from the present measurements. We found that the values of Riedel's characteristic constants of the ion species for the thermodynamic properties (density and speed of sound) are the same. This means that the contribution of the same ion specie to the total measured density and speed of sound is the same. Also, the Riedel's characteristic constants for the all cations are negative (except for S^+), while for anions are positive.

References

[1] Veniale F., Barberis E., Carcagiu G., Morandi N., Setti M., Tamanini M., Tessier D. (2004). Formulation of muds for pelotherapy: effects of maturation by different mineral waters, Appl. Clay. Sci. 25:135–148.

[2] Misirkhan A. Talibov , Javid T. Safarov, Egon R. Hassel, and Ilmutdin M. Abdulagatov. (2018). High-pressure and high-temperature density and vapor-pressure measurements and derived thermodynamic properties of natural waters of Yardymli District of Azerbaijan. High Temperatures-High Pressures 47:223–255.

[3] Misirkhan A. Talybov, Lala A. Azizova, Ilmutdin M. Abdulagatov. (2019). Experimental Vapor-Pressures and Derived Thermodynamic Properties of Geothermal Fluids from Baden-Baden Geothermal Field (Southeastern Germany). Journal of Energy and Power Technology 27:2-26.

[4] Ilmutdin M. Abdulagatov, Misirkhan A.Talybov, Lala A. Azizova. (2020). Measurements of the density, speed of sound, viscosity and derived key thermodynamic properties of geothermal waters from East Turkey. ELSEVIER, Geothermics 88:101884.

[5] Misirkhan A. Talybov, Ilmutdin M. Abdulagatov. (2021). High-temperature and high-pressure PVT measurements and derived thermodynamic properties of geothermal fluids from East Turkey. ELSEVIER, Geothermics 95:102125.

[6] Lemmon EW, Huber ML et al. NIST Standard Reference Database 23, NIST Reference Fluid Thermodynamic and Transport Properties, REFPROP, version 10.0, Standard Reference Data Program, National Institute of Standards and Technology: Gaithersburg, MD, 2018.

[7] Wagner W, Pruß A. (2002). New international formulation for the thermodynamic properties of ordinary water substance for general and scientific use, J. Phys. Chem. Ref. Data 31:387-535.

[8] Riedel L. (1951). The heat conductivity of aqueous solutions of strong electrolytes. Chem Ing Tech 23:59-64.

AUTOMATION OF TRANSPORT AND WAREHOUSE OPERATIONS BASED ON THE DEVELOPMENT OF ADAPTIVE SYSTEM TO REDUCE RISKS FOR MANAGING WAREHOUSE LOGISTICS AT AGRICULTURAL ENTERPRISES

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Abstract

Digital transformation is a comprehensive approach. The processes of transforming the enterprise functioning through the business procedures digitization and the automation of implementation and management of specialized software for internal and external interactions as part of the country's digital ecosystem form the basis of the approach. In this regard, as well as in the conditions of ensuring import substitution against sanctions policy, the most pressing issue is the development of domestic software for managing the domestic enterprises at various levels and agro-industrial spheres (AIC). It is the production process of agricultural enterprises, to a greater extent than enterprises of other industries, that is influenced by various risks caused by climatic, technological, biological, etc. factors. The article examines the provision of automation of transport and warehouse operations when managing logistics processes at an agricultural enterprise through the development of special software. A block diagram of the control process automation is presented, taking into account the level hierarchy, the architecture of the process control automation system, individual elements of the developed software product (the algorithm of the program for controlling an automatic pallet stacker, the visualization system: the push-button screen for information support and the main screen of the operator's touch panel). A mathematical model for a program to lay non-standard workpieces (packages) on a pallet with the optimization of their placement has been generated. The calculation of the project implementation economic efficiency is suggested. The payback period is five months, provided the operator has got the necessary competence level. The article concludes that a similar management system can be implemented at various enterprises with warehouse space (industrial, agricultural, service industries, cargo transportation, etc.) in order to reduce risks (related to technological, man-made and human factors) during loading and unloading of packaged raw materials and products, and considered as innovative resource-saving technology as well as the part of import substitution and adaptation of software when managing logistics processes in the context of digital transformation.

Keywords: management system, decision making, digitalization, production, agricultural enterprises, transformation, transport and warehouse equipment

I. Introduction

Currently, much attention is paid to improving management processes at enterprises. This is due to the widespread introduction of methods and means that allow the decision maker (DM) to optimize the management procedure. Digitalization of the economy favourably contributes to this process, and the unstable geopolitical situation boosts the development of domestic software for implementation at all levels of organization and industrial management of enterprises. Let`s take for example the industrial sector, where the production of bulk materials such as cement, soda, and lime occupies one of the leading roles now. As for the agro-industrial complex, a lot of manufacturing and food processing enterprises make a significant contribution to ensure the economic security of the country. At the present stage of development, they all need digital technological innovations [1]. The installation of automatic systems related to the transportation and storage of goods [2], the mobile microprocessor systems for automating transport and warehouse operations [3], etc., which increase management efficiency and, ultimately, production volume while reducing costs (thereby contributing to an increase in income), is currently a relevant issue, especially in the context of economic processes digitalization. Similar operations are carried out in agricultural enterprises during transport and warehouse operations in grain production, dairy farming, etc. Moreover, when loading and unloading packaged raw materials or finished products, various risks arise (including those depending on the human factor), including a violation of the container when falling, injury to workers, failure of the packaging composition by date of production, etc. In this case, automation of process control will reduce the likelihood of a risky situation, including technological or man-made ones (for example, when transporting fertilizers or pesticides), thereby eliminating an increase in costs. In addition, the seasonality of agricultural production, the influence of weather and climatic factors affect the uneven workload of employees throughout the year, therefore, automation of a number of processes reduces the cost of additional hiring during certain time periods.

The object of the research is the automated process control system with a pallet stacker in the context of optimizing the organization of transport and warehouse operations when managing logistics processes at the agricultural enterprise. For clarity, we will consider this equipment using the example of stacking single packages on a pallet (for other types of packages it is the same). Until recently, these operations were performed manually, the productivity of such work was about 50 packages per hour. Modern equipment allows for stacking at a speed of up to 3000 packages [4]. The choice of the research issue is substantiated by the importance to consider the problem of introducing automatic palletizers from the viewpoint of package placement optimization, as well as in the context of reducing risks and introducing energy and human resource-saving processes.

II. Methods

Methods of the systems approach, logical analysis and synthesis, optimization modeling and algorithmization were used while researching the issue.

There are robotic palletizers and palletizers of a continuous type on the market. The former are used for the workpieces of different volumes and shapes. Mechanical arms, suction cups and other tools allow you to grab and place any objects. At the same time, robotic palletizers have limited productivity, while palletizers of a continuous type allow stacking from 600 to 3000 packages per hour. The former are more flexible and at the same time quite compact, while the latter are massive, but at the same time have greater productivity. Palletizing robots are mainly used in pharmaceuticals and logistics. At enterprises producing products in bottles, bags and bags, belt (continuous type) palletizers are used [5, 6]. They have a wide range of designs and are used in various fields of production: textile, food or industrial.

Overview of palletizers

I. Manual palletizers are practically no longer used due to low productivity and the risk of human error.

II. A large number of Russian enterprises are equipped with the latest automatic equipment. However, Industria 4.0 has not yet reached everyone. As for the pallet stacker, there are still quite a few enterprises that use semi-automatic installations [7]. Such palletizers are less productive. In addition, there is a need to employ people as duty personnel (at least 4 people, since the installation operates around the clock). And these are additional wage costs. Operator`s work is monotonous, which increases the risk of human error. Semi-automatic pallet stackers are not always equipped with a monitoring and control system: an operator touch panel, a program for a specialist's automated workstation (AWS), a SCADA system.

III. Digitalization has affected almost all areas of human life including industry. The main advantage of the industrial enterprises` digital transformation is the increase in productivity as the product development, production, packaging and logistics take much less time, and production costs are reduced [8, 9].

The operation of equipment using sensors without human intervention according to a specially written algorithm means stability and safety. In addition, the introduction of digital technologies allows you to interact with machines using visualization systems and automated workplaces.

Analyzing various enterprises, we can safely say that the use of semi-automatic equipment in modern production is economically unprofitable [10]. If we consider new enterprises or those where complete re-equipment is planned, then for them it is most advisable to use automatic pallet stackers. However, at the moment, enterprises in which a semi-automatic unit operates dominate [11]. Buying a new one is a very expensive decision, and the payback period is not quick. In this regard, the question arises of digital transformation of the technological process through full automation of the palletizer using modern high-quality equipment with the ability to work around the clock without human intervention. Therefore, the purpose of this work is to develop a control system for a semi-automatic pallet stacker when it is converted into an automatic one.

III. Results

Automation system development

We have developed a block diagram for automating the process of managing transport and warehouse operations at enterprises using a pallet stacker. Figure 1 shows the hierarchy of its levels with the corresponding components. The scheme fully corresponds to the sequence of logistics process management stages implementation. The decision maker is equipped with an operator's workstation and an HMI panel (upper level), used as a graphical process control panel. Thanks to this electronic installation, which facilitates the visualization of information received from devices, the performance of the technological control object is analyzed (lower level) and further work is adjusted taking into account the controller data (middle level). Operational remote control, using support for selected protocols, allows you to implement the interaction of peripheral equipment at the field level and optimize the control procedure to select relevant management actions.

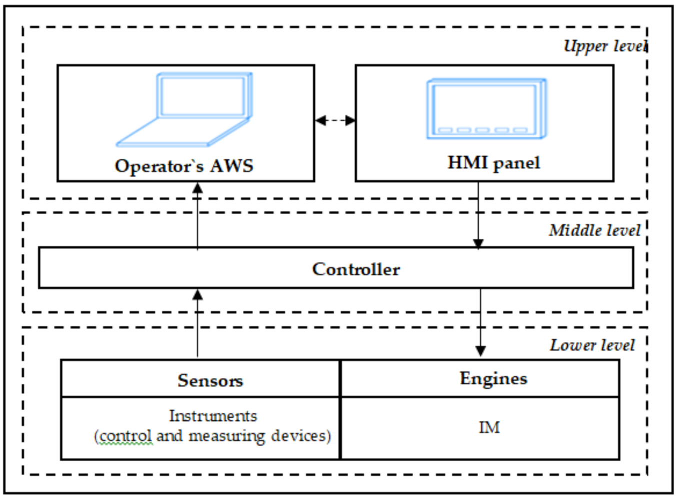


Figure 1: *Block diagram of automation of the management process*

Based on the block diagram, the architecture of the process control automation system was built (Figure 2).

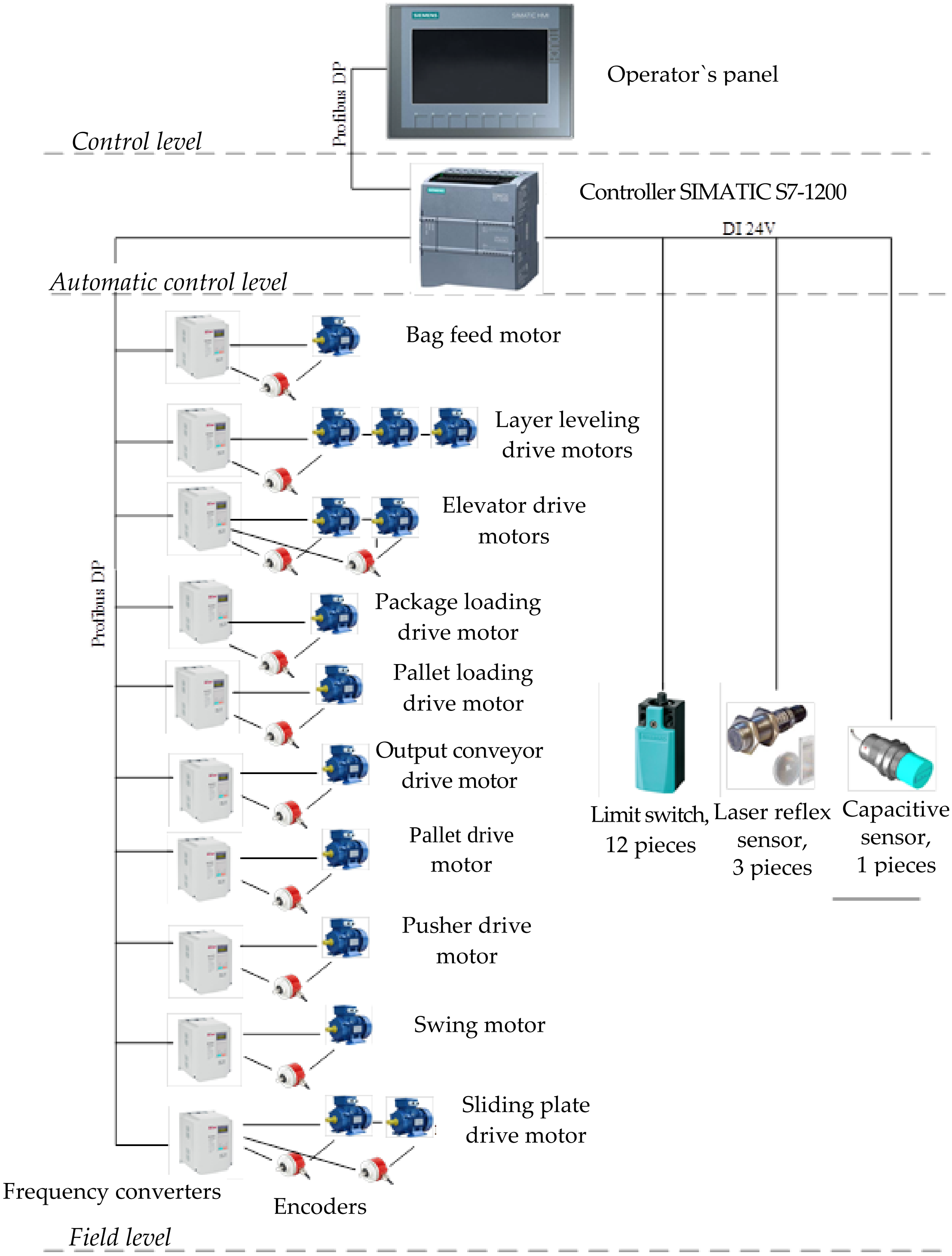


Figure 2: *Architecture of a process control automation system*

The field level consists of two limit switches, one capacitive and three laser reflex sensors. Also, in addition to sensors, the field level includes 14 asynchronous motors and 10 frequency converters, each controlling the speed of the drives of individual actuators. An encoder is connected to each frequency converter to provide speed feedback.

The field level is followed by the automatic control level, which consists of a programmable logic controller (PLC). All frequency converters are connected to the PLC via the ProfibusDP protocol. Limit switches and sensors are connected directly to the PLC.

The automated operator workstation consists of an HMI panel, which is also connected to the PLC via the ProfibusDP interface.

All drives as well as the control panel are connected to a programmable logic controller (Figure 3).

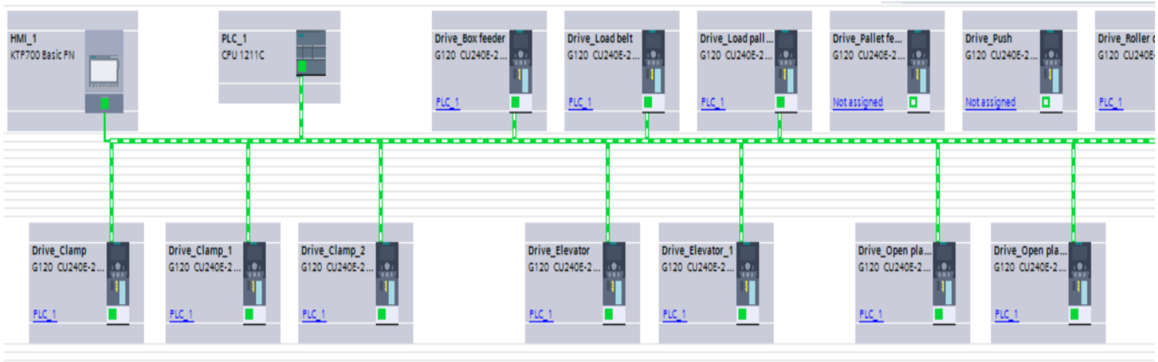
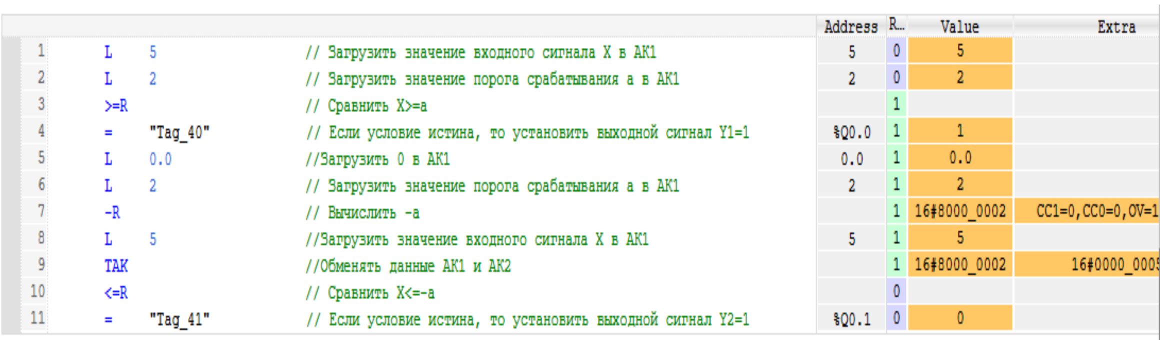


Figure 3: *Link with the controller*

All elements of the automation system architecture form a single automated system and provide a solution to all assigned automation tasks at this level.

Figures 4 and 5 show screenshots of the written pallet stacker control program.



				Address	R...	Value	Extra
1	L	5	// Загрузить значение входного сигнала X в AK1	5	0	5	
2	L	2	// Загрузить значение порога срабатывания a в AK1	2	0	2	
3	>=R		// Сравнить X>=a		1		
4	=	"Tag_40"	// Если условие истина, то установить выходной сигнал Y1=1	%Q0.0	1	1	
5	L	0.0	//Загрузить 0 в AK1	0.0	1	0.0	
6	L	2	// Загрузить значение порога срабатывания a в AK1	2	1	2	
7	-R		// Вычислить -a		1	16#8000_0002	CC1=0,CC0=0,OV=1
8	L	5	//Загрузить значение входного сигнала X в AK1	5	1	5	
9	TAK		//Обменять данные AK1 и AK2		1	16#8000_0002	16#0000_000
10	<=R		// Сравнить X<=-a		0		
11	=	"Tag_41"	// Если условие истина, то установить выходной сигнал Y2=1	%Q0.1	0	0	

Figure 4: *Reading signals from sensors*

Development of an adaptive system for searching the optimal location of non-standard workpieces.

The pallet stacker control program includes a special function for optimal placement of workpieces on a layer. This approach allows to place on pallets not only identical packages with strictly defined dimensions, but also completely different ones in shape and size. Such an adaptive system is especially important in the logistics of large enterprises that produce related products with different package dimensions on adjacent conveyor lines.

To perform this task, the following variables have been added to the program: L – length of the workpiece; S – is the area of the next layer; N – number of blanks. It is necessary to obtain m different types of workpieces with either length L_i or area S_i, where i is the type of workpiece ($i = 1, 2, ..., m$). The number of workpieces of the i-th type in the layer is known, i.e. the number of blanks that is necessary to form one layer – b_i. The total number of blanks produced by the enterprise is denoted by k. The arrangement of workpieces on a layer can be done in n ways. Then a_{ij} is the number of workpieces of the i-type, obtained by the j-method ($j = 1, 2, \dots, n$). The unused area in the j-method is C_j. It is necessary to arrange the workpieces in such a way that C_j (the total area of the gaps between the workpieces) is minimal. Let us denote by x_j the number of units of blanks cut by the *j* method. Find x_j>0 that satisfy the following restrictions.

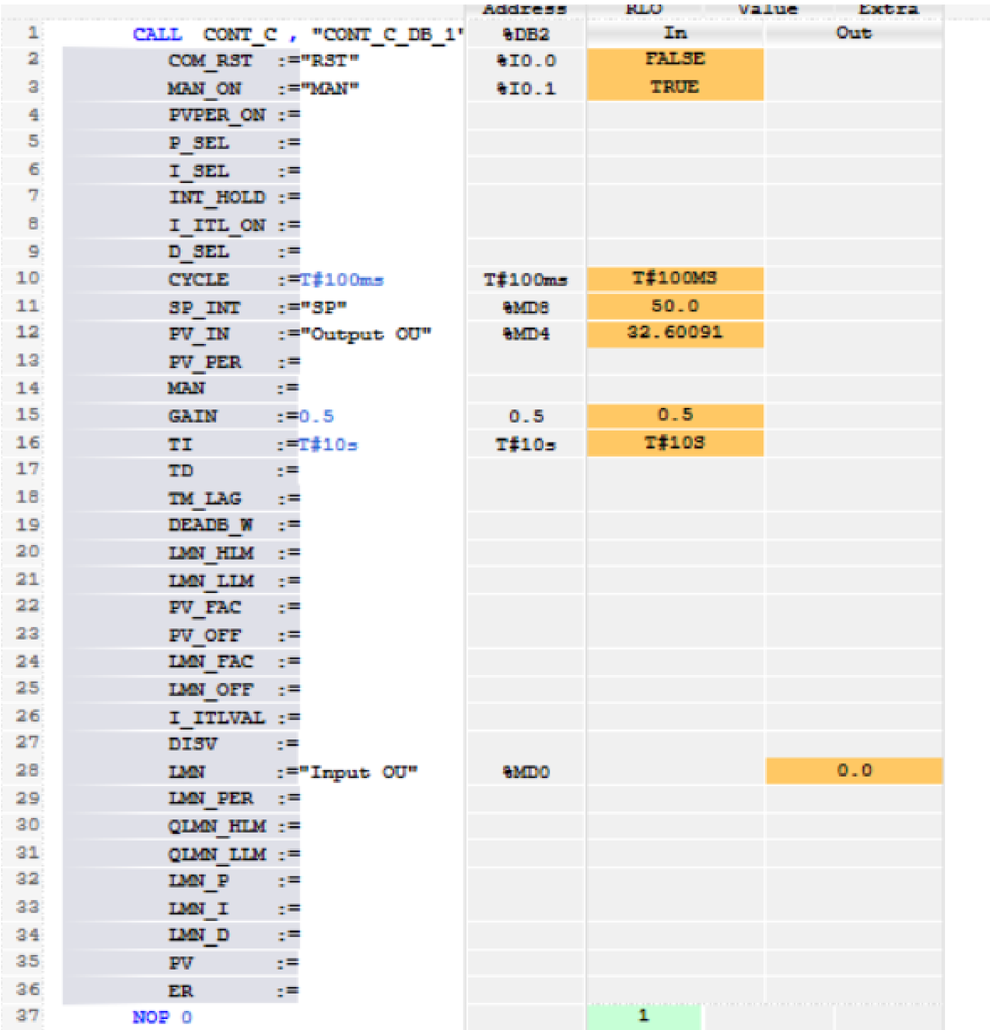


Figure 5: *Calling and setting up the control loop regulator*

Restriction on the number of blanks:

$$\sum_{j=1}^{n} x_j \leq N. \quad (1)$$

Production plan limitation:

$$\sum_{j=1}^{n} a_{ij} \cdot x_j = b_i, \quad (i = 1, \ldots, m). \quad (2)$$

This is exactly how many blanks of the *i*-type are obtained for all cut options. Based on the completeness condition, we obtain the following restrictions on the production plan:

$$\sum_{j=1}^{n} a_{ij} \cdot x_j = d_i \cdot k, \quad (i = 1, \ldots, m). \quad (3)$$

The total area of the gaps between the workpieces should be minimal, then the goal function will take the form:

$$\sum_{j=1}^{n} C_j \cdot x_j \to \min. \quad (4)$$

The value of the variables responsible for the number of blanks must be integer. To prevent the numbers with fractional parts, the program contains a solution to the linear integer programming problem, based on the following: it is necessary to calculate a value $X = (x_1, x_2, ..., x_n)$, for which the linear function:

$$Z = \sum_{j=1}^{n} c_j \cdot x_j \tag{5}$$

takes the maximum or minimum value subject to restrictions:

$$\sum_{j=1}^{n} a_{ij} \cdot x_j = b_i \quad (i = 1, ..., m); \tag{6}$$

$$x_j > 0, \quad (j = 1, \dots, n); \tag{7}$$

$$x_j \; - \text{ целые числа.} \tag{8}$$

Thus, the program calculates an option in which the maximum number of required blanks will be placed on the pallet with minimal gaps between each other.

IV. Discussion

Software development

The software under consideration is recommended to be installed on an automated workstation.

When launching the application, the following button form opens (Figure 6).

Figure 6: *Switch board "Information support for automated process control system of pallet stacker"*

This form contains a specific list of possible application working modes:

– requests for access to operational information;
– receiving a report – shift log;
– information about the developer.

The option to exit the application is provided.

Automation program development

To control an automatic pallet stacker, a program [12] is written in the visualized LAD language. The program assumes fully automatic operation without human intervention.

The operating algorithm is presented in Figure 7.

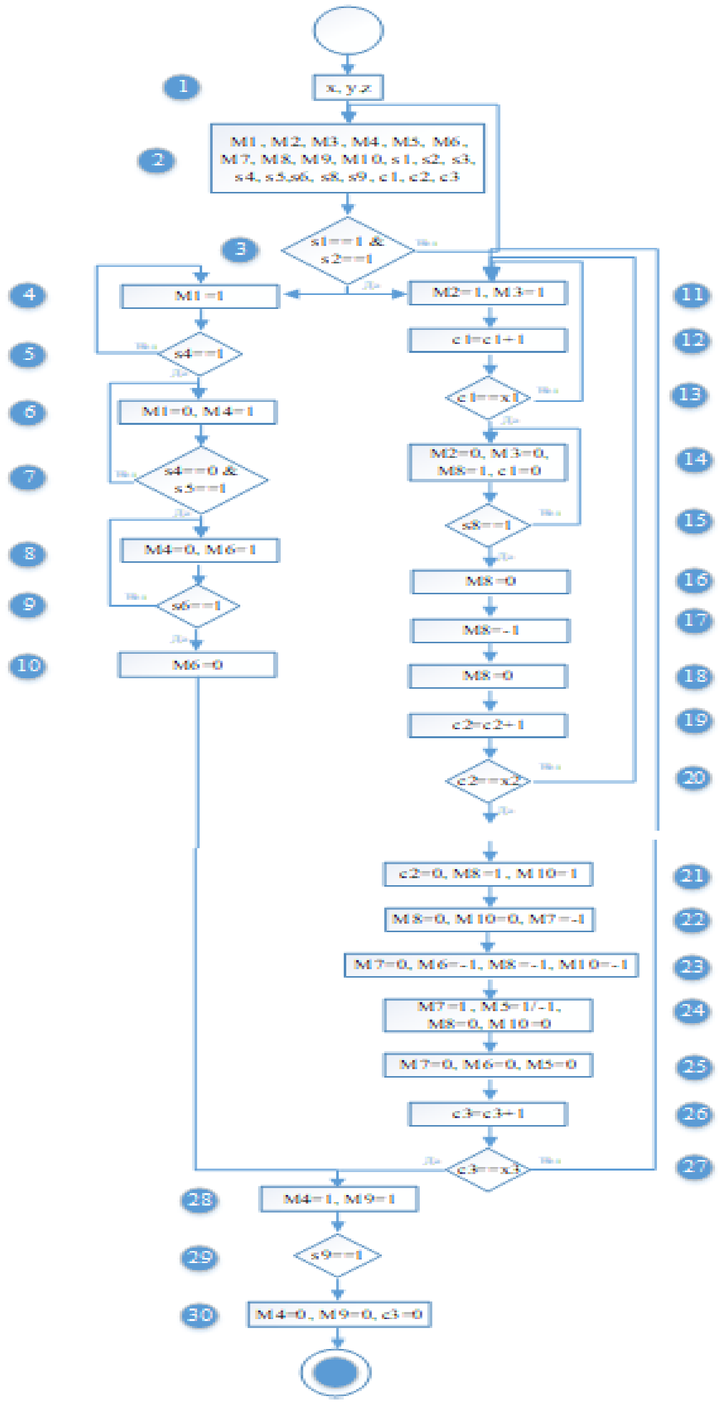


Figure 7: *Algorithm of the program for controlling an automatic pallet stacker*

The letter M denotes the corresponding drive, c – counter, s – sensor.

The program code provides for the main non-standard situations for displaying notifications and errors on the operator panel, which allows to quickly identify and eliminate the malfunction.

Visualization system development

A touch panel has been developed to visualize and control the technological process. It contains two screens. The first (Figure 8) is the main one, displaying the entire technological process; it is created directly for the operator's interaction with the automated system. The second screen displays diagnostic data.

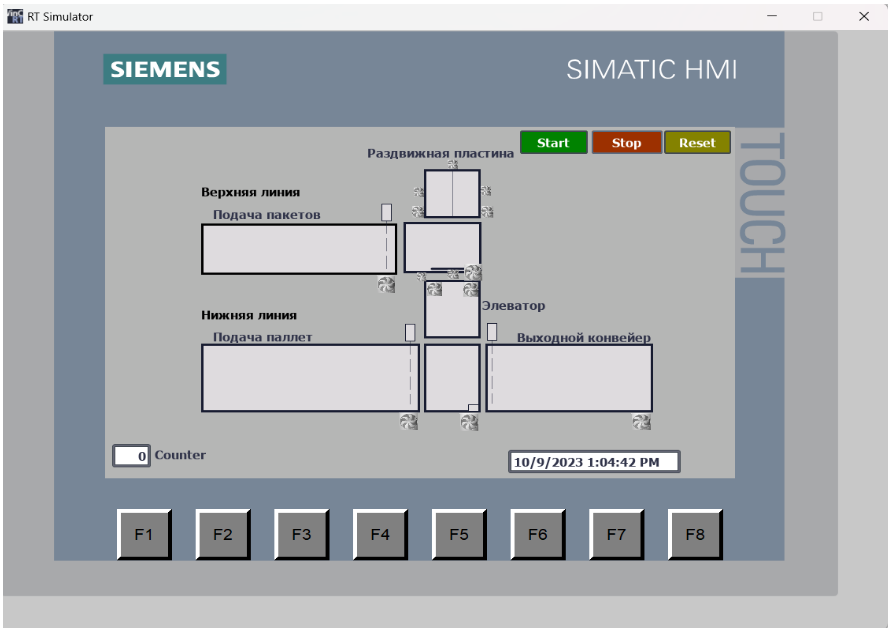


Figure 8: *Operator touch panel main screen*

The main screen contains three buttons for controlling the automatic palletizer: Start, Stop and Reset. These commands are duplicated with commands from the control cabinet. The F2 button scrolls to the second screen to view events that have occurred with the controller.

The tableau in the lower left corner displays the counted number of packages that have passed past the sensor installed on the conveyor feeding the packages.

The date and time are displayed at the bottom right.

The implementation of any innovation is known to require material and time costs. In addition, the level of competence of the specialist, who work on the new equipment, must meet the system requirements, otherwise, additional training costs will be required.

We have calculated the effectiveness of project implementation and the approximate payback period at one of the enterprises in AIC Orenburg region. Capital costs at the moment (capital costs mean the purchase of the necessary equipment for digitalization of the technological process and its installation) amount to 543,360 rubles, while profit from product sales will increase by 1,234,960 rubles.

The payback period of the project for the implementation of the developed control system for an automatic pallet stacker is calculated using the formula:

$$PP = \frac{I_0}{P}, \tag{9}$$

where PP is the payback period, months;

I_0 – initial investment, rub.;

P – net annual cash flow from product sales, rub.;

$$PP = \frac{543\ 360}{1\ 234\ 960} \approx 5 \text{ month.} \tag{10}$$

The payback period is quite short. The implementation of this project will significantly increase the enterprise competitiveness.

The presented project includes the purchase of new equipment and its installation. The experimental implementation of the developed product has proved that the supplementary operator training won`t be required.

The program for controlling the automatic pallet stacker can be used to organize the management of logistics processes within the framework of automation of transport and warehouse operations in the context of digital transformation at enterprises (with warehouse space) in a wide range of industries: in industry, in agriculture, in service sector, in the area of cargo transportation etc.

The developed control panel and software for the workstation displays the entire technological process and has all the necessary functions.

According to calculations, production volume will increase by 1.06%, and the profit from product sales will increase by 1.235 million rubles. The payback period of the project is about 5 months.

The developed automated system can be implemented both at a newly built enterprise and at the old one to replace outdated equipment. It is possible to modernize semi-automatic palletizers in order to fully automate them at the lowest cost.

This development contributes to the management processes digital transformation at the agricultural enterprise, which ultimately, together with the automation of technological processes and reducing risks (production, human, technological, etc.), will lead to increased production efficiency as a whole.

References

[1] Besaliev I. N., Bolodurina I. P., Parfenov D. I., Akimov S. S. (2021). Development of a digital model for assessing the influence of agroecological factors on the productivity of wheat grains. *IOP Conference Series: Earth and Environmental Science*, 624, 4-5 July 2020, Omsk City: 1-6.

[2] Malikov O. B. Transportation and Warehousing of Goods in Supply Chains, Moscow, 2014.

[3] Rubanov V. G., Kizhuk A. S. Mobile Microprocessor Systems for Automation of Transport and Warehouse Operations. Mobile Robotic Systems, Belgorod, 2011.

[4] Tsukanov A. V., Litsin K. V. (2023). Development of Automated System for Rolling Production Batch Cutting Machine. *Ferrous Metals*, 1:38-43.

[5] Rybin I. A., Rubanov V. G. (2017). Mathematical Model of a Mobile Vehicle Control System. *Mechatronics, Automation, Control*, 18, 5:333-340.

[6] Shmatova M. S., Sytov E. V., Vorotnikov S. A. (2021). Economic Efficiency of a Robotic Complex for Stacking Dairy Products. *Economics of Industry*, 14, 3:298-308.

[7] Baumeister G. (2018). Complete Technological Line for Packaging, Palletizing and Packing Bulk Building Materials of a Wide Range. *Cement and its Application*, 6:62-63.

[8] Shepel V. N., Speshilova N. V. (2023). Making Management Decisions: Classification of Problems, Mathematical Tools and Digitalization of its Application. *Material international scientific-practical conference: Digital transformation of social and economic systems*, 27 January 2020, Moscow:205-210.

[9] Shepel V. N., Speshilova N. V., Kitaeva M. V. (2018). Technology of Management Decision-Making At Industrial Enterprises In The Digital Economy. *International Scientific Conference: Global Challenges and Prospects of the Modern Economic Development*, LVII, GCPMED, 06-08 December 2018, Samara:1520-1531, URL: www.futureacademy.org.uk/files/images/upload/GCPMED%202018F155.pdf.

[10] Westhues R. (2015). Developments in Palletizing Technology. *Cement and its Application*, 4:64-67.

[11] Boguslavsky L. A. Technological Machines for Packaging Production, Moscow, 2014.

[12] Speshilova N. V., Rakhmatullin R. R., Tsukanov A. V. Program for Controlling an Automatic Pallet Stacke: State certificate on computer program registration, 2023685199, Rospatent, 2023.

SOME ASPECTS OF APPLICATION OF INNOVATIVE TECHNOLOGY TO INCREASE OIL RECOVERY

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Abstract

In the article, the study of the factors affecting the reduction of the oil yield of the oil fields located in the dry areas of Azerbaijan and in the final stage of development and the presence of large amounts of residual oil reserves in those fields are explained. At the same time, the problems of solving probes based on the application of modern innovative technologies and "smart" reagents for increasing oil production from those fields were explained with scientific and practical approaches.

Keywords: field, formation, development, oil recovery, flow rate, reagent, innovative technology

I. Introduction

Many fields of the Republic of Azerbaijan, exploited both onshore and offshore, have entered the final stage of development. The fields at the final stage are characterized by low oil flow rates - 0.8 t/day, high water cut - 85...98%, low reservoir pressure and temperature, formation of sand plugs in wells, high efficiency of "surface tension" of oil flow from the formation to the bottom of the well. Surfactants that affect the flushing and extraction of residual "dead oil" in fields are ineffective, and the high viscosity of reservoir oils has created difficulties in the application of progressive methods.

Despite the fact that 150-160 years have passed since oil was extracted from the onshore fields of Azerbaijan, the oil reserves that can be extracted from hydrocarbon fields that are still at the final stage of development are quite large. According to the latest estimate by specialists from the company De Golyer and MacNaughton, the potential of oil reserves on the Absheron Peninsula is 2 billion barrels (Fig. 1).

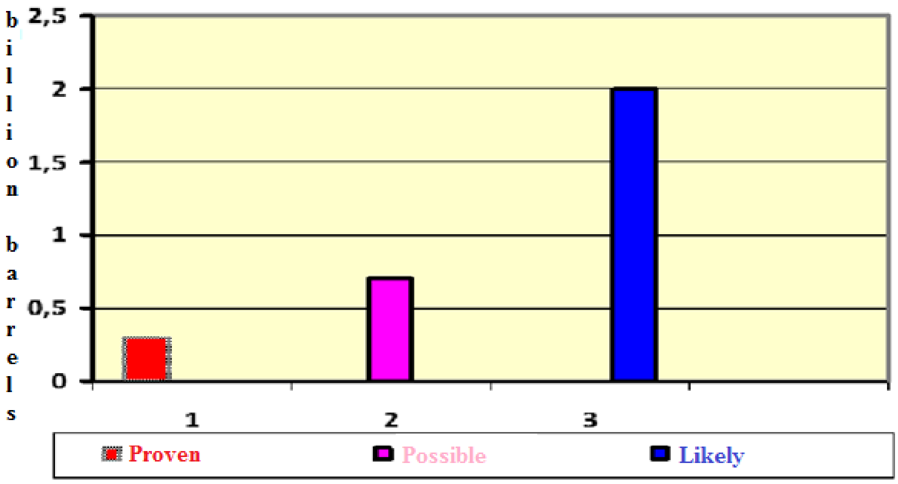

Figure 1: *Proven, possible and probable total onshore oil reserves*

Extracting oil from old fields is a complex production process involving many complex steps. To extract residual "dead oil", and their high prices have created difficulties in the application of advanced extraction methods [1].

Azerbaijan does not produce enough surfactants to extract residual “dead oil”, and their high prices have created difficulties in the application of advanced extraction methods/

In addition, in fields at a late stage of development, alkalis, acids and other reagents are used to increase oil production.

The use of polymers, polymer-dispersed systems and colloid-dispersed systems in oil production worsens the flow of fluid to the bottom of the well in oil-saturated reservoirs and water-flooded zones of the formation, creating conditions for increasing fluid resistance in the formation.

It is necessary to resolve issues that are associated with such features of the oil fields of Azerbaijan, such as the presence of various types of deposits and regimes, weak cementation of reservoirs of the productive strata, and development duration.

For these reasons, most oil reservoirs located on land are exploited with little oil production.

Proper execution and sequence of technological operations at each stage of oil production ensures maximum effect from the entire process, which is expressed in obtaining high-quality oil and maintaining the required production volumes. The maximum effect can be achieved only with high-quality compliance with all technological requirements put forward for this process. Intensification of oil production requires, first of all, a new scientific approach to justify attracting investments into fields and increasing the efficiency of technical and economic processes [2].

II. Methods

I. Enhanced oil recovery (EOR) methods used in the fields of Azerbaijan and abroad

The basis for creating EOR oil-displacing compositions are surfactants of various classes (mainly anionic or nonionic type) in combination with various components (electrolytes, alcohols, hydrocarbons, acids, etc.). For example, a composition for enhancing oil recovery is known, including an anionic surfactant (AS) and a nonionic surfactant (NSAS), where petroleum or synthetic sulfonates with an equivalent weight of 330 to 580 are used as surfactants, and oxyethylated alkylphenols are used as nonionic surfactants. with a degree of oxyethylation from 8 to 16 and additionally - a solvent with the following ratio of components, wt.%: petroleum or synthetic sulfonates with an equivalent weight from 330 to 580...590, ethoxylated alkylphenols with a degree of oxyethylation from 8 to 16...590, the rest - solvent. The disadvantages of this technical solution are the need to use a hydrocarbon solvent and a high concentration of surfactants, which increases the cost of the reagent.

In addition, the composition used in the implementation of the method for developing high-viscosity oil deposits under thermal influence on the formation is known, containing a complex surfactant neftenol VVD (1.0...5.0% wt.) or a mixture of nonionic surfactant (1.0...2.0% wt.) and anionic surfactant (0.5...1.0% wt.), ammonium nitrate (8.0...20.0% wt.), urea (15.0...40.0% wt.), ammonium thiocyanate (0.1...0.5% wt.) and water. In the reservoir, at high reservoir temperatures or thermal effects, urea is hydrolyzed to form an ammonia buffer system [3].

In world oil practice, a composition is used to enhance oil recovery, containing nonionic surfactants and nonionic surfactants, boric acid, glycerin and water. As specified surfactants, the composition contains a complex surfactant, neftenol VVD, or a mixture of nonionic surfactants AF912, or NP40, or NP50 and surfactants volgonate or sulfonal, or NPS6.

Often, gel-forming composites are treated with a water-repellent composition based on cationic surfactants when developing the bottomhole zone of water heating wells (in order to maintain stable reservoir pressure in injection wells and increase the ability to absorb water into the formation). As a result of treatment, the surface of the collector is covered with a monolayer of surfactant molecules, the charged part of the molecules is directed to the surface of the collector, and the hydrophobic part goes into the pore space. Due to the selective orientation of polar surfactant molecules, hydrophobization of the pore space occurs, which prevents intensive coordination interaction of the reagents of gel-forming compounds with the rock surface.

In addition, the disadvantages of the known methods are that an aqueous solution of urea is introduced into a layer with hydrochloric acid to produce an endothermic reaction with the release of heat. A large volume of air is injected into the well, followed by a mixture of steam so that a heat-generating reaction occurs. In this case, the reaction efficiency is not so high. Performing this operation requires a large amount of funds, the resulting result ends with little effect. For these reasons, these methods have not received widespread practical use in the fields.

II. The proposed innovative technology for increasing oil recovery using a "smart" composition

Allows to improve the rheological properties of formation rocks and increase the flow of residual oil to the bottom of the well by reducing its viscosity, changing wetting and surface tension between phases. To achieve this goal, in the first stage, the composition containing methyl alcohol, surfactant (SAM) and water is injected into the layer, which allows to achieve thermochemical effects in the layer. In the second stage, a composition containing a mixture of starch, glue (PVA) and water is injected to form an adsorption layer, create a buffer zone and conduct a thermochemical reaction in the buffer zone. In the third stage, a composition containing a mixture of magnesium, catalyst (Al2O3) and water is injected to carry out the thermochemical reaction in the buffer zone.

The novelty of the proposed innovative technology consists in the implementation of a thermochemical process using the proposed compositions for the creation of an adsorption layer and a buffer zone in the well bottom zone and formation based on a three-stage technology (Fig. 2).

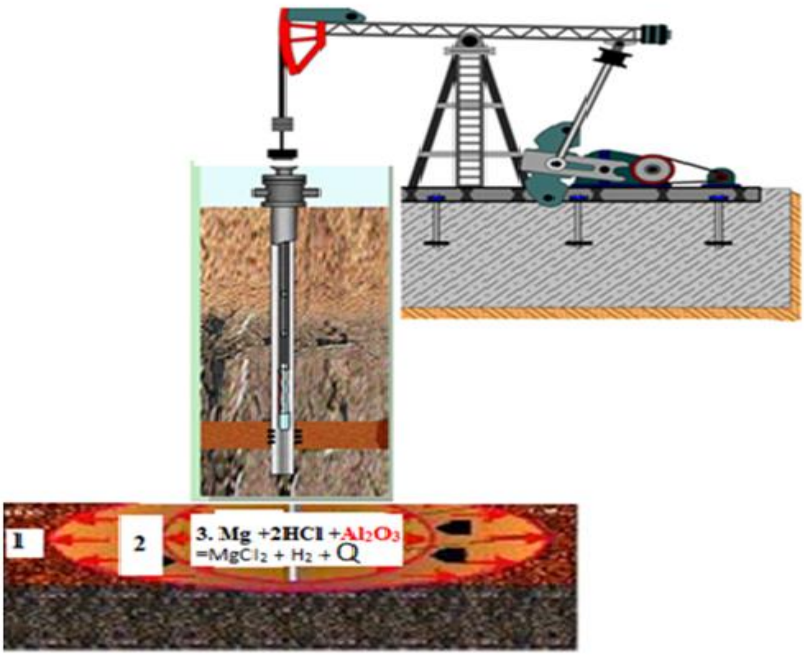

Figure 2: *The scheme of injecting "smart" composition into the well*

Methyl alcohol + SAM + water prepared and injected into the well in the first stage squeezes small particles of sand grains from the bottom zone of the well and washes the oil stuck to the sand rocks. As a result, the viscosity of the oil drops sharply, the flow of oil into the well is improved due to the decrease in surface tension. The fact that oil has a low specific gravity relative to water allows oil to accumulate in the upper part of the formation, and water to enter the lower part of the formation.

The starch + glue + water produced in the second stage creates a buffer zone in the well bottom zone and formation, preventing absorption of magnesium + Al2O3 + water mixture and hydrochloric acid.

In the third stage, a thermal reaction occurs as a result of the encounter of magnesium + Al2O3 + water mixture with hydrochloric acid in the bottom zone of the well.

As a result of the encounter of magnesium + Al2O3 + water mixture with hydrochloric acid in the bottom zone of the well, a thermal reaction occurs. A separate sequential supply of reagents for the implementation of a thermochemical reaction allows to prevent the reaction at the wellhead and inside the well by injecting a surfactant between them [4].

As a result of the reaction, high heat and gaseous hydrogen (H2) compress the methyl alcohol + SAM + water and starch + glue + water counterparts into the formation, enabling the fluid to flow to the bottom of the well. The following thermal reaction takes place in the buffer zone:

$$Mg + 2\,HCI + Al_2O_3 = MgCl_2 + H_2 + Q \quad (1)$$

Here, Q is the heat obtained as a result of the reaction (18.9 Megajoule of heat is obtained as a result of the reaction of 1 kg of magnesium with hydrochloric acid).

The prepared compositions were tested in 6 small production wells of the proposed technology "Bibiheybat" NGCI. The obtained results are shown in Table 1.

As can be seen from the table, the proposed method allows to increase the oil extraction coefficient. Conducting a thermochemical reaction in the well based on innovative technology reduces formation permeability, washes residual oil from formation rocks, separates oil from formation waters, lowers the viscosity of oil inside the formation, eliminates surface resistance, etc. allows to increase the amount of extracted oil due to its improvement.

Table 1: *Results of application of innovative technology*

Indicators	Number of wells			
	3115	3655	3646	3677
	Before the introduction of innovative technology			
Daily oil production, tons	0,5	1,7	0,5	1.2
	After the introduction of innovative technology			
Daily oil production, tons	2,0	3,1	2,0	4,0
Increase in daily oil production, tons	1,5	1,4	1,5	2,8

III. Results

1. On the basis of the proposed innovative technology, based on the works carried out in 3 stages in small oil-producing wells, increasing the permeability of formations in oil wells in operation, a sharp decrease in the viscosity of residual oils in the formation, cleaning the pores from contamination, washing oil stuck to the rock, separating oil from formation water, and the resulting high reaction temperature on the basis of reduction of surface tension, etc. creates an opportunity to increase oil production.

2. To increase the oil recovery of layers, the "smart" innovative composition has high wetting properties. oil-bearing pores.

3. Compared to the reagents in use, PAV has a simple preparation technology and is recommended for use in the oil industry. The price of production of the proposed composition is almost 2 times lower than other reagents produced.

References

[1] Karimov K.S., Shakhveranova E.Kh., Alizadeh Sh.R. Integrated assessment of the effective use of innovation potential in industry // Construction economics and management science and practical J. – 2022. – No. 2. – R. 388–398.

[2] Sentemov A.A. Enhanced oil recovery during surfactant-polymer flooding // Alley of Science. – 2018. – T. 3, No. 9(25). – pp. 347–351.

[3] Mirzajanzade A.Kh., Khasanov M.M., Bakhtizin R.N. Modeling of oil and gas production processes. Nonlinearity, unevenness, uncertainty. – M.–Izhevsk, 2004. – P. 123–125.

[4] Karimov K.S. Azerbaijan Intellectual Property Agency. "Method of increasing reservoir oil yield" Invention N İ 2023 0088 tatikh 01.12.2023. Baku

OPTIMIZATION OF THE ECONOMIC POTENTIAL OF THE INDUSTRY ON THE BASIS OF MATRIX ALGORITHM OF DECISION MAKING

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Abstract

The article is devoted to the issues of modeling the optimization of economic potential of the industry on the basis of matrix algorithm of decision-making. The article considers the algorithm of economic potential optimization based on matrix modeling (state matrices, indicative dynamics matrices, strategic decision-making matrices, matrices of economic potential optimization scenarios).
The adopted modeling format provides systematicity, comprehensiveness, integrity, hierarchy of numerous evaluation parameters, multilevel aggregation of dynamics indices, normalization of sub-indices, point positioning of the level of development of the economic potential of microeconomic systems with the choice of a variant of working out scenarios of strategic priorities of its development.
According to the results of approbation of the model of optimization of economic potential in the information field of the textile industry (Concern Bellegprom), clusters of similar enterprises were identified and variants of working out scenarios of market strategies for optimization of economic potential were developed.

Keywords: economic potential, matrix, dynamics, development, potential-efficiency, index, optimization, strategic scenario, means of scenario development

I. Introduction.

Optimization modeling in the trends of economic potential (EP) development in the industry provides for the development of actual models and methods that provide information-analytical decision support system (IAS DSS). In this direction, the least studied aspects include system interrelations and interdependencies of multifactor modeling of the level of ES development.

The purpose of the conducted research is the algorithmization, methodology and practical tools for selecting the optimal model of effective development of economic potential based on the results of its point positioning in the strategic decision-making matrix of the meso-level.

II. Methods and materials

The author's model of optimization of the EP industry based on a matrix decision-making algorithm is designed on the basis of a systematic, integrated and holistic approach. The EP optimization algorithm included the following steps:

- identification of the goals and objectives of the projected information and analytical decision support system for optimization of EP in the trends of mesorevelopment of the industry;

- carrying out the decomposition of the EP on the basis of structural, process, resource and market (product) approaches with the project of a two-level system of interrelations and interdependencies of indicators of local resource (productive) and institutional potentials (factor);

- formation of a system of indicators for assessing EP in the decomposition of local and private potentials (personnel, production, marketing, innovation and investment, scientific and information potentials);
- construction of matrices of the state of local potentials with an emphasis on the blocks of potential profitability, potential return, potential intensity in a series of dynamics;
- design of indicative dynamic matrices of local potentials with subsequent aggregation of indices of the first and second levels of generalization of potential profitability, potential return, potential intensity (subindexes: Irpi, Iipi, Irp, Iip,);
- point positioning of the level of EP development by integral subindices and the indicator of the third level of generalization (Iep) in the strategic decision-making matrix;
- economic interpretation of interrelations and interdependencies, comparisons, characteristics: identification of imbalances; factors that negatively affected the dynamics of the qualitative state and quantitative development of the EP;
- an extended study of individual structural elements of the EP with detailed factor parameters in particular efficiency matrices in the specific object analytical environment of microeconomic systems of the industry;
- development of options for working out scenarios for optimizing EP at the meso-level; building a vector of priorities for optimizing the sustainable development of EP of industry enterprises with the distribution of public-private partnerships;
- analysis of the compliance of indicators with the objectives of optimization of EP using perspective diagnostics of the effectiveness of decisions made in the reverse order of analytical procedures.

The distinctive features of the industry's EP optimization model based on a matrix algorithm consist in the continuity of the decision–making process: ensuring the consistency, complexity, integrity of a multidimensional, dynamic phenomenon - the economic potential inherent in economic systems; the implementation of structural, process, resource and market methodological approaches in the procedure of its decomposition; a qualitative assessment of the development of the EP, built in the matrix field of efficiency and allowing to establish the relationship and interdependence between the resource potential and the institutional potential ensuring its effectiveness; solving the problem of multi-criteria convolution at several levels of generalization in the construction of aggregated indices, which ensures the point positioning of the level of development of the EP in the strategic decision-making matrix; the formation of relationships and interdependencies in the format of induction, deduction with a vector of priority growth of the effectiveness of the EP in the long term both in its individual elements (the method of private matrices) and the EP as a whole in the context of sustainable development, structural optimization.

III. Literature review

Today, multidimensional scientific developments have been formed within the framework of optimizing the economic potential of enterprises. The theory of determining economic potential from a general theoretical standpoint is studied in the works of Malinovskaya (2006); Kleiner (2008). Many scientists dealing with the problems of economic potential consider this category as part of improving the efficiency of the national economy: Shimov (2012), Lapin (2006). The most common is the resource approach to determining economic potential, which is supported by scientists: Khanov (2007); Vinogradova et al. (2008); Malinovskaya (2008); Timofeeva (2009).

The studies of Kiseleva (2012), Ryazantseva and Aristarkhov (2012) determined the ability of an enterprise as a socio-economic system not only to achieve results in its current state, but also to fulfill strategic goals of sustainable development. The system of functions of the economic potential of the economic system has received theoretical development in the works of such scientists as Medvedeva et al. (2014), Nadvornaya et al. (2016), Artemyeva (2010).

Various aspects of the dynamism of economic potential are studied in the works of Rafikova

(2006); Babaeva et al. (2015); Nekozyreva (2008); Vrublevsky (2016).

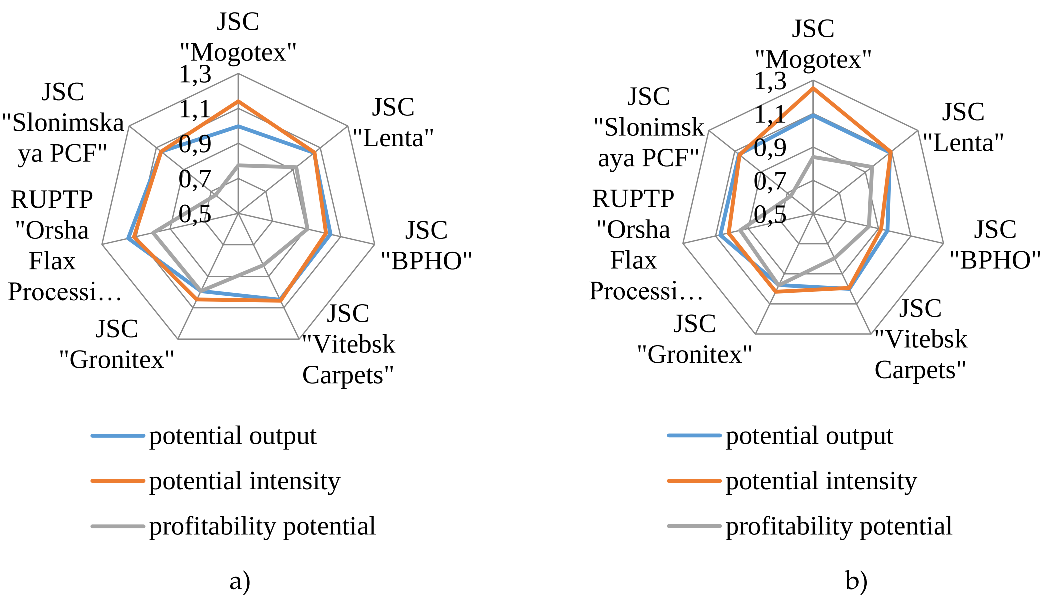
Some methodological aspects of economic potential assessment have been studied by scientists: Afinogenov et al. (2019), Khvorostov (2005), Gorbunova (2014), Vapne (2019), Gonin et al. (2014),), Sheshukova et al. (2013), Shcherbakov et al. (2019), Kovalev et al. (2006), Morozova (2009), Mogilina (2015), Nizamutdinov (2017), Peshkova (2017), Pisareva (2018), Rakhmanova (2018), Tashkinov (2018), Terekhova-Pushnaya (2019), Podolsky et al. (2020), Yarygina (2016), Gurieva (2018), and others.

At the same time, despite a sufficiently deep and thorough level of scientific elaboration of theoretical directions for optimizing economic potential, management science involves the development of key provisions of mathematical modeling of EP optimization procedures in modern conditions of globalization and international integration of national economies to solve many relevant theoretical, methodological and practical problems. Among the most important theoretical, methodological and practical directions of EP management are: the formation of the concept of optimizing economic potential at all levels of management in the context of economic globalization; the development of conceptual models of EP optimization that ensure consistency, complexity, program-target orientation of EP optimization strategies.

IV. Results and discussion

Approbation of the model of optimization of ES on the basis of the matrix algorithm of decision-making was carried out in the methodological blocks of information processing for the leading enterprises of the textile industry. Analytical calculations of private indicators of efficiency of local potentials use with the subsequent convolution and calculation of generalizing indices of potential-efficiency were made for strategic enterprises of Concern “Bellegprom”: JSC “Baranovichi Production Cotton and Paper Association” (Blakit; JSC “BPHO”), JSC “Gronitex”, RUPTP “Orsha Flax Factory”, JSC “Mogotex”, JSC “Lenta”, JSC “Vitebsk Carpets”, JSC “Slonimskaya KPF”.

According to the results of the analytical data system, the following conclusions can be drawn: the best results of the level of ES development in the considered time interval were demonstrated by RUPTP “Orsha Flax Mill”, JSC “Gronitex” (Figure 1).



a) aggregate indices of the first level of generalization of resource potential;
b) aggregate indices of the first level of generalization of institutional capacity

Figure 1: *Graphical interpretation of the partial values of the potential efficiency of the enterprises of the Bellegprom Concern*

Source: in-house development

Coordinates of the index of potential profitability of enterprises respectively made up in the composition (1.0; 0.994); (0.948; 0.976), which, taking into account the significance coefficient, provided higher values of the integral index (values of aggregated indices are higher than one). RUPTP "Orsha Flax Factory" is the only enterprise that has an integral aggregated index of the level of economic potential development with a small excess of one (Figure 2).

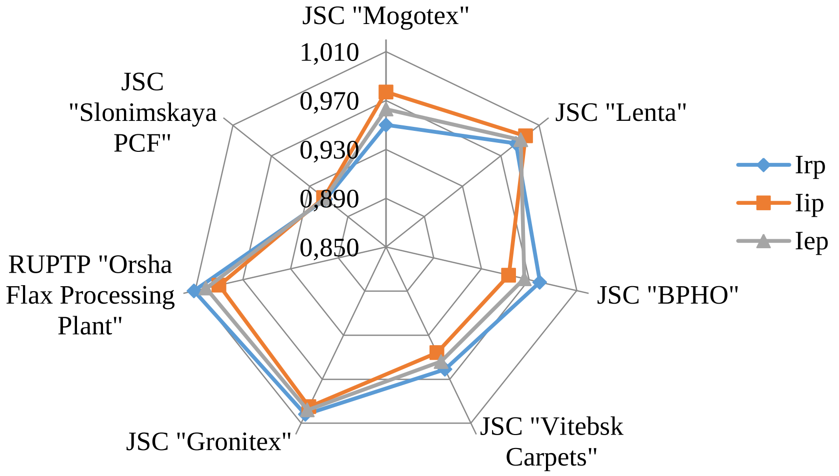


Figure 2: *Radar of the level of development of the economic potential of the enterprises of the Bellegprom Concern*

Source: in-house development

The lowest values of the considered aggregated indices were obtained for JSC «Slonimskaya PCF», JSC «Vitebsk Carpets», JSC «Mogotex», JSC «BPHO»: the aggregated index of the third level of generalization, respectively, amounted to 0.914; 0.954; 0.963; 0.966.

The integral indicator of the efficiency of using the economic potential of JSC «Lenta» (0.991); JSC «Gronitex» (0.998) has almost reached the criterion value.

The analysis of the dynamic series of indexed estimated parameters of the use of EP according to the selected vectors of its development diagnoses: the level of effectiveness of its use according to private indices of potential efficiency within the framework of local potentials; trends in the parameters of the effectiveness of the use of local potentials; development priorities according to criteria of potential efficiency; the need for preventive measures to optimize EP in order to prevent a crisis in the results of the system (Table 1).

Table 1: *Summary of average annual performance indicators for the first section of the output array of aggregated indices of textile industry enterprises*

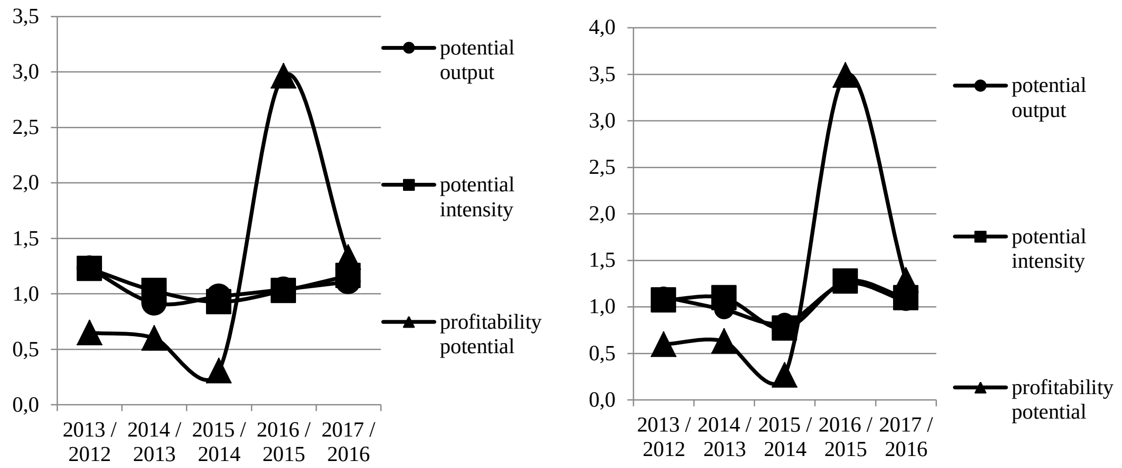
Dynamics comparison form	Local resource potential			Local institutional capacity		
	potential output	potential intensity	profitability potential	potential output	potential intensity	profitability potential
2013 / 2012	1,229	1,228	0,650	1,108	1,072	0,599
2014 / 2013	0,917	1,027	0,602	0,970	1,095	0,630
2015 / 2014	0,976	0,928	0,310	0,826	0,768	0,268
2016 / 2015	1,040	1,028	2,965	1,251	1,273	3,490
2017 / 2016	1,109	1,163	1,332	1,062	1,095	1,288
Average annual index	1,049	1,070	0,863	1,034	1,047	0,854

Source: in-house development

The lowest index values in the selected time interval fall on the profitability potential:

respectively, according to the local potentials of 2015 / 2014 in the amount of 0.310; 0.268. Accordingly, 2016 marked a significant increase in profitability potential: index values within the composition of 2.965; 3.490.

In 2016-2017, the level of indices of local resource potential is lower than the values of indices of potential return, potential intensity, potential competitiveness of local institutional potential, which corresponds to a decrease in the volume parameters of resources and expenditures of the providing potential and a corresponding increase in these efficiency fields (Figure 3).



a) b)

Figure 3: *Diagram of the level of development of the potential efficiency of the Bellegprom Concern in the cluster of selected enterprises: a) resource potential; b) institutional potential*

Source: in-house development

The average annual index of potential return and potential intensity for 2012-2017 in local potentials were marked by growth indices, while potential profitability decreased (average annual decrease indices 0.863; 0.854). Taking into account the importance of the considered parameters in the decision support system, the average annual index of changes in economic potential as a whole was marked by a decrease.

The average annual index of potential return and potential intensity for 2012-2017 in local potentials were marked by growth indices, while potential profitability decreased (average annual decrease indices 0.863; 0.854). Taking into account the importance of the considered parameters in the decision support system, the average annual index of changes in economic potential as a whole was marked by a decrease. The combined average annual index has a value above one for potential output, potential intensity: values of local resource potential (1,049; 1,070) above the level of local institutional potential (1,034; 1,047); the level of positioning of potential profitability is lower than the first two parameters and is almost the same for local potentials (0.863; 0.854). Analytical support for solving optimization problems at the industry level in the developed EP optimization model is based on the synergy of blocks of composition of aggregated indices of the second and third levels of generalization (Table 2).

In this block of analysis of the dynamics of the level of use of resource and institutional potentials of textile industry enterprises, an imbalance has been established, which was expressed in a more intensive development of potential output, potential intensity, potential profitability of the providing component of the composition – institutional potential. The aggregated indices on the right side of table 2 (the results of the institutional capacity analysis) indicate higher values of the development indices relative to the data of the local resource potential. For individual enterprises, for example JSC «Mogotex», the level of development of potential output, potential intensity, potential profitability of institutional potential is higher than similar indicators of resource potential, which corresponds to higher growth rates of production, sales, profit from sales relative to the costs of marketing activities, innovation– investment and scientific and information activities. The cluster of these enterprises also includes JSC «Lenta», JSC «Slonimskaya PCF».

Table 2: *The second section of the output array of aggregated indices of the second and third levels of generalization of the economic potential of enterprises in the textile industry*

The enterprise of the textile industry	Resource potential subindex	Institutional subindex capacity	Integral aggregated index of the level of development of the EP
JSC «Mogotex»	0,950	0,977	0,963
JSC «Lenta»	0,986	0,996	0,991
JSC «BPHO»	0,979	0,953	0,966
JSC «Vitebsk Carpets»	0,961	0,946	0,954
JSC «Gronitex»	1,002	0,995	0,998
RUPTP «Orsha Flax Processing Plant»	1,011	0,990	1,001
JSC «Slonimskaya PCF»	0,913	0,915	0,914

Source: in-house development

For all the studied enterprises of the textile industry, low values of integral indices of potential profitability were determined, which corresponds to a less intensive dynamics of profit growth from sales relative to production capital and fixed costs. The lowest values of the indices of profitability dynamics of resource and institutional potentials were noted for JSC «Slonimskaya PCF», JSC «Mogotex», JSC «Vitebsk Carpets»: the profile of integral indices of potential profitability of resource potential 0.667; 0.774; 0.830; institutional potential 0.671; 0.839; 0.795. The EP optimization system should provide for monitoring and controlling pricing in terms of profit generation as a source of own financing for extensive and intensive factors of positive EP development. Aggregated indices of potential output, potential intensity of textile industry enterprises are almost at the same level in both blocks of the composition. Certain «scissors» of the indicated indicators were obtained at JSC «Mogotex», which is due to the export orientation of production, the influence of external factors of globalization and international integration.

The format of the point positioning of the level of economic potential development was obtained based on the results of linear normalization of aggregated indices of the second level of generalization (Figure 4).

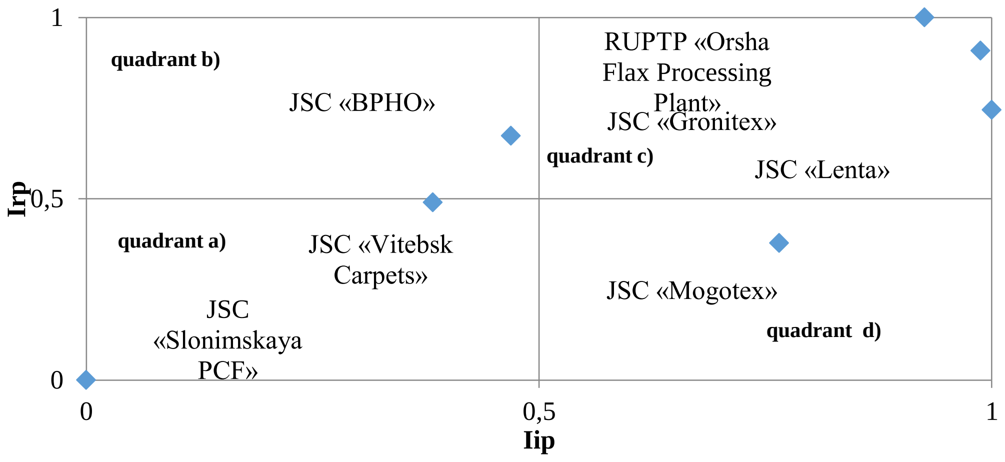


Figure 4: *Positioning textile industry enterprises in the strategic decision-making matrix*

Source: in-house development

According to the results of econometric estimation of interrelation of sub-indices (Irp, Iip) of the level of formation, use and development of economic potential of textile enterprises, the matrix of scenarios for optimization of the meso-level EP (textile industry) is constructed and variants of working out scenarios are established.

V. Conclusion

Thus, the developed model of optimization of the EP industry based on a matrix decision-making algorithm has the properties of complexity and integrity, which make it possible to substantiate the role and place of the process of optimizing economic potential in the trends of mesorevelopment, to determine the content of decision support processes for the sustainable development of the meso-level economic system.

The coordinates of the point positioning of the level of development of the EP enterprises of the textile industry made it possible to identify clusters of similar enterprises and develop options for working out scenarios. For example, JSC «Gronitex» and JSC «Lenta» (coordinates of points before normalization, respectively (1,002;0.995); (0.996; 0.986)) occupy approximately the same position in the subindex of local institutional potential: the aggregated index of resource potential is lower than the institutional one as a result of an insignificant parameter of potential profitability (with a high coefficient of significance when integrated) in the structure of the index of economic potential.

For these enterprises, it is advisable to implement elements of centered diversification strategies (SD-1) with an emphasis on investment and innovation activities in the production of new products based on the use of modern organizational and technological tools of the company's operational activities; the implementation of the most effective innovation and investment projects to reduce production risks.

References

[1] Ageev, A. I., Kuroedov, B. V., Mathews, R., & Sandarov, O. V. (2007). The strategic matrix of the company. Economic Strategies, 9(8), 90-99.

[2] Andrianov, D. L., & Grebnev, M. I. (2015). An overview of methods for aggregating production functions. Management of economic systems: an electronic scientific journal, (1 (73)), 4.

[3] Ibragimova, R. S., & Golovin, D. S. (2016). Methodological justification of the assessment of the economic potential of the enterprise. Modern high-tech technologies. Regional application, (3 (47)), 64-74.

[4] Ibragimova, M. H. (2015). Assessment of the company's economic potential for strategic management purposes. Management of economic systems: an electronic scientific journal, (10 (82)), 24.

[5] Kozhevnikova, M. V., Tsyganov, I. P., & Guseva, I. B. (2014). Analysis of methods for assessing the innovative potential of an industrial enterprise. Volga Scientific Bulletin, (12-3 (40)), 119-121.

[6] Mereste, W. I. (1982). On the matrix method of analyzing the economic efficiency of social production. Economics and Mathematical Methods, 18(1), 138-149.

[7] Mereste, W. I. (1985). Fundamentals of the theory of the efficiency field (a new approach to the study of production efficiency through its full-system modeling. Proceedings of the Tallinn Polytechnic Institute, (605), 5-34.

[8] Merkulova, E. Y. (2017). Technological and methodological basis of strategic analysis. Socio-economic phenomena and Processes, 12(3), 131-138.

[9] Narkevich, L. V. (1998). Privatization of retail trade enterprises and its impact on the economic efficiency of their business activities (Doctoral dissertation).

[10] Sologubova, L. A., Trunkina, O. V., Baibekova, F. N., & Kulakov, A. A. (2018). Decision-making using the hierarchy analysis method. Innovations in science, (4 (80)), 11-14.

[11] Narkevich L. V., Rogachev A. F., Terelyansky P. V. (2021). Digitalization of the economy as a factor of sustainable development of the regions of Russia and Belarus. In socio-economic systems: paradigms of the future (pp. 737-746). Cham: Springer International Publishing. DOI:10.1007/978-3-030-56433-9_78

[12] Belousova M. N., Belousov V. A., Narkevich L. V. (2021). Digital transformation of the educational process at the university in the context of globalization. In socio-economic systems: paradigms of the future (pp. 1267-1277). Cham: Springer International Publishing. DOI:10.1007/978-3-030-56433-9_133

[13] Niyazbekova, S. U., Moldashbaeva, L. P., & Uspambaeva, M. K. (2019). On institutional and legal problems of state audit and financial control. Bulletin of Moscow University S. Yu. Witte. Series 1: Economics and Management, 3(30), 15-20. DOI: 10.21777/2587-554X-2019-3-15-20

[14] Niyazbekova, S. U., & Ivanova, O. S. (2020). Development of fintech and big data in the financial sphere: features, problems, opportunities. Moscow University Journal S. Yu. Witte. Series 1: Economics and Management, 1(32), 30-36. DOI: 10.21777/2587-554X-2020-1-30-36

[15] Yarovenko, S. E., & Niyazbekova, S. U. (2021). Comparative analysis of global financial crises, their causes and consequences. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (4 (39)), 48-57. DOI: 10.21777/2587-554X-2021-4-48-57

[16] Niyazbekova, Sh. U., & Bunevich, K. G. (2020). A brief overview of the DANISH financial sector. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (3 (34)), 50-56. DOI: 10.21777/2587-554X-2020-3-50-56

[17] Niyazbekova, Sh. U., & Bunevich, K. G. (2017). Analysis of the socio-economic development of Astana city. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (3 (22)), 24-31. DOI: 10.21777/2307-6135-2017-3-24-31

[18] Effectiveness of Regulatory Mechanisms of the Oil and Gas Industry in the Context of Environmental Problems.Butova, T.,Varzin, V., Niyazbekova, S., Yessymkhanova, Z.,Anzorova, S. Lecture Notes in Networks and Systems, 2023, 575 LNNS, pp 38–49 DOI:10.1007/978-3-031-21219-2_4

[19] Risk and Uncertainty in the Management System of a Commercial Bank. Kunanbayeva, K.B., Niyazbekova, S.U.,Urekeshova, A.B., Varzin, V.V., Maisigova, L.A. Approaches to Global Sustainability, Markets, and Governance, 2023, Part F643, PP. 375–381 DOI:10.1007/978-981-99-2198-0_41

[20] Using mathematical statistics to optimize the process of crossovers using Data Center Infrastructure Management. Pavlyuk, I.D., Britvina, V.V., Gavrilyuk, A.V., Niyazbekova, S.U., Nurgazina, G.E. Proceedings of SPIE – The International Society for Optical Engineering, 2023, 12637, 1263709 DOI:10.1117/12.2681655

[22] The Study of Mathematical Models and Algorithms for Face Recognition in Images Using Python in Proctoring System. Nurpeisova, A., Shaushenova, A., Mutalova, Z., ...Semenov, A.,Maisigova, L. Computation, 2022, 10(8), 136 DOI: 10.3390/COMPUTATION10080136

[23] Sustainable Energy Efficient Human-Centered Digital Solutions for ESG Megacities Development. Barykin, S.E., Sergeev, S.M.,Kapustina, I.V., ...Niyazbekova, S.U., Karmanova, A.E. Frontiers in Energy Research, 2022, 10, 938768 DOI: 10.3389/fenrg.2022.938768

ANALYSIS OF FIRE PROBABILITIES OF BLOWOUT ACCIDENT FROM OIL RESERVOIR

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Abstract

The work analyzes the fire hazard categories of oil field facilities. It is shown that the analysis of the results of an accident with the release of all contents from an oil tank and calculation of the average release, and therefore the damage, reveal an 8.8-fold deviation from that adopted by the regulatory document. A fireball, as in the development of an accident, at oil field development sites cannot be realized, because properties of the products are incapable for instant evaporation even under preheating conditions.

Keywords: oil, reservoir, accident, thermal radiation, danger level, probable damage, spill diameter, fireball

I. Introduction

In case of fire, the parameters of the intensity of thermal radiation and the duration of exposure are used to determine the level of danger. The methodology for determining individual risk in a fire is presented in [1]. The safe level of thermal exposure to a person is determined by the intensity of thermal radiation not exceeding 4 kW/m^2. With a significant potential of the flammable liquid involved in the fire, the probability of injury to a person remote from the spill boundary is zero. A fire represents a process that results in a long-term realization of the potential of a combustible substance, in contrast to an explosion, in which the realization of the potential is fleeting process. Depending on the speed of ongoing processes, their power varies significantly. The greater the speed, the greater the power of implementation, and the losses (human and material). Analyzing fire as a process, we come to the paradoxical conclusion that flammable liquids do not burn. Their combustion is truly impossible, since it is an oxidation-reduction process, which is impossible inside a liquid. There is no oxidizing agent. The combustion of a liquid is a rather complex process, consisting of several successive stages. In relation to oil, which consists of a large number of hydrocarbon components, characterized by different boiling points and levels of saturated vapor pressure, the combustion process has its own characteristics. The main stages of this process are as follows: Heating of the liquid in order to increase the vapor pressure. Heating of the liquid must ensure its such a temperature in which a gas-air mixture with a concentration of flammable substance above the its surface is formed above its LCLC. An external ignition source ensures ignition of the mixture. The combustion of the gas-air mixture above the surface of the liquid ensures its further heating and intensifies the process of vapor release. The top layer of liquid warms up and combustion intensifies. At the initial stage of combustion, the lightest components evaporate from oil, the boiling point of which is significantly lower than the ambient air temperature. With the start of combustion, the process of oil distillation begins, as a result of which the lightest components pass into the vapor phase (and burn there), while heavier components accumulate in the liquid residue. The boiling point of the remaining components increases as the light components evaporate. If the onset of combustion corresponds to an oil temperature of 20°C, then after a certain period of time it increases to 60, 100°C, reaching a temperature of 300-400°C at the end of the process, when components with a high boiling point have accumulated in the residue. In case of tank fire, the water layer poses a serious danger. Water is always present in oil in small doses. Under the influence of gravity, it settles to the bottom of the tank and accumulates there to significant volumes. It is under excess pressure from the top layer of oil. By the end of burnout, the oil temperature reaches 300-400o C. The water heats up over the area of contact with the oil, reaching temperatures above 100° C. A further decrease in the oil level in the reservoir leads to rapid overheating of the water. The water instantly boils, a steam-water piston is formed, which throws burning oil out of the tank. A cloud of dispersed burning liquid is formed, which is thrown onto the surface of the earth, destroying all living things. Such a development of the accident is accompanied by a large number of people affected not only at the hazardous production facility, but also beyond. To protect tanks from fire, regulations require them to be equipped with stationary foam generators. According to the State Fire Service of the Nizhnevartovsk region, over 15 years, not a single case of successful protection has been recorded during fires in tanks equipped with foam generators. Foam generators failed at the initial stage of fire development, as a result of which all tanks burned out completely. Let us consider the fire parameters depending on the size of the evaporation surface. For example, we select a tank with a volume of 5000 m3, filled with oil, placed in an embankment. The diameter of the tank is 23 m, the height is 12 m. The dimensions of the embankment are 33x33 m. The release of the specified volume of oil onto the terrain without embankment provides an area of evaporation (at a specific oil consumption of 10 l/m2) of 500000 m2. The results of calculating the radius of the affected area R1 are presented in Table 1.

Table 1: *The results of calculating the radius of the affected area R1*

Fire option, Pa	Evaporation square, m^2	Mirror diameter, m	Flame height, m	Radius of the affected area, m
In the tank	415.5	23	22.23	11.5
In the embankment	1088	37.23	31.1	18.62
Unlimited surface	100137.5	357.07	149.54	178.54

Table 1 analysis of the results of calculating the parameters of a fire occurring under conditions of different restrictions revealed the effectiveness of localizing an oil spill in an embankment. The radius of the affected area is reduced by 9.6 times. Here is another example of the realization of the same potential under different conditions. Due to the results of implementation are the most dangerous fire balls (fire- in the terminology of V. Marshall [2]), as a type fire. GOST R 12.3.047-98 [3] defines a fireball as a large-scale diffusion flame of a burning mass of a fuel vapor cloud rising above the surface of the earth. Many protect institutes determine the parameters of fireballs and their consequences when developing projects for the development of oil fields. The main condition of the occurrence of a fireball is a salvo release of liquefied gas capable of instantaneous evaporation under atmospheric conditions in an amount of at least 35% of the mass. The specified conditions can be implemented when releasing liquefied gases (propane, butanes, and their mixtures). An oil release cannot lead to instantaneous evaporation of a significant mass, because the proportion of highly volatile components in it that are capable of release under ambient conditions environment, does not exceed 1% of the mass. Until the fields begin to create installations for processing APG with the release of natural gas liquids or propane-butane fraction, there risk of fireballs are excluded. Due to the lack of results from studies of fireballs carried out by Russian scientists, to substantiate our position we use the information presented in the book by Marshall B [2]. Conditions for the formation of this powerful phenomenon are presented in Table 2.

Table 2: *Conditions for the formation of this powerful phenomenon*

Classification of flammable substance on Marshall	Example	Flash point, ^0C	Vapour pressure, 20 ^0C, atm	Vapour fraction, mass	Probability of occurence		
					Flash	Fire spill	Fireball
Flot liquid	Lubricating oil		0.0001	Insignifica nt	Zero	Only in case of fire	Low
Flammable liquid	n-xylene	40	0.008	0.0005	Zero	High	Low
LFL	Octane	13	0.013	0.0015	Moderate	High	Low
LFL	Diethylene	45	0.58	0.024	High	High	Low
Cryogenic liquid	LHG	Low minus 160	0.1 (-160 ^0C)	0.04	High	High	Low
Liquefied flammable gas	LHG (propane, propylene, butane)	-107	1	0.4	High	Sometim es there is no liquid phase	High
Compressed flammable gas	Methane, Ethane, ethylene			1.0	High	Zero	High

As follows from the analysis of the data presented in the table, a fireball is realized when at least 40% of the mass of liquid gas or superheated liquid evaporates. Combustible liquids and flammable liquids do not form a fireball. Let's consider another example of the implementation of regulatory instructions: When determining the volume of emission from a unit during its complete depressurization, the standards require choosing the most unfavorable case in all respects. Let's consider the result of an analysis of an accident involving the release of all contents from an oil tank. The field tank performs the function of protecting external consumers from the issuance of substandard products. The reservoir operation cyclogram is shown in Fig. 1.

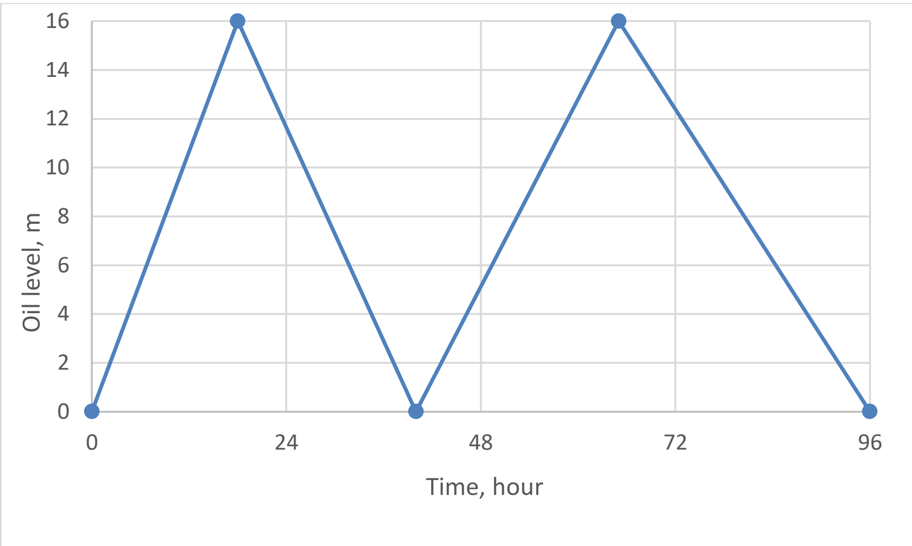

Figure 1: *Tank operation cyclogram*

The tank is filled within 24 hours. At the same time, quality control of commercial products is carried out. If the quality meets the requirements of the technical specifications, the tank switches to pumping oil into the main oil pipeline. Pumping continues for 24 hours. After this, the cycle is repeated. Guided by the requirements of air safety regulations, in case of emergency depressurization of a tank in the consequences of an accident, its entire volume must be taken into account. From the analysis of the cyclogram it follows that the lifetime of the maximum level is zero. The calculation of accident indicators should be carried out using statistical methods based on the laws of probability theory. The probability of 100% filling of the tank is determined by the ratio of the duration of existence of this filling to the duration of the cycle. In our example, the lifetime of 100% occupancy is zero. The cycle duration is 48 hours. Dividing zero by 48, we get the probability of such filling equal to zero. Taking into account 100% filling of the tank during an accident in a probabilistic representation will give a zero result of damage. To determine the average statistical volume of flammable liquid released onto the terrain in such an accident, we will draw up a table that determines the level of probable damage depending on the percentage of the tank being filled. Of course, the maximum or minimum filling of the reservoir correspond to a probability equal to zero, since in both cases the duration of extreme filling is zero. With a filling fraction of 0.5, the duration of this state is 0.5 and soon. Tank statistics at throughout the entire cycle of its work are presented in Table 3.

Table 3: *Tank statistics at throughout the entire cycle of its work*

Tank fill percentage	Filling probability	Probable damage	Normalized damage
1	0	0	1
0.9	0.1	0.09	1
0.8	0.2	0.16	1
0.7	0.3	0.21	1
0.6	0.4	0.24	1
0.5	0.5	0.25	1
0.4	0.4	0.16	1
0.3	0.3	0.09	1
0.2	0.2	0.04	1
0.1	0.1	0.01	1
0	0	0	1
Total	2.5	1.25	11
Average value	0.227	0.114	1
Ratio of average damage values		8.8	

II. Methods

All data is presented in relative units. It turned out that the calculation of the average emission, and therefore the damage, revealed an overestimation of the Damage accepted by the regulatory document by 8.8 times. We encounter such "errors" in almost all elements regulatory calculations approved "in accordance with the established procedure". The maximum value of the emission volume, determined according to the laws of statistics, turns out to be equal to 0.5 of the tank volume. This condition corresponds to an arithmetic average filling volume of 0.5 and a maximum probable damage value of 0.25. The average value of probable damage is 0.114. To determine the size of a flammable liquid spill, there are 3 methods in the current methodological and regulatory documents: FSS 105-03 [3-6] determine the area of a liquid spill using a specific flow rate of 10 l/m^2. Thus, the area of spill

$$F=100V \quad (1)$$

Where, F is measured in m^2, and the volume of the spill V in m^3. The spill diameter is determined from the equation area of the circle, that is

$$D= (4F/\pi)\ 0,5 \quad (2)$$

The RSES methodology [1] determines the spill diameter using the equation

$$D = (25,5\times V)0,5 \quad (3)$$

The methodology for risk analysis of main oil pipelines (MOP) [5] determines the spill area according to the equation

$$F=53,3\ (V)0,89 \tag{4}$$

The spill diameter is determined by equation (2). A comparison of the results of calculating the diameter of the spill, performed using the specified methods, is presented in the graphs of Fig. 2.

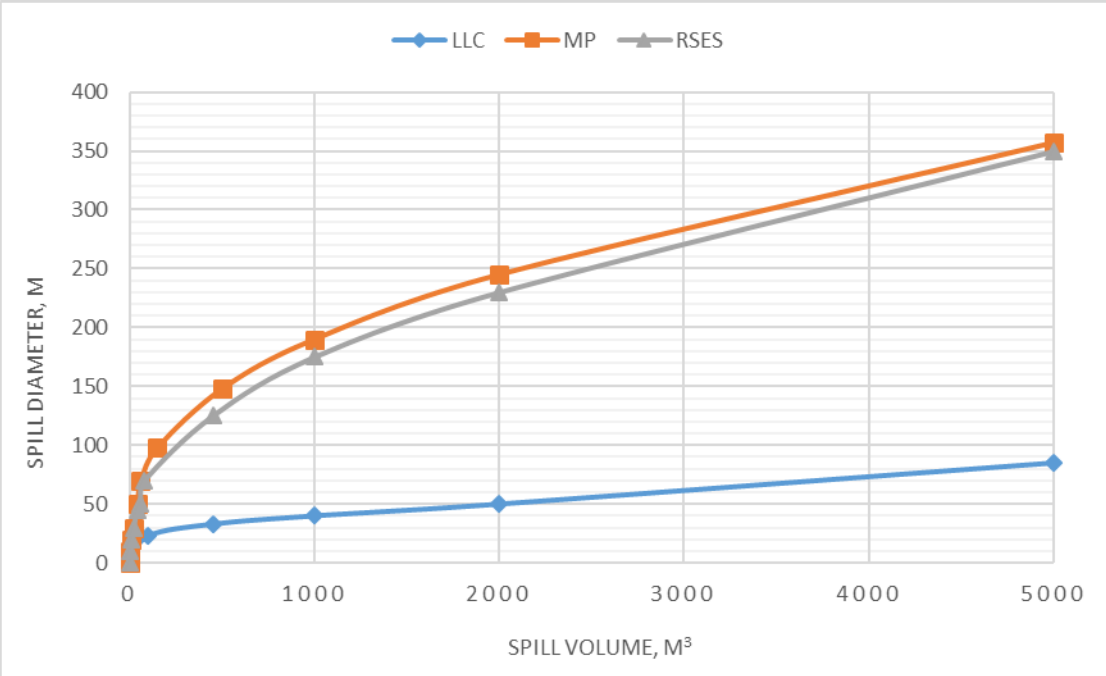

Figure 2: *Comparison of spill diameter due to various methods*

The compared methods have the status of normative documents. The result of calculating the diameter of a flammable liquid spill using various methods is different. The question arises, which of these methods should be preferred?

Where is the guarantee that the methodology chosen by the project organization will coincide with the choice of the expert organization. If different methods are used when developing the "Risk Analysis" section and during its examination, then the results should be considered "non-reproducible". A practical guide for the designer is that if there are several guidance documents on the same issue, any one of them can be used. The fact that the choice of the expert does not coincide with the choice of the project organization is not a problem for the project institute. This is a problem for developers of regulatory documents. As it follows from the analysis of the data presented in the table, a fireball is realized when at least 40% of the mass of liquid gas or superheated liquid evaporates. Combustible liquids and flammable liquids do not form a fireball.

III. Results

1. The fire hazard category of oil field facilities is determined by standards based on the indicators of explosion of gas-air mixtures.

2. Analysis of the results of an accident with the release of all contents from an oil tank and calculation of the average release, and therefore the damage, reveal an 8.8-fold deviation from that adopted by the regulatory document.

3. A fireball, as in the development of an accident, at oil field development sites cannot be realized, because properties of the products are incapable for instant evaporation even under preheating conditions.

References

[1] GOST R 12.3.047-98 "Fire safety of technological processes". General requirements. Control methods.

[2] Marshall V. Main hazards of chemical production. M.: Mir, 1987.

[3] NPB 105-03. Fire safety standards. Determination of categories of premises, buildings and outdoor installations based on explosion and fire hazards. M, 2003, p 48.

[4] Collection of methods for forecasting possible accidents, catastrophes, natural disasters in the Russian Emergency Situations Service. Book 2. Methodological guidelines for assessing the degree of risk of accidents at fire and explosion hazardous facilities.

[5] Methodological guidelines for assessing the risk of accidents on main oil pipelines. Guiding document. JSC "AK Transneft" M., State Unitary Enterprise Scientific and Technical Center "Prombezopasnost" Gosgortekhnadzor of Russia, 2002, p 120.

[6] Ismailov, G.G. and Zeynalova, G.A. Diagnostics of resky multiphase flow zones in oil pipelines. // Reliability: Theory and Applications, 2023 November, 5 (75), vol. 78, pp. 283-288.

ASSESSMENT OF THE CARBON FOOTPRINT OF INFRASTRUCTURES USING THEIR FULL LIFE CYCLE WITH ACCOUNTING FOR CLIMATE CHANGE

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Abstract

The article examines from an interdisciplinary perspective the problem of quantitative accounting, assessment and minimization of the carbon footprint (CF) of the infrastructures of the oil and gas sector (OGS) of the fuel and energy complex (FEC) of Russia at all stages of their life cycle (LC), including diagnostics, monitoring, maintenance, recovery from accidents and disasters. The ultimate goal of the study is to develop a working algorithm that allows formulating a global carbon balance equation according to the top-down scheme, which shows the contribution of each infrastructure to the global carbon footprint, taking into account climate change according to the criterion of the need to achieve zero CO_2 emissions by 2060, in accordance with the obligations assumed by Russia under the Paris Agreement of 2015.

Keywords: global warming, global carbon budget, greenhouse gas emissions, carbon footprint of infrastructure, decarbonization, carbon offsetting.

I. Carbon Footprint of the Oil and Gas Industry: State of the Art

The oil and gas industry is not the most important emitter of greenhouse gases (GHG), operations for the extraction and production of hydrocarbon fuels (HCF) account for only 10 % of global emissions. However, further use of HCF provides an additional 33 % of emissions in end-use areas. Over the entire cycle from extraction to end-use, 57 % of GHG emissions from oil are concentrated in the transport sector; in gas, 72 % of emissions occur in generation, industry and public utilities. In the extraction, processing and transportation of oil and gas, methane plays a significant 42 % role, associated with the extraction of natural gas and associated petroleum gas, as well as the transportation of dry stripped gas [1].

In terms of hydrocarbon fuels, most companies agree that in the baseline scenario, the energy transition will not lead to an absolute reduction in demand in the next 10–20 years. Thus, according to forecasts, oil consumption by 2030 will grow by 0–15 % compared to 2019, while gas demand will grow at least until 2040 within the range of 25–52 % [1].

To date, all major Russian oil and gas companies have implemented carbon management systems, including greenhouse gas emission accounting systems. When preparing reports on greenhouse gas emissions, the national methodology for quantifying GHG emissions approved by the order of the Ministry of Natural Resources and Environment of the Russian Federation dated 27.05.2022 No. 371 [2] is used, as well as foreign guidelines: the corporate standard for accounting and reporting of the Greenhouse Gas Protocol (GHG Protocol) of the World Business Council for Sustainable Development and the World Resources Institute [3], the international standard ISO 14064-1:2018 "Greenhouse gases. Part 1: Specification with organization-level guidance for quantifying and reporting greenhouse gas emissions and removals" [4].

All major Russian companies provide data on GHG emissions as part of their periodic reporting (environmental report, or as part of a sustainable development report or annual report). The total GHG emissions in the oil and gas sector of the Russian economy in 2019 amounted to 297.6 million tons of CO_2-eq., the total GHG emissions of the largest companies in the sector (PJSC Gazprom, PJSC Rosneft, PJSC LUKOIL, PJSC Gazprom Neft, PJSC Surgutneftegaz, PJSC Novatek, PJSC Tatneft and PJSC Transneft) amounted to 236.2 million tons of CO_2-eq. [1].

II. Statement of the problem

For a qualified and consistent assessment of the ecological/carbon footprint of the OGS of the Russian fuel and energy complex, it is necessary to conduct a specific analysis of their full life cycle (FLC) to assess (1) the value of the carbon footprint of the OGS as a random function of time and (2) its contribution to the industry's CF, which affects climate change on the planet.

The full life cycle of any OGS infrastructure (OGI) consists of: (1) extraction of raw materials required for the creation of this infrastructure; (2) processing of materials, manufacturing of the OGI components; (3) construction of infrastructure; (4) hydro testing of the OGI pipeline to check for defects; (5) operation of the system, including its diagnostics, monitoring and scheduled maintenance; (6) restoration of the infrastructure after each accident and (7) its disposal after its useful life.

The carbon footprint of OG infrastructure is an indicator of the environmental efficiency of its use at all stages of its life cycle, and is therefore of great interest to the public and investors. Decision makers (DM) on the methods of operating OGI should (in the context of the Paris Agreement) separately take into account the size of the current and cumulative CF they create and the discounted cost of its neutralization, taking into account the impact of climate change on the CF of OG infrastructure.

In the conditions of dynamic multifactorial uncertainty of the modern world, OGI management is carried out according to safety and risk criteria – determining indicators of the quality of their functioning. In this case, the target function (TF) of risk management is reduced to minimizing the generalized cost of operating an OGI facility over the period of time “from conception/cradle to grave”.

From a mathematical point of view, the problem of managing the risk of OGI is posed as a problem of optimizing the objective function, which in the context of the problem under consideration should adequately reflect the total present value of costs during the entire life cycle for:

1) creation and disposal of OGI;
2) technical maintenance, repair and restoration due to possible emergency situations;
3) restoration of the disturbed (due to the production activity of the system) ecological balance of the environment;
4) compensation for the system's CF; and
5) restoration of lost human health and monetary compensation for the possible loss of lives and limbs during the operation of OGI.

In the most general case, the problem of determining the man-made risk, interpreted as the product of the probability of failure (POF) and its consequences (losses/damage), expressed in monetary form, is solved as a problem of optimizing the target function of managing the risks of operating the OGI, which is reduced to the integral cost of owning the OGI over its full life cycle:

$$ {}_{\mathrm{OGI}}C_{\Sigma} = C_{\Sigma,c} + C_{\Sigma,in} + C_{\Sigma,r} + C_{\Sigma,cf} + C_{\Sigma,hl} \,. \quad (1) $$

Here $C_{\Sigma,c}$ is the total cost of design, construction and commissioning of the OGI, as well as its disposal after the end of its service life; $C_{\Sigma,in}$ is the total cost of all inspections on the OGI life cycle; $C_{\Sigma,r}$ is the total cost of all repairs/restorations during the life cycle of the OGI, including after accidents and disasters; $C_{\Sigma,cf}$ is the total costs of compensation for damage from CF; $C_{\Sigma,hl}$ is the cost of restoring lost human health and the amount of monetary compensation for possible loss of lives and limbs during the OGI life cycle.

When solving the problem of assessing and minimizing the CF size, it is necessary to take into account following circumstances.

The size of the CF when creating the OGI is determined by the facility design goals; at the same time, the CF size is subordinated to these goals and cannot be a limiting factor. It follows from this that compensation for the CF caused by the construction and commissioning of the OGI may require the use of special financial instruments (for example, planting a certain number of fast-growing and highly CO_2 absorbent tree species). At the same time, the size of the CF when utilizing such an OGI is also a certain function of its original goal.

The main carbon plume occurs during the operation of the OGI. It is a function of the volume and quality of diagnostics, monitoring, pipeline maintenance, as well as the consequences of OGI depressurization as a result of incidents, accidents and disasters.

Since all these operational events are modeled when constructing a set of OGI life cycle scenarios required to assess and minimize operational risk, the value of the CF is obtained as a natural consequence of the scenario under consideration. In this case, minimization of the CF for each virtual violation of the integrity of the pipeline or OGI vessel is possible in the process of making the next decision. This allows for effective management of the size of the carbon plume by selecting the optimal system design and optimal inspection technologies, scheduled repairs, and restoration of OGI after depressurization or an accident.

III. General algorithm for assessing the carbon footprint of OGI

Consider the general algorithm for assessing the carbon footprint of the OGI throughout its life cycle.

Since the sectoral CF is formed by individual infrastructures of companies/states, in order to reduce it, it is necessary to strive to reduce its carbon emissions at the level of each infrastructure, starting from the initial stage of the OGI life cycle – the production of its structural components and the construction itself. By analogy with the name of the life cycle stage, we will call the emissions of this stage the initial CF of the OGI.

The calculation of the natural gas transportation efficiency factor takes into account methane (CH_4) and carbon dioxide (CO_2) emissions, as well as energy consumption per unit of production generated at all stages of its life cycle. The share of other greenhouse gases (GHG) is no more than 1 % of all GHG emissions and they are not taken into account in the quantitative determination of the efficiency factor.

The OGI life cycle consists of the following stages:

I) production of materials from which the components of the OGI will be manufactured (extraction of raw materials for the production of structural materials is usually not considered in the calculation of the CF);

II) production of structural components of the OGI;

III) transportation, welding, laying of the OGI pipeline string and its protection from external influences, installation of all process equipment;

IV) operation of the OGI in a stationary mode, including scheduled and unscheduled diagnostics, technical repairs, maintenance;

V) processing/disposal of the OGI components after completion of its operation.

Now consider in general terms what the OGI's CF consists of and how it is calculated at each stage.

Stage I. Production of materials for the manufacture of components

At the stage of production of materials, the CF depends on the type of materials from which the structural components of the OGI are made, their weight and the GHG emission factors during the production of these types of materials.

$$CF_{\mathrm{I}} = \sum_i EF_i m_i \ , \tag{2}$$

where EF_i is the emission factor for the production of the i-th material; m_i — mass of the i-th material in the components of the OGI.

Examples include the production of steel or polymers needed to manufacture pipes and pipeline equipment, the production of concrete needed to construct compressor station buildings, the production of anti-corrosion materials used to protect pipes, etc.

Stage II. Production/manufacturing of structural components.

The components of the OGI include: oil and gas valves, taps, gas compressor station (GCS), oil pumping station (OPS), gas distribution station (GDS), gas control point.

At this stage, the energy consumption of the equipment used in the production of OGI components is generated by the energy consumption of the equipment and depends on the type, quantity, power consumption and operating time of this equipment.

$$CF_{\mathrm{II}} = \sum_i \sum_j EF_{ij} w_{ij} t_j \ , \tag{3}$$

where EF_{ij} is the emission factor when using the i-th energy source by the j-th type of equipment for the production of components; w_{ij} is the energy consumed (power) by the j-th equipment per unit of time (hour) from the i-th energy source; t_j is the operating time of the j-th equipment.

For example, in the production of steel pipes, emissions from energy consumption by equipment used to produce sheet steel from finished raw materials, subsequent calibration, stretching, cooling, cutting, welding and other technological processes are taken into account..

For gas (oil) pipelines, emissions from anti-corrosion coatings of pipe surfaces with special materials are also taken into account, which also have their own emission factors, and the emissions will depend on the area, thickness and density of these coatings. Emissions from the production of materials included in the coatings are calculated using formula (2), and from the coating process using formula (3).

Carbon emissions in OGI increase with increasing pipeline throughput: larger pipe diameters and wall thicknesses require more steel at the production stage.

The production of oil and gas pumping and other process equipment is also accompanied by carbon emissions, and OGI emissions at the stage of production of its components will depend on the design number of equipment of these types and are calculated based on the weight of the equipment and the average emission factor of the manufacturing industry in the region..

Stage III. Transportation to the site, welding, installation and laying of the pipeline and its protection from external influences, construction of compressor stations, oil pumping stations and other structural components of the oil and gas pipeline system.

The carbon footprint at this stage is calculated similarly to stage II, taking into account all types and quantities of energy-consuming machinery and equipment involved in the construction of the facility, and the time spent on their operation. For the construction of the OGI, it is necessary to perform:

- geological and geodetic studies of the area, preparatory work along the pipeline construction route (clearing vegetation, leveling the land plot, installing temporary roads for moving the construction equipment);

- transportation of OGI components and equipment to the construction site – pipes, pumps, compressors, shut-off valves, gas instruments, control and measuring devices, support structures, materials and structures for constructing a compressor station or a pumping station;
- excavation works for laying underground pipeline strings in trenches or construction of supports, columns, overpasses for ground oil and gas pipelines, measures to strengthen the soil and enhance its stability, construction works for the construction of industrial buildings and structures, installation of all technological units of the oil/gas pipeline;
- removal of construction waste;
- hydraulic testing, checking the tightness and functionality of systems and equipment before putting the entire system into operation.

Execution of all these works for the construction of an oil and gas pipeline require significant financial resources and the use of a large number of energy-intensive equipment, and therefore have significant GHG emissions already at the initial stage of the life cycle of the OGI before the start of its operation.

During the construction of a pipeline system on site, carbon emissions are generated by the equipment used, powered by various energy sources (fossil fuel, electricity): cranes, excavators, trucks, DC welding machines, electrode drying cabinets, etc., and are calculated based on the carbon emission factors from energy sources, power consumption and the time spent operating the equipment according to formula (3).

According to the source [5], the carbon emission level for the construction of large public buildings is set at 800.15–1296.44 kg/m², and to assess emissions during the construction of industrial buildings, such as oil pumping stations, gas compressor stations, an average value of 1000 kg/m² is selected.

Stage IV. Operation of the OGI.

At this stage, the largest emissions are generated in the entire life cycle of the infrastructure. (In many cases, the production stage is also characterized by large emissions.) A large number of emissions are due to significant energy costs, without which it is impossible to operate the infrastructure.

At the stage of operation of the OGI, the main emissions are formed during the operation of energy-consuming equipment. GHG emissions from the gas pipeline system are supplemented by emissions from:

- organized leaks from the pipeline system arising as a result of technological operations;
- unorganized leaks from technological equipment through connections and seals;
- emissions during emergency situations.

According to paragraph 3.3 of the Order of the Ministry of Natural Resources and Environment of the Russian Federation dated May 27, 2022 No. 371 "On approval of methods for quantitative determination of greenhouse gas emissions and greenhouse gas absorption" [2], fugitive emissions and emergency emissions are *not included* in the quantitative determination of fugitive greenhouse gas emissions in organizations.

In GI, the gas pumping units (GPU) installed at GCS are the main consumers of natural gas and sources of GHG emissions. The capacity of the GPU ranges from 6 to 25 MW, and from 1 to 10 GPUs, including backup ones, can be installed at each GCS. More than 80 % of the gas consumed for its own process needs during gas transportation is spent on fuel needs of the GPU.

GHG emissions generated during compressor operation are equal to

$$CF_{\text{comp.}} = \sum_{i=1}^{n} w_i EF_e t_i \,, \tag{4}$$

where w_i is the operating capacity of the i-th GPU; EF_e is the coefficient of conversion of electrical energy into CO_2 emissions; t_i is the operating time of the i-th GPU; n is the number of all operating GPU.

Carbon emissions increase with the increase in pipeline capacity due to the increase in energy consumption. During operation of the linear section of the main gas pipeline, fugitive emissions are also formed during repair work and maintenance, when technologically justified operations are carried out with the release of natural gas into the atmosphere. The quantitative determination of fugitive emissions of CO_2 and CH_4 for a time period t is carried out by a calculation method based on data on the consumption of the hydrocarbon mixture for the implementation of technological operations or the volume of their removal (bleeding, dispersion) without combustion or catalytic oxidation. The calculation is performed according to the formula [2, pp. 3.5, 3.6]

$$CF_{\text{fug.}i} = \sum_{j=1}^{n} \left(FC_j \cdot W_{i,j} \cdot \rho_i \cdot 10^{-2} \right), \quad (5)$$

where $CF_{\text{fug.}i}$ is the fugitive emissions of the i-th greenhouse gas for the period t, ton; FC_j is the consumption of the j-th hydrocarbon mixture for technological operations (volume of removal without combustion) for period t, thousand m^3; $W_{i,j}$ is the content of the i-th greenhouse gas in the j-th hydrocarbon mixture for period t, vol. %.; ρ_i is the density of the i-th greenhouse gas, kg/m^3; i is the CO_2, CH_4; j is the type of hydrocarbon mixture; n is the number of types of hydrocarbon mixtures used in technological operations (discharged without combustion).

The consumption of hydrocarbon mixture for process operations and the volume of hydrocarbon mixtures removed without combustion (FC_j) are determined based on actual instrumental or calculated data for the reporting period.

Stage V. Dismantling, transportation from the site, processing/utilization.

The dismantling process is similar to the construction process, but in reverse order, due to which carbon emissions at this stage can be considered similar to those at the construction stage. To them are added GHG emissions generated during the processing or utilization of infrastructure components at processing plants. The calculation of the CF at this stage is made using formula (3).

I. Compensation measures for CF infrastructure

Carbon footprint compensation measures for OGIs may include:

1) purchasing emission quotas from other oil and gas transportation companies that have been able to reduce their emissions below established limits;

2) investing in emission reduction projects (e.g., renewable energy sources) or offset projects (afforestation);

3) purchasing certificates from specialized organizations that finance GHG emission reduction projects.

IV. Carbon footprint of an accident or emergency

It should be noted that currently the calculation of the CF in the event of an accident of the OGI pumping hydrocarbons is not performed, which is a serious omission, since it does not allow for the accounting of a significant portion of emissions that affect climate change. In the event of an accident, the size of the leaks is determined and the damage is assessed, including the amount of

GHG emissions.

In order to prevent malfunctions of oil and gas pipelines and emergency situations, their regular diagnostics and inspections are carried out to detect and assess deformations, welding defects, dents, damage to pipeline protection, as well as possible leaks of natural gas. Monitoring of operational parameters (pressure, temperature) of pipelines and pressure vessels is also carried out.

The main reason for the cumulative growth of the carbon footprint of the gas condensate is the depressurization of its pipeline under pressure, accompanied by the release of gas condensate or crude oil. Possible causes (risk factors) of pipeline depressurization and design and technological measures to reduce the likelihood of these risks are presented in table 1 [6]. These measures, in essence, are passive or active preventive barriers that reduce the likelihood of the depressurization of the gas condensate.

Table 1: *Preventive barriers for oil and gas pipelines that reduce the likelihood of risks occurring and the severity of their consequences*

Risk factors	Preventive barriers
External corrosion	• Corrosion allowance calculated for a 30-year service life of the pipeline; • External anti-corrosion coating of the pipeline; • Cathodic protection calculated for a 30-year service life of the pipeline; • Conducting an inspection to determine the thickness of the pipeline and the presence of defects caused by corrosion.
Internal corrosion	• Corrosion allowance calculated for a 30-year pipeline service life; • Internal protective coating of the pipeline; • Conducting an inspection to determine the thickness of the pipeline and the presence of defects caused by corrosion.
Mechanical damage	• Protection of the pipeline with a protective casing; • Monitoring of vessels passing the area of the laid pipeline, as well as marking the location of the underwater pipeline on the navigation chart; • Permission to carry out any operations near the pipeline.
Earthquake	• Design of a pipeline capable of withstanding the maximum seismic activity recorded in the area for the last 2,000 years; • Monitoring of seismic activity in the area of possible pipeline reach.
Ice impact (stamukhas, hummocks)	• Pipeline design capable of withstanding ice impacts throughout the entire service life; • Annual inspection of the pipeline to determine the impact of ice formations.
Internal erosion	• Anti-friction coating that provides protection for the internal steel surface of the pipeline; filtration of the transported product to remove as much erosive impurities as possible.
Exceeding the maximum permissible pressure level	• Pipeline design capable of withstanding increased pressure; • Control of the parameters of the transported product; • Training for operators servicing the pipeline; Strict control of all operations carried out with the pipeline; • Equipping the pipeline with a system of safety valves.

Risk factors	Preventive barriers
Operational errors, pigging, and restoration	• Pipeline design that ensures unimpeded passage of the projectile; • Work permit to perform an operation using intelligent pigs; • Performing operations by trained personnel.
Maintenance errors	• Conducting maintenance strictly according to the existing maintenance program; • Work permit to conduct relevant work of any maintenance; • Conducting maintenance by specially trained personnel.
Hidden defects of material and/or welds	• Assessment and quality control during pipeline construction; • Pressure testing of the pipeline before starting its operation; • Testing the pipeline using defect detection equipment.

None of these *preventive* barriers (or even all of them together) guarantees the OGI against depressurization, so in practice they are supplemented with *parry* barriers, which are designed to reduce the consequences of OGI depressurization [7]. As an example, Fig. 1 shows a "Bow-Tie" diagram (BTD) with *preventive* (left) and parry (right) barriers for the case of exposure to external and internal corrosion.

Figure 1. *Bow-Tie diagram for pipelines exposed to external and internal corrosion*

Note to Fig. 1: Preventive barriers: 1 – corrosion allowance calculated for a 30-year pipeline operation period; 2 – external anti-corrosion coating of the pipeline; 3 – cathodic protection, for a 30-year pipeline operation period; 4 – inspection to determine the pipeline thickness and the presence of defects caused by corrosion; 5 – corrosion allowance, for a 30-year pipeline operation period; 6 – internal protective coating of the pipeline; 7 – inspection to determine the pipeline thickness and the presence of defects caused by corrosion. Parrying barriers: 1 – leak detection system; 2 – emergency shutdown: pressure relief; 3 – fire warning and extinguishing system; 4 – leak elimination plan; 5 – accident elimination plan.

An emission from a gas pipeline may result in the formation of a cloud of fuel-air mixture (FAM) and its subsequent ignition, with the formation of a burning torch or a spill fire [8]. An emission of a multiphase hydrocarbon medium may cause serious damage to the environment and lead to the loss of production due to the blocking of the export channel during the period of eliminating the consequences [8].

In light of the Paris Agreement, the risk analysis procedures carried out at the design stage of the OGI should not only assess their safety level, but also provide an assessment of the project's CF. At the stage of risk-oriented operation of the OGI, it is necessary to plan and implement organizational and technical measures to minimize the CF, by ensuring high reliability of the OGI according to the criterion of its integrity.

V. Conclusions

- It is necessary to initiate a topic on assessing the magnitude of the emissions arising from leaks and accidents of the oil and gas industry, which do not currently fall under the Order of the Ministry of Natural Resources and Environment of the Russian Federation dated May 27, 2022 No. 371 [2].
- It is advisable to introduce mandatory certification of each oil and gas industry facility for its emissions. This passport must be confirmed annually. The presence of such passports will allow monitoring the country's emissions and the rate at which Russia's emissions approach zero emissions. To fill out the passport, it is necessary to conduct a regular analysis of GHG emissions throughout the entire life cycle of the OGI, with mandatory consideration of emergency emissions.
- The largest emissions in the life cycle of the OGI are generated at the stages of their operation and construction. With the growth of the length and throughput of the OGI, its emissions also increase.
- To reduce GHG emissions into the atmosphere, the use of energy-efficient technology and process equipment, the use of new generation gas pumping units with low-emission combustion chambers is becoming a priority.

References

[1] Vygon G., Yezhov S., Kolbikova E., et al. (2021). Euro TOUR: the price of the issue. VYGON Consulting. – URL: https://vygon-consulting.ru/upload/iblock/f1e/fsslfi73x3khnz0tcb6sxlq70go5nfim/vygon_consulting_energy_transition.pdf (date of access: 18.04.2023).

[2] Order of the Ministry of Natural Resources and Environment of the Russian Federation dated May 27, 2022 No. 371 "On approval of methods for quantitative determination of greenhouse gas emissions and greenhouse gas absorption volumes".

[3] GHG Protocol Corporate Standard Accounting and Reporting. – URL: https://ghgprotocol.org/ (date of access: 18.10.2024).

[4] ISO 14064-1:2018 «Greenhouse gases. Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals». – URL: https://www.iso.org/standard/66453.html (date of access: 18.10.2024).

[5] Xu S., Wang J., Sun H., Huang L., Xu N., Liang Y. (2022). Life cycle assessment of carbon emission from natural gas pipelines. *Chemical Engineering Research and Design*, 185:267–280.

[6] Storozheva A.E. and Storozheva M.E. (2021). Reliability and risks of underwater multiphase pipeline. *Neftegaz.RU*, 11. – URL: https://magazine.neftegaz.ru/articles/transportirovka/707863-nadezhnost-i-riski-podvodnogo-mnogofaznogo-truboprovoda-/ (date of access: 12.09.2024).

[7] Sivokon I.S. Risks: structure and analysis. Moscow–Vologda : Info-Engineering, 2024.

[8] Samuseva E.A. Analysis of the danger of offshore pipelines for quantitative assessment of accident risks. Moscow : CJS "NTsI Industrial Safety Research", 2011.

INCREASING ENERGY EFFICIENCY IN ENERGY PRODUCTION: THE ROLE OF HEAT AND POWER COGENERATION SYSTEMS

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Abstract

Growing global demand for energy and reducing environmental impacts create a need for energy-efficient technologies. Combined heat and power (CHP) is more efficient than traditional methods in terms of efficiency because it produces both electricity and thermal energy. In this paper, we review the current state of combined heat and power (CHP) technology, evaluate its performance in various applications, and discuss the importance and challenges of its wider use. Combined heat and power systems have both environmental and economic advantages. This is primarily due to their high efficiency. Today, it already reaches 60%, which is 82% of the theoretically possible level.

Keywords: energy efficiency, combined heat and power, cogeneration, sustainable energy, energy-saving technologies

I. Introduction

In the structure of world energy, the share of combined-cycle plants (CCP) producing electric and thermal energy is increasing. In this case, thermal energy is used for additional production of electric energy. A combined-cycle plant consists of two separate units: a steam power unit and a gas turbine unit. Both natural gas and petrochemical products, such as fuel oil or diesel fuel, can serve as fuel for a CCP.

Systems that simultaneously produce both heat and electricity are called combined heat and power systems or "cogeneration" systems. Combined heat and power systems are widely used in the paper, chemical, pulp and paper, and oil refining industries. These industries make maximum use of combined heat and power systems to meet the needs of the industry using both electrical and thermal energy. Most combined heat and power systems use steam turbines (Rankine cycle) and gas turbines (Brayton cycle) to produce electricity. In gas turbines, the working fluid is air, while in steam turbines, the working fluid is steam. Using waste heat in power production is economically advantageous.

Fig. 1 and 2 show idealized diagrams of thermal power plant systems with steam and gas turbines.gas turbines.

Power systems that only produce electricity dump large amounts of waste heat into low-temperature reservoirs such as rivers, oceans, and the atmosphere. Systems that only produce heat do not utilize the potential of high-temperature working fluids to create work. Thus, CHP systems attempt to utilize fossil fuels as much as possible.

Combined heat and power systems produce both electricity and heat using a single fuel source. This is also an indication of the high efficiency of combined heat and power systems, as they produce both heat and electricity without reusing fuel, thereby reducing greenhouse gas emissions and reducing waste to the environment.

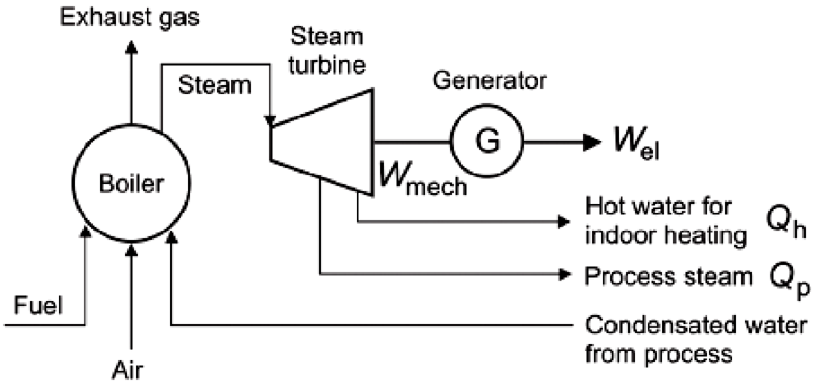

Figure 1: *Steam Turbine Combined Heat and Power System*

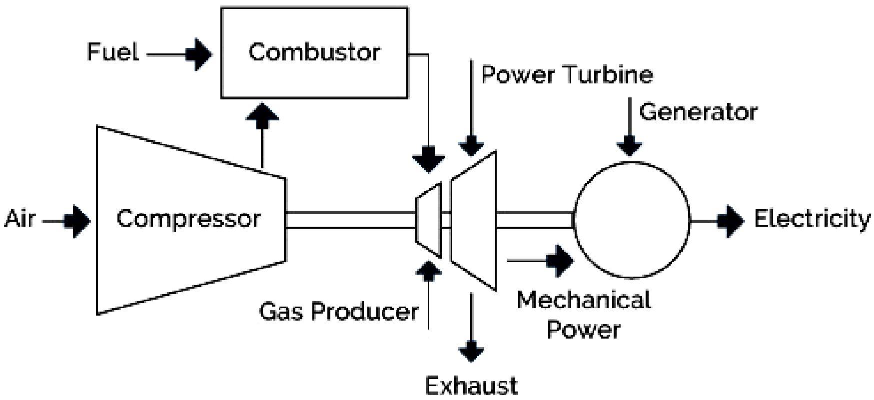

Figure 2: *Gas Turbine Combined Heat and Power System*

The concept of cogeneration was first used in the 19th century to produce industrial waste heat. Previously, this waste heat was used in industrial processes. Technological advances in the 20th century, as well as the development of turbine and engine technologies, have had a positive impact on the development of combined heat and power systems.

CHP technology has developed significantly in recent years. Advances in combustion engineering, materials science, and control systems have helped improve the efficiency and reliability of CHP.

CHP systems with different configurations such as gas turbines, steam turbines, and combustion engines have expanded the applications of CHP. The main results are that CHP reduces greenhouse gas emissions, increases efficiency, and saves energy or fuel, which reduces emissions to the environment.

In addition, research is focused on optimizing the integration of the CHP system with renewable energy sources. Combined cycle systems and fuel cells are also under development and are an ongoing topic of research.

II. Main configurations of the CHP system project

There are three main types of CHP plant configurations: a steam turbine design (Fig. 1), a gas turbine design (Fig. 2), and a combined cycle design that includes both a gas and steam turbine (Fig. 3).

A steam turbine is powered by high-pressure steam. This high-pressure steam is produced by a boiler or a heat recovery steam generator (HRSG). It differs from gas turbines in that it does not consume fuel directly. The fuel that powers the process is a fired boiler or plant equipment that produces heat for the HRSG.

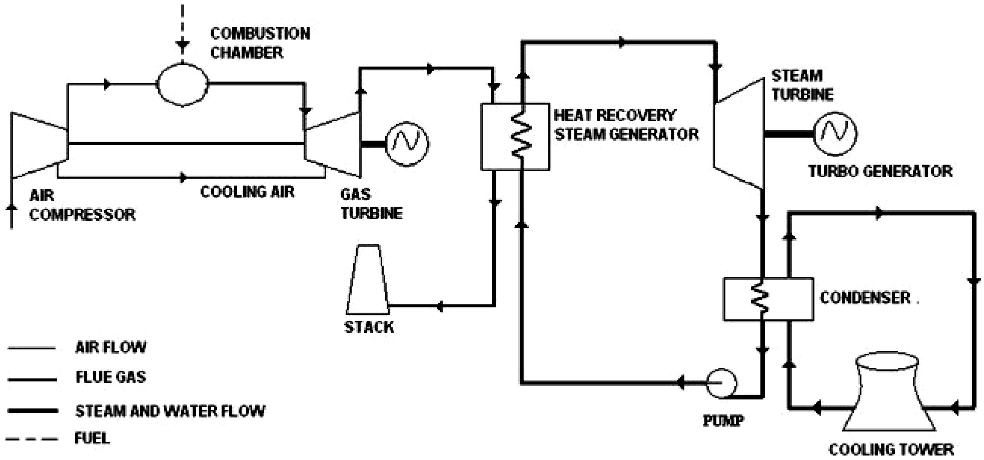

Figure 3: *Gas and Steam turbine design*

Steam turbines follow the Rankine cycle (see Fig. 1). This thermodynamic cycle involves pumping water at high pressure and heating it to produce high-pressure steam. Steam turbines convert the high-pressure steam into mechanical energy, which powers an electric generator. CHP systems use low-pressure steam from the steam turbine to meet on-site heating needs. The condensed liquid is returned to the pump and the process is repeated.

Gas turbines are open-cycle, constant-pressure heat engines. An application of the Brayton thermodynamic cycle. The gas turbine (see Fig. 4) compresses air and then mixes it with fuel. Combustion chamber. The combustor receives high-pressure fuel (200-400 psig) depending on the number of compressor stages and the compression ratio. If the fuel supply pressure at the field is insufficient, a gas compressor can be used to increase it. The combustor sends the hot gas to a turbine, which drives a mechanical shaft. The rotating shaft drives an electric generator and an air compressor.

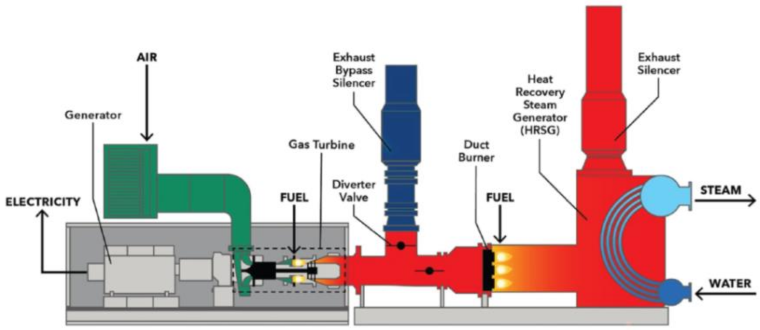

Figure 4: *Gas turbine design*

A combined cycle gas turbine (see Fig. 5) uses both a gas turbine and a steam turbine to generate electricity from the same fuel source, resulting in higher efficiencies than standard simple cycle plants. In a combined cycle plant, natural gas or other gaseous fuels are first burned in a combustion turbine to generate electricity.

After passing through the turbine, the hot exhaust gases retain useful energy that would otherwise be wasted. This residual heat is recovered by a heat recovery steam generator, which uses the thermal energy in the exhaust gases to boil water and generate steam.

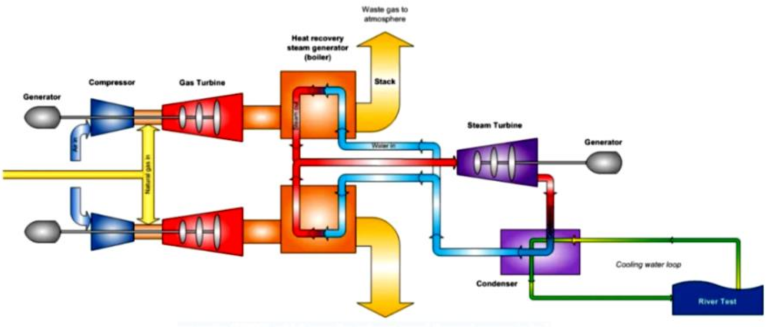

Figure 5: *Combine Cycle Gas Turbine Design*
https://www.marchwoodpower.com/ccgt/

III. Methods of calculation of system efficiency of heat and electricity production

CHP applications involve recovering heat that would otherwise be wasted in each application. Here's how CHP improves fuel efficiency.

The two metrics most commonly used to describe the efficiency of a CHP system are total system efficiency and net electrical efficiency.

The metric that compares the efficiency of a CHP system to its traditional counterparts (electricity supplied from the grid and useful heat generated in a local boiler) is called total system efficiency. Total system efficiency may be an appropriate performance metric for comparing the energy efficiency of a CHP system to traditional power sources on-site, if that's your goal.

Effective electrical efficiency is a metric used to compare electricity generated by power plants with electricity generated by cogeneration plants. If cogeneration power is to be compared with conventional electricity generation, the effective electrical efficiency metric is the correct choice. It is normal that one methodology does not fit all cases. Therefore, the methodology used must be chosen carefully and the results verified.

Overall System Efficiency

The overall system efficiency (ηo) of a CHP system is the net useful heating output (∑Q) and the sum of the net useful electrical output (W) divided by the total fuel energy input (Q), as shown below:

$$\eta_0 = \frac{W_0 + \sum Q_{TH}}{Q_{FUEL}}$$

Overall system efficiency is based on the fuel consumed and evaluates the combined outputs of the CHP plant (useful heat output and electricity).

CHP systems typically achieve overall system efficiencies of 65-70%.

Note that this methodology does not differentiate between electricity production and heat production. Thus, this methodology treats electricity and heat production as having equal value. In fact, electricity considered the more valuable type of energy due to its unique characteristics.

Effective Electrical Efficiency

Effective electrical efficiency compares the efficiency of combined heat and power systems to that of conventional power plants. The effective electrical efficiency calculation isolates the electrical output of a CHP system and takes into account the net heat output and fuel consumption.

The formula for calculating effective electrical efficiency is:

$$\mathcal{E}_{EE} = \frac{W_e}{Q_{FUEL} - \sum(Q_{TH}/\alpha)}$$

This metric is critical to comparing the efficiency of electricity generated by a CHP plant with electricity supplied from the grid, the primary source of electricity generation.

Effective electrical efficiency provides a clearer picture of the efficiency of electricity generated by CHP systems by calculating the thermal efficiency and the efficiency of conventional thermal generation.

Typical boiler efficiencies are 80% for natural gas boilers, 75% for biomass boilers, and 83% for coal boilers. Combustion turbine based CHP systems have an efficiency of 60-70%. Reciprocating engine based CHP systems have an efficiency of 70-85%.

IV. Advantages and disadvantages of combined cycle gas turbine plants

In the production of electricity, a combined cycle power plant is an assembly of heat engines that operate in tandem from the same heat source, converting it into mechanical energy to drive electric generators. The process begins with a gas turbine. In a gas turbine plant, the turbine is rotated by burning fuel (fuel oil, diesel fuel, natural gas). Natural gas enters the combustion chamber of the gas turbine, where it is burned, creating a stream of hot gas at high speed. The expansion of the hot gas flow through a series of turbine blades causes the turbine to rotate. The principle of operation is that in combined cycle plants, on the same shaft as the gas turbine is the first generator, which produces electric current due to the rotation of the rotor.

Then comes the stage of waste heat recovery. Passing through the gas turbine, the combustion products give it only part of their energy and at the exit from the turbine still have a high temperature (1300-1400°C). Then the combustion products enter the waste heat boiler (WHB), which is a series of heat exchangers that can transfer heat from the exhaust gases to water. There they heat the feed water and water vapor is formed. This reduces fuel consumption and increases the efficiency of the entire plant. The temperature of the combustion products is sufficient to bring the steam to the state necessary for the rotation of the steam turbine ($t=500^0$C and P=80 atm.). The second generator mechanically connected to the steam turbine.

Advantages of a combined cycle gas turbine plants

- *High efficiency.* Combined heat and power plants are known for their high thermal efficiency. By combining the steam and gas turbine circuits, this system is more efficient than traditional gas or steam turbine power plants because it uses a larger share of the energy contained in the fuel. Today, it already reaches 60%, which is 82% of the theoretically possible level. Previously, all the heat contained in the fuel that could not be converted into electricity was released into the environment, causing thermal pollution. The reduction in thermal emissions from a CCP compared to a steam power plant is exactly to the extent that the fuel consumption for electricity generation is lower. The use of a combined cycle reduces specific fuel consumption by approximately 6-12%.
- *Flexibility:* Combined cycle gas turbines operate efficiently at part load and provide stability during the growing but intermittent growth of renewable energy generation.
- *Low emissions.* Compared to other power plants, burning natural gas in a gas turbine results in lower emissions of pollutants and greenhouse gases, such as nitrogen oxides (NOx), sulfur dioxide (SO_2) and carbon dioxide (CO_2). The consumption of cooled water in a combined cycle plant is approximately three times less than in a steam power plant per unit of generated electricity. This is due to the fact that the capacity of the steam part of a combined cycle plant is 1/3 of the total capacity, and a gas turbine plant requires virtually no cooling water;
- *Fast start-up and load response.* The combined cycle gas turbine plant has high maneuverability, which is an important factor in ensuring the reliability of the power system, significantly easing the problem of covering the variable part of the electric load schedule. In addition, combined cycle gas turbine plants can function as power sources with both base and peak load. This means that they can operate continuously, providing a stable power base, and their ability to quickly increase capacity makes them valuable for meeting sudden surges in

demand;

- Combined-cycle power plants have a lower (approximately 40%) *specific cost of installed capacity*. This is due to the smaller volume of the construction part, the absence of a complex power boiler, an expensive chimney, a regenerative feed water heating system, the use of a simpler steam turbine and a technical water supply system, etc. CCP have a significantly shorter construction cycle. The main equipment of a CCP is delivered to the construction site in large modules, which allows for a significant reduction in installation time and provides the ability to introduce equipment in stages. It is much more profitable to build power plants with CCP than nuclear power plants;.
- *Significantly smaller construction cycle (9-12 months);*

Disadvantages of combined cycle gas turbine plants.

- *High temperatures mean high maintenance requirements*. Due to the high temperatures generated in a combined cycle power plant, care must be taken both at the design stage and during maintenance. The combustion chamber temperature can reach 1700°C, which is dangerous for the materials in the system and can reduce their service life.
- *Seasonal capacity limitations*. Seasonal capacity limitations are one of the disadvantages of combined cycle gas turbine plants, as combined cycle gas turbine plants are more efficient in the winter months due to heat recovery and the useful capacity is at its highest.

V. Practical use of a combined cycle gas plant

Currently, 3 combined cycle gas plants have been installed in Azerbaijan at the power plants of Azerenerji OJSC.

One of them is installed at the Sumgayit power plant with a capacity of 517 MW. According to experts' forecasts, the annual productivity of the Sumgayit Thermal Power Plant will be 3.8 billion kW/hours at a cost of 230 grams of fuel per 1 kW/hour of electricity. The demand for gas fuel will be 100 thousand m3 per hour or 630 million m3 per year. The general contractor for the construction of the power plant was Siemens.

At the Shimal State District Power Plant there is a combined cycle gas plant with a capacity of 400 MW, built by the Mitsui/Mitsubishi alliance. At the Shimal State District Power Plant (Shimal-2) there is another combined cycle gas plant with a capacity of 409 MW. Construction is carried out by the Japanese company Toyo Engineering Corporation.

According to Azerenergy estimates, due to the joint operation of the Shimal and Shimal-2 Combined cycle gas turbin units, the total volume of electricity generated by the power plant will be 5.7 billion kWh per year.

Currently, modernization work is ongoing at Azerbaijan's largest power plant, resulting in the construction of a combined gas turbine facility with a capacity of 1800 MW and its integration into the energy system.

The difference between the combined gas turbine station and the previous station is that while 335 grams of fuel used for 1 kW of energy in the previous station, this number will decrease by 110 grams to 225 grams in the new station.

As a result, the amount of waste released to the environment will decrease and 1.2 billion m3 of natural gas will be saved annually, and if the price of natural gas in Azerbaijan is taken into account, 200 million AZN financial funds will be saved annually. The efficiency of the station will increase between 22 percent and 60 percent.

Compared to steam power of the same capacity, the difference between combined heat and power plants is that the combined cycle gas turbin unit uses about three times less cooling water.

Today, the use of combined cycle gas turbines is a factor in energy security and welfare of the state.

VI. Conclusion

1. Combined Heat and Power systems increase efficiency by simultaneously producing both electricity and heat using a single fuel source. This not only reduces fuel consumption, but also reduces greenhouse gas emissions and waste to the environment.
2. Combined Heat and Power systems are more efficient than other conventional plants in different configurations. Brayton cycle gas turbine systems and Rankine cycle steam turbine Combined Heat and Power systems are economically and environmentally more efficient than other conventional plants.
3. The combined cycle gas turbine design, which combines both gas and steam turbines, is the most efficient in terms of efficiency, with efficiencies as high as 70%. Despite the disadvantages of temperature and seasonal power limitations, the benefits of combined cycle gas turbin are high.
4. The practical application of combined cycle gas turbin systems in Azerbaijan's power plants emphasizes their role in increasing the energy efficiency and sustainability of the country. The modernization and integration of new combined cycle gas turbin units is expected to significantly reduce fuel consumption and environmental impact, saving significant financial resources each year.

References

[1] Research and Development of the Combined Cycle Power Plants Working on Supercritical Carbon Dioxide by Andrey Rogalev, 2016

[2] Performance and Efficiency of Combined Cycle Power Plant Abdalla, Momin Elhadi, 2022

[3] Rajeshand R., Kishore P.S. Thermal efficiency of combined cycle power plant, International Journal of Engineering and Management Research, 229-234, 2018.

[4] Farouk N, Sheng L. Effect of Fuel Types on the Performance of Gas Turbines. International Journal of Computer Science Issues (IJCSI). 2013; 10(1):436.

[5] Mohapatra A.K., Sanjay: Thermodynamic assessment of impact of inlet air cooling techniques on gas turbine and combined cycle performance, Energy 68 (2014) 191-203.

THE CALCULATİON OF FİRE AND EXPLOSİON HAZARD PRESSURE İN THE ROOM

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Abstract

According to the normative document, the comparison of the calculation results of explosion pressure of the gas-air mixture in the room carried out in the work showed that the obtained result does not correspond to the established limit. This fact testifies to the unsuitability of the developed calculation methods. When determining the explosion pressure, it is necessary to use the explosion power hypothesis instead of HWS (hot water supply) energy hypothesis. The results of the calculation of the explosion parameters of the gas-air mixture based on the energy hypothesis using the concept of "TNT equivalent" do not correspond to the results of experimental studies.

This fact indicates the unsuitability of the calculation methods developed and approved in accordance with "the established procedure". The calculation results obtained according to the approved methods mislead consumers.

Keywords: gas-air mixture, explosion pressure, overpressure, fire hazard, hazard factor, probability

I. Introduction

In order to determine explosion hazard categories in the room, the indicator of "explosion overpressure" is used. If the overpressure exceeds 5 kPa, premises are classified as explosion and fire hazardous place. To determine the overpressure equation [1] is used:

$$\Delta P = 100(P_{max} - P_0)mZ/(V_{ac}\rho C_{st}K_l) \qquad (1)$$

where: P_{max} – maximum explosion pressure, which cannot be greater than 900 kPa; P_0 – initial pressure equal to 101 kPa; m – mass of combustible gas in kg; Z – coefficient of participation of combustible gas in the explosion, for methane Z = 0,5; V_{ac} – available room capacity, м^3; ρ – gas density kg/m^3; C_{st} – stoichiometric concentration of GG by % (volume), for methane C_{st} = 9,35 %; K_l – coefficient that takes into account the leakiness of the room, K_l = 3.

The amount of gas entering the room is determined on the basis of the following assumptions:

- The most unfavorable variant of the accident or period of operation in which the largest number of GG (gas generators) are involved in the explosion is selected as the calculated one;
- The entire contents of the apparatus enter the room;
- Gas leaks simultaneously from the pipelines supplying the apparatus through the forward and reverse flow during the time required to shut down the pipelines;
- Liquid evaporates from the container, from the liquid spillage surface and from freshly painted surfaces.

For an example of implementation of the described methodology, let us determine the explosion pressure in the room with a volume of 80 m^3, in which there is a block of 1 m^3, operating at a methane pressure of 4 MPa. At complete depressurization of the block, 40 m^3 of gas from the block and 60 m^3 of gas enters the room through the direct and return flows feeding the block. The total gas flow into the room reaches 100 m^3. The density of methane is 0,714 kg/m^3.

Substituting the data into the above equation gives an overpressure value in the room equal to 1850 kPa.

Comparing the obtained value of overpressure with the limit value of 900 kPa, we notice that the obtained result does not correspond to the established limit. A deeper analysis of the situation revealed another inconsistency of the explosion process with the physics of the phenomenon in question: gas exploded in the room in the absence of oxygen in the air, so the volume of gas entering the room was greater than the volume of the room.

II. Methods

What will be the excess pressure in case of gas explosion in the room?

To answer this question, it is sufficient to determine the volume of gas in the room corresponding to the stoichiometric composition of the gas-air mixture. For methane, the stoichiometric gas concentration is 9,35 %. If the capacity of the room is 80 m^3, the volume of gas involved in the explosion will be about 7,5 m^3, its mass is m = $V_{ac}\,\rho C_{st}/100$. If we substitute this mass of gas into the equation, the equation is reduced to the following form.

$$\Delta P = (P_{max} - P_0)Z/K_l \quad (2)$$

The overpressure in the room in an explosion of a stoichiometric gas-air mixture is 133 kPa.

The fire hazard category of the room after the explosion pressure adjusting remains unchanged (A), however, if it is necessary to determine the value of the impact zone radius, the result will be significantly different from the value obtained according to the NPB methodology.

According to the thermodynamics of gas oxidation process during a cloud explosion in an open space, the overpressure cannot be higher than 900 kPa. However, the format of the equation presented in the NBP allows any flow pressure not limited by this limit to be plotted. Due to the inconsistency of the presented equation with the physical meaning of the process at cloud explosion, for calculation of cloud explosion parameters we use the methodology of PB 09-540-03[2], as well as the data of W. Marshall [3] and S.I. Taubkin [4]. In accordance with this methodology, the overpressure of the explosion is determined depending on the TNT equivalent mass of the gas involved in the explosion and the dimensionless coefficient K, taken in accordance with Table 1.

Table 1: *Classification of destruction zones*

Class of destruction zones	Coefficient K	ΔP, кПа
0	1	500-800
1	3,8	100
2	5,6	70
3	9,6	28
4	28	14
5	56	2

The radius of the destruction zone is determined by the expression

$$R = K(W_т)^{0,333}/(1 + (3180/W_т)^2)^{0,167} \quad (3)$$

The TNT equivalent value W_T for a gas-air mixture is determined by the equation

$$W_т = 0,4\dot{q}zm/0,9/q_т \quad (4)$$

where

0,4 is the coefficient that takes into account the share of the explosion energy of the gas-air medium spent directly on the formation of the shock wave;

0,9 - fraction of TNT explosion energy spent directly on shock wave formation;

q` – specific heat of combustion of gas, kJ/kg;

q_T – specific energy of TNT explosion, equal to 4520 kJ/kg;

z – fraction of the gas mass involved in the explosion;

m – mass of gas in the gas-air mixture cloud, kg.

To determine the cloud explosion overpressure beyond the limits set by the table (at ΔP>100 kPa and ΔP<2 kPa), we use the dependence ΔP = f(K) in the following form

$$\Delta P = P_{max}/(1 + K^3)^{0,5} \quad (5)$$

where, P_{max} is the maximum explosion pressure of gas-air mixture, kPa.

In accordance with the instructions of NPB - 105-03 it is allowed to take the value ΔP_{max} = 900 kPa. According to the data of Taubkin S.I. [4], the specified value of the maximum overpressure at explosion of methane-air mixture is 606 kPa. Using the equation [5] at any value of the coefficient K the overpressure is within the established limitation of its maximum value.

In the work of Marshall B [3] we find an indication that the fatal injury of people in an explosion is realized in different conditions in different ways. A person in an open area may be affected by an air shock wave with an overpressure of 500-800 kPa. In buildings and premises a pressure of 100 kPa is sufficient for this purpose. It is found that in buildings and premises a person dies not from the pressure of the explosion, but from fragments of building structures.

The conditional probability of human injury in accordance with the guidelines of NPB 105-03 and SP 12.13130.2009 is determined by the value of the probit function.

$$Pr = 5 - 0{,}26 \ln V \quad (6)$$

Where, V – hazard factor determined by the equation

$$V = (17{,}5/\Delta P)^{8,4} + (290/i)^{9,3} \quad (7)$$

Here ΔP - is the overpressure of the explosion, kPa; i - is the impulse of the pressure wave, Pa/s.

To check the correctness of the conclusions of methodological and normative documents, let us perform a control calculation, the purpose of which is to determine whether the overpressure leading to fatal human injury (100 kPa) corresponds to the conditional probability of human injury equal to 100 %. As an example, we selected a cloud of methane-air mixture in which 500 nm^3 of gas is distributed. The calculation results are presented in Table 2.

As follows from the analysis of the calculation results, an overpressure of 100 kPa corresponds to a conditional probability of injury to people equal to 81 %. The conditional probability of 100 % corresponds to an overpressure of about 500 kPa. Obviously, the equation of the Probit-function presented in the normative documents corresponds to the scenario of ESW (explosive shock wave) impact on a person located at the outdoor site.

In order to determine the ECD in the room, the equation of the probit function must be transformed to the following form:

$$Pr = 7{,}4 - 0{,}25 \ln V \quad (8)$$

The results of the calculation are presented in Table 3.

The change of dependence for the probit-function provided convergence of the result of the explosion wave impact on a person in the room, the conditional probability of his injury is equal to 100 % at the pressure of ESW of 100 kPa.

IV. Discussions and Results

The results of the calculation of the explosion parameters of the gas-air mixture based on the energy hypothesis using the concept of "TNT equivalent" do not correspond to the results of experimental studies.

This fact indicates the unsuitability of the calculation methods developed and approved in accordance with "the established procedure". The calculation results obtained according to the approved methods mislead consumers.

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Table 2: *The results of calculations of hazard factor, overpressure of the explosion and impulse of the pressure wave*

Coefficient K	g m	ΔP кПа	Impulse i Pa/s	Hazard factor V	Probit function	CPIP %
0,43	0,99	818,10	4071,32	0,00	11,39	100,00
0,88	2,02	655,50	1989,40	0,00	9,66	100,00
1,33	3,06	464,22	1316,29	0,00	8,66	100,00
1,78	4,09	329,87	983,52	0,00	7,95	99,82
2,23	5,13	244,46	785,05	0,00	7,41	99,11
2,68	6,16	188,89	653,23	0,00	6,96	97,06
3,13	7,19	151,05	559,32	0,00	6,59	93,61
3,58	8,23	124,14	489,01	0,01	6,26	88,93
4,03	9,26	104,27	434,41	0,02	5,98	83,23
4,48	10,30	89,15	390,77	0,06	5,72	76,69
4,93	11,33	77,33	355,11	0,15	5,49	69,45
5,38	12,37	67,90	325,40	0,34	5,28	61,65
5,83	13,40	60,23	300,29	0,72	5,08	53,38
6,28	14,44	53,90	278,77	1,44	4,90	46,04
6,73	15,47	48,61	260,13	2,75	4,74	39,05
7,18	16,50	44,12	243,83	5,02	4,58	33,15
7,63	17,54	40,29	229,45	8,83	4,43	28,15
8,08	18,57	36,97	216,67	15,05	4,30	23,89
8,53	19,61	34,09	205,24	24,91	4,16	20,26
8,98	20,64	31,56	194,95	40,18	4,04	17,15
9,43	21,68	29,34	185,65	63,32	3,92	14,48
9,88	22,71	27,36	177,19	97,69	3,81	12,19
10,33	23,74	25,59	169,47	147,83	3,70	10,22
10,78	24,78	24,01	162,40	219,79	3,60	8,53
11,23	25,81	22,58	155,89	321,51	3,50	7,08
11,68	26,85	21,29	149,89	463,35	3,40	5,84
12,13	27,88	20,11	144,33	658,59	3,31	4,78
12,58	28,92	19,05	139,16	924,20	3,22	3,87
13,03	29,95	18,07	134,36	1281,59	3,14	3,10
13,48	30,99	17,17	129,87	1757,57	3,06	2,45
13,93	32,02	16,35	125,68	2385,47	2,98	1,91
14,38	33,05	15,59	121,74	3206,43	2,90	1,46
14,83	34,09	14,88	118,05	4270,86	2,83	1,09
15,28	35,12	14,23	114,57	5640,16	2,75	0,79
15,73	36,16	13,62	111,29	7388,65	2,68	0,56
16,18	37,19	13,06	108,20	9605,84	2,62	0,38
16,63	38,23	12,53	105,27	12398,89	2,55	0,25
17,08	39,26	12,04	102,50	15895,55	2,48	0,17
17,53	40,29	11,58	99,87	20247,28	2,42	0,12
17,98	41,33	11,15	97,37	25632,97	2,36	0,10
*) CPIP – conditional probability of injury to people						

Table 3: *The results of calculations of P_r*

Coefficient K	g m	ΔP кПа	Impulse i Pa/s	Hazard factor V	Probit function	CPIP %
0,9456	6,26	625,69	1859,50	0,00	13,11	100,00
1,7056	11,29	348,12	1030,92	0,00	11,27	100,00
2,4656	16,32	212,57	713,15	0,00	10,13	100,00
3,2256	21,35	144,59	545,12	0,00	9,29	100,00
3,9856	26,39	105,99	441,17	0,02	8,64	100,00
4,7456	31,42	81,84	370,52	0,10	8,10	99,85
5,5056	36,45	65,60	319,37	0,41	7,63	99,57
6,2656	41,48	54,09	280,63	1,36	7,23	98,51
7,0256	46,51	45,58	250,28	3,94	6,88	96,42
7,7856	51,54	39,09	225,85	10,23	6,56	93,24
8,5456	56,58	34,00	205,76	24,33	6,27	89,01
9,3056	61,61	29,92	188,96	53,73	6,00	83,82
10,0656	66,64	26,60	174,69	111,52	5,76	77,76
10,8256	71,67	23,85	162,42	219,48	5,53	70,92
11,5856	76,70	21,55	151,77	412,54	5,32	63,38
12,3456	81,73	19,59	142,43	744,95	5,13	55,21
13,1056	86,76	17,91	134,17	1298,57	4,94	47,69
13,8656	91,80	16,46	126,81	2193,82	4,76	39,99
14,6256	96,83	16,19	120,22	3604,06	4,60	33,56
15,3856	101,86	14,08	114,28	5773,92	4,44	28,16
16,1456	106,89	13,10	108,91	9042,54	4,29	23,63
16,9056	111,92	12,23	104,01	13872,69	4,15	1983
17,6656	116,95	11,45	99,53	20886,68	4,01	16,62
18,4256	121,99	10,75	95,43	30910,51	3,88	13,92
19,1856	127,02	10,11	91,65	45027,35	3,76	11,65
19,9456	132,05	9,54	88,16	64642,08	3,63	9,74
20,7056	137,08	9,02	84,92	91558,33	3,52	8,13
214656	142,11	8,55	81,91	128070,14	3,41	6,77
22,2256	147,14	8,11	79,11	177069,97	3,30	5,63
22,9856	152,17	7,71	76,50	242175,58	3,19	4,67
23,7456	157,21	7,35	74,05	327877,97	3,09	3,86
24,5056	162,24	7,01	71,75	439713,33	2,99	3,17
25,2656	167,27	6,69	69,56	584461,66	2,90	2,60
26,0256	172,30	6,40	67,56	770375,49	2,81	2,10
26,7856	177,33	6,13	65,65	1007441,96	2,72	1,68
27,5456	182,36	5,88	63,83	1307682,22	2,63	1,32
28,3056	187,39	5,64	62,12	1685492,09	2,55	1,00
29,0656	192,43	5,42	60,50	2158028,43	2,46	0,72
29,8256	197,46	5,22	58,59	2745646,08	2,38	0,46
30,5856	202,49	5,02	57,49	3472390,43	2,30	0,22
31,3456	207,52	4,84	56,10	4366551,28	2,23	0,00
*) CPIP – conditional probability of injury to people						

References

[1] NPB 105-103 (normative document).

[2] PB 09-540-03 "General rules of explosion safety for explosion and fire hazardous chemical, petrochemical and oil refining industries".

[3] Marshall V. The main hazards of chemical industries. M., Mir, 1987.

[4] Taubkin S.I.. Fire and explosion, peculiarities of their expertise. VNIIPO, M., 1999, 600 p.

[5] Mazur I.I., Ivantsov O.M.. Safety of Pipeline Systems. M., Publishing house. "ELIMA", 2024, 1100 p.

SELECTION OF THE OPERATION MODE OF A GAS-LIFT WELLS GROUP BASED ON THE THEORY OF DECISION-MAKING UNDER RISK CONDITIONS

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Abstract

A review of existing methods for assigning and regulating operating modes for groups of wells shows that they do not always allow to obtain satisfactory results, since the complexity and unpredictability of the behavior of the reservoir system and the supply system require approaches that would take into account the uncertainty of conditions.
In this article, when assigning injection modes, a probabilistic decision-making and a decision-making problem are used under conditions of uncertainty for a group of 15 possible wells of the VII formation of the considered field.
The choice of a rational injection strategy under risk conditions is made based on the following considerations: the known probabilities of each strategy result determine the mathematical expectation of each strategy utility. The injection strategy maximizing the expectation of utility is chosen.

Keywords: gas lift wells, working agent consumption, well operation mode, decision making, strategy, risk conditions, uncertainty conditions, matrix

I. Introduction

When controlling the processes of gas lift oil production, the main control parameter is the consumption of the working agent. In this regard, the problem of its rational distribution arises. Usually, the volume of compressed gas is limited, so the task is to distribute it over a group of wells in such a way as to ensure its total consumption minimum.

In practice, there are various methods of assigning operating modes for groups of gas-lift wells [1-5].

A method for operating a group of gas-lift wells, based on increasing for conditions of limited resources of the working agent the working agent consumption in wells with a maximum increase in flow rate is known [6]. An equal amount of gas is pumped into all wells, then the flow rate is measured for each well and the same increment of gas flow is set. After that, the flow rate is measured again, the wells are ranked in descending order of the increase in flow rates. Subsequently, the resources are distributed in such a way that at first the gas flow rate increase in the well is set with the maximum production increment (in the first well) until this increment becomes equal to that measured earlier in the second well. The process is carried out in a number of wells until all gas resources are exhausted. To improve the accuracy of the calculation, after the exhausting gas resources for each well, its flow rate is reduced by the same amount, the oil flow rate is measured for each well and the gas flow rate in the wells with a maximum decrease in flow rate is increased.

In [7], methods for assigning operating modes for groups of gas-lift wells producing non-Newtonian oils are studied.

Work [8] proposes a technique for choosing a certain "compromise" solution for a group of gas-lift wells. The mode is called "compromise" because it is not the best for all wells, however, extending it to a group makes it possible to achieve a total gain in the amount of fluid produced while reducing the flow rate of the injected agent. The choice of the mode was carried out using the apparatus of fuzzy sets theory [9, 10]. With this approach, the lack of information about the processes was modeled by a "fuzzy" (vague) formulation of goals and restrictions imposed on the functioning of the considered group of wells. In addition, the choice of mode was implemented based on the use of a generalized desirability function.

However, the above methods do not always allow to obtain satisfactory results, since the complexity and unpredictability of the behavior of the reservoir system and the supply system require approaches that would take into account the uncertainty of conditions.

Decision making theory, as one of the fundamental sections of the theory of operations research, is precisely aimed at solving such problems.

The content of the decision-making task is to determine the best or acceptable course of action to achieve one or more goals. It is obvious that the application of a scientific approach to the decision-making problem will contribute to the optimization of all management functions and thereby increase their efficiency.

Any decision-making process includes the following elements:

- Target. The need for decision-making is determined by the goal or several goals to be achieved;
- Alternative solutions - different options for achieving goals;
- External environment - the totality of all external factors affecting the outcome of the decision;
- Outcomes of the decision;
- Decision selection rules (decision rules). These rules make it possible to determine the most preferable solution in the sense of the chosen criterion.

In the considered problem of regulating the processes of gas-lift oil production, the goal of making a decision is to minimize the consumption of compressed gas, an alternative is the choice of an injection strategy, due to the choice of a decision-making criterion, the external environment is a combination of various factors affecting the state of the reservoir-well system, the outcome is obtaining a real economy of the injected working agent.

Decision making theory uses various procedures to formalize preferences, that is, to express them in a single quantitative measure. The basis for them is the utility theory [11, 12].

Depending on the conditions of the environment and the degree of awareness, there is the following classification of decision-making problems: deterministic tasks or tasks under conditions of certainty, probabilistic tasks or tasks under risk, tasks under uncertainty [13, 14].

Decision-making under certainty conditions is characterized by an unambiguous or deterministic relationship between decision-making and its outcome. In this direction, decision-making theory is considered from the position of mathematical programming: linear, non-linear, dynamic [11, 12]. These tasks include resource allocation, inventory management, and transport tasks. The application of mathematical programming methods requires the availability of complete and reliable information in the form of a deterministic mathematical model and the need for initial data. Under these conditions, the problem situation is completely defined and there is no need to further define it with a hypothetical situation. This means that all priori probabilities of situations are equal to zero, except for one, which is equal to one. Equality to unity of the probability of a certain situation means that this situation is the only reliable one. Goals under certainty conditions are formally defined and expressed as an objective function and constraints. Preferences are expressed as explicit preference functions. The selection criterion is also known in an explicit formal form. The presence of the above information allows us to build a fully formalized model of the decision-making problem and find the optimal solution.

II. Methods

Decision making under risk. This problem arises when each adopted strategy X_i is associated with a whole set of possible outcomes $O_1, O_2, \ldots, O_m$ with known probabilities $P(O_j/X_i)$. The solution is found using the theory of statistical decisions [16, 17]. Considering random events and processes the incompleteness and unreliability of information in real problems is taken into account in this theory. The description of regularities and behavior of these random objects is made with the help of probabilistic characteristics. The probabilistic characteristics themselves are no longer random, so formal optimization methods can be applied to find the best solution. In this regard, the problems considered in the theory of statistical decisions belong to a particular class of decision making problems under certainty probabilities or decision making under risk.

Formally, the problem model can be represented as a matrix the elements of which l_{ij} are the utilities of the result O_j when using the solution X_i (Table 1). Let conditional probabilities be $P(O_j/X_i)$, j = 1, m; I=1, n

Enter the expected utility for each strategy is entered:

$$E\{u(x_i)\} = \sum_{j=1}^{m} u(O_j, x_i) P(O_j/x_i); \quad i = 1, \ldots n \tag{1}$$

Table 1: *The usefulness of the result Oj when using the solution Xi*

$X_i \backslash O_j$	O_1	O_2	…………………	O_m
X_1	L_{11}	L_{12}	…………………	L_{1m}
X_2	L_{21}	L_{22}	…………………	L_{2m}
. . . . . .				
X_n	L_{n1}	L_{n2}	…………………	L_{nm}

The decision rules for determining the optimal strategy X_i are written as follows:

$$E\{u(x_i)\} = \max_{x_k} E\{u(x_k)\} \tag{2}$$

Choice of decisions under uncertainty conditions [13, 15]. These tasks are characterized by great incompleteness and unreliability of information, typical for gas lift oil production processes. The theory of decision making under uncertainty differs in that a large uncertainty of information does not allow to build a strictly formal scheme for finding the optimal solution. The theory presents only methods for narrowing the set of feasible solutions depending on the information uncertainty degree. One of the determining factors here is the external environment (or nature), which may be in one of the unknown states.

Then the mathematical model of the problem under uncertainty is formulated as follows.

There is some matrix with dimensions m×n (Table 1). The elements of this matrix l_{ij} can be considered as the utility of the result O_j when using strategy X_i.

$l_{ij} = (O_j, X_i)$, $j=1,\ldots, m$; $i=1,\ldots, n$.

Depending on the state of the environment, the result O_j is achieved with probability $P(O_j/X_i,S_k)$.

In addition, the observer does not know the probability distribution $P(S_k)$. Regarding the state of the environment, certain hypotheses can be made. The assumptions about the probabilistic state of the environment are called subjective probabilities $P'(S_k)$, k=1,…K.

If the observer known the value of $P(S_k)$ then we would have a problem of decision making under risk. In fact, the state of the environment is unknown and the probability distribution $P(S_k)$ is also unknown.

The decision is made on the basis of the selection criterion. Selection criteria allows to define a rule by which it is possible to get one optimal solution or narrow the initial set of solutions if there is a lack of information. In any problem, the choice of a solution is assumed. that the set of states of nature $S_1, S_2,…,S_n$ implies a complete system of incompatible phenomena, which is directly related to the given task and at the same time is unknown to the person making the decision.

For each of the criteria set out below, it is assumed that a problem of choosing a solution under uncertainty with actions (strategies) $A_1, A_2,…, A_m$, environmental states $S_1, S_2,…,S_n$, and utility payments u_{ij}; i=1,…,m; j=1,…, n is given.

The main decision-making criteria under conditions of uncertainty are:

- Maximum Wald criterion;
- Savage's minimax risk criterion;
- Criterion of insufficient reason of Laplace;
- Criteria for the indicator of pessimism - Hurwitz's optimism.

The application of these decision-making criteria is considered when choosing the operation modes of a group of gas-lift wells.

Deterministic and indeterminate tasks can be considered extreme cases, such as complete knowledge or complete ignorance of the results of the injection strategy.

Due to its complexity and the interconnectedness of individual wells, deterministic tasks rarely occur or are completely absent in the operation conditions of a group of gas-lift wells.

III. Results

The measurements data of fluid flow rate and compressed gas consumption of 15 gas-lift wells of the VII formation of the considered field for the period 2005-2009 were taken into account.

To assign the injection mode for the entire group of wells as a whole, we apply the above problem with risk (probabilistic problem).

For this purpose, it is convenient to represent problem situations in the form of a matrix, in which each column determines the possible result of obtaining extractions in the liquid Q_j (m^3/day), and each row determines the possible strategy for injecting compressed gas V_j (thousand m^3). The elements of this matrix $l_{ij}=u(O_j,V_i)$ determine the possible results of obtaining selections from these 15 wells (Table 2).

Table 2: *The utility of the result Qj obtained when using the strategy Vj*

V_j		Q_j		
		$Q_1 \le 50$	Q_2 50÷100	$Q_3 > 100$
V_1	2,3	24	72	121
V_2	2,8	20	76	121
V_3	3,5	46	88	123
V_4	4,0	40	83	121
V_5	4,5	38	82	125
V_6	4,7	32	81	121
V_7	5,0	40	85	126
V_8	5,5	34	87	126
V_9	6,2	40	87	127
V_{10}	6,6	38	85	121
V_{11}	7,0	40	82	115

Here l_{ji} is the utility of the result of obtaining Q_j when using the V_i strategy. The usefulness of the results is expressed as average selections.

Table 3 shows the frequency characteristics of obtaining results Q_j when choosing a strategy Vi.

Table 3: *The frequency response of obtaining the result Qj when choosing a strategy Vi*

V_j	Q_j		
	Q_1	Q_2	Q_3
V_1	2	4	3
V_2	1	6	2
V_3	1	8	4
V_4	2	8	4
V_5	3	9	3
V_6	1	7	5
V_7	1	7	4
V_8	1	9	3
V_9	2	6	2
V_{10}	1	6	3
V_{11}	1	4	3

Table 3 calculates the conditional probabilities

$$P(Q_j/V_i) = \frac{n_j}{N};\; j = 1,m; i = 1,n$$

where N is the total number of wells, N = 15.

The expected utility for each strategy is given

$$E\{u(V_i)\} = \sum_{j=1}^{m} u(O_j, V_i) P(O_j/V_i);\quad i = 1,n \tag{3}$$

Decision rules for determining the optimal strategy

$$E\{u(V_i)\} = \max_{V_k} E\{u(V_k)\} \tag{4}$$

We determine $P(Q_j/V_i)$ of the distribution probability (Table 4).

Table 4: *Conditional probabilities of the Qj distribution when choosing a strategy Vi*

V_j	$P(O_j/V_i)$		
	$P(O_1/V_i)$	$P(O_2/V_i)$	$P(O_3/V_i)$
V_1	0,13	0,27	0,20
V_2	0,07	0,40	0,13
V_3	0,07	0,53	0,27
V_4	0,13	0,53	0,27
V_5	0,20	0,60	0,20
V_6	0,07	0,47	0,33
V_7	0,07	0,47	0,27
V_8	0,07	0,60	0,20
V_9	0,13	0,40	0,13
V_{10}	0,07	0,40	0,20
V_{11}	0,07	0,27	0,20

The mathematical expectation of the utility of each strategy $Eu(V_i)$ is calculated:

$Eu(V_1)$ = 24x0,13+72x0,27+121x0,20 = 46,8;

$Eu(V_2)$ = 47,5; $Eu(V_3)$ = 83,1;

$Eu(V_4)$ = 81,9; $Eu(V_5)$ = 81,8;

$Eu(V_6)$ = 80,2; $Eu(V_7)$ =76,8;

$Eu(V_8)$ = 79,8 $Eu(V_9)$ =56,5;

$Eu(V_{10})$ = 60,9 $Eu(V_{11})$ =47,9

Obviously, it is rational to choose strategy V_3, since it maximizes the expectation of utility.

Based on the result obtained, injection mode V = 3,500 m^3 should be assigned for all wells in the group. Then for the group as a whole injection mode will be $\sum V$ = 52 500 m^3, which provides liquid withdrawal $\sum Q$ = 15 x Eu(V_3) = 1245 m^3/day. It should be noted that, in fact, the average combined gas flow rate is $\sum V_f \frac{\sum V}{N}$ = 71 000 m^3, and, accordingly, the liquid flow rate is $\sum Q_f = \frac{\sum q}{N}$ = 1226 m^3/day (V, q - respectively, the volumes of injection and withdrawal of fluid for individual wells).

Thus, by determining the injection strategy for a group of gas-lift wells as a whole, it is possible to reduce the consumption of the working agent up to 25% without loss in production.

IV. Discussion

The paper proposes the use of decision theory in conditions of incomplete information, when random factors have a significant impact on the processes occurring during gas lift oil production. In this regard, a methodology has been developed for selecting the operating mode for groups of interacting gas-lift wells based on the criteria of the decision making theory under risk conditions.

The performance of gas-lift wells is presented in the form of a matrix, each column of which determines the possible result of obtaining fluid withdrawals, and each row determines a possible strategy for injecting a working agent. Elements of the matrix determine the usefulness of the result of obtaining when using the strategy, expressed in the form of average values of selections.

The considered problem of regulating the processes of gas-lift oil production for the purpose of making decisions is minimizing the consumption of compressed gas by an alternative to an injection strategy choosing, due to the choice of a decision-making criterion by the external environment. The combination of various factors affecting the state of the reservoir-well system results in real savings in the working agent consumption.

For the group of gas-lift wells under consideration, an injection mode was proposed with a reduction in the working agent consumption up to 25%.

Thus, a decision-making algorithm under conditions of risk and uncertainty can be built on the basis of preliminary formation of options for decisions to be made, identification of risk events in each of them, and, factors of uncertainty, assessment of each of the alternatives according to the presented criteria, selection of the least risky and most acceptable option.

References

[1] Barashkin R.L., Samarin I.V. (2006). Simulation of operating modes of a gas-lift well. // Bulletin of the Tomsk Polytechnic University, v.309, №6, 42-46.

[2] Aliev F.A., Ismailov N.A. (2014). Optimization problems with periodic boundary conditions and boundary control in gas-lift wells. // Nonlinear oscillations, v.17, №2, 151-160.

[3] Aliev F.A., Ismailov N.A., Namazov A.A., Radzhabov M.F. (2016). Algorithm for calculating the parameters of the formation of a gas-liquid mixture on the shoe of a gas-lift well, / Proceedings of IAM, V.5, №1, 123-132.

[4] Mammadova G.G., Abbasova S.V. (2023). Development of a calculation scheme for selecting the optimal mode of operation of a gas condensate well taking into account the deformation conditions of the formation. // EUREKA: Physics and Engineering, Tallin, Estonia, №4, 3-11. DOI: 10.21303/2461-4262.2023.002948

[5] Abbasova S.V. (2022). Analysis and processing of the initial information data on fluid flow rates of the gas lift wells. Control and Optimization with Industrial Applications" COIA-2022. / 8th International Conference. Baku, Azerbaijan, 24-26.

[6] Vasiliev V.A., Belogortsev G.P., Guzhov A.I. (1986). Determination of the operation parameters of a gas lift in the mode of maximum liquid withdrawal. // Collection of scientific works of VNII. Issue. 97, 48-52.

[7] Ulyanov V., Kuchurin A., Kibirev E., Gryzunov A., Bak V.S., Rymarenko K.V., Nukhaev M.T., Dadakin N. Implementation of an intelligent gas injection control system to optimize gas-lift operation of wells at the Orenburg oil and gas condensate field / SPE-191533-18RPTC-RU.

[8] Bochkareva T.Yu. (1983). Forecasting of some technological indicators of oil production using fuzzy sets. Tem. collection of scientific papers "Diagnosis of technological processes and decision-making in oil and gas production", Baku, ed. Azineftekhim, 39-41.

[9] Bayramov I.Y., Gurbanov A.N., Sardarova I.Z., Mammadova G.G., Abbasova S.V. (2022). Creation of fuzzy models for the calculation of oil and gas reserves. 15th International Conference on Applications of Fuzzy Systems, Soft Computing and Artificial Intelligence Tools ICAFS 2022. Montenegro, Budva. Springer. 493-501. https://link.springer.com/chapter/10.1007/978-3-031-25252-5_65

[10] Bochkareva T.Yu., Kalinin V.V. (1985). Selection of the optimal regime for a group of gas-lift wells according to two criteria. // Collection of scientific papers "Physico-chemical methods for increasing oil and gas recovery of reservoirs". Baku, ed. Azineftekhim, 56-61.

[11] Wagner G. (1972). Fundamentals of operations research. Volume 1. - M.: Mir, 235.

[12] Blackwell D., Girshik M.A. (1958). Theory of games and statistical solutions. M.: IL, 374.

[13] Taha H. (2019). Operations research. - M.: Williams I.D., 1056.

[14] Podinovsky V.V. (2015). Risk measures as selection criteria for probabilistic uncertainty // Artificial intelligence and decision making., № 2, 60-70.

[15] Evstratov R.M. (2013). Uncertainty, probability, action as the main components of entrepreneurial risk. Fundamentals of the EUP, №1(7).: [Electronic resource]. Access mode: http://cyberleninka.ru/article/n/neopredelennost-veroyatnost-deystvie-kak-glavnye-sostavlyayuschie-predprinimatelskogo-riska/ (date of access: 17.08.2017).

[16] Karalambos D. Aliprantis, Subir K. (2016). Chakrabarti. Games and decision making. M.: Ed. house of the Higher School of Economics, 543.

[17] Adamchuk A.S., Amirokov S.R., Kravtsov A.M. (2014). Mathematical methods and models of operations research. Stavropol: North Caucasian Federal University (NCFU), 163.: [Electronic resource]. Access mode: URL: https://biblioclub.ru/index.php?page=book&id=457131 (date of access: 07/07/2023).

DEVELOPMENT OF A METHODOLOGY FOR RISK ASSESSMENT AND SELECTION OF MEASURES FOR THEIR MANAGEMENT AT THE FACILITIES LOCATED IN HIGH LANDSLIDE-PRONE TERRITORIES

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Abstract

As a quantitative measure of risk, an indicator was used simultaneously taking into account two characteristics of a landslide: 1) probability of landslide; 2) the amount of damage caused by the landslide. The probability of suffering damage from a landslide is defined as a conditional probability depending on the probability of the occurrence of an adverse event and the probability of suffering damage from a landslide caused by this event. A graphical methodology for comparing approaches for determining landslide risk parameters with and without protective measures was provided. The condition of combining the risks of various negative events was used for the assessing of integral risk magnitude. A formula was derived with known values of cost indicators for results and expenditures for determining the absolute value of the effect of implementing protective engineering measures to reduce risk at sites located in high landslide-prone territories. The measure of effectiveness was the relative indicator of accident or disaster risk reduction per unit cost of activities aimed at mitigating it.

Keywords: risk, landslide, methodology, probability, engineering measure

I. Introduction

Most of scientific studies describe the concept of "risk", along with the probability of the occurrence of an adverse event, also includes another characteristic associated with this event - the amount of damage caused. This leads to interpretation of a quantitative measure of risk as a mathematical expectation of damage determined on a set of possible adverse events (average risk values).

Assuming that the damage from the landslide is zero, no deformed and destroyed area is at risk. A similar situation occurs with zero probability of a landslide, although the possible damage from it would be enormous. The situation is perceived as dangerous, risky only in cases where the probability of a landslide and the possible damage from its occurrence are different from zero or are real in everyday understanding.

The study of problems of analysis and risk assessment of landslide processes is devoted to the work of I.T. Aitmatov, K.C. Kozhogulov and O.V. Nikolskaya [1, 2], I.O. Tikhvinsky [3], A.L. Ragozin [4], Kh.Kh.Einshtein and K.S. Karama [5], N. Jenny [6], G.P. Postoyeva [7], V.G. Tishina [8], R.I. Choudkhary and P. Felentje [9], K.Sh.Shaduntsa, S.I.Mathsia and E.V.Bezgulova [10, 11] and other researchers.

In a previously published article by the authors [12], a detailed analysis of the above works was carried out and it was revealed that the methodological approaches of various authors differ in originality. Simultaneously, a systematic approach is clearly observed in all studies. Depending on the specialization of various authors, the specifics of system approaches also change (geological engineering, geomechanical, geoecological, geotechnical and mixed), but in almost all cases, applied methods of probability theory are used to one degree or another.

As W. Morris notes [1], one of the main difficulties in management activities is the need to make decisions under conditions of uncertainty or with incomplete knowledge about the possible consequences of the actions taken.

The fundamentals of the science of managing complex systems are presented in the monographs of W. Morris [13], M. Starr [14], E.M. Khazen [15], B. Gurney [16], I.V. Prangishvili [17], S. Yang [18] and et al.

As noted by N.A. Makhutov and R.S. Akhmetkhanov [19], for optimal risk management, the systemic properties of objects and the systemic properties of risks should be taken into account. An analysis of international experience in the development and application of organizational and economic risk management mechanisms shows that there's a fairly large number of mechanisms aimed at reducing the level of risk [20, 21].

V.N. Burkov [22] studying mechanisms for managing the risk level, as is customary in the theory of active systems, believes, that the structure of ecological-economic system in which the mechanism operates is two-level. The top level is occupied by the control body. In addition, at the top level there may be one or more insurance organizations. The lower level of this system is occupied by objects whose activities pose a potential threat emergency.

II. Description of the developed methodology for determining the risk magnitude of a landslide on a landslide-prone slope

As a quantitative measure of risk, it's advisable to use an indicator that simultaneously takes into account two characteristics of a landslide: 1) the probability of a landslide; 2) the amount of damage caused by the landslide. Based on the above, the measure of slope landslide risk is the average landslide risk indicator, calculated according to the following formula:

$$R = \sum_{i=1}^{n} P_i X_i , \tag{1}$$

where P_i is the probability of damage from a landslide X_i as a result of one of the possible impacts on a landslide-prone slope; X_i – the amount of damage from a landslide, expressed in cost terms; R – quantitative measure of landslide risk (average landslide risk), expressed in the same indicators as damage; n is the number of possible damage options that can occur during various types of landslide phenomena on a landslide-prone slope.

Thus, for the purpose of determining the risk magnitude of landslide phenomena according to expression (1), it's necessary to have information expressing the correspondence of the values of P_i and X_i, i=1, 2, ..., n. In the simplest case, such information allows to determine the law of probability distribution in the space of damage from landslide phenomena.

Assuming a continuous dependence of the probability P_i on the values of damage from landslide x, we obtain

$$P_i = P(x), \tag{2}$$

and expression (1) can be presented in integral form:

$$R = \int_{-\infty}^{\infty} xP(x)dx \cdot \quad (3)$$

In general case, when damage from a landslide can occur as a result of various unfavorable and independent events (impacts on a landslide-prone slope), the average risk of a landslide occurrence (process) can be determined according to the following formula:

$$R = \sum_{i=1}^{n} \sum_{j=1}^{m} P_{ij} X_i , \quad (4)$$

where P_{ij} is damage probability of landslide X_i upon the an event occurrence (i.e. impact on a landslide-prone slope) of type j.

In the probability of receiving damage from a landslide, formula (4) is defined as a conditional probability according to the following product:

$$P_{ij} = P_j P_i (j), \quad (5)$$

where P_j is the occurrence probability of an adverse event of j type (negative impact on a landslide-prone slope), contributing to the development of a landslide, $P_i(j)$ – the probability of receiving damage from a landslide X_i with a negative impact on a landslide-prone slope of j type.

Provided that damage from various impacts on a landslide-prone slope is measured on the same scale (for example, in value terms), and taking into account formula (5), to determine the average risk of a landslide, the following formula can be used instead of expression (4):

$$R = \sum_{i=1}^{n} \sum_{j=1}^{m} P_j P_i (j) X_i . \quad (6)$$

Formula (6) represents, that P_i expresses the distribution law of probabilities of negative factors impact on a landslide-prone slope, and $P_i(j)$ – distribution laws of damage from landslides for each of such negative impacts on a landslide-prone slope.

Formulas (1) – (6) determine the average risk of a landslide on a landslide-prone slope, regardless of the activity of an object located on the slope and exposed to a landslide hazard. It's advisable to consider the system "structure + people + technology + biota" as an object on a landslide slope. In the general case, an object represented by a person (who builds, operates structures and controls technology and biota) can perform two types of activities.

1. An object located on a landslide-prone slope can take measures to prevent or reduce losses from an adverse event (this means protective engineering measures). In this case, the object itself does not affect the possibility of its manifestation. The risks of such events are called "pure risks". These measures are associated with certain costs. In this case, in the formula for the average risk of a landslide, it's necessary to link the probability of damage from a landslide $P_i(j)$ with the costs incurred to prevent (reduce) it. In this case, expression (6) will take the following form:

$$R = \sum_{i=1}^{n} \sum_{j=1}^{m} P_j P_i (j, z_j) X_i , \quad (7)$$

where $P_i (j, z_j)$ is the damage probability of a landslide X_i upon the occurrence of a negative impact of type j and protective engineering measures taken against the specified negative impact with costs z_j;

The differences in formula (6) on the one hand and (7) on the other can be illustrated by the graph presented in Fig. 1.

In Fig. 1, $P(x)$ means the distribution of losses during a slope landslide in the absence of protective engineering measures, $P[X(z)]$ is the corresponding probability when carrying out protective engineering measures.

$\Delta X = X - X(z)$ - reducing the damage amount from a landslide as a result of implementing protective engineering measures.

2. The facility may take an adventurous position in relation to the development or exploitation of a landslide-prone slope, consciously choosing a situation characterizing different probability of landslide(s) occurring on the specified slope. The facility may choose a more risky situation with a greater likelihood of damage, expecting to receive additional benefits (at the same time, the requirements of regulatory documents for the construction and operation of structures on landslide-prone slopes are partially or completely ignored). In most cases, the object relies on the concept of "may blow over." Often the object consciously tries to compensate for deliberate adventurism by insuring its investments.

The risks of this kind can be called "adventurous speculative risks." Taking into account the possibility of such a choice, the average risk of a landslide is determined on the basis of the following expression:

$$R = \sum_{i=1}^{n} \sum_{j=1}^{m} g_{ij}(V) P_j P_i(j) X_i, \tag{8}$$

where $g_{ij}(V)$ is the probability of an object choosing a situation characterized by the probability of a landslide P_i on a landslide-prone slope with a negative impact on the j-type slope.

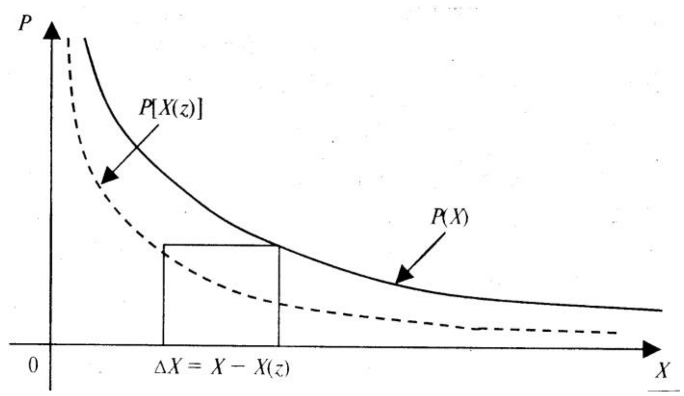

Figure 1: *Comparison of approaches for determination of the risk parameters of landslide manifestations when implementing and not implementing protective engineering measures on a landslide-prone slope*

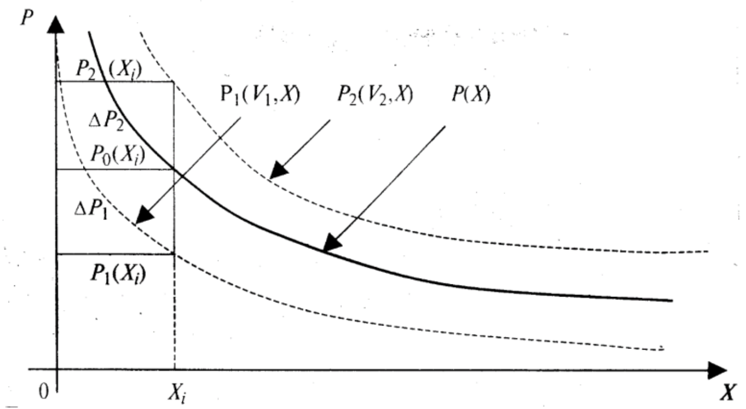

Figure 2: *Comparison of approaches for determination of the risk parameters of landslide manifestations on a landslide-prone slope in the initial state and during "adventurous" development*

The peculiarity of the approach for determining landslide risk on the basis of expression (8) can be illustrated by the graph presented in Fig. 2.

As is evident from Fig. 2, $P(X)$ means distribution law of damage from landslides in the initial state of a landslide-prone slope, $P_1(V)$ distribution law of damage from landslides in a more risky situation (adventurous approach).

As can be seen from Fig. 1 and 2, with different approaches to the development of landslide-prone slopes, it's possible to achieve various types of positive and negative risks of landslides.

III. Selection of risk management measures in high landslide-prone slope

Risk management at facilities located in high landslide risk zone is based on the developments of the general theory of risk analysis and that part of it relating to risk management [23]. In this regard, general principles and approaches are usually used when forming management decisions, the scientific justification of which is developed by the general risk theory.

It should be borne in mind that each of the listed approaches operates within the framework of a certain system of measures regulating management activities to reduce risk at facilities located in landslide-prone areas and the conditions for its implementation. According to their composition, they are divided as follows:

– regulatory measures representing the rights and obligations of parties, objects and other participants in the field of risk management;

– administrative measures related to the implementation of functions of control over the results and financial support of activities (if necessary, with enforcement of their implementation);

– economic measures involving economic stimulation of risk reduction activities at facilities located in high landslide hazard areas, the organization of its financial support, environmental and social interests of public development;

– technical measures determining the scope of possible technical solutions for reducing risk at facilities located in high landslide-prone areas, associated with the implementation of individual work aimed at protecting against the impact of the "field of damage and destruction" caused by a negative event, to reduce the potential damage and suchlike.

It should be noted that regulatory and administrative measures for risk management at facilities located in high landslide-prone areas with a generally form a set of restrictions, unconditional responsibilities for various participants in this activity, and limit the scope of their possible behavior in the socio-economic system. Effectiveness of risk management activities within this framework is determined by the correct choice of the system of permissible measures and the rational use of available economic and material resources in their implementation.

Economic results are taken into account in the vast majority of cases when developing territorial, engineering, technical and economic regulations and using administrative levers to regulate risk management at facilities located in high landslide-prone areas. If the regulatory framework and administrative framework interfere with the adoption of cost-effective decisions, as a rule, they are modified and changed as management experience accumulates.

However, in specific conditions, the management body, development of solutions in the field of risk management at facilities located in high landslide-prone areas, is always within the framework of certain legal, administrative and environmental restrictions, which it should not violate. Effectiveness of the decisions for reducing risk depends on the economic feasibility of the chosen system of management measures, taking into account these limitations.

The set of technical measures to influence risk at facilities located in high landslide-prone areas determines the space of possible solutions that can actually be implemented in each specific situation. Their composition is associated with the accessible level of scientific and technological development of society, since in market conditions the necessary equipment and technologies can be purchased practically without any restrictions, provided financial opportunities.

For the practice of risk analysis, the principle of integral hazard assessment is extremely important, according to which risk management at facilities located in high landslide-prone areas must comprehensively consider the entire range of events and the risks associated with them when developing management decisions. The fact is that negative events that cause damage and the damage themselves in real life can be interrelated.

From the point of view of theory and practice of risk assessment at facilities located in high landslide-prone areas, the simplest situation arises when considering the list of negative independent events. In this case, the integral risk R_{int} can be presented as a simple arithmetic sum of the risks from each negative event:

$$R_{\text{int}} = \sum_i R_i \ , \tag{9}$$

where R_i is the risk from the *i* negative event.

In the presence of interrelated risks at facilities located in high landslide-prone areas, expression (9) isn't suitable for assessing the magnitude of the integral risk. In certain situations this is due to risk absorption effects. Therefore, to assess the of the integral risk magnitude, you should use the formula for combining the risks of various negative events:

$$R_{\text{int}} = \bigcup_i R_i \ , \tag{10}$$

Where $\bigcup_i$ - represents the operation of combining sets.

In the case of non-overlapping risks at facilities located in high landslide-prone areas, expression (10) is equivalent to expression (9).

Note that the simplicity or complexity of the formula for assessing the integral risk at facilities located in high landslide-prone areas doesn't automatically transfer to management decisions. For example, expression (9) in no way means that managing the integral risk in each such case is reduced to a set of measures to manage each of them. It's due to the fact that risk reduction often measures at facilities located in high landslide-prone areas are aimed at blocking the main source of danger.

Taking into account the principle of integral hazard assessment when developing management measures to reduce risk at facilities located in high landslide-prone areas, in practice, can significantly complicate the solution of the problem, taking it beyond traditional optimization problems to maximum efficiency under given restrictions. As a result, in practical studies, control decisions can often be obtained on the basis of the methods, for example, simulation modeling.

It allows us to consider many different scenarios for the development of the consequences of negative events at facilities located in high landslide-prone areas, taking into account the likelihood of each, and compare them with each other in terms of consequences, complexity and effectiveness of using risk reduction methods for each of them. The most "rational" system of risk reduction measures is usually selected on the basis of such a comparison.

It should be noted that general approaches for determination of the effectiveness of any protective measures differ little in different types of life activities. All of them in one way or another involve comparison, comparison of results (*W*) achieved using the set of measures under consideration with the costs of them (*Z*).

With known values of cost indicators of results and costs, the absolute value of the effect from the introduction of protective engineering measures to reduce risk at facilities located in high landslide-prone areas may be determined according to the following formula:

$$E(Z,T) = W - Z = \sum_{t=1}^{T} \left(\sum_{i=1}^{k} W_{it} - \sum_{j-1}^{n} Z_{it} \right), \tag{11}$$

where *T* is the total operating time of the enterprise included in the project; W_{it} − result in the i direction in period *t*; Z_{jt} − costs in the *j* direction in period *t*.

Considering that the results of the implementation of protective measures in the case of pure risks manifest themselves in the form of a decrease in mathematical expectations of damage, expression (11) can be presented in the following form:

$$E(Z,T)=\sum_{t=1}^{T}\left\{\sum_{i=1}^{k}\left[\overline{X}_{it}-\overline{X}_{it}(Z)\right]-\sum_{j=1}^{n}Z_{jt}\right\}, \tag{12}$$

where $\overline{X}_{it}$ − is the average level of damage that occurred in period *t*, before the introduction of risk-reducing protective measures at the enterprise; $\overline{X}_{it}(Z)$ – the average level of damage determined after the implementation of risk-reducing protective measures at facilities located in areas with a high landslide hazard.
The index

$$\mathrm{I}(Z,T)=\sum_{t=1}^{T}\left(\sum_{i=1}^{k}\overline{X}_{it}+\sum_{j=1}^{n}Z_{jt}\right), \tag{13}$$

represents the total value of risk management costs at facilities located in high landslide-prone areas when implementing a set of control measures Z.
In the case of applying speculative risks at objects located in high landslide-prone areas, expression (11) for the assessment of the effectiveness of measures, the following relationship can be used:

$$E(Z,T)=\sum_{t=1}^{T}\left[\overline{\Pi}_t(Z)-\overline{\Pi}_t\right], \tag{14}$$

where $\overline{\Pi}_t(Z)$ is the expected average profit from an object located in high landslide-prone area in a year t if any protective measures *Z* are taken in relation to the risk, not necessarily related to its reduction; $\overline{\Pi}_t$ - expected average profit in the absence of these measures.

In general, the expected profit should be assessed taking into account the probability distribution of possible methods of operation of an object located in high landslide-prone area, the risk of losses from negative events and the costs of implementing risk management measures:

$$\overline{\Pi}_t=\overline{D}_t(Z)-R_t(Z)-\sum_{j=1}^{n}Z_{jt}, \tag{15}$$

where $\overline{D}_t(Z)$ is the expected amount of income in year *t*, when choosing a risk management strategy, is characterized by a set of costs $Z_{jt,}\ j=1,2,3,...,n;$ $R_t(Z)$ - the risk level at an object located in high landslide-prone area in year *t*, estimated by the expected average amount of damage.

Profit is determined in a similar way in the absence of measures *Z*. In a real situation, the indicators $\overline{\Pi}_t$ and $\overline{\Pi}_t(Z)$ can change places, for example, in cases where a more risky solution is deliberately chosen for an object located in high landslide-prone area in the hope of getting more profit by refusing from the implementation of known protective measures.

As a measure of efficiency, a relative indicator of reducing the risk of accidents or catastrophes at facilities located in areas with a high landslide hazard per unit cost of costs for measures to reduce it can be used:

$$E(R/Z)=\frac{R_1-R(Z)}{Z}=\frac{\sum_t R_{1t}-\sum_t R_t(Z)}{\sum_t Z_t}, \tag{16}$$

where R_1 is the risk indicator at the enterprise before the implementation of protective measures; $R(Z)$ - risk indicator at the enterprise after the implementation of protective measures; *Z* – cost of protective measures to reduce risk at the enterprise; $R_{1t}, R_t(Z), Z_t$ - values of the considered indicators in the period *t*.

Expression (16) is based on the indicators of both individual and social risk at a facility located in high landslide- and collapse-prone areas.

IV. CONCLUSION

By the authors for the first time as a quantitative measure of risk of a landslide, an indicator was used simultaneously taking into account two characteristics of a landslide: 1) probability of landslide; 2) the amount of damage caused by the landslide. It was revealed that the probability of suffering damage from a landslide is defined as a conditional probability depending on the probability of the occurrence of an adverse event and the probability of suffering damage from a landslide caused by this event. The authors have developed a graphical methodology for comparing approaches for determining landslide risk parameters with and without protective measures was provided. The condition of combining the risks a landslide by the authors of various negative events was used for the assessing of integral risk magnitude. The authors proposed the measure of effectiveness was the relative indicator of accident or disaster risk reduction per unit cost of activities aimed at mitigating it.

References

[1] Aitmatov I.T., Kozhogulov K.Ch., Nikolskaya O.V. (1999). Geomechanics of landslide-prone slopes. Bishkek, ILIM, 209 p.

[2] Kozhogulov K.Ch., Nikolskaya O.V. (2003).Assessment of the risk of landslide formation and activation during development of mountainous territories of Kyrgyzstan. Proceedings of the All-Russian Conference "RISK - 2003", Vol. 1, Moscow, Publishing House of Peoples' Friendship University of Russia, pp. 138-142.

[3] Tikhvinsky I.O. Landslide risk assessment at the regional and local levels. Proceedings of the All-Russian Conference "RISK - 2000", Moscow, Ankil, 2000, 480 p.

[4] Natural hazards of Russia. Assessment and management of natural risks (Edited by Ragozin A.L.). M., KRUK, 2003, 320 p.

[5] Einstein H.H., Karam K.S. (2001). Risk assessment and uncertainties. Int.conf. "Landslades-Causes, Impacts and Countermeasures". Davos, Switzerland, , p.457-488.

[6] Geotechnical Institute Varia 501, Linkoping, 2001, 76 p.

[7] Postoev G.P. (2003). On the issue of quantitative assessment of landslide risk. Proceedings of the All-Russian Conference "RISK-2003", Vol.2, M., Publishing House of Peoples' Friendship University of Russia, pp.48-50.

[8] Tishin V.G.(2006) Methodology for constructing a risk map for the landslide area of the city of Ulyanovsk. Proceedings of the All-Russian Conference "RISK-2006", Moscow, Publishing House of Peoples' Friendship University of Russia, pp. 219-222.

[9] Chowdhury R., Flentje P. (2003). Role of slope reliability analysis in landslide risk management. Bul. Eng. Geol. Env., 62, pp. 41-46.

[10] Shadunts K. Sh., Matsiy S. I., Bezuglova E. V. (2002). Landslide risk analysis based on probabilistic calculations. Design, construction and technical operation of buildings and structures. Collection of scientific papers of the Kuban State Agrarian University, Krasnodar, pp. 166-178.

[11] Matsiy S. I., Bezuglova E. V. (2007). Landslide hazard and risk of soil displacement on slopes. «Geoecology. Engineering geology. Hydrogeology. Geocryology», No. 6, pp. 537-546.

[12] Gabibov F.G., Mamedov F.Sh. (2008). On the state of the issue of studying the problems of analysis and assessment of the risk of landslide processes. «Ecology and water management», No. 3, Baku, pp. 67-74.

[13] Morris W.T. Management Science. Moscow, Mir, 1971, 304 p.

[14] Starr M. Production Management. Moscow, Progress, 1968, 398 p.

[15] Khazen E.M. Methods of optimal statistical solutions and optimal control problems. Moscow, Soviet Radio, 1968.

[16] Gurney B. Introduction to Management Science. M., Progress, 1969, 430 p.

[17] Prangishvili I.V. Entropy and other systemic patterns: Issues of complex systems management. M., Nauka, 2003, 428 p.

[18] Young S. Systemic management of the organization. M., Sovetskoe radio, 1972, 456 p.

[19] Makhutov N.A., Akhmetkhanov R.S. (2012). Systems approach to risk assessment and management// Problems of safety and emergency situations, No. 5, pp. 56-68.

[20] Burkov V.N., Gratsiansky E.V., Dzyubko S.I., Shchepkin A.V. Models and mechanisms of safety management. M., Sinteg, 2001, 160 p.

[21] Burkov V.N., Novikov D.A., Shchepkin A.V. (2009). Economic mechanisms for managing the level of risk in the natural and man-made sphere// Problems of safety and emergencies, No. 4, pp. 30-39.

[22] Burkov V.N., Novikov D.A., Shchepkin A.V. Mechanisms for managing ecological and economic systems. Moscow, Fizmatlit, 2008, 243 p.

[23] Vladimirov V.A., Izmalkov V.I., Izmalkov A.V. Risk assessment and management of technogenic safety. Moscow, FID "Business Express", 2002, 184 p.

THE GEOLOGICAL RISK OF CHANGING THE PARAMETERS OF THE RESERVOİRS DEPENDING ON THE DEPTH IN A NUMBER OF FIELDS OF THE BAKU ARCHIPELAGO

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Absract

Geological risk belongs to the doubt and variableness of the reservoir characteristics and internal structure, like as porosity, permeability, heterogeneity, thickness, faults, crucks, and seals. These characteristics identify the amount and quality of the hydrocarbons in deposits, as well as the recovery coefficient and the production rate. Geological risk possible to reduce by acquiring and analyzing more data, like as seismic, well logs, core sampling, and producing history. In addition, by using suitable methods and models to assess the range of possible outcomes.

So, this paper discusses the results of studying terrigenous Mesozoic and Cenozoic rocks of the Sangachal-deniz-Duvanny-deniz-Khara-Zira oil and gas bearing region of the Baku archipelago element of the South Caspian depression as possible reservoirs of oil and gas, its characteristics and geological risk in changing of reservoir parameters [1].

To explain the nature of the change in rocks by depth, graphs of the dependence- dependence of porosity on depths were plotted.

The depth of occurrence of these rocks along the well sections varies from several hundred meters (Khara-Zira field) to 5500-6000 m (Sangachal-deniz, Duvanny-deniz fields). The wells uncovered rocks from the Quaternary to the middle Miocene (Chokrak). Well sections are represented by alternation of sands, sandstones, dolomites and clays. The wells completely uncovered the section of the Productive Series (PS). The maximum thickness of the PS in the Sangachal-deniz field and in the north-east part of Khara-Zira is 3950-4000 m. Hypsometrically elevated parts of the Sangachal-deniz and Duvanny-deniz structures, the thickness of the PT varies within 2960-3600 m. The minimum thickness of the PS was discovered by wells in the southwestern limb of the Sangachal-deniz uplift up to 3000 m.

The type of structure is brachianticline, which are associated fields. The arch part is fragmented by faults into blocks that these blocks are oil and gas-condensate. In the oil of the field, the amount of resin is 8-27%, asphaltene mass- 0.2-1.1%, paraffins- 6.0-20.1%. The content of light fractions, which have a boiling point of up to 300° C, varies between 31.4-40.0%, gasoline- 4.5%, naphtha- 12.1%. The hydrocarbon composition of oil is noted in the following order: methane- 52.1-66.8%, aromatic hydrocarbons- 12.2-21.5%, naphthenes- 12.3-35.1%. The density of reservoir oil ranges from 0.729 to 0.780 g/cm^3, and the density of degassed oil is 0.869-0.889 g/cm^3, condensate 0.759-0.797 g/cm^3.

The results of determining the porosity of samples taken from drilled wells were used, in addition, the density and permeability of rocks were studied by mechanical analysis of numerous samples. The porosity of the studied samples varies from 1.5 to 38%, the density in wet samples varies from 1.72 to 2.97 g/cm^3, and in dry samples from 1.72 to 2.97 g/cm^3, permeability - from 0 to 863·10^{-15} m^2. But at some depth, the permeability reaches 1910·10^{-15} m^2.

Keywords: porosity, permeability, mechanical analysis, section, clay, graphs of the dependence, sandy-silty rocks

I. Introduction

The Baku archipelago covers a large water area in the southwest part of the Caspian Sea [2, 3, 14, 18]. Ttectonically, it is the continuation of the South Gobustan and Lower Kura depressions toward the sea. Khara-Zira, Zanbil, Sangi-Mugan, Garasu, Gil, Kurdashi, Daşlı islands and many underwater salses such as Umid, Babek, Yanan Tava, Ateshgah, Mugan-deniz, etc. is known here that formed by the activity of mud volcanoes [11, 22]. Most of the deposits discovered here are related to mud volcanoes, for instance, Khara-Zira, Sangachal-deniz, Sangi-Mugan, Garasu, Duvanni-deniz, Kurdashi, Daşlı and etc. (Fig. 1).

The Sangachal-deniz-Duvanni-deniz-Khara-Zira island oil-gas-condensate field, which is related to the structures discovered in the northern part of the archipelago, is located 50 km southwest of the Baku city [3] (Fig. 2).

Since 1935, geophysical exploration (gravimetric, electrical exploration, aerial photoplanning, seismic exploration), structural and structural-prospecting drilling has been carried out in the field. Since 1951, the field deep exploration drilling have been involved. As a result of the conducted works, the geological structure of the field was studied, oil-gas-condensate horizons were discovered.

The oil content of the field was confirmed in 1963 by testing in well 24, drilled in the limb of the Duvanni-deniz structure. Here, primarily, an oil gush with a flow rate of 250 t/day was obtained from the VII horizon of the Productive series. In 1965, 150 t/day of oil was obtained from this horizon in the Sangachal-deniz structure, for this year, 300 000 m^3/day of gas was obtained from the VIII horizon in well 29 in the Duvanni-deniz field. İn 1974, 200 t/day of oil was obtained from the V horizon in well 361. Until 1995, 158 exploratory wells were drilled in the field, most of which are [3, 5].The oldest sediments are of middle Miocene age in the well section. The top of well sections are represented by Productive series, Absheron, Aghjagil and Quaternary [3].

This deposit as a whole was formed on the anticlinal belt created by local structures of Sangachal-deniz, Duvanni-deniz and Khare-Zira Island, complicated by the regional fault extending from the northwest to the southeast from the tectonic point of view. The studied deposit is represented by a single structure- brachyanticline, extending in the northwest-southeast direction along the VIII horizon and measuring 30x11 km. Transitional parts of local structures are manifested by densification of isohypses (Fig. 2).

The Sangachal-deniz local structure, which is separated from the Kanizadag structure by a long and shallow saddle, and from the Duvanni-deniz structure by a short and shallow saddle, has an asymmetric structure and a dome shape.

The Duvanni-deniz structure is complicated by a mud volcano. Its northeastern limb bend under the 45-50^0, and the southwest limb inclined under 35-40^0 dip angle.

The arch part of the Khara-Zira island structure is compounded by the mud volcano of the same name.

A longitudinal tectonic fault passes through the arch parts of the structures that make up the deposit as a whole. This fault is revers type in Sangachal-deniz area, and normal fault type in Duvanni-deniz area. This fault, which complicated the field, caused the northeast limb of the Sangachal-deniz structure to rise with an amplitude of 200-600 m, and the limb of the same name of the Duvanny-deniz structure to descend with an amplitude of 500-1400 m. The fault, which complicates the structures along its longitudinal axis, diverges into two tectonic faults with an amplitude varying from 30 to 150 m towards the southeast. As a result, the structure is divided into three parts: the northeast limb, the central part, and the southwest limb [3] (Fig. 2).

Figure 1: *Location scheme of fields and local uplifts of Baku archipelago*

II. Analysis of the problem

Porosity, as well as permeability, are considered to be one of the most significant indicators when determining the reservoir properties of terrigenous sedimentary rocks. The values of these properties are known to depend on a number of factors, such as the substantial and granulometric composition, the degree of sorting, the nature of the location of the clastic particles, the occurrence depth, the degree of compaction, the connection of pore spaces, the size of the particles, the structure and texture, and others.

The main components of the described rocks are sand, sandstone, siltstone, aleurolit, chlidolite and clay. The effect of specified rocks on the values of porosity and permeability is different depending on the size of the grains.

In accordance with this, during studying the relationship between reservoir properties and the composition of rocks, the following components were distinguished, which have different effects on the studied parameters.

- fraction of sand and coarse-grained siltstone, which is larger in the range of 0.1-0.01 mm. The presence of these fractions is favorable for reservoir properties [14].
- fraction of clay, medium- and fine-grained siltstone, fraction finer than 0.01 mm. They relatively weakly affect the values of porosity, but sharply reduce the permeability of reseroirs.
- the insoluble rock part, represented mainly by chlidolite. It reduces porosity and permeability.

III. Discussion of the problem

In the geological level of connections between porosity and permeability, there are opposite views. Some researchers argue that there is a direct dependence between them, and other researchers, on the contrary, deny this connection. It should be noted that the porosity and permeability of reservoir rocks depend on lithology, on the structure of the pore space, the depth of collection thicknesses and at the same time from cementing materials. To clarify the connections between these properties of rocks, it is necessary to take into account the composition of the latter. Thus, the cross section of the area under the study is mainly consists well-sorted sandstone-aleurolits, clayey-sandy, clayey-aleurolit-sandstones. Didn't consider some depth intervals they have high porosity and permeablity. However, in the depth intervals with low porosity and permeablity the percentage of cement materials is observed in the study area. Thus, by the large content of cement materials (over than 20%) the permeability don't dependence from porosity, while these rocks in most cases practically permeable due to secondary porosity, faults with less scale amplitudes, forming under the influence of over lying rock strata and compressing stresses [10].

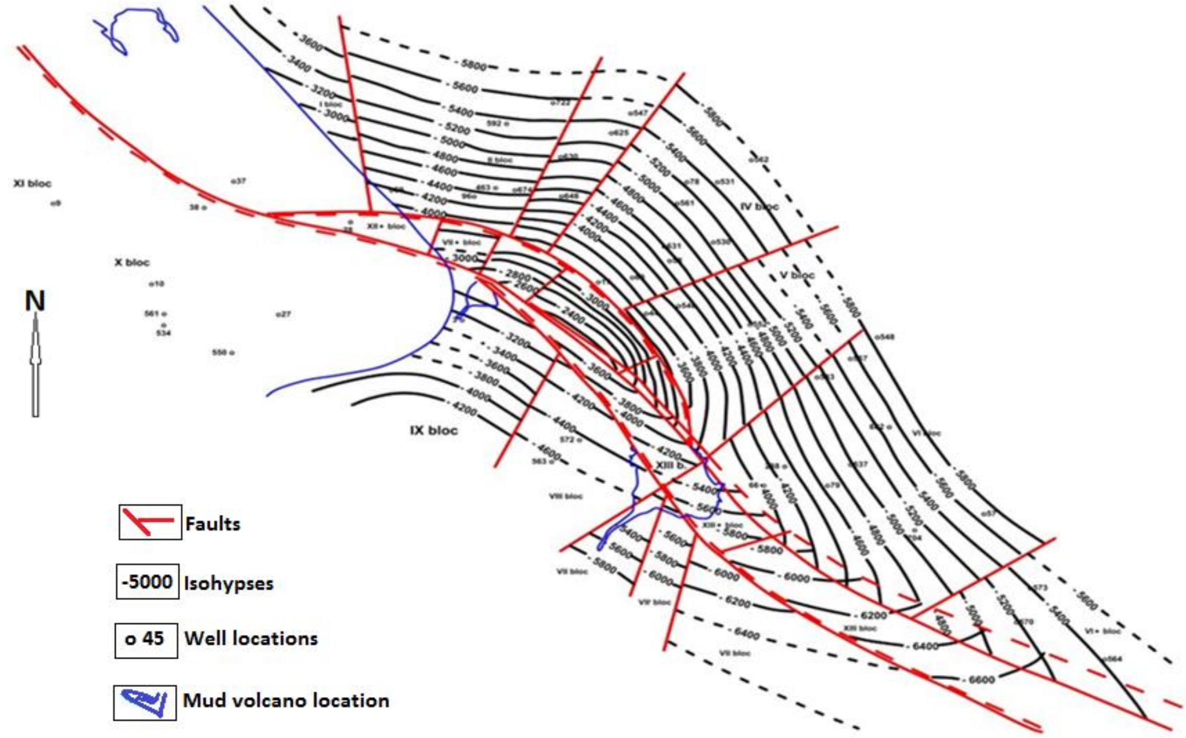
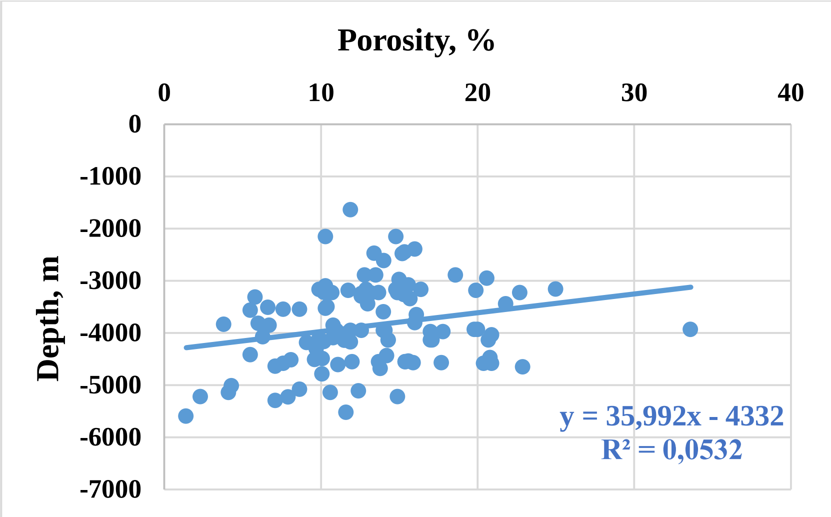


Figure 2: *Structure map of the Sangachal-deniz-Duvanni-deniz-Khara-Zira field*

IV. Methods

One of the structures of the research area is Sangachal-deniz field. In the sections of wells drilled in this field, clayey-silty sandstones, clayey-silty sandy loams, clayey-sandy aleurolits and clayey aleurolits are distinguished by relatively high porosity [3, 17]. The porosity of these deposits varies within the range of 5.5-22.9%, 5.5-33.6%, 2.3-20.4%, 3.8-20.7%, respectively (Fig. 3).

With a higher content of clayey aleurolit particles, porosity decreases to 4-15% with the exception of depths of 3164 and 4140 m. At these depths, rock porosity is 22.9% and 20.7%, respectively. Apparently this is due to the compaction and fracturing of clayey rocks under the load of the overlying ones. Due to present a sufficient percentage of chlidolite by depth, the porosity is reduced to 5.5%, with the exception of rocks with a high degree of sorting of terrigenous material. Along the section from top to bottom, clayey-sandy subaleurolits with a porosity of 11-21% are observed with a higher content of the fraction finer than 0.01 mm in the range of 12.0-20.9%. The carbonate content of rocks varies between 2.3-15.0%, but there are exceptions. At a depth of 4302-4610 m, the carbonate content of chlidolites and aleurolit-clayey sandy loams is expected to increase, reaching values of up to 33.4-35.8%. Such a situation could not affect the porosity and permeability of rocks; they are almost impermeable.



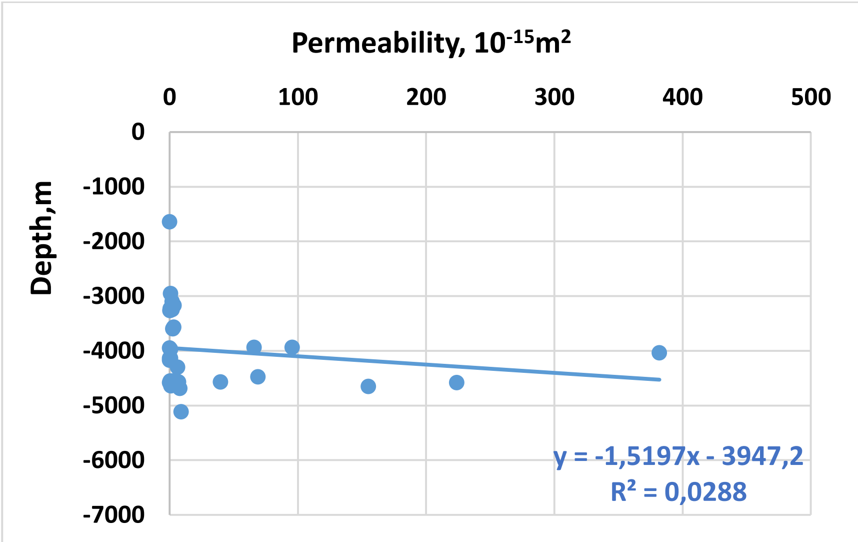


Figure 3: *Graph of the dependence of rock porosity and permeability on the occurrence depth in the Sangachal-deniz field*

In the Duvanny-deniz field, the rocks that make up the section, with the exception of some occurrences, are highly porous. The porosity of clayey-silty sandstones varies within 17-34%, while the porosity of clayey-silty sandy loams, clayey-sandy aleurolits and clayey aleurolits varies within 16-25%, 18.0-30.0% and 30.3-23. 0% accordingly. Despite the fact that the content of the fraction finer than 0.01 mm is 63%, the porosity in most cases is over 17%. The distinctive nature of the field section is noted at a depth of 3632 m, where porosity and permeability are higher (23% and $541 \cdot 10^{-15}$ m^2, respectively) (Fig.4). As noted above, this depends on the degree of fracturing of the rocks composing the field section. It should be noted that under this condition, the permeability of the rock is higher and amounts to $166\text{-}167 \cdot 10^{-15}$ m^2; in some cases, the permeability value reaches up to $266\text{-}294 \cdot 10^{-15}$ m^2 due to the appearance of additional cracks with depth in the rocks.

Manifestations of the chlidolite fraction smaller than 0.01 mm negatively affect the permeability of rocks, so that the permeability decreases to $42 \cdot 10^{-15} m^2$, even in some cases to $2.2 \cdot 10^{-15} m^2$. The distinctive character of the Duvanny-deniz field section is the presence of silty-sandy loams (fractions finer than 0.01 mm are 45.3%), which has a bad effect on the permeability of rocks.

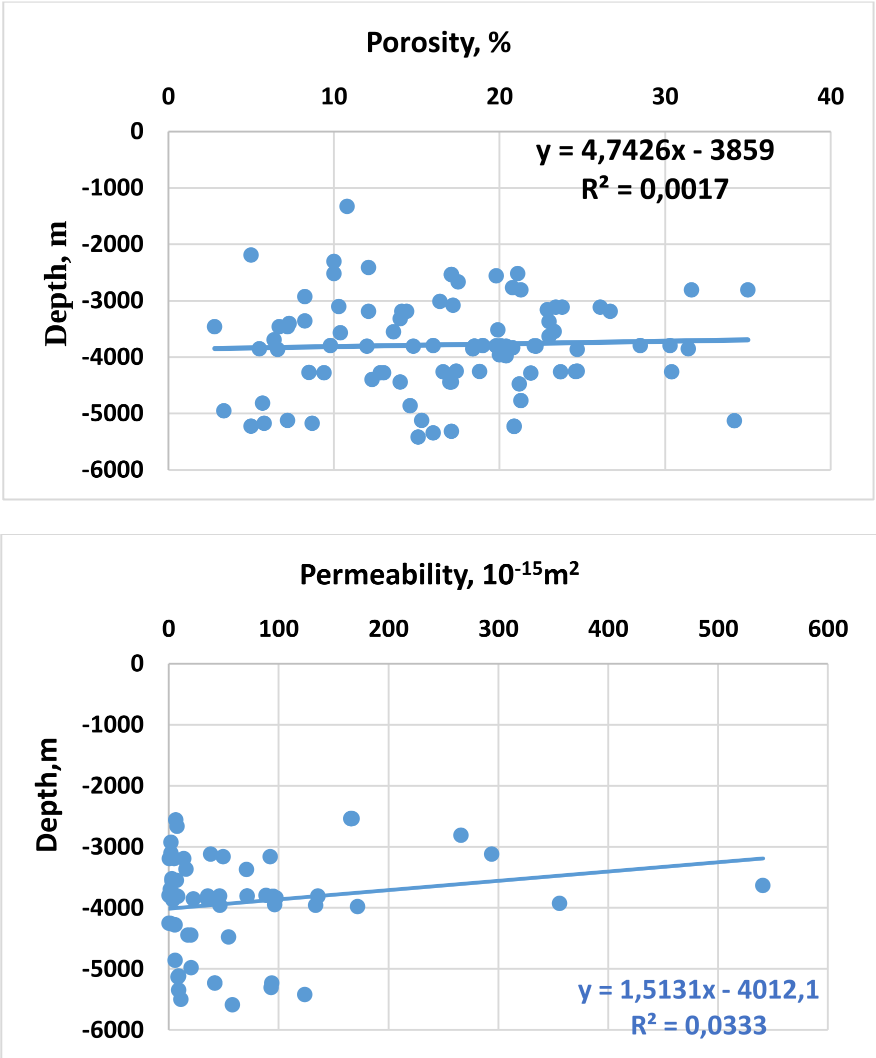


Figure 4: *Graph of the dependence of rock porosity and permeability on the occurrence depth in the Duvanny-deniz field*

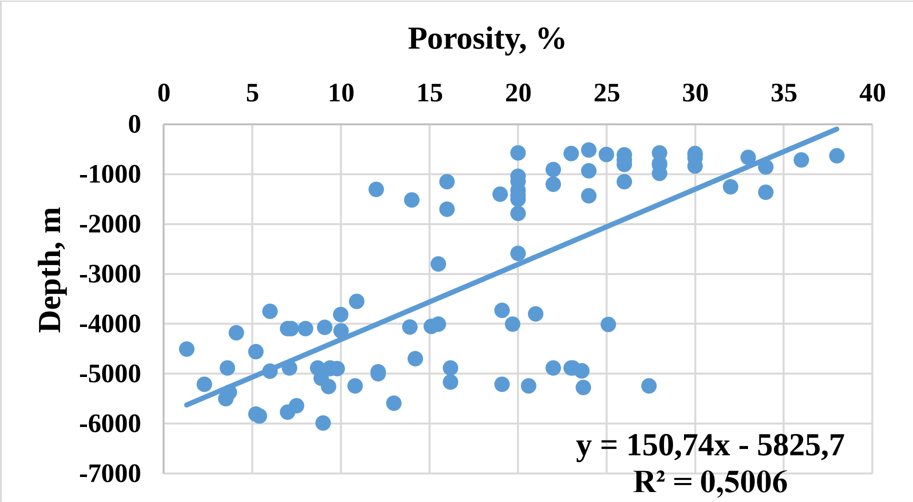
With the exception of some depths along the section from top to bottom, clayey-sandy subaleurolits with a porosity of 12.0-20.8% are observed with a higher content of the fraction finer than 0.01 mm (35.5%) in the range of 5.0-9.0%.

The carbonate content of sediments along the section of the field varies from 4.2% to 25.4%.

Deposits of the Productive series, deposits of the Absheron and Gadim Khazar stages are wide spread along the Khara-Zira field [3, 16]. The section of the structure consists of rocks similar to previous fields.

In all cases, terrigenous rocks are permeable. The permeability of rocks along the section of the area varies between of 0.1-267·10^{-15} m^2 with the exception of some depth intervals. Analysis of core materials taken from great depths (4982-4988 m) showed that despite the presence of clay fractions, the permeability of reservoirs (sands and sandstones) varies in a wide range of 132-1910·10^{-15} m^2, which is an indicator of a high degree of sorting of reservoir rocks, as well as fracturing of clayey deposits. In this case, the porosity of the rocks is 16.2-23.1%. The porosity of clayey-silty sandstones and clayey aleurolites along the field section ranges from 23-34% and 28-38%, respectively (Fig.5).

From the above it follows that the amount of clayey-sandy aleutolites and clayey rocks varies for different fields. At the same time, the physical properties of these rocks vary in a wide range [15]. This difference is shown to be due to varying degrees of compaction and occurrence depth of the sediments. Lithological differences in sediments are compacted to varying degrees under the same geological conditions. With depth, the clays compact at first very quickly, then slowly. It should be noted that in some places this pattern is violate; compaction accelerates and then slows down. Sandstones and coarse-grained aleurolites containing other small fragments are compacted to a lesser extent, and their porosity is reduced by an average of 2-3% for every 700-800 m.



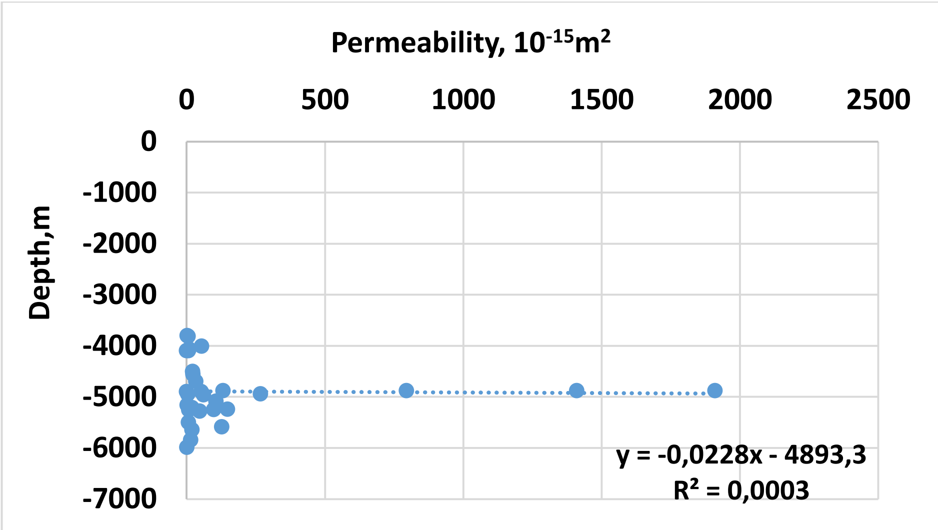


Figure 5: *Graph of the dependence of rock porosity and permeability on the occurrence depth in the Khara-Zira field*

As can be seen from the plotted graphs, the relationship between rock permeability and burial depth is less clear, but in general the pattern remains the same- the greater the burial depth, the lower the permeability of terrigenous rocks (see, Fig. 2, 3, 4).

V. Conclusions

1. Depending on the depth, the increase in the density of rocks under the influence of geostatic pressure leads to a decrease in their porosity and permeability. Compaction of different types of rocks occurs with unequal intensity.

3. At great depths (over 4900 m), due to subsidence in sands, sandstones and clayey sandstones, a very wide range of changes in porosity and permeability is observed in the Khara-Zira deposits. This circumstance is an indicator of industrial accumulation and must be taken into account when assessing the prospects for oil and gas potential.

4. There is no regulation in changes in porosity and permeability with depth, which is associated with the lithology of the rocks.

5. With increasing burial depth, porosity increases in places. This is due to the fracturing of rocks under the load of overlying rocks.

6. The cementing material (carbonate content, chlidolite fraction, tiny particles, loam, sandy loam) greatly affects the permeability and porosity of terrigenous rocks, and at different depths it varies. The greater the depth of the rocks, the less cement they must contain in order for them to be permeable.

Reference

[1] Gurbanov, V.Sh., Sultanov, L.A., Valiev, S.A., Babaeva, M.T. (2015). Lithological-petrographic and reservoir characteristics of Meso-Cenozoic deposits in the northwest part of the South Caspian depression. *Geology, prospecting and exploration of oil and gas fields*, 17, 5-15. DOI: 10.15593/2224-9923/2015.17.1.

[2] Gahramanov, G.N. (2015). The main reasons for the failure of prospecting and exploration work in a number of areas of the Baku archipelago. *Geology, prospecting and exploration of oil and gas fields*, 2(39), 33-37.

[3] Mukhtarova X.Z., Nasibova G.J., Ganbarova Sh.A. (2023). Reservoırs and traps]. *Textbook*, 287.

[4] Mukhtarova, X.Z., Nasibova, G.J., Jafarzadeh R.F. (2021). The influence of tectonic factors and seal rocks on the oil and gas potential of the southern part of the Absheron archipelago. // Multidisciplinary Scientific Journal, 1 (51), 9-16. https://rsglobal.pl/index.php/wos/issue/archive.

[5] Mukhtarova, X.Z., Nasibova, G.J., (2022). The mechanism of formation and prospects of non-structural traps in the South Caspian megadepression. // Geology, Geography and Geoecology, 31(3), 529-538. doi:10.15421/112249.

[6] Mukhtarova, X.Z., Nasibova, G.J., (2023). Geodynamic regime and prospects for oil and gas potential in the South Caspian Basin. // Geology, Geography and Geoecology, 32(3), 352-359. DOI: https://doi.org/10.15421/112349

[7] Mukhtarova, X.Z., Nasibova, G.J., (2023). Prospects for the oil and gas potential of the sedimentary strata of the South Caspian Basin according to paleotectonic and geodynamic criteria. *Geology, Geography and Geoecology*, 32(1), 153-.163. doi:10.15421/112315.

[8] Makhous, M., Galushkin, Yu.I. (2005). Basin analysis and modeling of the burial, thermal and maturation histories insedimentary basins. *Paris: Editions Technip*, ISBN: 2-7108-0846-3.

[9] Nasibova, G.J., Mukhtarova, Kh.Z., Ganbarova, Sh.A., Zeynalova, S.A., Ismayilova, M. M. (2023). The influence of compressive stresses on folding in the Middle Kura depression and the Turkmen shelf. // Journal of Geology, Geography and Geoecology, 32(2), 352-359. doi:10.15421/112332.

[10] Narimanov, N. R. (2008). The influence of geodynamic processes on oil and gas formation in the South Caspian depression. // Azerbaijan Oil Economy, 8, 1-7.

[11] Narimanov, N. R., Babayev, N. I., Gahramanov K. N., Cavadzadeh Z. (2018). Cenozoic stage of development of local structures of the Lower Kura depression and Baku archipelago related to their oil and gas prospective. // London, Geological Journal, 1-12, DOI: 10.1002/gi.3304.

[12] Narimanov, N. R. (2003). Oil and gas generation of South Caspian depression. // Azerbaijan Oil Economy, 7, 1-7.

[13] Guliev, I. S., Kerimov, V. Yu., Osipov, A. V., Mustaev, R. N. (2017). Generation and accumulation of hydrocarbons in the conditions of great depths of the earth's crust. *SOCAR Proceedings*, 1, 4-16. DOI:10.5510/OGP20170100302

[14] Hasanov, A.B., Ganbarova, Sh.A. (2021). Distribution characteristics clay content in the section of SCB (for example, the Hamamdag-deniz-Nakhchivan field). Baku, // News of Azerbaijan technical educational institutions, Volume 23, No 3, 12–16.

[15] Ganbarova, Sh. A., Kerimov, V. M. (2022). Assessment of the relationship of reservoir properties of hydrocarbon fields in the Lower Kura depression (Kursengi and Southern Kursengi areas). // Journal of Geology, Geography and Geoecology, 31(2), 223-232. DOI: https://doi.org/10.15421/112221

[16] Hasanov, A.B. Paşayev, N.V., Karimov, V.M. Ganbarova, Sh.A. (2023). Assessment of the deep oil and gas bearing potential onshore in the west of Azerbaijan (Tarsdallar area). // Journal of Geology, Geography and Geoecology, Vol 32(1), 36-43. DOI: https://doi.org/10.15421/112304

[17] Kerimova, K. A. (2023). Study of petrophysıcal parameters of productıve serıes by use of well data. // Geophysical Journal, 3, vol 45, 135-142. https://doi.org/10.24028/gj.v45i3.282421

[18] Kerimov, K. M., Rahmanov R. R., Kheirov, M. B. (2001). Oil and gas contet of South Caspian megadepression. Baku, Publishing house "Adiloglu", 316.

[19] Guliyev I. S., Kerimov V. Y., Mustaev R. N., Bondarev A. V. The Estimation of the Generation Potential of the Low Permeable Shale Strata of the Maikop Caucasian Series. / SOCAR Proceedings. 2018. No.1. pp. 4–20.

[20] Gurbanov V. Sh., Narimanov N. R., Sultanov L. A., Babaev M. S. Geological structure and reservoir properties of meso-cenozoic depositsof Dzharly-Saatli oil and gas region at great depths. Izvestiya Uralskogo gosudarstvennogo gornogo universiteta. 2016. No. 2(42). pp. 25–27.

[21] Gasanov A. B., Gakhramanly S. M. Petrophysical features and recovering prospects of the "Pereriva" formation at the Gunashli deposit in Azerbaijan. // Tochnaya nauka. 2019. No. 51. pp. 19–26.

[22] Gasanov A. B., Kyazimov R. R., Mamedova D. N., Mutallimova O. M. Variations in reservoir pressure, permeability and porosity in the deep South Caspian oilfields. // Trudy Instituta geologii Dagestanskogo nauchnogo tsentra RAN. 2016. No. 66. pp. 242–247.

[23] Ali-zade A. A., Akhmedov G. A., Akhmedov A. M., Aliev A. K., Zeynalov M. M. Geology of oil and gas reservoirs in Azerbaijan. Moscow : Nedra, 1966. 392 p.

OPTIMIZATION OF THE ECONOMIC POTENTIAL OF THE ENTERPRISE ON THE BASIS OF A STRATEGIC DECISION-MAKING MATRIX

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Abstract

The article is devoted to the issues of modeling the optimization of economic potential of the enterprise on the basis of matrix algorithm of decision-making. The article considers the final stage of algorithmization of system-scenario multifactor modeling of optimization of economic potential on the basis of strategic decision-making matrix, which includes analytical tools for point positioning of the level of economic potential development in the context of variability of complex analytical scenarios of growth of potential-efficiency of the enterprise taking into account the factors of globalization and international integration.

At the enterprise level the optimization strategic task of economic potential management is solved, which provides for the use of more detailed decomposition of economic potential, a wide range of indicators taking into account the specifics of the enterprise's activity, accurate determination of the values of the elements of potential. The development of economic and mathematical model of economic potential management at the level of textile industry enterprises is made in accordance with the general theory of systems.

In order to optimize management, modeling interactions between the parameters of the economic potential of textile enterprises is an effective management tool and relates to solving the task of targeted management related to the multilevel system of private criteria, their unequal value, the need to simultaneously take into account both quantitatively and qualitatively specified indicators of private potentials. Based on this definition, further modeling of economic potential and methods of its analysis are possible.

The model experiment allowed us to develop a scenario series of optimization of economic potential according to the criterion of growth potential-efficiency of its development level in the future; to carry out typologization of the description of functional tools of market strategies.

Keywords: economic potential, matrix, dynamics, development, potential-efficiency, index, optimization, strategic scenario, means of scenario development

I. Introduction.

The development of the theory and practice of system optimization modeling of the economic potential (EP) of microeconomic objects is considered an urgent direction of designing an information and analytical decision support system (IA DSS). In this context, the microeconomic system is considered as an object possessing dynamically developing economic potential and having the result of its level of development, quantifiably measured by potential efficiency.

Economically competent use of the EP optimization theory allows you to anticipate changes in the target indicators of its development.

The purpose of the study is to develop the optimization of the EP of microeconomic systems based on the strategic decision-making matrix integrated into the IA DSS of the enterprise.

The tasks are set: to develop the format of a strategic matrix for managing the development of economic potential in a system of indicators of market and factor potentials (a two-dimensional model of the efficiency of using the level of economic potential); to deduce the threshold values of the integral index of market potential in the procedure of typology of enterprises; to present conceptual approaches to diagnostics based on the matrix of management decisions in the subsystem for developing strategic scenarios.

II. METHODS AND MATERIALS

The EP optimization model goes through a number of stages of algorithmization of analytical information processing, the final of which is the positioning of the level of development of the economic potential of microeconomic systems in the matrix of decision-making strategies. This stage of the IA DSS design algorithm in the subject area of EP optimization is preceded by the following blocks: a hierarchical model of a multi-criteria assessment of economic potential, which includes five levels of disaggregation of a generalized target criterion; fuzzy mathematical modeling and multi-criteria analysis of the market and factor potentials of microeconomic systems; mathematical modeling and analysis of the dynamics of integral indicators of the level of EP development in decomposition; econometric mathematical model and multifactorial correlation and regression analysis of EP optimization.

Economic and mathematical information processing based on the strategic decision-making matrix provides for setting goals, directions and criteria for the development of the EP microeconomic system; designing a matrix of decision-making strategies with subsequent positioning of the level of development of the EP microeconomic system; effective implementation of complex data analysis scenarios based on optimizing the pace and proportions of the development of integral indicators of market and factor potentials with step-by-step detailing of production, human resources, innovation and investment potentials; design of a DSS for optimizing the EP of a microeconomic system of fuzzy data analysis scenarios.

The target vector of optimization of the EP microsystem of the enterprise in the study provides for ensuring its sustainable development in the long term: increasing investment and export attractiveness, increasing the efficiency of using EP (based on the criterion of intensification) for all elements of decomposition; the criterion of EP development is focused on the outstripping growth of the integral indicator of market potential relative to the growth rate of the integral indicator of factor potential, provided an optimal combination of production, personnel, innovation and investment potentials; building up innovative and investment potentials in accordance with the design and target vector of EP development; system-scenario multifactorial modeling of EP optimization taking into account the factors of globalization and economic integration (points of growth of integration ties in the format of the Union State, the Eurasian Economic Union).

The matrix of EP optimization strategies at the micro-level of the enterprise is designed based on the selected decomposition of the EP, the hierarchy of structural elements, a sufficiently deep format for detailing the estimated parameters of the level of development of the EP, the characteristics of internal and external factors. Integrated indices of market potential development (characterizes the market effectiveness of using the EP system, taking into account the dynamics of the enterprise's market share under the influence of factors of globalization and integration) and factor potential generated on the basis of indices of the development of production, personnel, innovation and investment potentials (characterizes the dynamics of resource capabilities of the EP systems that ensure the production competitiveness of products and the rating of their positioning in the market).

The author's matrix of decision–making strategies has the property of a high degree of detail and sensitivity of the dimensional scale of the quadrants in accordance with the coordinate points of the selected indicators: a dependent variable is an integral indicator of the development of market potential, an independent variable is an integral indicator of the development of factor potential; implements the relationship "the level of development of the EP – the efficiency of the use of the EP – the effectiveness of the functioning of the microeconomic system".

The positioning of the EP development level at the enterprise level is detailed taking into account the developed information and analytical environment in the matrix field of coordinates: the typologization format is tied to the boundaries of the 16 quadrants of the matrix (high level of development, above average level of development, below average level of development, low level of development). Each quadrant of the matrix is subject to economic interpretation in accordance with a combination of interval values of integral indices of market and factor potentials, given in the graph of characteristics of the zones of the field of the strategic decision-making matrix.

For each type of interval values of integral indices, taking into account external and internal factors, a vector of scenarios for the development of EP was selected and a market strategy for optimizing EP was adapted. The concept of diagnostics based on the decision-making matrix in the subsystem for the development of strategic scenarios for the development of EP includes the specification of: quadrant zones; typology of the microeconomic system according to the intervals of values of integral indices of EP; characteristics of the zones of the field of the strategic matrix according to the values of indicators; the content of the strategy and the vector of scenarios for the development of EP, taking into account the balance of the indicators of the matrix.

In the conducted research, the IA DSS optimization of the EP was carried out on the basis of the use of strategic scenarios in the following areas: pessimistic and optimistic. The format of the pessimistic scenario reflects the target indicators of EP development in quadrant a) (normalized indices of market and factor potentials, respectively, Irp [0÷0.5]; Ifp [0÷0.5]); optimistic scenario – in quadrant b), d), c) (normalized indices of market and factor potentials, respectively, Irp [0.5÷1.0]; Ifp [0.5-1.0]).

The starting point for scenario design is the position of the enterprise's EP development level in the coordinate system of the strategic matrix in the reporting period (the state of the EP at the endpoint of the dynamic series). The projected trajectory of movement in the strategic field of the matrix is set in accordance with the chosen EP optimization strategy and the variability of scenarios based on the genetic and target development options. The criterion of the positivity of the development of EP potential is the target integral indicator of economic potential, the increase of which corresponds to the increase of EP, taking into account the factors of globalization of production and interregional integration.

III. LITERATURE REVIEW

The study was based on the analysis of the works of Andreychikov et al. (1998), Bruskin (2016), Zadeh (1976), Mereste (1982), Chegerova (2021), Diligensky et al. (2004), Saati (1991), Kerns (1991), Savitskaya (2023), Finogenko (2017) in the field of system analysis, information and analytical system design and decision theory. The theory of market management strategies is considered in the works of Kuroedov et al. (2007). Some methodological aspects of economic potential assessment have been studied by scientists: Afinogenov et al. (2019), Khvorostov (2005), Gorbunova (2014), Vapne (2019), Gonin et al. (2014),), Sheshukova et al. (2013), Shcherbakov et al. (2019), Kovalev et al. (2006), Morozova (2009), Mogilina (2015), Nizamutdinov (2017), Peshkova (2017), Pisareva (2018), Rakhmanova (2018), Tashkinov (2018), Terekhova-Pushnaya (2019), Podolsky et al. (2020), Yarygina (2016), Gurieva (2018), and others.

The lack of a systematic theoretical and methodological approach to mathematical modeling of dynamic processes of the state and changes in economic potential, providing a genetic format for optimizing its development, actualizes the tasks of scenario modeling of optimization of EP enterprises.

IV. RESULTS AND DISCUSSION

The information base of the model experiment was the reporting data of textile industry enterprises: 56 factors were identified, rolled up on the basis of the fuzzy modeling method into integral indices of market, production, personnel, innovation and investment potentials with access to global factor potential (Table 1); a polynomial regression relationship between market and factor potentials was established, which was used to calculate target indicators in enterprise EP optimization scenarios.

The structural model of IIP quality in the cluster of analyzed textile industry enterprises showed a fairly high spread of integral parameters of local potentials (for example, the spread of the level of the integral indicator of investment potential development by enterprises for 2019-2023 was stated from

0.0014 (enterprise 3) to 1.0059 (enterprise 1). The average annual rate of change in the integral indicators of market and factor potentials in the decomposition indicated imbalances in the dynamics and prospective scenario development of the EP.

Table 1: *Structural dynamic model of quality of EP of textile industry enterprises*

Time series (year)	An integral indicator of market potential	Integral indicator of factor potential including decomposition elements			
		production	personnel	innovation	investment
Enterprise 1					
2014	0,6246	0,3082	0,6535	0,6358	0,7400
2015	0,6029	0,2399	0,5894	0,7403	0,6568
2016	0,5248	0,2023	0,2357	0,8469	0,5105
2017	0,4360	0,3431	0,2484	0,9218	0,4545
2018	0,5845	0,3849	0,4371	0,9710	0,7583
2019	0,5635	0,4241	0,4788	0,6321	0,5297
2020	0,4475	0,2457	0,3690	0,7465	0,3352
2021	0,5775	0,5482	0,3787	0,7993	0,7583
2022	0,6553	0,8632	0,7225	0,7139	1,0059
2023	0,6460	0,8052	0,6743	0,8741	0,5632
The average annual rate of change, %	100,38	111,26	100,35	103,60	97,01
Enterprise 2					
2014	0,5067	0,6239	0,2518	0,5182	0,6105
2015	0,4384	0,2774	0,2177	0,5347	0,6185
2016	0,3871	0,2396	0,1978	0,6709	0,8561
2017	0,4100	0,4986	0,2238	0,7478	0,8990
2018	0,4356	0,4863	0,2492	0,6786	0,7815
2019	0,4319	0,5581	0,2052	0,6598	0,7142
2020	0,3707	0,2946	0,1896	0,6315	0,8494
2021	0,4508	0,4552	0,1959	0,6568	0,7515
2022	0,5284	0,6895	0,2499	0,8210	0,8777
2023	0,4042	0,7589	0,2557	0,6666	0,9740
The average annual rate of change, %	97,52	102,20	100,17	102,84	105,33
Enterprise 3					
2014	0,3724	0,6915	0,3660	0,4810	0,5724
2015	0,3695	0,2201	0,2187	0,5332	0,1670
2016	0,5414	0,2828	0,1361	0,7524	0,0960
2017	0,6072	0,4410	0,2195	0,7682	0,1261
2018	0,5412	0,3836	0,1876	0,6415	0,0878
2019	0,4219	0,4919	0,2476	0,6147	0,4819
2020	0,4407	0,4638	0,1979	0,6081	0,1678
2021	0,2968	0,1449	0,2057	0,6006	0,0014
2022	0,5275	0,7807	0,3708	0,5270	0,6442
2023	0,4549	0,7909	0,2757	0,4759	0,5746
The average annual rate of change, %	102,25	101,50	96,90	99,88	100,04
Note: enterprise 1 – JSC «Mogotex»; enterprise 2 – JSC «Lenta»; enterprise 3 – JSC «BPHO»					

Source: in-house development

Diagnostics of integral indicators in the dynamics of 2014-2023 for enterprises of the textile industry is characterized by the following provisions:

- enterprise 1: the most significant increase in the integral indicator is attributed to production potential (11.26%) with a simultaneous lag in personnel, innovation and investment potentials, which corresponds to a low level of growth in market potential (average annual growth rate of 100.38%);
- enterprise 2: high levels of innovation and investment potentials are indicated (the average annual increase, respectively, amounted to 2.84; 5.33%); low levels and intensity of dynamics in terms

of personnel potential and the rate of decline in terms of market productive potential (an average annual relative decrease of 2.48 %;

- enterprise 3: the general profile of integral indicators shows the active dynamics of the development of market potential (average annual growth rate of 102.25%) with a significant lag in the development of innovative, investment, human resources and production potentials.

The harmonious development of the economic potential of the microeconomic systems of enterprises as a whole is designed in the scenario format of the predictive development of the EP.

The regulations for the construction of strategic scenarios for the optimization of the EP included:

- the target values of the integral indicators of production, personnel, innovation, and investment potentials are set in accordance with the structure of the elements of factor potential corresponding to the largest value of the integral index of market potential in a series of dynamics over 10 years using the method of structural analogy;
- calculation of integral indicators of production, personnel, innovation, investment potentials was carried out in accordance with the boundaries of target indicators, the point of positioning of the enterprise in the strategic decision-making matrix for optimizing the EP in the last year of the studied series of dynamics and the optimal structure of factor potential;
- calculated values of the integral index of market potential are determined based on econometric models of regression dependence;
- interval grouping of target indicators was performed in groups of scenarios pessimistic, optimistic: the boundaries of the intervals are reduced to the format "lower bound – upper bound";
- the lower limit of the target integral indicator of factor potential is established based on the calculated values of the integral indices of production, personnel, innovation and investment potentials linked to the boundaries of the quadrants of the strategic matrix and the optimal structure of the factor potential of the analyzed enterprises;
- when designing the upper limits of the target indices of production, personnel, innovation and investment potentials, we proceeded from the balance of gains in the indices of market and factor potentials;
- based on the obtained regression dependence, the calculation of the lower and upper limits of the target market potential indices was performed;
- the target index of factor potential is calculated by multiplicative convolution using established significance coefficients;
- scenarios of target indicators for the optimization of EP enterprises: a set of target indices for the development of EP in tabular form (working out for the enterprise 1 table 2);

Table 2: *Scenarios of target indicators for optimization of EP of the enterprise 1*

EP optimiza-tion scenario	An integral indicator of market potential	Factor potential of the enterprise 1				
		the integral indicator	including decomposition elements			
			production	personnel	innovation	investment
Пессимистичный						
1	0,499-0,524	0,383-0,422	0,197-0,217	0,419-0,460	0,407-0,448	0,474-0,521
2	0,558-0,585	0,479-0,527	0,247-0,271	0,523-0,575	0,509-0,560	0,592-0,652
3	0,612-0,643	0,575-0,633	0,296-0,326	0,628-0,691	0,611-0,672	0,711-0,782
4	0,665-0,706	0,671-0,738	0,345-0,380	0,732-0,806	0,713-0,784	0,829-0,912
5	0,725-0,781	0,767-0,844	0,395-0,434	0,837-0,921	0,814-0,896	0,948-1,043
6	0,797-0,876	0,863-0,949	0,444-0,489	0,942-1,036	0,916-1,008	1,066-1,173
Оптимистичный						
7	0,886-0,974	0,959-1,035	0,493-0,533	1,046-1,130	1,018-1,099	1,185-1,280
8	0,999-1,122	1,054-1,139	0,543-0,586	1,151-1,243	1,120-1,209	1,303-1,407
9	1,141-1,311	1,150-1,242	0,592-0,640	1,256-1,356	1,222-1,319	1,422-1,535
10	1,319-1,456	1,246-1,309	0,641-0,674	1,360-1,428	1,323-1,390	1,540-1,617
11	1,537-1,718	1,342-1,409	0,691-0,725	1,465-1,538	1,425-1,496	1,659-1,742

12	1,803-2,036	1,438-1,510	0,740-0,777	1,569-1,648	1,527-1,603	1,777-1,866

Source: in-house development

- normalization of indicators of target indices for the development of EP enterprises in order to position them in the strategic decision-making matrix for the optimization of EP (the values of integral indicators of the market and factor potentials of the enterprise 1 in the scenarios are shown in Table 3);

Table 3: *Linear normalization of integral indices in the system of strategic scenarios for optimization of EP of the enterprise 1*

EP optimization scenario	The designation of the scenario on the graph	The integral indicator				Normalized integral indicators			
		market potential		factor potential		market potential		factor potential	
		lower bound	upper bound	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound
Pessimistic	1	0,499	0,524	0,383	0,422	0	0	0	0
	2	0,558	0,585	0,479	0,527	0,045	0,041	0,091	0,097
	3	0,612	0,643	0,575	0,633	0,086	0,079	0,182	0,194
	4	0,665	0,706	0,671	0,738	0,127	0,120	0,273	0,291
	5	0,725	0,781	0,767	0,844	0,173	0,170	0,364	0,388
	6	0,797	0,876	0,863	0,949	0,228	0,233	0,455	0,485
Optimistic	7	0,886	0,974	0,959	1,035	0,297	0,298	0,545	0,564
	8	0,999	1,122	1,054	1,139	0,383	0,396	0,636	0,659
	9	1,141	1,311	1,150	1,242	0,492	0,520	0,727	0,754
	10	1,319	1,456	1,246	1,309	0,629	0,616	0,818	0,815
	11	1,537	1,718	1,342	1,409	0,796	0,790	0,909	0,907
	12	1,803	2,036	1,438	1,510	1	1	1	1

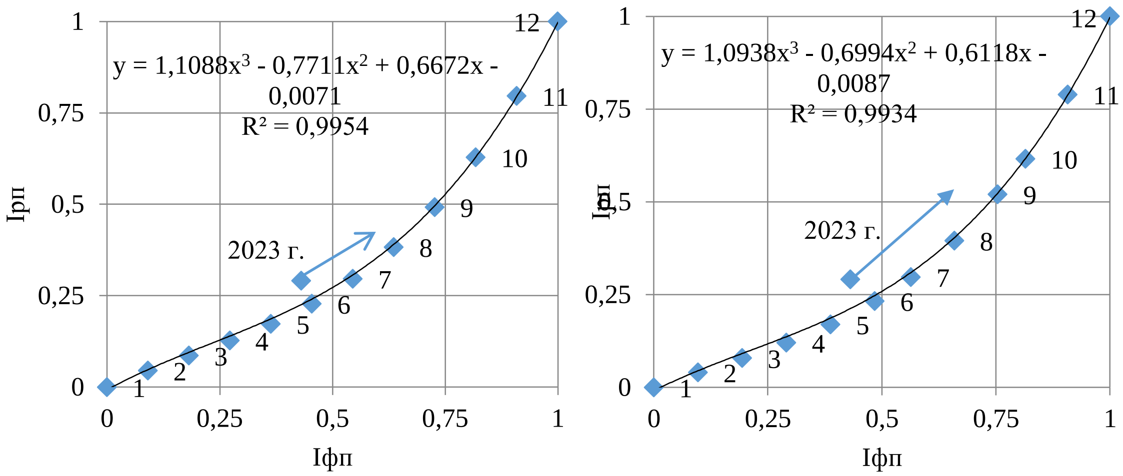
Source: in-house development

- diagnostics based on the strategic decision-making matrix (Table 4) and the construction of strategic scenarios for the optimization of EP in the matrix field of economic potential (Figure 1);

Table 4: *Results of predictive diagnostics based on the strategic matrix of EP optimization*

Enterprise	Scenario trend of EP development	Optimistic scenarios of EP development			EP optimization Strategy
		quadrant	coordinate points (Ifp; Irp) in the strategic matrix		
			lower bound	upper bound	
Enterprise 1	d_2; c_4; c_3	d_2	7 (0,545; 0,297) 8 (0,636; 0,383)	7(0,564; 0,298) 8 (0,659; 0,396)	Market Development Strategy (SF2)
		c_4	9 (0,727; 0,492) 10 (0,818; 0,629)	9 (0,754;0,520) 10 (0,815;0,616)	Horizontal Diversification Strategy (SD2)
		c_3	11 (0,909; 0,796) 12 (1; 1)	11 (0,907;0,790) 12 (1; 1)	Conglomerate Diversification Strategy (SD3)
Enterprise 2	a_3; d_2; c_2; c_3	d_2	7 (0,518; 0,396)	7 (0,576; 0,687)	Market Development Strategy (SF2)
		c_2	8 (0,641; 0,760) 9 (0,731; 0,864)	8 (0,675; 0,807) 9 (0,773; 0,903)	Conglomerate Diversification Strategy (SD3)
		c_3	10 (0,820; 0,943) 11 (0,910; 0,989) 12 (1; 1)	10 (0,872; 0,966) 11 (0,970; 0,985) 12 (1; 1)	Conglomerate Diversification Strategy (SD3)
Enterprise 3	a_4; a_3; d_2; c_1; c_4; c_3	d_2	7 (0,556; 0,479)	7 (0,556; 0,479)	Market Development Strategy (SF2)
		c_1	8 (0,704; 0,638) 9 (0,741; 0,680)	8 (0,676; 0,607) 9 (0,741; 0,679)	Strategy of Centered Diversification (SD1)
		c_3	10 (0,815; 0,767) 11 (0,926; 0,904) 12 (1; 1)	10 (0,815; 0,766) 11 (0,926; 0,903) 12 (1; 1)	Conglomerate Diversification Strategy (SD3)

Source: in-house development



a) b)

Figure 1: *Positioning of ES development scenarios in the matrix of EP optimization strategies of enterprise 1: a) by lower boundary of intervals; b) by upper boundary of intervals*

Source: in-house development

- estimation of EP utilization efficiency in scenario variants (enterprise 1, Table 5);

Table 5: *Economic effect in the context of prognostic scenario indices of the development of the EP of the enterprise 1*

EP optimization scenario	The target integral indicator of economic potential		Prospective baseline rates of change, %	
	lower bound	upper bound	lower bound	upper bound
Pessimistic	0,438	0,470	103,36	111,04
	0,517	0,556	122,19	131,22
	0,593	0,638	140,10	150,70
	0,668	0,722	157,82	170,52
	0,746	0,812	176,12	191,72
	0,829	0,912	195,81	215,36
Optimistic	0,922	1,004	217,67	237,19
	1,026	1,130	242,40	267,03
	1,146	1,276	270,62	301,42
	1,282	1,380	302,78	325,99
	1,436	1,556	339,26	367,49
	1,610	1,753	380,28	414,13
Comparison base	It is established according to the trend of the integral indicator of economic potential over 10 years: 0.423 (the average geometric value in the range of Iep dynamics).			

Source: in-house development

- the development and specification of the content of EP optimization strategies was carried out in accordance with the developed typologization of functional tools for the growth of potential efficiency of microeconomic systems.

As an indicator controlling the level of positivity (growth) of the efficiency potential in the mathematical model, the target integral indicator of the EP was adopted, the value of which, in the context of the studied enterprises, was distributed in the following directions:

- enterprise 1) is achieved already at the first point of the scenario format: the increase in the integral indicator of the EP along the lower; upper boundary, respectively, amounted to 3.36; 11.04% relative to the average value of the parameter for a number of dynamics over 10 years; in the group of optimistic scenarios, the growth of the integral indicator of the EP by more than 2 times (the highest value corresponds to the 12 scenario with a conglomerate diversification and an increase in the generalizing parameter along the boundaries by 3.80; 4.14 times, respectively);

- enterprise 2) is achieved at the second point of the scenario format: the increase in the integral indicator of the EP along the lower; upper boundary, respectively, amounted to 7.10; 17.68%; the increase in the group of optimistic scenarios ranges from 124.94 to 291.30 %;

- enterprise 3) is achieved at the second point of the scenario format: an increase of 9.41; 14.97%; a variation of the relative increase in the group of optimistic scenarios – from 74.11 to 150.33%.

V. CONCLUSION

Thus, a model for optimizing the economic potential of an enterprise based on a strategic decision-making matrix, designed based on the synthesis of the theory of fuzzy sets, the method of hierarchy analysis, the method of scenario verification of forecasts, which allows you to position the economic potential of an enterprise in a strategic matrix with a high level of reliability and select a scenario trajectory of the program-target vector of optimization of economic potential according to the criteria of economic growth taking into account the factors of globalization of production in the industry.

Testing of the developed system-scenario multifactorial model of EP optimization in the information field of textile industry enterprises has shown: the genetic variant is characterized by a low level of economic potential efficiency, negative dynamics of a decrease in integral indicators, an imbalance of structural elements in the decomposition, subject to significant fluctuations in indicators.

In the prognostic direction, an algorithm of scenario verification is undertaken when making decisions to optimize EP in the system of strategic development of market factors of globalization and international integration. During the model experiment, the developed scenarios are filled with functional tools for increasing the potential efficiency of the system in accordance with the types of strategies.

References

[1] Diligensky, N. V., Dymova, L. G., & Sevastyanov, P. V. (2004). Fuzzy modeling and multi-criteria optimization of production systems in conditions of uncertainty: technology, economics, ecology.

[2] Andrianov, D. L., & Grebnev, M. I. (2015). An overview of methods for aggregating production functions. Management of economic systems: an electronic scientific journal, (1 (73)), 4.

[3] Ibragimova, R. S., & Golovin, D. S. (2016). Methodological justification of the assessment of the economic potential of the enterprise. Modern high-tech technologies. Regional application, (3 (47)), 64-74.

[4] Ibragimova, M. H. (2015). Assessment of the company's economic potential for strategic management purposes. Management of economic systems: an electronic scientific journal, (10 (82)), 24.

[5] Khadzaragova, E. A. (2015). On methods of scalarization of vector estimates in multi-criteria optimization problems. Fundamental and Applied Research: Problems and Results, (18), 123-127.

[6] Mereste, W. I. (1982). On the matrix method of analyzing the economic efficiency of social production. Economics and Mathematical Methods, 18(1), 138-149.

[7] Finogenko, I. A., & Dyakovich, M. P. (2017). The method of hierarchy analysis and the construction of integral indicators of complex systems. Bulletin of Russian Universities. Mathematics, 22(6-1), 1335-1340. DOI: 10.20310/1810-0198-2017-22-6-1335-1340

[8] Merkulova, E. Y. (2017). Technological and methodological basis of strategic analysis. Socio-economic phenomena and Processes, 12(3), 131-138.

[9] Narkevich, L. V. (1998). Privatization of retail trade enterprises and its impact on the economic efficiency of their business activities (Doctoral dissertation).

[10] Sologubova, L. A., Trunkina, O. V., Baibekova, F. N., & Kulakov, A. A. (2018). Decision-making using the hierarchy analysis method. Innovations in science, (4 (80)), 11-14.

[11] Narkevich L. V., Rogachev A. F., Terelyansky P. V. (2021). Digitalization of the economy as a factor of sustainable development of the regions of Russia and Belarus. In socio-economic

systems: paradigms of the future (pp. 737-746). Cham: Springer International Publishing. DOI:10.1007/978-3-030-56433-9_78

[12] Belousova M. N., Belousov V. A., Narkevich L. V. (2021). Digital transformation of the educational process at the university in the context of globalization. In socio-economic systems: paradigms of the future (pp. 1267-1277). Cham: Springer International Publishing. DOI:10.1007/978-3-030-56433-9_133

[13] Chegerova, T. I., Nekhai, E. V., & Kruchinsky, N. G. (2021). Mathematical forecasting methods for managing the training process of qualified athletes: Message 1. Development of expert assessments. Applied Sports Science, (2 (14)), 43-51.

[14] Vasilyeva, L. V. (2017). Analysis of methodological approaches to the construction of integrated economic indicators/L. V. Sidorov. Economic Research and Development, 12, 8-18.

[15] Bruskin, S. N. (2016). Methods and tools of advanced business analytics for corporate information and analytical systems in the era of digital transformation. Modern Information Technologies and OT-education, 12(3-1), 234-239.

[16] Niyazbekova, S. U., Moldashbaeva, L. P., & Uspambaeva, M. K. (2019). On institutional and legal problems of state audit and financial control. Bulletin of Moscow University S. Yu. Witte. Series 1: Economics and Management, 3(30), 15-20. DOI: 10.21777/2587-554X-2019-3-15-20

[17] Niyazbekova, S. U., & Ivanova, O. S. (2020). Development of fintech and big data in the financial sphere: features, problems, opportunities. Moscow University Journal S. Yu. Witte. Series 1: Economics and Management, 1(32), 30-36. DOI: 10.21777/2587-554X-2020-1-30-36

[18] Yarovenko, S. E., & Niyazbekova, S. U. (2021). Comparative analysis of global financial crises, their causes and consequences. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (4 (39)), 48-57. DOI: 10.21777/2587-554X-2021-4-48-57

[19] Niyazbekova, Sh. U., & Bunevich, K. G. (2020). A brief overview of the DANISH financial sector. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (3 (34)), 50-56. DOI: 10.21777/2587-554X-2020-3-50-56

[20] Niyazbekova, Sh. U., & Bunevich, K. G. (2017). Analysis of the socio-economic development of Astana city. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (3 (22)), 24-31. DOI: 10.21777/2307-6135-2017-3-24-31

[21] Effectiveness of Regulatory Mechanisms of the Oil and Gas Industry in the Context of Environmental Problems.Butova, T.,Varzin, V., Niyazbekova, S., Yessymkhanova, Z.,Anzorova, S. Lecture Notes in Networks and Systems, 2023, 575 LNNS, pp 38–49 DOI:10.1007/978-3-031-21219-2_4

[22] Risk and Uncertainty in the Management System of a Commercial Bank. Kunanbayeva, K.B., Niyazbekova, S.U.,Urekeshova, A.B., Varzin, V.V., Maisigova, L.A. Approaches to Global Sustainability, Markets, and Governance, 2023, Part F643, PP. 375–381 DOI:10.1007/978-981-99-2198-0_41

[23] Using mathematical statistics to optimize the process of crossovers using Data Center Infrastructure Management. Pavlyuk, I.D., Britvina, V.V., Gavrilyuk, A.V., Niyazbekova, S.U., Nurgazina, G.E. Proceedings of SPIE – The International Society for Optical Engineering, 2023, 12637, 1263709 DOI:10.1117/12.2681655

[24] The Study of Mathematical Models and Algorithms for Face Recognition in Images Using Python in Proctoring System. Nurpeisova, A., Shaushenova, A., Mutalova, Z., ...Semenov, A.,Maisigova, L. Computation, 2022, 10(8), 136 DOI: 10.3390/COMPUTATION10080136

[25] Sustainable Energy Efficient Human-Centered Digital Solutions for ESG Megacities Development. Barykin, S.E., Sergeev, S.M.,Kapustina, I.V., ...Niyazbekova, S.U., Karmanova, A.E. Frontiers in Energy Research, 2022, 10, 938768 DOI: 10.3389/fenrg.2022.938768

ON THE PROBABILITY OF COLLAPSING OF SUPPORTS IN A PIPELINE MOUNTED ON FLEXIBLE SUPPORTS

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Abstract

When laying pipelines using concrete supports and frames in the overhead laying scheme, the pipes may experience deformation and tension due to the height at which they are installed, typically between 1.0-1.5m from the ground surface. The installation of overhead pipeline on hard or collapsible foundations causes bending due to the combined weight of the pipes and the transported product. This text discusses the use of three moment equations to solve this problem.

Keywords: pipeline, support, bending moment, supporting reaction, collapse coefficient

I. Introduction

Experience indicates that supports installed on pipelines operated at hazardous production facilities commonly exhibit the following types of defects:

- corrosion damage to support elements [1-3]
- external corrosion of pipelines in the area of supports
- failure of welded joints of support elements welded along the pipe;
- crushing;
- slipping of pipelines from support surfaces;
- collapse of supports;
- failure of hangers, etc.

It is widely acknowledged that the three moment equations can be expressed as [4-6]:

$$M_{n-1}l_n + 2M_n(l_n + l_{n+1}) + M_{n+1}l_{n+1} =$$
$$-6\left(\frac{\omega_n a_n}{l_n} + \frac{\omega_{n+1}b_{n+1}}{l_{n+1}}\right) - 6EJ\left(\frac{\Delta_{n+1}-\Delta_n}{l_{n+1}} - \frac{\Delta_n-\Delta_{n-1}}{l_n}\right) \quad (1)$$

Here: Δ, $\Delta_{n-1}, \Delta_n, \Delta_{n+1}$-collapse of supports, i.e., vertical displacement of supports as a result of rock collapse;EJ - is the hardness of the pipe.

According to Winkler's hypothesis, vertical subsidence can be calculated as:

$$\Delta_n = R_n \cdot \delta \quad (2)$$

Here: R_n-support reactions, δ-rock (soil) settlement capacity, $m/k\,N$.

It is evident that the support collapses due to the displacement of the rock. As shown in expression (2), the collapse of the support is directly proportional to its reaction. [7-8]

II. Methods

Let 's consider the beam (pipeline) installed on rubber supports (Fig . 1).

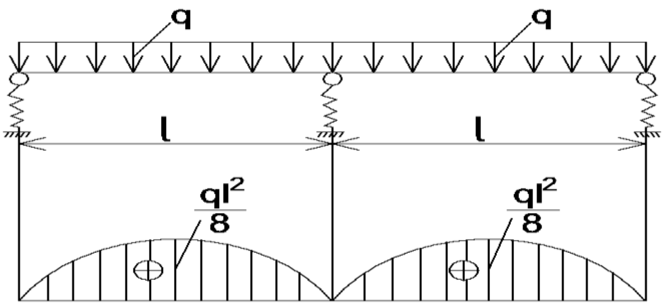

Figure 1: *Pipeline on elastic supports*

If the load on a beam is evenly distributed across its spans, the three moment equations for a beam with *n* spans and a distance of l_n between supports are as follows:.

$$M_{n-1}l_n + 2M_n(l_n + l_{n+1}) + M_{n+1}l_{n+1} = -6\left(\frac{\omega_n a_n}{l_n} + \frac{\omega_{n+1}b_{n+1}}{l_{n+1}}\right) \quad (3)$$

Here, ω_n -q represents the areas of the bending moment curves caused by the load. a_n represents the distance from the center of each epur to the left support, while b_{n+1} represents the distance from the center of each subsequent epur to the right support.

$$\omega_1 = \omega_2 = \omega_3 = \cdots = \omega_{n-1} = \omega_n = \frac{2}{3}\frac{ql^2}{8}\cdot l = \frac{ql^3}{12},$$

$$l_1 = l_2 = l_3 = \cdots = l_n = l, a_1 = b_2 = a_2 = b_3 = \cdots = \frac{l}{2}$$

$$\frac{\omega_n a_n}{l_n} = \frac{\omega_{n+1}b_{n+1}}{l_{n+1}} = \frac{ql^3}{12}\cdot\frac{l}{2\cdot l} = \frac{ql^3}{24}$$

Starting from this point, we can write:

$$\frac{\omega_1 a_1}{l_1} + \frac{\omega_2 b_2}{l_2} = \frac{ql^3}{12}, \qquad 6\frac{ql^3}{12} = \frac{ql^3}{2}$$

According to Figure 2.5, we can write using expression (1):

$$\frac{\Delta_{n+1} - \Delta_n}{l_{n+1}} - \frac{\Delta_n - \Delta_{n-1}}{l_n} = \frac{\Delta_2 - \Delta_1}{l} - \frac{\Delta_1 - \Delta_0}{l} = \frac{1}{l}(\Delta_2 - 2\Delta_1 + \Delta_0)$$

According to formula (3).

$$\Delta_2 - 2\Delta_1 + \Delta_0 = \delta(R_2 - 2R_1 + R_0)$$

In Figure 2.5, since $M_0 = M_2 = 0$, we can express the reactions as follows:

$$R_2 = \frac{1}{l}\left(\frac{ql^2}{2} + M_1\right) = R_0,$$

$$R_1 = \frac{1}{l}(ql^2 - 2M_1)$$

and

$$R_2 - 2R_1 + R_0 = \frac{1}{l}(-ql^2 + 6M_1)$$

In this case, formula (1) can be written as follows :

$$4M_1 = -\frac{ql^2}{2} - \frac{6EJ\delta}{l^2}(R_2 - 2R_1 + R_0) = -\frac{ql^2}{2} - \frac{6EJ\delta}{l^3}(-ql^2 + 6M_1) \quad (4)$$

$\frac{6EJ\delta}{l^3} = \eta$ If we sign with , we get :

$$4M_1 = -\frac{ql^2}{2} + \eta ql^2 - 6\eta M_1.$$

or

$$M_1(4+6\eta) = -\frac{ql^2}{2}(1-2\eta)(5)$$

Consider its effect on the stiffness of the supports (EJ) by setting different values of the settlement coefficient δ:

1. $\delta = 3 \cdot 10^{-4}$ m/kN ; $ql^2 = 2060\ kNm$; $E = 2{,}1 \cdot 10^5\ MPa$; $J = 57 \cdot 10^{-4} m^4$; $l = 20m$; $\eta = 0{,}425$.

Then

$$4 + 6\eta = 6{,}55; 1 - 2\eta = 0{,}15$$

becomes and we get $M_1 = -47{,}2\ kNm$

M_1 a small value of the moment indicates that the stiffness of the elastic support is low. In order to increase the hardness, let's accept the value of the coefficient of collapse of the rock as small:

2. If $\delta = 2 \cdot 10^{-4}\ m/kN$if, then $\eta = 0{,}2835$ and $M_1 = -156{,}46\ kNm$. The bearing moment value increase suggests that as the subsidence coefficient decreases, the rock stiffness increases. This causal relationship indicates that the bearing moment also increases.. It should be noted that the stiffness of the pipe and the stiffness of the rock (elastic support) are different concepts.

If the supports were not elastic in the considered case:

$$M_1 = -\frac{ql^2}{2} = -2060 kNm \text{and} M_1 = -515 kNm$$

would be taken. This means that large flexibility cannot be allowed, that is, as the coefficient of collapse increases, the pipeline can bend more. As a result, it is inevitable that greater stress and deformations will occur in the pipeline. Therefore, it is necessary to increase the stiffness of the supports as much as possible.

Let's consider the calculation of the support moment generated at one transition of the pipeline on elastic supports (Fig. 2).

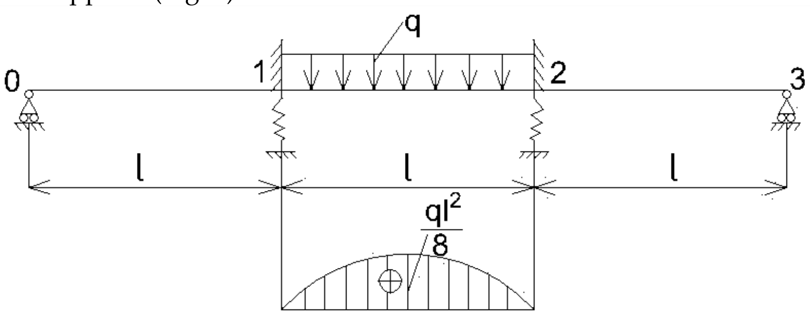

Figure 2: *A pipeline span on elastic supports*

Applying formula (1), we can write down the following expressions from Figure 2:

$$\begin{cases} 2M_1 + M_2 = -\dfrac{ql^2}{4} - 2\eta(M_1 - M_2) \\ M_1 + 2M_2 = -\dfrac{ql^2}{4} - 2\eta(M_2 - M_1) \end{cases}$$

and:

$$\begin{cases} 2(1+\eta)M_1 + (1-2\eta)M_2 = -\dfrac{ql^2}{4} \\ (1-2\eta)M_1 + 2(1+\eta)M_2 = -\dfrac{ql^2}{4} \end{cases}$$

Assuming $\delta = 1 \cdot 10^{-4} sm/kq$, then $\eta = 0{,}142$ and

$$\begin{cases} 2{,}284M_1 + 0{,}716M_2 = -103 \\ 0{,}716M_1 + 2{,}284M_2 = -103 \end{cases}$$

will be. Hence $M_1 = -M_2 = -341kNm$. This means that when the core fracture ratio is small, the bearing moment increases.

Applying equation (1) to the pipeline (beam) on the supports shown in Fig. 3 and making the appropriate transformations yields the following system of equations for this beam:

$$\begin{cases} 2(1+\eta)M_1 + (1-3\eta)M_2 + \eta M_3 = -(1+2\eta)\dfrac{ql^2}{4} \\ (1-3\eta)M_1 + (4+6\eta)M_2 + (1-3\eta)M_3 = -(1-2\eta)\dfrac{ql^2}{2} \\ \eta M_1 + (1-3\eta)M_2 + 2(1+\eta)M_3 = -(1+2\eta)\dfrac{ql^2}{4} \end{cases}$$

$$\eta = \frac{6EJ\delta}{l^3}; \delta = 1 \cdot \frac{10^{-4}m}{kN}; \frac{ql^2}{4} = 1030kNm$$

by accepting

$$\frac{ql^2}{2} = 2060kNm$$

etc. by solving the required equations ,

$$M_1 = M_2 = M_3 = -343\ kNm$$

we get

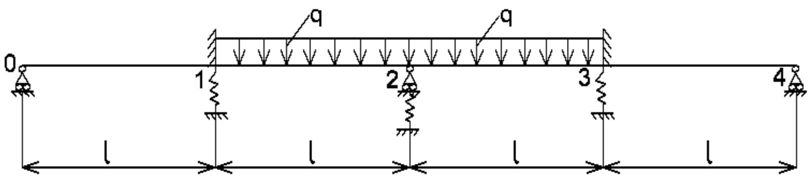

Figure 3: *Two spans of the pipeline on elastic supports*

III. Results

The impact of the settlement coefficient's smallness on the support moments' value is evident. Additionally, the support moments' calculation indicates that all transitions are under the same conditions and subject to the same effects. The rock's inability to subside corresponds to the subsidence coefficient's small value.

References

[1] GOST 22130-86 Parts of steel pipelines. Movable supports and hangers. Technical conditions.

[2] D 03-606-03 Instructions for visual and measurement inspection.

[3] Safety Manual "Recommendations for the arrangement and safe operation of process pipelines".

[4] Birger I.A.. Rods, Plates. Shells. "Levand", 2015, p.392

[5] Volmir A.S. Flexible plates and shells. Moscow, Gostekhizdat, 1956, p. 417

[6] Iskandarov E.Kh. Technologies of construction and installation of oil and gas pipelines - Baku: - "Science" Publishing House, - 2022, - p.416

[7] Abyshova R.M., Mustafaev M.I. Investigation of causes and nature of main pipelines rupture. International and Regional Importance of the Baku-Tbilisi-Ceyhan Oil Pipeline, Proceedings of the International Conference. Baku, 6-7 June 2002, pp. 128-130.

[8] Abishova R.M., Mustafaev M.I. Quality indicators of mechanical systems. ASOIU, 2016. p.57

THE ROLE OF DIGITAL PERSONALITY IN PROMOTING SUSTAINABLE BEHAVIOR

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Abstract

In the context of rapid technological advancement and global environmental challenges, digital identity emerges as a crucial tool for promoting sustainable behavior. Digital identity refers to the way individuals express themselves and interact within the online space, influencing their actions and choices in the real world. This paper explores various aspects of digital identity, including its impact on the formation of sustainable habits and practices, the enhancement of environmental awareness, and the development of social responsibility. It analyzes how social media platforms and digital technologies can be utilized to create communities that foster the exchange of sustainable practices and ideas. Additionally, the challenges related to data security and privacy that may affect the use of digital identity in achieving environmental goals are discussed. In conclusion, the necessity of integrating digital identity into strategies for promoting sustainable behavior is emphasized, as it can contribute to a more conscious and responsible relationship with the environment.

Keywords: digital identity, sustainable behavior, environmental awareness, social media

I. Introduction

In an era defined by rapid technological advancement and escalating environmental challenges, the urgency to promote sustainable behavior has become paramount. The world faces a myriad of pressing issues, including climate change, resource depletion, pollution, and biodiversity loss. These challenges necessitate innovative and effective approaches to inspire individuals and communities to adopt more sustainable practices. One promising avenue is the integration of digital identity into sustainability efforts. As societies become increasingly digitized, understanding how digital identity can shape behaviors and attitudes toward the environment is essential.

Digital identity refers to the online persona that individuals cultivate through their interactions on various digital platforms, including social media, forums, and other online communities. This identity encompasses not only personal information but also the values, beliefs, and behaviors individuals express in the digital realm. With the advent of social networks and online communication, people are no longer passive consumers of information; they actively engage, share, and influence one another's behaviors. This engagement provides fertile ground for promoting sustainable practices, as individuals can leverage their digital identities to advocate for environmental issues and inspire change.

Digital identity can significantly impact sustainable behavior in several ways. First, it influences how individuals perceive themselves in relation to sustainability. When people align their digital identity with eco-friendly values—such as reducing waste, conserving energy, and supporting local businesses—they are more likely to adopt these behaviors in real life. For instance, individuals who showcase their sustainable practices online may feel a heightened sense of accountability to continue these actions, as their peers reinforce these behaviors through likes, shares, and comments.

Additionally, digital identity fosters community building around shared sustainability goals. Online platforms enable individuals to connect with like-minded people, forming communities that support and encourage sustainable practices. These communities can facilitate the exchange of ideas, resources, and information about sustainable living, creating a sense of belonging that motivates individuals to engage in environmentally friendly behaviors. As these digital communities grow, they can amplify their collective influence, driving broader societal change.

Another critical aspect of digital identity's role in promoting sustainable behavior is its capacity to raise awareness about environmental issues. Digital platforms serve as powerful channels for disseminating information about sustainability, from climate science to local conservation efforts. Influencers, activists, and organizations can use their digital identities to share compelling narratives, engage followers, and mobilize action. This can include campaigns to reduce plastic use, promote renewable energy, or support wildlife conservation initiatives.

Moreover, digital identity enables the sharing of educational resources, helping individuals understand the impact of their choices on the environment. Online tutorials, webinars, and interactive content can provide valuable insights into sustainable practices, making it easier for individuals to incorporate eco-friendly habits into their daily lives. By harnessing the power of digital identity, individuals can become informed advocates for sustainability, influencing others and contributing to a larger movement toward environmental responsibility.

Despite its potential, the integration of digital identity into sustainability initiatives is not without challenges. Privacy concerns are paramount, as individuals may hesitate to share personal information or engage in online discussions about their eco-friendly choices due to fears of data misuse or surveillance. The need for robust data protection measures is essential to ensure that individuals feel safe in expressing their digital identities.

Furthermore, the phenomenon of "greenwashing" poses a significant challenge. As businesses and organizations increasingly adopt sustainability messaging, discerning authentic commitments from superficial marketing tactics can be difficult for consumers. Digital identity can inadvertently contribute to this issue, as individuals may align their online personas with sustainable practices that do not reflect their real-world behaviors. This disconnect can undermine the credibility of sustainability efforts and diminish trust in digital advocacy.

II. Methods

To explore the role of digital identity in promoting sustainable behavior, three distinct methods were employed: survey analysis, interviews and focus groups, and case study analysis. Each method contributed unique insights into the relationship between digital identity and sustainable practices.

1. Survey Analysis

A comprehensive survey was distributed across various demographic groups to gather quantitative data. The survey included questions on digital identity usage (e.g., social media, digital platforms) and sustainable behaviors (e.g., recycling, energy conservation, ethical consumption). Respondents were asked about:

How often they engaged with digital platforms that focus on sustainability.

Whether their online identity influenced their real-world sustainable actions.

Perceived barriers to adopting eco-friendly behaviors through digital means.

Analysis: The data was statistically analyzed to find correlations between digital engagement and sustainable behavior, using regression models and cross-tabulation to identify trends across different age groups, education levels, and regions.

2. Interviews and Focus Groups

Semi-structured interviews and focus group discussions were conducted with key participants, including sustainability advocates, environmental researchers, and digital platform developers. These qualitative methods provided a deeper understanding of:

Personal experiences with how digital identity influences their commitment to sustainable practices.

Motivations for engaging in online sustainability communities and how digital identities shape those motivations.

Challenges and opportunities faced in promoting eco-consciousness through digital identities.

Analysis: Thematic analysis was employed to identify common themes such as social accountability, digital peer influence, and the impact of digital rewards systems on promoting environmentally responsible behavior.

3. Case Study Analysis

Several case studies of digital platforms that successfully promote sustainability (e.g., apps or websites dedicated to green living, carbon footprint tracking, or ethical shopping) were analyzed. The focus was on:

How these platforms construct and maintain user digital identities that align with environmental values.

The mechanisms used to encourage sustainable actions, such as gamification, social sharing, or incentives.

The long-term impact of these platforms on user behavior and environmental outcomes.

Analysis: Comparative analysis was conducted across case studies to evaluate which strategies most effectively integrate digital identity with sustainable behavior. Specific factors such as user engagement levels and measurable environmental impact were compared.

By combining these three methods, the study offers a comprehensive understanding of how digital identity can drive sustainable behavior and what strategies can further enhance this connection.

III. Results

Although discussions on sustainability and its relevance began to surface prominently towards the end of the last century, particularly with the 1972 Stockholm Conference organized by the United Nations (UN) (Rodrigues, 2009), concerns regarding this issue actually date back to the first (1760-1840) and second (1850-1945) industrial revolutions. The industrial revolution led to a dramatic increase in the production of goods and wealth, raising people's purchasing power. However, it also resulted in negative outcomes, including increased economic inequalities and significant environmental impacts due to heightened production. During this time, economists like John Stuart Mill (1848) and Thomas Malthus (1878) warned of the adverse effects that unchecked economic and population growth could have on both the environment and human well-being. Furthermore, the industrial revolution introduced a surge in consumption, making it a central aspect of economic development and shaping human relations. Mass production created an environment where consumerism—driven by the need to quickly dispose of goods—became normalized and encouraged. Over time, the satisfaction of personal desires began to take precedence over the fulfillment of genuine needs. This "consumerism," the ever-increasing production and acquisition of non-essential goods in pursuit of well-being, has since become a critical consideration within the sustainability discourse, as it places tremendous pressure on natural resources and the environment. Growing concerns over long-term environmental degradation sparked global events and environmental movements in the late 1960s and 1970s, which initiated widespread debates on the limits of growth and how environmental issues could be integrated into mainstream development goals. One significant milestone in this sustainability debate was the UN World Commission on Environment and Development's (WCED) 1987 "Our Common Future" report. It was one of the first comprehensive efforts to establish a global agenda for rethinking the human development model. The report defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". It highlighted poverty in developing nations and rampant consumerism in developed countries as key factors preventing equitable development and causing serious environmental crises, which in turn sparked extensive academic and political discussions worldwide. This evolving sustainability discourse eventually found its way into business practices, with the introduction of the "Triple Bottom Line" concept. This framework expanded corporate objectives beyond just economic factors, proposing that sustainability involves the pursuit of economic prosperity, environmental protection, and social equity in an interconnected manner. In environmental terms, this approach urged businesses to preserve natural capital and maintain the planet's life support systems by balancing resource generation, consumption, and waste management.

IV. Discussion

Scientific and academic advancements in sustainability, alongside technological innovations and the rise of an eco-friendly culture, have fostered an environment where brands are increasingly motivated to address environmental issues and contribute to their resolution. Consequently, numerous online brand campaigns have emerged, wherein companies raise awareness about environmental challenges and strive to encourage sustainable behaviors among consumers. Many brands are now implementing pro-environmental initiatives, such as creating digital re-commerce platforms that promote conscious consumption.

However, while some brands successfully influence consumers' pro-sustainability behaviors through these actions, others fall into the trap of greenwashing, which can have detrimental effects not only on the brands themselves but also on consumers' willingness to engage in environmentally friendly practices. To ensure the success of their online environmental campaigns and effectively inspire pro-sustainability in their consumers, brands must establish a well-defined and authentic environmental purpose. This means aligning their communications with their actual practices to avoid inconsistencies. Specifically, brands must ensure that their environmental stance is congruent with their corporate identity, values, business operations, and overall mission. Additionally, brands must engage authentically and actively with the causes they advocate.

Lin emphasizes that companies should invest their resources and expertise in areas where they possess knowledge and a competitive advantage. They should also ensure that their internal policies align with the environmental purpose they wish to project in their campaigns. Collaborating with activists is crucial for understanding and fulfilling their collective moral responsibilities toward communities and the environment.

For brands to effect meaningful changes in consumers' pro-sustainable behavior, their environmental positions must be perceived as genuine and sincere. Authentic environmental activism requires maintaining a continuous alignment between a brand's stated intentions—reflected in its communication messages—and the actions it takes, such as implementing pro-environmental corporate practices, forming partnerships with environmental organizations, and supporting environmental initiatives.

Beyond establishing a coherent environmental purpose and maintaining authenticity, companies must communicate their environmental stances and actions effectively to ensure they resonate with the target audience and catalyze positive environmental changes. According to Key et al. (2021) and Taylor et al. (2001), brand activist communications should prioritize dialogic communication, facilitating ongoing interactions and providing relevant information to the target audience. Companies must understand how their audience receives and interprets their messaging, creating campaigns that align with consumers' expectations, experiences, and comprehension of the environmental issues at hand.

To encourage consumers to adopt pro-sustainable behaviors and commit to conscious consumption, brands should not only inform consumers about their environmental policies and the importance of the advocated environmental issues but also educate them on how to act and consume more sustainably. This could involve providing guidance on the responsible use and disposal of products. Additionally, brands must consistently convey their perspective across all online and offline communications, capturing and reinforcing the essence of their environmental stance with transparency and credibility. This includes highlighting their environmental strengths while also acknowledging areas for improvement.

In summary, companies need to be intentional in communicating their environmental positions and causes, grounding their messages in tangible evidence of their environmental performance. This could include third-party audits or ecolabels to reduce the risk of consumer alienation and enhance their capacity to drive pro-environmental behaviors. Given the significance of environmental communication within the realm of new digital platforms, particularly in market contexts, further investigation into how these platforms can facilitate or hinder pro-environmental change is essential. Future research could explore how brands' online environmental communication strategies impact various stakeholders, including employees and shareholders, analyze consumer reactions to greenwashing on social media, and examine whether such campaigns hinder conscious consumption by fostering skepticism. Additionally, studying how brands can make environmental issues more appealing to consumers through immersive technologies like augmented and virtual reality could prove valuable. Internally, it would be insightful to investigate how brands leverage digital technologies to reduce their ecological footprints, for instance, by enhancing internal communication regarding sustainability, improving supplier product breakage management, or optimizing distribution routes.

References

[1] Podkolzina I.M., Taranova I.V., Paytaeva K.T., Revunov S.V., Abrosimova T.F. Innovative approaches in financial support for regional economic security// The Challenge of Sustainability in Agricultural Systems. Heidelberg, 2021. C. 549-558.

[2] Faka A. Assessing Quality of Life Inequalities. A Geographical Approach // International Journal of Geo-Information. 2020. Vol. 9. 600 p.

[3] Caeiro, S., Sandoval Hamón, L.A., Martins, R., Bayas Aldaz, C.E. (2020). Sustainability Assessment and Benchmarking in Higher Education Institutions: A Critical Reflection. Sustainability 2020, 12, 543.

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. C. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

RESEARCH ON THE UTILIZATION OF SECONDARY ENERGY RESOURCES AND FUEL SAVING IN INTERNAL COMPUSTION ENGINE POWER PLANTS

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Abstract

Heat of exhaust gases from stations operating with internal combustion engines (ICE) and heat of cooling water have been investigated in the paper. In such situations, 60% of the fuel heat is lost through the exhaust gas from the engines and cooling water. Various schemes are proposed for using this heat. When implementing these schemes, steam, hot water and cold can be obtained from waste gases. Then the efficiency of the station increases, specific fuel consumption and the amount of flue gases emitted into the atmosphere and environmental loads are reduced.

Keywords: diesel engines, flue gases, cooling water, fuel economy, efficiency, ecology

I. Introduction

Currently, in Azerbaijan, the majority of electricity is generated in steam turbine, combined, recycled, steam-gas and modular power plants with an internal combustion engine (ICE) [1]. Internal combustion engines of modular power plants are mainly used to maintain balance in the energy system. These stations are quickly launched and stopped quickly. In variable modes it is advisable to use such stations. ICEs of modular power plants mainly use natural gases.

Exhaust gases with a temperature of 500-520^{0}C are released into the atmosphere. Thus, in such stations, 50-60% of the fuel heat is released into the atmosphere by exhaust gas and cooling water and pollutes the environment. By using different schemes, heat of the flue gases can be used and ultimately the efficiency of the installation increases, specific fuel consumption and the environmental load are reduced.

II. Research

The studies were carried out at the Sangachal modular power plant with a capacity of 300 MWt. The station houses 18 four-stroke diesel engines. The power of each engine is 16.6 MWt. The engines run on gas. Below is the composition of the gas:

CH_4=93,9%; C_2H_6=3,1%; C_2H_8=1,1%; C_4H_{10}=0,3%; C_5H_{12}=0,1%; CO_2=0,2%; N_2=1,3%; Q^w_l=33500 kJ/m^3.

Each unit has a fuel consumption of B = 3500 m^3/hour. The temperature of the exhaust gas from the engine is 500^{0}C. Calculations were carried out according to [2].

For combustion of 1 m^3 of fuel, air consumption V_0=9.8 m^3/ m^3, the amount of flue gases produced during combustion is V_g=13.032 m^3/m^3. The excess air coefficient is accepted as α=1.2.

For stations, the total fuel consumption is:

B_{total}=18*3500=63000 m^3/hour.

The heat received in one unit is:

Q_{unit}=B* Q^w_l=3500*33500=117,25*10^6 kJ/hour.

The heat throughout the station is:

Q_{unit}=18* Q_{unit}=18*117,25*10^6=2110,5*10^6 kJ/hour=586,2 MWt.

A scheme is proposed for using the heat of exhaust gases from the engine and cooling water, it is shown in Fig. 1.

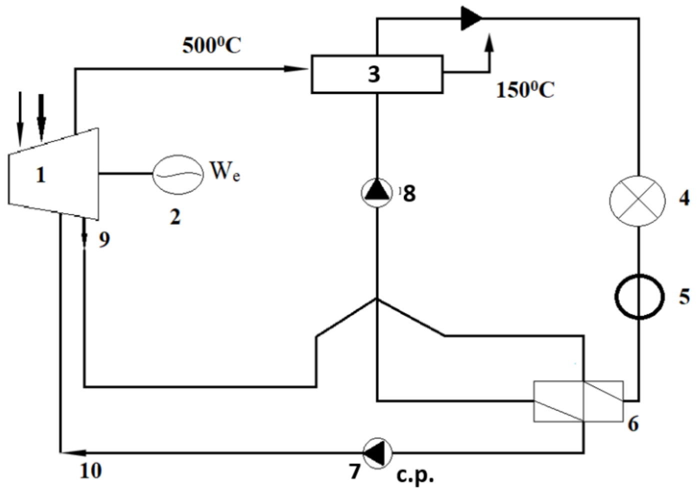

Figure 1: *Scheme of using the heat of exhaust gases and cooling water for heating and hot water supply*

1-Internal combustion engine; 2-electric generator; 3-recovery boiler; 4-heat consumer; 5-network pump; 6-heat exchanger; 7-circulation pump; 8-feed pump; 9-warm water leaving the engine (85-90^{0}C); cooled water (75-77^{0}C) for the engine.

The waste leaving the internal combustion engine at a temperature of 500^{0}C is fed into the waste heat boiler. The steam or hot water produced in the boiler is supplied to the heat consumer. From the consumer, condensate is supplied to the heat exchanger using a network pump. There, due to the heat of the cooling water leaving the engine, it is heated and supplied to the waste heat boiler using a feed pump. In the heat exchanger, the incoming hot water from the engine gives off its heat to the condensate, then cools and returns to the engine.

Enthalpy of gases entering the waste heat boiler [2]:

H_g=7963.67 kJ/m^3

The temperature of the gases leaving the boiler is accepted $t_{e.g.}$ = 150^{0}C, then the enthalpy of the exhaust gases is:

$H_{e.g.}$=2295 kJ/m^3

Then, when burning 1 m^3 of gas in a waste heat boiler, the heat used is:

ΔH=H_g-$H_{e.g.}$=5568 kJ/m^3; Q_g= B_{total}*ΔH=63000*5668.27 kJ/m^3=357*10^6 kJ/m^3=99 MW

Then heat savings

Δη=(99/586.2)*100%=16.8%

Gross station efficiency is η^{gr}_{st}=51%

When using exhaust gases from the engine, the gross efficiency of stations η^{gr}_{st}=51%+16.8%=67.8%

Specific fuel consumption under normal conditions:

V^{gr}_{st}=123/ η^{gr}_{st}=123/0.51=241 g/kW

When using exhaust gas heat

V^{gr}_{st}123/0.678=181.41 g/kW

Specific fuel consumption savings:

ΔV^{gr}_{st}=241-181.41=59.6 g/kW

Fuel savings across the entire station will be 17,880 T/h.

III. Calculation of heat loss of cooling water

In each engine, the cooling water leaves at a temperature of 85⁰C, is cooled in the heat exchanger to a temperature of 77⁰C and returns to the engine. Water circulates in the system for 120 T/h (Fig. 2).

In one engine the heat loss is:

Q=120 T/hour * (85-77) ^{0}C*1,16 $\frac{kW*h}{T*°C}$ =1113,6kW

Throughout the station:

∑ Q=18*1113,6=20044,8 кW=20 MW

20 MW of heat is lost with cooling water. To use this heat, the surface of the heat exchanger is calculated

F= Q*10³/K* Δt_{av}= $\frac{1113,6*10^3}{2000*11,3}$ =50 m²

Average temperature difference

$$\Delta t_{av} = \frac{\Delta t_{big} - \Delta t_{small}}{\ln \frac{\Delta t_{big}}{\Delta t_{small}}} = \frac{17-7}{ln\frac{17}{7}} = \frac{10}{ln2{,}43} = 11{,}3℃$$

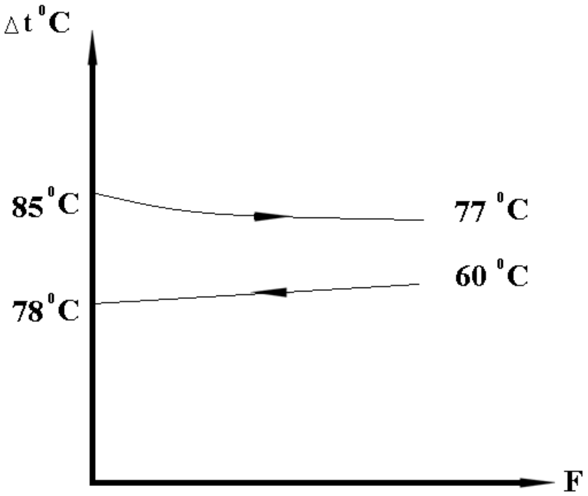

Figure 2: *Change in temperature difference across the surface of the heat exchanger*

Each unit will require a heat exchanger with a heating surface of 50 m². At the plant, the heat loss from exhaust gases is 99 MW, and with cooling water – 20 MW. Together, 119 MW of heat is lost at the station.

The calculation shows that for the climatic conditions of Baku, the heating load per 1000 people will require 780 kW of heat, and for hot water supply per 1,000 people will be needed 349 kW of heat [3]. Thus, to provide 1000 people with heating and hot water supply, 1129 kW or 1.129 MW of heat is needed. Then 99 MW of heat can be provided to $\frac{99\cdot1000}{1,029}$ = 96210 population with heat and hot water supply.

In such powerful power plants, additional electrical energy can be obtained from the heat of exhaust gases [4]. In industry, secondary energy resources are used to produce electrical energy. The most common method to generate electricity from secondary waste is the Rankine steam cycle (Fig. 3).

Here, secondary resources (exhaust gases coming from the engine) are used to produce steam in the recovery boiler. The resulting steam is then fed into a steam turbine. In a turbine, thermal steam is converted into mechanical energy, and in an electric generator, mechanical energy is converted into electrical energy. Also, in modular power plants exhaust gases 500^{0}C, along with thermal and electrical energy, can be used to produce cold (trigenation scheme) [5].

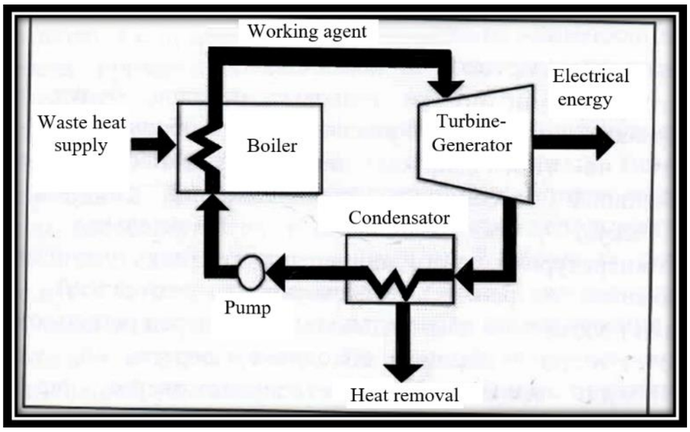

Figure 3: *Rankine cycle of a heat engine*

Currently, absorption refrigeration machines (ARMs) are widely used in industry. These machines require the following sources to operate:

1. Heat source.

A) Hot water with a temperature above 85^{0}C

B) Steam with a pressure of 0.1 MPa

B) Exhaust gases with temperatures above 230^{0}C

D) Natural gases

It can be seen that such sources are located in modular stations.

ARM consists of heat exchangers (generator, condenser, evaporator, absorber) in which on one side a LiBr solution or water (or water vapor) circulates under a vacuum, on the other side cooled water and cooling water circulate and a heating source in this case is water.

ARM operating principle:

The supplied heating source - hot water - heats the LiBr aqueous solution in the generator and generates water vapor from the solution, which in turn heats the cooling water in the condenser of the refrigeration machine and condenses to clean water. The resulting clean water then enters the evaporator (in a high vacuum state) and is dispersed over the copper pipes in the evaporator, taking heat from the cooled water, cooling it to 7^{0}C. The heated cooling water in the condenser, in turn, enters the cooling tower to discharge the resulting heat into the ARM. Water vapor from the evaporator enters the absorber, where it is absorbed by the concentrated solution coming from the generator. The resulting diluted solution is pumped back to the generator for heating, forming a cycle.

The main advantage of absorption plants in comparison with steam compressors is the low electricity consumption of up to 5-10 kW, for example, to produce 1 MW of cooled water, the ARM will consume 4.9 kW, then a freon cooler. It consumes about 250-300 kW.

ABHM have other advantages:

The use of cheaper energy (thermal) for drive compared to expensive electricity uses environmentally friendly refrigerant water. Service life is up to 30 years without major repairs. It has less noise and vibration. It is easier to operate, and has automatic control system it is used. In a power plant with an internal combustion engine.

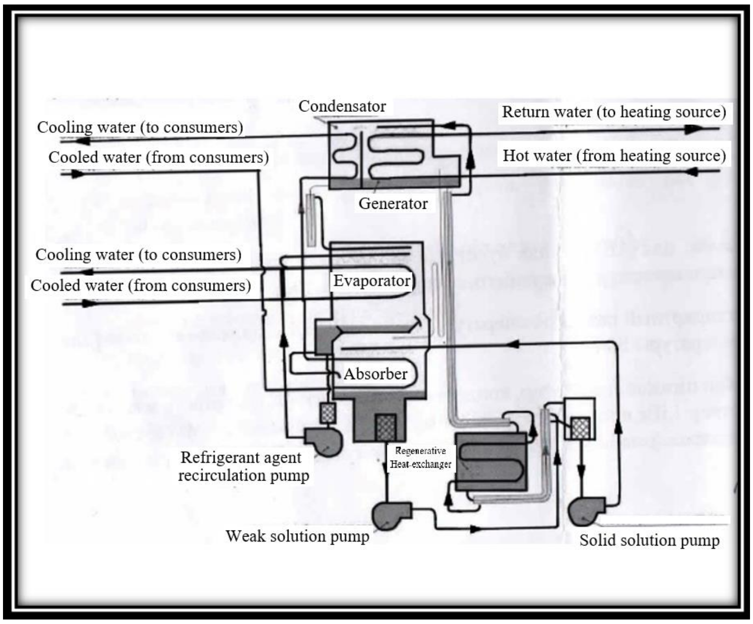

Figure 4: *Absorption lithium bromide refrigeration machines*

Power plants with combined production of heat, electricity, and cold (trigeneration plants) use fuel in the most efficient way and at the same time reduce carbon dioxide emissions. The overall efficiency of the station can exceed 90%. Trigeneration plants provide the ability to produce three important products - electricity, heating and cooling - using one power plant. Such stations can also be used for large facilities such as airports, shopping centers and other building complexes. This versatility does not compromise high reliability and excellent flexibility.

IV. Conclusions

1. The operation of modular power plants with a diesel engine with a capacity of 300 MW has been studied.
2. It was revealed that the loss of heat, fuel from exhaust gases is 99 MW, and with cooling water 20 MW.
3. Different schemes are proposed to use these losses, and by using heat at the station, additional electrical energy, steam, hot water and cold can be obtained.
4. The resulting thermal energy can provide 93,310 people with heat and hot water supply, the efficiency of the station increases by 16.8% and fuel savings will amount to 17.880 T/hour, the amount of emitted flue gases and environmental loads will decrease.
5. The introduction of trigeneration schemes increases the efficiency of the station, gives additional electrical energy received and steam generation, hot water and cold.

References

[1] Electricity Information 2017 Edition – Paris: International Energy Agency 2017 – p.71.

[2] Thermal calculation of boiler units using a computer. Kazan State Energy University. 2015 p.32

[3] Feyziev G.G., Jalilov M.F., “Heat supply” Textbook “Yurd”, NPB, p. 575.

[4] Ivashenko E.Yu. Technologies for recycling thermal waste. Minsk, VNTU. 2014-p. 108.

[5] Dzino A.A., Malinina O.S. Absorption refrigeration machines. Educational and methodological manual. ITMO University St. Petersburg 2016. p. 39.

ON SOME NEW ISSUES RELATED TO THE RISKS OF INCORRECT DATING OF DOCUMENTS IN THE LEGAL PROCESS (MINI REVIEW)

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Abstract

When appointing an examination of the statute of limitations of a document, the courts traditionally take into account the expert's experience expressed in the years of expert activity, the timing and cost of the examination. However, any traditional approach tends to become obsolete. When assessing the quality of the choice of expert methods, one should first take into account the social damage that may arise as a result of receiving court decisions based on erroneous or unfair conclusions of an expert. And only secondarily evaluate the cost and timing of the examination.

Almost all such examinations in Russia are performed by gas chromatography. At the same time, there is already an awareness in the world that it is necessary to look for an alternative to this method. The number of refused expert opinions containing the wording "not possible" is close to 100%.

The reason for this is that, in addition to the limitations inherent in the chromatography method, an incorrect physicochemical model of the process, based more on everyday experience than on scientific knowledge, is proposed for data processing.

World science in this matter goes in two directions: attempts to improve chromatographic methods by means of complicated procedures of sample preparation, search for new components with long "evaporation" period, adaptation of sampling devices and extraction methods, etc, and develops new, non-chromatographic, physicochemical models of degradation of writing compositions.

The lag of domestic science has led to a sharp decline in the quality of methodological support for determining the age of documents and created the risk that a large number of legal disputes related to the examination of the age of a document will be resolved not in favor of the truth.

Meanwhile, the other extreme is unacceptable: a complete refusal to standardize forensic methods. Improves the quality of forensic methods, the development of a special system of standards or technical regulations is required. Alas, the norms of metrology, the courts are considered as secondary and insignificant, which contradicts world experience.

Keywords: statute of a document, dating of the document, limitations of a document

II. Introduction

When appointing an examination of the statute of limitations of a document, the courts traditionally take into account the expert's experience expressed in the years of expert activity, the timing and cost of the examination. However, any traditional approach tends to become obsolete.

When assessing the quality of the choice of expert methods, one should first take into account the social damage that may arise as a result of receiving court decisions based on erroneous or unfair conclusions of an expert. And only secondarily evaluate the cost and timing of the examination. The damage from expert errors can be many times greater than the procedural and monetary savings.

This phenomenon can be very clearly seen in the example of the modern Russian state of methodological support for examinations of the age of documents. Forensic examination of the prescription of a document (more precisely, the totality of its individual details) is a type of forensic technical examination of a document, along with handwriting examination and examination of document materials.

II. Discussion

Determining the limitation of the manufacture of props is one of the most difficult forensic technical examinations of documents. In addition to complexity, it is also one of the most popular, since, from the point of view of an unscrupulous participant in the process, "correcting" the date of production of a document is the easiest way to obtain irrefutable evidence in the Court [1]. Almost all such examinations in Russia are performed by gas chromatography. At the same time, there is already an awareness in the world that it is necessary to look for an alternative to this method. The method has many limitations and problems associated with hypersensitivity to interfering assay factors. The main limitation is the "depth of analysis" within 1-2 years ago. This is certainly not enough, since for most of the analyzed details a much larger age is declared. This can be clearly seen from the publications of the Russian Federal Center for Forensic Expertise [1-3], in which Russian Federal Center for Forensic Expertise specialists are trying to make improvements to the methodology as they gain experience in its application. But the approach based on the adaptation of experience does not lead to an improvement in the method, and the number of refused expert opinions containing the wording "not possible" is close to 100%. The situation is slightly better on the world expert platforms, but even there, the percentage of "failures" is approaching 70% [4].

The reason for this is that, in addition to the limitations inherent in the chromatography method, an incorrect physicochemical model of the process, based more on everyday experience than on scientific knowledge, is proposed for data processing. At the everyday level, you can very easily and clearly imagine how "high-boiling" components of writing materials evaporate. And by controlling this dynamics, you can calculate the "age" of the props. More often than others, for this purpose they try to use the dynamics of changes in the concentration of glycerol and 2-phenoxyethanol. Further, at the level of the same everyday experience, it is tempting to use the publicly available EXCEL program and get a "satisfactory" approximation of the evaporation dynamics by a function of the form:

$$C=Ax^{-b} \quad (1)$$

where x is the age of the stroke; the values of coefficient A and exponent b are found as a result of the modeling procedure.

This simplistic approach contradicts some of the fundamentals of physical chemistry.

Table 1: *Some properties of individual analytes of writing materials [5, 6]*

Component	Boiling temperature (°C)	Equilibrium saturated vapor pressure at 20 °C (kPa)
2-phenoxyethanol	244	0,001
glycerol	290	0,0004 (50 °C)
water	100	0,31
ethanol	78	5,8

It can be seen from the table that both glycerol and 2-phenoxyethanol are not volatile liquids.

They have very high boiling points close to 300 °C and extremely low vapor pressures under normal conditions, which is easy to verify by comparing them with really volatile liquids: water and ethyl alcohol. Glycerol vapors begin to appear only when it is heated above 50 °C. At room temperature, glycerol does not evaporate. Consequently, the dynamics of the content of glycerol and 2-phenoxyethanol is not associated with their evaporation. Нужно искать иные причины, т.е. химические реакции, в результате которых компонент деградирует в составе материала письма. In this case, one should use the basic equation of chemical kinetics, the so-called "Arrhenius equation", similar to the models of foreign authors [7].

World science in this matter goes in two directions:

- attempts to improve chromatographic methods by means of complicated procedures of sample preparation, search for new components with long "evaporation" period, influence of paper sheet, adaptation of sampling devices and extraction methods, sample weight and desorption time, etc. [8-10].
- develops new, non-chromatographic, physicochemical models of degradation of writing compositions. As a rule, they are based on spectroscopy methods using modern mathematical methods for processing measurement results [11]. There is undoubtedly progress in this direction, but the final goal is still far away.

Unfortunately, domestic science has not been involved in the world process for a long time. Fundamental research in this area has not been conducted since the end of the last century (the accumulation of experience in the use of a single technique cannot be attributed to the scientific process). Periodic publications of the experience accumulated in the Russian Federal Center for Forensic Expertise do not affect the fundamental basis of the method. The overwhelming majority of experts have the illusion that there is and cannot be an alternative to gas chromatography in the version of the 80-90s of the twentieth century. Unfortunately, this turned out to be a favorable ground for the emergence of entire groups of non-state "pseudo-experts" who, knowing the weaknesses of chromatographic analysis, undertake to carry out any examinations of the prescription of a document by fitting to a predetermined result. Only in December-January 2023-2024, the Courts of St. Petersburg and the Leningrad Region considered 5 Cases containing "research by the Expert" Mr. I.N.P., where the chromatographic method "established" the age of documents dated 2005, 2012, 2013, 2017. Confidence in his impunity is based on the fact that there is no reference method of analysis. And such cases are not isolated.

The argumentation of reviewers pointing out to the Courts the obvious inconsistencies of such pseudo-expertises with the fundamental scientific basis of chromatography and physicochemical analysis, as a rule, does not find support in the Court. The argumentation of reviewers, as a rule, is based on fundamental arguments that are obscure to the Court, and unscrupulous experts - on personal experience and everyday ideas of the judges and lawyers. And argumentation, requiring fundamental special knowledge, is usually perceived as incomprehensible and alien to everyday perception.

Thus, the lag of domestic science has led to a sharp decline in the quality of methodological support for determining the age of documents and created the risk that a large number of legal disputes related to the examination of the age of a document will be resolved not in favor of the truth. In addition to material, economic and financial damage, which, in theory, can be calculated, there is significant social damage from the fact that a "gap" has appeared in the country's judicial system that allows the Courts to be misled in the interests of one of the parties. This undermines confidence in the judicial system as a whole. This trend has long worried the qualified expert community. Most often, the problem is proposed to be solved by creating professional departmental councils, and commissions consisting of trusted specialists who will weed out unscrupulous experts and monitor the scientific validity of expert research. However, this measure will not have the desired effect if the members of such councils do not have the necessary amount of fundamental knowledge, but will be guided only by personal experience of using a limited number of methods. Therefore, structures authorized by the government of the Russian Federation, primarily the Academy of Sciences of the Russian Federation (Resolution of the Government of the Russian Federation of December 30, 2018 No. 1781 "On the implementation of scientific and scientific-methodological management of scientific and scientific-technical activities of scientific organizations and educational organizations of higher education, as well as examination of scientific and scientific-technical results obtained by these organizations, and on amendments to certain acts of the Government of the Russian Federation") and the Federal Agency for Technical Regulation and Metrology (Rosstandart) (Federal Law of June 26, 2008 No. 102 "On Ensuring the Uniformity of Measurements"). To assess the qualifications of an expert, it is also advisable to attract information from the database of the Russian Science Foundation eLIBRARY.RU (https://elibrary.ru/elibrary_about.asp), which gives a statistical assessment of the scientific qualifications of all specialists of the Russian Federation.

The scientific validity of expert methods is inseparable from the requirements of their reasonable standardization to the extent necessary to prevent improvisations of unscrupulous experts. The basics of national standardization are described in No. 184 "On Technical Regulation". National standards and all-Russian classifiers of technical, economic and social information, as well as control over the implementation of the Federal Law of June 26, 2008 No. 102 "On ensuring the uniformity of measurements" are under the jurisdiction of Rosstandart. Unfortunately, forensic activities are not included in the list of areas of activity subject to mandatory standardization.

E.R. Rossinskaya points out that: "The process of expert research includes both standardized components and components that determine the action of a forensic expert approximately, in general terms. The methodology always contains rules and recommendations on the key points that determine the research design. No method can provide for the entire content of a particular study. Therefore, creative components are usually present in every expert study" [12, p. 15-16]. This indisputable statement, however, gives rise to unscrupulous experts to "justify" the rejection of metrology requirements and create arbitrary self-invented methods, without caring about their scientific validity, which does not allow the introduction of standardization in the forensic field in full.

Meanwhile, the other extreme is unacceptable: a complete refusal to standardize forensic methods. o improve the quality of forensic methods, the development of a special system of standards or technical regulations is required. The technical regulations of expert research should include unifying requirements that ensure the general scientific and metrological reliability of research, as well as procedural requirements. Standardization and unification of forensic technical examination of documents should, first of all, relate to methods of preparing objects for research, storage, sampling and transportation, and, necessarily, metrological support. Alas, the norms of metrology, the courts are considered as secondary and insignificant, which contradicts world experience.

B Importance should be given to unification [13] - establishing the optimal number of standard operations, primarily of a procedural nature. All this work should be carried out taking into account the fact that when improving the quality of forensic technical examination of documents, society faces a contradictory but feasible task: standardization and unification while maintaining the freedom of the expert in the choice of methods and means of examination, according to Federal Law of May 31, 2001 No. 73 "On state forensic activity in the Russian Federation".

It should also be mentioned about the organoleptic group of methods, which, paradoxically, also play, in the future, an important role in improving the quality of forensic methods for determining the age of a document. This group of methods, by analogy, in relation to STED, can include "expert experience". This method cannot be completely excluded from consideration, although, as mentioned above, its absolutization, which is practiced by the judicial authorities, is more harmful than beneficial to improving the quality of methods. The objectivity of the organoleptic method depends on the qualifications, experience and abilities of the persons conducting the examination. This should be added (in relation to expert activity) the level of cognitive abilities of the expert. This group of methods can be used in commodity science to determine the quality of products, the use of which is associated with emotional effects on the consumer. Moral satisfaction from the fact of establishing justice in a judicial dispute can also be attributed to emotional reactions.

Meanwhile, world science is actively engaged in the problem of quantitative registration, objectification and elimination of subjectivity of criteria for organoleptic "experience".

It should be taken into account that a scientific direction has already emerged in this area, replacing the organoleptic subjective perception of the properties of materials with an instrumental one. We are talking about a group of technologies from the "electronic nose and electronic tongue" family. Electronic language technology, consisting of non-selective sensors, is a quasi-organoleptic method for representing the composition of chemical mixtures. An electronic tongue (nose) is a package of sensors, preferably miniature ones, each of which cannot have high levels of sensitivity and selectivity for the components being measured, but the cumulative signal of such families of sensors carries additional information about the structure and properties of the system, which cannot be obtained using each sensor separately.

The sensor package data is processed digitally and visualized as clusters of values on the coordinate plane of the selected components. The aggregate signal forms a visualized image of the system. Such technologies are also called "multisensory" [14]. This concept, imitating the human organs of touch, was implemented in the development of the already mentioned analytical tools "electronic nose" and "electronic language" [15-17], which were introduced into use in 1995 as a result of joint Russian-Italian developments.

The electronic language proposed in 1995 is already positioned as a sensor used to analyze any solution consisting of a complex set of components using a package of non-specific chemical sensors and image recognition [18-20]. For this electronic language, a new method of mathematical processing of the cumulative signal of groups of sensors using chemometric analysis was used. The obtained result could be easily visualized in the form of a 2D or 3D graphical model in the selected coordinate system. That is, in this field there is a symbiosis of the visual image, digital model and verbal description of the composition of the system. This greatly simplifies a number of analytical and expert tasks, as the visual image often simplifies verbal descriptions. In addition, a set of digital and visual data allows you to simulate the next stage of the human nervous system: the processing of an array of information by the brain, which is performed by software of the highest level. And then move on to sending commands to actuators and devices.

Chemometrics is a synthetic discipline located at the intersection of chemistry and mathematics. It allows you to implement complex data processing algorithms, in particular, the results of multidimensional and multifactorial experiments. The following methods are widely known in chemometrics: ANN (artificial neural network), DASCO (discrete analysis with short covariance matrix), INLR (implicit nonlinear latent regression), PARAFAC (parallel factor analysis), PAT (process analytical testing), PCA (principal analysis components), PCR (principal component regression), PLS (projection to latent structure), etc.

The most commonly used method of mathematical processing of electronic signals of the electronic tongue and electronic nose is the chemometric method of the principal components of PCA.

In turn, with the development of chemometrics, manufacturers of measuring instruments began to actively create equipment capable of measuring in the form of multidimensional data sets, rather than individual digital files or values [21].

Chemometric methods are already being introduced into forensic practice abroad. For example, in a forensic environmental examination [22]. An attempt has been made to apply it to the forensic technical examination of documents [23 – 25]. For this purpose dates of actual execution of document details are transformed into figures of spatial clusters on plane of coordinates of selected components of value matrices.

In the absence of such a presentation, specialists and experts would be faced with the difficult problem of verbally describing the results obtained for unprepared listeners. Demonstration of a visual picture of chemometric clusters, for example, during a court hearing, according to the plan, will help the judge understand the logic of the expert who made the conclusion based on the measurement results. Unfortunately, legal proceedings have not yet adapted this form of argumentation and prefer to rely on formalized verbal images and concepts, but we believe that we are talking about the near future, since scientific and technological progress will force the parties to the process to master this "language". We deliberately focused on this group of methods in such detail, since the use of a chemometric apparatus for the purpose of establishing the statute of limitations of a document in order to improve the quality of methods will actively develop in world science in the coming years in those areas of forensic examination where the main role, so far, is played by the experience and subjective opinion of the expert.

III. Conclusion

Summing up, it should be noted that the state of fundamental science in the field of dating documents in the Russian Federation is characterized by a set of problems. The necessary scientific research in this area is not carried out. In non-state expertise, there are entire groups of unscrupulous specialists who carry out conclusions by adjusting to a predetermined result. They argue their unreliable results with understandable at the household level, but not at all with scientific arguments. Legal proceedings are not yet ready for modern natural science and technical argumentation. Very often, the Court and the legal profession prefer to rely on concepts from the field of personal and everyday experience. An important task of improving the quality of forensic research is the mastery by the Judicial and Lawyer Corps of the language of fundamental scientific concepts and modern methods of mathematical processing of the results of expert research. Digital visualization of the results of expert research can provide significant assistance in this matter.

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References

[1] Skoromnikova O.A., Borisova E.A. The practice of applying the methodology «determining the prescription of the execution of details in documents by the relative content of volatile solvents in strokes» in forensic institutions of the Russian Ministry of Justice // Theoretical and applied aspects of the use of special knowledge in criminal and civil proceedings: a collection of articles. Vol. 6: Current issues in forensic examination of documents. Moscow: RGUP, 2022. P. 205–211. (In Russ.)

[2] Bezhanishvili G.S. and others. Possibilities of analyzing volatile components of ballpoint pen pastes using gas chromatography // Expert technology. 1988. Vol. 102. P. 96–111. (In Russ.)

[3] Trosman E.A., Chertkova T.B., Yurova R.A., Borisova E.A., Skoromnikova O.A., Timofeeva V.I. Document dating analysis based on relative content of volatile solvents in strokes: Methodological recommendations. Moscow: RFCFS, 2015. 25 p. (In Russ.)

[4] Koenig A., Weyermann C. Ink dating, part I: Statistical distribution of selected ageing parameters in a ballpoint inks reference population // Science and Justice. 2018. Vol. 58. №1. P. 17–

30. https://doi.org/10.1016/j.scijus.2017.08.002

[5] CRC Handbook of Chemistry and Physics. 90th Edition / edited by David R. Lide. CRC Press (Taylor and Francis Group). Boca Raton. FL. 2009. – 2804 p. https://doi.org/10.1021/ja906434c

[6] Yalkowsky S.H. Handbook of aqueous solubility data. CRC Press, 2003. – 1512 p. https://doi.org/10.1201/9780203490396

[7] Cantu, A.A. A study of the evaporation of a solvent from a solution – Application to writing ink aging // Journal of Forensic Sciences. 2012. Vol. 219. P. 119–128. https://doi.org/10.1016/j.forsciint.2011.12.008

[8] Sun, Q., Luo, Y. How much can a forensic laboratory do to discriminate questioned ink entries // Journal of Forensic Sciences. 2016. Vol. 61. №4. P. 1116–1121. https://doi.org/10.1111/1556-4029.13067

[9] Sherma, J. Advances in the thin-layer chromatographic forensic analysis of inks // Journal of Liquid Chromatography & Related Technologies. 2016. Vol. 39. №12. P. 549–557. https://doi.org/10.1080/10826076.2016.1183130

[10] Ni, Y., He, N. Study of ink aging: Targeting triethylene glycol in carbon-based black gel ink strokes on paper // Forensic Science International. 2020. Vol. 311. Article 110296. https://doi.org/10.1016/j.forsciint.2020.110296

[11] Díaz-Santana, O., Conde-Hardisson, F., Vega-Moreno, D. Comparison of the main dating methods for six ball-point pen inks // Microchemical Journal. 2018. Vol. 138. P. 550–561. https://doi.org/10.1016/j.microc.2018.01.045

[12] Forensic examination: typical mistakes / ed. E.R. Rossinskaya. Moscow: Prospekt, 2016. – 544 p. (In Russ.)

[13] Hvorecky, J., & Korenova, L. Quality of textbooks from the knowledge management perspective // Alteridad. 2023. Vol. 18. №2. P. 273-284. https://doi.org/10.17163/alt.v18n2.2023.10

[14] Vlasov, Yu.G. ISFET's and other miniature chemical sensors: Perspective of the development and analytical application of multisensors arrays with selective and non-selective membranes // Annali di Chimica. 1997. Vol. 87. №3–4. P. 261–272

[15] Jiang, H., Zhang, M., Bhandari, B., & Adhikari, B. (2018). Application of electronic tongue for fresh foods quality evaluation: A review // Food Reviews International. 2018. Vol. 34. № 8. P. 746–769. https://doi.org/10.1080/87559129.2018.1424184

[16] Vlasov, Y., Legin, A., Rudnitskaya, A., Di Natale, C., D'Amico, A. Nonspecific sensor arrays («electronic tongue») for chemical analysis of liquids // Pure and Applied Chemistry. 2005. Vol. 77. № 11. P. 1965–1983. https://doi.org/10.1515/ci.2006.28.2.32

[17] Podrażka, M., Bączyńska, E., Kundys, M., Jeleń, P. S., & Witkowska Nery, E. Electronic tongue—a tool for all tastes? // Biosensors. 2017. Vol. 8. № 1. P. 3. https://doi.org/10.3390/bios8010003

[18] Tan, J., & Xu, J. Applications of electronic nose (e-nose) and electronic tongue (e-tongue) in food quality-related properties determination: A review // Artificial Intelligence in Agriculturel. 2020. Vol. 4. P. 104–115. https://doi.org/10.1016/j.aiia.2020.06.003

[19] Ross, C.F. Considerations of the use of the electronic tongue in sensory science // Current Opinion in Food Science. 2021. Vol. 40. P. 87–93. https://doi.org/10.1016/j.cofs.2021.01.011

[20] Wu, X., Tahara, Y., Yatabe, R., & Toko, K. Taste sensor: Electronic tongue with lipid membranes. analytical sciences. 2020. Vol. 36. № 2. P. 147-159. https://doi.org/10.2116/analsci.19r008

[21] Brereton, R.G. Chemometrics. Wiley-VCH, 2018. 464 p. https://doi.org/10.1002/9781118904695

[22] Otto M. Chemometrics: Statistics and Computer Application in Analytical Chemistry. Wiley-VCH, 2023. 432 p. https://doi.org/10.1002/9783527843800

[23] Gorshkova K.O., Rossinskaya E.R., Kirillova N.P., Fogel A.A., Kochemirovskaia S.V., Kochemirovsky V.A. Investigation of the new possibility of mathematical processing of Raman

spectra for dating documents // Science & Justice. 2020. Vol. 60. №5. P. 451–465. https://doi.org/10.1016/j.scijus.2020.06.007

[24] Ershova, K.O., Kochemirovskaia, S.V., Ciesla, R., Kirillova, N.P., Mokhorov, D.A., & Kochemirovsky, V.A. Physicochemical analysis of the age of handwritten inscriptions on documents: Trends and prospects // Expert Systems with Applications. 2022. Vol. 205. Article 117683. https://doi.org/10.1016/j.eswa.2022.117683

[25] Mokhorov D.A., Kochemirovsky V.A. Dating of the document: Monograph / Institute of Advanced Research and Expertise. St. Petersburg: Publishing and Printing Association of Higher Educational Institutions, 2023. 262 p. (In Russ.)

ECONOMETRIC ASSESSMRNT OF THE IMPACT OF VOLUME OF RADON EMISSIONS PER CAPITA IN THE REPUBLIC OF AZERBAIJAN

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Abstract

The Republic of Azerbaijan is an oil and industrial country rich in natural resources. Determining and analyzing the activity of natural radionuclides in nature, studying the physical essence and mechanism of action of oil and gas deposits, radioactive aerosols in the environment are among the most urgent issues of the day.

It is important to study the physical nature and mechanism of action of radioactive aerosols generated in the environment in oil and gas extraction areas. The indicated radioactive substances show themselves as sources of α, β, γ - radiation, and their organotrope entering the living organism leads to undesirable pathology by having a bilateral, that is, synergistic effect. It is very important to investigate the individual and cumulative effects of these harmful effects.

Keywords: oil and gas deposits, natural radionuclides, radiation source, environment, harmful effects, radioactive substances, econometric evaluation

I. Introduction

The growing demand for oil and gas in the world economy has created conditions for increasing oil and gas production. As a result, the volume of radon gas generated during oil and gas refining has increased. Although global gas consumption in 2019 was lower than in 2018 (+2.6%), this growth continued (record year + 5.1%). Despite a 3.1% increase in natural gas demand in 2019 in the United States, the world's largest gas consumer with the emergence of new gas-fired power plants, gas prices have fallen. Growth by sector was uneven. Thus, although it was 7% in the energy sector, there no significant change in the utilities, trade and industry sectors [1].

II. Methods

In China, the increase in gas consumption has halved (+ 8.6%) due to the slowdown in economic growth and the easing of the policy of replacing coal with gas. China ranks 24% of global growth, ranking second in the world in terms of demand growth (+ 8.6%).

Consumption in the EU increased by + 3.1% due to improved demand in natural gas production countrie such as Spain, Germany and Italy, as well as Russia, Australia, Iran, Algeria and Egypt [1].

In Asia, the decline continues in Japan and South Korea due to declining demand in the energy sector (declining electricity consumption and increasing competition from nuclear and RES power plants). [2]

In Latin America, gas consumption remains stable; Brazil and Argentina saw a slight decline, while Mexic saw a 4.4% increase. Radon emissions have continued to rise in coal- and hydrocarbon-producing countries such as Russia, Australia, Iran, South Africa and Algeria. The following graph provides information on radon gas emissions in the CIS and AR [3].

As can be seen from the picture data the dynamics of radon emissions in 2000-2019, mainly in the CIS countries in 2002-2008, including the Republic of Azerbaijan, increased and in 2008-2010 this increase was observed in Azerbaijan with a decrease.

III. Results

In 2011-2016, the volume of radon emissions increased in Azerbaijan. Thus, compared to 2011, the volume of radon emissions in Azerbaijan increased by 18.9% to 33.3 thousand tons, and in the CIS countries decreased by 7.4% in the same period and amounted to 2300 thousand tons. In 2019-2022, this figure increased in the CIS and Azerbaijan.

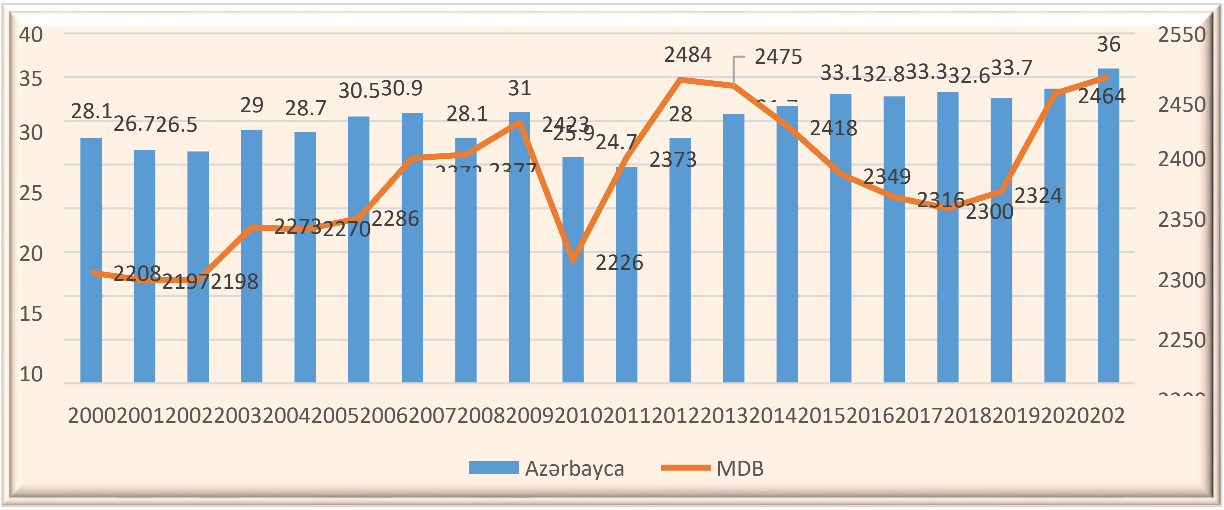

Figure 1: *Dynamics of radon gas emissions in the CIS and the Republic of Azerbaijan for 2000-2022, thousand tons*

China ranks first in the world in terms of radon emissions. The volume of radon emissions in this country at that time was 11,535,200 tons. The top ten includes China, the United States, India, the Russian Federation, Japan, Germany, Iran, South Korea, Indonesia and Saudi Arabia. Azerbaijan ranks 66th in the world in terms of radon emissions (36.0 thousand tons) [4].

The volume of CO_2 emissions in the Republic of Azerbaijan was higher during the former USSR. This can be seen more clearly in the chart below [5].

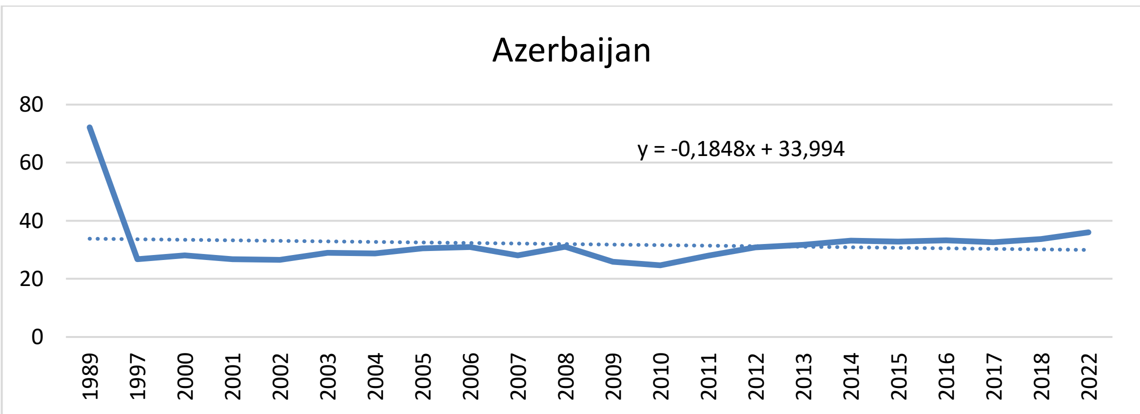

Figure 2: *Dynamics of radon gas emissions in the Republic of Azerbaijan for 1970-2022, thousand tons*

As can be seen from the data in the table, the volume of radon emissions increased to the peak in the Republic of Azerbaijan in 1970-1989. Thus, in 1989, this figure was 72.2 thousand tons compared to 1970.This means an increase of 2.23 times. As can be seen from the trend model, which shows the dependence of the volume of radon emissions in the Republic of Azerbaijan on the time factor, the time dependence is weak in terms of the correlation coefficient [1].

Increasing the amount of radon waste has a negative impact on human health by increasing the amount of waste per capita. From this point of view, one of the most important issues is the interaction of the volume of radon emissions in the Republic of Azerbaijan with radon emissions per capita. The chart below shows this information [6].

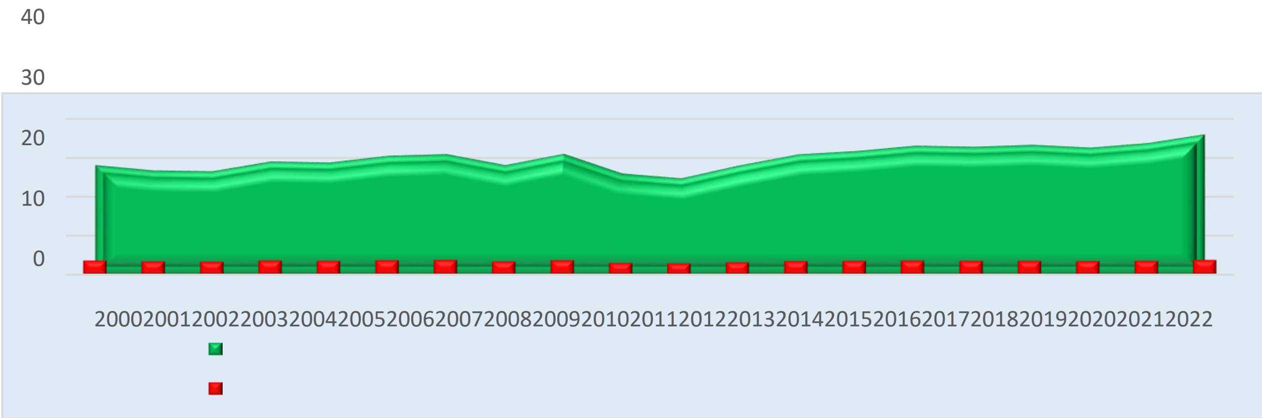

Figure 3: *Dynamics of radon gas emissions in the Republic of Azerbaijan for 1970-2022, thousand tons*

The impact of increasing radon emissions on per capita radon emissions can be explored.

Many ready-made mathematical software packages, including EViews, MatLab, MS Excel, MathCad, etc., are used to conduct regression analysis of the dependence of radon emissions per capita on the increase in radon emissions in the Republic of Azerbaijan [1]. It should be noted that the Eviews software package is more universal for the purpose of regression analysis, so using this software package, we obtain the following result based on the data in Fig. 3 above.

As can be seen from the Eviews application software package, there is an average correlation between the variables Y and X, expressed by the model Y = 0.0535 * X +1.726 (R2 = 0.524850). Thus, the degree of dependence between the indicators on the Cheddock scale, the fact that the quantitative value of the density of the connection is in the range of 0.3-0.5, show that the quality characteristic of the strength of the connection dependence is average [7], [2].

Based on this correlation equation, it can be concluded that the increase in the volume of radon emissions in the Republic of Azerbaijan is characterized by a 1.73 increase in radon gas per capita.

As can be seen, model (1) is statistically significant according to the table based on the EViews application software package. This significance is primarily explained by the fact that the coefficient of the free variable X, the free limit C, is higher than their standard errors.

Since it is important to check the adequacy of the established model, this adequacy can be determined using the F-Fisher criterion as one of the traditional methods. Expressing the regression equation as a whole (2) F-Fisher criterion to test the statistical significance of the model should be compared with the value of *F*figure (a; m; n - m - 1) [2]. Table 2 showing the results of the Eviews software package according to F- statistics (Fisher's criterion) = 19.88 .If we define the value of the table F in EXCEL using the formula *F*figure (a; m; n - m - 1)= F (0,05; 1; 18) = 4,41

When the F-Fisher criterion is compared with the value of *F* figure (a; m; n - m - 1), it appears that the F-Fisher criterion is>*F*figure (19,88> 4,41). The regression equation as a whole is statistically significant [2]. This means the adequacy of the established model (1).

Table 1: *Regression analysis of the dependence between the increase in the volume of radon waste and the radon waste per capita*

DependentVariable: Y
Method: Least Squares
Date: 27/03/24 Time: 20:02
Sample: 2000/2022
Included observations: 20

Variable	Coefficient	Std.Error	t-Statistic	Prob.
X	0.053474	0.011992	4.459007	0.0003
C	1.725654	0.362742	4.757242	0.0002
R-squared	0.524850	Meandependentvar		3.335500
AdjustedR-squared	0.498452	S.D.dependentvar		0.222154
S.E.ofregression	0.157329	Akaikeinfocriterion		-0.766310
Sumsquaredresid	0.445546	Schwarzcriterion		-0.666736
Loglikelihood	9.663096	Hannan-Quinncriter.		-0.746872
F-statistic	19.88274	Durbin-Watsonstat		0.927251
Prob(F-statistic)	0.000303			

Based on the results obtained from the Eviews application software package, the regression equation will be as follows:
EstimationCommand:
=========================LS YXC
EstimationEquation:
=========================Y =C (1) *X+C (2)
SubstitutedCoefficients:
=========================
Y=0.0534743869455*X+1.72565358101
Source. The Eviews application was developed by the author based on the software package.

The result of autocorrelation in the model can be determined based on the Darbon-Watson statistics in Table 3.1, obtained from the EViews application software package. As can be seen from the table, DW is equal to 0.927.In this case,

For 4 observational variables m = 1 and n = 20 observations at the significance level α = 0.05, the Darbon-Watson crisis points will be as follows [2].

$$d_l=0,902, \qquad d_u=1,118$$

$$d_l=0,902<DW=0,927<d_u=1,118 \tag{1}$$

As there is no conclusion on the existence of autocorrelation . [2].

dl = 0.902 <DW = 0.927 <du = 1.118 (3.1)

The regression equation as a whole is statistically significant and the constructed Y = 0.0535 * X +1.726 model is adequate.

Prices for radon gas per capita in the Republic of Azerbaijan and standard errors, found by the regression equation obtained on the basis of the Eviews application software package, as well as a number of characteristics of the use of the equation for forecasting purposes are shown in the graph below.

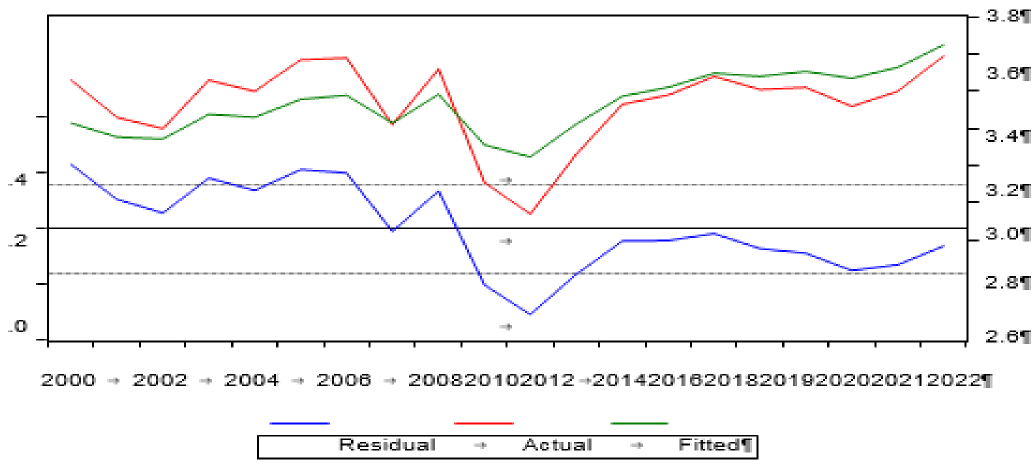

Figure 4: *Prices of radon gas per capita in the Republic of Azerbaijan by years, standard errors, characteristics for forecasting [8],[9].*

Using the graph, it is possible to determine the expected forecast prices for radon gas per capita in the Republic of Azerbaijan. Evaluation the impact of the increase in radon gas emissions during oil and gas refining in the Republic of Azerbaijan on the level of radon gas per capita by elasticity coefficient is also an important issue.

As a result of the study, by calculating the coefficient of elasticity for the linear regression equation above the degree of influence of the relationship between these indicators can be expressed as a percentage (1).It should be noted that the coefficient of elasticity is the percentage increase in the dependent variable due to a 1% increase in the free variable x included in the model or decrease is calculated according to the following formula [2].

$$E_{CO^2} = \frac{a_1 x_1}{y} \quad (2)$$

Here, αi are the coefficients of the above contact equation. $\bar{x}$ is the calculated average of CO_2 emissions for the studied periods, $\bar{y}$ is the calculated average of the level of radon gas per capita in the Republic of Azerbaijan for the studied periods. The elasticity coefficients calculated on the basis of these indicators will be as follows for the built model.

$$E_{CO^2} = \frac{a_1 x_1}{y} = \frac{0.0535 \times 30.105}{3.3355} = 0.482871 \quad (3)$$

Calculations show that a 1% increase in radon gas emissions in the Republic of Azerbaijan leads to a 0.483% increase in the level of radon gas per capita in the Republic of Azerbaijan.

If we establish a correlation-regression relationship between the volume of radon gas emissions in the Republic of Azerbaijan and the level of radon gas per capita in the Republic of Azerbaijan in MS Excel, we get the following result.

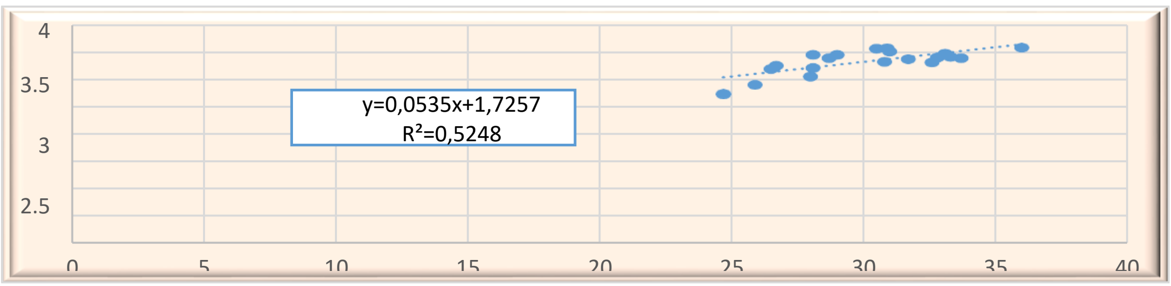

Figure 5: *Correlation-regression relationship between the volume of radon gas emissions in the Republic of Azerbaijan and the level of radon gas per capita [8]*

The correlogram of radon gas emissions of oil and gas refining in the Republic of Azerbaijan with the level of radon gas per capita in the Republic of Azerbaijan according to the Eviews software package will be as follows.

Table 2: *Oil and gas processing with per capita radon gas levels suspension of radon gas waste generated during*

Date:27/03/24 Time:20:25
Sample:2000/2022
Included observations: 20

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. |*** |	. |*** |	1	0.419	0.419	4.0618	0.044
. |* . |	. *| . |	2	0.097	-0.096	4.2899	0.117
. *| . |	. *| . |	3	-0.083	-0.106	4.4668	0.215
***| . |	***| . |	4	-0.382	-0.366	8.4806	0.075
.**| . |	. | . |	5	-0.283	0.022	10.835	0.055
. *| . |	. *| . |	6	-0.201	-0.108	12.104	0.060
. *| . |	. | . |	7	-0.109	-0.032	12.503	0.085
. | . |	. | . |	8	0.055	-0.033	12.616	0.126
. *| . |	.**| . |	9	-0.115	-0.315	13.146	0.156
. *| . |	. *| . |	10	-0.100	-0.078	13.590	0.193
. | . |	. | . |	11	0.041	0.048	13.672	0.252
. | . |	. *| . |	12	-0.028	-0.108	13.715	0.319

The Eviews application was developed by the author based on the software package.

The linear coefficient of double correlation is calculated to estimate the density of the relationship between the studied indicators. This ratio is determined according to the following formula [2] [10].

IV. Discussion

Value of the coefficient [-1; 1] varies in the range. The closeness of the rxy-coefficient to the unit indicates that there is a close correlation between these indicators. The fact that $rxy = 0$ indicates that there is no linear dependence.

Although the ratio is zero and there is no linear relationship between the subjects, there may be a nonlinear relationship. The degree of dependence between the indicators is determined mainly by the Cheddock scale. The linear coefficient of double correlation also determines the direction of cause and effect. Thus, if $rxy> 0$, there is a direct relationship between the indicators. That is, as the causal factor (x) increases, so does the value of the outcome indicator (y).

If $rxy<0$, then there is a feedback between the indicators.is, as the cause factor (x) increases, the value of the outcome indicator (y) decreases. The CORREL statistical function is used to determine the linear coefficient of double correlation based on the Eviews application software package.

According to the table, R2 = 0.525 means that the corresponding regression equation is explained by 52.5% of the variance results, and 47.5% by the influence of other factors.

The dynamics of the Fitted and Actual values, as well as the residuals between them, according to the regression equation of the built-in model (2) and the Eviews application software package, are given in the graph below [2].

There is a mean correlation expressed by the linear regression equation Y = 0.0535 * X +1.726.

References

[1] Nuraliyeva R.N., Economic and ecological problems of the development of the fuel energy complex of Azerbaijan. Baku, 2010.

[2] Yadigarov T.A. Solving operations research and econometric issues in MS Excel and Eviews-12 software packages: theory and practice. Baku-2020.

[3] Seminsky K.Zh., Bobrov A.A. The first results of studies of temporary variations in soilradon activity of faults in western pribaikalie. // Geodynamics & Tectonophysics. 2013; 4(1): 1-12. (In Russ.) https://doi.org/10.5800/GT-2013-4-1-0088

[4] Gülaliyev, M. G., Nuraliyeva R.N. Assessing the Impact of the Oil Price Shocks on Economic Growth in Oil-Exporting Arab Countries. // WSEAS Transactions on Business and Economics Vol. 19, p. 462 – 4732022. DOI: 10.37394/23207.2022.19.42

[5] Gülaliyev, M. G., Mamedova G.V. (2020) Consumer Surplus Changing in the Transition from State Natural Monopoly to the Competitive Market in the Electricity Sector in the Developing Countries: Azerbaijan Case. *International Journal of Energy Economics and Policy.* 10(2), 265-275. DOI: https://doi.org/10.32479/ijeep.8909

[6] Ismail, K., The Structural Manifestation of the Dutch Disease: The Case of Oil Exporting Countries, International Monetary Fund. No. w/10/102, 2010, pp.37

[7] SSCRA. (2022), State Statistical Committee of Republic of Azerbaijan. Available from: https://www.stat.gov.az/menu/4/e-reports . [Last accessed on 2022 December10].

[8] SRM. (2022), Strategic Road Map on Development of Utilities (Electricity and Thermal Energy, Water and Gas) in the Republic of Azerbaijan. Available from: https://www.president.az/articles/22368 . [Last accessed on 2022 Apr 25].

[9] Gadom Djal Gadom, Armand Mboutchouang Kountchou and Abdelkrim Araar, The impact of oil revenues on wellbeing in Chad. // Environment and Development Economics, 23, 2018, pp.591–613.

RISK REDUCTION IN WELL FLOW LINES BASED ON EARLY DIAGNOSIS OF COMPLICATIONS

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Abstract

The reliability of the system for collecting products from oil, gas and gas condensate fields directly depends on the condition of the well flow lines. Many years of experience in the exploitation of offshore fields in the Azerbaijani sector of the Caspian Sea shows that various kinds of complications arise in the flow lines of wells associated with salt deposits, asphalt base, tarry oil and paraffin deposits, fluid accumulation, pressure pulsations, etc.

The listed complications lead to the formation of blockages in the flow lines, an increase in the mechanical load on the equipment and, ultimately, to a decrease in the productivity of lines and wells, up to the point of stopping their operation. Work to restore these lines takes quite a long time and requires significant costs.

Reducing technological risks in the operation of well flow lines is closely related to diagnosing their condition. But planned diagnostic work involving forces and equipment often in practice reveals complications at a late stage of their development and engineering decisions are made to shut down wells and restore lines.

In connection with the above, the issues of diagnosing complications at an early stage of their formation acquire current and practical importance. Timely cleaning of flow lines and regulation of operating conditions of production wells, such as the selection of an adequate wellhead pressure regime and other technological solutions, can prevent a negative scenario for the development of complications. In turn, for early diagnosis of complications it is necessary to find a diagnostic criterion. determining the beginning of their formation. Due to the fact that the main flow parameters at the metering nodes are continuously recorded in real time, it would be advisable to develop an appropriate diagnostic criterion based on the results of studying the dynamics of time series for the main indicators of flow lines.

For this purpose, in this work, flow lines of wells in the Bulla-Deniz field (Azerbaijan) were studied. The main indicators for the studied lines were length and diameter, pressure at the beginning and end of the line, gas factor and line productivity. Based on these indicators, data processing was carried out and corresponding statistical estimates were obtained.

The results of the analysis revealed a stable correlation between gas factor indicators and flow line performance. It was established that a sharp decrease in line productivity with an increase in the gas factor manifested itself in wells in which restoration work was carried out due to complications that arose. This makes it possible to use this behavior of the curves of the dependence of flow line productivity on the gas factor as a criterion for diagnosing complications at an early stage of their formation.

The results of this research can be recommended for use in the operation of a system for collecting and transporting oil and gas field products.

Keywords: flow lines, risk analysis, diagnosis of complications, gas factor, line productivity

I. Introduction

Well flow lines, as an element of the gas and oil collection network, are pipelines originating at the wellhead and ending at the entrance to group metering installations [1]. Many years of operating experience show that various kinds of complications arise in flow lines, the elimination of which requires stopping the operation of wells and carrying out repair work, accompanied by significant downtime and, as a consequence, material and labor costs.

In work [2], using the example of Russian fields, it is shown that the accumulation of liquid, especially at the late stage of development, leads to a number of complications both in flow lines and in the operation of process equipment at the collection point. Among them, one can highlight an increase in hydraulic resistance, the observation of volley releases of liquid into separation units, pressure pulsations and the formation of hydrate plugs with a decrease in temperature in winter. The authors here also propose, in order to reduce the risk of liquid accumulation, optimal regulation of gas extraction modes, which, ultimately, should also significantly increase the operating efficiency of separation units.

The authors in another work [3] list asphalt base oil, tarry oil and paraffin deposits, the formation of emulsions, hydrates, and inorganic salts as the main factors leading to complications in field pipelines. The researchers in this work brought some clarity to the conditions and mechanism of formation of the above factors and listed existing methods for reducing the risk of their formation.

Technological risks associated with the formation of hydrate plugs and the loss of paraffin deposits in pipeline lines have been studied in detail in studies [4]. Here, the authors proposed a probabilistic model for assessing the above risks in pipelines transporting oil and gas, tested it on real field data and showed fairly good performance.

In offshore oil and gas production, flow lines are connected to a subsea pipeline that transports well production to onshore collection and treatment facilities. In this regard, the above complications in the operation of flow lines lead to potential hazards in the operation of underwater pipelines, which were analyzed in detail for the conditions of the Caspian Sea in [5].

Reducing risks in the operation of well flow lines and, in general, subsea pipelines, field process pipelines and other pipeline communications is directly related to the ability to diagnose their condition. It is important to note here that quite often, diagnostic work begins to be carried out after complications have arisen in their work and work to restore them requires significant costs. Therefore, issues of early diagnosis, that is, timely detection of the onset of complications, have always been of scientific and practical interest and remain relevant today.

For example, in article [6] the use of fractal analysis for diagnosing liquid inclusions in gas flows in field gas pipelines is justified. Based on field data, flow characteristics were constructed for the flow lines of selected wells and the corresponding values of the fractal dimension were obtained using the coating method. A stable correlation has been established between changes in fractal dimension and the presence of liquid inclusions in gas flows. The presence of such a stable connection was also confirmed by the results of studies conducted in [7].

Thus, a change in the fractal measure of flow characteristics curves seems to be a fairly effective analytical criterion for early diagnosis of complications in the operation of flow lines of wells, in particular the accumulation of the liquid phase in them.

II. Methods

As the object of research 23 flow lines of the "Bulla-Deniz" field (Azerbaijan) have been taken and dynamics of the change of average values of the following indices have been analyzed: oil consumption, gas consumption, pressure at the beginning and end of the line, gas factor, average temperature of the flow and productivity of the flow line. All these indices are presented in the Table 1.

Studied lines were divided into two groups due to their productivity on the basis of hyperbolic value of distribution to reveal the flow lines in the operation of which complications occurred [8].

Table 1: *Values of operational parameters of the flow lines*

Flow lines	Diameter D, m	Length L, m	Rate of oil, q_{oil} ,t/day	Rate of gas q_{gas} , m^3/day	Pressure at the beginning P_1 , MPa	Pressure at the end P_2 , MPa	Gas factor q , m^3/t	Temperature t , °C	Ourput of line t/day/MPa
9	0,102	1250	253	76	5,8	2,2	300	50	70,3
60	0,102	1500	462	72	7,2	2,2	156	45	92,4
67	0,102	1700	410	30	4,5	0,8	143	57	110,8
57	0,102	1500	285	25	6,3	4,2	88	58	135,7
65	0,102	1000	200	46	9,6	4,7	230	44	40,8
62	0,102	1800	150	28	4,4	2,0	187	43	62,5
61	0,102	1250	300	44	6,8	3,0	98	40	107,1
71	0,102	1250	385	44	5,8	2,0	114	47	101,3
34	0,102	1000	450	36	6,0	2,2	120	49	118,4
48	0,102	1250	210	45	3,9	1,9	110	38	105,0
43	0,102	1750	190	21	5,0	0,8	110	37	45,2
122	0,102	1200	181	80	7,0	2,0	442	35	36,2
100	0,102	1200	310	53	4,4	2,1	170	55	134,8
84	0,102	1350	220	22	5,1	2,0	100	45	70,9
80	0,102	1250	255	65	4,0	1,8	254	53	115,3
32	0,102	1500	250	47	3,5	0,9	188	53	96,1
45	0,102	1650	225	20	4,7	1,2	88	59	64,3
85	0,102	1750	150	40	4,9	3,5	266	35	107,0
76	0,102	1750	140	38	5,9	4,5	271	29	100,0
39	0,102	1500	60	6	3,7	2,3	100	54	42,8
36	0,102	1400	180	25	4,4	2,8	140	32	112,5
105	0,102	1300	320	39	6,4	3,9	310	42	94,1
17	0,102	1300	230	57	6,0	3,5	250	40	92,0

Flow lines with output below 92 t/day/MPa refer to the first group and above 92 t/day/MPa were collected to the second group. After division into groups we proceeded with big probability that complications have occurred in the lines with small productivity. That's why flow lines have been separately taken on each group: № 9, 65, 43 and 122 — from the first group line; № 61, 57 and 48 — from the second group line. Samples on monthly indices of oil consumption; gas factor and line productivity have been prepared individually. These indices have been processed for establishing static relations between existing methods of data analysis.

III. Results and discussion

The results of data processing have revealed definite regularity in the behavior of the dependence curves of flow line productivity on the gas factor. Thus, for the flow lines of the second group where no complications were observed (lines N 61, 57 and 48) gas factor weakly influences oil consumption change at the same pressure drops. By the other words points plotted on the coordinates of flow line productivity ($q_{oil}/\Delta P$,t/day/MPa) and gas factor index (q) are located on the straight line rather accurately (Figure, a). As it is seen from the figure increase of gas factor index doesn't considerably influence flow line productivity decreases. Together with it, analysis of dependency of productivity on the gas factor index for flow lines of the group (lines 9, 62, 43 and 122), where complications were observed has revealed the following stable regularity. In these lines productivity considerably decreases by the increase of gas factor (Fig. 1). It can be explained by that due to the complications occurred in the lines, oil consumption decreases, part of the gas dissolves in the sediments and as a result productivity of flow lines reduces.

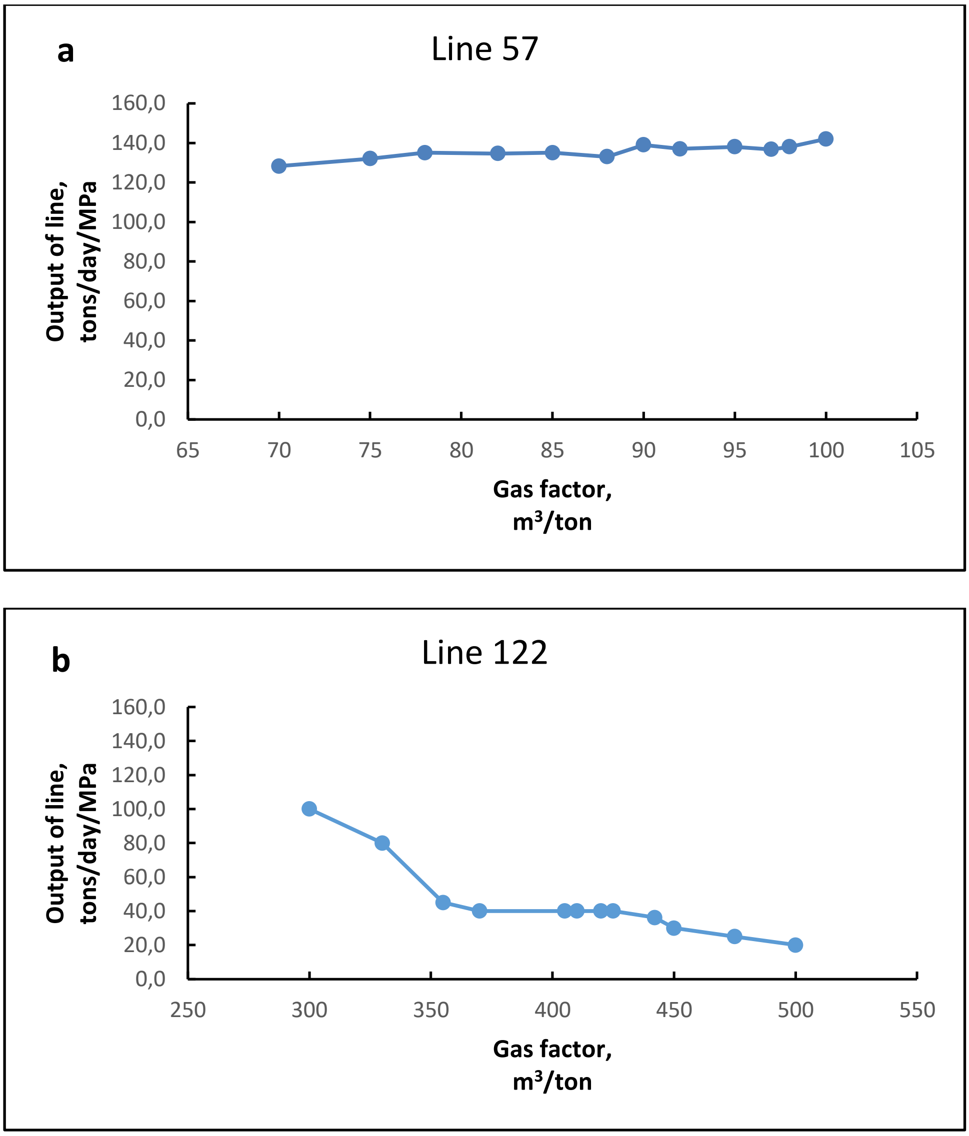

Figure 1: *The curves of the influence of the gas factor on the output of the flow lines*

The result of the carried out researches allow us to determine the following main conclusion that considerable decrease the productivity by gas factor increase is the diagnostic criterion for early revealing of the occurrence of complications in the flow lines and carrying out recovery works in time.

References

[1] Lutoshkin G.S. Collection and preparation of oil, gas and water. Moscow, 2016.

[2] Rotov A.A., Istomin V.A., Cheltsova T.V., Mitnitsky R.A. Technology of liquid removal from gas collection network pipelines due to a short-term increase in gas extraction. // Gas industry. Special issue. No. 1 (782), 2019, pp. 86-92.

[3] Gurnitskaya E.Yu., Zubairov T.A. Analysis of the influence of the main complicating factors identified during operation in industrial pipeline transport // Transport and storage of oil products and hydrocarbon raw materials. No. 2-3, 2021, pp. 77-80.

[4] Hongfei Xu, Faisal Khan, Seungho Jung, Qingsheng Wang Probabilistic model for hydrate and wax risk assessment in oil and gas pipelines // Process Safety an Environmental Protection, 170 (2013), pp.11-18.

[5] Ismayilov R.A., Asgerova R.I., Ismayilov I., Guliyeva T. Risk assessment in subsea pipelines for the Caspian Sea conditions // RT&A, Special Issue No5(75), Volume 18, November 2023, pp.422-427.

[6] Ismayiov R.A., Askerova R.I., Fractal analysis for modes of the field pipelines / Readings of A.I. Bulatov: Materials of IV International scientific and practical conference. Conference bulletin, v.3, Krasnodar: Publishing House-South, 2020, pp.113-120.

[7] Ismayilov R.A., Bakhisheva Z.I. Fractal analysis of flow characteristics of delivery lines on the Karadag UGS // Proceedings of Azerbaijan High Technical Educational Institutions, Volume 25, Issue 4(144), 2023, pp.17-22.

[8] Edward L. Robinson Data analysis for scientists and Engineers. Princeton University Press. -2016, 408p.

AUTOMATED CONTROL SYSTEM FOR THE SUPPLY OF LIQUID FUEL TO A TUBE FURNACE

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Abstract

For optimal control of technological processes in explosion- and firehazardous industries, which include oil and gas refining, chemical and petrochemical objects, one of the main and pressing issues is the effective control of the liquid fuel supply to tube furnaces. To automatically regulate the output temperature of the raw materials supplied to the furnace on the liquid fuel line, an appropriate actuator is used. At the same time, gas fuel is continuously supplied to the tube furnace. The main reason for the intermittent supply of liquid fuel is that it is used as a feedstock for other technological installations It is known that feeding fuel into a tube furnace is unsafe for the technological process as a whole, that is, it is a process of a certain increased danger. This can lead to unwanted fires and explosions in the workplace. Therefore, to reduce some technical and technological risks, it is important to use liquid fuel with appropriate breaks, since the use of dry gas in a technological system poses a certain danger.

Keywords: technological process, liquid fuel, technological risk, tube furnace, control system, gas fuel

I. Introduction

Oil refining is a large-scale production, consisting of a large number of complex technological installations, which are complexes of many interconnected technological apparatuses [1-11]. One of such important and complex oil refining technological apparatuses is tube furnaces. Tube furnaces are used in the following oil refining installations: primary oil refining as part of Atmospheric Vacuum Tube installations; reforming; hydrocracking; viscosity breaking; delayed coking installation; isomerization; hydrogen production by steam reforming, etc. [12, 13].

It is known that tube furnace is a technological apparatus for heating a flow or carrying out a high-temperature chemical reaction due to the heat that is released during the combustion of organic fuel, that is, it is intended for heating hydrocarbon raw materials by open fire heating of tubular coil with gases in the combustion chamber from the combustion of liquid or gaseous fuel. After heating hydrocarbons in tube furnaces, they are subsequently sent to distillation columns to separate them into components (diesel fuel, heating oil, gasoline, etc.).

Thus, tube furnaces are used in any oil refinery and petrochemical plant in all major refining processes [14-17]. This is due to the fact that a tube furnace is the most cost-effective and efficient process for heating oil fractions.

Due to the lack of fuel gas produced in oil refineries, liquid fuel is also used to heat raw materials in process tube furnaces.

Combustion of liquid fuel in tube furnaces at oil refineries is ineffective from an economic and environmental point of view, since, on the one hand, environmental pollution by flue gases increases, and on the other hand, the possibility of using liquid fuel (fuel oil) as a raw material is reduced. Therefore, rational use and saving of liquid fuel is a very important and pressing problem in similar industries and is of great importance for the entire economy as a whole.

For this purpose, thorough research work was carried out in the field of the raw materials heating process entering the tube furnace in an oil refinery and the following shortcomings were identified:

1) the existing fuel network management system (processing of gaseous fuel, as well as its use) does not meet the requirements of modern automated operational control systems (there is no effective and optimal automated control system between production and relevant consumers);

2) since the total amount of fuel gas used in technological installations cannot provide the amount of fuel required to heat raw materials in tube furnaces, they also use liquid fuel along with dry gas. At the same time, to control the required temperature of the product at the outlet of the tube furnace, dry gas is continuously supplied to the technological system. It is important to note that when gas is supplied to the system, there is a possibility of an explosion and fire hazard in a tube furnace. This circumstance turn, can lead to certain technological and technical risks when heating the raw materials used. Thus, this affects the correct and efficient functioning of the automated control system as a whole.

In addition, it should be noted that in oil refineries regulate the temperature of the feedstock leaving the tube furnaces and select the gas fuel flow rate. On the other hand, adjusting the temperature of the raw material at the outlet of the tube furnace with gas flow leads to the fact that part of the dry gas is released into the flare line to equalize the pressure in the fuel network to a given value.

II. Development of an automated control system for the supply of liquid fuel to a tube furnace

From the factors mentioned above, it is clear that to eliminate the corresponding technological and technical risks arising in the gas and fuel technological network, it is necessary to create an automated control system for liquid fuel processing. At the same time, the automated control system for emergency situations must ensure that the following conditions are met:

- the pressure in the gas distribution point must be maintained constant (stable) according to the set point value;
- the discharge of dry gas from the gas distribution point to the flare line of the technological system should be minimized;
- the temperature of the raw materials at the outlet of the tube furnaces must be maintained constant (stable) in following the set point value.

An automated control system that meets the above requirements is presented in Fig. 1. When the gas pressure (position 5-1) coming from the gas distribution point increases, (position 5-2) and the pressure regulator (position 5-3) acts on the valve (position 5-4) located at the entrance to the tube furnace, according to a command received from the setting device, increasing its throughput.

In this case, the pressure of the gas supplied after the gas separator to the tube furnace (position 6-1) drops. In this case, to stabilize the pressure of the fuel gas supplied to the tube furnace according to the set point value, it acts on the secondary device (position 6-2), from there on the regulator (position 6-3), the control valve (position 6-4), increasing the capacity of this valve. In this case, the temperature of the raw material at the outlet of the tube furnace by the set point value is realized as follows.

Signals from thermocouples installed on the ridge wall and the outlet of the tubular furnace (position 1-1) and (position 2-1) are supplied, respectively, to temperature converters (position 1-2) and (position 2-2), and then they go to electric-pneumatic transducer (position 1-3) and (position 2-

3), and from them they are further sent to secondary devices (position 1-4) and (position 2-4).

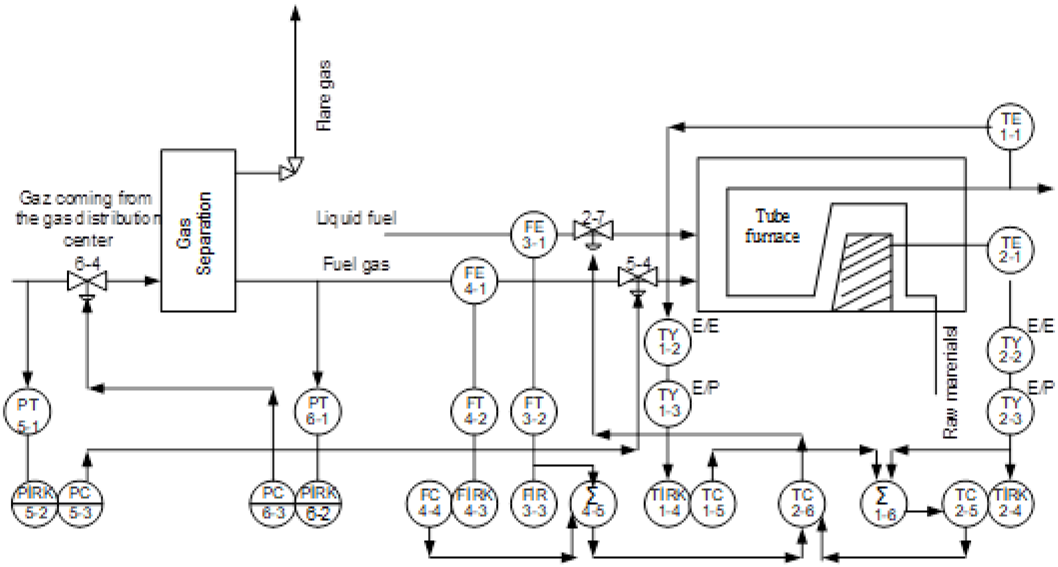

Figure 1: *Structural scheme of an automated system for the supply of liquid fuel to a tube furnace*

Having received a set point value from the output of the device (position 1-4), the controller signal (position 1-5) goes to the summator (position 1-6).

At the same time, the input of the summator (position 1-6) also receives a signal from the output of the electro-pneumatic transducer (position 2-3). At the same time, the output signal of the summator (position 1-6), as a variable value, is supplied to the temperature controller (position 2-5) by the set value coming from the secondary device (position 2-4).

The output signal of the temperature controller (position 2-5) is fed to the input of another temperature controller (position 2-6) as a set point value. The temperature controller input (position 2-6) receives signals from flow sensors (position 3-1) and (position 4-1) as variable values. The output signal of the temperature controller (position 2-5) is fed to the input of another temperature controller (position 2-6) as a set point value.

The temperature controller input (position 2-6) receives signals from flow sensors (position 3-1) and (position 4-1) as variable values. Pneumatic signals from local devices (position 3-2) and (position 4-2) are accumulated in the summator (position 4-5) and then the output signal of this summator in the variable value form is supplied to the input of the temperature controller (position 2-6). As a result, the temperature controller output (position 2-6) acts as a force on the control valve (position 2-7), reducing its flow capacity.

It should be noted that if the pressure in the gas distribution center drops below the set point value, the automated control system presented above has the opposite effect.

Let's look at a microprocessor system for controlling the process of heating raw materials in tube furnaces.

It is known that heating raw materials in tube furnaces during primary oil refining is a very complex heat engineering process, the correct implementation of which depends on the correct control of numerous technological parameters of the apparatus under study. Therefore, it is necessary to create a control system in tube furnaces that ensures stable maintenance of operating parameters under technological requirements. The structural scheme of such a system is presented in Fig. 2.

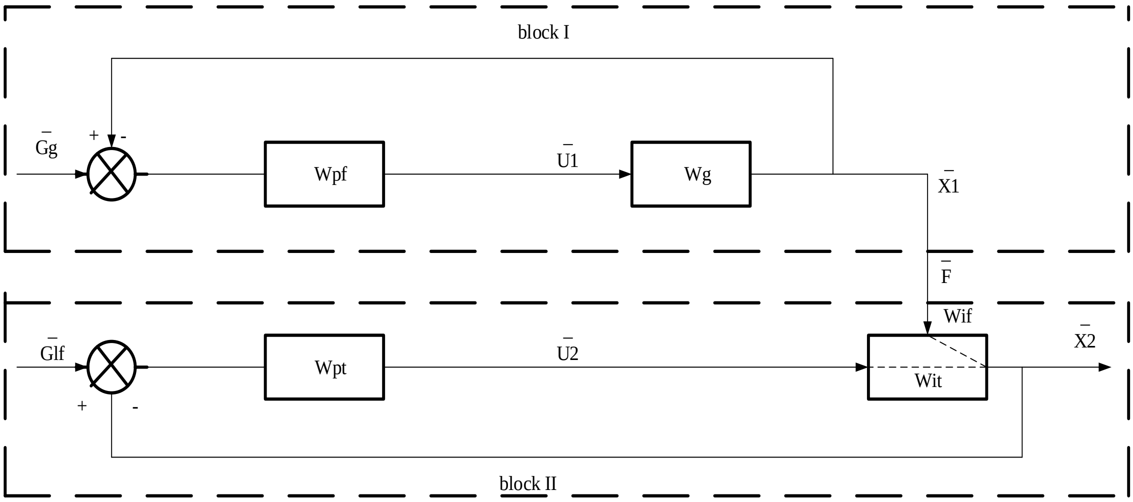

Figure 2: *The structural scheme of a microprocessor control system*

Here W_{pf} and W_{pt} are the diagonal matrices for the transfer functions of the multichannel flow and temperature controller, respectively. W_{if} and W_{it} – transfer functions matrices of the technological object for gas flow and between the temperature channels of the raw material at the tube furnace outlet. $\bar{G}_g$ and $\bar{G}_{lf}$ are vectors of set point values for gas and liquid fuel consumption. $\overline{X1}$ and $\overline{X2}$ are the vectors of output parameters (temperature). $\overline{U1}$ and $\overline{U2}$ are vectors of regulatory actions. As can be seen from Fig. 2, the control system consists of two control blocks – I and II. With the help of block I, the optimal gas fuel division between technological tube furnaces is realized, and with the help of block II, a constant (stable) temperature at the outlet of the tube furnaces is maintained. Analysis of this structural scheme shows that, on the one hand, a change in vector G1 along the direct channel has a disturbing effect on the output parameter $\overline{X1}$. On the other hand, since block I is powered by the collector, changing the regulator in it causes a change in the adjacent controlled parameter in the same block. Therefore, in technological tube furnaces, disturbing influences arising in the system for regulating mode parameters are transmitted not only through a direct channel but also through a transverse channel.

Therefore, to improve the quality of regulation, it is necessary to create an autonomous regulation system in block I and an invariant regulation system in block II, based on the above principles.

It is known that when controlling technological processes in oil refineries, not one, but several tube furnaces are used. Therefore, to correctly and effectively regulate the temperature at the outlet of tube furnaces, a combined computer control system has been created.

The structural scheme of the proposed combined computer control system is shown in Fig. 3. The system operates in the following order: changing the set point value of the regulator in accordance with the optimal price of fuel gas is carried out by the dispatcher (operator). But after converting the current values of regulating and disturbing influences into a direct current signal with a 4-5 mA strength, through the appropriate electronic type converters, they are supplied to the input of an analog-to-digital converter located in the control computer complex. The analog-to-digital converter, in turn, converts the analog signal into codes. After the analog-to-digital converter, the signal through the multi-channel control software module also determines the magnitude of the control action, and this signal is sent to the input of the digital-to-analog converter located in the computer. The direct current signal (4-20) mA, which appears at the output of the digital-to-analog converter, is converted through an electro-pneumatic converter into a pneumatic signal (0.2-1) kg/cm² and acts on certain actuators. Current technological parameter values characterizing the heating process raw materials in tube furnaces are displayed on the display screen, and the operator enters into dialogue with the control computer complex to complete the task.

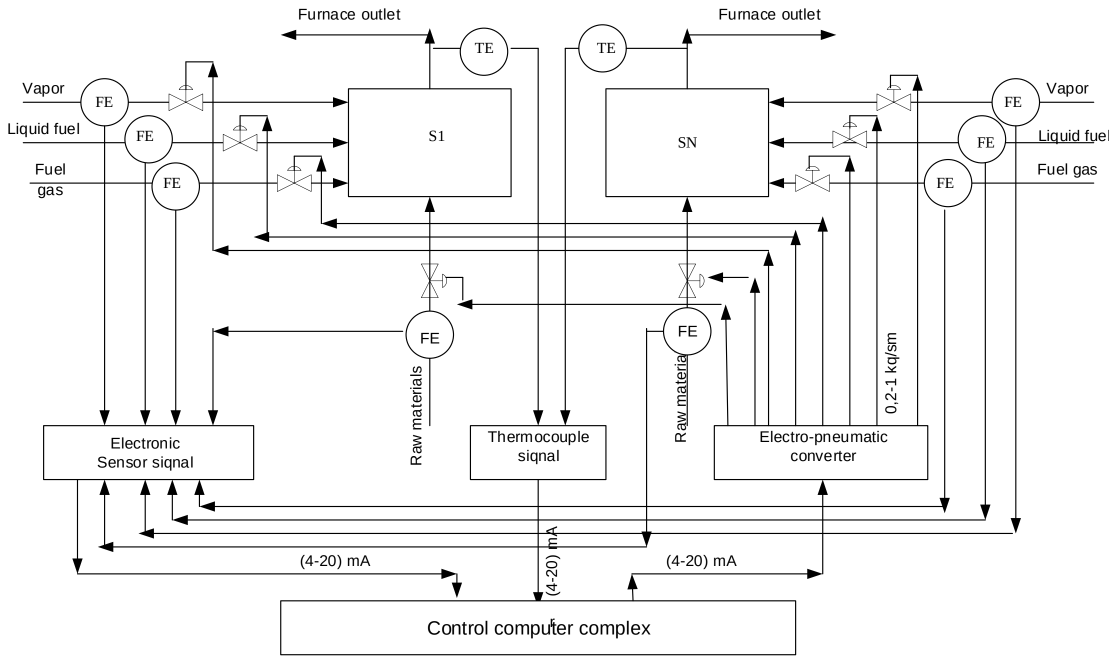

Figure 3: *Structural scheme of a combined computer control system*

III. Conclusion

An automated control system for the supply of liquid and gas fuel to a tube furnace has been developed. When supplying gas from a gas distribution center to a tube furnace, a system has been developed to regulate the flow and fuel gas pressure. To regulate the temperature of the raw material supplied to the tube furnace, which is important for the technological process, an actuator installed on the liquid fuel line is used.

Heating raw materials in a tube furnace is a complex process. In this process, stable preservation of the many mode parameter values must be ensured by the set point value. In this regard, the proposed microprocessor system for controlling the consumption of liquid and gaseous fuel, quality indicators, temperature, and pressure has been developed.

To maintain a stable temperature of the output raw material in tube furnaces, a control computer complex is proposed in a combined computer control system.

Thus, based on the above, various types of automated control systems have been developed to maintain the necessary and required temperature of the technological process under study.

References

[1] Guseinov I.A., Khanbutaeva N.A., Melikov E.A., Efendiev I.R. Models and Algorithms for a Multilevel Control Systems of Primary Oil Refinery Installations. // Journal of Computer and Systems Sciences International, Pleiades Publishing, Ltd., 2012, Vol. 51, No. 1, pp. 138-146. DOI: 10.1134/S1064230711060098

[2] Xanbutayeva N.A., Melikov E.A. Algorithm optimization static rejimes installation of primary oil refining. // National Science Review, Chinese Academy of Sciences, Oxford University Press, 2017, Vol. 4, No. 4 (2), pp. 1459-1466.

[3] Melikov E.A. Process optimization for catalytic reforming. // Journal of Engineering and Technology Development Research, Germany, 2022, No. 1, pp. 17-18.

[4] Melikov E.A., Maharramova T.M. Power qualıty control for bitumen productıon. // Ekoenergetics, Baku, Azerbaijan, 2022, No. 4, pp. 37-40.

[5] Maharramova T.M., Melikov E.A. Energy saving system in vacuum unit. // Ekoenergetics, Baku, Azerbaijan, 2022, No. 3, pp. 8-12.

[6] Melikov E.A. Decomposition algorithm and mathematical models of hierarchical structure of control of the process of primary oil processing. // Prospecting and Development of Oil and Gas Fields, No. 2 (67), 2018, pp. 75-82. DOI: 10.31471/1993-9973-2018-2(67)-75-82

[7] Aliev I., Melikov E.A. Experimental method for constructing a mathematical model of a hydrogenation oil cleaning installation. // Scientific Journal of İtaly "Annali d'Italia", 2023, No. 39, pp. 78-82. DOI: 10.5281/zenodo.7568947

[8] Hesenli V., Melikov E.A. Principles of constraction a control and regulation system for a technological complex, including a vacuum block. // Scientific Discussion (Praha, Czech Republic), 2023, No. 73, pp. 35-38. DOI: 10.5281/zenodo.7626743

[9] Magerramova T.M., Melikov E.A. Strategy for optimizing the functioning of the vacuum block at the technological equipments. Herald of the Azerbaijan Engineering Academy // The international science-technical journal, 2023, Vol. 15, No. 2, pp. 110-115.

[10] Safarova A.A., Melikov E.A., Magerramova T.M. Constructıon of a multı-connected control system for safe coke productıon. Reliability: Theory and Applications, Electronic Journal of International Group on Reliability Journal is Registered in the Library of the U.S. Congress, USA. // Journal Reliability: Theory and Applications, Special Issue, 2023, Vol. 18, No. 5 (75), pp. 510-517. DOI: https://doi.org/10.24412/1932-2321-2023-575-510-517

[11] Hasanov Kh., Melikov E.A. Increasing the extraction of vacuum gas oil at the ELOU-AVT unit. Proceedings of Azerbaijan High Technical Educational Institutions (PAHTEI). // Multidisciplinary Journal, Refereed & Reviewed Journal, 2023, Vol. 35, No. 12, pp. 251-257.

[12] Safarova A.A., Melikov E.A, Magerramova T.M. Control of a tube furnace in conditions of risk and increased explosion hazard. Reliability: Theory and Applications, Electronic Journal of International Group on Reliability Journal is Registered in the Library of the U.S. Congress, Spesial Issue, USA / (The 4-th Eurasian Conference and Satellite Symposium, RISK-2022, Baku, Azerbaijan), 17(SI 4 (70)), 2022, pp. 516-521. DOI: https://doi.org/10.24412/1932-2321-2022-470-516-521

[13] Safarova A.A., Magerramova T.M., Melikov E.A., Huseynov I.A. Analysis and solving the problem of synthesis of an automatic control system for a tube furnace. // Journal of Harbin Engineering University, China, 2023, Vol. 44, No. 10, pp. 1357-1365.

[14] Safarova A.A., Melikov E.A, Magerramova T.M. Optimal control of the alkylation process reactors. // Operational Research in Engineering Sciences: Theory and Applications (ORESTA), Belgrade, Serbia, 2023, Vol. 6, No. 1, pp. 312-321. DOI: https://doi.org/10.31181/oresta/0601130

[15] Guseinov I.A., Kurbanov Z.G., Melikov E.A., Efendiev A.I., Efendiev I.R. Nonstationary Multistage Process Control in the Petrochemical Industry. // Journal of Computer and Systems Sciences International, Pleiades Publishing, Ltd., 2014, Vol. 53, No. 4, pp. 556-564. DOI: 10.1134/S1064230714030095

[16] Merdanov E., Melikov E.A. Simulation of a reactor for the selective hydrogenation of acetylene-containing impurities. // Polish Journal of Science, 2023, No. 59, pp. 116-118. DOI: 10.5281/zenodo.7638458

[17] Melikov E.A., Maharramova T.M., Ahmadova S.Sh. Study of propylene glycol production plant as an automation object. / Materials of VII International scientific and practical conference ("Readings of A.I. Bulatov") (in Russian), 2023, Vol. 2, pp. 97-100.

ANALYSIS OF THE TECHNOLOGY FOR PREVENTION OF HYDRATION RISKS IN TRANSPORTATION PROCESS OF GAS BY PIPELINE

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Abstract

In the article, the solution of the issues of transportation of the produced product in the oil and gas extraction department occupies one of the main places. Pipelines belong to technological systems that represent fire-explosion dangerous objects with a complex structure capable of hydrate formation, erosion, ignition, explosion and environmental pollution. By reducing technological risks that may occur in underwater pipelines, it is possible to ensure technological and environmental safety at sea and protect marine bioresources. Risk analysis using statistical data can reveal the negative consequences of natural hazards and other external influences on the pipeline system.

Keywords: gas, hydrate, oil and gas extraction, pipelines, risk, hydrocarbon accumulation, gas condensate, paraffin, condensate

I. Introduction

Researches and field works should be carried out to improve the technological process and develop new scientific and technical proposals in order to reduce hydrate formation and other possible technological risks during the process of gathering and preparing gases produced from gas condensate deposits for transportation. These research works should be carried out in several directions [1,5]. It can be determined by studying the operation of separate devices of hydrocarbon gas collection and transport preparation units operating in the oil and gas extraction station. Reducing the risks of hydrate formation during exploitation in field conditions, choosing the optimal technological mode of operation for the collection and preparation of hydrocarbon gases for transportation and the selection of reagents with high efficiency during the process are important issues [2,4].

II. Research and analysis of results

It is known that both underground and surface gas pipelines are constantly exchanging heat with the environment. For this purpose, it is considered technically, technologically and economically efficient to develop, apply reagents in the technological process to reduce the risk of hydrate formation, drying of gas from water vapors, corrosion, salt and paraffin deposits in the gas hydrocarbon collection, preparation for transporting and transportation system. Taking these into account, it is appropriate to analyze and improve the technological processes applied in the oil and gas industry in recent years to reduce the operational costs incurred in the gas collection, preparation for transporting and transportation processes, prepare quality indicators in accordance with international standards, and to decrease the risks of hydrate formation that may occur.

Since the efficiency of low-pressure gas collection and transportation processes depends on the compliance of the equipment related to these processes with the requirements of relevant technologies, the operating modes of pipelines and compressor stations should be investigated.

The study of the influence of the low-pressure gas transportation pipelines on the indicators of the station until the reception of the compressor station is carried out on the following issues.

The indicators of the compressor station consist of its destination parameters. These parameters are related to the following factors:

- factors that have a positive or negative effect on the operation of the compressor units of the low-pressure gas pipelines before the station reception;
- factors that increase or decrease the gas permeability of low-pressure gas pipelines;
- ambient temperature and humidity affecting gas pipelines and compressors.

The main factors affecting the ability of low-pressure gas transmission pipelines to the compressor station reception: depend on the diameter of the pipeline, its length and the curves of the pipelines.

In order to study the gas permeability of the pipelines, the construction of each pipeline is determined, after recording its starting and ending points, important factors affecting the compressor station, increasing or decreasing its productivity are determined.

The construction of plugs and connecting devices installed at the beginning and end points of the pipeline and the opening and closing times cause changes in gas parameters (pressure, temperature, and quantity) and thus affect the indicators of the compressor station.

The results of the conducted research and field work showed that as a result of the change of thermodynamic parameters (P, T, Q, etc.) in the process of transporting natural and associated gases, the gas phase leaves the liquid phase (water + condensate + oil fractions + paraffin deposits, etc.) on the inner surface of the gas pipelines. This creates difficulties in its turn. Thus, the formation of hydrate in the system creates an emergency situation, in addition to reducing the productivity of gas pipelines, leading to the loss of large volumes of gas and condensate. Overcoming these difficulties requires additional operating and energy costs.

Taking these into account, it is appropriate to consider in advance and report the temperature regime of the area where the gas pipelines pass, depending on the season, in order to ensure the smooth transportation of low-pressure gases to the compressor station.

The results of the research and field works carried out in the DWF show that the development of new scientific and technical proposals to ensure the unimpeded transportation of low-pressure gases from deep sea foundations to the under-construction FCS (field compression stations) is one of the urgent issues of the day.

The results of the conducted field studies showed that in order to increase the efficiency of the gas lines between the DWF and clean the liquid phase (water + condensate) falling into the line, it is planned to release a ball in each line of the project. However, the results of field studies show that an additional force is needed to ensure the movement of the ball inside the pipeline.

It is known that since the pressure of the surrounding gases is too low, 0.15-0.20 MPa cannot ensure the internal movement of the ball in the pipeline and its cleaning from the liquid mixture. Taking these into account, it is more effective to increase the efficiency of low-pressure gas transportation by using a number of technologies, as low-pressure gas transportation lines pass through complex relief areas.

During the movement of the gas through the seabed pipes, the liquid contained in it separates and after a certain time passes, preventing the passage of the gas, it ensures the formation of hydrate. Although this problem has been tackled in various ways, its solution is still relevant. Let's look at finding the pressure needed to clean up liquid build-up and eliminate the risk of hydrate formation when transporting gas through a pipeline on the seabed. In the first option, let's look at the worst case, that is, when the pipes are completely filled with a liquid mixture.

If to assume that the fluid is incompressible, its equation of motion is as follows [3]

$$0 \le s \le \frac{\ell}{2} \qquad m\frac{dv}{dt} = P \cdot f - 2\pi R(\ell - s) \cdot \tau - \rho g s f \sin\phi \tag{1}$$

Here $\sin\phi = \frac{2H}{\ell}$, $m=\rho\pi R^2(\ell - s)$ is the mass of liquid; ρ - the density of the liquid; ℓ; R, f - the length of the pipe, the inner radius of the pipe, and the cross-sectional area, respectively, τ - the friction between the fluid and the inner surface of the pipe wall is the shear stress.

If to substitute the mass of liquid in expression (1), we get the following equation:

$$\rho\pi R^2(\ell - s)\frac{dv}{dt} = Pf - 2\pi R(\ell - s)\tau - \rho g s f \sin\phi \tag{2}$$

The relationship between the frictional stress and the average speed can be found as follows:

$$\tau = \mu v \tag{3}$$

μ - is the resistance coefficient between the surface of the liquid and the pipe wall. If to consider equation (3) in expression (2) and simplify, we get:

$$\rho\pi R^2(\ell - s)\frac{dv}{ds}v = Pf - 2\pi R(\ell - s)\mu v - \rho g s f \sin\phi \tag{4}$$

Since the speed in the first approximation is small, if to ignore the resistance force, we get the following equation from expression (4):

$$\rho\pi R^2(\ell - s)\frac{dv}{ds}v = Pf - \rho g s f \sin\phi \tag{5}$$

If to integrate the differential equation (5), we get:

$$P = \frac{\rho v^2}{2\ln 2} + \frac{\rho g \ell \sin\phi}{\ln 2}\left(\ln 2 - \frac{1}{2}\right) \tag{6}$$

By expression (6), giving the value of v, it is possible to calculate the pressure needed to squeeze out half of the liquid collected in the pipeline.

In the second option, after the level of the liquid in the pipeline falls to the height H, the pressure required to raise it is found as follows.

The equation of motion of liquid in a pipe:

$$m\frac{dv}{ds}v = P \cdot f - \rho g f(H - s\sin\phi) \tag{7}$$

$$m = \rho f\left(\frac{\ell}{2} - s\right)$$

If to substitute the mass of the liquid in equation (7), we get it:

$$\rho f\left(\frac{\ell}{2}s\right)v\frac{dv}{ds} = Pf - \rho g f(H - s\sin\phi) \tag{8}$$

If to integrate the differential equation (8), we get

$$P = \frac{\rho v^2}{2\ln 2} + \rho g\left(H\ln 2 + \frac{\ell}{4}\sin\phi - \frac{\ell}{2}\ln 2\sin\phi\right)\frac{1}{\ln 2} \tag{9}$$

Considering the equations (6) and (9), the parameters of the pipes, l =3000m; H=200m; R=0.15m; ϱ = 10^3 kg/m^3; Numerical reports were made at values of v= 0.5m/sec. The results of the reports show that the pressure required to remove the first half of the liquid collected in the pipe is P≅0.3ϱgH, and to remove the second half is P ≅ (0.7÷1)ϱgH, that is, for the considered case P_{max} ≅ (1.4÷2.0) MPa, it is possible to completely clean the liquid accumulated in the pipe.

Based on the results of field research, the working pressure required to compress and remove the liquid collected from the pipe passing through the bottom of the sea was determined by means of a mathematical report. In order to ensure unhindered transportation of low-pressure gases between deep water foundations, high pressure (P ≅ 8-10 MPa) supplied to the gas lift system in separate foundations is drawn from the gas lines and low-pressure gas (P=1.5-2.0 MPa) should be given to the line.

Initially, the following technological scheme (Fig. 1) is proposed to ensure unhindered transportation of low-pressure gases between DWFs:

According to the scheme, a gas line (1.5-2.0 MPa) is taken (3) in addition to the high-pressure gas pipelines (1) supplied to the gas lift system (10) from DWF and supplied to the low-pressure gas line (5). Due to the high-pressure gas generated in the system, the liquid phase falling on the pipe is compressed and removed and collected in the liquid tank (8) located on the base.

The proposed method is simple and can be performed by making some changes in the technology of the field equipment located in the foundations. Based on the results of the research and analysis of the low-pressure gas lines to be supplied from the deep-water foundations to the FCS, the following scientific and technical proposals have been developed to ensure the unhindered transportation of gases. The results of the research and mining works carried out in the DWF showed that it is possible to ensure the unhindered transportation of low-pressure and high-pressure gases from deep seabeds to FCS.

The proposed scheme for the transportation of low-pressure gases between DWFs (Fig. 1).

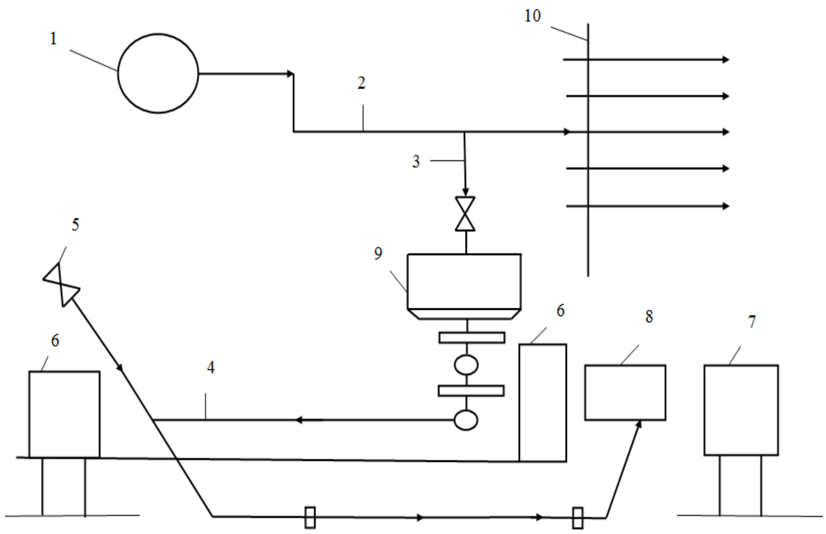

Figure 1: *1-high pressure gas condensate well; 2,3,4- high pressure gas line; 5- low pressure gas line; 6,7- DWFs; 8-liquid tank; 9- capacity for reagent; 10- gas line supplied to gas lift wells*

III. Conclusions

The purpose of reducing the risk of hydrate formation in the system of gathering, preparing for transporting and transportation of natural and associated gases is to find the rate of consumption of the reagent.

Improvement of the internal elements of the separators operated in each base where the waste gases are collected and installation of two and multi-stage separator devices in the technology.

Preparation and reporting of design documents for the construction of the separator and its internal elements.

The use of gel-containing pistons to remove the liquid falling in the low-pressure gas transport system.

Using mechanical pistons to clean the gas lines from the liquid mixture.

Creation of a foaming system based on foaming reagents of different composition and supply to the gas line.

References

[1] Risk Management normative documents of SOCAR approved on 24.10.2008.

[2] Korotaev Y.P., Gvozdev B.P., Gritsenko A.I. "Preparation for gas transport" M. Nedra 1992, 240 p.

[3] Bekirov T.M., Shatalov T. M. "Collection and preparation for transportation of natural gases" M. Nedra 1993

[4] Methodological instructions for conducting an analysis of hazardous production facilities RD 03-418-01. Gosgortechnadzor of Russia, 2001.

[5] Aleksandrov A.B., Aleksandrov A.I. et. al. Analysis of the breakdowns and accidents in the oil and gas complex of Russia. - M.: "Hazard Analysis" LLC, 2002., p. 309.

IMPROVING THE RELIABILITY OF ENGINE TIMING PARTS WITH THE USE OF ADVANCED NICKEL-COPPER COATINGS

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Abstract

Wear and deterioration of the technical condition of the gas distribution mechanism during operation leads to a malfunction of the diesel engine, a decrease in its power, an increase in specific fuel consumption, the formation of carbon deposits on pistons and parts of nozzle sprayers, accelerated wear of the crank mechanism. The need for restoration is dictated by the low post-repair resource of these parts. The currently existing methods for restoring guide bushings are complex and expensive. The chemical method of coating deposition is very promising and simple, since a relatively thin coating layer provides the necessary performance properties to the surfaces of the parts. This article presents one of the ways to restore the guide bushings, with the results of the conducted research.

Keywords: resource, restoration, timing mechanism, guide sleeve, wear, part

I. Introduction

One of the main components of which is the valve group: valve, seat and guide sleeve. The bushing is the main resource-determining link and when it is worn out, the entire gas distribution mechanism cannot work normally. Choosing the optimal way to restore the performance of worn-out machine parts is one of the main issues in the development of technological processes. When applied by chemical deposition on such coatings, there is no thermal effect on the part, leading to its warping, a change in the structure of the base metal and its physico-mechanical properties.

Ni-P-Cu coatings are more promising for restoring the operability of valve guide bushings. When using this method, the cost of expensive equipment is not required, since the equipment of electroplating workshops can be used when applying chemical coatings. In this regard, the urgent task of repair production is to develop a technology for restoring guide bushings using hard and wear-resistant coatings.

II. Results

The formation of the chemical coating was carried out in acidic solutions at a temperature of 90-95 ° C. These modes were chosen as ensuring the formation of high-quality coatings in a stable solution with sufficiently high deformation and strength properties, high adhesion strength and deposition rate. The deformation and strength properties of the coatings were studied according to the standard procedure (GOST 11262). The thickness of the coating on the samples varied from 10 to 300 microns. The samples for wear tests were rollers with a diameter of 50mm and a width of

12mm coated with Ni-P-Cu alloy and pads with a width of 10mm. When studying the deformation and strength properties of Ni-P-Cu chemical coatings, studies were carried out on samples with a copper content from 0 to 1.5% under various heat treatment modes. The microhardness of the coatings was determined on the PMT-3 device by indentation of a diamond pyramid according to GOST 9450-76. For this purpose, cylindrical samples with a diameter of 10mm and a height of 40mm were pre-made.

The coating was applied to a polished, polished, and then degreased surface. The tests were carried out at a load of 50 g. All samples coated with the Ni-P-Cu chemical alloy were subjected to heat treatment. The thermal treatment of the coatings was carried out in a muffle furnace for an hour. To measure the roughness of the surfaces of the semi-finished coatings, a profilograph profilometer mod. 2.01 of the Kalibr plant was used. The structure of the obtained Ni-P-Cu coatings was studied using a MIM-7 microscope.

The elemental composition of the coating and the presence of copper in it were determined using laser emission analysis. The research was carried out on a Carl Zeiss installation. Jena, consisting of an LMA-10 laser microanalyzer with a solid-state laser and a PGS-2 spectrograph.

III. Discussion

The wear resistance of the Ni-P-Cu coating was evaluated on the SMC-2 laboratory installation according to the roller-deck scheme. The pads were made of 40KHN steel. The hardness of the pad was 55...60HRC. Ni-P-Cu coating was applied to the rollers. The tests were carried out in the load range from 6.0 MPa to 12.0 MPa. The tests were carried out on M-10G2 engine oil. Operational comparative tests of engines with restored and serial guide bushings were carried out on MAZ vehicles with YAMZ 236 and YaMZ 238 engines. Before operational tests, experimental engines with restored and serial valve guide bushings were adjusted and run-in on the stand for 10 hours. During the operational tests, the following were monitored: engine operating time and performance indicators [1-15].

One of the main factors affecting the properties of the coating is the temperature of the solution, with a change in which the copper content in the coating changes (Fig. 1), which strongly affects the rate of deposition of the coating.

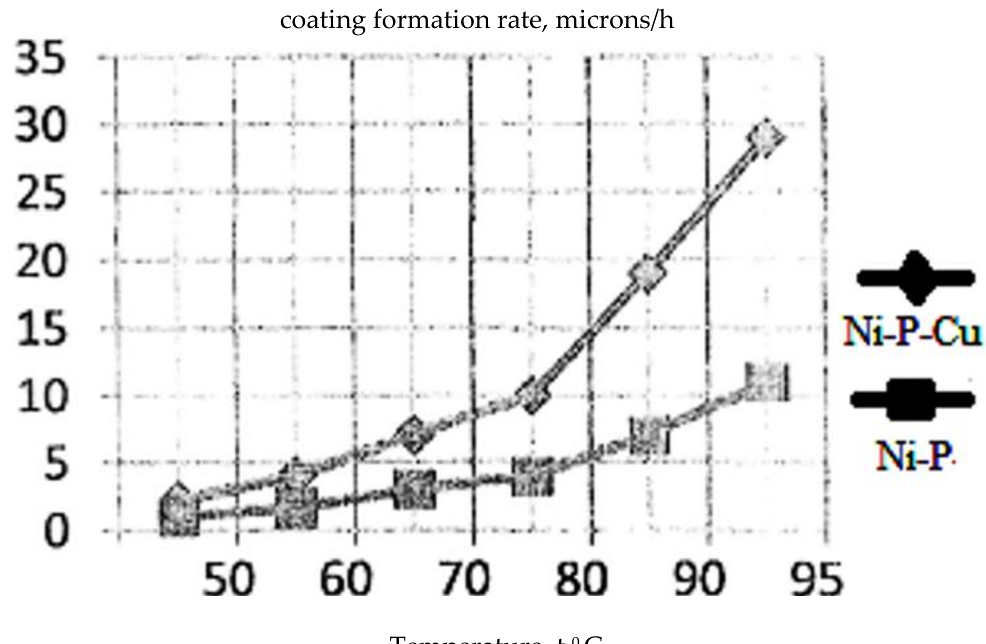


Figure 1: *Dependence of the coating formation rate on the solution temperature*

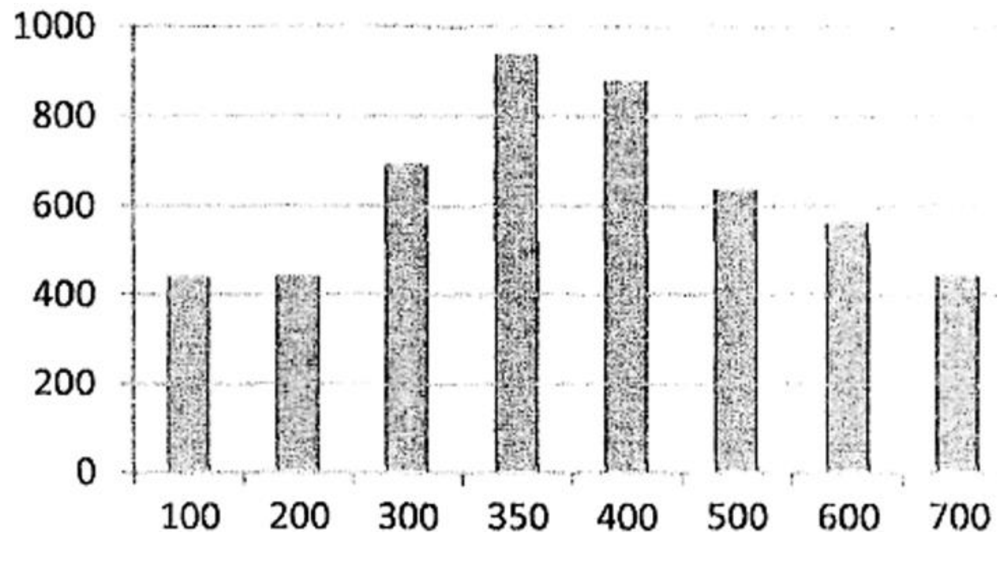
Comparison of Ni-P-Cu coatings before and after heat treatment shows that the presence of heat treatment eliminates layering in the coating and promotes the formation of a more finely crystalline uniform structure. After heating, the layering in the sediments disappears, and the size of the Ni3P particles is further enlarged. When the coatings are heated, phosphorus diffuses from them into the base metal, at the boundary of which a new phase is formed, probably iron phosphide Fe3P.

The precipitates of the chemically reduced coating immediately after their preparation, characterized by an amorphous structure with a random distribution of phosphorus in it, are metastable both in terms of "crystallinity" and in terms of "equilibrium" of the system of a mixture of a solid solution of phosphorus in nickel and a Ni3P compound. When chemically reduced nickel is heated, the amorphous precipitate turns into a crystalline one, which corresponds to two phases, namely the nickel phase (more precisely, the solid solution of phosphorus in nickel) and the intermetallic compound Ni3P. As the heating temperature increases, the amount of Ni3P phase increases due to the decomposition of the solid solution.

The conditions of formation of nickel-phosphorus-copper coatings and their structural features have a decisive influence on their performance characteristics. The heat treatment consists in heating the Ni-P-Cu coated part to a temperature of 400 ° C and keeping it at this temperature for at least 1 hour. The dependence of microhardness on the heat treatment temperature is shown in Figure 2. It should be noted that the disappearance of the amorphous component and the appearance of crystalline nickel and the Ni3P phase occurs after the first minute of annealing, but the maximum hardness is achieved much later. This can be caused by two successive processes: the transformation of a supercooled "liquid" solution into a supersaturated crystalline one and the precipitation of Ni3P from the latter.

In the case of heat treatment at 200 ° C, no changes in hardness occurred even with prolonged heating for 21 hours. As a result, it was found that the maximum microhardness of the Ni-P-Cu coating is 10 Gpa. The average value of the roughness parameter of the Ni-P-Cu chemical coating was 0.08microns.

microhardness, kg/mm^2



Temperature t ^{0}C

Figure 2: *Dependence of the microhardness of the coating on the heat treatment condition*

Comparative laboratory tests have shown that nickel-phosphorus-copper coatings have a wear resistance 1.5 times higher than 40KHN steel. The setting of samples made of 40KHN steel occurs after 0.83 h at a load of 1.25 kN, and samples with a chemical Ni-P-Cu coating after 1.41 h at a load of 2.12 kN. The increase in the setting load of Ni-P-Cu coated samples is explained by the characteristics of this alloy.

In addition, the absence of cracks also prevents the friction surfaces from setting, since the detached particles, falling into the gap of the friction surfaces, can cause them to jam. The high wear resistance of the Ni-P-Cu coating is due to the significant microhardness of such coatings, as well as structural features.

The corrosion tests carried out made it possible to establish that the Ni-P-Cu alloy after heat treatment at 400 °C has a corrosion resistance 1.2 times higher than 40KHN steel.

Since corrosion processes begin on exposed surfaces, a denser and finer grain structure prevents the spread of corrosion into the depth of the coating due to the absence of cracks and pores in it. Based on the conducted laboratory studies, a technology for restoring the guide bushings of the YaMZ-236 and YaMZ-238 engines was developed. According to the data obtained from operational tests, the resource of the guide bushings of YAMZ engine valves, restored using a chemical coating of nickel-phosphorus-copper, is 1.3-1.5 times higher than the resource of serial guide bushings installed by the manufacturer [16-19].

IV. Conclusion

1. When carrying out wear tests on the SMC-2 friction machine, the wear of samples coated with a nickel-phosphorus-copper chemical coating is 1.5 times less than samples made of 40KHN steel. The setting load of samples coated with Ni-P-Cu coating is 1.2 times higher than samples made of 40KHN steel.

2. The corrosion resistance of the studied samples coated with Ni-P-Cu chemical coating exceeds the corrosion resistance of 40KHN steel samples by 1.2 times.

3. The operational tests carried out showed that the service life of the valve guide bushings, restored using a chemical coating of nickel-phosphorus-copper, is 1.3-1.5 times higher than the serial ones.

References

[1] Varnakov V.V., Didmanidze O.N. Reliability of technical systems./ Textbook for university students studying agroengineering specialties / Ulyanovsk, 2004. p.136.

[2] Shakhov V.A., Uchkin P.G., Zatin I.M., Sosnitsky D.A. Application of additive technologies in the restoration of machine parts. In the collection: Improvement of engineering and technical support of production processes and technological systems. Materials of the national scientific and practical conference with international participation dedicated to the 70th anniversary of the Faculty of Engineering of the Orenburg State University. 2021. pp. 58-61.

[3] Toigambaev S.K. Restoration of bronze sliding bushings by centrifugal casting using electric arc heating. / Mechanization and electrification of agriculture. 2015. No. 7. pp. 28-32.

[4] Toigambaev S.K., Didmanidze O.N., Apatenko A.S., Parlyuk E.P., Sevryugina N.S. Operability of technical systems. Textbook for universities on the study of the discipline. Moscow, 2022. p. 379.

[5] Kravchenko I.N., Galinovsky A.L., Kartsev S.V., Korneev V.M., Toigambaev S.K., Abdumuminova D.T. Investigation of the effect of the plasma deposition process regime parameters on the porosity of coatings. / AIP Conference Proceedings. 44. Сер. "XLIV Academic Space Conference: Dedicated to the Memory of Academician S.P. Korolev and Other Outstanding Russian Scientists - Pioneers of Space Exploration" 2021. p. 150026.

[6] Toigambaev S., Golinitskiy P., Antonova U., Cherkasova E., Temasova G. Metrological support of cylinder liner inspection. / В сборнике: Journal of Physics: Conference Series. II International Scientific Conference on Metrological Support of Innovative Technologies (ICMSIT II-2021). Krasnoyarsk, 2021. p. 52023.

[7] Bayakhmetova, A., Bayakhmetova, L., Bayakhmetova, L., Daniyar, M., & Shchepkina, N. (2023). Ecological aspects of the model of transformation of the eating behavior of students in Kazakhstan. In *E3S Web of Conferences* (Vol. 460, p. 11009). EDP Sciences.

[8] Troyanskaya, S. et al. Instruments for financing and investing the «green» economy in the country's environmental projects / // E3S Web of Conferences: 22, Voronezh, 08–10.12.2020. – Voronezh, 2021. – P. 10054. – DOI 10.1051/e3sconf/202124410054.

[9] Bayakhmetova, A., Bayakhmetova, L., & Bayakhmetova, L. (2023). Impact of financial literacy on investment decisions in developing countries: The example of Kazakhstan. *Asian Development Policy Review*, *11*(3), 167-181.

[10] Akimov V.V., Belousova E.V. Development of methodological foundations for sustainable rural development // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2019. – № 2 (29). – Pp. 16-23. doi: 10.21777/2587–554X–2019–2–16–23

[11] Akimov V.V., Belousova E.V., Muzyka O.S. Prospects for the development of agglomeration in Kazakhstan as a complex of innovative and active territories (IAT) // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2020. – № 2 (33). – Pp. 73-78. doi: 10.21777/2587–554X–2020–2–73–78

[12] Archimandritova A.V., Suptelo N.P. Fundamentals of analytical support for choosing a model of innovation in the field of pipeline transport // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – № 1 (40). – Pp. 85-94. doi: 10.21777/2587-554X-2022-1-85-94

[13] Baburin S.N. Legal and spiritual and moral foundations of the digital future of mankind in the era of increasing environmental disaster // Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences. – 2019. – № 4 (22). – Pp. 6-12. doi: 10.21777/2587-9472-2019-4-6-12

[14] Buravtsev A.V. Stratified method of constructing a complex system // Educational resources and technologies. – 2017. – № 3 (20). – Pp. 23-32. doi: 10.21777/2500-2112-2017-3-23-32

[15] Abramova M., Varzin V. et al. Features of the mechanism for implementing sustainable development through the green economy. E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

[16] Kubova R.M., Kubov V.I., Bozhenko A.L. Extrapolation of experimental and model characteristics of the atmosphere as sources of green energy // Educational resources and Technologies. – 2018. – № 3 (24). – Pp. 56–62. doi: 10.21777/2500–2112–2018–3–56–62

[17] Kuksin I.N. Digitalization – a new reality in law // Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences. – 2020. – № 1 (23). – Pp. 6–12. doi: 10.21777/2587–9472–2020–1–6–12

[18] Makovetsky, M.Y., Rudakov, D.V.: Features of the formation of Russian management. Econ. Manage. – 2021. – № 1 (36). – Pp. 79–86. doi: 10.21777/2587–554X–2021–1–79–86

[19] Panshin BO.NI., Serebryakov DM.AN. Methodological and method aspects of assessing the social and economic effectiveness of social innovations // Economics and Management. – 2020. – № 2 (33). – P. 7-14. doi: 10.21777/2587-554X-2020-2-7-14

ELİMİNATİON OF THE TRAUMATİC FACTORS OF A FİRE

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Abstract

The extreme conditions of firefighting personnel are characterized by strong psychotraumatic factors from a psychological point of view. Psychological preparation for extinguishing fires in difficult conditions and eliminating their consequences requires improving the efficiency of combat operations, saving people from fires, protecting material values from destruction, and raising the level of psychological resilience, which is the basis of the rescuers' own safety.

Keywords: emergency events, psychological preparation, psychological resilience, psychotrauma, mental processes, safety

I. Introduction

On May 19, 2015, the fire that occurred in a multi-storey residential building located at 200/36 Azadlig Avenue, Binagadi District, Baku city, alarmed not only the residents of the building, but almost the entire population. Dozens of people who did not live in that building, relatives and acquaintances, ordinary citizens also went to the scene. Most parents were inevitably worried about their children. It is possible that this sensitivity becomes chronic in some people.

In psychology, this is called psychotrauma, i.e., anxiety disorder. It was possible to clearly feel this shock and anxiety from the statuses shared on social networks about the fire [1].

The reason for this was people's psychological unpreparedness for events. Psychologists have determined that people who are psychologically unprepared for natural events, man-made accidents, military armed struggle, and ecological disasters have a deplorable negative effect on both the events and the results of activities during the elimination of their consequences [2].

In the article, in order to increase the efficiency of solving fire safety problems, the psychological preparation of fire extinguishing personnel - as a system of purposeful effects of the actions of their leaders during emergency situations in peace and military times, gaining experience in successful operation in conditions modeled by QX and DTI, development of important qualities for the profession and personal self-improvement in military personnel, rescuers and the ways and methods of achieving the goal of forming and strengthening psychological stability by conducting psychological training in civil workers were discussed.

The formation of professional continuity (preparation) of employees of the Ministry of Emergency Situations (MES) of the Republic of Azerbaijan during the course of daily service and combat training activities is carried out as part of the main duties. The main purpose of this activity is to change the nature of the impact of the stress that occurs in extreme conditions on the functioning of the psyche and to influence the activity of military personnel (rescuers): it should cover mental states of neutrality and even stimulating states.

II. Methods

During the training and upbringing of each specialist of the Ministry of Emergency Situations, the qualities necessary for the formation of a wide range of professional activities are provided. However, the experience of performing tasks in extreme conditions shows that each previously formed quality, when changing the conditions of the rescuer's activity (natural disaster, accident, catastrophe, the impact of accidents by negative factors, the relief of the area, weather, vision, etc.), in particular, emergency-rescue it may not manifest itself during the transition to the conduct of work. There are also many examples where an expert performs a task successfully for training sessions and does not perform the actions at all well when the conditions are changed. At this time, the passive-defense reflexes actually cause the behavior of the rescuer under the influence of inappropriate conditions and reduce the efficiency of the service activity [3, 4].

So, the novelty factor sometimes plays a decisive role in the emergence of previously formed qualities in a person and in the performance of actions. The task of the head of the psychological training of the personnel is to prepare a preliminary model of possible natural disasters or emergency situations during training and educational exercises. Carrying out the exercises in the conditions corresponding to the real situation makes it easier to form the necessary psychological qualities for professional activity, and the efficiency of the time spent increases. In other words, as a result of daily educational preparation - it means action on the list of unexpected, new, unknown things in emergency situations. Therefore, it provides advance preparation for the measures to completely minimize what is expected and possible to occur in the performance of emergency rescue works.

Let's look at the mechanism of psychological preparation that occurs due to the internal and external influences on the psyche of the conditions created for military personnel (rescuers). In order to get answers to these and other questions, if we approach the essence of the main theoretical and practical issues of psychological training, it is likely that the challenge in the psyche of rescuers is the purposeful formation and strengthening of image models of actions appropriate to the situations. The logic here should be as follows: if in military personnel (rescuers) and the civilian population there is a large amount of mental images corresponding to the upcoming events, which are maximally suitable for the extreme conditions of fire, formed qualities, then there is less possibility of falling into a situation of unpredictability, uncertainty and novelty, and as a rule , in turn creates a passive-defense reflex that leads to the formation of harmony in the work, the commission of unlikely actions is eliminated.

To better understand this issue, let's look at what the action image itself reflects. A mental image is what a person sees, hears and experiences. In the mind of the savior, his actions were like a psychological model and nothing else. This is not a picture of any situation, but it is of greater importance. This process is quite complicated and temporary, it is not a reflection of objective reality, but it also ensures the establishment of the rescuer's future activities, adequate to the real situation for the purpose of re-creating the images experienced and seen before. Operational structure - the motives, needs and goals of military personnel (rescuers) act as regulators of their professional activity. Therefore, it will be methodologically correct if, during the course of all daily activities, the manager will stick to the organization of his psychological preparation and will regularly spend his efforts on the formation of the concepts and the basic model of the upcoming operations.

It is important to take into account that for rescuers, the manner of performing this or that action and its specific content, as well as its importance, are defined. It is a fact that it looks very good in terms of good preparation in relation to the profession, in terms of saving, implementing, managing, etc., skills with high professional qualities. However, in extreme conditions, if the basic concepts of the model of future activity are not well developed, calling their actions purposeful, then it is likely that the tasks will not be performed effectively.

The level of extremity of military servicemen (rescuers), psychological properties of personality, self-regulatory (directive) mechanism and influencing factors of FH conditions is determined by psychological continuity. However, if the mental stability of the rescuer is determined by the individual typological characteristics, emotional irritation and emotional disturbance occur, then first of all, the clear expression of the subject's volitional effort and ability is determined by the degree of his emotionality. In addition, psychological resilience, for example, in extreme conditions, can be acquired or innately determined by the subject's personal qualities and psychophysiological mechanisms, which allow to consciously or unconsciously react (resistance) to emotogenic factors.

III. Results

As a result of the psychological preparation of military personnel (rescuers) during their daily activities, psychological stability (readiness) is formed in time, that is, the system of psychological qualities determines the potential capabilities of rescuers to successfully carry out emergency rescue and other urgent tasks and to overcome difficulties [5].

It is very important to form the conditions that ensure the success of achieving the goals of the level of mobilization and the desire of the psyche to overcome the difficulties of the upcoming service activity, the state of psychological satisfaction of the military personnel (rescuers) immediately before the tasks set in the process of psychological preparation.

The analysis of psychological preparation shows that the main place in its structure is occupied by psychological qualities - psychological satisfaction and persistence. The same components appear in the structure of psychological satisfaction and psychological sustainability: motivational, emotional, cognitive, intellectual, operational and voluntary.

The motivational component comes from the desire of military personnel (rescuers), specialists to overcome obstacles, show themselves to withstand the difficulties of the service, courage, determination, initiative to carry out emergency rescue work, what they are capable of, self-affirmation in the rescue team.

The emotional component is expressed in the confidence of military personnel (rescuers) and employees, as well as in their doubts about their abilities to perform this or that voluminous work, and in the feeling of excitement and satisfaction in the fulfillment of the assigned tasks.

The cognitive component characterizes the degree of understanding and understanding of the tasks, the assessment of the possibilities of managing one's own behavior and psyche, and the perceptions of the nature of the difficulties of the upcoming emergency rescue work.

The intellectual component characterizes the rescuer's thinking type and mental capacity.

The operational or mobile component refers to the methods and tools used by the specialist during emergency rescue operations.

The voluntary component is expressed in the ability to overcome stress and fatigue, subordination of all forces to achieve, determination to fulfill the tasks set and self-control and self-regulation in the process of fulfillment, patience, self-control.

In the emergence of readiness, motivational, cognitive, intellectual components take the leading place, followed by active, voluntary and emotional psychological components.

The will takes a leading position in the formation of psychological stability. Because willpower is related to purposefulness, focus, regularity, consistency, and a systematic way of thinking, it helps overcome whatever might undermine effort.

The lack of willpower can lead to the fact that people set very insignificant life goals for themselves, show laziness in their activities, instead of being in a healthy self-criticism spirit, they engage in unnecessary and useless regrets, feeling guilty. The psychological stability of the employee of the Ministry of Internal Affairs of Azerbaijan in his professional activity is characterized by a great feeling of confidence as a successful result of this activity, related to the motivational characteristics of achieving the goal. However, this promotion is typical only for certain types of people, who always intend to achieve the exact result.

Volitional effort is the energy source of emotions and thoughts, with the help of which we send mental energy from one source to another energy source, to a new address. The will eliminates the conflicts of various directions of psychic energies and sends a psychic energy signal to the physiological level, activates other forms of energy, in particular, changes the way of life, overcomes distance, changes the direction of unpleasant and non-level works, etc.

We do not know faceless cold will in life. For example, I.M. Sechenov saw the cause of human activity in stimulating the sense of hearing that gives a certain meaning to his actions (in physical passions), in his thinking and in the actions of his spiritual feelings.

M.Y. Basov (1922) made the directing function of the will the subject of his analysis. The will is understood as a mental mechanism, its identity as a regulator (director) of mental functions, their combination or change in accordance with the problem to be solved. M.Y.Basov wrote that the personality's power over its spiritual conditions is possible when its spirituality contains only one regulatory factor. This factor is a strong personality and circumstances. The name of this factor is will. According to him, the will-directing function always focuses on the "act of regulation". M.Y. Basov considers voluntary effort as "directive subjective expression of voluntary function" and attention as "the same event, only show different terms". According to him, perception, thinking, emotions (feelings) are regulated by changing the content of consciousness, i.e. by distraction Basov believed that the will does not have the power to create actions, thoughts or abilities, but only regulates them.

The idea of regulating various mental processes and voluntary activity of a person L.S. It was developed in the works of Vygotsky. Accepting the will function of choice and compulsion of action, L.S. Vygotsky considered basic mental processes and voluntary regulation of behavior in the problem of will. And from here, the question of the establishment of the will, the issue of the will in its framework changes from here. The original problem is not a product of action, but "self-handling" shows originality. In this problem, as one of the stages of "mastering one's own behavior" of the will, we call the "mental continuity" of a person as a formative. K. Levin believes that the control of emotions (affects) and actions is the essence of the human will.

Most national and foreign authors in the field of psychology (Collins and others) define will as a special human ability. Even Aristotle noted that the will determines the ability of activity that arises from the person himself. Like D. Locke, he understood the human will as the ability to act. Every real voluntary action, L.S. Vygotsky noted that it is a selective act, which includes conscious choice and decision-making. L.S. Vygotsky's function of the will is to create an activity, noting its motivation and determination, selection and regulation of the goal, implementation of the activity and the participation of personal education with the initiator, he defines various characteristics of his activity, first of all, the qualities of the will (perseverance, determination, perseverance, etc.). For example, bravery and determination in the field of will, overcoming the fear of death, manifests itself in rescuers.

Rescuers develop willpower in the following directions:

- The formation of individual physiological and psychological tolerance to prepare for the elimination of various difficulties in the intense rhythm of the activity in extreme conditions;
- Increasing the level of continuity of professional skills for flexible and timely performance of duties;

- Formation of psychological preparation for unexpected actions;

- By creating and strengthening psychological qualities in rescuers, by developing in them unpretentiousness (lack of satisfaction), simplicity (non-demandingness), moderation in demands and wishes, which can replace the tendency to comfort and eliminate the inability to perform emergency rescue work in the event of unfavorable natural and climatic conditions;

- The formation of group unity with psychological continuity based on the performance of service duties of Azerbaijan Ministry of Defense employees within the rescue team.

Undoubtedly, during the lifeguards' daily service and combat training activities, psychological preparation or pre-sustainability is formed, which, as a system of psychological qualities (knowledge, habits and skills), conditions a person's potential opportunities to successfully overcome difficulties and successfully fulfill the tasks.

In the process of receiving tasks and directly directing human resources to their fulfillment, the psychological preparation for the MFA specialists of the Republic of Azerbaijan to start their fulfillment at any time is included in the first plan. The mobilization and enthusiasm, activity and direction of rescuers' psyche to overcome any difficulty should be taught through special exercises. That is, psychological preparation is a stage of historical transition from everyday life situations to the performance of official duties.

With the beginning of the performance of new tasks (assignments), psychological continuity begins to manifest itself in the form of the experience of new, previously absent qualities in the form of combinations in the organization of activity and the preservation of the functionality of previously formed or with the formation of new qualities. In other words, at the same time, long-term preparation forms psychological stability in advance. These abilities are formed on the basis of previously acquired knowledge, skills, habits, experiences and other important professional qualities.

Timely psychological preparation should not reduce the ability of rescuers to work full-time, that is, increase the efficiency of their activities in the first hours after the disaster, and allow them to help the victims the most at that time. The preparation of specialists for action in the field of Emergency Situations in many cases significantly reduces human and material damage and losses.

In the organization of psychological training, the head of the accident and rescue units should proceed from the principle of pre-formation of the main concepts of the action model in relation to images. This means that any intention in the implementation of psychological preparation should be based on the importance of the tasks and the strengthening of beliefs, the collection of ideas about the conditions for performing emergency rescue work, and the strengthening of motivational goals. For this purpose, self-proven methods of conducting psychological training can be widely applied, mainly methods related to verbal and verbal influence of commanders and chiefs, methods of persuading, inducing, influencing the psychology of subordinates by other specialists [6, 7].

It should be noted that psychological preparation for solving tasks alone, setting goals, is not enough in a combat situation. Successful rescue operations often depend on the formation of realistic mental images. For this, lifeguards must fill the mental image of the professional activity model with what can be perceived by the senses, physically (body) by performing training exercises during day and night training.

It is possible to widely use the methods that allow to strengthen the model of actions on the basis of images of the qualities that are necessary for professionalism. They may include: - exercises and actions in military units, ships, tankdromes, airfields, training grounds, fire drills, special simulators, etc.; - obstacles, fences, debris area, special lanes for eliminating water borders, single obstacle lane, physical and sports activities of rescuers; - sports games and competitions; - psychological actions for purposeful development of intellectual, emotional and voluntary qualities; - the organization of psychological trainings on the strengthening of the collective is of particular importance for the formation of psychological compatibility, collectivism, reciprocity, etc.

Pedagogical-psychological literature has many suggestions about the organization and implementation of psychological training with different approaches, taking into account the organization and implementation of psychological training, conducting psychological training with special measures or conducting training (operational planning department) at the same time during education (educational institutions). Because training, upbringing and psychological preparation are actually closely related and interdependent, it is necessary to look at what qualities, characteristics, mental processes and situations are formed in each of the listed areas. Carrying out the most general analysis, it can be noted that the behavioral customs and habits of the employees of the Ministry of Internal Affairs of the Republic of Azerbaijan are improved in various conditions during the education process, as well as their voluntary qualities are developed: the emotional-voluntary field of personality is developed and its adaptation to new conditions is carried out; they envisage rescuers purposefully carrying out emergency rescue work under conditions of possible difficulties, they are instilled with citizenship, courage, perseverance, perseverance, confidence, etc., the importance of their own activities.

In the training process, moral-will qualities and emotions (courage, bravery, courage, determination, initiative, fulfillment of ready tasks, sense of collectivism) are formed and strengthened, and motivational goals are activated in order to provide the necessary assistance to the victims; through the collection of knowledge about the ideas relevant to these or other emergency situations, the habits and skills corresponding to the development of psychological preparation and resilience take place [7].

However, it would not be correct to refer to training and education to form psychological resilience. The tasks solved by training and upbringing are wider than psychological preparation. However, among these tasks, it serves to form psychological and special qualities that can be solved only in the process of psychological preparation exercises, which are necessary for the performance of a number of tasks. For example, development and strengthening of skills and habits needed to perform specific tasks; Special qualities characteristic for increasing the cognitive processes, motives, and skills of the Azerbaijan Ministry of Internal Affairs specialist, or caution, vision, thinking, coordination in movement, activation of stress tolerance, etc. in lifeguards.

Thus, formation of important professional qualities (courage, heroism, citizenship, etc.) is carried out with the help of psychological preparation exercises. It is more characteristic of them than specific methods (training, ideomotor exercises, studying the main signs of characteristic situations, etc.)[8,9].

Specific training and other professional qualities are developed in rescuers with the aim of understanding the issues of tasks set in the process of psychological preparation, creating confidence in rescuers in the necessity of their unconditional fulfillment.

The main directions of psychological training of military personnel (rescuers) and employees:

- preparation of rescuers for all kinds of self-sacrifice, formation of beliefs, behavioral style of saving victims, formation of scientifically based knowledge on committing selfless actions for the sake of saving victims;
- raising the level of professional skills and habits, psychological and physiological endurance, unpretentiousness in desires and needs, simplicity and gentleness in lifeguards;
- to be involved in state policy, to instill trust in commanders, chiefs and leadership, unconditional fulfillment of orders and development of goals for subordination, loyalty, reliability in education;
- reduction of mental injuries.

Conducting rescue work (adequacy of actions and mental state in the conditions of carrying out accident-rescue work) requires strict adherence to the principles of psychological preparation.

IV. Conclusion

During the performance of the tasks solved in the rescue units of the military formations and in various parts, the psychological preparation depends on the professional-tactical conditioning of the content, the degree of ensuring content activity safety during the execution of training and work depends to a large extent on the efficiency of the work done. In addition, in the situations of created service and combat tasks, compliance with the psychological compatibility of training and service tasks increases the quality of performance of combat tasks.

Psychological stability is a complex of special measures included in the professional training system and the entire rescue service. With the direct help of psychological preparation, providing maximum adaptation between individual and collective professional characteristics, specialty elements and skills, emergency rescue and other urgent tasks, and real psychological requirements is important in eliminating psychotrauma during activity.

References

1. www.aile.lent.az/read/11487

2. Ojagov H.O. Life safety in emergency situations. Baku,: "Chashioglu" 2010. 398 p.

3. Gozelov S.S., Manafov F.A. //Factors affecting the activity in emergency situations of various nature. // "News" Scientific-methodological journal of AMI. Baku.: 2011. pp. 44-47.

4. Zhiganov K. V., Danilov P. V., Pronin A. V., Titova E. C. The effect of fire hazard factors on the rescuer's psyche // Young student. — 2017. — No. 2. — C. 693-696.

5. Ojagov H.O., Gozalov S.S., Iskenderov Y.Ch. // Formation of psychological characteristics of people in emergency situations of various nature. "Harbibilik" magazine, 2012. N1., p.67-72

6. Aliyev N. A., Gozalov S.S. // Improving the efficiency of the military training process, "Military knowledge" magazine, 2007. No. 4. , p. 70-78

7. Gozalov S.S. The role of psychological service in the activities of personnel in emergency situations of various nature, // "Military knowledge" magazine, 2009. N6. , pp. 56-63

8. Psychological stability in emergency situations. Course lecture. Part III. - Novogorsk: - 2000; АГЗ МЧС России

9. Psychology of extreme situations for rescuers and firefighters/ general editor. Yu.S. Shoigu. M.: Smysl, 2007

ANALYTICAL DETERMINATION OF THE CRITICAL VALUE OF WELL FLOW RATE DURING FLOWING OPERATION

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Abstract

The purpose of this study is to propose a methodology for determining the critical flow rate in flowing wells to prevent the collapse of the productive formation, taking into account the homogeneity of the rocks. The method of operating wells, in which the rise of hydrocarbons from the bottom of the well to the surface occurs due to natural (reservoir) energy, is called flowing. Flowing of oil wells occurs due to hydrostatic pressure or the energy of compressed gas, as well as due to the energy of compressed rocks. The influx of oil to the bottom of wells occurs due to the difference between reservoir and bottomhole pressure. In the case when the pressure of the liquid column (to the wellhead of the filled well) is less than the reservoir pressure, the well will flow. Flowing well production is a method of hydrocarbon production in which the pressure in the formation is high enough to cause the product (such as oil or natural gas) to spontaneously rise to the surface without the additional use of artificial pumps or other devices. Basic concepts of flowing include:

1. Hydrostatic head: The natural pressure created by the hydrostatic column of fluid in a formation allows production to rise to the surface.

2. Compressed Gas Energy: In some cases, the presence of compressed natural gas in the formation can provide additional energy to lift production.

3. Energy of compressed rocks: During fracturing or other geological processes, additional dynamic conditions may be created that promote flow.

The influx of oil or gas to the bottom of wells occurs due to the pressure difference between the formation and the bottom. When reservoir pressure exceeds pressure at the bottom, this can lead to flowing - raising production to the surface. Maintaining flowing conditions can be an important aspect of well operation, and engineering efforts may include pressure control, calculations of optimal production rates, use of water injection techniques (If there is water in the formation), and other techniques to ensure efficient production.

Most often, in the flow of wells the gas contained together with oil in the formation plays the main role, including in cases where the gas under reservoir conditions is completely dissolved in oil and a homogeneous liquid moves through the formation. The structure of productive formations can be different, including layered and heterogeneous formations. This can lead to uneven hydrocarbon production and problems with water cut in permeable layers. For successful oil or gas production from such reservoir formations, the difference between the reservoir pressure and the pressure at the bottom of the well plays a key role. If the pressure in the liquid column is lower than the reservoir pressure, the well may begin to flow. Often the gas contained together with oil in the formation plays an important role in the flow of wells. Even if gas is completely dissolved in oil and a homogeneous liquid moves through the reservoir, its presence can significantly affect the pressure and dynamics of production. For example, when the pressure at the bottom decreases, gas can be released from the solution, increasing the volume and pressure inside the well and promoting its flow. Effective management of the production process includes not only pressure control, but also evaluation of gas factors, optimization of production rates and use of water injection technologies to minimize the negative effects of heterogeneity of formations and ensure the most efficient production of hydrocarbons. Flowing of an oil well can occur depending on the operating mode of the energy source, *including hydrostatic pressure or expansion energy of the gas contained in the oil. In some cases, gushing can occur simultaneously due to both energies. Hydrostatic pressure created by the column of oil and other fluids in the formation can be the main source of energy for a blowout. If the formation pressure is high enough and has good permeability, oil can rise to the surface under the influence of this pressure. If the oil contains dissolved gas, its release and expansion when reaching the surface can also contribute to blowout. Gas expansion creates additional pressure inside the well, which can increase the flow of oil and gas to the surface. When both of these mechanisms operate simultaneously, this can lead to more intense flowing and increased hydrocarbon production. However, control over this process is important to avoid unwanted consequences such as oil spills or loss of hydrocarbons into the environment. In this context, engineers and well operators actively monitor and adjust production parameters to ensure safe and efficient operation.*

Keywords: oil and gas condensate field, bottomhole pressure, operating methods, hydrostatic head, acceleration of gravity, fluid filtration, back pressure at the wellhead, stress state, hydrostatic head

I. Introduction

However, most often the main role in the flow of oil wells is played by natural gas contained together with oil in the reservoir. This applies even to situations where gas is completely dissolved in oil and movement through the formation occurs as a homogeneous liquid.

In this case, all the gas is in a dissolved state in the oil, and the bottomhole pressure is determined as the pressure of a column of homogeneous liquid filling the well, according to the formula

$$P_{b.h.} = H\rho g + P_{fr} + P_w \quad (1)$$

where, $P_{b.h.}$ pressure, MPa; H – well depth, m; ϱ – liquid density, kg/m^3; g-free fall acceleration, m/s^2; P_{fr} – hydraulic pressure loss due to friction during fluid movement in pipes, MPa; P_w – back pressure at the wellhead, MPa. Friction pressure losses are determined using the Darcy-Weisbach formula:

$$P_{fr} = \frac{\lambda \cdot L}{d} \cdot \frac{v^2}{2} \cdot \rho \quad (2)$$

where λ is the coefficient of hydraulic resistance; d – diameter of pump-compressor (lifting) pipes, m; ν – speed of fluid movement in the rising pipes, m/s; L – length of the lifting pipes, m. The numerical value of λ is determined depending on the surface roughness of the lifting pipes and the Reynolds criterion:

$$\lambda = \frac{64}{\mathrm{Re}} \quad when\ \mathrm{Re} = \nu \cdot d/\upsilon < 2320 \quad (3)$$

$$\lambda = \frac{0{,}3164}{\sqrt[4]{\mathrm{Re}}} \text{ when } \mathrm{Re} > 2320 \quad (4)$$

where υ is the kinematic viscosity of the liquid, m^2/s.

Bottomhole pressure is determined from the basic equation of fluid inflow to the bottom of the well:

$$P_{b.h.} = P_c - \sqrt[n]{Q/C} \quad (5)$$

where Q is the well flow rate m^3/day;

C – productivity coefficient, this is the ratio of well flow to depression: m^3/(day MPa);

P_c – contour or reservoir pressure, MPa;

n – coefficient equal to 1, when a straight indicator line leaves the origin; if the movement of fluid in the formation obeys Darcy's law, then the speed of fluid movement in the formation is directly proportional to the pressure drop;

n<1, when the line is convex relative to the pressure drop axis;

n>1, when the line is concave relative to the pressure drop axis

Substituting values (2) and (5) into equation (1), the pressure at the wellhead is determined taking into account n=1:

$$P_w = P_{for.} - Q/C - H \cdot g \cdot \rho - \lambda \cdot L/d \cdot \nu^2/2 \cdot \rho \tag{6}$$

In this case, the bottomhole pressure will be determined as follows;

$$P_{b.h.} = P_c - \frac{Q}{C} \tag{7}$$

II. Statement and solution of the problem

It is known that when the operating mode of oil and gas wells is chosen incorrectly, formation collapse occurs, i.e. a critical stress state arises in the formation. Therefore, solving this problem is very important for preventing emergency situations [1÷5].

Let us consider the stressed state of the bottomhole part of the well, taking into account fluid filtration in the formation. Rocks are accepted as an isotropic body. The stress state of the near-wellbore is characterized by the following equilibrium equation (Lame parameters):

$$\frac{d\sigma_r}{dr} + \frac{1}{r}\left(\sigma_r - \sigma_\varphi\right) = 0 \tag{8}$$

r de σ_r, σ_φ - radial and circumferential stress, respectively

It is known that the production rate of wells, i.e. the influx of fluid to the bottom of wells occurs due to the difference between the reservoir and bottomhole pressure. The internal (bottomhole) pressure of the well will take the value as (5).

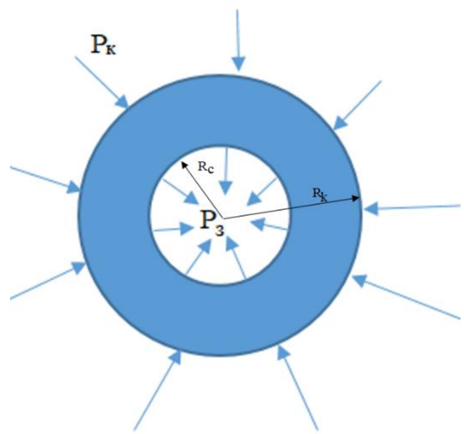

Figure 1: *Stress state at the bottom of the well*

In the case under consideration, the boundary conditions have the form;
at r=R_c; σ_r=$P_{b.h.}$; at r=R_c; σ_r=-P_c. Then the general solution to equation (8) will take the form:

$$\begin{cases} \sigma_r = \dfrac{-R_w^2 P_3 - R_c^2 P_c}{R_c^2 - R_w^2} + \dfrac{R_c^2 R_w^2 (P_{b.h.} + P_c)}{R_c^2 - R_w^2} \cdot \dfrac{1}{r^2} \\ \sigma_\varphi = \dfrac{-R_w^2 P_3 - R_c^2 P_c}{R_c^2 - R_w^2} - \dfrac{R_c^2 R_w^2 (P_{b.h.} + P_c)}{R_c^2 - R_w^2} \cdot \dfrac{1}{r^2} \end{cases} \tag{9}$$

R_w is the radius of the well, R_c is the radius of the formation contour.

Considering that the maximum stress occurs in the inner wall of the well, i.e.

$$\text{at } r = R_c \qquad \sigma_r = P_{b.h.}; \qquad \sigma_\varphi = -P_{b.h.} - \frac{2R_c^2}{R_c^2 - R_w^2} P_c \tag{10}$$

The failure condition for isotropic rocks has the form;

$$\sigma_r^2 + \sigma_\varphi^2 = 2\sigma_t^2 \tag{11}$$

where σ_t is the rock strength limit.

If (10) is taken into account in (11), we obtain the following expression;

$$P_{b.h.}^2 + m^2 P_c P_{b.h.} + 0{,}5 m^4 P_c^2 - \sigma_t^2 = 0 \tag{12}$$

where- $m^2 = \frac{2R_c^2}{R_c^2 - R_w^2}$

Considering that the radius of the formation contour R_c compared to the well radius R_w is too large, therefore $m^2 = \frac{2R_c^2}{R_c^2 - R_w^2}$ will take the value $m^2 \approx 2$

The solution of equation (12) with respect to $P_{b.h.}$ determines the critical value of the bottomhole pressure

$$P_{b.h.} = -P_c \pm \sqrt{\sigma_t^2 - P_c^2} \tag{13}$$

For real solutions, equation (12) must satisfy the following condition:

$$\sigma_t^2 - P_c^2 \geq 0 \tag{14}$$

Conditions (14) are satisfied for any rock.

From (13) we determine the critical value of bottomhole pressure;

$$P_{cr} = \left| -P_c + \sqrt{\sigma_t^2 - P_c^2} \right|$$

If we assume that the movement of fluid in the formation obeys Darcy's law, then the speed of fluid movement in the formation is directly proportional to the pressure drop, i.e. n=1, then for the critical value of the well flow rate Q_{cr}, taking into account the homogeneity of the rocks, we obtain the following expression;

$$Q_{cr} = P_c K \left(2 - \sqrt{\left(\frac{\sigma_t}{P_c}\right)^2 - 1} \right)$$

III. Conclusions

1) A method for calculating the stress state at the wellbore is proposed and the critical value of the bottomhole pressure is determined.

2) Based on this method, the critical value of the well flow rate was determined at which a formation collapse may occur.

References

[1] Basarygin Yu. V., Bulatov A. I., Proselkov Yu. M. /Technology of major repairs of oil and gas wells/: Textbook for universities. - Krasnodar, Publishing house "Sov. Kuban", 2002. p. 584.

[2] John Carroll. Natural gas hydrates / Transl. from English – M.: JSC "Premium Engineering", 2007. p. 306.

[3] Tagirov K.M., Gnoevykh A.N., Lobkin A.N. Opening of productive oil and gas bearing layers with anomalous pressures. / – M.: Nedra, 1996. p. 183.

[4] Mamedov A. A. Prevention of violations of casing columns. – M.: Nedra, 1990. – p. 240.

[5] Gasanov A. P. Restoration of emergency wells. Directory. – M.: Nedra, 1993. p.128.

[6] Orudzhev Yu.A., Gulgazli A.S., Shirali I.Ya. "Stability of oil and gas well walls during drilling" LAMBERT Academic Publishing. 2012. p.97.

ON THE CALCULATION OF THE INTENSITY OF THERMAL RADIATION IN A FIRE

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Abstract

The paper analyzes the existing methods of calculating the intensity of thermal radiation at fire, which are presented in normative and methodological documents.
It is established that the existing method of calculation contains errors and does not allow obtaining a reliable result. The method of calculation of the conditional probability of people being affected by fire is not suitable for practical application, as outside the burning spill of flammable liquid the UWPL is always equal to zero, and inside the spill the method has no solution.

Keywords: Fire, probability, thermal radiation, oil spill, premises, personnel.

I. Introduction

As it is known, in order to calculate the intensity of thermal radiation at fire there are several normative documents containing the calculation methodology [1÷5]. Sources [1, 2, 3] contain practically the same calculation methodology. All sources give the same formula, but it has different spelling.

The main disadvantage of the considered methodology is that it does not allow to determine the value of the probit function, and hence the value of the conditional probability of defeat of a person located in the focus of combustion. Outside the combustion center at any scale of release (up to 50000m3 of oil was investigated) the probability of human injury is equal to zero. The question arises, who needed to develop such a complex calculation methodology, if the result is known without its implementation: in the area of the spill we have full uncertainty, and beyond its boundaries - zero result. The zero result outside the spill boundary can be declared without performing the calculation.

Some design organizations take the liberty of claiming that in the burned area the conditional probability of human casualties is 100%. This is not true. This assumption has a practical refutation.

Different representation of equations of one and the same methodology in four existing normative documents leads the designer to the state of complete distrust to normative documents. The designer cannot establish the validity of this or that edition of the calculation methodology, because the authors of normative and methodological documents do not respond to the requests of design institutes, referring to the fact that any normative work in the Russian Federation has been stopped with the release of the Federal Law of December 27, 2002 № 184-F3 "On Technical Regulation". The designer is forced to look for additional sources allowing to solve the problem with a higher degree of confidence.

A different methodology is available in the normative document «VNII GOCHS» "Methodology for assessing the consequences of accidents at fire-explosive facilities" (1994) [4]. The use of this methodology allowed to exclude doubtful points in calculations, and also to get the main transition of conditional probability of human casualty with the change of distance to the place of combustible liquid ignition. Comparing the last calculation methodology with the methodology of GOST and NPB, different estimation of heat flux on the surface of burning spills draws attention. If in GOST and NPB for an oil spill fire the intensity of thermal radiation from the flare surface is 10-25 kW/m², and with increasing spill diameter this value decreases and does not exceed 10 kW/m², then in the methodology of VNII GOCHS this value has a constant value of 80 kW/m².

Figure 1 shows the results of calculating the intensity of thermal radiation (ITR) at a distance of 2 m from the boundary of 10 m³ of oil according to the methods of NPB [2], VNII GOCHS [4] in comparison with the experimental data of Taubkin S.I. [5].

Comparison of the presented results reveals the following:

1. The NPB methodology gives a variable value of ITR. At small spill area the intensity increases up to 9 kW/m², after which it stabilizes at a constant level. The level of thermal radiation at any value of the spill area does not pose a danger to humans, as they have time to leave the danger zone before the start of the impact. The conditional probability of injury to a person outside the burning area at any oil spill area is zero.
2. The GOCHS methodology defines ITR as a constant value at a much higher level than the FSS methodology. This methodology ensures smooth transition of the conditional probability of human injury when increasing the distance to the boundary of the spill from one to zero, which corresponds to the physical model of the phenomenon under study, although the constancy of the intensity of thermal radiation itself does not agree with the results of experiments presented in the work of Taubkin S.I.
3. The results of the experiment of Taubkin S.I. indicate that the intensity of thermal radiation should increase with increasing the area of the oil spill. To ensure this condition, it is necessary to change the dependence of the surface radiation of the combustion torch. With the growth of the oil spill area this indicator should increase. In GOST R 12.3047-98 and PNB 105-03 it decreases with increasing spill diameter.

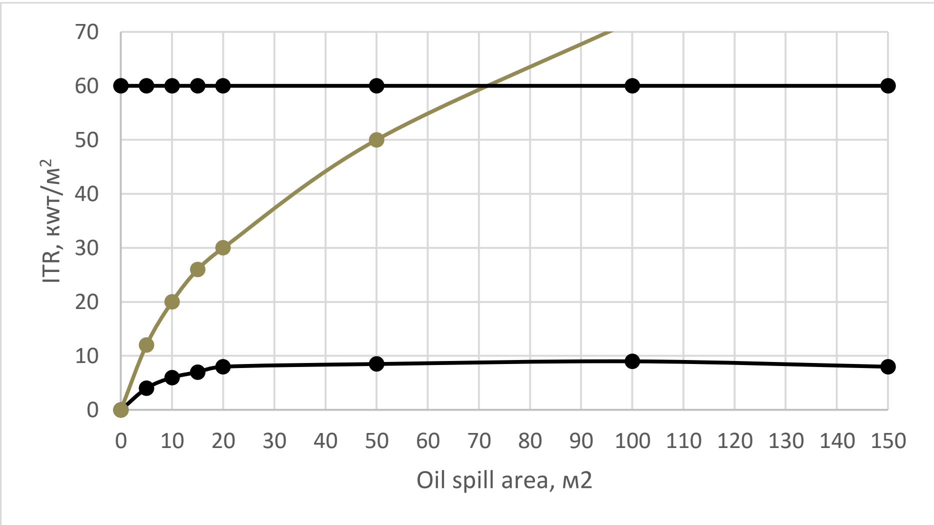

Figure 1: *Comparison of thermal radiation intensity by different methods*

In Fig. 2 shows the dependence of the conditional probability of injury to people from distance to the place of oil release according to the fire safety standards (FSS 105) method. In Fig.3 presents the calculation results in the form of a graph of the dependence of the conditional probability of injury to a person on the distance to the place of the oil release using the authority for civil defense and emergency situations method.

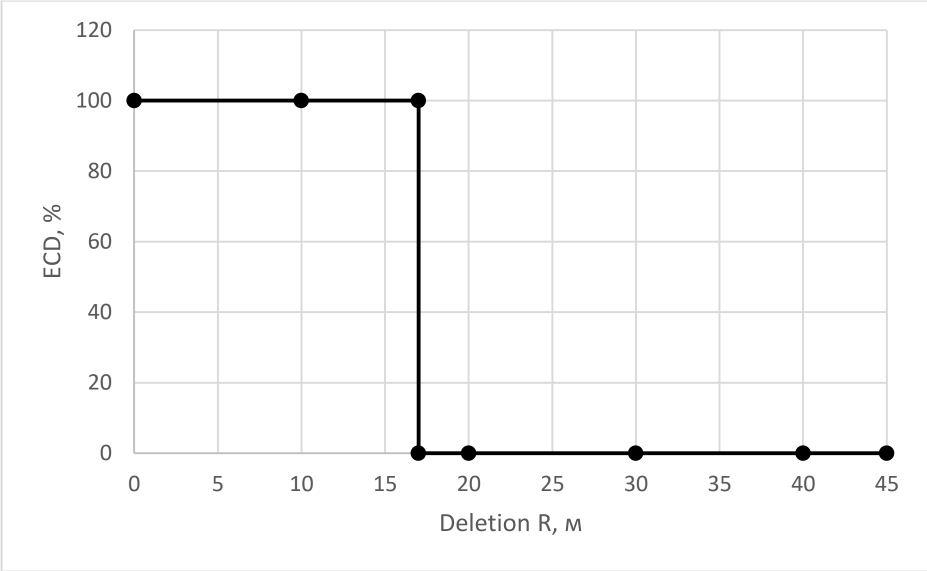

Figure 2: *Dependence of the ECD on the distance to the release site in an oil fire*

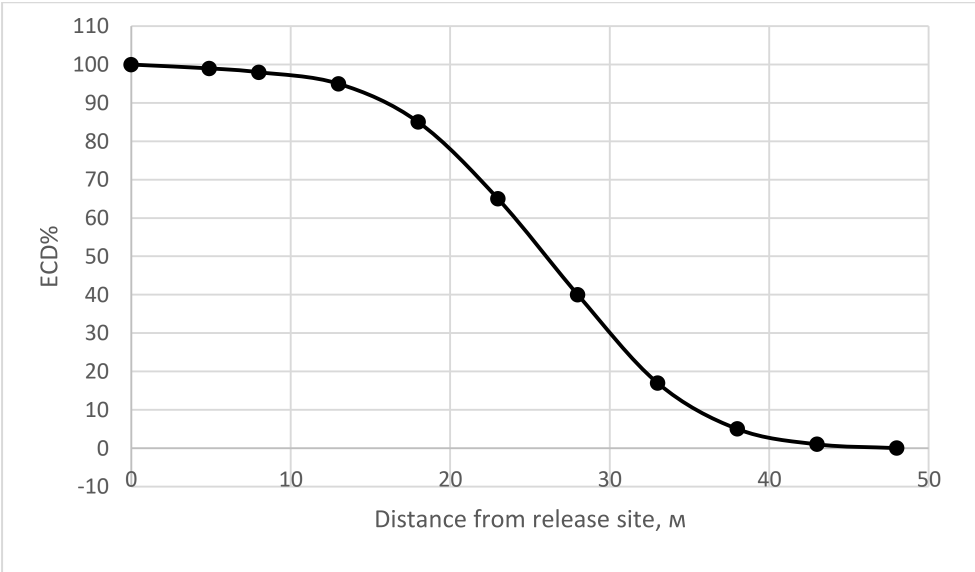

Figure 3: *Conditional probability of people being affected by fire*

A comparison of the considered methods based on the result of calculating the probability of injury to people in a fire revealed, in our opinion, the unsuitability of the fire safety standards method, since it determines the probability of injury depending on the value of the probit function, which is essentially continuous, and the calculation result does not correspond to the continuity condition.

II. Methods

In FSS 105-03 presents methods for calculating the explosion pressure of a hot water supply cloud in an outdoor installation and calculating the conditional probability of injury to a person. Let's consider how these methods are ensured to correspond to each other.

On page 2 of the FSS it is stated that "These standards do not apply to assessing the level of explosion hazard," although all parameters characterizing the fire hazard of outdoor installations are determined by the standards through explosion parameters. In particular, the explosion pressure at an outdoor installation is determined by the equation:

$$\Delta P = P_0(0.8M_{pr}{}^{0.33}\text{Mпр}0.33/r + 3M_{pr}{}^{0.66}/r^2 + 5Mpr/r^3) \qquad (1)$$

Here Mpr – reduced mass of flammable gas participating in the explosion, expressed in TNT equivalent, кg; r – distance to gas release, m.

Analysis of the presented equation reveals that the pressure tends to infinity as r tends to zero. This pressure dependence during the explosion of a hot water cloud is in conflict with the thermodynamics of the process under consideration. It is known that during the explosion of a hot water supply consisting of air and associated petroleum gas components, the pressure cannot exceed 900 kPa. This feature of the hot water supply explosion is indicated in FSS 105-03 on page 7. For example, find the pressure of the explosive at a distance of 0.5 m, as well as the distance from the explosion site of 1 kg of the reduced mass of methane, at which a pressure of 100 kPa and a pressure of 5 kPa are provided. The explosive pressure at a distance of 0.5 m from the release site is 5408 kPa, which significantly exceeds the maximum value of the explosion pressure.

An explosive pressure of 100 kPa is provided at a distance of 2.65 m, and a pressure of 5 kPa is provided at a distance of 20 m from the place of gas release. Using the equation i=123 Mpr 0.66/r, where i is the pressure wave impulse in Pa min, we determine its value at the found values of r.

İ(100)=1230x10.66/2.65=46.42 Pa min; and İ(5)=123x10.66/20=6.15 Pa min.

Based on the values of ΔP and i, determine the value of the probit function-Pr;

Pr=5-0.26Ln(V), where V=(17500/ΔP)8.4 + (290/i)9.3.

Here ΔP – is the excess explosion pressure in Pa.

After substituting the values into the presented equations, we obtain for ΔP equal to 100 kPa and ΔP equal to 5 kPa the values of Rg, respectively, 0.55 and minus 4.25, which corresponds to the conditional probability of human injury equal to zero.

What is the danger of the investigated air pressure levels? The NPB does not contain data on the assessment of the consequences of the explosion. In GOST R 12.3.047-98 [1] we find that an overpressure of 100 kPa leads to the complete destruction of building structures. In case of complete destruction of building structures, people in the building will probably die. Why is there no data about it in the normative document? It should be assumed that the conditional probability of human injury at such a pressure is estimated at 100%. The result of the calculation according to the methodology of the National Fire Safety Regulations gives a different result - 0%

III. Results

1. The existing method of calculating the intensity of thermal radiation in a fire, presented in normative and methodological documents because of the error does not allow to obtain a reliable result.
2. Methods for calculating the conditional probability of people being affected by fire are not suitable for practical application.

References

[1] GOST R 12.3.047-98 "Fire safety of technological processes" General requirements. Control methods.

[2] FSS 105-03 Fire safety standards. Determination of categories of premises, buildings and outdoor installations on explosion and fire hazard. Moscow, 2003, 48 p.

[3] SP 12. 13130.2009. Determination of categories of premises, buildings and outdoor installations on explosion and fire hazard. M., 2009.

[4]. Methodology for assessing the consequences of accidents at fire and explosion hazardous facilities. «VNII GOCHS», 1994.

[5] Taubkin S.N. Fire and explosion, peculiarities of their expertise. Moscow, 1999, 600 p.

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PART-2
REDUCING THE RISKS OF CLIMATE-RELATED NATURAL DISASTERS

A HYBRID FORECASTING MODEL BUILDING STRATEGY

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Abstract

The article discusses the classification of existing models for predicting given events according to the statistics of all their forecasts and an algorithm for using the intersection or combination of sets of forecasts projections with other models to find the best pairs. The following terms were introduced: "necessary", "sufficient", "unnecessary" and "insufficient" forecasting models. This is discussed…this is discussed in the earthquake forecasting examples, and insufficient similarly be used to predict other events.
We explained what "necessary" and "sufficient" models are. For "unnecessary" models, an algorithm is given for how to choose a hybrid model - the intersection of two or more models that together give a forecast with a higher probability. We also discussed "sufficient" models and an algorithm for selecting such "sufficient" models, the combination of which completely covers all past events, that is, the combination of such "sufficient" models becomes "necessary".
Discusses how one can obtain a "sufficient" or "nearly sufficient" forecasting model by combining "necessary" models, and by combining "sufficient" models to obtain a "necessary" or "almost necessary" models. Also unnecessary models is discussed. In our earlier work, these models were not taken into account; such models were removed from the model database. Similarly, when considering "sufficient" models, if the forecast of the occurrence of an event is specified redundantly, such a model can be excluded from the set of "sufficient" models.
From "sufficient" models we obtain the "necessary" model, which will be both "sufficient" and "necessary" at the same time. In addition, we combine enough models to get the "necessary" model.
All of this uses forecast statistics to strategically select a hybrid model.

Keywords: classification of forecasting models, intersection and combination of forecasting models, necessary, sufficient, unnecessary, and insufficient forecasting models

I. Introduction

When modeling any processes, when it is necessary to test hypotheses about asynchronous processes, forecasting models are often used, which makes it possible to analyze their effectiveness [1,2]. We aim to create a new hybrid model based on existing models that will improve forecast accuracy. This increases the relevance of the topic under discussion.

The most popular existing forecasting model is Bayesian, mainly used to prove asynchronous hypotheses [3,4]. We aim to compare all existing forecasting models with the model we presented and thus obtain a new model (building a forecasting model with parallel data) that further improves forecasting accuracy.

In general, the prediction of asynchronous processes is often not justified because these models are mostly "necessary" and “unsufficient”. “Sufficient” models for predicting defined asynchronous processes either do not exist or are very rare.

Forecasting models can be divided into two groups: “necessary“ models and “sufficient“ models [5,6]. “Necessary” forecasting models are those models whose set of forecasts always includes, those from events that have already occurred. Such models often make incorrect predictions, but they predict every event that occurs. “Sufficient” forecasting models are those whose forecasts are always correct, but they cannot predict all events that occur.

If enough models predict that an event will occur, then that event will happen, but there may be events that they do not predict. In practice, there may be too few such “sufficient” models (for example, in earthquake forecasting) or too many (for example, in economics).

Forecasting models are characterized by a probability of success, which is not unique to statistical models [7,8]. The probability of validity of a forecasting model is the ratio of the number of events With the number of forecasts predicted by a given model, expressed as a percentage, that is, the relative frequency of occurrence (occurrence of an event), expressed in %.

The question arises of when to select the best model from among the “necessary” models, as well as when to identify “sufficient” models. The algorithm in [9] will initially analyze all existing models and identify a pair of models, a triple, a quadruple, etc. models to obtain the appropriate number of “necessary” models, the joint use of which (the intersection of models) gives the best result. Also, from “sufficient” models, a union of “sufficient” models is obtained, which is closer to predicting all occurring events.

Obviously, after each event, a situation may arise when we already have new “necessary” models, or from the old “necessary” models it turns out that some of them are no longer “needed”, that is, they are not predictable. all events I which have already occurred, the models are then reviewed again, removing this unnecessary model from their set and starting to search for new pairs.

As for sufficient models, after each event, new “sufficient” models may appear, whose predictions give better results when combined with the predictions of other models.

Let us consider algorithms for constructing hybrid models using the example of earthquake forecasting. As characteristics of each earthquake, we took the earthquake magnitude, date of occurrence, time, and name of the epicenter.

II. Developing necessary forecasting models

Note: $\mathrm{Mod}_1, \mathrm{Mod}_2, \ldots$ and so on earthquake forecasting models, which provide some predictions based on their predecessors (such as when an earthquake will occur, in what location, and with what magnitude). From these models, only the “necessary” models should be selected; this condition in the case of the earthquake problem means the following: if, for example, during T time an earthquake occurred, n only those models that predicted all these earthquakes should be considered. Let's assume the following models: $ModN_1, ModN_2, \ldots, ModN_n$ (n=5 in the following example), what each model is and what earthquake precursors it predicts are not important when considering the algorithm.

For each model, it is necessary to count the number of forecasts, and the number of justified and unjustified forecasts, and calculate the probability of justification for each model. It is clear that the sum of justified and unjustified forecasts gives the total number of forecasts. As for the probability of justification, it is calculated for each model and determines how many times an earthquake was predicted and how many times an actual earthquake occurred (see Table 1).

Table 1: *Calculation of justification probabilities for one "necessary" model*

Model	Number of forecasts	A successful number of predictions (m)	Unsuccessful number of predictions	Probability of success (%)(P)
$ModN_1$	92	2	90	2.17
$ModN_2$	80	2	78	2.50
$ModN_3$	81	2	79	2.46
$ModN_4$	97	2	95	2.06
$ModN_5$	82	2	80	2.43

In Table 1, m the number of events that occurred, and P_i indicates A_i the number of times all events predicted by the model will occur. From this table, we calculated probabilities of forecasting success for 5 models (%) .

When predicting earthquakes, the author of each model claims that his model is the best, and explains this by the fact that his model predicted all the earthquakes that occurred. Neither of them gives the number of incorrect predictions and therefore does not calculate the probability of their being correct, which are quite small numbers.

The probability of a model's prediction being justified may be quite small but for this model, there is another model that, together with the probability of success, gives us a better result. Let us show the correctness of this with our example.

At the next stage of the algorithm, we need to consider pairs of models. For each model, it is necessary to count the number of realized forecasts, and the number of justified and unjustified forecasts, and also calculate the probability of justification for each pair. Let us introduce the following notation: – $P_{i,j}$is the probability of the forecast cross-section being justified $ModN_i$ and $ModN_j$.

The following table shows these values (see Table 2).

Table 2: *Probabilities of justifying forecast intersections*

$P_i \cap P_j$	P_1	P_2	P_3	P_4	P_5
P_1		9	10	22	27
P_2	9		5	74	40
P_3	10	5		65	37
P_4	22	74	65		63
P_5	25	40	37	63	

If you specify the probability $P_{i,j}$ joint justification two models $ModN_i$ and $ModN_j$, then we obtain the following values (see Table 3):

Table 3: *Probabilities of validity of model predictions for couples*

$P_{1,2}$	$P_{1,3}$	$P_{1,4}$	$P_{1,5}$	$P_{2,3}$	$P_{2,4}$	$P_{2,5}$	$P_{3,4}$	$P_{3,5}$	$P_{4,5}$
9	10	15	25	5	74	40	65	37	63

Let us analyze the constructed table using the corresponding diagram (see **Figure 1**), from which it can be seen that the best result $P_{2,4}$ gives a combination of two models $ModN_2$ and $ModN_4$. The likelihood of their joint acquittal has already increased to 74%. Although individually these models have much lower acquittal rates of 2.50% and 2.06% than the others. In the example discussed, two or more pairs of models may show the same result. At this point, the expert must decide which one should be used.

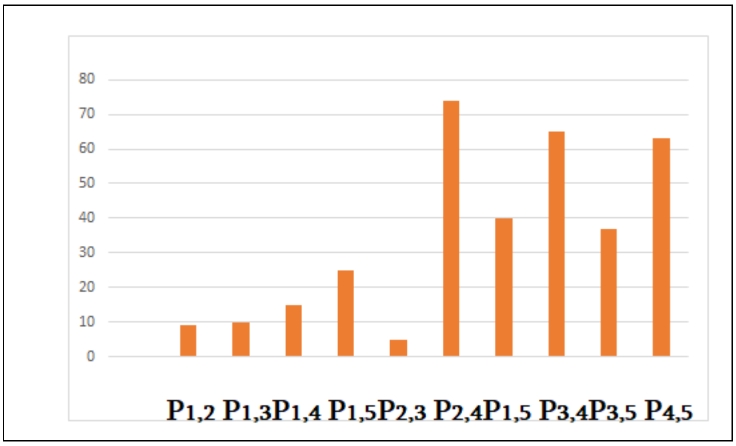

Figure 1: *Probability diagram for justifying pairs of models*

Let us analyze the constructed table using the corresponding diagram (see Figure 1), from which it can be seen that the best result $P_{2,4}$ gives a intersection of of two models $ModN_2$ and $ModN_4$. The likelihood of their joint acquittal has already increased to 74%. Although individually these models have much lower acquittal rates of 2.50% and 2.06% than the others. In the example discussed, two or more pairs of models may show the same result. At this point, the expert must decide which one should be used.

In addition to the "necessary" models, the example of earthquake prediction also included "sufficient" models, for example, there were three models: $ModS_1$, $ModS_2$ and $ModS_3$(see **Table 4**):

Table 4: *Calculation of success probabilities for individual "sufficient" models*

Model	Number of forecasts	A successful number of predictions	Unsuccessful number of predictions	Probability of success (%)
$ModS_1$	7	10	7	100
$ModS_2$	5	10	5	100
$ModS_3$	4	10	4	100

Each "sufficient" model predicted the occurrence of an event, but could not fully predict the occurrence of all events. $ModS_1$ The model predicted the occurrence of the event only in 7 cases out of 10, the second model $ModS_2$ _ðა in 5 cases and the third model $ModS_3$ – ðაin 4 cases. Even if we combine the predictions of these three "sufficient" models, their sum will be 7+5+4>10, but this does not mean that the combination of these models predicted all ten events.

Probabilities need to be calculated successfully for each pair of "sufficient" models, as in the case of "necessary" models (see **Table 5**):

Table 5: *Probabilities success of a combination of forecasts*

$P_i \cup P_j$	*P1*	*P2*	*P3*
P1		8	9
P2	8		10
P3	9	10	

This applies not only to the prediction of earthquakes but also to the prediction of any other event, both static (most often this is the task of forecasting natural disasters) and dynamic prediction, for example, economic fields [1].

It should be said that existing forecasting systems do not divide models into "necessary" models and "sufficient" models. They work with all models, which, if it does not complicate the task, then distorts the accuracy of the forecast.

III. Processing "unnecessary" forecasting models

We discussed a new approach to the forecasting process and demonstrated that forecasting is improved by using "necessary" models of forecast pairs, triplets, quadruples, etc., with a joint review [10,11]. Algorithms have also been formulated on how to determine the "necessary" models, and how to obtain from "necessary" models to „almost sufficient" models. Even for "sufficient" models it is determined how to obtain an „almost necessary" model from them.

Theoretically, it seems that one of the pairs of models may be a "unnecessary model", and the other also a "unnecessary" model, but it is also possible to find a pair (three) that will be close to the "sufficient" model. Let's consider algorithms for processing "unnecessary model " forecasts.

Let's say we are considering a case where an event (for example, an earthquake) occurred several times (for example, 5) and there are three models for predicting this event: *Model I* (I), *Model II* (II).) and *Model III* (III). It is necessary that the model predicts The model must predict at least one…at least one of the events and the set of forecasts has an intersection with the set of forecasts of other forecasting models. *Model I* predicted 3 events, *Model II* predicted 4 events, and *Model III* predicted 1 event (see **Figure 2**). The circles in the figure indicate the events that occurred, and the numbers indicate the names of the models that predicted the occurrence of this event:

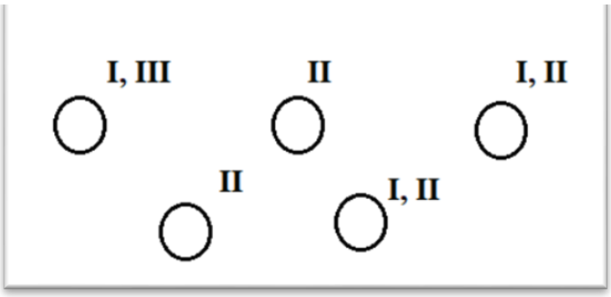

Figure 2: *Forecasting events by forecasting events*

Let us consider the set of events predicted and not predicted by each model, in the case of three models (see Figure 3). Events that these models could not predict are indicated by dots, events that were predicted by these models are indicated by circles.

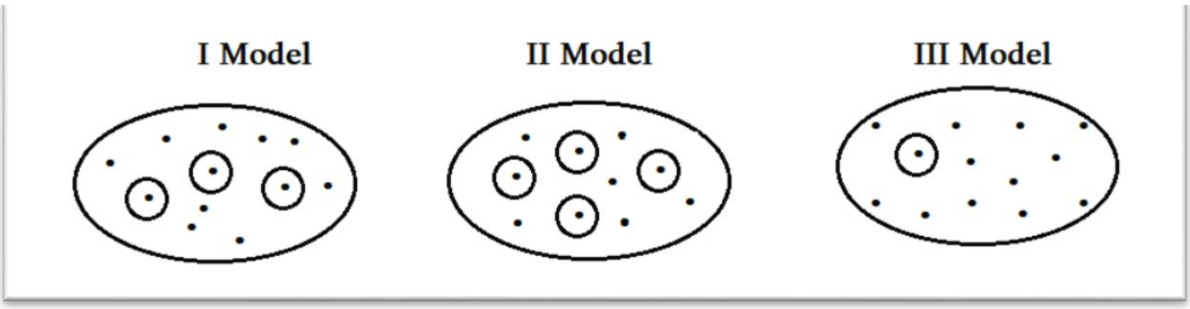

Figure 3: *"Unnecessary" models.*

Let us denote P_i by P_j and N not obligatory models forecasts and consider their intersection P_{ij} (see Figure 4):

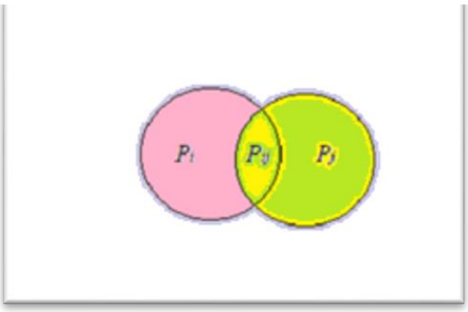

Figure 4: *Intersection of predictions of two models*

If we consider the model's predictions as a possible intersection of sets of events, then three cases can arise here (see Figure 5): when the intersection is greater than the events that have already occurred, when the intersection is smaller, and when they coincide. The event set in the image is marked in blue, and the events in the intersection set are marked in yellow.

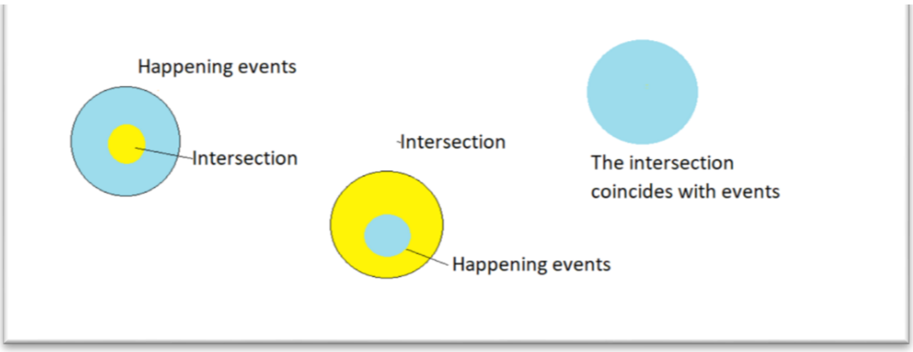

Figure 5: *Occurring events and forecasts of unnecessary models*

If the intersection of models coincides with the set of already existing events, this is the best case, since the set of models involved in the intersection becomes a "sufficient" model for prediction.

Let's look at an example. For each model, count the number of forecasts made, the number of events, and the number of justified and unjustified forecasts, and calculate the probability of justification for each model (see Table 6).

Table 6: *Calculation of justification probabilities for individual "unnecessary" models*

Model	Number of forecasts	A successful number of predictions (m)	Number of events that occurred	Unsuccessful number of predictions	Probability of success (%)(P)
$ModNN_1$	92	3	5	2	3.2
$ModNN_2$	80	4	5	1	5.0
$ModNN_3$	81	1	5	4	1.2

As the next step of the algorithm, we need to consider pairs of models. For each model, it is necessary to count the number of realized forecasts, the number of justified and unjustified forecasts, and also calculate the probability of justification for each pair. Let us introduce the following notation – $P_{i,j}$ $P_{i,j}$ this is the probability of the forecast intersection being justified $ModN_i$ and $ModN_j$. The following table shows these values (see **Table 7**):

Table 7: *Probabilities success of a combination of forecasts in the case of " unnecessary" models .*

$P_i \cap P_j$	P_1	P_2	P_3
P_1		5	6
P_2	5		3
P_3	6	3	

From Table 7 we can conclude that the intersection of two unnecessary models leads to an "almost sufficient" model.

This way we can use "unnecessary" models if we select "unnecessary" models from models of forecasting with a certain filter. It is possible to use "unnecessary" models in some positions, because the intersection of unnecessary models can give us "almost sufficient" models.

IV. Discussion

We explained what "necessary" and "sufficient" models are. For "unnecessary " models, an algorithm is given for how to choose a hybrid model - the intersection of two or more models that together give a forecast with a higher probability. We also discussed "sufficient" models and an algorithm for selecting such "sufficient" models, the combination of which completely covers all past events, that is, the combination of such "sufficient" models becomes "necessary".

Discusses how one can obtain a "sufficient" or "nearly sufficient" forecasting model by combining "necessary" models, and by combining "sufficient" models to obtain a "necessary" or "almost necessary" model.

In our earlier work, these models were not taken into account; such models were removed from the model database. Similarly, when considering "sufficient" models, if the forecast of the occurrence of an event is specified redundantly, such a model can be excluded from the set of "sufficient" models.

From "sufficient" models we obtain the "necessary" model, which will be both "sufficient" and "necessary" at the same time. In addition, we combine enough models to get the "necessary" model.

All of this uses forecast statistics to strategically select a hybrid model.

References

[1] Yanchenko, A.K., Tierney G, Lawson J. "Multivariate dynamic modeling for Bayesian forecasting of business revenue." - Models in Business, 2023.

[2] Chelidze T., G.Melikadze, T.Kiria, T.Jimsheladze, G.Kobzev. Statistical and Non-linear Dynamics Methods of Earthquake Forecast: Application in the Caucasus. Frontiers in Earth Science, 2020, https://doi.org/10.3389/feart.2020.00194.

[3] Bansal, N. K., Hamedani, G. G. & Maadooliat, M. (2015). Testing Multiple Hypotheses with Skewed Alternatives. Biometrics, 72(2): 494-502.

[4] Huynh C. (2014) Estimation of Type III Error and Power for Directional TwoTailed Tests Using PROC POWER. Ph.D., Department of Psychology, University of Manitoba, Winnipeg, Manitoba, Canada.

[5] Gasitashvili, Z., Pkhovelishvili, M., Archvadze, N. Reducing risks through improvement of preduction models. Theory and Applications. 2022, 17, pp. 197–202.

[6] Prangishvili, A., Gasitashvili, Z., Pkhovelishvili, M., Archvadze, N. Predicting Events by Analyzing the Results of the Work of Predictive Models. 2022, 1562 CCIS, pp. 64–78.

[7] Phkhovelishvili, M., Archvadze, N., Gasitashvili, Z. Peculiarities of the Hybrid Model Built Using Parallel Data. Proceedings - 2022 7th International Conference on Mathematics and Computers in Sciences and Industry, MCSI, 2022, pp. 66–70.

[8] Aliyev, V., Gasitashvili, Z., Pkhovelishvili, M., Archvadze, N. Algorithm for building a hybrid mode of the existing risk model. Reliability: Theory and Applications. 2022, 17, pp. 106–110.

[9] Pkhovelishvili, M., Archvadze, N., Shetsiruli, L. Optimization of Expert Solutions for Events Forecasting.

[10] Proceedings - 2023 International Conference on Control, Artificial Intelligence, Robotics and Optimization, ICCAIRO 2023, 2023, pp. 82–85.

[11] Aliyev, V., Pkhovelishvili, M., Archvadze, N., Gasitashvili, Z., Tsiramua, Z. Hybrid Prediction Method Using Experts and Models. 2023 5th International Conference on Problems of Cybernetics and Informatics, PCI 2023, 2023.

THE MANAGEMENT OF NATECH EVENTS IN SEVESO SITES FOR THE CASE OF FLOOD RISKS

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Abstract

The Seveso III Directive 2012/18/EU imposes an obligation for the site operator to identify the major risks of the establishment, taking also into account technological accidents such as fires, explosions, and toxic releases that can occur following natural disasters (so-called NaTech risks). Floods, which are amplified by climate change, are among the most widespread natural dangers in European countries. The Safety Management System for the Prevention of Major Accidents in Seveso Sites is important in ensuring the correct implementation of the prevention and protection measures against major accidents originating from these events, with specific procedures for extreme weather conditions. Starting from the main outcomes of the analysis of industrial accidents, where floods have been identified as a significant and triggering cause, a specific focus is then presented on the main types of plants, infrastructures, and industrial equipment vulnerable to extreme weather conditions. These lessons learned are also useful examples of how organizations could manage these problems, through specific procedures, good practices, and methods used to assess the industry's response to NaTech issues. A practical case of application of safety evaluations has therefore been reported for a type of industrial plant that is particularly relevant on the Italian territory, namely the underground storage of natural gas. The risks of floods are particularly relevant because of the extension of these plants over large areas, which means that parts of them can pass through areas subject to flooding. Finally, the article describes an in-depth analysis carried out on the NATECH risk of flooding for industrial plants, starting from the Italian technical regulation, with details to be considered in the risk assessment for the identification of the critical elements for safety, as well as the main prevention and protection measures for equipment.

Keywords: Seveso, SMS, procedures, NATECH, events, flood

I. Introduction

The Seveso III Directive 2012/18/EU, implemented in Italy by the D.Lgs. 105/2015 [1], imposes an obligation for the site operator, in identifying the hazards and assessing the major risks of the establishment, to take the NATECH risks into account, paying attention to the entire spectrum of natural hazards that may affect the site. With the term NaTech, the international literature identifies technological accidents, such as fires, explosions, and toxic releases that can occur inside industrial establishments and along distribution networks and pipelines following natural disasters.

The evaluation of the effects of natural events on Major Accident Hazard establishments requires a systemic and multidisciplinary approach concerning the complexity of the contexts to be analyzed both from the plant and structural point of view. The methodological approach for assessing the NATECH risks of Seveso sites must be based on meeting the objectives underlying the regulatory text, which consist of preventing major accidents connected to the presence of dangerous substances and limiting their consequences for human health and the environment.

It is therefore considered necessary, with this paper, to provide support for the evaluation of the implementation of the Safety Management System for the Prevention of Major Accidents

(SMS-PMA) during the control activities on Seveso establishments, with specific attention to the checks to be carried out during inspections regarding the NATECH risks, according to the D.Lgs. 105/2015.

II. Methods

The incidental data extracted from the e-MARS database of the European Commission show that from 1985 to today in the EU countries, there has been an average NATECH accident per year, while about 7000 accidents that occurred in industrial sites, collected in the Bank UK-HSE MHIDAS data [2], 3% of accidents are classified as NATECH having been induced by natural events such as earthquakes (8%), floods (16%), landslides (7%), strong winds (13 %) and lightning (56%). Fig. 1 is shown below, which represents the number of accidents occurring as a function of extreme natural events [3].

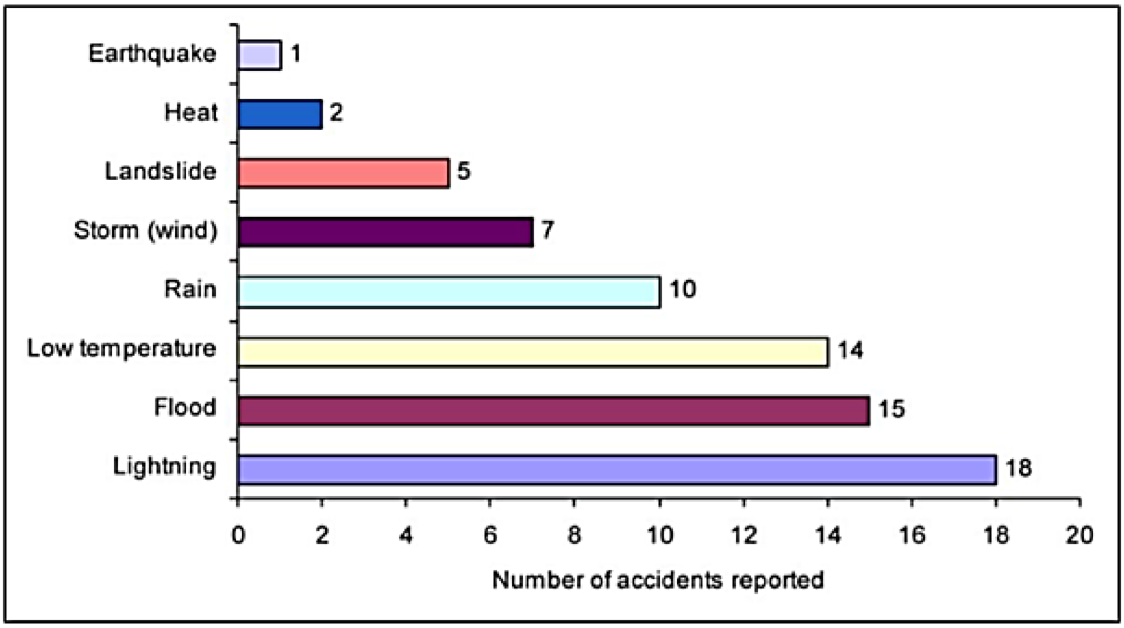

Figure 1: *Number of accidents occurring as a function of extreme natural events*

In Table 1 below it is possible to summarize the main types of plants, infrastructures, and industrial equipment vulnerable to natural hazards in the event of adverse weather conditions.

Table 1: *Equipment and plants vulnerable to natural hazards*

Industrial equipment and plants	Natural hazards for adverse conditions
Gas, fuel oil, and coal thermoelectric power plants	Floods
Pipelines for the transmission and distribution of gas, oil pipelines	Floods (Landslides)
LPG depots	Floods
Mineral oils depots	Floods, lightning, strong winds, storms
Refineries and chemical and petrochemical plants:	
Process columns	Strong winds, storms
Above ground tanks	Strong winds, storms, floods, lightning
Mounded tanks	Floods
Pipelines (also underground)	Floods
Motors, pumps, compressors	Floods

Control room and instrumentation	Floods, lightning
Warehouses of packed products	Floods
Service utilities commonly found in industrial plants whose failure can lead to hazardous situations: boilers; refrigeration systems; cooling towers; power supply; water treatment; torch systems	Strong winds, storms, floods, lightning, changes in water availability, increases in water temperatures, and decreases in availability of cooling water
Toxic products depots	Floods
Warehouses of phytosanitary products	Floods
Coastal depots, plants, and terminals	Sea storms, sea level rise

I. Floods

As indicated in Table 1, floods (which in turn may or may not be a direct consequence of the occurrence of earthquakes), with consequent landslides (depending on the terrain) are the most widespread natural danger in our country, and many productive activities in all sectors are vulnerable in the event of adverse weather conditions.

The danger of floods can never be eliminated and therefore every manager of a Seveso establishment must prepare in advance to limit the impact that a flood could have on its activities, through dedicated planning that considers that an event of this type could trigger or make a major accident more serious, directly or indirectly.

He must therefore provide, through the adaptation of its SMS-PMA (Safety Management System for the Prevention of Major Accidents), the necessary measures to prevent or limit the consequences for human health and the environment.

Directive 2007/60/EC relating to the assessment and management of flood risks (Floods Directive - FD) [4], provides the elements for the assessment and management of this type of risk which in Italy is implemented with D.Lgs. 49/2010 [5].

II. Industrial accidents following floods

Following continuous torrential rains which lasted several days, the plants of a refinery located in the port area flooded (Mohammedia refinery in Morocco in 2002). Production was stopped due to the water level. A violent fire followed, as well as several explosions of tanks, electrical equipment (transformers), and pipes. Four hours later, fires persisted in the gas and crude oil sectors of the refinery. The fire was extinguished after 20 hours. Two people died and four were injured. Extensive material damage resulting from the accident led to the closure of the refinery and the suspension of all activities.

The sequence of fires was caused by the flood that moved the exhausted oil, displacing it from the sewer system. The waste oil that floated on the surface then encountered the hot parts of the systems, causing several fires and explosions in the pipes and electrical transformers. From the above it is fundamental:

- Implement effective procedures to prevent the rapid distribution of flammable liquids by alluvial waters;
- Good maintenance practice is to make sure the drains are clean so that they don't block the water drain.

The site manager, to mitigate the impact of a flood, must undertake a series of improvement actions to make the perimeter of the plant, buildings, or specific areas within buildings or equipment containing hazardous substances (in quantities and conditions such as to cause a major accident), inaccessible to water.

These actions include the following types of protection (or combinations thereof): Construction of defense works (structural measures, such as embankments, drainages, stabilization, roofing); Closure of openings and water entry points; Waterproofing of walls; Seal the penetrations in the walls; Installation of pumps for the collection and removal of water (dewatering pumps); Installation of non-return valves; Ensure a control plan periodically and be carried out afterward a flood and before an expected flood.

The site manager should also locate fire pumps, sprinklers, suppression systems, and other fire suppression systems, with associated electrical equipment, outside of flood hazard areas or above the maximum achievable water level.

If there is critical equipment for process safety, production, or operations that are located at a lower level than the maximum achievable by the water, the site manager must ensure they are flood-proof (if their functionality is required during the flood for safety reasons or to ensure continuity of production). In the case of electrical equipment, it must be designed to work even if continuously immersed and have an electrical classification IP X8 (protected by permanent immersion in water - submersible to 3 m depth in continuous immersion and in any case for more than one hour, resistant to a pressure of at least 10 bar exerted in all directions).

III. Results

I. The case of underground natural gas storage as strategic assets

The underground natural gas storage are located in depleted underground deposits of the same mineral. The storage of natural gas is an industrial process that consists of injecting gas into an underground rock system, to guarantee its accumulation and subsequently supply it in a second phase, to face a market demand or to face situations of lack/reduction of supply. Storage therefore play a strategic function for national energy reserves, being considered strategic assets for the Italian industry.

In summary, the process in which natural gas intervenes is represented by two phases that alternate during a year of operation:

- The phase of injection of gas through wells, in the spring-summer period, which consists of storing the natural gas coming from the network transport in the field through the wells after compression
- The gas supply phase, in the autumn/winter period, during which the gas is supplied, dehydrated, treated, and redelivered to the transport network.

The main areas involved in the process concern: reservoirs, wells and cluster areas, compression plants, treatment plants, and pipelines. Twelve underground natural gas storage sites are in Italy, operating in five different regions in the central north of the country [6].

To provide technical support for the assessment of the safety reports of underground natural gas storage establishments, pursuing a uniform assessment throughout the national territory, also given the peculiarity of these establishments, the Guidelines "Underground storage of natural gas - Guidelines for the evaluation of Safety Reports", issued in October 2018 [7] were drawn up by a Working Group set up by the Italian National Authorities involved in industrial control activities on Seveso establishments. The Guidelines deal in depth with the issue of risk analysis, and also include NaTech risks of floods, based on a national overview of the Safety Reports presented by the site managers of the underground natural gas storage.

Finally, the Internal and External Emergency Planning for NaTech events must necessarily consider that such events may involve a plurality of contemporary emergencies, the interruption of electrical and telephone lines and communication routes. It is therefore necessary to implement and deepen these aspects in emergency planning, taking care of the training of both plant personnel and external intervention structures.

II. NaTech Risk Assessment in Underground Natural Gas Safety Reports

A complete NaTech risk analysis consists of the following steps:

- Preliminary analysis, carried out through territorial contextualization, historical analysis of natural events, and assessment of the hazards of each NaTech event considered for the site
- Identification of equipment exposed to risk

• Identification of prevention and mitigation measures, possible estimate of occurrence frequencies and areas of damage, relative integration of the scenarios in the Safety Report

Based on the Safety Reports examined, the site Managers completed the first of the phases indicated; in some specific situations, the second phase and part of the third phase have also been completed, as requested by the Competent Authorities, identifying the prevention and mitigation measures. Based on the safety reports examined, the technical assessment of the scenarios still must be faced. Given the relevance of the NaTech risk of floods, because of the extension of these plants over large areas, which means that parts of them can pass through areas subject to flooding, particular attention has been paid to the hydrogeological risks.

III. The evaluation of the hydrogeological risks

Natural gas storage, compared to other types of establishments, have the peculiarity of insisting on vast territories belonging to municipalities, provinces, and sometimes even different regions, as they consist of compression and treatment plants, pipeline connections, well areas, cluster areas, and related equipment.

It can be stated that it is not uncommon for a part of the plants to be in areas subject to risk of hydrogeological instability and flooding, as identified by the sector planning tools, prepared by the competent district basin authorities for the area. In some cases, although the risk maps didn't cover specific areas, the plants were affected by instability and flooding phenomena, based on the data deriving from the analysis of the historical experience gained and from the consultation of specific databases.

In the implementation of the Seveso III Directive, attention was paid to also carrying out the analysis of technological risk induced by instability and flooding. To date, also thanks to the indications contained in the Guidelines, the Companies have produced an in-depth analysis of the risk of damage to equipment and piping because of instability or flooding. The following paragraphs indicate the methodologies that have been applied to assess these risks, their limits, and the margins for improvement.

IV. Failure risk analysis

In situations in which the plants and pipes are in areas subject to hydrogeological instability, specific studies were requested from the Site Manager, also following the indications of the Guidelines, for the evaluation of risk and planning intervention actions to mitigate it.

The studies produced have addressed the problem in the way described below. The available bibliographic studies on the geological, geomorphological, and hydrogeological structure of the study area were first described. Investigations were carried out on the seismicity of the territory on a local scale. The pipeline routes and plant areas were reported on the thematic maps drawn up by the competent Basin Authorities. The study was therefore carried out through careful surveys in the field, extended to all plant areas and along the connecting pipelines, with particular attention to the areas affected by criticalities even if not registered by the territorial planning tools. The predisposing factors for the establishment of conditions of instability (morphological configuration, geo-lithological nature of the sediments present) and the determining factors (periods of intense precipitation) were therefore identified. The surveys carried out were promptly reported in synoptic cards, accompanied by extensive photographic documentation, and then reported on detailed thematic maps.

The main problems highlighted were:

• Areas subject to erosion. For the areas subject to erosion, areas with surface erosion on slopes denuded by vegetation cover and areas subject to river erosion, in turn, distinguished between bottom or bank erosion, were distinguished

• Areas subject to slope instability. The areas with problems relating to the stability of the slopes have been divided according to their degree of danger to the integrity of the pipelines, distinguishing the following types: Active landslide, Quiescent landslide, stabilized landslide, surface landslide, widespread instability

The analysis and survey activity highlighted various areas with articulated morphologies, which indicate a certain propensity for the slopes to fall apart. Some of these situations were considered "to be monitored over time", to detect any changes.

In the areas of fluvial relevance, problems have been found in progress, following the erosive actions carried out by the waterways. For these problems, the Company has prepared and implemented structural interventions consisting of moving the pipelines or restoring the bank. For each area, the Company has defined the interventions and checks to be carried out, considering the situation observed, to safeguard the integrity of the conduct and to follow any developments in the failures.

The mentioned periodic monitoring activities have been included in the Safety Management System and are subject to verification during the inspections provided for the D.Lgs. 105/2015. Periodically, following the monitoring activities, the Company communicates to the Competent Authorities the planning of improvement, consolidation, and restoration interventions, with all the necessary authorizations from the bodies in charge. The Site Manager has also identified prevention/mitigation measures, consisting in the interception of equipment and pipes in the areas at risk, in the event of a weather alert.

The methodology chosen certainly constitutes a starting point for the analysis and management of the risk deriving from failures.

In situations that need more attention, a possible action for improvement can be identified in associating visual monitoring with instrumental measurements aimed at quantifying any landslides. In fact, in this way, it will be possible to identify attention limits, so as to guarantee the persistence of security conditions. Further actions can be carried out, such as intensifying monitoring and carrying out stability checks of the slopes, in case of more severe conditions.

If the results of the further actions indicated above shows situations of increased risk above "acceptable" values, without prejudice to any mandatory provisions implementing in the planning tools, it will be necessary to plan structural interventions aimed at guaranteeing the stability of the plants. Typical examples are:

- Construction of consolidation and stabilization works for risk mitigation, after a hydrogeological compatibility study and approval by the competent Authorities
- Delocalization of pipes and systems

A further aspect of improvement is the in-depth study of the accident scenarios resulting from instability, by evaluating the probability of loss of containment, subsequent ignition of the released gas and calculation of the areas of damage.

V. Hydraulic risk analysis: the consideration of flooding

For plants and structures located in areas at risk of flooding, the site Managers were asked to carry out a specific risk assessment. The study produced was of a multidisciplinary type and started from field surveys in all plant areas and along the connection network falling within areas even if not recorded by the territorial planning tools. In particular, the following activities were preliminarily carried out:

- Survey for the topographical definition of the study area.
- Geo-gnostic and geophysical investigations campaigns aimed at the stratigraphic, hydrogeological and seismic reconstruction of the study area. These studies make it possible to identify the characteristics of the subsoil and the seasonal groundwater levels.
- Vegetational surveys and development of the relative cartography.
- Bibliographic studies of the geological, geomorphological and hydrogeological structure of the study area, supplemented by hydro-morphological survey activities in the field to apply the IDRAIM (Italian acronym for "Hydromorphological evaluation system, analysis and monitoring of watercourses") methodology [8]. This methodology is aimed at understanding the aspects of fluvial dynamics of the watercourses and at the classification of areas most dangerous due to erosion by the watercourses, providing an overall picture of the hydro-geomorphological evolution processes.

- Detailed hydrological-hydraulic studies for the hydrographic areas. These studies make it possible to analyze the flooding problem in correspondence with the plant areas, carrying out a detailed hydraulic study to determine the water tie rods with a return period of 200 years.
- Evaluation of erosive phenomena at the bottom of the riverbed, in correspondence with river areas where the crossing of the watercourse by operational methane pipelines is detected.

The mentioned activities allowed a complete view of any hydraulic criticalities that could affect the surface systems. Once the plants located in the areas at risk of flooding have been identified, the study analyzed the as-built documentation relating to the plant areas concerned, studying the characteristics of the foundations, the equipment present and the ground, and specifically: dimensions of the foundations; depth of the laying surface; characteristics of the material constituting the foundations: weight of equipment; diameter and thickness of the pipes; depth of burial; characteristics of the pipe's material; weight of the pipes; soil characteristics.

This detailed analysis, aimed at acquiring all the necessary information relating to the Cluster areas, well areas, and connections, proved to be functional to the verification of the hydrostatic thrusts for the equipment and pipelines.

The risk analysis was completed through geotechnical, load bearing, and lifting capacity checks, for the foundations of the equipment involved and for the sections of pipelines that are potentially floodable or with the presence of seasonal groundwater above the pipeline. A bearing capacity analysis of the foundations was also performed as required by the Technical Standards for Construction. If the checks relating to the buoyancy thrusts and the analysis of the bearing capacity in the event of flooding were not satisfied, without prejudice to any mandatory provisions, it would be necessary to plan structural interventions.

These interventions are aimed at guaranteeing the stability of the structures and the absence of containment losses in the event of flooding, also considering the ongoing climate changes, which make intense and sudden phenomena more and more frequent. They may consist in the relocation of the plants to areas outside those of risk or in interventions to make the structures safe, after a hydraulic compatibility study and approval by the Competent Authorities. Also, for the risk of flooding, as for the seismic and instability risk, the risk analysis carried out up to now by the Site Manager can be completed with the analysis of the accident scenarios resulting from flooding.

IV. Conclusions

The results of the NATECH risks assessment must be considered in the location, design, construction, and operation of the industrial establishment, as well as in the implementation of mitigation measures and emergency planning. The site operator of industrial establishments under the Seveso directive should develop appropriate measures to address natural hazards, to allow the maintenance of control of the plants vital to safety and their safe operation.

In this sense, the Safety Management System for the Prevention of Major Accidents, and the relative integration with the operational management of the establishment, plays an important role in ensuring the correct implementation of the prevention and protection measures against major accidents originating from NaTech events, with specific procedures for extreme weather conditions, such as heavy rainfall, lightning, strong winds and extreme temperatures.

Starting from the main outcomes of the analysis of some industrial accidents, where natural hazards have been identified as a significant and triggering cause, it is possible to focus the main types of plants, infrastructures, and industrial equipment vulnerable to extreme weather conditions. These lessons learned are also useful examples of how organizations could manage these problems, through specific procedures, good practices, and methods used to assess the industry's response to NaTech issues.

In this framework, the technical evaluation of NaTech risks of underground natural gas storage, as national strategic assets for the national supply of energy sources within the diversification policies, is of particular importance. In addition to the peculiarity of using a natural reservoir for storage, they also extended over large areas, as they consist of multiple plants joined by pipelines (compression and treatment stations, well areas, cluster areas). The characteristics of the activity made it necessary to draw up a Guideline for the assessment of safety reports, focusing attention on natural events or disasters that can induce one or more technological accidents such as fires, explosions, and releases, with particular attention to hydrogeological risk.

The extension of these establishments over large areas means that parts of the system, and particularly the connecting pipes, can cross areas subject to instability and flooding. The analysis conducted in the safety reports has certainly made it possible to focus attention on the problems present; the assessment must be completed with the study of possible accident scenarios deriving from natural risks of floods, to adopt the necessary measures for the prevention, mitigation and management of the emergency.

References

[1] DECRETO LEGISLATIVO 26 giugno 2015, n. 105. SO n. 161 del 14 luglio 2015 "Attuazione della direttiva 2012/18/UE relativa al controllo del pericolo di incidenti rilevanti connessi con sostanze pericolose". (GU 14 luglio 2015, n. 161, S.O.)

[2] https://www.hse.gov.uk/research/journals/mrn698a.htm (accessed 26/10/2021)

[3] https://emars.jrc.ec.europa.eu/en/emars/content (accessed 26/10/2021)

[4] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment of flood risks (Text with EEA relevance) Oj L 288, 06/11/2007, p. 27-34

[5] DECRETO LEGISLATIVO 23 febbraio 2010, n. 49. "Attuazione della direttiva 2007/60/CE relativa alla valutazione e alla gestione dei rischi di alluvione". (GU 02 aprile 2010, n. 77)

[6] Inventario nazionale degli stabilimenti suscettibili di causare incidenti rilevanti ai sensi dell'art. 5, comma 3 del Decreto Legislativo 26 giugno 2015, n. 105

[7] Gli stoccaggi sotterranei di gas naturale - Linee Guida per la valutazione dei Rapporti di Sicurezza. Coordinamento per l'uniforme applicazione sul territorio nazionale di cui all'art. 11 del decreto legislativo 26 Giugno 2015 n. 105

[8] IDRAIM - Sistema di valutazione idromorfologica, analisi e monitoraggio dei corsi d'acqua. Manuali e linee guida 113/2014. ISBN: 978-88-448-0661-3

RISK-ORIENTED APPROACH TO THE RECONSTRUCTION OF RESIDENTIAL BUILDINGS AND STRUCTURES IN THE ARCTIC ZONE

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Abstract

The report is dedicated to the study of various approaches in regards to the reconstruction of residential buildings and structures in the Arctic zone using a risk-based approach. The aim of the research is to develop methods that take into account the specific climatic and geological conditions of the Arctic in view to minimising risks in the design and construction works. The objective of the study includes the following (i) analysis of existing methodologies, (ii) assessment of their applicability in Arctic conditions and (iii) development of new approaches that take into consideration the regional specificities. The relevance of the topic is due to the growing interest in the development of the Arctic and the need to ensure the safety and comfort of living in harsh climatic conditions.

The study uses data on climatic and geological peculiarities of the Arctic zone, as well as modern methods of risk analysis. Modelling and forecasting methods have been applied to assess the impact of various factors on the stability and durability of buildings. Expert judgements and empirical data from research and monitoring of existing construction projects in the Arctic have also been used.

The results of the study have shown that the application of a risk-based approach can significantly improve the reliability and safety of reconstructed buildings in the Arctic zone. Key risk factors were identified, such as interalia geotechnical risks, risks of heat losses and energy efficiency of buildings, specificity of building materials, risks in adapting to changing climate, transport and logistics. An algorithm for calculating the degree of risks in the reconstruction of buildings and structures in the Arctic zone was designed accordingly, which includes 4 actions. The formula for assessing the degree of risks in reconstruction in the Arctic zone is developed. Weight characteristics of each risk factor are determined by the method of expert evaluations. Variation of each risk factor at three levels: unsatisfactory, good, excellent is performed. An adapted scale for qualitative assessment of the degree of risk in reconstruction in the Arctic zone was also developed.

The details of the obtained results have an important practical significance for construction and reconstruction of facilities in the Arctic. This implies that the recommendations can be used in the design and planning of construction works, which will reduce the probability of accidents, risks and hazards, thus increase the durability and life span of buildings. The implementation of the proposed methods shall largely contribute to the sustainable development of infrastructure in the Arctic zone, hence ensuring the safety and comfort of living.

Keywords: Arctic, reconstruction, residential buildings, risk-based approach, climatic conditions, geological features, wind loads, construction technologies, efficiency improvement

I. Introduction

The Russian Federation has significant territories in the Arctic region, and therefore development and research in this area is challenging to the Russian Federation. The Arctic zone comprises of extensive natural resources, including oil, gas, mineral wealth and fish. Infrastructure development and residential renewal are becoming crucial for attracting investment and creating a favourable economic background. The Arctic has significant potential for development and research aimed at improving the comfort of human habitation in this climatic zone [1-3].

The Arctic region is currently undergoing a gradual transformation in the context of global climate change which will cause this location to become a centre of intense change. Given the fact that this unique region, known for its distinctive climate, is undergoing significant transformations, same will as a result affect all aspects of its existence. Against this background, special attention is being given to residential structures, which face the dual challenge of maintaining their functionality and efficiency in order to cope with the increasing warming of the Arctic region, as well as adapting to the potential threats posed by these changes [4-6].

The unique climatic conditions of the Arctic zone, such as fluctuating temperatures, regular snowfalls, high winds and changes in permafrost conditions, affect residential buildings, making them more vulnerable and requiring comprehensive solutions to maintain their functionality and safety. These atmospheric conditions can cause significant damage to wall cladding materials, roofing and windows, making it necessary not only to modernise but also to change building standards to meet the new Arctic conditions. In this regard, the issue of reconstruction of buildings and structures becomes even more urgent with the active development of Arctic territories and the increasing need for housing [7,8].

Reconstruction of buildings and structures in turn helps to solve the problem of providing people with comfortable and safe housing. Our participation in the research on reconstruction in the Arctic zone gives Russia an opportunity to become actively involved in the design of updated standards, norms, guidelines and regulations in the region. The development of innovative technologies and solutions will subsequently strengthen the country's position as a key participant in international cooperation and partnership in the Arctic area [9].

The purpose of this research is to study the peculiarities of reconstruction of residential buildings in the Arctic zone under the conditions of modern climatic changes, as well as to identify ways and means to reduce risks related to the organisation of reconstruction work on buildings and structures.

Taking into consideration the gradual warming of the Arctic region, and its impact on the overall building structure as well as the technical issues associated with permafrost thawing and extreme weather events, it will be our responsibillity to detect, diagnose and identify these specific problems. Consequently we will propose new approaches to organising reconstruction works aimed at improving the sustainability of residential buildings in this region.

The main direction of the scientific research is to develop a risk-oriented approach to the reconstruction of residential buildings and structures in the Arctic zone. It differs significantly from the current understanding of the problem [10-12]. This approach complements and deepens the already known methods, offering new solutions to improve the stability and durability of buildings in a changing climate [13-15].

In addition, the article introduces new facts, conclusions and recommendations based on the conducted research. The obtained results have an important practical significance and can be used in the design and planning of construction works, which will reduce the probability of accidents and increase the durability of buildings.

The purpose of this report proceeds from the scientific problem and consists in the study of the peculiarities of reconstruction of residential buildings in the Arctic zone using a risk-oriented approach [16]. Methods that allow taking into account specific climatic and geological conditions of the region are thoroughly discussed in this report, and innovative solutions are being proposed to mitigate risks in the design and construction works. This study will serve as a basis for the development of a comprehensive methodology to improve the efficiency of the organisation of reconstruction of buildings and structures in the conditions of the far north and the Arctic zone of the Russian Federation, based on neural modelling. The use of modern information technologies and artificial intelligence will significantly improve the quality of management and planning processes in the reconstruction of buildings and structures [17-19].

II. Methods

In the Arctic region, where climate and natural conditions pose specific risks for residential renovation, an in-depth study of the problems and the development of effective strategies and technical solutions are required. By analysing the main types of risks, such as geotechnical risks, heat losses, building material features, adaptation to changing climate and transport and logistics risks, ways to address them have been identified.

The table laid down below gives a comprehensive view of the risks and the corresponding solution strategies. Each category of risks is described in more details, thereafter the main areas of technical solutions are presented. This analytical approach outlines the main risks in reconstruction in the Arctic zone and identifies strategic methods to effectively address these technical risks.

Table 1: *Risks and solutions for reconstruction in the Arctic zone.*

№	Name of risk	Description	Solutions
1	Geotechnical risks	In Arctic permafrost conditions, ground thawing can lead to deformation of foundations and walls of buildings. This creates the need to develop special geotechnical solutions aimed at stability and prevention of deformations due to changes in frozen soils.	Permafrost thawing: Develop engineering methods to stabilise frozen ground, such as freezing technologies. Introduction of freezing systems that use refrigerants to keep the ground stable. Foundation deformations: Application of pile foundations to account for changes in frozen soils. Investigation of optimal pile depth and pile location parameters to minimise the impact of permafrost thawing.
2	Heat loss risks and energy efficiency of buildings	The Arctic zone is characterised by low temperatures, which causes the problem of heat loss in buildings. Efficient insulation and innovative heating technologies become important to maintain comfortable conditions inside the dwelling and reduce energy consumption.	Innovative insulation: Development and use of new thermal insulation materials such as vacuum panels and thermal insulation coatings. This will help to reduce heat loss and ensure efficient heat retention in buildings. Heating technologies: Introducing heat pumps and thermal storage technologies to provide an efficient heating system capable of maintaining comfortable conditions in cold climates.
3	Specificity of construction materials	Traditional building materials may not be able to cope sufficiently with the Arctic climate. For example, moisture freezing in the structure of walls can cause damage. The development and use of specialised	Heat resistant materials: Development of building materials capable of maintaining structural integrity at low temperatures and preventing moisture from freezing inside walls. Introduction of new formulations resistant to arctic conditions. Use of composites: The use of composite materials that combine strength with

		building materials that are resistant to low temperatures is becoming an important aspect of reconstruction.	thermal insulation properties to create more resilient structures in Arctic conditions.
4	Risks in adapting to a changing climate	Projected changes in the climate, such as increasing temperatures and the frequency of extreme weather events, require the development of buildings that can adapt to variable conditions. This includes strengthening structures, improving drainage systems and adapting to new building standards.	Reinforcement of structures: Developing structures that can withstand high winds, snowfall and other extreme weather conditions. Strengthening structural elements of buildings to increase their resilience to variable conditions. Drainage Improvements: Designing effective water collection and drainage systems to prevent the negative effects of snow and ice melt on roofs and around foundations.
5	Transport and logistics	The remoteness and inaccessibility of the Arctic territories create difficulties in the delivery of construction materials and equipment. Logistical problems can significantly increase costs and complicate the reconstruction process.	Local production bases: Establish local production bases for building materials, reducing dependence on long-distance supplies and simplifying logistics. Delivery technologies: Introduce delivery technologies such as drones or mobile warehouses to deliver materials and equipment to remote areas more efficiently and reliably.

In the context of residential building renovation in the Arctic zone, facing technical challenges requires not only engineering solutions, but also careful analysis, evaluation and process optimisation. Based on the results of the study, key challenges have been highlighted:

- Geotechnical risks
- Heat loss risks and energy efficiency of buildings
- Specificity of construction materials
- Risks in adapting to a changing climate
- Transport and logistics

In order to achieve our goal, it is necessary to solve the tasks, approaching it in a systematic way. This approach requires not only traditional engineering solutions, but also the introduction of modern technologies.

III. Results

One of the contemplated areas of state-of-art technology is the use of neural modelling for real-time prediction, optimisation and decision making. Neural networks have proven their effectiveness in a variety of areas including data analysis, process optimisation and forecasting. The application of neural modelling can play a key role in addressing the identified risks presented in our table, providing accurate and adaptive approaches to complex engineering problems.

Such an integrated approach, combining traditional engineering methods and neural modelling capabilities, can improve the efficiency, accuracy and sustainability of reconstruction processes in the Arctic zone. The following table systematises the problems and solutions and assesses the feasibility of applying neural modelling in each area.

Table 2: *Ways to predict and address risks using neural modelling.*

Risks and Aspects	Solutions	Neural modelling capabilities
Geotechnical risks	- Development of technical solutions for stabilisation of frozen soils. -Application of pile foundations taking into account changes in frozen soils.	Prediction of ground deformations and optimisation of foundation parameters based on data on local climatic conditions.
Heat loss risks and energy efficiency of buildings	-Development of new thermal insulation materials. - Introduction of heat pumps and heat storage technologies.	Optimisation of heating and ventilation systems using neural networks to adapt to changing temperatures.
Specificity of construction materials	- Development of building materials resistant to low temperatures. - Use of composite materials.	Analysis of material properties, prediction of their behaviour under Arctic climate conditions.
Risks in adapting to a changing climate	- Strengthening of structures. - Improvement of drainage systems.	Prediction of extreme weather conditions and optimisation of structural changes in buildings.
Transport and logistics	-Creating local production bases. -Use of delivery technologies.	Optimisation of logistics networks and prediction of optimal routes for material delivery

The result of the study is the formed algorithm for calculating the degree of risks in the reconstruction of buildings and structures in the Arctic zone, which includes 4 actions: analysing and assessing risks; correlating the risk factor with Table 4, determining the quantitative value of risk according to Formula 1, determining the qualitative value of the degree of risk according to Table 5. In order to assess the degree of risk, we can use a mathematical apparatus to quantify the degree of risk. The formula for assessing the degree of risk in reconstruction in the Arctic zone can be presented as follows:

$$R = (W1 \times F1 + W2 \times F2 + \cdots + Wn \times Fn) \quad (1)$$

Where:

R - risk level

Wi - weighting factor for each risk factor

Fi - value of each risk factor

Each risk factor will be assigned the following designations: F1-Geotechnical risks, F2-Risk of heat loss and energy efficiency of buildings, F3-Specificity of building materials, F4-Risk in adapting to a changing climate, F5-Transport and logistics.

The next stage of the study was to determine the weighting characteristics of each risk factor using the expert judgement method. The method of expert judgement allows to create a certain collective consciousness formed from the opinion of a group of experts. This approach is more effective than the opinion of a single person.

In our case, expert analysis can be used to determine the weighting of factors. The experts participating in the study were included in the national register of specialists. This fact allowed us to judge about the competence of experts and their extensive experience in the field. Upon completion of the experts' questionnaires, data processing was carried out. The results were plotted in a graphical form for better visualisation and understanding, a histogram of factors with the minimum limit of significance of factors was built.

Weighting factors: W1 = 0,3 (Geotechnical risks); W2 = 0,2 (Heat loss risks and energy efficiency of buildings); W3 = 0,2 (Specificity of construction materials); W4 = 0,15 (Risks in adapting to a changing climate); W5 = 0,15 (Transport and logistics)

In Table 3, each of the risk factors is represented as one of three alternatives: unsatisfactory, good, excellent. In order to further use these qualitative characteristics in the form of quantitative ones, the concept for unsatisfactory 0,3, for good 0,5, for excellent 0,8 was introduced.

Table 3: *Varying organisational and technical factors.*

Risk factor	unsatisfactory- 0,3	good-0,5	excellent – 0,8
Geotechnical risks	-Frost thaw does not exceed 10% of the total area of the construction site. -Foundation deformations do not exceed 5% of the total building height.	-Melting of permafrost does not exceed 5% of the total area of the construction site -Foundation deformations do not exceed 2% of the total building height.	-Frost thawing is absent or does not exceed 1% of the total area of the construction site. -Foundation deformations are absent or do not exceed 1% of the total building height.
Heat loss risks and energy efficiency of buildings	-Heat losses through walls and roofs do not exceed 20% of the total heat load of the building. -Energy efficiency of heating and air conditioning does not exceed 10% of the total energy consumption of the building.	-Heat losses through walls and roofs do not exceed 10% of the total heat load of the building. -Energy efficiency of heating and air conditioning does not exceed 5% of the total energy consumption of the building.	-Heat losses through walls and roofs are absent or do not exceed 5% of the total heat load of the building. -Energy efficiency of heating and air conditioning is absent or does not exceed 2% of the total energy demand of the building.
Specificity of construction materials	-Resistance to low temperatures does not exceed 50% of the total area of the building materials. -Resistance to wind loads does not exceed 30% of the total area of the building materials.	-Resistance to low temperatures does not exceed 70% of the total area of the building materials. -Resistance to wind loads does not exceed 50% of the total area of the building materials.	-Resistance to low temperatures is absent or does not exceed 90 per cent of the total area of the building materials. -Resistance to wind loads is absent or does not exceed 70 per cent of the total area of the building materials.
Risks in adapting to a changing climate	-The increase in temperatures does not exceed 2°C from the average temperature over the last 10 years. -An increase in the frequency of extreme weather events does not exceed 10 per cent of the average frequency over the last 10 years.	-The increase in temperatures does not exceed 1°C from the average temperature over the last 10 years. -An increase in the frequency of extreme weather events does not exceed 5% of the average frequency over the last 10 years.	-Temperature increase is absent or does not exceed 0.5°C from the average temperature over the last 10 years. -An increase in the frequency of extreme weather events is absent or does not exceed 2% of the average frequency over the last 10 years.
Transport and	-Accessibility to the construction site does	-Accessibility to the construction site does	-Accessibility to the construction site is absent

logistics	not exceed 50% of the total construction site area.	not exceed 70% of the total construction site area. -Transport problems do not exceed 10% of the total area of the construction site.	or does not exceed 90% of the total construction site area. -Transportation problems are absent or do not exceed 5% of the total construction site area.

One of the most convenient ways to construct an integral indicator is the generalised Harrington desirability function. This function is based on the transformation of natural values of private indicators of different physical nature and dimension into a single dimensionless scale of desirability (preference). We adapted this scale to our obtained data, and the adapted scale was summarised as detailed in the table below (Table 4).

Table 4: *Adapted scale of the degree of risk.*

Risk level R	Risk assessment
Low risk	R < 0,39
Medium risk	0,4 ≤ R ≤ 0,6
High risk	R > 0,61

This range allows us to assess the degree of risk qualitatively. Low risk: the degree of risk is below 0,39 which indicates that the risk is minimal and does not require special attention. Medium risk: the degree of risk is between 0,4 and 0,6 which means that the risk is moderate and requires some attention and appropriate measures to minimise it. High risk: the degree of risk is above 0,61 which shows that the risk is high and requires serious attention and urgent measures to minimise it.

IV. Conclusions

The research conducted on the topic of risk-based approach in the reconstruction of residential buildings and structures in the Arctic Zone has highlighted key aspects that influence the efficiency and success of the reconstruction process in an extreme climate. The main results of the research are presented below:

- The study confirmed the urgency of the problem of reconstruction of residential buildings in the Arctic zone, especially in the context of a changing climate and warming.
- The study highlighted the technical challenges faced by engineers in reconstruction in Arctic conditions, such as: geotechnical risks, heat loss risks and energy efficiency of buildings, specificity of construction materials, risks in adapting to the changing climate, transport and logistics.
- An algorithm for calculating the degree of risks in the reconstruction of buildings and structures in the Arctic zone was formed.
- An approach to the assessment of reconstruction efficiency is developed, including criteria of satisfactory, good and excellent performance for the main factor.

References

[1] Tsygankova A.A., Romanchenko O. V., Shemetkova O. L. Infrastructure of the Arctic zone of the Russian Federation: state, economic instruments of development and priority projects. Regional Economics and Management: electronic scientific journal. - 2016. - №. 4 (48). - p. 181-193.

[2] V. Savinova, M.M. Brodach, Features of design and construction in the Arctic region. High Technology Buildings. - 2018. - № 4.

[3] N.S. Kalinina, N.V. Morozov, Architectural, technical and design features of designing residential and public buildings in the Far North. System Technologies. - 2019. - № 3(32).

[4] Khubaev, A.O. Improvement of the production process of winter concreting on the basis of the potential of organizational and technical solutions: specialty 05.02.22 "Production organization (by branches) »: dissertation for the degree of Candidate of Technical Sciences /2022. - 178 p.

[5] Khubaev A.O., Determination of the efficiency of the production process of winter concreting based on field studies. E3S Web of Conferences: Ural Environmental Science Forum "Sustainable Development of Industrial Region" (UENF-2023), Chelyabinsk, April 25-28, 2023. Vol. 389. - Chelyabinsk: EDP-Nauka, 2023. - P. 06012. - DOI 10.1051/e3sconf/202338906012.

[6] A. Lapidus, A. Khubaev, T. Bidov, A. Regression analysis of the calculation of organizational and technological potential for the production of cold-weather concreting. IOP Conference Series: Materials Science and Engineering: 23, Construction - The Formation of Living Environment, 55 Giai Phong Road, Hanoi, September 23-26, 2020. - 55 Giai Phong Road, Hanoi, 2020. - P. 072033. - DOI 10.1088/1757-899X/869/7/072033.

[7] T.H. Bidov, A.O. Khubaev, A.A. Shabanova, Organizational and technical modeling of the complex system of concrete works production in winter period during the construction of residential buildings. Construction and Geotechnics. - 2021. - T. 12, № 2. - p. 15-25. - DOI 10.15593/2224-9826/2021.2.02.

[8] A.A. Lapidus, A.O. Khubaev, Increasing the efficiency of winter concreting production through the use of software "potencial-cwc". Izvestiya Tula State University. Technical Sciences. - 2020. - № 5. - p. 18-26.

[9] Akshov E.A. Use of computational design and artificial intelligence in modeling architectural objects. Architecture and Modern Information Technologies.-2023.-№. 2(63).-p.298-315.

[10] S. O. Abioye, L. O. Oyedele, L. Akanbi, Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. Journal of Building Engineering. – 2021. – Vol. 44. – P. 103299. – DOI 10.1016/j.jobe.2021.103299.

[11] Koshelev V. A. Risk management mechanism in construction. Voprosy ekonomiki i prava. - 2014. - №. 74. - p. 122-127.

[12] S.S. Korabelnikova, S.K. Korabelnikova, Digital technologies as an element of risk reduction in construction. Discussion. - 2019. - № 2(93). - p. 18-27. - DOI 10.24411/2077-7639-2018-10002.

[13] A.A. Lapidus, I.L. Abramov, T.K. Kuzmina, A.I. Abramova, Sustainability of the activity of construction organizations under the conditions of risk factors. Industrial and Civil Engineering. - 2023. - № 11. - p. 97-104. - DOI 10.33622/0869-7019.2023.11.97-104.

[14] Abramov I., AlZaidi Z. A. K., Evaluation of the Effective Functioning of Construction Enterprises in the Conditions of Occurrence of Diverse Risk Factors. Buildings. – 2023. – T. 13. – №. 4. – p. 995. – DOI 10.3390/buildings13040995.

[15] A. Lapidus, I. Abramov, T. Kuzmina, Abramova A., Alzaidi Z.A.K. Study of the Sustainable Functioning of Construction Companies in the Conditions of Risk Factors. Buildings. – 2023. – Vol. 13, No. 9. – P. 2282. – DOI 10.3390/buildings13092282

[16] Schreiber, I. Abramov, Z. Al-Zaidi, Assessment of risk-forming factors of construction production in conditions of uncertainty. E3S Web of Conferences. – EDP Sciences, 2021. – T. 258. – p. 09052. – DOI 10.1051/e3sconf/202125809052

[17] Aleksandr Makarov, "Organization of Construction Quality Control based on a Priori Risks of Works," International Journal of Engineering Trends and Technology, vol. 71, no. 1, pp. 134-140, 2023. Crossref, https://doi.org/10.14445/22315381/IJETT-V71I1P212

[18] P. Szymanski, "Risk management in construction projects", Procedia Engineering 208, 174–182 (2017). https://doi.org/10.1016/j.proeng.2017.11.036

[19] T. Wang, et al, "A meta-network-based risk evaluation and control method for industrialized building construction projects", Journal of Cleaner Production 205, 552–564 (2018). https://doi.org/10.1016/j.jclepro.2018.09.127

[20] B. G. Hwang, X. Zhao and L. P. Toh, "Risk management in small construction projects in Singapore: Status, barriers and impact", International Journal of Project Management 32(1), 116–124 (2014). https://doi.org/10.1016/j.ijproman.2013.01.007

USE OF GIS TECHNOLOGIES AND ARCGIS SOFTWARE IN THE DETERMINATION OF OIL POLLUTION IN THE CASPIAN SEA

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Abstract

Earth remote sensing (ERS) is one of the most important and rapidly developing types of space activities, which is most susceptible to innovation. It ensures the rapid receipt of practically significant results, which are already making a major contribution to the economy of developed countries of the world. This sector of space activity is based on the use of high science-intensive technologies and the latest achievements of fundamental and applied science. Space information is used in many areas, primarily for preventing and eliminating the consequences of natural disasters and man-made accidents, research and rational use of natural resources,environmental protection, energy, urban planning, transport complex, meteorology and climatology, forestry and agriculture, cartography, creation of geographic information systems, etc.
Naturally, this information should be widely used for the benefit of the oil and gas industry.
One of the most perfect tools for monitoring natural objects is remote sensing. Techniques for non-contact measurements provide extensive operational information about environmental changes. This is especially true for water pollution. Remote sensing methods are dominant in the large-scale comprehensive study of pollution areas in the Caspian Sea. In order to determine the dynamics of pollution of the Caspian Sea, assessment of the situation parameters based on space images and conducting complex monitoring are urgent issues.

Keywords: monitoring, multispectral, aerospace, ArcGIS, Caspian Sea

I. Introduction

As the first step in solving the problem of pollution of the sea surface with oil products, monitoring of polluted basins is one of the important issues. This requires the joint use of remote sensing methods (RS), aircraft and space systems for observation of water areas, detection of pollution, physical characteristics and control of its distribution in areas. The monitoring system should also provide observation in any weather, should not depend on lighting conditions (cloud cover), determine the volume, type, and location of pollution [1].

Remote Sensing (Earth Remote Sensing) transmitters must work on a real-time scale and distinguish anthropogenic pollution from biogenic substances formed in the sea as a result of the life activity of marine organisms. Modern ERS tools used for detection use a wide range of electromagnetic radiation wavelengths: ultraviolet and visible (0.26-0.8 μm), near (0.9 - 3 μm) and far (7 - 14 μm) infrared, ultra high frequency (1-100 sm) bands. They provide virtually real-time marine observations today.

Already at the present time, with the use of aerospace methods and technologies, it is possible to solve many problems in the interests of the oil and gas industry, first of all, who, how:

- conducting fundamental scientific research processes of the formation of hydrocarbon immigration using aerospace information;

- the study of the geological structure of oil and gas-bearing territories, including the study of lineament network and deep tectonics, annular structures,

- conducting tectonic zoning of these territories on the basis of space data for the informational support of prospecting work for the discovery of new and prospective evaluation of existing oil and gas deposits;

- monitoring of the current condition of oil, gas and product pipelines for the detection of leaks, violations of the technical condition, etc.;

- determination of potentially dangerous sections of pipelines, including assessment of changes in floodplains of rivers, reservoirs and swamps as a result of changes in permafrost and hydrophysical properties of soils,

- assessment of the dynamics of the frozen soil regime and the results of its impact, as well as the identification of the most favorable geoecological conditions for the laying of new pipelines;

- monitoring of dangerous natural and man-made processes during the development and transportation of hydrocarbons, including earthquakes,floods, avalanches, landslides, tsunamis, tropical cyclones, etc. on the basis of aerospace data;

- remote monitoring of the ice situation in arctic regions, in vol including locations of drilling platforms and the Northern Sea Route;

- operational space monitoring of fires in buffer zones of main pipelines and other objects of the oil and gas complex;

- environmental monitoring of places of extraction, transportation, processing and distribution of hydrocarbons on land and at sea to assess the consequences and reduce risks from the activities of enterprises in the oil and gas industry, including: no contamination of soil, vegetation and snow cover with petroleum products within the limits of drilling wells, oil storage facilities and oil pumping stations; marine platforms, places of loading, unloading and movement of ships for the transportation of oil, petroleum products and liquefied gas;

- underground and underwater pipelines; revealing the blooming of lakes as a result of the introduction of mineral and organic suspensions, etc.;

- control of tempos and evaluation of the efficiency of recultivation of lands and polluted territories based on aerospace data.

- carrying out ecological passporting of objects of the oil and gas industry using aerospace information;

- determination of the location of pipelines, structures and other objects of the oil and gas industry and formation of their cadastres based on aerospace data;

- creation of digital maps, three-dimensional terrain models, geoinformation systems (GIS) of different thematic orientation for oil and gas districts and others. with the use of aerospace information;

- remote monitoring of unsanctioned cuts into main oil and product pipelines;

- detection of unauthorized economic and construction activities, as well as the appearance of man-made objects in the zones of withdrawal of objects of the oil and gas complex based on aerospace data;

- remote monitoring of districts of construction of new facilities of the oil and gas complex;

- monitoring from space of places of combustion of accompanying gas and control of the functioning of torch installations;

- informational provision of long-term planning and management of the activities of these enterprises and the liquidation of accidents on them using aerospace data and others.

The spectrum of these tasks can be expanded as the methods, technologies and technical means of remote sensing and processing of the received information are developed.

II. Research object and methodology

Geographical Information Systems (GIS) are widely used today to determine water quality models and parameters. As we know, ArcGIS software is one of the integrated programs included in the GIS system. In this article, ArcGIS 10.4.1. the version of the software was used, the parameters causing oil pollution in a certain area of the Caspian Sea and the assessment of the degree of pollution were analyzed.

In order to determine the sources of pollution of the Caspian Sea in the Neftchala area, the space image of the AZERSKY satellite provided by Azercosmos was used. Satellite resolution 1.5m panchromatic / 6m multispectral; color range: 4 bands (red, blue, green, near infrared); shooting scene: min. 60X60km, max. 60X600km; height: 694.9 km; ability to draw the same point: 2 days (45°) .

Due to the fact that the Caspian Sea is a unique lake, it is very important today to evaluate its characteristics and ecological condition, as well as to study its hydrometeorological, hydrogeological and hydrophysical characteristics, and to analyze the variability of hydrochemical and hydrobiological processes. Among the problems of the Caspian Sea, along with the fluctuation of the level, the pollution of the sea waters and the related deterioration of the environmental conditions are the most important problems of the last period. The main sources of pollution of the Caspian Sea are the rich natural resources of its basin and the sewage flows of cities and industrial facilities located on the coasts of its basin, oil tankers, offshore oil fields, oil refineries, ship and boat lubricants, oil pipelines, oil wells, accidents, as well as the negligence of service personnel. The dynamics of the ecological situation of the Caspian Sea and, at the same time, its pollution by oil products occupy a key place in the ecological assessment. The first step is to identify the sources that pollute the sea as a result of natural and anthropogenic influences. A deeper study of the interaction of hydrophysical processes occurring in the water basin is important in order to reveal the regularity of the characteristics of the distribution of pollutants throughout the water area. On the other hand, the study of these factors separately and at the same time reveals that they play a more influential role and shows the main reasons for such a distribution [1,4].

III. Analysis of results

The spatial image includes the combination of the image of the Neftchala area in 2020 in panchromatic and multispectral bands (Figure 1). The description opens in the ArcMap version 10.4.1 interface of the ArcGis software. ArcMap has high-quality cartographic production functions that enable graphical and verbal data display, data registration, query and analysis, and development of images and reports. "Add Data" command is used to open the spatial image in ArcMap.

In order to facilitate the processing of the space image, a range shift was performed between the bands of the (Mosaic_2020) image presented to us.

With this, it is more convenient to work on the objects we need in the image. It should be noted that the color range of the image consists of 4 bands (Blue Band_3, Green Band_2, Red Band_1, Infrared Band_4). As seen in the mosaic image, Red Band_1 to Red Band_4, Green Band_2 to Green Band_1, Blue Band_3 to Blue Band_2, and Infrared Band_4 to Infrared Band_3.

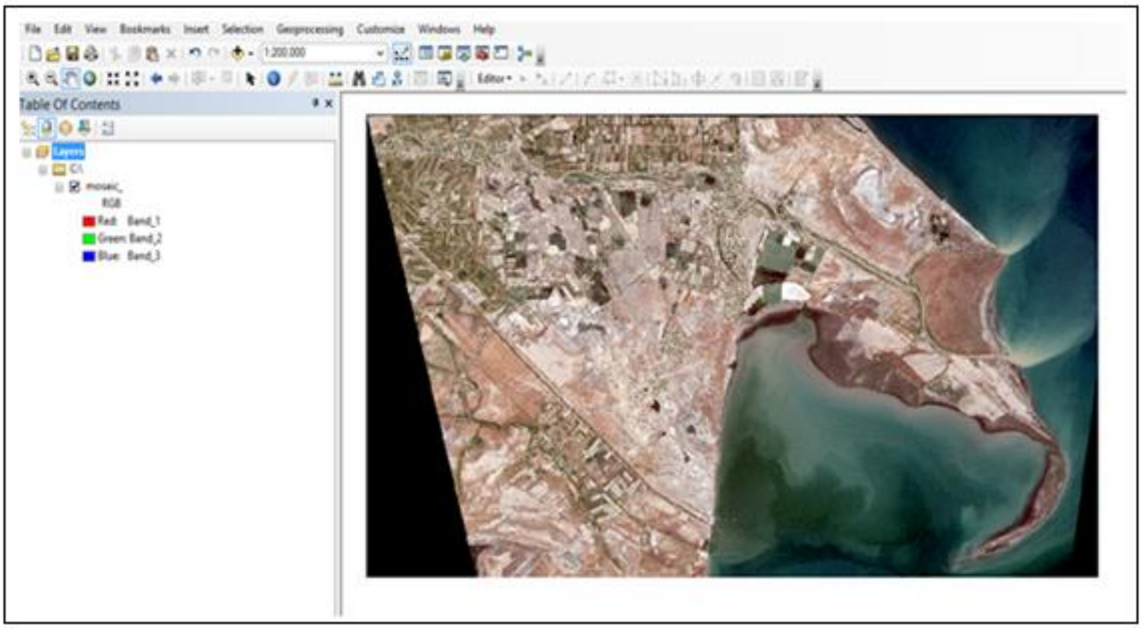


Figure 1: *Space image of Neftchala area in panchromatic and multispectral bands*

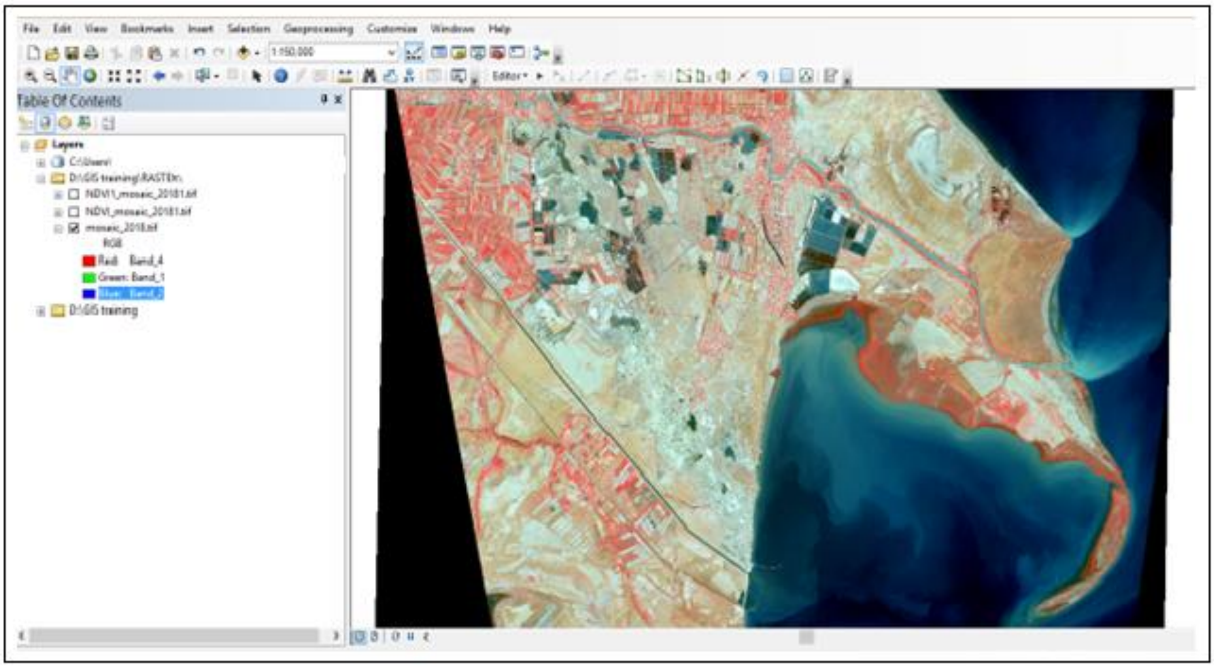


Figure 2: *Bandwidth-shifted space image*

After changing the color ranges, we get a chance to more clearly select water bodies in the image, and the "Start Editing" command is selected from the "Editor" button on the ArcMap toolbar, and mapping work is carried out on the image (Fig. 3).

Hasanabad and Gobu canals have been designated in the description and processing works have been carried out on them (Figure 3). It should be noted that the Hasanabad collector starts from Boyat village of the region, passes through the territory of "Anshad-Petrol" MM, collects groundwater in the flow direction and flows into the Caspian Sea. Where the stream empties into the sea, the coastline is semi-swamped.

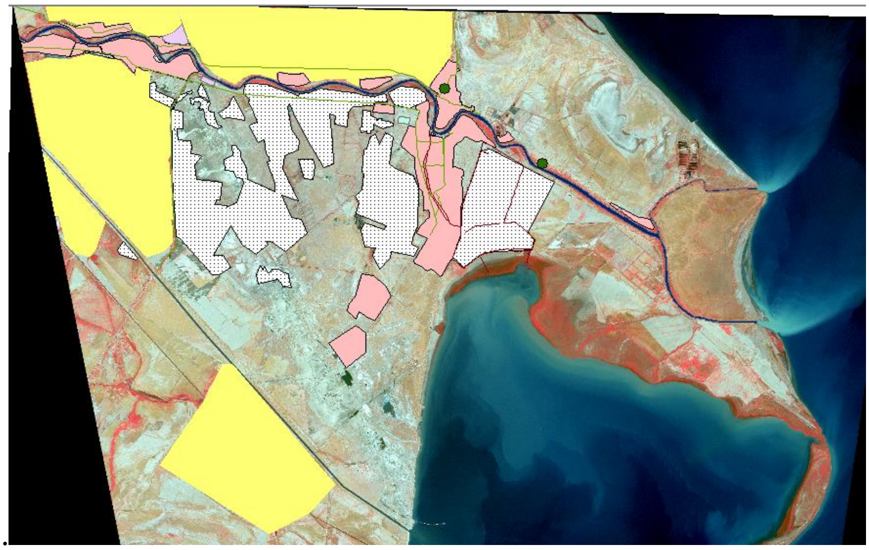
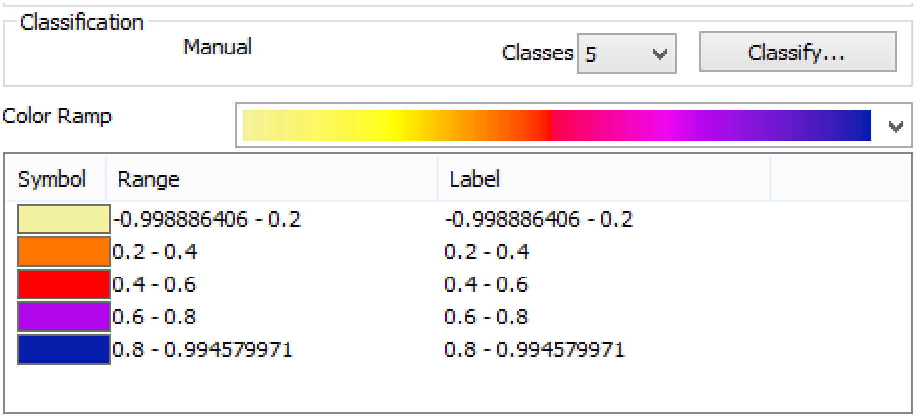


Figure 3: *ArcGis 10.4.1 in Neftchala area. conducting vectorization work through software*

Mapping works are carried out mainly in the coastal part of the Neftchala area close to the Caspian Sea, as well as on runoff waters discharged into the Caspian Sea, fishing facilities, unused land and other objects. Neftchala region is from Salyan to the north, Masalli, Lankeran to the south. It borders Bilasuvar and Jalilabad from the west, and the Caspian Sea from the east for 123-130 km.



Classification
Manual
Classes 5
Classify...
Color Ramp

Symbol	Range	Label
	-0.998886406 - 0.2	-0.998886406 - 0.2
	0.2 - 0.4	0.2 - 0.4
	0.4 - 0.6	0.4 - 0.6
	0.6 - 0.8	0.6 - 0.8
	0.8 - 0.994579971	0.8 - 0.994579971

Figure 4: *Classification assessment of the Caspian Sea with NDWI*

In NDWI, a combination of green (Band_2) and near-infrared (Band_4) bands was used as a range for defining and delimiting the open water surface (1). The NDWI (Normalized Water Index Difference) index is expressed as follows.

$$NDVI = \frac{GREEN}{GREEN+NİR} \qquad (1)$$

Here, NDWI - Normalized Water Index Difference
GREEN - Green range
NIR - Near Infrared range.

In our research, using the NDWI index, we were able to clearly determine the level of pollution of the Caspian Sea in our aerospace image. For more accurate monitoring, 5 values are included in the classification of the image (Fig. 4).

As can be seen from Fig. 5, the degree of water transparency increases from orange to blue. The white color represents dry land.

We clearly see that the Hasanabad channel in the Neftchala area coincides with the ground data mentioned above as a result of the email, and that it pollutes the Caspian Sea. The water discharged from the canal is represented by the orange color of the NDWI index according to the level of pollution.

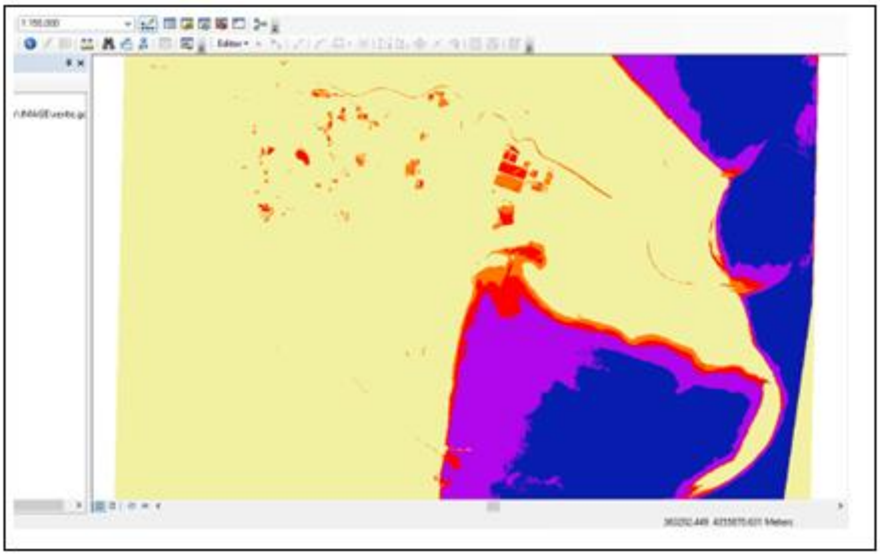


Figure 5: *ArcGis 10.4.1 of the Caspian Sea in Neftchala area. contamination rate estimation through software*

The cartographic basis for the oil pollution distribution map is the GIS-Caspian Ecological program overlay, which contains the following data: the coastline of the Caspian Sea, the hydrographic network (rivers and lakes), settlements, locations of oil fields on the shelf and on the coast, important oil pipelines of the region, the integrated scheme of the flow, digital model of underwater topography.

After preparing the cartographic base, an information layer containing data on the distribution of oil and oil products cover was added to the map. Then the layers are automatically combined and the final shape of the map is made.

The obtained map of the distribution of oil and oil products cover in the water area of the Caspian Sea characterizes its situation (real scale 1:1 500 000). The general pattern of distribution and transport of oil and oil products cover is related to the active exploitation of oil fields on the shelf and on the coast and is consistent with the global flow system of the Caspian Sea.

As can be seen from the map, the water area of the Caspian Sea is highly polluted by oil products. Due to the modern development trend of oil fields in the Caspian Sea, it can be concluded that if appropriate measures are not taken, the scale of pollution will increase. In this regard, the need to create an international oil pollution monitoring system based on a periodically updated map of their distribution, integrated with the geodatabase [2-4] is obvious.

In order to solve the issue of efficient use of resources, it is important to take an ecological-economic approach, and even to protect the environment and bioresources together with industrial activity in the shelf area. The main indicator of the level of change in the ecological situation is the concentration of pollutants and the distribution of areas in the water area. The analysis and evaluation of the indicators of oil products in the area of the Caspian Sea belonging to the Republic of Azerbaijan and the construction of maps based on the data collected in recent times have been of great importance in solving environmental issues.

As can be seen from Fig. 7, high-volume oil pollution (0.20-0.15 mg/l) in the Baku Bay area is characterized by the next result based on the average annual oil pollution data for 2017-2020. For these years, the average annual distribution of petroleum products areas in the Caspian Sea area was determined by the degree of pollution in those areas (0.09-0.06 mg/l). Analyzing the dynamics of the ecological situation based on the average annual calculations of these indicators and the constructed maps is very useful for predicting the ecological situation in the future from a scientific theoretical point of view.

Figure 6: *Average annual distribution of oil products to fields for 2017-2020*

Crude oil spills on land and seas have created the need to develop environmentally friendly and efficient methods for cleaning up these pollutions. Petroleum hydrocarbons, which cover large areas of the water surface with the thinnest layer, reduce the amount of dissolved oxygen by reducing gas exchange. A surface layer that reduces water evaporation leads to a violation of heat transfer. A further decrease in the amount of dissolved oxygen is associated with the biodegradation of hydrocarbons by microorganisms. As a result of these processes, decomposition products that are toxic to living organisms also accumulate in water. In addition, in the presence of oil hydrocarbons, the toxicity of other pollutants, especially metals and chlorinated hydrocarbons, becomes more pronounced. Due to the negative effects on living organisms in the environment, it is necessary to eliminate the consequences of oil spills. As can be seen from the literature [5-7], in modern times, various reagents and there are many methods of cleaning oil-contaminated objects using adsorbents.

IV. Conclusion

Based on the NDVI and NDWI indices, the pollution dynamics of the coast line of the Caspian sector of the Caspian Sea were investigated, the values of these indices were calculated, the pollution zones corresponding to certain intervals were determined and the corresponding areas were calculated. It has been shown that using GIS technologies and remote sensing data, it is possible to calculate the change and pollution of the coastal zone of the

Azerbaijani sector of the Caspian Sea based on the values of NDVI and NDWI indices. The proposed methodology allows to easily calculate what part of the total area the research area is. The obtained results can be used in the assessment of the change trend of the objects and processes that shape the dynamics of the coastline in the following periods and in the preparation of predictive proposals.

Figure 7: *Integrated map of distribution of oil, oil products and surfactants in the Caspian Sea*

References

[1] Kasymov A.G. Caspian Sea. L., Hydrometeoizdat, 1987, 151s.

[2] Mamedov R.M. Alizade A.A., Budagov B.A. Geographical Atlas of the Caspian Sea, Baku, Nafta Press, 1998, 274 p.

[3] Panin R.M., Mamedov R.M., Mitrofanov I.V. Modern state of the Caspian Sea. Moscow, Nauka, 2005, p. 16-19.

[4] Mamedov R.M., Hydrometeorological variability and ecogeographical problems of the Caspian Sea. Baku: "Elm", 2007, 436 p.

[5] Oluka N.N., George Z.G. ,Activated Carbon from Bamboo and Banana Wood Fibers as Adsorbent Materials for the Removal of Oil Samples. Biointerface Research in Applied Chemistry. 2022. P.2701.

[6] Sippel İ.Ya., Akhmetgaleeva G.A., Magdin K.A.,Removal of oils from water surfaces with modified Linden sawdust. / IOP Conference Series: Earth and Environmental Science. 2021. P.-1.

[7] Chukaeva L. M, Zaytseva T., Matveeva V., Sverchkov I. ,Purification of Oil-Contaminated Wastewater with a Modified Natural Adsorbent. Ecological Engineering & Environmental Technology. 2021. P.22.

ASSESSMENT OF THE LONG-TERM RISK OF DANGEROUS HURRICANES ON THE TERRITORY OF GEORGIA USING DATA FROM 1961 TO 2022

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Abstract

Based on the data from the catalog we compiled about natural disasters in Georgia, the frequency and probability of max hurricane magnitude in various zones of Georgia for the period 1961-2022 was studied. On the nature of the distribution of wind speed, frequency, intensity and magnitude of hurricanes, 3 zones are distinguished on the territory of Georgia. Zone 1 covers the Main Caucasus Range, the Likhi Range, as well as a small area of the interior of the Colchis Lowland and a small area of the flat part of Kvemo Kartli. Zone 2 covers the intermountain depression of Georgia - the Black Sea coast, the Colchis lowland, the Imereti Upland, the plains and foothills of eastern Georgia, with the exception of a small territory of the interior of the Colchis lowland and a small territory of the flat part of Kvemo Kartli, which are included in zone 1. Zone 3 covers the western part of Meskheti ridge, a significant part of the Trialeti ridge and the Akhalkalaki plateau. In particular, the following results were obtained. The most active hurricane zone is zone 1 (the frequency of hurricanes is 15 per year and the repeatability *period is 0.09 years, ≈ 1 month). The least active hurricane zone is zone 3 (1-2 hurricanes occur per year,* repeatability *period is 0.9 years, ≈ 10-11 months). The highest frequency of hurricane magnitudes by zone is as follows: zone 1 - 3.6÷4.0 (87%), zone 2 - 3.1÷3.5 (44%), zone 3 - 3.6÷4.0 (more than 60%). In the first two zones, as magnitudes increase, their frequency decreases significantly. The probability curves for the max magnitude of hurricanes are well approximated by polynomials of the 5th degree. The expected hurricane magnitudes in these zones are: in zone 1 - 5.8, in zone 2 - 5.5 and in zone 3 - 4.5 with a probability of 0.2%, 0.5% and 1%. The repeatability periods of such magnitudes are 500 years, 200 years and 100 years, respectively. Thus, in the coming decades, it is most likely that the magnitude of hurricanes in zone 3 will increase to 4.5; some increase in the magnitude of hurricanes to 5.5 in the long term is possible in zone 2, and in zone 1, hurricanes will intensify to magnitude 6 is unlikely. A map of zoning the territory of Georgia according to the max possible hurricane magnitudes has been developed. There are two areas with the highest max magnitude, reaching 6 (the Southern part of the Likhi Range in Western Georgia and a small area of the flat part of Kvemo Kartli in Eastern Georgia). Hurricanes with magnitudes 5 and 5.5 are possible in some areas. In a significant part of Georgia, the max hurricane magnitude can reach 4.5.*

Keywords: hurricane, provision, frequency, period, magnitude

I. Introduction

The strongest gusts of wind recorded on Earth are associated with tornadoes and reach speeds of up to 500 km/h. If a tornado of such force passes through a populated area, there will be practically nothing left of it [https://www.meteovesti.ru/news/63388088280-kakovo-maksimalnoe-znachenie-skorosti-vetra-zafiksirovannoe-na-zemle]. An automatic weather station on the Australian island of Barrow during Cyclone Olivia on April 10, 1996 recorded a gust speed of 113 m/s (408 km/h) [https://en.wikipedia.org/wiki/Cyclone_Olivia], and on April 12, 1934 at the Mount Washington Observatory in New Hampshire the speed the wind gust was 103 m/s (371 km/h) [1]. Winds of 333 km/h (about 87 m/s) were recorded at the US air force base in Greenland and Adélie Land in Antarctica (https://ru.wikipedia.org/wiki/%D0%92%D0%B5%D1%82%D0%B5%D1%) [80].

Along the entire Gulf Coast, wind speed reaches 157 knots (more than 80 m/s), (1 knot = 0.514 m/s). The highest wind speeds are along the Gulf Coast from Texas to Alabama. Using the Bayesian approach, the maximum possible coastal wind speed here can be 208 knots (more than 106 m/s) [2].

A study of high winds in Florida found that the city of Miami can expect hurricane-force winds of 50 m/s (45.5–54.5 m/s - 90% confidence interval) or stronger to occur on average once every 12 years, and in the city of Pensacola hurricane winds of 50 m/s (46.9–53.1 m/s, 90%) or stronger can be expected to occur every 24 years [3].

The Monte Carlo simulation method was used to estimate hurricane wind speeds along the Persian Gulf and the east coast of the United States. Estimated calculations of hurricane wind speeds were made at a height of 10 m above the ground in open areas near the coastline and at a distance of 200 km inland. Estimated hurricane wind speeds were found to best fit Weibull distributions [4].

Maximum hurricane wind speeds in China show a decreasing trend over large areas. Only in the southeast of the Tibetan Plateau does the wind speed not significantly decrease, but, on the contrary, even increase [5,6].

A weakening of hurricane winds was also noted in North America [7,8], regions of Europe [9,10], Australia [11], etc. Tendencies of increasing strong and stormy winds over the world's oceans were noted [12]. According to passive microwave satellite data [13], wind speed in the tropics for the period 1987–2006 increased on average by 0.6% per decade, while for all oceans the average trend was 1.0% per decade.

Hurricanes pose a danger to Georgia. Research on hurricane winds in Georgia has a long history, although the most relevant work has been carried out in recent years. In the article [14] for the period 1961-2008, the statistical structure of hurricane winds was studied, the number of days and duration of hurricane winds were determined, the empirical functions of their distribution and the size of their areas were studied. The monograph [15] examined the geography, structure, areas and dynamics of hurricane winds, and in article [16] the spatial distribution of hurricane winds was assessed, the maximum economic losses were calculated, and a map of expected risks was constructed. The paper [17] presents preliminary studies of hurricanes winds in Georgia in the period 1961-2022. Over the entire study period, about 1600 cases of hurricane winds were recorded. During the year, hurricanes occur on average 20 times, with the highest number of cases recorded in 2002 – 81. The average speed of hurricane winds in general for Georgia is 36 m/s, the highest speed reached 56 m/s. The average hurricane area is about 1200 sq. km, and the maximum hurricane area exceeds 10000 sq. km. There is no clear relationship between the hurricane area and the corresponding material damage, which can most likely be explained by the heterogeneity of the level of urbanization of comparable areas that experience varying degrees of damage. The long-term changes in hurricane activity reveal a cyclical nature, which can be explained by the peculiarities of atmospheric circulation. In general, over the entire period there has been a tendency for hurricane activity to weaken.

This article is a logical continuation of these studies [14-17]. It uses observational materials for the period 1961-2022 to assess the long-term risk of dangerous hurricanes in Georgia [18].

II. Methods

The article uses materials from the catalog about natural disasters in Georgia [18]. These data comply with World Meteorological Organization standards. All measurements of wind speed were carried out at a height of 10 m above the ground surface. In the catalog, the strength of a hurricane is expressed through magnitude (M), which was defined as a value proportional to wind speed, the proportionality coefficient is conventionally taken to be 0.1 s/m.

Statistical methods for processing climatological data were used. The assessment of the long-term risk of dangerous hurricanes is carried out on the basis of an empirical probability curve showing the probability or probability of exceeding a given value among the totality of the series. The coordinates of the supply curve were calculated directly from the values of the initial series of observations; for each member of the series, the empirical supply was determined using the Gauss formula:

$$P = m/n \cdot 100\%$$

where m is the number of hurricane events of a given magnitude, n is the total number of hurricane events.

III. Results

Based on the nature of the distribution of wind speed, frequency, intensity and magnitude of hurricanes on the territory of Georgia, 3 zones have been identified [19].

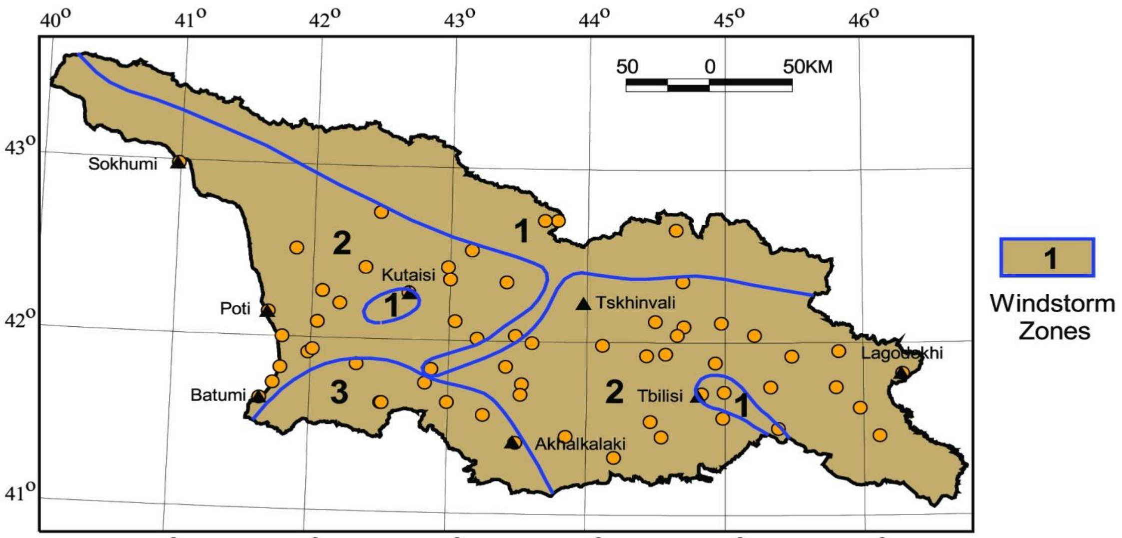

Figure 1: *Zoning of the territory of Georgia according to the nature of the distribution of wind speed, frequency, intensity and magnitude of hurricanes, and the distribution of observation points whose data were used [19].*

Zone 1 covers the Main Caucasus Range, the Likhi Range, as well as a small area of the interior of the Colchis Lowland and a small area of the flat part of Kvemo Kartli. Zone 2 covers the intermountain depression of Georgia - the Black Sea coast, the Colchis lowland, the Imereti Upland, the plains and foothills of Eastern Georgia, with the exception of a small territory of the interior of the Colchis lowland and a small territory of the flat part of Kvemo Kartli, which are included in zone 1. Zone 3 covers the western part of Meskheti ridge, a significant part of the Trialeti ridge and the Akhalkalaki plateau.

From Fig. 1 it follows that the selected zones are not uniformly illuminated by meteorological observations. The densest observation network is in zone 2, which occupies mainly the flat part of the territory of Georgia. In zone 3, on the Main Caucasus Ridge, there is a very sparse observation network.

Table 1 presents information about the meteorological coverage of these zones and the main statistical characteristics of hurricanes in zones of Georgia that differ in the nature of hurricanes. It follows from the table that the most active hurricane zone is zone 1, where the frequency of hurricanes is 15 per year and the repeatability period is 0.09 years (about 1 month). The frequency of hurricanes in zone 2 is 7, and their repeatability period is reduced to 0.14 years (2-3 months). The least active hurricane zone is zone 3, where only 1-2 hurricanes occur per year, and their repeatability period is 0.9 years, i.e. 10-11 months. When converted to one point, the frequency of hurricanes by zones are: 1.7; 0.15 and 0.2; the repeatability period - 0.6, 7 and 5 years, respectively.

Table 1: *Density of the meteorological network and average statistical characteristics of hurricanes in different zones.*

Zone	Number of points (m)	Frequency of hurricanes per year (N)	Repeatability period, T(N) years	Hurricane frequency per 1 point (n= N/ m)	Repeatability period for 1 point on average, T(n) years
1	9	15	0.09	1.7	0.6
2	45	7	0.14	0.15	7
3	6	1.2	0.9	0.2	5

Figure 2 shows histograms of the frequency of occurrence of various hurricane magnitudes. As it follows from this Figure the nature of the distribution of magnitude frequency in different zones is significantly different. In zone 1, in most cases (87%), the smallest magnitudes of 3.6-4.0 characteristic of the zone prevail, and with increasing magnitudes their frequency also decreases. In zone 2, the highest frequency of occurrence of 44% corresponds to gradation 3.1-3.5, and with increasing magnitudes their frequency of occurrence decreases significantly. In zone 3, the predominant frequency of gradation with the highest magnitude values is 3.6-4.0, which exceeds 60%.

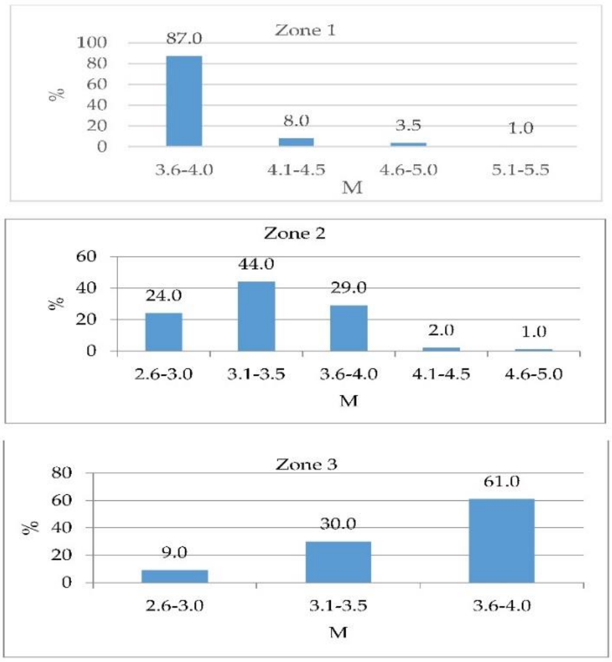

Figure 2: *Repeatability of different gradations of hurricane magnitudes in different zones.*

Figure 3 shows the probability curves for the maximum magnitude of hurricanes in different zones of Georgia, characterized by different wind speed regimes, and with different values of frequency, intensity and magnitude of hurricanes, as well as their approximation by a 5th degree polynomial.

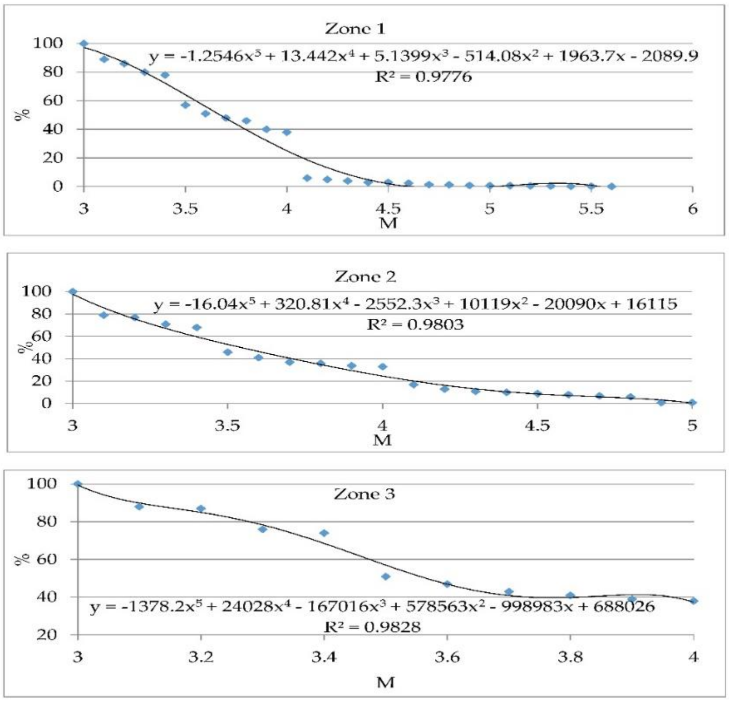

Figure 3: *Curves of provision for the maximum magnitude of hurricanes and their approximation by a 5th degree polynomial for various zones (R^2 - coefficient of determination).*

From Figure 3 it follows that the coordinates of points calculated directly from the values of the initial series of observations are well approximated by polynomials of the 5th degree. The coefficient of determination is significant and exceeds 0.97. Thus, the resulting equations can be used to calculate the magnitude of hurricanes of any provision.

Table 2 presents the observed and expected hurricane magnitudes, according to our expert estimates, and the corresponding probabilities for various zones of Georgia.

Table 2: *Values of observed and expected hurricane magnitudes (M_{max}) and corresponding provision (P%) and repeatability periods.*

Zone	Observed M_{max}	Provision, P%	Repeatability period, years	Possible M_{max}	Provision, P%	Repeatability period, years
1	5.6	0.4	250	5.8	0.2	500
2	5.0	1	100	5.5	0.5	200
3	4.0	38	2.6	4.5	1	100

From Table 2 it follows that in the most hurricane-active zone 1, the magnitude reaches 5.6 with a provision of 0.4%, i.e. the repeatability period is about 250 years. In zone 2, the highest magnitude reached 5.0, the provision of which is only 1%, and the repeatability period is 100 years. The highest hurricane magnitude in zone 3 was recorded as 4.0 with a provision of about 40%. Therefore, the repeatability period for this magnitude is about 2.6 years. According to expert estimates, the expected hurricane magnitudes in these zones are 5.8, 5.5 and 4.5, respectively, with provision of 0.2%, 0.5% and 1%. The repeatability periods of such magnitudes are 500 years, 200 years and 100 years, respectively.

Thus, in the coming decades, it is most likely that the magnitude of hurricanes in zone 3 will increase to 4.5; a slight increase in the magnitude of hurricanes to 5.5 in the long term is possible in zone 2, and in zone 1, an increase in hurricane magnitude to 6 is unlikely.

IV. Discussion

1. Based on the nature of the distribution of wind speed, frequency, intensity and magnitude of hurricanes, 3 zones are distinguished on the territory of Georgia. The most active hurricane zone is zone 1, where the frequency of hurricanes is 15 per year and the return period is 0.09 years (about 1 month). The frequency of hurricanes in zone 2 is 7, and their repeatability period is reduced to 0.14 years (2-3 months). The least active hurricane zone is zone 3, where only 1-2 hurricanes occur per year, and their repeatability period is 0.9 years, i.e. 10-11 months. When converted to one point, the frequency of hurricanes by zone is 1.7; 0.15 and 0.2, and the repeatability period is 0.6, respectively; 7 and 5 years old.

2. The nature of the distribution of magnitude frequency in different zones is significantly different. In zone 1, in most cases (87%), the smallest magnitudes of 3.6-4.0 characteristic of the zone prevail, and with increasing magnitudes their frequency also decreases. In zone 2, the highest frequency of occurrence of 44% corresponds to gradation 3.1-3.5, and with increasing magnitudes their frequency of occurrence decreases significantly. In zone 3, the predominant frequency of gradation with the highest magnitude values is 3.6-4.0, which exceeds 60%.

3. The probability curves for the maximum magnitude of hurricanes are well approximated by polynomials of the 5th degree. The coefficient of determination is significant and exceeds 0.97.

4. In the most hurricane-active zone 1, the magnitude reaches 5.6 with a probability of 0.4%, i.e. The r repeatability period is about 250 years. In zone 2, the highest magnitude reached 5.0, the probability of which is only 1%, and the repeatability period is 100 years. The highest hurricane magnitude in zone 3 was recorded as 4.0 with a probability of about 40%. Therefore, the repeatability period for this magnitude is about 2.6 years.

5. The expected magnitudes of hurricanes in these zones are in zone 1 -5.8, in zone 2 - 5.5 and in zone 3 - 4.5 with a probability of 0.2%, 0.5% and 1%. The repeatability periods of such magnitudes are 500 years, 200 years and 100 years, respectively. Thus, in the coming decades, it is most likely that the magnitude of hurricanes in zone 3 will increase to 4.5; some increase in the magnitude of hurricanes to 5.5 in the long term is possible in zone 2, and in zone 1, hurricanes will intensify to magnitude 6.

V. Conclusion

In the future, an even more detailed study of hurricane winds in Georgia is planned, including studies of tornadoes that have appeared in recent years in the continental part of the country.

Acknowledgments

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References

[1] Kravchuk P.A. (1993). Records of nature. L., Erudite, 216 p.

[2] Jagger T.H., Elsner J.B. (2006). Climatology Models for Extreme Hurricane Winds near the United States. *Journal of Climate*. Vol. 19, Iss. 13, pp. 3220–3236. doi.org/10.1175/JCLI3913.1

[3] Malmstadt J.C., Elsner J.B., Jagger T.H. (2010). Risk of Strong Hurricane Winds to Florida Cities. *Journal of Applied Meteorology and Climatology*. Vol. 49, Iss. 10, pp. 2121–2132.

doi.org/10.1175/2010JAMC2420.1

[4] Batts M.E., Simiu E., Russell L.R. (1980). Hurricane Wind Speeds in the United States. *Journal of the Structural Division*. Vol. 106, Iss. 10, pp.269-280. doi.org/10.1061/JSDEAG.0005541

[5] Chen L., Lia D., Pryor S.C. (2013). Wind speed trends over China: quantifying the magnitude and assessing causality. *Int. J. Climatology*. 33, pp. 2579–2590. DOI: 10.1002/joc.3613

[6] Jiang Y., Luo Y., Zhao Z., Tao S. (2010). Changes in wind speed over China during 1956–2004. *Theoretical and Applied Climatology*. 99, pp. 421–430. DOI: 10.1007/s00704-009-0152-7

[7] Klink K. (1999). Trends in mean monthly maximum and minimum surface wind speeds in the coterminous United States, 1961 to 1990. *Climate Research*. 13, pp.193–205.

[8] Tuller S.E. (2004). Measured wind speed trends on the west coast of Canada. *International Journal of Climatology*. 24, pp. 1359–1374. DOI:10.1002/JOC.1073

[9] Brazdil R., Chroma K., Dobrovolny P., Tolasz R. (2009). Climate fluctuations in the Czech Republic during the period 1961–2005. *International Journal of Climatology*. 29, pp. 223–242. DOI: 10.1002/joc.1718

[10] Pirazzoli P.A., Tomasin A. (2003). Recent near-surface wind changes in the central Mediterranean and Adriatic areas. *International Journal of Climatology*. 23, pp. 963–973. DOI: 10.1002/joc.925

[11] Mc Vicar T.R, Van Niel T.G, Li L.T., Roderick M.L., Rayner D.P., Ricciardulli L., Donohue R.J. (2008). Wind speed climatology and trends for Australia, 1975–2006: Capturing the stilling phenomenon and comparison with near-surface reanalysis output. *Geophysical Research Letters*. 35, L20403. DOI: 10.1029/2008GL035627

[12] Young I.R., Zieger S., Babanin A.V. (2011). Global trends in wind speed and wave height. *Science.* 332, pp. 451–455. DOI: 10.1126/science. 1197219

[13] Wentz F.J., Ricciardulli L., Hilburn K., Mears C. (2007). How much more rain will global warming bring? *Science*. 317, pp. 233–235. DOI:10.1126/science.1140746

[14] Elizbarashvili E.Sh., Varazanashvili O.Sh., Tsereteli N.S., Elizbarashvili M.E. (2013). Hurricane winds on the territory of Georgia. *Russian Meteorology and Hydrology* Vol. 38, Iss. 3, pp. 168–170. DOI: 10.3103/S1068373911060069

[15] Elizbarashvili E.Sh., Elizbarashvili M.E. (2012). Natural meteorological phenomena on the territory of Georgia. Tbilisi. 104 p. (in Russian).

[16] Varazanashvili O., Tsereteli N., Amiranashvili A., Tsereteli E., Elizbarashvili E., Dolidze J., Qaldani L., Saluqvadze M., Adamia Sh., Arevadze N., Gventcadze A. (2012). Vulnerability, Hazards and Multiple Risk Assessment for Georgia. *Natural Hazards*. Vol. 64, pp. 2021-2056. DOI 10.1007/s11069-012-0374-3

[17[Elizbarashvili E.Sh., Varazanashvili O.Sh., Amiranashvili A.G., Fuchs F., Basilashvili Ts.Z. (2023). Statistical Characteristics of Hurricane Winds over Georgia for the Period 1961–2022. *European Geographical Studies*. Vol. 10(1), pp. 8-18, DOI: 10.13187/egs.2023.1.8, https://egs.cherkasgu.press

[18] Varazanashvili O., Gaprindashvili G., Elizbarashvili E., Basilashvili,Ts., Amiranashvili A., Fuchs S. (2023). The First Natural Hazard Event Database for the Republic of Georgia (GeNHs). Catalog, 270 p. http://dspace.gela.org.ge/handle/123456789/10369; DOI: 10.13140/RG.2.2.12474.57286

[19] Varazanashvili O., Gaprindashvili G., Elizbarashvili E., Amiranashvili A., Basilashvili Ts., Fuchs S. (2023). New Parametric Catalogs of Natural Hazard Events for Georgia. *Transactions of Mikheil Nodia Institute of Geophysics*, ISSN 1512-1135, vol. LXXVI, pp.168-177, (in Georgian).

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ASSESSMENT OF THE POTENTIAL FOR USE OF THERMAL WATERS OF THE ABSHERON PENINSULA AS A RENEWABLE ENERGY SOURCE

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Abstract

The use of thermal waters as a source of renewable energy is considered one of the most important issues. Clean energy can improve human health in the long term by minimizing the risk of climate change, while also reducing deaths from air pollution in the short term. The risk of exhausting the oil and gas resources used by the countries of the world for many years is increasing over time. Also, considering that the oil and gas sector is one of the main causes of climate change, it is necessary to move away from this type of fuel. In this case, there is a need to use alternative and renewable energy sources in the world.

Addressing climate change requires a shift away from fuels such as hydrocarbons to renewable energy sources such as solar, wind, hydro and geothermal. Renewable energy sources are carbon-free and produce fewer emissions, making them an important component in reducing greenhouse gas emissions. Overall, the transition to renewable energy sources is critical to addressing climate change and ensuring a sustainable future for the planet. The favorable geographical position and climatic conditions of the Apsheron Peninsula allow the widespread use of ecologically clean alternative (renewable) energy sources. So, in addition to oil and gas deposits, thermal waters (Bilgah, Dubendi-Zira, Buzovna, Gala, Karachukhur, Lokbatan, Mardakan, Nardaran, Pirshagi, Sabunchu, Surakhani, Shikhov, etc.) are widespread here.

The operating reserve of thermal waters with a temperature of 40-90 ^{0}C on the Absheron Peninsula is 20,000 m^3/day. Although the studies conducted in the study areas show that the forecast reserves of thermal waters here are 27125 m^3/day, it is not doubtful that this indicator is many times higher.

The article describes the perspective of using thermal water deposits on the Apsheron peninsula as an alternative energy source. The analysis of funds and printed materials on thermal water deposits of the research area shows that the energy resources collected in this area can be considered as alternative energy and are of great importance for the future economy of the region. Studies show that the water temperature is high in the zones where the tectonic faults spread directly. As mineral water resources from thermal waters, it is also considered useful for the development of balneological, sanatorium-health complexes.

Keywords: climate change, alternative energy source, geological conditions, degree of mineralization, mineral waters

I. İntroduction

Apsheron peninsula, which is the research area, belongs to the southeastern part of the Greater Caucasus in terms of morphostructure. The sediments of the Cretaceous, Paleogene, Neogene and Quaternary periods are involved in the geological structure of Apsheron. The floors of the upper division of the Cretaceous system are involved. The sediments of these floors came to the surface in north-western Apsheron. The Paleogene system is characterized by strata of the Paleocene, Eocene, Oligocene departments. The Paleocene department is characterized by the

Sumgayit formation. This stratum is characterized by lower, middle and upper semi-stratums. The lithological composition consists of clay, marl, and sandstone layers and its thickness is 80-325 meters. The Miocene branch of the Neogene system is characterized by the Upper Maykop formation, Torton, Sarmatian, and Meotis floors. Clay facies prevailed in Upper Maykop. The Pliocene branch of the Neogene system is characterized by the Pont, Productive layer, Agcagil layers [1].

According to the tectonic structure, the Apsheron peninsula is divided into Western, Central anticlines and Eastern Apsheron synclinal areas.

In the research area, winter months are mild, summer months are hot, and autumn and spring months are cool. Atmospheric sediments fall less in these areas, and strong winds prevail. The type of climate belongs to semi-desert, dry, desert climate. Autumn months are warmer than spring. March and the first half of April correspond to winter, the second half of April and May correspond to summer. In these areas, January, the coldest month, has an average monthly temperature of 1.1 ^{0}C, and June, the hottest month, has an average monthly temperature of 27 ^{0}C. The average annual temperature ranges from 14.3 to 14.7 ^{0}C. The absolute minimum air temperature varies from -18 ^{0}C to -21 ^{0}C [2,3].

In the years when the weather is very hot, the highest temperature is 36-39 ^{0}C in the coastal zone of the sea, and 40-43 ^{0}C in the areas far from the sea coast. The minimum value of the average daily absolute air humidity occurs in January, and the highest value occurs in July-August.

The hydrogeological conditions of the Absheron Peninsula are extremely complex. In Western Apsheron, clay sediments of rocks older than the Quaternary period prevailed. Groundwater in these areas is sporadically distributed in Upper Pliocene and Quaternary sediments. The groundwater spread in these sediments is characterized by a high degree of mineralization. These waters are not suitable for drinking or use for economic purposes. Groundwater with sweet and weak mineralization is very rare [4,5].

Pressurized groundwater in pre-Quaternary sediments is commonly associated with oil fields. Most of these waters have a high degree of mineralization. Iodine, bromine, potassium, lithium and other microcomponents are widely distributed in these waters.

Groundwater is almost ubiquitous in Eastern Apsheron. Groundwater in Eastern Apsheron is mainly distributed in Quaternary sediments. The depth of groundwater is from a few cm to 20 m and more. The direction of groundwater flow is from the central parts of the Apsheron peninsula to the shores of the Caspian Sea.

The degree of mineralization and chemical composition of groundwater is very complex. The chemical composition is mainly hydrocarbonate-chlorine. Salty chlorinated waters are widespread mainly in Bina-Hovsan muldas, where oil-waste waters are spread, while in other areas weakly saline and saline waters are widespread. Pressurized waters in Upper Pliocene and Quaternary sediments are fresh and weakly saline. Underground pressurized waters lying in older strata are characterized by high mineralization rates [6,7].

II. Methods

The formation of groundwater in the Apsheron peninsula took place under different conditions. Both natural and man-made factors played a role in the formation of underground water in the Apsheron Peninsula.

Geological-geomorphological conditions are the most important factor in the formation of groundwater on the Apsheron Peninsula. Since clayey rocks of various ages spread in Western Apsheron cover the earth's surface, they did not create conditions for the formation of groundwater in this area. In some areas, as a result of the outcrop of limestone and sandy rocks, it has created conditions for the formation of groundwater here. Geological-geomorphological conditions in Central and Eastern Apsheron are favorable for the formation of groundwater. So, since the lithological composition of these areas includes sand, sandstone, and limestone, groundwater is spread everywhere in these areas. As is known, relief plays a key role in the formation of groundwater. Therefore, in the Apsheron peninsula, groundwater is more common in the low areas of the terrain. Thus, atmospheric sediments, which are already small in these areas, are collected and filtered underground, forming groundwater.

Climatic factors are quantitative and qualitative indicators of groundwater formation. On average, 227 mm of annual precipitation falls in the study area, and evaporation is 947-1344 mm. The total mineralization rate of atmospheric precipitation varies from 56 to 208 mg/l. 184.8 kg/ha of salt fall during the year due to atmospheric precipitation. 12.9% of these salts were NaCl. In addition, water formed from condensation vapors in the air plays an important role in the formation of groundwater.

Artificial factors play an important role in the formation of groundwater on the Apsheron Peninsula. Artificial factors are formed as a result of human activity. These include irrigation of fields, feeding with highly mineralized water extracted from oil wells, losses from the Samur-Apsheron canal, etc. includes. Apart from these, groundwater in the Baku synclinal soil is also fed by losses from water lines. As underground water resources are limited in the Apsheron peninsula, the waters of the Samur-Apsheron canal were widely used for irrigation purposes. Due to the losses from this channel, fresh groundwater is found in areas along the channel suitable for the formation of groundwater. According to calculations, the annual loss from this channel is 5-10%.

The process of formation of hydrogeological conditions on the Apsheron Peninsula is extremely complex. Geomorphological, tectonic, geological-lithological conditions, the activity of the Caspian Sea, and climate indicators are involved to some extent in the process of underground water formation. It is impossible to reconcile with the classifications determined in the process of formation of hydrogeological conditions in Apsheron territory and accepted for general geological structures. Distribution of geological stratigraphic divisions on the Apsheron peninsula, their lithological compositions are heterogeneous on the area, and the geomorphological-tectonic structures of the areas confirm the so-called.

Common patterns for the studied areas include uneven distribution of surface water, lack of rivers, low atmospheric precipitation, and several times more evaporation than atmospheric precipitation.

In the territory of the Apsheron peninsula, clayey facies are abundant in stratigraphic units of different ages. The collector layers involved in the cutting are in the form of laminations, the aquifer rocks contain clay, the layers separating them consist of solid, thick-layered clays, the presence of various salts in the clay rocks, etc. created conditions for the formation of fresh and slightly saline water horizons in these areas. Complex tectonic conditions in the researched areas also confirm what we said. Thus, the alternating anticlines and synclines consisting of rocks of different ages in the area, the presence of numerous tectonic fractures and disturbances have led to the formation of water complexes that are completely unrelated to each other [8,9].

The natural state of hydrogeological conditions in Apsheron Peninsula is uncertain in different areas. So, with the exception of some areas of Western Apsheron, fundamental changes have occurred as a result of human anthropogenic activity in most areas. For many years, in some areas of the Apsheron Peninsula, the groundwater levels have approached the ground surface, their distribution areas have increased, and the process of sweetening of groundwater has begun. In some areas, the opposite was observed. All this had a certain effect on the formation and change of the hydrodynamic and hydrochemical conditions of the areas [11,12].

Apsheron Peninsula is one of the most widespread areas of thermal and mineral waters in the Republic of Azerbaijan (Fig. 1). The operating reserve of thermal waters with a temperature of 40-90 ^{0}C on the Apsheron Peninsula is 20,000 m^3/day.

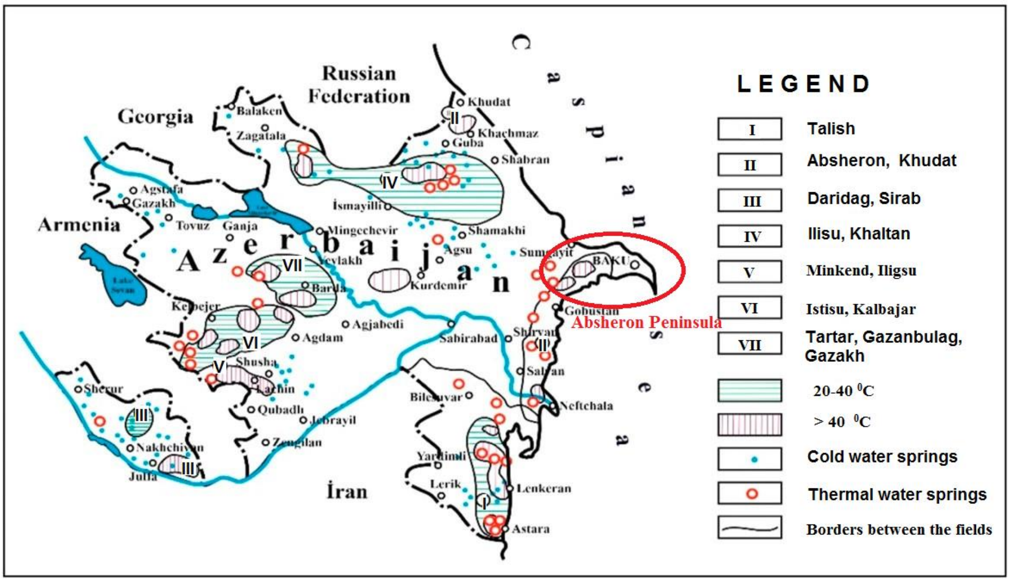

Figure 1: *Mineral-thermal waters map of Azerbaijan*

Formation water temperature. When determining the temperature of the layers, the terms geothermal step and geothermal gradient are used. The temperature of formation water inside the hydrocarbon deposits is taken according to the geothermal gradient of the formation. Taking this into account, it is possible to calculate the temperature of the water inside the layer using the following formula:

$$T = a + H/k$$

T – formation water temperature, °C;
a – average annual temperature on the earth's surface;
H – the depth where the layer is located, m;
k – geothermal gradient, m/°C.

The temperature of the layers was measured for the first time in 1880 on the Apsheron Peninsula (Sabunchu) at a depth of 100-200 m. Later Sh.F. Mehdiyev for the first time determined the geothermal stage by conducting large-scale research works in the Balakhani-Sabunchu-Ramana oil fields. As a result of these studies, it was determined that the geothermal step in shallow oil fields of Apsheron region varies between 21-37 m [11]. Temperatures can reach higher levels in layers in deep deposits. Table 1 provides information on temperature indicators of different depths in the structures of the Apsheron Peninsula.

Table 1: *Temperature indicators of different depths in the structures of the Apsheron Peninsula*

Temperature indicators	Depth, m								
	1000	1500	2000	2500	3000	3500	4000	4500	5000
Average temperature of rocks, ^0C	43	52	60	70	78	86	97	105	112
Geothermal step, m/^0C	33,6	38,8	42,9	44,1	46,4	48,2	48,4	49,1	50,7
Geothermal gradient, ^0C/100 m	2,97	2,57	2,32	2,26	2,15	2,07	2,06	2,03	1,96

The Apsheron Peninsula has a large number of thermal water resources. Thus, among the largest thermal water deposits, Dubendi-Zire, Surakhani, Baku Muldasi, etc. can be shown. Although the studies conducted in the study areas show that the forecast reserves of thermal waters here are 27125 m^3/day, it is not doubtful that this indicator is many times higher (Table 2).

Table 2: *Forecast reserves of thermal waters of Apsheron Peninsula*

Thermal water deposits	Forecasting reserve, m^3/day
Buzovna	4
Gala	1006
Surakhani	2811
Baku Muldasi	3087
Bine-Govsan	1270
Dubandi-Zire	18947
Total	27125

Jurassic and Cretaceous sands and sandstones, flysch clay shales, Paleogene and Neogene clay rocks are mainly involved in the geological structure of the areas where thermal and mineral water deposits are spread.

Mineral-thermal water deposits of Apsheron are concentrated in different stratigraphic horizons. It should be noted that the formation of mineral thermal waters of the Absheron Peninsula is also greatly influenced by mud volcanoes and various types of reservoir waters of oil fields. About 80% of the 20 deposits registered here are hydrogen-sulfide (H_2S), and about 20% are methane (CH_4)-containing gases.

While chlorinated-sodium waters with a high content of calcium and magnesium form a specific group on the Apsheron Peninsula (Surakhani, Amirjan, etc.), mineral waters in the Shikhov region, located in the southwest of Baku, are characterized by a chlorinated-hydrocarbonate-sodium type composition.

The Apsheron peninsula is rich in mineral and thermal waters, important for treatment. Hydrogen sulphide mineral water wells and sources are located near Surakhani, Amirjan, Gala, Binagadi settlements, in Pirallahi, and therapeutic mud volcanoes - Lake Boyukshor, Masazir, Murdalabi, Fatmayi, Ramana, etc. spread in the areas. Here, three processes – oiliness, mud volcanism and mineral water formation processes occur in interaction.

Mineral-thermal waters of the Apsheron Peninsula are found in different stratigraphic horizons - in the sediments of the Pont floor characterized by sand and limestone-sandstone intermediate clays, in the sandstone sediments of the productive layer with a large thickness. Hydro-geothermal indicators calculated for different depths of the aquifer complex of the Absheron Peninsula are given in Table 3.

Table 3: *Hydrogeothermal properties of the Apsheron Peninsula aquifer complex (Productive layer)*

<table>
<tr><th>The field</th><th>Well №</th><th>Hydrogeological survey depth, m</th><th>The temperature of the water at the wellhead, ⁰C</th><th>Degree of mineralization of water, g/l</th><th>The main microcomponents, mg/l</th><th>Gas content of water</th></tr>
<tr><td rowspan="2">Buzovna</td><td>3^2</td><td>1953-1390</td><td>42</td><td>116</td><td rowspan="4">J-24 Br-198</td><td rowspan="11">CH_4</td></tr>
<tr><td>4^2</td><td>1464-1389</td><td>46</td><td>114</td></tr>
<tr><td rowspan="7">Gala</td><td rowspan="2">62</td><td>1705-1582</td><td>52</td><td rowspan="3">134</td></tr>
<tr><td>1566-1410</td><td>45</td></tr>
<tr><td>1162</td><td>1612-1574</td><td>40</td><td>J-30</td></tr>
<tr><td rowspan="2">1028</td><td>1516-1501</td><td>38</td><td rowspan="2">144</td><td>Br-214</td></tr>
<tr><td>1634-1614</td><td>42</td><td rowspan="3">J-28</td></tr>
<tr><td>1323</td><td>1714-1701</td><td>40</td><td rowspan="2">156</td></tr>
<tr><td rowspan="2">Surakhani</td><td>1^2</td><td>2218-1967</td><td>42</td></tr>
<tr><td>14</td><td>2172-2024</td><td>48</td><td>146</td><td>J-28 Br-</td></tr>
</table>

					192	
	2r	1668-1487	50		Br-142	
	1222	2172-2024	48	136		
		1712-1710	43			
Baku Muldasi	1304	1853-1720	47		J-32 Br-214	
	1415	2122-1996	46	118		
Zire	36	2828-2790	38	128	J-28 Br-199	
		2724-2636	57			
Bine-Govsan	628	1318-1197	53		J-29 Br-320	
		1145-1063	37			
	849	1300-1213	39			
	1046	1196-1110	39			
	1214	1352-1247	43	138	J-26,8 Br-296	
	1416	2122-1996	42			
Duvandi-Zire	925	1063-949	36			
	707	1044-982	36			
	808	1383-1291	42	142	J-26 Br-216	
	36	2828-2740	48			
	114	843-799	36			
	707	968-876	40			
	628	1004-913	42			
	800	1243-1144	45	124	J-28 Br-23,4	
	926	831-800	39			
	1106	1194-1103	38	166	J-24,8	
	1527	848-816	39	138	J-26	
	1032	956-892	41		Br-214	
	1101	987-928	40			
	1227	932-873	350			
	1070	998-960	36			
	932	997-936	37			
	1323	963-899	36			
	953	921-790	44			
	628	709-680	37	124	J-28,8 Br-204	CH_4
	800	1049-876	42			
	904	809-757	37			
	925	762-595	42			
	1527	770-623	36			
	1146	843-663	36			
	948	480-470	35			
	649	915-728	35			
	211	1247-1048	36	114	J-32 Br-199	
	1304	1384-1118	52			
	1046	882-705	48			
	925	1063-949	48			
	114	843-799	50	128	J-33,4 Br-214	
	707	968-876	38			
	628	1004-913	36			
	800	1243-1144	40			
	926	831-800	44			
	1106	1194-1103	45			
	1527	848-816	42			
	1032	956-892	38			
	1101	987-928	39			
	1227	932-873	41			
	1070	998-960	40	136	J-26	

	932	997-936	37		Br-214	
	1323	963-899	36			
	953	921-790	44			
	628	709-680	37			
	800	1049-876	44			
	904	809-757	36			
	925	762-595	35			
	1527	770-623	35			
	1146	843-663	36	146	J-29,8 Br-190	
	948	480-470	44			
	649	915-728	35			
	211	1247-1048	40			
	1304	1384-1118	40			
	1046	882-705	48	142	J-28	
	877	940-804	38		Br-198	
	130	1003-785	42			
	152	1030-804	38			
	144	1258-997	42			
	1501	1715-1480	47	136	J-29	
	1518	1693-1470	50		B-215	
	1408	1623-1400	47			
	41	1580-1353	36			
	36	2556-2243	48			
	628	605-572	39			
	841	550-492	36			
	800	792-709	38			
	904	710-664	38	136	B-215	
	1106	792-709	36			
	1515	1266-895	36	144	J-28 Br-214	
	1822	1827-1402	45			
Duvanni	50	926-880	54			
	55	2933-2915	56	35		CH_4
	4	1788-1684	76	36	J-28,9 Br-48	
	15	1798-1774	58	34		
	58	2448-2413	36	33		
Kenizdag	27	3200-3100	66	56	J-24 Br-98	
	56	1848-1814	48	44		
	38	1863-1806	49	44		
	26	1824-1823	47	36	Br-42	
Garadag	14	1346-1344	44			
	53	1695-1603	45			

As a result of the conducted research, the highest temperature of thermal water in the Apsheron peninsula was recorded in Duvanni area (76 ^{0}C), Surakhani area (52 ^{0}C), and Kenizdag area (56 ^{0}C) (Table 4). There is no doubt that the temperature is even higher as you go deeper.

III. Results

It is of great importance to comprehensively study underground thermal water, which is an ecologically clean source of energy, along with other types of fuel (mainly oil, gas) and provide it to the people.

The formation of hydro-geothermal conditions on the Apsheron peninsula reflects the geological-lithological, geomorphological, tectonic conditions of the area. The formation of hydrochemical conditions was influenced by waste water from oil fields and various household wastes. Along with these factors, the rocks of the aeration zone are also important in the formation of the chemical composition.

On the Apsheron peninsula, thermal and mineral waters are distributed in Khazar-Khvalin, Baku, Apsheron, and Productive layer sediments. There is a little hydraulic connection in the sediments of the Caspian-Khvalin. The pressurized waters lying in the Baku-Productive layer sediments have no hydraulic connection. Hydrochemical conditions were formed separately.

Table 4: *Hydro-geothermal properties of thermal waters on the Apsheron Peninsula*

The field	Calculated wells	Geological age and depth of the aqueous complex	Degree of mineralization of water, g/l	water temperature, ⁰C	Main components, mg/l
Buzovna	32, 4	N_2^1b 1950-1390	116	42	J-24 Br-198
Gala	62, 1028, 1162, 1323	N_2^1b 1714-1410	134	38-52	J-28-30 Br-214
Surakhani	12, 22, 14, 11, 12	N_2^1b 2218-1487	132-146	42-50	J-28 Br-192
Baku Muldası	1304, 1415	N_2^1b 2122-1720	118	46-47	J-32 Br-214
Bine-Govsan	628, 849, 1046, 1214, 6, 1304, 1416	N_2^1b 2122-1063	134-138	37-53	J-29 Br-320
Dubendi-Zire	707, 808, 628, 926, 1527, 1227, 932, 152, 144, 1822, 1518, 628, 926, 1046	N_2^1b 2828-595	114-144	35-50	J-26-32 Br-198-216
Garadag	14, 26, 38, 53, 56	N_2^1b 1863-1344	36-44	45-48	J-22 Br-92
Duvanni	22, 24, 40, 45, 47, 50, 51, 58	N_2^1b 2933-880	33-44	36-76	J-16-28,9 Br-209
Kenizdag	27	N_2^1b 3200-3100	34	56	J-24 Br-98

The operating reserve of thermal waters with a temperature of 40-90 ⁰C on the Apsheron Peninsula is 20,000 m^3/day. Although the studies conducted in the study areas show that the forecast reserves of thermal waters here are 27125 m^3/day, it is not doubtful that this indicator is many times higher.

The thermal and mineral waters of the Apsheron Peninsula contain various gases that have a positive effect on the human body, specific chemical components and pharmacological ingredients, and useful biologically active elements, so they can be used for the treatment of many diseases. Although mineral-thermal water deposits containing iodine, bromine and other chemicals with great healing power are currently not used enough, their widespread use in the field of balneology and spa treatment in the near future is currently considered promising and necessary.

References

[1] Geology of Azerbaijan. 2008. Vol. VIII. Hydrogeology. Baku, Nafta-Press. 380 p.

[2] Israfilov, Yu.H, Israfilov, R.H., Guliyev, H.H., Efendiyev, G.M. 2016. Risk assessment of the water resources losses of the Azerbaijan republic due to climate changes. // News of ANAS,

Earth Sciences, № 3-4. 37-47.

[3] Taghiyev A.Sh. Climate change and water resources management. İnternational Scientific Cenference on Sustainable Development. Baku, 24-25 november, 2017. 55-61.

[4] Tagiev, I. I., Tagiev, A. Sh. (2016). Current state and general objectives of the use of mineral and thermal waters in Azerbaijan. // Eurasian Scientific Association, 2(10), 177-178. (in Russian)

[5] Taghiyev A.Sh. Hydrogeological conditions of the Ganykh-Ayrichay basin and prospects for the use of groundwater. / Proceedings of the conference, PART II, pp.201-203.

[6] Tagiyev, I.I., Ismailova, M.M., Karimov, V.M., Sharifov, J.J. (2022). Prospects for using thermal water in Kalbajar district and other regions (Azerbaijan) as an alternative energy. // Reliability: Theory & Applications, 17(SI 3 (66)), 76-81. DOI: https://doi.org/10.24412/1932-2321-2022-366-76-81

[7] Tagiev I.I. 2001. Status and problems of protection of the environment and nature use in the Republic of Azerbaijan, Ministry of Science and Technology of the USSR, Moscow.

[8] Ismailova, M.M. (2006). Environmental problems associated with utilization of mineral waters in urbanized areas of Azerbaijan. In: Tellam, J.H., Rivett, M.O., Israfilov, R.G., Herringshaw, L.G. (eds) Urban Groundwater Management and Sustainability. NATO Science Series, vol 74. Springer, Dordrecht. https://doi.org/10.1007/1-4020-5175-1_23

[9] Babayev, A.M., 2000, The Mineral Waters of Mountain-Folded Zones of Azerbaijan, unpublished monograph (in Azerbaijani)

[10] Tagiyev, I.I., et al. 2001, Resources of Thermal Mineral Waters of Azerbaijan, unpublished monograph (in Russian)

[11] Mehdiev Sh.F. On the hydrochemical zoning of formation waters in oil and gas bearing areas of the South Caspian depression. “Scientific Notes” ATU, No. 1, 1967 (in Russian)

[12] Mehdiev Sh.F., Akhundov A.R., Voroshilov E.A. The influence of artificial flooding on the hydrochemistry of an oil reservoir. Baku, Maarif Publishing House (in Russian)

ENGINEERING AND ECOLOGICAL METHODS FOR PROTECTION AGAINST CATASTROPHIC NATURAL PROCESSES CAUSED BY GLOBAL CLIMATE CHANGE

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Abstract

The paper discusses issues related to global climate change. It's identified that climate change is associated with global warming, caused by a sharp increase in the concentration of greenhouse gases in the atmosphere. Climate warming is accompanied by intense snowmelt and water evaporation. The cloud cover that accumulates in the atmosphere contains a tremendous amount of water, which falls as prolonged heavy rainfall, leading to catastrophic floods accompanied by mudflows, landslides, and erosion processes. The authors developed simple, reliable, and relatively inexpensive protective structures used during floods, mudflows, and landslides. Additionally, new designs for coastal protection were developed. The construction of these structures utilizes waste materials such as recycled tires and reinforced concrete sleepers.

Keywords: engineering-ecological, method, protection, disaster, global, climate, atmosphere, water, waste, warming, coastal protection, flood, mudflow

I. Introduction

Global climate change has become a major scientific and political issue only in recent decades. Politicians around the world often avoid analyzing survey results that indicate growing public concern. Scientific journals are overloaded with publications on this topic, analyses, and commentaries.

In May 1990, climatologists from around the world, in a report for the Intergovernmental Panel on Climate Change (IPCC) established in 1988 by the UN General Assembly to draw the attention of world leaders to the serious problems of global climate change, stated it very clearly. "We are confident," said more than 300 scientists from over twenty countries, "that emissions into the atmosphere caused by human activity are leading to a significant increase in the concentration of greenhouse gases in the atmosphere. This increase in carbon dioxide concentration enhances the greenhouse effect, resulting in additional warming of the Earth's surface.

Even 25 years ago, scientists had predicted, based on climate computer models, an average temperature increase of about 1°C over thirty years if the rate of greenhouse gas emissions in the atmosphere remained at the levels existing at the end of the last century. An increase of one degree may not seem significant, but this is an average across the entire globe, where temperatures have never risen this quickly based on paleoclimatic data. In less than half a century—if current trends continue - we will face temperatures unprecedented since humanity has existed on the planet.

At that time, the scientists and IPCC experts stated that their estimates were likely to be somewhat understated: the number of uncertainties inevitably present in climate change calculations is immense; and warming is likely to be exacerbated by a series of natural processes.

If the current trend continues, by 2030-2050, the atmosphere will contain a quantity of greenhouse gases that will have a heat-absorbing capacity twice that of the carbon dioxide present in the atmosphere in the mid-twentieth century.

It should be expected that global warming will continue indefinitely unless actively mitigated by the efforts of the human community.

No one can predict with certainty what changes will occur in ocean currents or how the climate will change in any specific location on Earth with the disappearance of Arctic ice.

II. Main Causes and Forecast of Further Climate Warming on the Planet

The reasons for the accumulation of greenhouse gases are not as well defined as is often claimed. The primary cause is industry, which relies on fossil fuels as an energy source. Deforestation is also responsible, as it can lead to a significant increase in carbon dioxide concentration in the atmosphere if remaining forests are systematically destroyed. Additionally, there has been a sharp increase in forest fires, often caused by criminal elements for personal profit. A third source of carbon dioxide in the atmosphere is the decomposition of organic matter in the soil due to warming.

Warming on Earth will occur through physical, chemical, and biological processes at both local and global scales. The central question is whether the quantitative effects of these changes will lead to rapid or slow warming. Negative feedback will reduce the rate of warming if it starts to occur more intensely, while positive feedback will amplify it. Such feedbacks can involve changes in cloud cover or snow cover, as they affect the Earth's surface albedo and, consequently, the amount of energy absorbed. An increase in snow or cloud cover will raise the albedo, reduce the amount of solar energy retained, and decrease the warming process, creating negative feedback. A decrease in the Earth's surface albedo works in the opposite direction, creating positive feedback. These changes were taken into account by climatologists when they conducted quantitative assessments of warming.

Cities, hydroelectric stations, irrigation systems, navigation, changes in waterways, transport, marine life, fishing, and oceanic and coastal water circulation all depend on the freshwater flows that are formed.

Forecasts of changes in surface runoff are unreliable, as are other potential consequences of warming on Earth. Within a narrow range of 1°C to 2°C of overall warming, the general picture seems clear. Beyond this range, the consequences of warming become uncertain. Meanwhile, long-term costly projects require further forecasting of precipitation, the results of which become dubious.

According to forecasts from the second working group of the IPCC, large-scale flooding may occur, for example, in many rivers of Western Europe and the northern rivers of Russia.

IPCC specialists, based on climate models, concluded that if measures are not taken to halt greenhouse gas emissions, sea levels could rise by 10-30 cm by 2030 and by 30-100 cm by the end of the current century. This increase will result from the expansion of seawater due to warming and the melting of glaciers. It is assumed that the effects of melting Greenland and Antarctic ice sheets will be minimal during this century. Other scientists believe that the melting of Antarctic ice will lead to a sea-level rise of more than 5 meters. These analyses are only hypothetical, and local effects may be more significant depending on whether the continental plates in a given area are rising or sinking.

III. Intensification of Catastrophic Processes Due to Global Climate Warming

Since the late 20th century, the frequency of floods has increased, as have the damages caused by them. Currently, the area prone to flooding exceeds 3 million km^2, home to 1 billion people.

Thousands die from floods each year, with annual losses amounting to tens of billions of US dollars. Floods lead to diseases, famine, and numerous ecological problems.

Global climate warming is accompanied by intense snowmelt and water evaporation. The accumulated cloud cover in the atmosphere contains vast amounts of water, which falls as prolonged heavy rainfall, creating catastrophic floods along with mudflows, landslides, and erosion processes.

Due to sharp warming, glacial mudflows caused by intensified glacier melting have become more frequent. These glacial mudflows result from the bursting of subglacial lakes and reservoirs, and they almost always have catastrophic consequences

There is a need to develop economically and ecologically efficient engineering measures to prevent or at least significantly reduce the damage from the increasing catastrophic events caused by global climate changes.

The intensity of glacier melting in mountainous regions, driven by global warming, has led to the emergence of numerous glacial lakes. Recent studies have identified over 2,300 glacial lakes in Nepal and Bhutan, of which 20 have been classified as high-risk for bursting [1].

Global warming has sharply increased the incidence of major floods, inundations, and mudflow processes. These processes intensify erosion, the destruction of riverbanks, lakes, and seas, as well as landslide phenomena.

The aforementioned issues highlight the need for effective engineering methods for flood protection, bank erosion control, mudflows, landslides, and other catastrophic and emergency events. There is significant interest in using recycled waste materials in the construction of protective structures.

IV. On the Use of Recycled Tires in the Construction of Protective Structures Against Catastrophic Natural Phenomena

The most common type of consumer waste is recycled automobile and tractor tires. Globally, half of all synthetic and natural rubber produced (over 15 million tons annually) is used for tire manufacturing, and ultimately all produced tires become waste after a certain period. The lifespan of automobile and tractor tires is shorter than that of most rubber products [2].

The authors have developed simple and relatively inexpensive protective structures using recycled steel-belted tires for use during floods. A filtering dam, constructed on the tributaries of major rivers, can create a temporary reservoir in flood zones and is laid across the tributary channel in the form of a trapezoidal prism. The dam is made of cylindrical gabions filled with soil. The shells of the cylindrical gabions are made from interconnected recycled steel-belted tires of the same type. The gabions are laid in layers along the tributary channel, alternating layers with longitudinal and transverse orientations relative to the flow. Longitudinal rows of gabions are spaced apart. This construction allows for the building of protective dams in riverbeds of any configuration and in any geological conditions with minimal material costs.

The authors have also developed a flood protection dam to safeguard populated areas, agricultural, and industrial facilities from flooding. This dam includes interconnected cells with vertical flexible walls made from outer and inner shells. Recycled steel-belted tires of the same type are used as shells, connected by various fastening elements (metal or polymer). The cavity formed by the tires is filled with ballast material (local soil). The shells are reinforced with cross-members made of flexible impermeable material. The upper cross-members are connected by tensioning to anchors, designed as screw piles or braces. The feasibility of using this flood protection dam is due to the increased efficiency of a lightweight structure that can be installed and reinstalled multiple times at various locations with minimal labor costs.

Numerous designs of mudflow protection structures using recycled tires have been developed. The authors analyzed 18 designs from engineers in Azerbaijan, Kazakhstan, Russia, and Georgia that utilize recycled tires [3]. These designs can be divided into four groups: 1) mudflow protection structures where recycled tires are used as damping and cushioning elements;

2) structures primarily consisting of recycled tires connected in blocks with flexible cables and fasteners; 3) structures where recycled tires are variously threaded onto stakes driven into the riverbed or anchored to a foundation; 4) complex mudflow protection structures where recycled tires work in conjunction with horizontal and vertical beams, as well as anchored flexible connections, functioning as permeable, deformable structures. Research shows that the simplest and most reliable designs are those in the third group.

In recent decades, engineers have noted the potential for using recycled tires as structural components for bank stabilization retaining walls [4]. Retaining walls made from recycled tires are threaded onto piles and secured to the foundation with tensioned flexible cables. Some designs use both piles and tensioned flexible cables. The cavities of the tires may be empty or filled with soil or dry ballast.

The authors have developed a device to protect riverbanks from erosion. The bank stabilization structure includes piles placed at equal distances. Recycled tires are threaded onto the piles, with adjacent rows laid in staggered patterns. The cross-section of the piles should be elliptical, matching the cross-section of the through hole formed when laying tires with staggered seams in adjacent rows. After driving the piles, the tires are threaded in rows; for example, the first row is threaded onto the piles such that each tire is threaded onto each pair of piles starting from the second pile, and so on, depending on the design. This results in the staggered placement of tires.

Heavy rainfall, intensified by global climate warming, leads to noticeable erosion processes. There are many design innovations for anti-erosion structures made from recycled tires. The authors analyzed 109 patents for inventions from the former USSR, the Russian Federation, and the Republic of Azerbaijan. These structural solutions can be classified into 5 classes [5]. The first class includes structures made from whole recycled tires [6]. The second class consists of anti-erosion structures made from whole and cut recycled tires [7]. The third class includes anti-erosion structures made from recycled tires cut in various ways. The fourth class consists of anti-erosion structures assembled from blocks of recycled tires. The fifth class includes complex anti-erosion structures where recycled tires are used not only as protective coverings but also as anchoring and reinforcing elements; where elements made from recycled tires are combined with reinforced concrete and other structural elements; and where recycled tires are connected horizontally and vertically with metal cables and used as flexible dams placed across water flows.

V. On the Use of Recycled Railway Concrete Sleepers in the Construction of Protective Structures Against Catastrophic Natural Phenomena

Decommissioned railway concrete sleepers accumulate in large quantities and are often sent for disposal. Currently, there are three methods for recycling concrete sleepers:

– storing or burying them at designated sites and landfills;

– using concrete sleepers in the construction of lightweight building foundations;

– processing concrete sleepers in crushing plants to obtain artificial gravel and scrap metal in the form of broken reinforcement.

Using whole recycled concrete sleepers for constructing protective structures is a highly economical and environmentally friendly approach, as it eliminates the need for costly and energy-intensive processing. Their residual strength is sufficient to effectively counteract the negative forces created by catastrophic and emergency natural phenomena and processes. Numerous designs have been developed by engineer Yu.P. Kozhin, et al. Notable examples include structures for avalanche and mudflow protection [8], retaining walls with various configurations utilizing recycled concrete sleepers [9, 10, 11], bank stabilization structures made from interconnected recycled sleepers [12], and modular frames containing protective plates fixed to counterforts [13], which are shaped like triangular frames. Additionally, there is a design for river regulation aimed at protecting riverbanks from erosion [14].

The authors have developed bank stabilization structures that incorporate recycled concrete sleepers into the shelves of channel (or I-beam) piles. Standard metal channel or I-beam profiles are used as piles. Various mudflow protection structures have also been developed, where horizontal beams in the form of recycled concrete sleepers are inserted onto different notched posts anchored to the riverbed.

The unique mechanical and geometric properties of recycled steel-belted tires and concrete sleepers present engineers with opportunities to create new cost-effective protective structures against various catastrophic phenomena caused by global climate change on Earth.

VI. Conclusions

1. Global warming is accompanied by intense snowmelt and evaporation. The cloud cover accumulated in the atmosphere contains a vast amount of water, which falls as prolonged heavy rainfall, resulting in catastrophic floods, mudslides, landslides, and erosion processes.
2. The most common type of consumer waste consists of recycled automobile and tractor tires. The unique geometric and mechanical properties of steel-belted recycled tires allow for their effective use in the design of protective structures. The authors have developed relatively simple and cost-effective protective structures made from recycled steel-belted tires for use during floods.
3. The authors analyzed 18 designs of mudslide protection structures developed by engineers from Azerbaijan, Kazakhstan, Russia, and Georgia that utilize recycled tires.
4. In recent decades, engineers focused on the potential use of recycled tires as structural components in bank stabilization retaining walls. The authors developed a device for protecting banks from erosion. The bank stabilization structure includes piles placed at equal intervals, onto which recycled tires are threaded, with adjacent rows laid in staggered seams.
5. The authors analyzed over a hundred patents for anti-erosion structures made from recycled tires. These design solutions can be divided into five classes.
6. Decommissioned railway concrete sleepers accumulate in large quantities and are often sent for disposal. The use of whole recycled concrete sleepers for constructing protective structures is highly economical and environmentally friendly, as their residual strength is sufficient to effectively counteract the negative forces created by catastrophic and emergency natural phenomena and processes.
7. The authors analyzed known designs for avalanche and mudflow protection, retaining walls with various configurations using recycled concrete sleepers, and bank stabilization structures made from interconnected recycled sleepers and modular frames securely fixed to counterforts. There is also a design for river regulation intended to protect riverbanks from erosion.
8. The authors developed bank stabilization structures that incorporate recycled concrete sleepers into the shelves of channel (or I-beam) piles. Various mudslide protection structures have also been designed, where horizontal beams in the form of recycled concrete sleepers are inserted onto different notched posts anchored to the riverbed.

References

[1] Global Warming Triggers Glacial Lakes Flood Theat. 2002.

[2] Gabibov, F.G., Mammadli, R.A., Ojagov, G.O., Bayat, H.R., Habibova, L.F. (2010). Scientific, technical and economic foundations of the use of recycled tires in solving certain problems of engineering geoecology. Proceedings of the jubilee conference dedicated to the 80th anniversary of the Department of Soil Mechanics, Foundations and Foundations, the 110th anniversary of the birth of N.A.Tsytovich, the 100th anniversary of the birth of S.S.Vyalov. Moscow, MGSU, pp. 151-156.

[3] Gabibov, F.G., Ojagov, G.O., Habibova, L.F., Safarova, N.A., Mammadli, R.A. (2013). Self-protective structures from recycled automobile tires. "Georisk", No. 4, pp. 30-35.

[4] Gabibov, F.G., Khalafov, N.M., Habibova, L.F. (2015). Structures of retaining walls with elements from recycled metal-cord tires. "Construction and Architecture of Azerbaijan", No. 4, Baku,, pp. 27-38.

[5] Gabibov, F.G. (2018). Classification of anti-erosion structures based on recycled tires. "Ecology and Development of Society", No. 2(25), St. Petersburg, pp. 21-24.

[6] Gabibov, F.G. (2018). Classification of anti-erosion structures constructed using recycled tires. Bulletin of the International Academy of Sciences of Ecology and Life Safety, Volume 23, No. 3, St. Petersburg, pp. 29-32.

[7] Gabibov, F.G., Danyalov, Sh.D., Habibova, L.F. (2023). Classification of protective coatings of slopes of hydraulic structures made in a complex of whole and cut old tires. Bulletin of the International Academy of Sciences of Ecology and Life Safety, Volume 28, No. 3, St. Petersburg, pp. 159-163.

[8] Kozhin, Yu.P., Azarsky, A.I. Retaining wall Kozhin, Yu.P., Azarsky, A.I. (1993) USSR copyright certificate for invention No.1808043.

[9] Kozhin, Yu.P., Azarsky, A.I., Sokolov, V.V. (1990). Retaining wall. USSR Copyright certificate for invention No. 1555427.

[10] Kozhin, Yu.P. (1992). Retaining wall Kozhina Yu.P. USSR Copyright certificate for invention No. 1715992.

[11] Kozhin, Yu.P. (1995). Anti-landslide structure Kozhina Yu.P. Patent of the Russian Federation for invention No. 2034957.

[12] Kozhin, Yu.P., Mogilevsky, E.A., Azarsky, A.I., Sokolov, V.V. (1990). Device for fixing slopes of reservoirs. USSR copyright certificate for invention No. 1573076.

[13] Kozhin, Yu.P., Kadukin, V.I. (1992). Coastal protection structure. USSR Copyright certificate for invention No. 1772298.

[14] Kozhin, Yu.P. (1992). Semi-dam for river regulation. USSR Copyright Certificate for invention No. 1708986.

THE NECESSITY OF MULTI-PURPOSE MONITORING OF THE REPUBLIC OF AZERBAIJAN'S WATER RESOURCES

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Abstract

The Republic of Azerbaijan's climate is changing, and the signs of shortcomings with the water resources are everywhere, and predominantly associated problems are getting increasingly severe. In turn, the synoptic weather systems leading to decreasing low precipitation levels due to climate change have aggravated the country's water scarcity in recent years, as all other environmental relational parts frequencies are meaningfully changing. Most frequently, the reduction in rainfalls persistently affects agriculture, infrastructure, the environment, and ecosystems in many ways. We do not yet know where, when, and how much water sources are lost from water reserves, for instance, the Caspian Sea storage.

Consequently, the country's vulnerable water resources must be carefully monitored in different ways and scales precisely and wisely. It seems that according to the possibilities of technologies, software, and expert forces, it is now time to take executive measures to solve this critical problem of the country comprehensively. Accordingly, multi-platform and multi-purpose monitoring systems are almost immediately required to construct a relevant applied-based nationwide wide-ranging water resources database. Major watersheds must be watchfully experimented with by employing advanced integrated and fused real, near real-time, and intelligent smart monitoring systems directed to advanced machine-deep-learning approaches.

Keywords: multi-purpose monitoring, real monitoring, near-real monitoring, smart monitoring, water resources

I. Introduction

The water crisis in the Republic of Azerbaijan is entering a new pattern where its impacts are becoming visible in the daily lives of millions of people (Safarov et al., 2018). Several strong signs are showing significant changes in the process of reducing water resources, particularly in the semiarid and drought-prone parts of the country with increasing vulnerability to this natural hazard (Safarov et al., 2017). Water scarcity and drought issues are among the biggest challenges facing the country. This phenomenon can be due to the appearance of changes in the frequency of atmospheric systems and less precipitated clouds associated with the precipitation potential in these systems (Rasouli, 2011). The water source of the country is related to the arrival of moist air masses from outside the country, especially from the west, northwest, and occasionally from the southwest (Mammadov et al., 2009; Bayramov, 2020). Clearly, during the past decades, the frequency of occurrence of these systems has decreased, and sometimes, with destructive floods, whenever large amounts of water resources are out of reach of the country. In addition, the river network in Azerbaijan is unevenly distributed over the territory, and, drinking water in Azerbaijan is mainly sourced from such distributed rivers.

The bad news is that the Caspian Sea- the largest landlocked water body worldwide- has been facing a decrease in water and its consequences such as changes in the coastal environment and ecology of the coasts (Rasouli and Imrani, 2023). Various reports indicate that the water level of the Caspian Sea has decreased by 2 meters in recent years and could drop by 9 to 18 meters by the end of the 21st century *(*Lahijani et al., 2023*)*. If we count the effects of climate change and the current water consumption policies to this category, we will witness exponential crises in the country's water resources (Safarov et al., 2020). Water scarcity in Azerbaijan could lead to a complex social-ecological challenge, and various factors contribute to it differently, including agriculture, urbanization, climate change, population growth, land-use change, and an ineffective water management system (Chen et al., 2017).

In such a situation, policymakers and experts in the fields related to water resources science should take fundamental steps for the country's vulnerable water consumption. One of the most important is obtaining accurate information through multipurpose and multimeter monitoring methods. Nowadays, we can refer to real-time, near real-time, and smart-monitoring systems as intelligent measurements of related parameters (Rasouli and Mammadov, 2021). After a detailed knowledge of the quantitative and qualitative characteristics of the water resources, it is possible to witness positive consequences with optimal water consumption policies. Hence, with the aim of systematic access to comprehensive and accurate information and in the category of resources in crisis of the country, it is possible to use modern methods of remote sensing, especially of the types of receiving all data related to water resources at the time having the following:

- ✓ Observation and detection of water data types from natural and non-natural environments of the country,
- ✓ Operating special tools with high technology in the accurate detection of water elements,
- ✓ Recognition of water resources at different temporal and spatial scales,
- ✓ An accurate understanding of water surface changes in the country water basin contexts,

II. Result and Discussion

Real-Time Monitoring Systems (RTMS).

One of the main aims of remote sensing is the observation and detection of dissimilar data types from physical and non-physical environments of the water surfaces (Sharma et al., 2021). Based on the RTMS, special tools with superior technology in water resource elements are vital for our country's current water crises. Each RTMS provides new raw data or higher levels for other information-producing systems. Some scientists believe that any RTMS can be considered the driver of Spatial Information Science (SIS) with the goal of sustainable water resources management policy (Rasouli et al., 2021). An RTMS acts to detect the physical characteristics of an area covered by water by measuring its reflected and emitted radiation at a distance (typically from active or non-active sensors). Since Apollo 17 captured the famous Blue Marble photograph of the earth in 1972, we have had a good idea of "what our planet looks like." Such shots show satellite imagery, real-time cloud cover, precipitation, and many other water-related layers worldwide. Meanwell, the modern remote sensing technique is widely used to delineate surface water bodies, estimate meteorological variables like precipitation, calculate hydrological state variables like soil moisture and land surface characteristics, and estimate fluxes such as evapotranspiration.

In the same way, it is vital to accurately measure the critical conditions of our country's water resources. An example of this type of real-time remote sensing is the NASA meteorology satellite systems. Such systems can monitor not only the atmospheric conditions (for example, cloud characters) covering the country for every 30-minute interval but also check the conditions of the land surface and water resources, for instance, the Caspian Sea changes. Among other real-time sensors of the active type, we can mention the meteorological Doppler Radar, which measures different rainfall parameters as it can estimate the intensity and accumulation of daily rainfall with suitable spatial and diurnal resolutions (Rasouli et al., 2014). In the same way, surface precipitation rate, daily rainfall resolution, and intensity can be produced in 15 minutes. To watch the country's water surface context and changes accurately real-time remote sensing detection is needed (Rasouli et al., 2010). Compared with the traditional methods, the proposed framework is an adaptable remote sensing detection framework for most of the country's water surface observation. Despite the existence of real-time measurement devices, we have the possibility and ability to use the existing real-time systems in a way to solve the water crisis in the declaration.

Near Real-Time Water Sources Monitoring (NRTWSM).

An NRTWSM system could be defined as the observation of water bodies such as lakes, oceans, and rivers from a distance to describe their surface, color, state of ecosystem health, and productivity timely. This kind of remote sensing technology assists in monitoring water quality by detecting parameters such as turbidity, chlorophyll concentration, and temperature. The sensors can identify pollutants and harmful algal blooms in water bodies, helping authorities take timely actions to safeguard water quality and public health, evolving rapidly. Many sensors, for example, most Sentinel (1-6) satellites incorporating applied algorithms, are making significant advancements in water resources applications (EU's Copernicus Programme, 2021). Thus, a broad range of applications of remote sensing in water resources can be summarized under three classes water resources mapping, estimation of the hydro-meteorological state variables and fluxes, and applications of the remote sensing data in water resources management. Under each section, details of the sources of the country's remote sensing data products that could addressed, if any, are also included.

For many years, NRTWSM has been increasingly used as a complementary source of information in water networks and, in many cases, is the only feasible source. Satellite-based sensors are making direct and indirect measurements of nearly all components of the hydrological cycle (Han et al., 2017). These include precipitation, evaporation, lake and river levels, surface water, soil moisture, snow, total water storage, and subsurface water. Accordingly, these sensors currently provide critical information in monitoring the evolution of hazards and their impacts. Although some of these satellite remote sensing products are in their initial stages, there are some advantages and positive signs in their use for NRTWSM. Large spatial coverage and high temporal resolution (sub-daily for geostationary and equatorial orbiting satellites) means they can provide near-nationwide information in near real-time (Liu et al., 2020). These data can be processed and transformed the raw data collected by the sensors into meaningful information for water resources researchers and managers. It may include pre-processing, which involves correcting errors, distortions, and noise caused by the sensors, the atmosphere, and the terrain. NRTWSM allows scientists to record the quantity and qualities of water bodies around the country, which provides information on the presence and abundance of optically active natural water components. Despite the many views and different sensors and methods of applying NRTWSM, users can refer to Sentinel-1 & 6 (active), Sentinel-2, Sentinel-3, and Landsat 8 and 9 as non-passive imagery. NASA's atmosphere section is another example of a near real-time capability that supports interested users in monitoring a wide variety of water-based-created data and parameters (NASA, 2013). These data are made available much quicker than routine image processing allows (Rasouli et al., 2021). Most data products are available within three hours of satellite observation, with imagery generally available 3-5 hours after the observation stage. To access these valuable data in monitoring water resources, researchers only need the specific cases usable for most geographic regions of the country.

Smart Water Resources Monitoring Systems (SWRMS).

In recent years, SWRMS systems have emerged as powerful tools in this endeavor, providing real-time data and actionable insights to promote sustainable water usage and reduce waste (Saqib et al., 2015). Water demand in urban and rural areas countrywide has increased due to population growth and climate change. In today's situation, SWRMS could integrate sensors, meters, and advanced analytics to continuously monitor and analyze water usage patterns within a particular area. Technically, all SWRMS tools can be connected to a central hub and mobile application by providing users with real-time insights into their water resources under the study. By introducing SWRMS, it is possible to leverage the capabilities of the Internet of Things (IoT) to collect and analyze real-time data on water consumption. These systems comprise sensors, meters, and intelligent software that work together to provide a comprehensive view of water usage in the agricultural and residential sectors. SWRMS has many key features and advantages of real-time data, leak detection, usage analytics, remote control, and integration with other IoT devices.

At a controllable SWRMS approach, incorporating into a society-used water consumption offers numerous benefits for homeowners, water utilities, environment water usage, leak prevention, cost savings, and Environmental impacts. At a glance, conserving water through SWMS minimizes the strain on local water resources and reduces energy consumption associated with water treatment and distribution (Palermo et al., 2022). These systems contribute to a more sustainable future by preserving precious water supplies for the next generations. Given these issues, water utilities need a well-planned SWRMS to monitor remotely every part of the water cycle—from sourcing to treatment to delivery to consumption—to respond faster to changing conditions, minimize disruptions, and operate more efficiently. Participants can explore the following areas of interest in this challenge:

- Monitoring of water level and condition (through advanced telemetric devices, drones, or pressure sensors, among others)
- Demand forecasting or monitoring consumption to help manage the pressure and speed of water
- Asset management, detecting leaks, and predictive maintenance
- Staff safety and operational performance; including status reporting like workforce capacity and activities
- Tailored customer service, for example, real-time updates on closures and disruptions, hourly consumption, leak detection, and customer feedback,

In the recent years, several innovations have been made in the field of communications that are transitioning to the Internet of Things with the progression of advancements in technology. In water domain sections, Wireless Sensor Networks (WSN) are one of those independent sensing devices to monitor physical and environmental conditions along with thousands of applications in other fields (Taheria et al., 2020).

III. Conclusion

All water sources in the Republic of Azerbaijan are undergoing significant changes, as the signs of environmental damage can be seen everywhere in our beloved homeland. There are extensive changes in water territories that seem unavoidable in large dimensions. Such changes in water environments could affect industrial sections, agriculture activities, people's health, and the national economy in many ways. To access these aims, meteorologists, climatologists, water scientists, and managers have to watch and get accurate information about the water resources through one unique applicable policy to reduce the disastrous consequences of unintelligent use of limited and vulnerable water resources.

It is now possible to introduce a modern multi-platform, and with dissimilar purposes suited to the country's water resources sections with reasonable time, energy, and costs. Applying advanced image processing methods and informed interpretation of the ending results can lead to the applied pure sciences. The design of timely, purposeful, and multi-purpose decision-making databases can be of considerable help to researchers and managers of water fields.

If truth be told, most water resources are ever-changing meaningfully throughout the country. We have lost some of the lakes during the last few years. The Caspian Sea coastal areas are changing meaningfully and may seriously affect infrastructure, the environment, and ecosystems in many ways:

- In most parts of the country, particularly in Aran County, water resources are declining sharply.
- The Azerbaijan geo-environment must be watchfully monitored employing modern remote sensing technology.
- Advanced image processing is a better way to reach practical and accurate knowledge of water topics and associated environmental matters.
- Some advanced image processing, such as OBIA, Fuzzy, and Machine-Learning / Deep learning, could provide essential water databases for management plans.
- A combination of multi-platforms such as real-time, near-real-time, and smart-monitoring systems is almost immediately required if it is not too late.

References

[1] Bayramov, A. The Reality of Environmental Cooperation and the Convention on the Legal Status of the Caspian Sea. Central Asian Survey. – 2020. No 39 (4), p. 500–519.

[2] Chen, J., Pekker, T., Wilson, C., Tapley, B., Kostianoy, A. Cretaux, J., & Safarov, E. Long-term Caspian Sea level change. Geophysical Research Letters. – 2017. Vol. 44, p. 6993-7001.

[3] EU's Copernicus Programme. Sentinel High-Level Operations Plan (HLOP) Copernicus Space Component Mission Management Team Reference COPE-S1OP-EOPG-PL-15-0020. – 2021. Issue 3, Revision 1.

[4] Han, D.Z.; X.G. Chen, Y.X. Lei, Y. T. Dai and X. Zhang. Real-time data analysis system based on Spark Streaming and its application", Journal of Computer Applications. – 2017. vol. 37, no. 5, p. 1263-1269.

[5] Lahijani, H.; Leroy, S.A.G.; Arpe, K.; Crétaux, J. F. Caspian Sea level changes during the instrumental period, its impact and forecast: A review, Earth-Science Reviews. – 2023. vol. 241, p. 104428

[6] Liu, Z., Shi, C.L., Meyer, D. NASA Global Satellite and Model Data Products and Services for Tropical Meteorology and Climatology, Remote Sens.- 2020. vol. 12(17), p. 2821.

[7] Mammadov R.M., Safarov S.H., Safarov E.S. Current changes of the atmospheric precipitation regime on the territory of Azerbaijan // Geography and Natural Resources. Elsevier. – 2009. vol. 30 (4). p. 403–407.

[8] NASA. NASA EOSDIS Global Hydrology Resource Center, GHRC User Services Office National Space Science and Technology Center, USA. – 2013. p.45.

[9] Palermo, S.A.; Maiolo, M.; Brusco, M.; Pirouz, B.; Greco, E.; Spezzano, G.; Piro, P. Smart Technologies for Water Resource Management: An Overview, Sensors. – 2022. vol. 22(16), p. 6225.

[10] Rasouli, A. A. An Introduction to Satellite Meteorology and Climatology, Tabriz University Publisher. – 2011. p. 455.

[11] Rasouli, A. A. and Mammadov, R. Preliminary Satellite Image Analysis" Lambert Publishing Company, Germany. – 2021. p. 256.

[12] Rasouli, A. A. Omidfar, M. Rostamzadeh, H. and Sarisarraf, B. Evaluation of Tabriz Doppler Radar Data Using Synoptic Concurrent Data by Analyzing Intensive Rainfall over Urmia Lake Basin. - 2014, v. 24, p. 247-266.

[13] Rasouli, A. A.; Naghdifar, R.; Rasoli, M. Monitoring of Caspian Sea coastline changes using object-oriented techniques. Procedia Environmental Sciences. – 2010. v. 2, p.416-426.

[14] Rasouli, A.A. Imrani, Z. Object-oriented analysis for assessing risks and natural disasters: explaining the geo-ecological contexts of Azerbaijan", Ministry of Science and Education Republic of Azerbaijan, Institute of Geography, Republic of Azerbaijan. – 2023. p. 478.

[15] Rasouli, A.A.; Milani, M.; Milan, B. Mastering Object-Based Image Analysis: "Imaging the Azerbaijan Geo-Environment". iKSAD Publishing House, Turkey. – 2021. p. 324.

[16] Safarov S.H., Huseynov J.S., Ibrahimova I.V., Safarov E.S. The main features of temperature changes, occurring over the territory of Caspian Sea in Azerbaijan / Understanding the problems of inland waters: A case study for the Caspian basin. Baku. – 2018. p. 100– 105.

[17] Safarov S.H., Nasibli A.A., Huseynov J.S., İbrahimova İ.V. Influence of Climate Warming on Hail Events in the Western Part of Azerbaijan // Proceedings of International Scientific Conference on Sustainable Development Goals. – 2017. 24–25 November 2017, Baku, Azerbaijan. Baku, p. 83–89.

[18] Safarov, S.H.; Huseynov, J. Safarov, E. Modern Changes in Precipitation on the Caspian Coast of Azerbaijan. Journal of Oceanological Research. -2020. v.48(1). p.2.

[19] Saqib, J. M.; Jamilb, A.; Mazharc, A.; Ikrama, A.; Ahmeda, A.; Munawar, U. Smart Environment Monitoring System by Employing Wireless Sensor Networks on Vehicles for Pollution Free Smart Cities, Procedia Engineering. -2015. v.107, p. 480 – 484.

[20] Sharma, S.; Sahoo, P. and Oza, S.K. Real Time Patient Monitoring System, International Journal of All Research Education and Scientific Methods. -2021. v. 9, p. 2455-6211.

[21] Taheri, F.; M. D. Haese; D. Fiems; G. Hosseininia; H. Azadi. Wireless sensor network for small-scale farming systems in southwest Iran: Application of Q-methodology to investigate farmers' perceptions, Computers and Electronics in Agriculture. – 2020. p.177, 105.

TRAVELERS' ENVIRONMENTAL RESPONSIBILITY IN THE CITY OF BATUMI AND THE CITY'S SUSTAINABLE DEVELOPMENT

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Abstract

The tourism destination is always the point of intercrossed interests. The case of seaside resort city of Batumi reveals the Society's aspiration to be sustainable and the local government's intention to cope with ecological and social risks along with tourism industry actions oriented primarily on (as short run as possible) highest profits. The interest conflicts could be overcome by the orientation on the responsible traveler segment. The research presents the relationship between the level of environmental responsibility of the travelers and the level of environmental-friendly actions of the locals, industry and local government. The modern tourism history of the city reveals the changes in the behavior of the citizens, developments in the strategies of the tourism industry actors and the modernization of measures the local government implements. It appears that these changes rely on the changes in the level of responsibility of the city's visitors. Several directions to modernize city's advertisement campaign on the responsible traveler have elaborated.

Keywords: sustainability, responsibility, traveler, city, tourism industry

I. Introduction

The tourism destination could be presented as a set of the relationships between 4 main actors: Traveler, industry, locals and government. It also could be described as a set of dilemmas of sustainable development (see Table 1 below):

Table 1: *Actors and dilemmas of the sustainable development of the city*

Elements of Sustainability			
Tourism Actor	Economic	Social	Environmental
Traveler	Seeks Outstanding Experience	Interacts with locals	Additional load on Environment
Industry	Seeks for profit	Employs and pays	Additional load on Environment
Locals	Seek for vacancies and salaries	Tries to adapt	Seeks for quality of life
Government	Seeks for economic growth	Tries to balance	Tries to regulate

Mohan [3] Used Case study to reveal tourism potential to strengthen the sustainable development in Tobago. One of the recommendations of the research was the action of policymakers as catalysts of the change. It is Quite interesting work because it reveals that the sustainable development goals could be achieved if the stakeholders have the interest to participate in.

Panasiuk [4] discussed the case of sustainable development of the cities under the influence of rising tourist flows. The work is very interesting because it reveals the problems that could be created by overtourism and sets the principles for sustainable urban tourism development policy.

Much interesting work of Lee, Hunter and Chung [2] suggests the idea of smart tourism city – the concept that could overcome one of the dilemmas of tourists-locals conflict. The authors give the solution for one of the issues of sustainability, outline the importance of Information communication technologies and the role of the government in implementation of smart tourism city concept.

Another interesting concept for the city sustainable development that tries to solve conflict between city's economic development goals and necessity to maintain the quality of life for locals is presented in the work of Riffat, Povel and Aydin [6]. The researchers reveal key schemas and solutions for future cities those trying to elaborate the principles the future cities should follow to maintain the harmony between economic and environmental goals.

Day, Morrison and Coca-Stefaniak [1] call for rethinking the approaches to sustainability to cope with challenges that modern world sets for tourism development, especially in the big cities those are characterized by higher level of urbanization and host the higher level of tourist flows. They suggest that interdisciplinary approaches to city development problems could solve the dilemmas of sustainable development.

Pavlic, Portolan and Butorac [5] investigate the importance of principles of sustainability to develop the urban tourism. They use the case of Dubrovnik to reveal the necessity of sustainable approaches to the city's tourism development. The study gives the several recommendations for city tourism policy makers to implement the principles of sustainability.

Tierney, Hunt and Latkova [7] use factor analysis to identify the travelers' attitude to green practices of tourism industry. The authors trace the relationship between requests of travelers and sustainable management decisions in the tourism industry.

The presented research aims to reveal the ways the travelers' environmental responsibility defines the decisions made by tourism stakeholders in the destination. The research uses the case study of city of Batumi – seaside resort located in the south-west of Georgia on the east coast of the black sea. The city's tourism history could be counted since 1881 when the seaside boulevard idea was formed and the city started to implement it. Modern tourism history of the city starts the couple of decades ago as it recovers its popularity at old market segments and gains more and more travelers from new market segments. Today the city of Batumi is the dynamic, developing seaside resort, striving for becoming the tourist city for all seasons, with higher rates of tourist flows and high rates of tourism-related investment. All the dilemmas listed above could be easily observed in the city's performance through the stakeholder analysis.

The research was conducted in two steps: 1) the theoretical framework was created to reveal the ways the travelers' attitude to environmental-friendly behavior and practice influence on the decisions in the city's tourism field; 2) The case of the city of Batumi was discussed following the schema elaborated at previous step; 3) the key conclusions were made.

II. Travelers' environmental responsibility as a key determinant of destination sustainable development

The key idea of development the sustainable tourism destination is that the main incentive, main factor that stimulates the environment-friendly actions and decisions trough the stakeholders of the tourism industry, is the traveler. Similar to the traditional free market signal system, where the consumer sets the requirements for the goods and services, gives signals to the product market and entrepreneurs and those give the signals to resource markets an resource holders, the traveler sets the conditions for environmental-friendly actions, gives signals to the locals, tourism industry and government to change their actions and decisions (see Fig. 1 below).

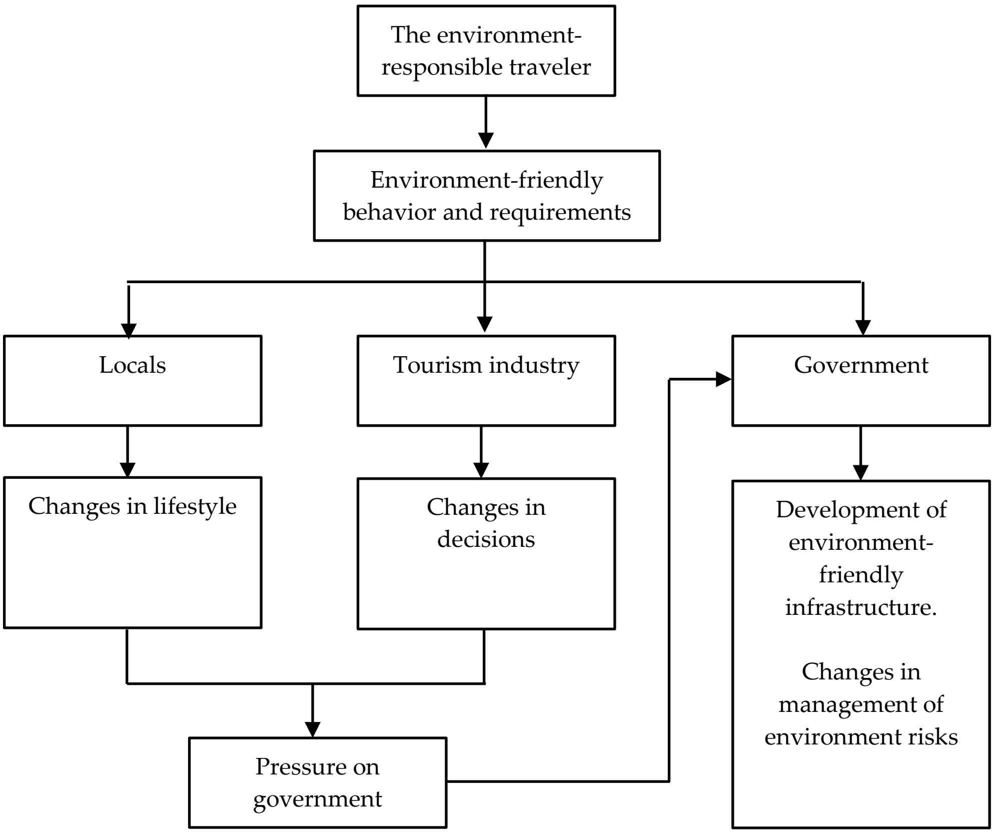

Figure 1: *Traveler as an incentive for environment-friendly actions and decisions*

The modern traveler could be characterized as a person who looks for original experience. Mostly the term "original experience" is associated with the sustainability principles: it implies the respect of local culture, tradition and lifestyle and intends such a behavior that doesn't harm nature. More of that, the modern traveler not only reveals environment-friendly action, it requires it from the others – the traveler makes his/her choices during travel according to the requirements of sustainability. It means, that the destinations those do not meet these requirements will lose their competitive advantages and will be defeated in the long-run period. The modern traveler directs the ways the destinations should be developed in a sustainable manner.

The tourism industry is in the direct relation with the traveler and tries to adapt to the requirements of modern traveler. The adaptation process takes the several forms: implementing the sustainable decisions for waste management, energy and water consumption; pay more attention to the green areas; changing approaches to the construction plan exterior and interior decisions; investing in more sustainable-friendly technologies.

The changes in the behavior of locals are the result of intercultural communication. The intercultural influence is the most latent process that could be revealed (if ever) after the years of interaction, but it is most important one because its influence covers the minds of the population and leads to the changed behavior and creates the context in which all the sustainable-friendly private and public decisions will be perceived as a normal for particular society.

The local government is affected by the traveler in two ways: directly and indirectly. The direct pressure takes the form of raised tourist flows those create the problems with transport infrastructure, utilities, safety, environment, attractions etc. The indirect pressure comes from the locals and the industry trying to urge government to change its tourism policy strategies to meet the new challenges set by modern treveler. In a response the government modernizes all the spheres of city's life – revises city development plans to allow tourism and other superstructure objects to grow; develops the transport infrastructure; modernizes city municipal transport; introduces new systems in a waste, water and electricity supply management; tries to introduce alternative energy projects etc. Another change for the local government is related to the management of the environmental risks as the tourism develops the local safety system conditions, resources and performance are continuously improving to meet and operatively cope with environment crisis issues and problems. Government allocates more financial, human and material resources into the monitoring of environment conditions raising the readiness of the city for different environment crisis situations.

III. The case of the city of Batumi – the travelers changing the city

The city of Batumi hosts the beach tourism travelers from neighbor countries and it was the first and traditional segment of market for the city, but new tourism history of the city reveals the rising importance of cultural tourism during whole year represented by the visitors from both neighbor and Europe-origination, plus important segment of Israeli and Arab-originated travelers. They define the type of influence on the city's tourism stakeholders (see the Figure 2 below):

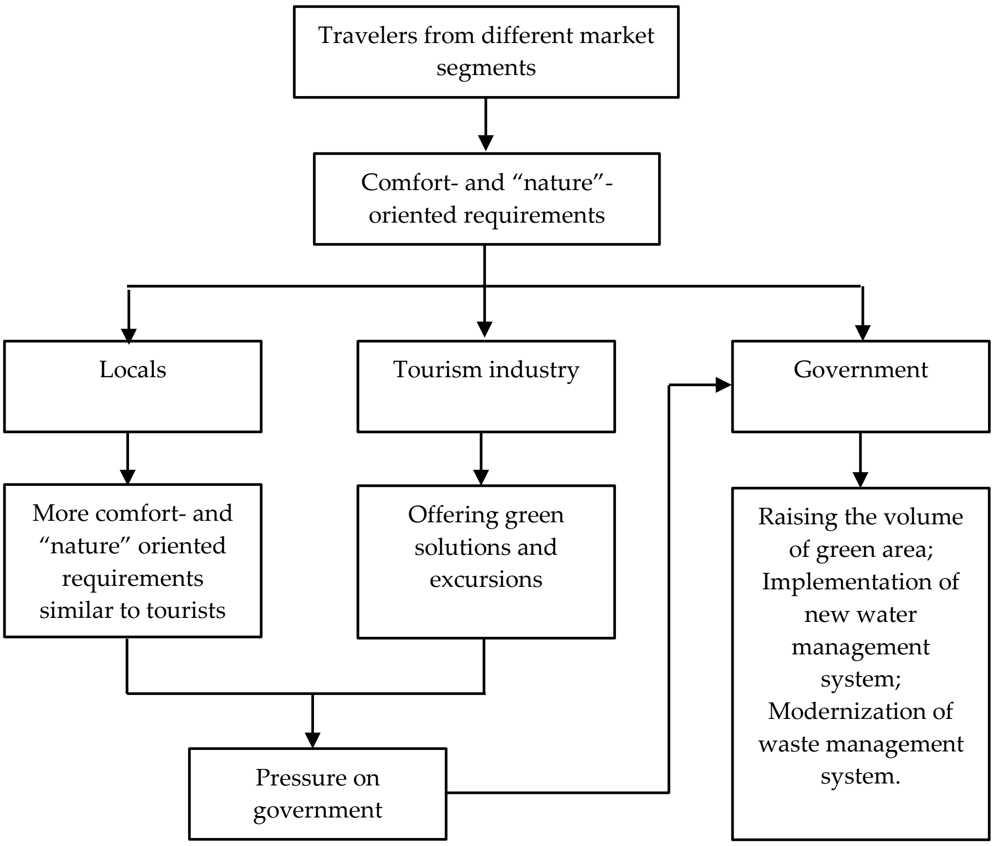

Figure 2: *Tourism stakeholders' adaptation to the Traveler in the city of Batumi*

The modern tourists visiting Batumi are more oriented on the comfort and nature. They look for comfortable, clean apartments near the sea and spend the evenings walking the boulevard and parks; they visit city's Botanical Garden and nearby natural attractions (national parks and villages); They are much familiarized with the city's natural and cultural attractions and enjoy every moment visiting the city. They are aware about local culture and nature and expose it in the communication with the locals and industry.

The industry reacted in a several ways. Huge development firms started the huge construction projects to ensure the sufficient quantity of rooms for rising number of the travelers. The construction boom is continuing now. But the content of such a boom is changing – decades ago the development firms did not play much attention to the sustainability issues – the faster and cheaper the project will be implemented the higher the profit will be gained. But today many development firms start to offer the original projects and the sustainable solutions play one of the important roles in such an offer. The other form of adaptation comes from the small tour-operators, mostly represented by small companies or the individual entrepreneurs those offering the number of nature-type excursions to the visitors. The dozens of such a tour-operators invading the places where the tourists flow making their offers.

The city's government adaptation process is also worth to mention. First of all, the government extends the boulevard. It is the key competitive advantage of the city and as the boulevard stretches its length the new investment and tourists rising flows follow it. Second, the government raises its investment in the safety of the seaside – it implements the beaches protecting measures, improves the quality and rises the quantity of the resources to rise the readiness of the safety system to effectively cope with crisis situations (storms, soil washing etc.). Third, It implements new water management and waste management systems in the city; Fourth, it rises the green area in the city by the construction of new parks.

The reaction of the locals is quite interesting. Similar to the tourists, the locals are more tend to the comfort and nature. It is quite typical for locals to reshape their yards in a green manner, to use less private transport, to "escape" in the villages etc. Couple of decades are not enough to change the locals' attitude and the above-mentioned changes could be discussed as the negative reaction on the rising tourist flow, attempt to rise the distance from tourists, but the fact is that, positively or negatively, tourists stimulate the locals to be more sustainable.

IV. Conclusions

In a modern Urbanized world, the issue of the sustainability of the cities, especially under the rising tourist flow, is the most important question for the city development sphere. Most researches in thew field recommend the government actions but pay less attention on the changes in the travelers' minds that could be the solution for all the sustainable goal dilemmas the cities face today.

The environment-responsible traveler affects on all the stakeholders of the tourism in the city – locals, industry and government. More of that, the local government is under the double pressure – it is affected by the traveler and is affected by the locals and industry those previously affected by the traveler also.

The modern tourism history of the city of Batumi reveals the changes the changed-mind travelers stimulate: The industry starts to offer more green solutions ion construction projects and more green excursions; local government modernizes the waste and water management systems, raises the volume of green area in the city and improves the readiness to natural crisis; the locals also start to behave more sustainable.

References

[1] Day J. Morrison A.M. Coca-Stefaniak J.A. (2021). Sustainable tourism in urban destinations. // International Journal of Tourism Cities, 7(4):881-886

[2] Lee P. Hunter W.C. Chung N. Smart Tourism City: Developments and Transformations.

(2020). Sustainability, 12:3958

[3] Mohan P.S. (2021). Sustainable tourism and the Sustainable Development Goals in sub-national island jurisdictions: The case of Tobago. // Island Studies Journal, 17(2):168-191

[4] Panasiuk A. (2020). Policy of Sustainable Development of Urban Tourism. // Pol. J. Sport Tourism, 27(2):33-37

[5] Pavlic I. Portolan A. Butorac M. (2013) Urban tourism towards sustainable development. International // Journal of Multidisciplinarity in Business. Vol.1, No.1:72-79

[6] Riffat S. Powell R. Aydin D. Future cities and environmental sustainability. (2016). // Future Cities and Environment, 2:1

[7] Tierney P. Hunt M.M. Latkova P. Do Travelers Support Green Practices and Sustainable Development. // Journal of Tourism Insights: Vol. 2: Iss. 2, Article 5.

ENVIRONMENTAL RISK MANAGEMENT IN THE STRUCTURE OF GLOBAL RISK ASSESSMENT

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Abstract

This article examines the role of environmental factors in contemporary global politics and economics. The authors analyze the main environmental hazards, including climate change, natural disasters, biodiversity loss, and natural resource depletion. Statistical data on the impact of these issues on various aspects of society are presented. Particular attention is paid to methods of assessing and managing environmental challenges, including the use of various indices and indicators. The article emphasizes the importance of an integrated interdisciplinary approach to hazard analysis and the need to consider socio-economic factors. The authors discuss risk management strategies, including preventive measures, adaptation, and mitigation. In conclusion, recommendations are offered for enhancing environmental policy, including strengthening the regulatory framework, developing infrastructure, and involving various stakeholders in the environmental risk management process.

Keywords: environmental risks, climate change, natural disasters, biodiversity, risk management

I. Introduction

Environmental factors play a significant role in modern global politics. Scientific and technological progress and increasing human impacts have led to adverse environmental changes, including resource depletion, decreased biodiversity and an increase in natural disasters. This forms new ideological patterns and behavioral strategies at the individual and institutional levels [1].

The modern natural environment is in a state of ecological crisis, characterized by long-term unfavorable changes in the biosphere. There is a steady trend towards deterioration of the environmental situation globally and locally. Some researchers believe that humanity exists in a period of permanent eco -catastrophes - critical states of ecosystems leading to their change or destruction [2][3].

The analysis shows a correlation between the environmental crisis and the aggravation of socio-economic and political risks. U. Beck [4] focused on the need for international cooperation in the field of environmental safety.

According to the Center for Research on the Epidemiology of Natural Disasters, in 2022 there were 387 natural disasters, causing 30,704 deaths and affecting 185 million people [5]. Economic damage is estimated at US$223.8 billion. A comparative analysis with 2021 (10,492 dead, 101.8 million injured) reveals a trend toward escalating risks.

- The most significant natural disasters of 2022:
- Heat wave in Europe: 16,305 deaths
- Drought in Uganda: 2465 deaths
- Floods in Pakistan and India: 1,739 and 2,035 deaths respectively
- Research indicates the uneven distribution of social costs of natural disasters [6][7] with the

predominant vulnerability of rural areas [8][9].

Analysis of social vulnerability to environmental disasters reveals a correlation with the economic development of territories. Research shows that low-income groups are at increased risk due to housing inequality and limited access to evacuation and recovery resources [10].

Statistics show that people in the poorest countries are 6 times more likely to suffer from emergencies [11].

The economic costs of environmental disasters in 2022 amounted to US$223.8 billion. During the period 1998-2017. financial losses from natural disasters increased by 151% [5].

According to the Allianz Global Corporate & Specialty (AGCS) study, based on assessments of 2,712 experts from 94 countries, climate change and natural disasters are among the top risks for government and business, along with cyber threats and macroeconomic factors [12].

- Climate change has a multifaceted impact on the global economy and social sphere, as evidenced by a number of studies and statistics.
- Food Security : According to Global Commission on Adaptation (2019), if the trend towards an increase in average temperatures of 1.5-3°C continues, a 30% reduction in crop yields is expected by 2050 [13]. This comes against the backdrop of a projected 50% increase in global food demand, which could lead to a significant increase in global hunger.
- Water resources: According to the UN World Water Development Report (2021), between 2 and 4 billion people suffer from water shortages on a permanent or seasonal basis [14]. It is predicted that by 2030, humanity will face a 40% water shortage if current rates of economic development continue. WHO Global Water, Sanitation and Hygiene Annual Report (2022) indicates that 1.4 million deaths each year are attributable to lack of consistent access to quality water and sanitation [14].
- Health: A study published in The Lancet Planetary Health (2022) shows that air pollution causes more than 6.5 million deaths each year, and water pollution causes 1.4 million [15]. The World Health Organization predicts that climate change will cause 250,000 additional deaths annually from 2030 to 2050 [16].
- Economic impact: The World Bank predicts that for the Middle East and North Africa, by 2050, the economic cost of water shortages caused by climate change could amount to 6-14% of the region's GDP.

A study presented at the World Economic Forum (2022) indicates that heat stress could reduce total hours worked by more than 2% globally by 2030, equivalent to a potential economic loss of US$2.4 trillion [17].

Agriculture: UN World Water Development Report (2023) notes that about 25% of the world's arable land experiences economic water stress, which is due less to hydrological constraints than to institutional and economic factors [18].

These data demonstrate the complex and interconnected nature of the impact of climate change on various aspects of the global economy and social development. They emphasize the need for an interdisciplinary approach to solving environmental problems and the development of adaptation strategies at the national and international levels.

The state of the environment and the general trends in the dynamics of its development largely determine the vector of development of the human community and states, which actualizes the need to develop a system of strategic political management for a timely response to changes in biogenic constants and leveling environmental risks. The multifaceted nature of environmental problems indicates that mechanisms that can counter socio-economic and political risks are also important for their solution.

Among the global environmental risks on a scale of the next 10 years, the following types are distinguished:

- Climate change:

An increase in temperature above the annual average from spring to autumn increases the risk of droughts, which negatively affects the moisture content of agricultural land and crop yields [19].

Accelerated melting of glaciers poses a serious threat to coastal areas [20].

The rate of sea level rise has doubled over the past 30 years, and this trend is likely to continue.

- Natural disasters:

According to the UN, over the past 50 years the number of natural disasters has increased 5 times [21].

In the Russian Federation, according to the Ministry of Emergency Situations, from 2016 to 2022 the number of natural emergencies increased from 42 to 78 cases [22].

In 2022 in Russia, the greatest threat was posed by hydrological (floods, floods) and meteorological (storms, hurricane winds) phenomena.

The problem of forest fires, threatening more than 40% of the territory of the Russian Federation, is getting worse [23].

- Biodiversity change:

About 1 million species of plants and animals are on the verge of extinction in the coming decades [24].

The World Meteorological Organization predicts that at 2°C warming, the number of species at risk of extinction will be 30% higher than at 1.5°C warming [24].

Warming of 1.5°C could destroy up to 90% of coral reefs, and warming of 2°C could destroy up to 99% [1].

The loss of species disrupts the balance of local ecosystems, affecting agriculture, livestock farming and fishing.

- Natural resource crisis:

The world's population reached 8 billion in October 2022, increasing the demand for resources [25].

At the current level of consumption, proven gas reserves will last for 52 years, oil – for 47 years, coal – for 130 years [25].

The transition to green energy carries risks of depleting rare metals and elements needed to produce solar panels, wind turbines and electric vehicles.

The uneven geographic distribution of these resources could hamper the global transition to low-carbon technologies.

- Anthropogenic influence:

The CO2 content in the atmosphere is 150%, CH4 (methane) – 264%, N2O (nitrogen oxide) – 124% of pre-industrial levels [25].

The influence of CO2 on climate lasts for centuries, in contrast to CH4, which exists in the atmosphere for 9-10 years [26].

High concentrations of greenhouse gases are accelerating climate change, which could lead to faster melting of polar ice caps, rising sea levels and an increase in the frequency of extreme natural events [27].

These data highlight the interconnectedness and complexity of environmental problems that require the development and implementation of effective strategies at the global and local levels to minimize negative impacts and adapt to changing conditions.

It is also important to note that the problem is the nonlinear nature of the development of environmental risks, which implies more difficult to predict dynamics of environmental changes under the influence of various factors, as well as the emergence of the issue of accumulation of risk potential over time [28].

The risk of ineffective human action to solve the problem of climate change in recent times is also quite high. A confirming circumstance is the fact that despite the actions taken by the international community, keeping the level of climate change at the level of 1.5 ° C set by the Paris

Agreement seems practically unattainable, which increases the risk of negative consequences for the planet [29]. Despite some signs of environmental progress, at current dynamics and full implementation of national climate commitments until 2030, temperature changes will at best be kept to 2.4-2.8°C by the end of the century, demonstrating the need significant revision of the measures taken due to their lack of effectiveness [30].

II. Methods

To predict the development of environmental risks, analyze the overall effectiveness of actions taken, as well as their long-term planning, various indicators and indices that make up risk assessment systems are important.

Environmental Risk Assessment – Environmental Risk Assessment – aims to identify and analyze potential environmental risks arising from human activities that may cause harm to people and/or ecological systems [31].

The Global Climate Risk Index analyzes and ranks the extent to which countries and regions are exposed to climate-related extreme weather events (storms, floods, heat waves, etc.) [32].

Environmental Performance Index , which analyzes the overall performance of states' environmental policies in the context of three main categories: environmental protection, ecosystem viability and climate change [33]. This rating also ranks the states in question according to the degree of their environmental efficiency: for example, in the 2022 report, Russia ranks 112th in the overall rating of 180 countries [33].

The Green Growth Index assesses countries' progress towards achieving sustainable development goals across four dimensions: resource management, natural capital protection, green economic opportunities and social inclusion [34].

The Global Green Economy Index measures the performance of the green economy across four key dimensions: climate change, industrial decarbonization, ESG investing and environmental stewardship [34].

The World Risk Index analyzes the risk of natural disasters resulting from extreme natural events, taking into account a country's exposure and vulnerability to risk [35]. The above indices make it possible to evaluate certain components of the general environmental state of countries and regions of the world.

A more comprehensive approach is featured in the Sustainable Development Goals Index compiled by SDSN and Bertelsmann Stiftung [36]. It is based on the 17 socio-ecological development goals outlined in the 2030 Agenda adopted in 2015 by the UN General Assembly [37]. The most difficult to achieve are the following environmental sustainable development goals (SDGs): SDG 12 – transition to sustainable consumption and production patterns, SDG 13 – combating climate change, SDG 14 – conservation of oceans and seas, sustainable use of marine resources, SDG 15 – protection terrestrial ecosystems and biodiversity [37]. All of these goals relate to the environmental sphere, which demonstrates the high complexity of the practical implementation of environmental actions by states around the world. This problem is exacerbated in low-income countries due to the lack of infrastructure and mechanisms to deal with environmental problems, which demonstrates the greater environmental vulnerability of less developed countries.

III. Results

A comprehensive multidisciplinary risk analysis should include not only an assessment of the influence of a certain factor, but a set of various risk determinants and their influence on each other [39]. Thus, the factor of climate disasters in 2020 was significantly aggravated by the development of the Covid -19 pandemic, which caused a high burden on healthcare systems, energy supplies, and the work of emergency services in many countries [38].

It is also worth noting that when assessing overall environmental risk, it is important to consider responses, as they play a key role in achieving potential outcomes and are also determined by political and economic components [39]. This approach provides a holistic perception of real or predicted risk, since it explains why, in some cases, decision makers do not take action to reduce risk: the reason may be possible reputational risks, insufficient funding, untested technological solutions, etc. [40].

Decision-making, in turn, can be accompanied not only by positive consequences and risk mitigation, but also by aggravation of current problems, including through numerous compromises and associated benefits for the actors, which can change the overall nature of the risk and its complexity. Thus, taking into account socio-economic, political factors, regional characteristics, and the interaction of management systems at different levels makes it possible to more accurately assess environmental risks and conceptualize strategies to mitigate potential negative effects.

Environmental risk management consists of several stages of risk management:

1. primary analysis and identification of risks;
2. determination of the main directions for their leveling;
3. assessment of probability, influencing factors, probable damage;
4. development and planning of risk reduction measures [41].

Natural disaster risk management must be based on a structural understanding of the formation and evolution of natural disasters, disaster mitigation and subsequent recovery. Taking into account the factors mentioned above, as well as the use of developed geotechnical and environmental engineering systems, should help improve the assessment and identification of natural risks and reduce disaster risk in general [42]. It is also important to analyze the social context, structural forces and conjunctural factors that make up the contextual framework of the problem under study.

A separate factor that can also potentially have a significant impact on managing environmental risks and reducing the negative consequences of climate change is the use of information systems and artificial intelligence. In the context of digitalization, the competent use of modern technologies can help solve existing problems and achieve sustainable development, but this strategy also has potential adverse consequences in case of irresponsible use of information systems [43][44].

In general, risk management methods are divided into 4 categories [45]:

1. risk avoidance methods;
2. methods of risk localization;
3. risk dispersal methods;
4. risk compensation methods.

In relation to environmental issues, it is worth noting that the option of evading an unfavorable natural phenomenon is not always possible, therefore it seems important to pay attention to procedures for minimizing negative effects. At the same time, some environmental risks can be mitigated by localization if they are clearly identified, the source is determined, and ways to influence the process are established. Risk reduction also occurs through the dissipation method when distributing areas of responsibility between various actors and structures, including political organizations, business structures, non-profit associations and individual local communities. Methods for compensating for environmental risk involve the development of strategic planning to predict scenarios for the development of natural and man-made disasters and the development of tools for their prevention.

An environmental risk management strategy typically reflects one of several principles [4]:

1. the zero-risk principle, based on the premise that there is no harm to the environment and there is no need to do anything;

2. the principle of minimal risk, which implies the development of options for minimal impact on the biosphere;

3. the principle of balanced risk, which takes into account the anthropogenic factor and implies the implementation of measures to reduce negative effects on the natural environment and potential dangers to the population;
4. the principle of acceptable risk, which is based on an assessment of the costs and benefits of certain business strategies; this principle often leads to a conflict of economic and environmental interests.

In this case, the most effective is the balanced risk approach, which allows one to assess the degree of negative impact on the environmental situation at the national, regional or local level and develop a set of measures to prevent and minimize possible negative effects, as well as reduce the impact of adverse anthropogenic factors.

Environmental risk management includes both a preliminary risk assessment and forecasting of possible scenarios for its implementation, as well as the use of preventive measures to counter the risk, as well as measures to mitigate the consequences. In this case, when forming a strategy for dealing with the risks of natural disasters, three stages of the life cycle of a natural disaster will be taken into account:

1. pre-event stage: assessment of potential impact and development of preventive measures;
2. post-disaster response: a phase that facilitates the strategic mobilization of resources and technical support regarding previously identified critical aspects;
3. post-event stage: assessment of the damage caused by the disaster, measures to prevent its socio-territorial consolidation and accelerate recovery processes.

Depending on the phase of the natural disaster cycle, the following options for management activities in relation to natural disasters can be distinguished:

- prevention and minimization: a type of preventive measures aimed at significantly transforming or eliminating certain areas of risk in order to prevent the occurrence and development of adverse consequences;
- recovery: in the event of a disaster that has already occurred, measures are taken to restore infrastructure and repair damaged material objects;
- compensation: measures aimed solely at redressing damages through payments to injured people.

For accurate results of forecasting environmental risks, it is important to assess in advance the degree of vulnerability to extreme events. One of the factors that increases the vulnerability of an area and the uneven distribution of disaster risk is socio-economic inequality. Poor and marginalized populations often live in areas more prone to natural disasters and therefore face greater risks to life, health and finances; Education and age factors greatly influence the level of awareness of what needs to be done in the event of a disaster, and also affects the ability to access warnings, understand them and respond correctly - for example, older people often need additional support in emergency situations Social vulnerability affects not only behavioral responses to natural disasters, but also the ability to recover after it. Therefore, taking into account heterogeneity in society is important for correct analysis of the distribution of potential environmental risk and recovery trajectories.

Also an important part of the work on environmental risk management is the implementation of adaptation policies to prepare for the inevitable consequences. For its implementation, it seems important to develop strategic management at the state and regional levels, taking into account an understanding of the geographical, climatic, socio-economic and other characteristics of the territory. Increasing resilience, a developed system for preventing and responding to the most common natural disasters in the region, and an active information and communication policy aimed at increasing public awareness of behavior in the event of an emergency will reduce socio-economic risks in the event of environmental disasters.

To summarize, it can be argued that today environmental problems are associated with significant social, economic and political risks. Climate change and the increase in natural disasters - floods, droughts, hurricane winds and record temperatures - threaten the food security of individual states and world regions, for example, East Africa. The problem of ensuring access to water in the countries of the Middle East and North Africa also remains. The lack of constant access to water and necessary sanitation conditions increases the risk of epidemic outbreaks of various diseases. Also, in conditions of insufficient resources, geopolitical tension arises between states, which reduces the level of security in the region. Macropolitical and economic factors such as geo-economic confrontation and military conflicts are additional catalysts for environmental problems.

Integrated environmental risk management involves primary analysis and identification of risk, taking into account the influence of a combination of various factors on it, identifying directions for their leveling, designing possible risk scenarios and assessing the likelihood of their occurrence, as well as the likely consequences, taking measures to counter risks and minimize them consequences. An important role is played by forecasting and the scenario method, which allows one to calculate the possible effects of a potential environmental disaster or catastrophe, as well as determine their impact on the aggravation of other current or upcoming crises. The implementation of predictive models, scenario analysis and integrated data collection mechanisms into environmental risk management will improve the ability to effectively prevent and mitigate emerging environmental risks. In recent years, the role of modern technologies and machine learning in risk management has also increased.

IV. Conclusion

An important area within which it is worth developing a risk management system at various levels is adaptation to the consequences of the crisis and mitigation of the consequences. Since not all environmental risks can be prevented, strategic planning should include development in conditions of environmental crisis with minimal damage. Measures to create and regularly modernize infrastructure that is somewhat resilient to climate change and to introduce renewable energy sources seem to be effective.

Improving the regulatory framework is also a significant stage in the development of the state's environmental policy. Regulations and strategic planning documents with mandatory, clearly defined standards and environmental performance indicators, as well as strict liability measures, are designed to ensure effective environmental protection. Increasing the effectiveness of measures taken is possible through the development of environmentally oriented interaction between authorities at various levels, business structures, non-profit organizations and associations, individual local communities and groups and civil society.

In conditions of geopolitical uncertainty and rapidly changing environmental conditions, as well as high socio-economic costs of unfavorable environmental conditions, priority should be given to the use of methods to anticipate and counter possible risks and minimize future negative effects. Environmental problems belong to the category of long-term risks, which complicates their management due to the difficulty of reaching a compromise in making political decisions, the consequences of which will manifest themselves after a certain time and at the moment may not seem to be of sufficient priority to the political and economic elite. More active involvement of the scientific community and practitioners of strategic risk management in the decision-making process is potentially intended to help find a compromise and limit the negative anthropogenic impact on the environment.

Successful Russian practices that demonstrate a new level of risk management deserve special attention in the context of environmental risk management. One of the significant steps towards managing climate change is the new Russian Climate Doctrine adopted in October 2023, according to which Russia must achieve carbon neutrality by 2060. It is important to note the features that form the basis of the new doctrine: special attention to NPOs, public organizations and business. The need to involve different structures and communities in addition to the state itself is emphasized, since the problem of climate change cannot be solved solely by one actor. For future changes, it is clear that the new doctrine means the prolongation of existing federal projects in the field of nature protection and climate change. And non-profit and public organizations will have to replicate the successful practices of climate policy programs. For example, the reforestation campaigns “Garden of Memory” and “Save the Forest,” which have planted more than 220 million trees throughout Russia since 2019, will likely develop and transfer the experience gained internationally.

Based on the practices listed above, a number of common themes should be identified for animation in other industries, both within the state and for the world as a whole.

1. Involving all key actors in network interaction in environmental risk management: government, business and the non-profit sector;

2. Non-triviality and creativity in environmental issues allows us to most successfully involve people in the agenda, which is necessary for successful risk management in the field of ecology;

3. The integration of innovative computer technologies and artificial intelligence allows for the implementation of higher quality and more effective projects and programs for assessing and managing environmental risks.

Thus, it should be noted that at the present stage, the risk potential of environmental problems is regularly increasing, which determines the actualization of the development of strategic risk management to manage environmental risks both at the global level and at the level of individual states and regions. As it was established, to counter them, it is necessary to implement a set of political, legal, economic and social measures to develop the state’s environmental policy. In conditions of high socio-economic costs of unfavorable environmental conditions, an important role in environmental risk management is given to the use of methods to proactively, minimize relevant risks and level out possible negative effects.

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References

[1] Aleksandrov S.V. Ecological disaster as a permanent phenomenon of modern society // International scientific research journal. 2021. Vol . No. 1 (103). Part 2, January. pp. 37–40.

[2] Ecological disasters: structural and functional analysis / Institute of Sociology of the Russian Academy of Sciences, Yanitsky O. N. // Official website of the Institute of Sciences of the Russian Academy of Sciences - 2013. P. 21 [Electronic resource]. URL : http :// www . isras . ru / publ . html ? id =2794 (access date: 10/13/2022)

[3] Timofeev A.D. Semantics of the concepts “Ecological crisis” and “Ecological catastrophe” // News of the Russian State Pedagogical University named after. A . AND . Herzen . 2015. No. 176. WITH . 132.

[4] Beck U. Risk society : On the way to another modernity / Trans. with him. V. Sedelnik, N. Fedorova. - M.: Progress-Tradition, 2000. P. 34.

[5] 2022 Disasters in numbers. [Electronic resource]. URL : https :// reliefweb . int / report / world /2022- disasters - numbers (date of access: 10/13/2023)

[6] Norman J Vig , Michael E Kraft. Environmental policy: new directions for the twenty-first century - DC CQ Press, 2017 – 456 p.

[7] Cappelli F. et al. The trap of climate change-induced “natural” disasters and inequality // Global Environmental Change. 2021. Volume 70. P. 2.

[8] Adger , WN Vulnerability // Global Environmental Change. 2006. 16(3). p. 268–281.

[9] O. Drakes, et al., Social vulnerability and short-term disaster assistance in the United States // International Journal of Disaster Risk Reduction. 2021. 53 (2). p. 7-8.

[10] Van Zandt, S., Peacock, W.G., Henry, D.W., Grover, H., Highfield, W.E., & Brody, S.D. Mapping social vulnerability to enhance housing and neighborhood resilience // Housing Policy Debate. 2012. 22(1). p. 29–55.

[11] Economic Losses, Poverty and Disasters 1998-2017. P 3 [Electronic resource]. URL: https :// www . preventionweb . net / files / 61119_credeconomiclosses . pdf (date access : 10/11/2022)

[12] Allianz Risk Barometer 2023. URL: https://www.allianz.com/en/economic_research/publications/specials_fmo/global-risk-barometer.html

[13] Adapt Now: A Global Call for Leadership on Climate Resilience. Washington // Rotterdam: Global Commission on Adaptation. 2019. September. P. 6. [Electronic resource]. URL: https :// gca . org / wp - content / uploads /2019/09/ GlobalCommission _ Report _ FINAL . pdf

[14] The United Nations world water development report 2021: valuing water; facts and figures. P. 2-3. [Electronic resource]. URL : https :// unesdoc . unesco . org / ark :/48223/ pf 0000375751

[15] R. F. Beng, et al. Pollution and health: a progress update // The Lancet Planetary Health. 2022. Vol 6. P 536.

[16] Climate change. URL: https://www.who.int/health-topics/climate-change#tab=tab_1

[17] K. Matsumoto. Climate change impacts on socioeconomic activities through labor productivity changes considering interactions between socioeconomic and climate systems // Journal of Cleaner Production. 2019. Vol 216. P. 528-541.

[18] Here's how heat waves can impact economies, as well as people and wildlife. URL : https :// www . weforum . org / agenda /2022/07/ heat - waves - economy - climate - crisis / (date of access: 10/15/2022)

[19] Global Risks Report 2023. [Electronic resource]. URL : https://www.weforum.org/publications/global-risks-report-2023/ (access date: 10/23/2023)

[20] Provisional State of the Global Climate in 2022 . [Electronic resource]. URL : https :// public . wmo . int / en / our - mandate / climate / wmo - statement - state - of - global - climate (date of access: 10/26/2022)

[21] Weather-related disasters increase over past 50 years, causing more damage but fewer deaths. [Electronic resource]. URL : https :// public . wmo . int / en / media / press - release / weather - related - disasters - increase - over - past -50- years - causing - more - damage - fewer (date of access: 10/26/2022)

[22] State report "On the state of protection of the population and territories of the Russian Federation from natural and man-made emergencies in 2016." – M.: Ministry of Emergency Situations of Russia. M.: FGBU VNII GOChS (FC), 2017, – 360 p.

[23] The global assessment report on biodiversity and ecosystem services. [Electronic resource]. URL : https :// ipbes . net / sites / default / files /2020-02/ ipbes _ global _ assessment _ report _ summary _ for _ policymakers _ en . pdf (access date: 10/26/2022)

[24] State of the Global Climate 2021. P 39 [Electronic resource]. URL : https :// library . wmo . int / index . php ? lvl = notice _ display & id = 22080#. YojzsXXP 02 y (date of access: 10/26/2022)

[25] Day of Eight Billion. [Electronic resource]. URL : https :// www . un . org / en / dayof 8 billion (access date: 10/26/2022)

[26] WMO Greenhouse Gas Bulletin No. 19: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2022. P. 2. [Electronic resource]. URL: https://library.wmo.int/ru/records/item/68532-no-19-15-november-2023 (access date: 11/20/2023)

[27] Tan, X., Liu, Y., Dong, H. et al. The health consequences of greenhouse gas emissions: a potential pathway // Environ Geochem Health. 2022. 44. P. 2955–2974.

[28] Magnan, AK, Pörtner , HO., Duvat, VKE et al. Estimating the global risk of anthropogenic climate change. Nat. Clim. Chang. 2021. No. 11. P. 879, 885.

[29] Climate Action Tracker. 2021. "Glasgow's 2030 credibility gap: net zero's lip service to climate action." The Climate Action Tracker. 11 November 2021. https://climateactiontracker.org/publications/glasgows-2030-credibility-gap-net-zeros-lip-service-to-climate-action/ (date access : 02/17/2023)

[30] Boehm S. et al. State of Climate Action 2022. P . 10. https :// climateactiontracker . org / publications / state - of - climate - action -2022/ (date of access: 02/17/2023)

[31] L. V. De Luca Peña et al. Towards a comprehensive sustainability methodology to assess anthropogenic impacts on ecosystems: Review of the integration of Life Cycle Assessment, Environmental Risk Assessment and Ecosystem Services Assessment // Science of The Total Environment. 2022. Volume 808, 152125. P. 2.

[32] The Global Climate Risk Index 2021 [Electronic resource]. URL: https://bvearmb.do/bitstream/handle/123456789/1306/Global%20Climate%20Risk%20Index%202021.pdf (date access : 03/28/2023)

[33] The Environmental Performance Index. [Electronic resource]. URL : https :// epi . yale . edu / (access date: 03/28/2023)

[34] Global Green Growth Institute (GGGI) Green Growth Index. [Electronic resource]. URL : https :// gggi - simtool - demo . herokuapp . com / (access date: 03/28/2023)

[35] World Risk Report 2023. [Electronic resource]. URL: https://weltrisikobericht.de/wp-content/uploads/2023/10/WRR_2023_english_online161023.pdf (access date: 09/28/2023)

[36] Sustainable Development Report 2023. [Electronic resource]. URL : https :// sdgs . un . org / gsdr / gsdr 2023 (date of access: 09/25/2023)

[37] Transforming our world: The 2030 Agenda for Sustainable Development. [Electronic resource]. URL: https://unctad.org/system/files/official-document/ares70d1_ru.pdf (access date: 03/25/2023)

[38] NP Simpson et al., A framework for complex climate change risk assessment // One Earth. 2021. No. 4. P. 493.

[39] Phillips, C. A. et al. Compound climate risks in the COVID-19 pandemic // Nature Climate Change. 2020. 10(7). P. 586–588.

[40] Lawrence, J., Blackett, P., and Cradock-Henry, N.A. Cascading climate change impacts and implications // Climate Risk Management. 2020. 29(81). P. 1-15.

[41] Haikola , S., Hansson, A., and Anshelm, J. From polarization to reluctant acceptance–bioenergy with carbon capture and storage (BECCS) and the post-normalization of the climate debate // Journal of Integrative Environmental Sciences. 2019. 16(1). P. 45–69.

[42] Orlova, L. N. Environmental risk management in the practice of economic activity of economic structures / L. N. Orlova // Waste and resources. 2020. T. 7, no. 2. P. 5.

[43] P. Cui, J. Peng, P. Shi et al. Scientific challenges of research on natural hazards and disaster risk // Geography and Sustainability 2 (2021). P. 222.

[44] YK Dwivedi et al. Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action // International Journal of Information Management. 2022. Volume 63. P . 34.

[45] Krui M., Galai D., Mark R. Fundamentals of risk management. – M.: Unity, 2011. P. 24.

VARIABILITY IN THE NUMBER OF DAYS WITH HAIL IN THE WARM HALF OF THE YEAR ON THE TERRITORY OF GEORGIA IN 1941-2021

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Abstract

Some results of a study of the variability of the number of days with hail in the warm half of the year (April-October) for 22 weather stations in Georgia from 1941 to 2021, on average for five climatic zones, which includes four climatic groups according to the Köppen classification, are presented. Zones I and III – warm oceanic climate/humid subtropical climate (Cfa): Zone I – Kutaisi, Mta-Sabueti, Senaki, Shovi, Zugdidi; Zone III – Kvareli, Lagodekhi, Telavi. Zone II – warm continental climate/humid continental climate (Dfa): Bolnisi, Gori, Khashuri, Marneuli, Pasanauri, Stepantsminda, Tbilisi, Tianeti. Zone IV – temperate oceanic climate (Cfb): Bakhmaro, Chakvi, Khulo. Zone V - temperate continental climate/ humid continental climate (Dfa): Bakuriani, Borjomi, Tsalka. The statistical characteristics of the following parameters were studied. H(I)…H(V) - average number of days with hail per meteorological station in the warm half of the year for climatic zones I...V, respectively. H(I-V) - average number of days with hail per meteorological station for all climatic zones. H(I)'…H(I-V)' - mean per decade rate of change of the H(I)…H(I-V) in 1941-1950 … 2011-2021. In particular, the following results were obtained. The smallest range of changes in H values is observed in the first climatic zone (0÷1.8), the largest - in the fifth (0÷8.3). The linear correlation between the studied parameters between individual zones vary from 0.27 (pair H(I) - H(IV), negligible correlation) to 0.55 (pairs H(II) - H(III) and H(II) - H(V), moderate correlation). The variability of the average ten-decade number of days with hail per weather station change from 0 (Zone IV, 2011-2021) to 5.9 (Zone V, 1941-1950). Trend of the mean number of days with hail per meteorological station year for all climatic zones in Georgia in 1941-2021 is quite satisfactorily described by a fourth power polynomial. The variability of H(I)'…H(I-V)' change from -1.48 in 1941-1950 to 2.09 in 2011-2021 (Zone V).

Keywords: natural disaster, hail, Köppen climate classification, statistical analysis

I. Introduction

Georgia is one of the most hail-prone countries in the world. Therefore, in this country, many works are devoted to the problem of hail damage, the basis of which is hail climatology. The study of the number of days with hail, both in general in Georgia and in its individual regions, has been carried out for many decades [1-11]. In particular, the features of the distribution of the number of days with hail in the warm half of the year for 15 climatic zones of Georgia in the period 1941-1990 were studied [3,11], data on damage from hail storms are provided [5,6,8,11], the variability of the number of days with hail and the connection of this variability with aerosol pollution of the atmosphere have been studied [11], etc.

In 2022-2023, work was carried out to prepare [12,13] and create [14] a systematized catalog for five types of natural disasters in Georgia (landslides, mudflows, hurricane winds, floods and hail).

In particular, using the data from this catalog, work was carried out on a statistical analysis of the number of days with hail in Georgia in 2006-2021 [15], analysis of damage from hail to agricultural crops in Kvemo Kartli (Georgia) [16], studying of long-term variability in the number of days with hail in Tbilisi (1891-2021) [17] and forecasting this variability until 2085 [18].

Our last paper [19] presents some results of a statistical analysis of data from 30 meteorological stations of Georgia on the number of days with hail in the warm half of the year in 1941-2021. In particular, the following results were obtained: data on the average and maximum values of the number of days with hail in 1941-2021, 1941-1980 are provided (first time period) and 1981-2021 (second time period); correlations between the studied parameters for the specified time periods were studied; it was found that in the second period of time, compared to the first, at 21 stations there is a decrease in the average number of days with hail, at 8 stations this number does not change, and only at one station there is an increase in the average number of days with hail; the dependence of the average and maximum number of days with hail on the terrain height was studied for 24 meteorological stations located at a level of less than 1500 m for the specified time periods; it was found that in the second period of time, compared to the first, the tightness of the correlation between the number of days with hail and the altitude of the area weakens.

This study is a continuation of work [19]. Some results of a study of the variability of the number of days with hail in the warm half of the year (April-October) for 22 weather stations in Georgia from 1941 to 2021, on average for five climatic zones, which includes four climatic groups according to the Köppen classification, are presented below.

II. Study area, material and methods

Study area is Georgia and their five climatic zones, including four climatic groups according to the Köppen classification (Fig. 1, Table 1).

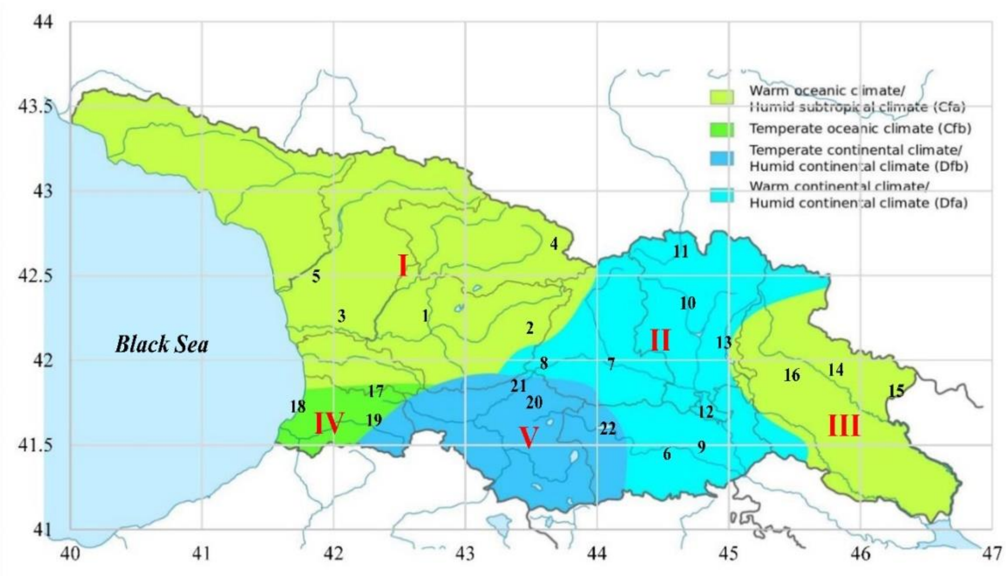


Figure 1: *Köppen climate classification map of Georgia.*
https://commons.wikimedia.org/wiki/File:Köppen_climate_classification_map_of_Georgia.svg

Table 1: *The number of meteorological stations, their coordinates, altitudes and the number of zones of their location (Fig. 1).*

N	Zone	Location	Lat, °N	Lon, °E	H,m	N	Zone	Location	Lat, °N	Lon, °E	H,m
1	I	Kutaisi	42.27	42.70	120	12	II	Tbilisi	41.70	44.83	437
2	I	Mta-Sabueti	42.20	43.50	2470	13	II	Tianeti	42.11	44.97	1100
3	I	Senaki	42.27	42.07	28	14	III	Kvareli	41.95	45.82	450
4	I	Shovi	42.70	43.68	1520	15	III	Lagodekhi	41.82	46.28	450
5	I	Zugdidi	42.51	41.87	100	16	III	Telavi	41.92	45.48	490
6	II	Bolnisi	41.45	44.54	550	17	IV	Bakhmaro	41.85	42.33	1950
7	II	Gori	41.98	44.11	588	18	IV	Chakvi	41.73	41.73	30
8	II	Khashuri	41.99	43.60	680	19	IV	Khulo	41.65	42.31	1044
9	II	Marneuli	41.49	44.80	420	20	V	Bakuriani	41.75	43.53	1700
10	II	Pasanauri	42.35	44.69	1050	21	V	Borjomi	41.85	43.41	850
11	II	Stepantsminda	42.65	44.64	1750	22	V	Tsalka	41.60	44.09	1450

As follows from Fig. 1 and Table 1, the distribution of meteorological stations by climatic zones is as follows. Zones I and III – warm oceanic climate/humid subtropical climate (Cfa): Zone I – Kutaisi (1), Mta-Sabueti (2), Senaki (3), Shovi (4), Zugdidi (5); Zone III – Kvareli (14), Lagodekhi (15), Telavi (16). Zone II – warm continental climate/humid continental climate (Dfa): Bolnisi (6), Gori (7), Khashuri (8), Marneuli (9), Pasanauri (10), Stepantsminda (11), Tbilisi (12), Tianeti (13). Zone IV – temperate oceanic climate (Cfb): Bakhmaro (17), Chakvi (18), Khulo (19). Zone V - temperate continental climate/ humid continental climate (Dfa): Bakuriani (20), Borjomi (21), Tsalka (22).

The work used catalog data [14] on the number of days of hail in warm period of year (April-October) for the above indicated meteorological stations in 1941-2021.

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods of random events and methods of mathematical statistics for the non-accidental time-series of observations [20-22].

The following designations will be used below: Mean – average values; Max - maximal values; Min – minimal values; St Dev - standard deviation; R^2 – coefficient of determination; R – coefficient of linear correlation; α - level of significance; the difference between two average values was determined using the Student's criterion with $\alpha \leq 0.05$; K_{DW} – Durbin-Watson statistic. The curve of trend is equation of the regression of the connection of the investigated parameter with the time at the significant value of the determination coefficient and such values of K_{DW}, where the residual values are accidental. If the residual values are not accidental the connection of the investigated parameter with the time we will consider as simply regression.

The degree of correlation was determined in accordance with [20]: very high correlation ($0.9 \leq R \leq 1.0$); high correlation ($0.7 \leq R < 0.9$); moderate correlation ($0.5 \leq R < 0.7$); low correlation ($0.3 \leq R < 0.5$); negligible correlation ($0 \leq R < 0.3$).

H(I)…H(V) - average number of days with hail per meteorological station in the warm half of the year for climatic zones I...V, respectively. H(I-V) - average number of days with hail per meteorological station for all climatic zones. H(I)'…H(I-V)' - mean per decade rate of change of the H(I)…H(I-V) in 1941-1950 … 2011-2021.

III. Results

The results in Fig. 2-5 and Table 2,3 are represented.

In Fig. 2 time-series of the mean number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021 are presented. In Table 2 statistical characteristics of Fig. 1 data is represented.

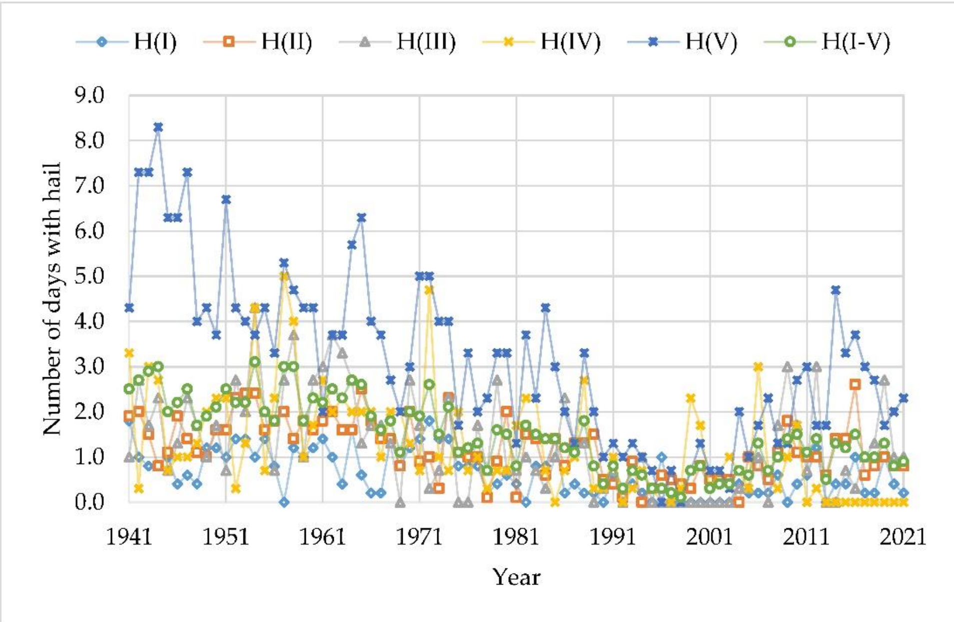


Figure 2: *Variability of the mean number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021.*

Table 2. *Statistical characteristics of the mean number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021. R_{min} = 0.22, α = 0.05*

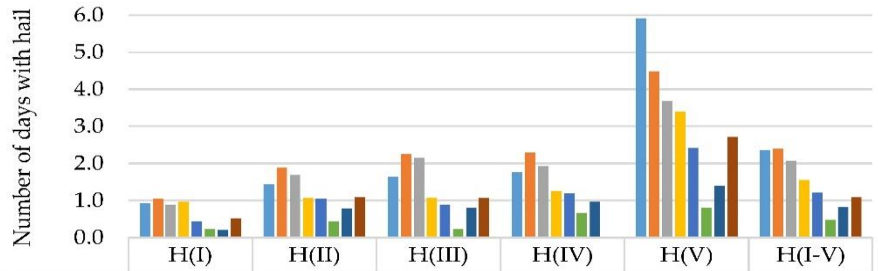
Variable	H(I)	H(II)	H(III)	H(IV)	H(V)	H(I-V)
Max	1.8	2.6	4.3	5.0	8.3	3.1
Min	0	0	0	0	0	0.1
Mean	0.6	1.2	1.3	1.2	3.1	1.5
St Dev	0.51	0.64	1.09	1.17	1.88	0.79
	Correlation Matrix					
H(I)	1	0.46	0.38	0.27	0.47	0.61
H(II)	0.46	1	0.55	0.33	0.55	0.73
H(III)	0.38	0.55	1	0.36	0.41	0.71
H(IV)	0.27	0.33	0.36	1	0.37	0.66
H(V)	0.47	0.55	0.41	0.37	1	0.85
H(I-V)	0.61	0.73	0.71	0.66	0.85	1

As follows from Fig. 1 and Table. 2, the distribution of the mean number of days with hail per weather station on the territory of Georgia is quite uneven. In particular, the smallest range of changes in H values is observed in the first climatic zone (0÷1.8), the largest - in the fifth (0÷8.3). In general, in Georgia the H values vary from 0.1 to 3.1. Average values of H changes from 0.6 (first zone) to 3.1 (fifth zone). Mean value of H(I-V) is 1.5.

In general, the linear correlation between the studied parameters is significant. At the same time, between individual zones the R values vary from 0.27 (pair H(I) - H(IV), negligible correlation) to 0.55 (pairs H(II) - H(III) and H(II) - H(V), moderate correlation).

From Fig. 2 it follows that in general the number of days with hail in Georgia for averaging intervals of 20-30 years tends to decrease. So, in 2001-2021 compared to 1941-1960 the average number of days with hail per meteorological station decreased as follows: H(I) from 1.0 to 0.4, H(II) from 1.7 to 0.9, H(III) from 1.9 to 0.9, H(IV) from 2.0 to 0.5, H(V) from 5.2 to 2.1, H(I-V) from 2.4 to 1.0. In 1991-2021 compared to 1941-1970 the average number of days with hail per meteorological station decreased as follows: H(I) from 0.9 to 0.3, H(II) from 1.7 to 0.8, H(III) from

2.0 to 0.7, H(IV) from 2.0 to 0.5, H(V) from 4.7 to 1.7, H(I-V) from 2.3 to 0.8.



	H(I)	H(II)	H(III)	H(IV)	H(V)	H(I-V)
1941-1950	0.9	1.4	1.6	1.8	5.9	2.4
1951-1960	1.0	1.9	2.3	2.3	4.5	2.4
1961-1970	0.9	1.7	2.1	1.9	3.7	2.1
1971-1980	1.0	1.1	1.1	1.3	3.4	1.6
1981-1990	0.4	1.0	0.9	1.2	2.4	1.2
1991-2000	0.2	0.4	0.2	0.7	0.8	0.5
2001-2010	0.2	0.8	0.8	1.0	1.4	0.8
2011-2021	0.5	1.1	1.1	0.0	2.7	1.1

Figure 3: *Variability of the mean decade number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021.*

The variability of the average ten-decade number of days with hail per weather station is as follows (Fig. 3): H(I) - weak variability from 0.9 to 1.0 in 1941-1980, a sharp decrease from 0.4 to 0.2 in 1981-2010, an increase to 0.5 in 2011-2021 ; H(II) - increase from 1.4 to 1.9 in 1941-1960, constant decrease from 1.7 to 0.4 in 1961-2000, increase from 0.8 to 1.1 in 2001-2021; H(III) - dynamics similar to the previous zone, growth from 1.6 to 2.3 in 1941-1960, constant decrease from 2.1 to 0.2 in 1961-2000, growth from 0.8 to 1.1 in 2001-2021; H(IV) - increase from 1.8 to 2.3 in 1941-1960, decrease from 1.9 to 0.7 in 1991-2000, increase to 1.0 in 2001-2010, decrease to 0 in 2011-2021; H(V) - continuous decrease from 5.9 to 0.8 in 1941-2000, increase from 1.4 to 2.7 in 2001-2021; H(I-V) - unchanged in 1941-1960 (according to 2.4), constant decrease from 2.1 to 0.5 in 1961-2000, increase from 0.8 to 1.1 in 2001-2021.

Trend of the mean number of days with hail per meteorological station in the warm half of the year for all climatic zones in Georgia in 1941-2021 is quite satisfactorily described by a fourth order polynomial (Table 3, Fig. 4).

Table 3. *Coefficients of the regression equation for the trend of the mean number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021.*

$\alpha(R^2) < 0.005;\ 0.01 < \alpha(K_{DW}) < 0.05$

$H = a \cdot X^4 + b \cdot X^3 + c \cdot X^2 + d \cdot X + e$, *X – number of years, 1-1941….81-2021*

Variable	a	b	c	d	e	R^2	K_{DW}
H(I)	1.67E-07	-1.33E-05	-0.00021	0.01231	0.924484	0.371	1.64
H(II)	-3.85E-07	8.40E-05	-0.00566	0.112247	1.148299	0.400	1.88
H(III)	-6.48E-07	0.000144	-0.00992	0.207335	0.959126	0.346	1.84
H(IV)	-8.21E-07	0.000145	-0.0086	0.162483	1.274063	0.329	1.99
H(V)	8.53E-07	-0.00011	0.005349	-0.19542	6.788456	0.659	1.55
H(I-V)	-1.41E-07	4.52E-05	-0.00353	0.053348	2.265498	0.719	1.56

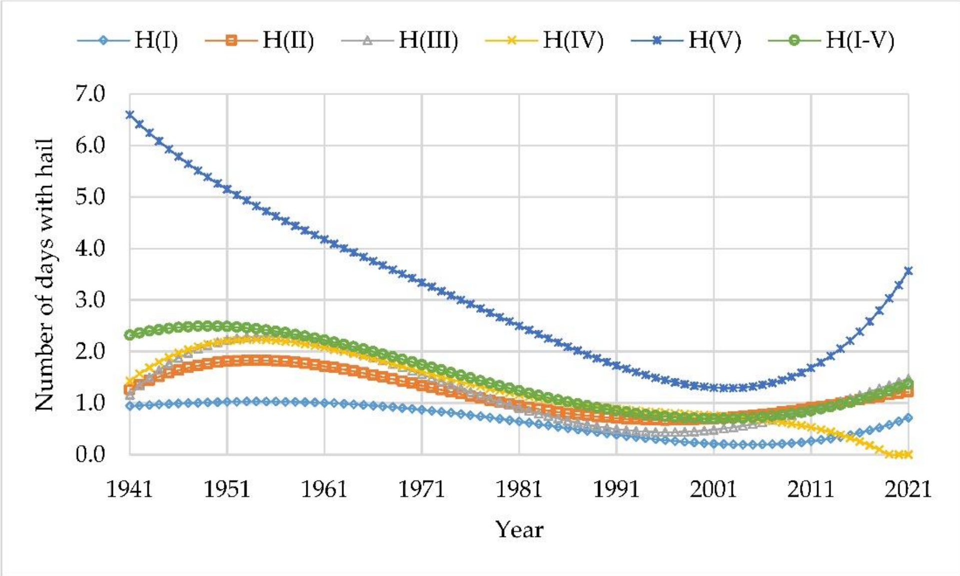
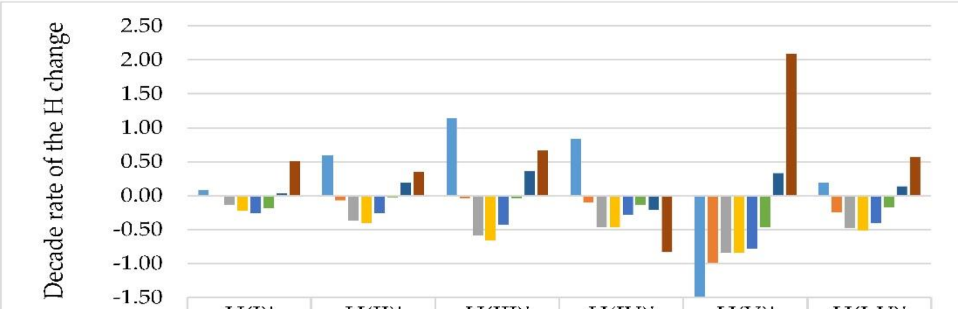


Figure 4: *Trend of the mean number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021.*

Using the data from Fig. 4 mean per decade rate of change of the mean number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021 are calculated (Fig. 5). H(I)'… H(I-V)' = 10·mean dH/dX, for X from 1 to 70 and = 11·mean dH/dX, for X from 71 to 81 (Table 3).



	H(I)'	H(II)'	H(III)'	H(IV)'	H(V)'	H(I-V)'
1941-1950	0.09	0.59	1.14	0.84	-1.48	0.20
1951-1960	-0.01	-0.07	-0.03	-0.10	-0.99	-0.25
1961-1970	-0.13	-0.37	-0.58	-0.46	-0.84	-0.47
1971-1980	-0.22	-0.40	-0.66	-0.46	-0.84	-0.51
1981-1990	-0.25	-0.25	-0.43	-0.28	-0.78	-0.40
1991-2000	-0.18	-0.02	-0.03	-0.14	-0.46	-0.17
2001-2010	0.03	0.20	0.36	-0.21	0.33	0.14
2011-2021	0.50	0.35	0.67	-0.82	2.09	0.57

Figure 5: *Mean per decade rate of change of the mean number of days with hail per meteorological station in the warm half of the year for climatic zones in Georgia in 1941-2021.*

The variability of average per decade rate of change of the mean number of days with hail per meteorological station is as follows (Fig. 5): H(I)' - from -0.25 in 1981-1990 to 0.50 in 2011-2021; H(II)' - from -0.40 in 1971-1980 to 0.59 in 1941-1950; H(III)' – from -0.66 in 1971-1980 to 1.14 in 1941-1950; H(IV)' – from -0.46 in 1961-1970 and 1971-1980 to 0.84 in 1941-1950; H(V)' - from -1.48 in 1941-1950 to 2.09 in 2011-2021; H(I-V)' – from -0.51 in 1971-1980 to 0.57 in 2011-2021.

IV. Discussion

In Georgia, as one of the most hail-prone countries in the world, many studies have been devoted to the study of hail processes, the basis of which is hail climatology. In 2023, a systematic catalog of five types of natural disasters in Georgia was created (landslides, mudflows, hurricane winds, floods and hail) [14]. From this catalog, data on the number of days with hail in the warm half of the year (April-October) was selected for 22 weather stations in Georgia from 1941 to 2021.

Our early studies used long-term continuous data (1941-1990) on number of hail days at 123 weather stations [3]. Accordingly, statistical characteristics were studied in detail, including the variability in the number of days with hail for 15 climatic zones of Georgia over the specified 50-year period of time. After 1990, the number of weather stations decreased significantly, and we proposed a different approach to studying long-term variations in the number of days with hail. Namely, an analysis of the variability of the number of days with hail averaged per meteorological station for five climatic zones, which includes four climatic groups according to the Köppen classification. In our opinion, this approach is promising and will be developed by us in the future.

V. Conclusion

In the future, it is planned to study in more detail time series of number of days with hail averaged per one meteorological station for indicated above 5 climatic zones (autocorrelation analysis, periodicity, etc.), as well as to conduct an interval forecast of the number of days with hail, taking into account periodicity, etc.

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References

[1] Kurdiani I.G. (1935). O grozakh i gradobitiyakh v Kakhetii. Tbilisi, Gruz. geogr. obshch. (in Russian).

[2] Gigineyshvili V.M. (1960). Gradobitiya v Vostochnoy Gruzii. Leningrad, Gidrometeoizdat, 123 s. (in Russian).

[3] Amiranashvili A.G., Nodia A.G., Toronjadze A.F., Khurodze T.V. (2004). Some Statistical Characteristics of the Number of Days with Hail into the Warm Half-Year in Georgia in 1941-1990. // *Trans. of Institute of Geophysics of Acad. of Sc. of Georgia*. v. 58, pp. 133-141, (in Russian).

[4] Amiranashvili A., Varazanashvili O., Nodia A., Tsereteli N., Khurodze T. (2008). Statistical Characteristics of the Number of Days with Hail Per Annum in Georgia. // *Trans. of the Institute of Hydrometeorology*. vol. 115, Tbilisi, pp. 427 – 433, (in Russian).

[5] Varazanashvili O., Tsereteli N., Amiranashvili A., Tsereteli E., Elizbarashvili E., Dolidze J., Qaldani L., Saluqvadze M., Adamia Sh., Arevadze N., Gventcadze A. (2012). Vulnerability, Hazards and Multiple Risk Assessment for Georgia. // *Natural Hazards*. Vol. 64, Number: 2021-2056.

[6] Elizbarashvili E., Amiranashvili A., Varazanashvili O., Tsereteli N., Elizbarashvili M., Elizbarashvili Sh., Pipia M. (2014). Hailstorms in the Territory of Georgia. // *European Geographical Studies*. Vol. 2, No. 2. pp. 55-69. (in Russian).

[7] Tatishvili M.R., Kartvelishvili L.G., Mkurnalidze I.P. (2016). Thunderstorm and Hail Processes over Georgian Territory. Against Global Climate Change Background. // *Journal of the Georgian Geophysical Society*. Iss. B, Physics of Atmosphere, Ocean and Space Plasma, vol. 19B, Tbilisi, pp. 111-119.

[8] Amiranashvili A., Dzodzuashvili U., Lomtadze J., Sauri I., Chikhladze V. (2015). Some Characteristics of Hail Processes in Kakheti. // *Trans. of Mikheil Nodia Institute of Geophysics*. vol. 65, Tbilisi, pp. 77 – 100, (in Russian).

[9] Amiranashvili A.G., Bliadze T.G., Jamrishvili N.K., Khurodze T.V., Pipia M.G., Tavidashvili Kh. Z. (2017). Comparative Analysis of the Distribution of Number of Days with Hail Per Annum on the Territory of Kakheti According to the Data of the Meteorological Stations and State Insurance Service of Georgia. // *Journal of the Georgian Geophysical Society*. *Issue: A. Physics of Solid Earth*, v. 20 A, Tbilisi, pp. 44 -56.

[10] Beglarashvili N., Janelidze I., Pipia M., Varamashvili N. (2020). Hail Storms in Kakheti (Georgia) in 2014-2018. Int. Sc. Conf. „Modern Problems of Ecology". Proc. v. 7. Tbilisi-Telavi, Georgia, 26-28 September, 2020. pp. 176-179.

[11] Kartvelishvili L., Tatishvili M., Amiranashvili A., Megrelidze L., Kutaladze N. (2023). Weather, Climate and their Change Regularities for the Conditions of Georgia. (Book). Publishing House "UNIVERSAL". Tbilisi. p. 406.

[12] Varazanashvili O.Sh., Gaprindashvili G.M., Elizbarashvili E.Sh., Basilashvili Ts.Z., Amiranashvili A.G. (2022). Principles of Natural Hazards Catalogs Compiling and Magnitude Classification. // *Journal of the Georgian Geophysical Society, Physics of Solid Earth, Atmosphere, Ocean and Space Plasma*, v. 25(1). pp. 5-11.

[13] Gaprindashvili G., Varazanashvili O., Elizbarashvili E., Basilashvili Ts., Amiranashvili A., Fuchs S. (2023). GeNHs: the First Natural Hazard Event Database for the Republic of Georgia. EGU General Assembly 2023, EGU23-1614.

[14] Varazanashvili O., Gaprindashvili G., Elizbarashvili E., Basilashvili Ts., Amiranashvili A., Fuchs S. (2023). The First Natural Hazard Event Database for the Republic of Georgia (GeNHs). Catalog, 270 p.

[15] Amiranashvili A., Basilashvili Ts., Elizbarashvili E., Gaprindashvili G., Varazanashvili O. (2022). Statistical Analysis of the Number of Days with Hail in Georgia According to Meteorological Stations Data in 2006-2021. Int. Conf. of Young Scientists "Modern Problems of Earth Sciences". Tbilisi, November 21-22, 2022. pp. 164-168.

[16] Amiranashvili A., Bolashvili N., Elizbarashvili E., Liparteliani G., Suknidze N., Tsirgvava G., Varazanashvili O. (2023). Statistical Analysis of the Number of Days with Hail and Damage to Agricultural Crops from it in Kvemo Kartli (Georgia). Int. Sc. Conf. "Geophysical Processes in the Earth and its Envelopes". November 16-17, 2023, pp. 133-137.

[17] Amiranashvili A., Elizbarashvili E., Varazanashvili O., Pipia M. (2023). Statistical Analysis of the Number of Days with Hail During the Warm Season in Tbilisi in 1891-2021. // *Trans. IHM, GTU.* vol.133. pp. 74-77. (in Georgian).

[18] Amiranashvili A., Elizbarashvili E., Pipia M., Varazanashvili O. Expected Changes of the Number of Days with Hail in Tbilisi to 2085. (2023). / Int. Sc. Conf. "Geophysical Processes in the Earth and its Envelopes". Proc., Tbilisi, Georgia, November 16-17, 2023. pp. 138-142.

[19] Amiranashvili A., Beglarashvili N., Elizbarashvili E., Varazanashvili O., Pipia M. (2024). Statistical analysis of data from 30 meteorological stations of Georgia on the number of days with hail in the warm half of the year in 1941-2021. // *Trans. of IHM, GTU*. vol. 135, pp. 32-38 (in Georgian).

[20] Hinkle D. E., Wiersma W., Jurs S. G. (2003). Applied Statistics for the Behavioral Sciences. Boston, MA, Houghton Mifflin Company, 756 p.

[21] Förster E., Rönz B. (1979). Methoden der korrelations - und regressionsanalyse. – Ein Leitfaden für Ökonomen. Verlag Die Wirtshaft Berlin. 324.

[22] Kendall M.G. (1981). Time-series. Moscow, 200, (in Russian).

CARTOGRAPHIC DISPLAY OF LANDSLIDE AREAS AND LANDSCAPE-GEOMORPHOLOGICAL PROFILING OF LANDSLIDE SLOPES IN THE TERRITORY OF THE CHECHEN REPUBLIC

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Abstract

Landslide processes are typical for the territory of the Chechen Republic. Loose deluvial material on the slopes created favorable conditions for the development of fertile soils and mountain agriculture in the main areas of residence of Chechens in the low-mountain and mid-mountain parts of the region. Population growth and the use of new technologies for land cultivation, irrigation, road construction - all this led to an increase in the load on the slopes and, as a consequence, to the activation of landslide activity. Mass destruction of houses and roads, often accompanied by human casualties, led to an outflow of population from the mountains to the plain, planned resettlements from areas of increased landslide danger. All this could have become one of the factors increasing social tension in the region in the late 1980s. Currently, the problem of reducing the risks of landslide danger in the region has not been solved, although there are detailed studies. The purpose of this work is to develop a comprehensive geoecological approach to landslide mapping using the landscape concept. To achieve this goal, two levels of mapping detail were used: 1) mesoscale mapping of landslides in the mountainous part of the territory of the Chechen Republic; 2) large-scale mapping in a key area in the low-mountain zone.

Keywords: landscape-landslide areas, relief, slope exposure

I. Introduction

Landslide processes are widespread in the mountains and are the result of a complex combination of exogenous and endogenous processes, which are also affected by economic activity. The study of landslides is relevant due to the increased risks associated with the implementation of projects for the recreational development of mountains, road construction, and communication lines. For a long time, the study of landslide processes was the prerogative of industry specialists, mainly engineering geologists and geomorphologists. The development of this field has attracted specialists studying not only geology and relief, but also vegetation, climate, and socio-economic processes in areas with landslide processes. Currently, landslide mapping cannot be done without reflecting on the maps the connections between natural components (relief, lithology, climate, vegetation), on the one hand, and natural and anthropogenic ones, on the other. This formulation of problems fits into the integrated direction of studying mountainous areas. The development of an integrated geoecological direction of landslide mapping is facilitated by modern methods of geoinformation mapping using high-resolution remote sensing materials obtained at certain intervals [3,9].

II. Methods

The work is based on field research materials combined with image interpretation. Landslide identification was based on images provided by the Google Earth service. It was a detailed analysis of images from different years together with field surveys that formed the basis for creating the database. The algorithm for identifying and analyzing landslide dynamics includes a detailed review of the territory of the Chechen Republic using images of different scales, plotting the identified landslide processes on maps in the GIS environment, verifying the established landslide areas using images from different years, and field surveys to establish the nature of landslide dynamics. As a result, about 2,400 landslide areas were identified, and after clarification and generalization, 1,800 landslides in the Chechen Republic were entered into the database. At the regional level, landslide mapping was based on establishing the locations of landslide manifestations, their confinement to slopes of different exposures and inclinations, as well as to certain landscapes. For this purpose, slope and aspect maps obtained using geoinformation modeling were used, as well as a landscape map created earlier in the field [4,12].

For a more detailed assessment of the complex of natural and natural-anthropogenic connections underlying landslide manifestations, landscape mapping of a typical landslide in the low-mountain zone of the Chechen Republic was carried out. For this purpose, a combination of field and office interpretation of large-scale photographs of different years was used, with the allocation of landscape contours and elements of the landslide body.

Landslide mapping varies in industry and complex scientific fields. The study of landslide phenomena has long been the prerogative of geologists and geomorphologists. There are more than 140 definitions of landslides in the literature, most of which are based on geological and geomorphological classification features. Over the past decades, many fundamental works have been published that consider landslides as geological bodies and complex slope processes [6]. As a rule, a classic landslide map included graphic tools and symbols that showed the geological and geomorphological features of the landslide: a breakaway wall, a pressure shaft, boundaries and composition of rocks, groundwater, etc. Much attention was paid to profiling in order to show the angles of inclination and bends, the relationship of geological rocks in the structure of landslides. In rare cases, information about vegetation was used as additional designations. Landslide mapping from a geoecological perspective shifts the focus to the entire host landscape, and the mapping is based not on the landslide bodies themselves, but on the so-called landscape-landslide complexes. A comprehensive study of landslide phenomena within the landscape concept takes into account the hierarchical structure of natural differentiation, which implies that in addition to studying individual landslide bodies, it is necessary to study the structure of natural complexes from local to regional levels of landscape differentiation. At the regional level, the study of landslides implies taking into account the altitudinal-zonal structure of landscapes. At the local level, mapping aims to reflect landscape-landslide complexes: in addition to the landslide body, mapping includes elements of the landscape structure and land use.

III. Results

The mountainous part of the Chechen Republic is characterized by a complex relief, the predominance of sedimentary rocks of different ages (from Neogene-Paleogene deposits in the foothills to Cretaceous and Jurassic in the foothills and highlands), subject to exogenous processes. The orographic features of the ridges and the composition of the sedimentary rocks that compose them, metamorphosed to one degree or another, reflect a consistent transition from low-mountain ridges to mid-mountain and mid-mountain basins (Rocky ridge) up to the highlands of the Lateral ridge.

Layer-by-layer visualization, with an emphasis on a particular relief characteristic, makes it possible to approach the analysis of landslide distribution from different angles. The maximum height of landslides identified in the Chechen Republic reaches 2700-2800 meters on the northern slopes of the Snow ridge (on the border with Dagestan). As will be shown below, these territories and landscapes are characterized by severe degradation of the soil and vegetation cover as a result of long-term grazing. The lowest absolute heights (about 100 m), to which landslides are confined, are typical for the slopes of the Gudermes Ridge. Here, landslide stimulation is associated with oil production areas. Most landslides are confined to the altitude step from 500 to 600 meters (193 landslides). The second maximum (146 landslides) gravitates towards heights of 1700-1800 meters.

Above 2000 meters, the number of landslides drops sharply due to worsening conditions for landslide formation: rocky slopes and a decrease in the thickness of the loose cover, a decrease in anthropogenic activity, etc. The slope of the surface determines the potential energy of the relief and the intensity of the processes of exogenous geodynamics, including landslides of various types. Slopes also increase from north to south along with the growth of absolute height.

The ratio of the areas of slopes of northern and southern exposures is approximately the same due to the sublatitudinal bends of river valleys and the extension of ridges. The distribution of landslides is also approximately the same, which indicates a weak influence of slope exposure on landslide formation processes; landslides are formed almost equally on slopes of different exposures, although there are some deviations [2,10].

As can be seen from figures 1 and 2, the greatest number of landslides (55%) are confined to slopes of warm exposures (southern, southwestern and southeastern). Although in terms of area, slopes of northern orientation prevail in the region, related to the northern slope of the ridges of the North Caucasus. All this emphasizes the complex nature of the confinement of landslides to slopes of various exposures and different steepness. The revealed regularities can be explained by the following hypotheses: 1) the slopes of southern exposures are less forested, and therefore less resistant to landslide formation; 2) the slopes of southern exposures were more developed, which means that the soil and vegetation cover was changed here, which could also lead to instability of the slopes to landslide formation. The combination of the terrain height, slope inclination and slope exposition generally provides the set of conditions that are inherent in landslide formation. Slope inclination, height and slope exposition are three variables, the combination of which allows us to assess the nature of the combination of factors and highlight the role of each of them in landslide formation. Exposition differences do not play a large role in the confinement of landslides to small angles of inclination (up to 150). This is generally consistent with the known geoecological regularities: the differentiating role of exposition is weak for slopes of small steepness. With increasing steepness, the role of "warm" exposures increases, where most landslides occur. The differentiation of landslide distribution by exposure is most noticeable in the altitude range of 500-2000 meters. Here, the difference in the intensity of landslides on the slopes of southern (frequently) and northern (comparatively less) exposures is especially noticeable. With increasing absolute altitude (more than 2000 meters above sea level), this pattern does not manifest itself [7,11].

Landslides in mid-mountain and low-mountain forest landscapes are a special phenomenon. Such landslides often occur in old forests far from settlements. A number of landslides can only be detected from photographs; there are no roads or paths to them, and they can only be reached along river beds. The most striking example of landslide manifestation in mountain-forest landscapes, transitional from mixed to broad-leaved, is a landslide near the Sharoargun river opposite the village of Ulus-Kert. The study area is characterized by the development of landslides, the formation and development of which are caused by the impact of mainly regional factors, such as the clay composition of rocks, physicochemical and deformational features of rocks, which determine their ability to quickly loosen and soften, neotectonic movements, bottom and lateral erosion, seismicity and hydrometeorological factors [1,5]. The scheme of the Ulus-Kert landscape-landslide complex reflects the main features of the integration into the altitudinal-zonal structure and the relationship with the dominant background natural complexes at the level of groups and types of landscapes. The landscape-landslide complex in plan has several longitudinal parts with different ages of landslide activation (Fig. 1,2). The upper wall of the breakaway is at an absolute height of about 770 m above sea level, and the discharge ends in the river bed at an altitude of 410 m. There are several classic landslide elements characteristic of a block landslide: 1 - landslide block; 2 - landslide terrace area; 3 - landslide failure wall; 4 - landslide pressure shaft ending in the river.

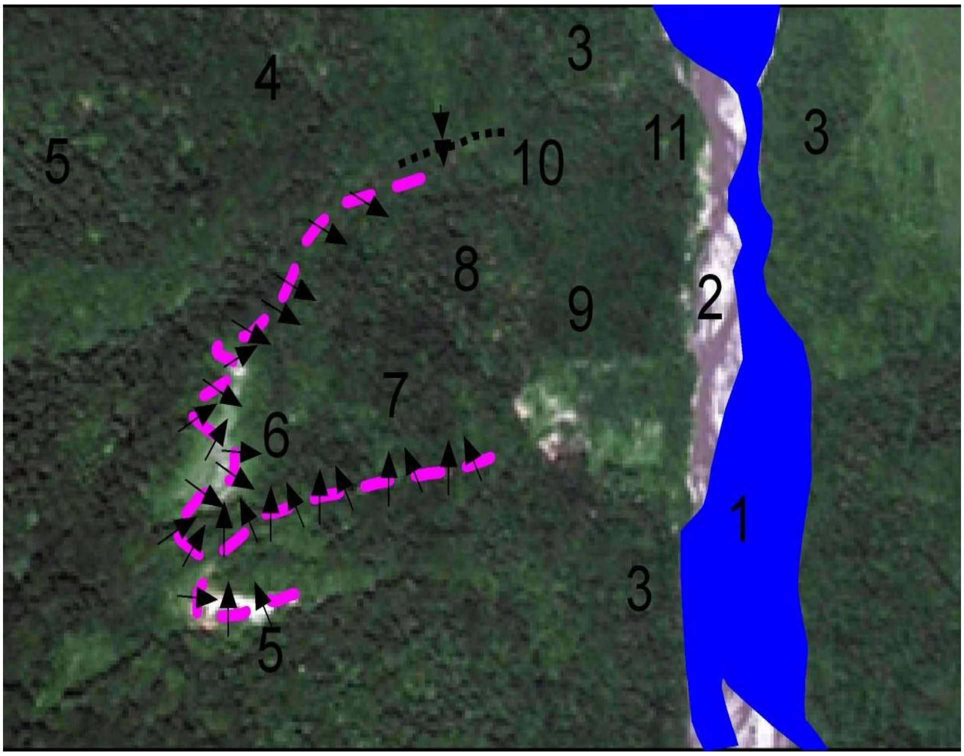

Figure 1: *Landslide in the bed of the Chanty-Argun River*

Legend: 1 - floodplain natural complexes (river bed), 2 - high floodplain overgrown with shrubs (about 10 years), 3 - slopes of river terraces under small forests of beech, hornbeam, hawthorn, maple; 4 - under hornbeam-beech forests with undergrowth of hawthorn and maple on mountain brown soils, 5 - beech forests on mountain brown soils, 6 - landslide failure wall, not sodded; 7 - area of the upper landslide terrace with clumps of beech undergrowth, less often hornbeam and hazel; 8 - section of the slope of settling, hummocky-ridged under the "drunken" forest of beech, hornbeam on pocket and skeletal brown soils, 9 - the site of the lower landslide terrace under blackberry thickets and willow clumps, 10 - lateral depressions of settling under beech forests, 11 - pressure landslide rampart under willow thickets with alder.

Analysis of landscape embeddedness shows that landslide formation sharply contrasts with mountain-forest landscapes, characterized by a relatively stable state of slopes. Landslide foci in this case are not typical for local geosystems. Rather, they characterize a certain shift in the regional ecobalance.

For a more comprehensive understanding of the landslide phenomenon, considering it as a landscape-landslide complex, it is necessary to take into account its embeddedness in the landscape structure (Fig. 3). [4,10]. Embeddedness in the landscape structure of the Kert landscape-landslide complex is characterized by the following features:

1) at the level of landscape types - a weakly contrasting ecotone position between the mountain-forest and mountain-forest-meadow-steppe zone, as well as between mountain-forest broad-leaved and mountain-forest mixed landscapes;

2) at the level of landscape groups: the borderline position between rocks with different proportions of clays and sandstones of Paleogene-Neogene age is weakly expressed. A more important factor is the location in the zone of tectonic faults and seismic dislocations;

3) at the level of landscape types - fragmentation of forest cover due to successional

differences in forests of different ages and phytomass reserves. The dynamics of landslides may seem quite simple: the deepening river bed washes away the right side and leads to instability of the slopes. However, field studies have shown that other factors may also play a role in the dynamics of landslides: increased seismicity, contrast of rocks forming the slope, succession processes in forests leading to an increase in above-ground phytomass with a decrease in sod cover in dead-cover beech forests, leading to the development of erosion centers, torrential precipitation at the beginning of summer, leading to instability of soils to erosion, etc. [9].

Figure 2: *Landslides Manifestation in the bed of the Chanty-Argun River (from the side of the village of Kert*

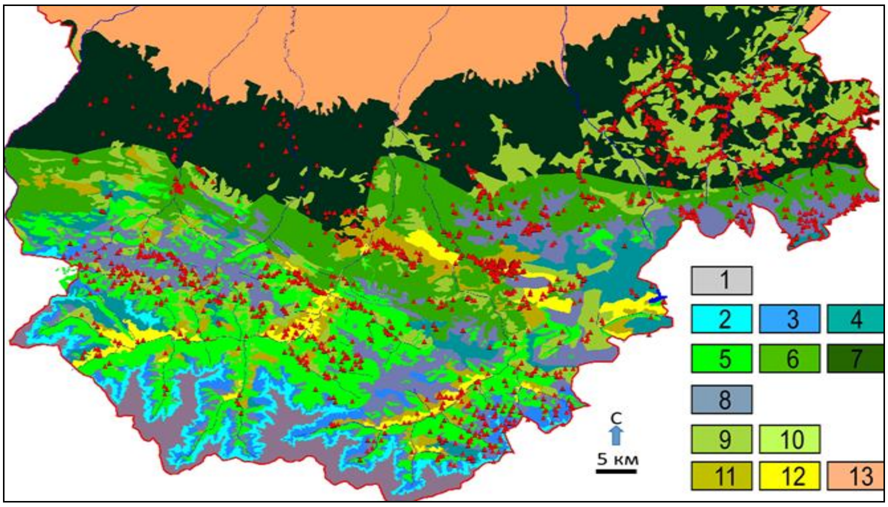

Figure 3: *Mapping of landslide areas in the mountainous part of the Chechen Republic*

Landscape differentiation at the level of landscape groups is determined by differences in rock types and relief. As can be seen from the map of landslide distribution by landscapes, the altitudinal-zonal distribution of landslides is discrete and uneven: areas of landslide concentration alternate with areas where they are practically absent.

IV. Discussion

An analysis of landslide distribution in the mountainous part of the Chechen Republic showed that the maximum height of the identified landslides reaches 2700-2800 meters on the northern slopes of the snow Ridge. The lowest absolute heights (about 100 m), to which landslides are confined, are observed on the slopes of the Gudermes ridge, which is associated with oil production. Most landslides (out of 1800 identified) are confined to the altitude interval from 500 to 600 meters (193 landslides). The second maximum (146 landslides) is confined to heights of 1700-1800 meters. The largest number of landslides is confined to slopes with a steepness of 25-350. The number of landslides on steep slopes (more than 350) decreases, but still remains relatively large. The largest number of landslides (55%) are confined to slopes with warm exposures (southern, southwestern and southeastern). This is due to the deforestation of the southern slopes and anthropogenic activity. Large-scale mapping of the landslide made it possible to identify the main elements of the landscape structure, which are at different stages of vegetation succession and experience different anthropogenic loads. The ecotone position between two types of landscapes (mountain-forest and mountain-forest-meadow-steppe) plays an important role in the dynamics of the Belgatoy landscape-landslide complex [8]. The dynamics of landslide processes in this area are largely due to the fragmentation of forest natural complexes due to selective deforestation, construction of plowed terraces and serpentine roads. Landscape-geomorphological large-scale profiling and mapping of specific landslide areas and landslides using GPS and GIS technologies (primarily, superimposing layers of geology, quaternary deposits, vegetation on a digital elevation model is an effective method for analyzing landslide mechanisms in specific natural and economic conditions. GIS modeling allows us to establish a number of patterns in the distribution of landslides. However, formal tools of morphometric analysis cannot fully explain the distribution of landslides and their nature. Field data are needed for this.

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References

[1] Beroev S. B., Khatsaeva F. M. Priority areas of environmental management of mountainous territories of the Republic of North Ossetia-Alania. Sustainable development of mountainous territories. 2019. T. 11, № 4(42). P. 429-435. DOI 10.21177/1998-4502-2019-11-4-429-435

[2] Bogdanova N. D., Razumova N. V., Razumov V. V. [et al.] Highways of the Chechen Republic under the influence of landslide processes. GeoRisk. 2023. T. 17, № 2. P. 40-61. DOI 10.25296/1997-8669-2023-17-2-40-61

[3] Gunya A. N., Gakaev R. A. Landscape approach to studying landslides (on the example of the mountainous territory of the Chechen Republic). Problems of regional ecology. 2024. № 1. P. 64-73. – DOI 10.24412/1728-323X-2024-1-64-73

[4] Gunya A. N., Gakaev R. A. The nature of landslide manifestations in low-mountain forest-steppe landscapes of the Chechen Republic. Theoretical and applied problems of landscape geography. VII Milkovsky readings: Proceedings of the XIV International landscape conference. In 2 volumes, Voronezh, May 17-21, 2023. Volume 1. Voronezh: Voronezh State University, 2023. P. 103-104. DOI 10.17308/978-5-9273-3692-0-2023-103-104

[5] Gunya A. N., Gakaev R. A., Badaev S. V. Landscape-landslide zoning of the territory of the Chechen Republic and measures to optimize the dynamics of landslide formation. News of the Dagestan State Pedagogical University. Natural and exact sciences. 2022. Vol. 16, No. 4. P. 30-37. DOI 10.31161/1995-0675-2022-16-4-30-37

[6] Gunya A. N., Petrushina M. N., Kolbovsky E. Yu. [et al.] Mapping of mid-mountain and high-mountain landscapes of the Chechen Republic to substantiate promising areas and axes of

development (based on the results of the VI North Caucasian complex expedition). Modern problems of geology, geophysics and geoecology of the North Caucasus: Collective monograph based on the materials of the X All-Russian scientific and technical conference in 2 parts, Grozny, October 14-16, 2020. Volume X. Part 2. Grozny: OOO Format, 2020. Pp. 342-350.

[7] Daukaev A. A., Dadashev R. K., Gatsaeva L.S., Gakaev R.A. Landslides and mudflows in the Chechen Republic: Synergetic aspects. IOP Conference Series: Earth and Environmental Science : International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering 2019. Vol. 378. Saint-Petersburg: Institute of Physics Publishing, 2019. P. 012084. DOI 10.1088/1755-1315/378/1/012084

[8] Daukaev A. A., Abumuslimov A. A., Gakaev R. A. Geological and Geomorphological Conditions for the Formation of Landslide Processes in the Mountainous Part of the Chechen Republic and Measures to Fight Them. The Second Eurasian RISK-2020 Conference and Symposium : Innovations in Minimization of Natural and Technological Risks. Minimization of the Most Prevalent Project Risks in the Oil and Gas Industry. Abstracts, Tbilisi, April 12–19, 2020. Tbilisi: AIJR Publisher, 2020. P. 64-65. DOI 10.21467/abstracts.93.36

[9] Kolbovsky E. Yu. Modeling of landscape locations (on the example of the territory of the Argun Museum-Reserve). North Caucasian complex expedition. Volume Issue 2. Grozny. Chechen State University, Academy of Sciences of the Chechen Republic, 2021. R. 7-42.

[10] Purekhovsky A. Zh., Gunya A. N., Kolbovsky E. Yu. Dynamics of high-mountain landscapes of the North Caucasus according to remote sensing data in 2000-2020. News of the Dagestan State Pedagogical University. Natural and exact sciences. 2022. T. 16, № 2. P. 72-84. DOI 10.31161/1995-0675-2022-16-2-72-84.

[11] Razumov V. V., Tlisov M. I., Molchanov E. N. [et al.]. Assessment of the natural potential and ecological state of the territory of the Chechen Republic. St. Petersburg: Gidrometeoizdat, 2001. 159 p.

[12] Tucker C.M., Hribar M.Š., Urbanc M., Bogataj N., Gunya A., Rodela R., Sigura M., Piani L. Governance of interdependent ecosystem services and common-pool resources. Land Use Policy. 2023. T. 127. C. 106575.

PRODUCTION ASSESSMENT ON EFFICIENCY OF USING ALTERNATIVE ENERGY SUPPLY OPTIONS

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Abstract

The article considers the theoretical and methodological basis associated with the study of problems in the field of increasing the efficiency of using alternative energy supply options for production. The potential of alternative energy and the possibility of its use in the energy supply of production has been investigated and evaluated. A mechanism for analyzing the use of alternative options in the energy supply of production has been developed. The reserve possibilities associated with the use of alternative energy sources have been studied. A model for evaluating the efficiency of using alternative energy sources is proposed. A mechanism has been developed to increase the efficiency of using alternative energy supply options for production.

Keywords: efficiency, alternative energy supply options, expenses, energy sources, cost, investment

I. Introduction

Nowadays, factors such as rapid development of industry and agriculture along with the increase in the number of people and the rising standard of living of the people, sharp increase in the number of energy-usage in households, increase of the demand for organic and inorganic fuels day by day proves to be challenging, and leaves us crossroads to face the global environmental problems, and to search for the application of new, ecologically clean energy sources, is causing scientists to think more often on the above matter.

Over time, it is inevitable that the countries of the world will face the exhaustion of non-renewable energy sources - oil, gas and coal. In addition to depletion of these sources, it is also observed that they are becoming more expensive. Also, the negative impact of traditional energy exploitation, burning and other factors on the ecological situation of our planet is becoming more and more evident. To prove the usefullnes of the transition, since the use of renewable energies as alternative energy sources is more ecologically efficient, it is necessary to investigate their sources, ways of using them, their effects on nature, and many more issues as they have become very relevant in the current period. Wind, solar, wave and hydrological energy of small rivers are just such sources and their potential possibilities are limitless and inexhaustible. What we mentioned above reflects the relevance of the topic [3].

II. Methods

The economic indicators of using alternative energy sources are somewhat more expensive than the economic indicators of using traditional energy sources. Turkish scientist Muhammet Kayfeci has investigated some of the renewable energy sources in detail. The first area observed in this regard will be solar energy. Solar energy is radiant energy produced by the conversion of hydrogen into helium at high pressure and heat in the core of the sun. The amount of energy generated by the sun in 1 second is more than the amount of energy used by society. The world receives only one billionth of the energy from the sun. The volume of solar rays entering the earth's surface is 0-1100 W/m2. According to the researches of Muhammet Kayfeci, we can concentrate the application of solar energy in 2 groups.

Group I – Conversion of heat obtained from solar energy into electrical energy

Group II – Direct conversion of solar energy into electrical energy

In the system belonging to group I, heat is first obtained from solar energy. In addition to using this heat energy directly, it can also be used in electricity production. In group II, solar rays are directly converted into electrical energy through systems mentioned as Photogalvanic. The most basic system investigated here in connection with our topic is the application of the system mentioned as solar panels or photovoltaic panels. These panels are semiconductor materials that directly convert sunlight falling on their surfaces into electrical energy. These panels are mostly square and round and have a surface area of about 100 cm2 and a thickness of 0.2-0.4 cm. When light falls on the surfaces of the panels, an electric voltage is generated at their ends. In this regard, the source of the electric energy provided by the panel is the solar energy falling on the surface. Many panels are placed parallel to each other to increase the volume of generated energy. The structure in this form is called a photovoltaic model. These models create systems that provide energy from several W to MW. The productivity of panels used for obtaining solar energy varies according to the type of materials used in production.

15%-17.5% in monocrystalline structures

12%-14% in polycrystalline structures

In siliceous structures, a productivity of 5%-8% is created. [5]

Associate Professor Sabahatdin Unalan divided the use of solar energy into 3 parts according to the limits of heat during his research:

- Low heat level (below 150°C) – used for salt production, heating of buildings, drying of crops in the farm.
- Medium heat level (150-600°C) – start small motors and generate electricity with steam generator
- High heat level (600 °C and more) – electricity production, creation of exotic substances, use of solar ovens.

Currently, the technical potential of wind energy in the world is calculated as 53,000 tWts/year. The most important parameter in calculating the amount of energy generated using wind power is wind speed. From this point of view, the amount of wind energy that can be produced is expressed in the following form:

$$P = \frac{1}{2}\rho A V^3 \tag{1}$$

P – amount of energy produced;

A – Rotor swept area;

ρ – air mass density;

V – air velocity.

Rick DeGunther, a graduate of Stanford University, considered the following alternative energy source in his research. The aim of these studies is to identify different renewable energy sources and discover the possibilities of their effective use.

Biomass, which is the main source of energy in many parts of the world, is the biological mass formed as a result of plants converting solar energy into chemical energy through photosynthesis. Biomass energy is the type of energy produced as a result of using biomass waste by burning it or going through different procedures. Biomass energy sources include 3 elements, which are part of the daily life of 1/3 of the world's population. They include natural products, animal manure, industrial and household waste. Turning waste into usable energy has very little negative impact on the environment.

Hydroelectric power - water in lakes, seas or rivers evaporates under the influence of the sun, and the resulting water vapor moves and falls on the slopes of mountains in the form of rain and snow, feeding water basins. Here, the production of energy consists of the energy generated during the movement of a large amount of water from a certain height to a lower level, using turbines to bring it into the form of mechanical energy.

There are 3 systems for using wave energy. A Shoreline system is a system fixed on the seashore, easy to maintain and does not require underwater electrical wiring. The OVC system is located under water, and as a result of the wave hitting the system, the water level rises, the air level is compressed, and the turbine rotates and electricity is produced. The pendular system is a cube-shaped system with one side facing the sea. The cover placed on it moves back and forth under the influence of the wave and produces electricity (2). Jenny Hayward and Peter Osman in their article "The potential of wave energy" suggested that wave energy is important and proposed 3 devices for its use. The point absorption device is located in the depths of the water and moves as a result of the pressure generated regardless of the direction of the wave movement and energy is produced. A device called linear absorption has large propellers relative to the height of the wave and rotates depending on the speed of the wave and produces energy. The device called Terminator works only due to the waves in the direction in which it is installed.

Determining the kWh costs resulting from the application of different technologies makes it possible to compare those technologies and determine which one is more efficient (5). The calculation of the cost of energy production is as follows:

$$C_e = [CI + (M \cdot CI \cdot V_u)] \div (P \cdot h \cdot V_u) \tag{2}$$

C_e-cost of energy production (USD/kW);
CI-initial cost of installation;
M-maintenance costs (annual interest on initial cost of installation);
V_u-the number of useful years that can be used;
P-installed power (kW);
h-annual usage hours [6].

Along with the positive aspects of alternative energy types, there are also negative aspects and they are reflected in Table 1.

Table 1: *Advantages and disadvantages of energy types*

Types of energy	Advantages	Disadvantages
Sun	It is an inexhaustible, abundant, cheap, non-dependent resource	The constant absence of sunlight, the lack of sunlight during the winter months and the absence of it at night
The wind	It is found freely in the atmosphere, its price does not increase over time, maintenance and use costs are low	The initial investment cost is very high, there is a mismatch between supply and demand, and it is noisy
Geothermal	Productivity is more than 95%, lack of meteorological dependence, minimum area requirement	Lack of portability, cannot be produced everywhere
Hydroelectricity	No waste during production, high productivity, cheap energy production	The cost of creating a HPP is high, it affects the climate where it exists, and it affects animals and plants.
Biomass	The possibility of storage, the possibility of using everywhere, not causing acid rain	Release of methane gas that can affect the ozone layer, high demand for water.
Wave	It is infinite, has no impact on the environment, the possibility of turning salt water into fresh water	A system must be built for each wave height, it is noisy, and maintenance costs are expensive.

Another criterion is the evaluation of the investment in the field of alternative energy, where there are 3 methods.

Payback period – It is used to calculate how many years the initial investment will be returned

Net Present Value (NPV) - if the present value of the amount of money received in the future is greater than the amount of the initial investment, the project will be implemented.

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - \dot{I} \quad (3)$$

CF_t- cash flow at the end of year t

İ- initial investment

r- discount rate/required rate of return on investment

n- duration of the project

Internal rate of return (IRR) is an indicator of the net cost for the project equal to zero. It covers the situation where the costs are equal to the future cash flows.

III. Results

Thus, the following are the conclusions and suggestions we have obtained thanks to our research:

1) The development of the alternative energy market will create conditions for the formation of the need for specialized personnel not only in this field, but also in repair, assembly, logistics and sales - new jobs will be opened.

2) An entrepreneur who applies renewable energy systems will not incur additional costs for obtaining energy from the state and will make a profit as a result.

3) In order to increase the efficiency of using solar energy in the production process, the use of PV panels, the panels should be placed at an inclination angle of 25°, and in order to minimize the amortization period, which has the ability to pay 80% of the consumer demand, including the number of sunny and windy hours in our country. However, I suggest the establishment of systems in this field, the implementation of transfers by the state to entrepreneurs, and the creation of photovoltaic systems with monocrystalline structure from wave and hydroelectric power in regions with abundant water bodies, as well in the places where industrial enterprises are located.

IV. Discussion

I. Study of backup possibilities related to the use of alternative energy sources.

Below is the trend of the cost of production of 1 kWh of energy between (2014 –2022).

According to the forecasts of the International Renewable Energy Agency, it is estimated that by 2025, the costs incurred for the production of 1 kWh of energy will decrease by 30-50%. Also, it is thought that the investment volume for 1 kW will decrease from the level of 5000-6000 US Dollars to the level of 3500-4000 US Dollars.

Naturally, the decrease in investment and production costs will lead to the establishment of new systems in this field and the opening of new jobs. In particular, the development of the alternative energy market will create conditions for the formation of the need for specialized personnel not only in this field, but also in repair, assembly, logistics and sales. The International Renewable Energy Agency reports that 10 million people are currently working in this field. In the last 4 years, the number of workers working in the fields of solar and other energy production has doubled, and it is planned that 24 million people will be employed by 2030. The distribution of employees by fields is as follows [2]

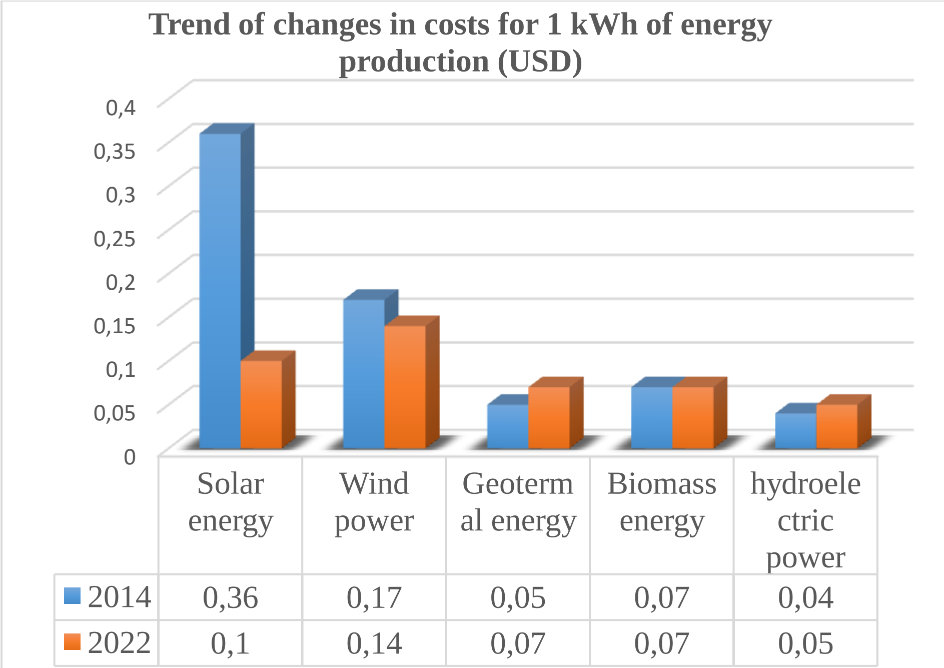

Figure 1: *The trend of change in the costs incurred for the production of 1 kWh of energy provided by the IRENA organization.*

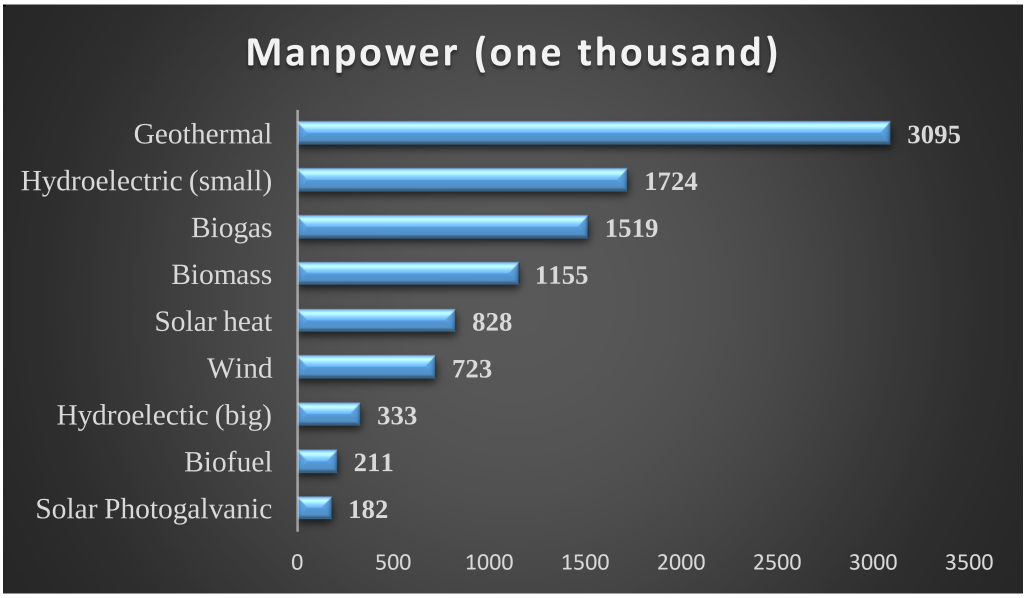

Figure 2: *Number of employees working in the field of alternative energy*

II. The efficiency of using alternative energy sources evaluation model

As a result of our research, we have identified a number of positive and negative aspects of renewable energy sources. Currently, the most widely used solar energy systems around the world have a certain economic benefit, both economically and environmentally. First of all, let's note that photovoltaic panels used for obtaining solar energy are monocrystalline, polycrystalline and thin-layer silicon crystals. [4] To determine the efficiency that those panels give us, the calculation of the hourly ray coming to the horizontal surface is initially calculated by the formula (4):

$$\dot{I}_{TE,s} = \dot{I}_{be,s} + \dot{I}_{de,s} + \dot{I}_{re,s} \tag{4}$$

In this calculation, the hourly solar radiation arriving at the horizontal surface $İ_{TE,s}$ (kVth/m2)), direct (or direct) rays falling on the surface $İ_{be,s}$ (kVth/m2), scattered rays $İ_{de,s}$ (kVth/m2) and $İ_{re,s}$ (kVth/m2) are defined as the sum of reflected rays. In Liu and Jordan's model, the calculation of direct (or direct) solar radiation falling on the surface is determined by the formula (5):

$$İ_{be,s} = İ_{b,s} R_b \quad (5)$$

Here $İ_{b,s}$ (kVth/m2)is the hourly amount of direct rays falling on the horizontal surface, and , R_b is the energy conversion factor of that ray.

Calculations on electricity production based on the sun's rays falling on the earth's surface have been carried out. As a result of these calculations, the total collector area $A_k(m^2)$, hourly electricity production $E_s(kWts)$ (6), daily electricity production $E_{gün,n}(kWts)$ (7), monthly electricity production $E_{ay,i}(kWts)$ (8) and annual electricity production $E_i(kVts)$ are given in equations (9)

$$E_s = İ_{TE,s} * A_k * \eta^* \quad (6)$$

$$E_{g,n} = \sum_{s=5:00}^{19:00} E_s \quad (7)$$

$$E_{a,i} = \sum_{n=1}^{y} E_{gün,n} \quad (8)$$

$$E_i = \sum_{i=1}^{12} E_{ay,i} \quad (9)$$

Here, the s-index indicates the time at which the calculations are made, the n-index indicates the number of days in a year, the i-index indicates the month in which the calculations are made, and the y-index indicates the number of days in a month η* the electricity production of the panel due to the heat from the sun [8]

In our article above, we mentioned that the use of solar energy systems has both economic and environmental benefits. First, let's consider its environmental efficiency and do the math. As we know, a certain amount of CO2 emissions are released into the environment during the production of heat or electricity using traditional fuels.

Solar photovoltaic systems are used to reduce this and for a healthier environment. As a result of the application of those systems, the amount of CO2 emission avoided in general was calculated in the equation $T_{avoided - CO_2}$ (kg CO_2) (10), the produced emission factor $n_{CO_2}(\frac{kgCO_2}{kwts})$. The produced emission factor is given below (Table 2), and the product of the annual energy production volume and the production rate of the corresponding fossil fuel indicates how much CO_2 emissions are prevented.

During the production of photovoltaic panels, the average emission factor is 3,301$(\frac{kgCO_2}{kwts})$ and is negligible and is marked as n_{PV-CO_2}.

The emission factor $T_{PV-CO_2}(kgCO_2)$ (11), the amount of avoided CO_2 T_{CO_2} $(kgCO_2)$ during the construction of those systems is (12) is shown in the equation, and the power of the overall built photovoltaic system is expressed as $P_g(kWt)$.

Table 2: *Produced emission factor*

Fuel type	Emission factor $(\frac{kgCO_2}{kwts})$
Natural gas	0.201
Oil	0.266
Brown coal	0.327-0.414
Stone coal	0.322-0.358

$$T_{avoided-CO_2} = E_{il} * n_{CO_2} \quad (10)$$

$$T_{PV-CO_2} = n_{PV-CO_2} * P_g \quad (11)$$

$$T_{CO_2} = T_{avoided-CO_2} - T_{PV-CO_2} \quad (12)$$

The next efficiency we will consider is economic. The first area to be calculated is depreciation. Depreciation is denoted by t (year), in equation (13) the initial construction cost G (dollars), the total PV cost G_{PV}, the land cost G_{land} for the creation of solar energy systems is calculated in proportion to the total profit level.

$$t = \frac{G + \text{Gland} + G_{PV}}{K_{top}} \tag{13}$$

The monthly, total, LEIQ, and total local product profit to be obtained during the construction of photovoltaic systems are expressed by formulas (14), (15), (16), (17), respectively. Before moving on to the calculations, it should be noted that wholesale electricity prices $F_{k-1,i}$ is a variable parameter, so different results are always obtained. When calculating the profit to be obtained, the increase in electricity prices is assumed to be approximately 10%. In this regard, the "m" coefficient, which takes into account the increase, was mentioned in the calculation 3.11 regarding the electricity price.

$$F_{k,i} = F_{k-1,i} * (1 + m) \tag{14}$$

$$F_{i-ort} = \frac{\sum_{k=1}^{z} F_{k,i}}{z} \tag{15}$$

$$K_{ay,i} = E_{ay,i} * F_{i-ort} \tag{16}$$

$$K_i = \sum_{i=1}^{12} K_{ay,i} \tag{17}$$

In the formula (14), the electricity sales price for any month is calculated with $F_{k-1,i}$. In the above formulas, the k-index is the number of years, the z-index is for determining the estimated depreciation period as a year, and the i-index is the number of months. As a result of the calculation by formula (15), the annual average electricity price is determined according to the estimated amortization period for each month. [7]

According to the law of unlicensed electricity production, the amount paid by the state for each kilowatt of energy produced with alternative energy and sold to the grid $F_{LE\dot{I}Q}$significantly positively affects the amortization period in economic and technical matters. If the total LEIQ profit is K_{t-leiq}, the electricity consumption according to the consumption demand is shown as $E_c(kVts)$, the total profit from the LEIQ is calculated as follows:

$$K_{t-leiq} = F_{leiq} * (E_i - E_c) \tag{18}$$

PV panels, which provide the production of electricity from solar power plants to the grid, provide state subsidies for each kW if they are produced locally. If we express that paid aid as F_{local}, then the total local profit obtained will be as follows.

$$K_{t-leiq} = F_{local} * (E_i - E_c) \tag{19}$$

As a result of this final calculation, the total efficiency or gain obtained from the use of GES is equal to the sum of the gain obtained from the use of LEIQ, the use of domestically produced PV, and the prevention of the emission factor that jumps into the environment.

$$K_t = K_{t-leiq} + K_{t-leiq} + K_i + K_{CO_2} \tag{20}$$

$t = (G + +G_{PV})/[(F_{local} * (\sum_{i=1}^{12} \sum_{n=1}^{y} \sum_{s=5:00}^{19:00} \mathrm{I}_{TE,s} * A_k * \eta^*)) + (F_{leiq} * \sum_{i=1}^{12} \sum_{n=1}^{y} \sum_{s=5:00}^{19:00} \mathrm{I}_{TE,s} * A_k *$
η∗))+i=112(i=112n=1ys=5:0019:00ITE,s∗Ak∗η∗∗k=1zFk−1,i∗1+mz+i=112n=1ys=5:0019:00IT E,s∗Ak∗η∗∗nCO2−nPV−CO2∗Pg∗FCO2] (21)

$\eta^* = \mathrm{I}_{TE,s}/(\frac{12*3600}{\pi} G_{sc}(1 + 0.033 \cos\frac{360n}{365})*[\cos\varphi \cos\delta\,(\sin\omega_2 - \sin\omega_1) + \frac{\pi(\omega_2-\omega_1)}{180} \sin\varphi \sin\delta]) * (\eta_r -$
$\mu((T_a + (PN\c{C}\dot{I} - 25^{\circ}C)\frac{I_{TE,s}}{1000}) - T_r))$ (22)

G_{sc} − constant sunlight
PNÇİ – Normal operating temperature of the panel($^{\circ}C$)
η_r − performance indicators of the PV system during the test (%)
T_r − The temperature at which the PV system is tested

$\mu -$ Thermal coefficient of PV system

As a result of the calculations, it was determined that if the average monthly solar energy falling on 1 m^2 of surface is 120-130 kW, then the photovoltaic system used in the GES with a total power of 100 kW is placed at an angle of inclination of 30° and the productivity is 14-15%, and it produces approximately 70,000 kW annually. produces electricity (22). In this case, the amortization period of that PV system is determined to be 10 years (21). The entrepreneur who built this system would have made a profit of approximately 17,000 dollars because he did not buy 70,000 kW of electricity from the state grid. Also, with the construction of this system, 13,873 kg of CO_2 emission factor is prevented from being thrown into the environment. [1]

There are two computer simulations used in this area. One is called RetScreen and the other is called Enhanced simulation. Both simulations were used for systems with a power of 100 mW in areas with 1200-1800 kW of solar energy per 1 m^2 of horizontal surface annually, and the results are listed in Table 3.

The reasons for the differences resulting from the use of both simulations are that the developed simulation, unlike RetScreen, takes into account the increase in the price of electricity production, the amount of CO_2 produced by PV production, the land costs related to the construction of PV systems, and other parameters. The use of this simulation is considered to be more effective because the developed simulation provides conditions for obtaining more extensive, detailed and reliable results.

Table 3: *The results of the simulations used*

Parameter	RetScreen	Advanced simulation	Offset (%)
$E_i(kWts)$	142.000	144.572	-1.8
$T_{CO_2}(ton)$	28.5	29	-1.8
$t(i)$	7.2	7.0	2.7

As we mentioned above, there are monocrystalline, polycrystalline and thin-layer silicon crystal types of photovoltaic systems. Their efficiency differs from each other. Let's consider which one is more efficient:

1) When we use thin-film silicon crystal PV panels, to build a system with 1000 panels with a power of 100 kW, it will cost approximately \$85,000, additional installation costs of \$97,000, and land costs of \$68,950, for a total cost of \$250,950. happens. Since the prices of thin-film silicon crystal PV panels are more expensive than polycrystalline panels, it causes us to invest an additional \$19,000. At this time, we can produce 45,000 kilowatts of electricity annually. A total profit of \$18,000 is obtained during the application of a thin-film silicon crystal PV system, the amortization period is 14 years, and the amount of CO2 emissions avoided is 8,000-9,000 kg.

2) When monocrystalline PV panels are used, the total cost under the same requirements is \$245,000. However, due to the high productivity of this type of PV panels, the volume of electricity production has changed and increased compared to polycrystalline panels. As a result of the application of such a system, more than 72,000 kilowatts of electricity is produced annually and \$22,000 in profit is obtained. The amortization period is reduced to 11 years, and a total of 14,000 kg of CO2 emissions are prevented.

3) As a result of research on polycrystalline PV panels, it was determined that the amortization period is 9-10 years and it has the ability to satisfy more than 80% of the proposed demand.

Table 5: *Amortization periods that occur as a result of changes in inclination angles in the conditions of meeting consumer demand*

$E_i(kWts)$	Lack of government support for CO_2 mitigation and the use of locally produced PV panels						Availability of government support for CO_2 mitigation and use of locally produced PV panels					
Angles of inclination	20	25	30	35	40	45	20	25	30	35	40	45
186.000	8.60	8.58	8.65	8.78	8.98	9.25	8.53	8.51	8.58	8.71	8.90	9.18
203.000	8.54	8.52	8.60	8.72	8.90	9.16	8.44	8.42	8.49	8.61	8.79	9.05
222.000	8.11	8.09	8.16	8.27	8.44	8.68	8.01	7.99	8.06	8.17	8.34	8.57

Also, the creation of such a hydroelectric power plant is important in terms of environmental protection. Thus, by selling the energy obtained from here to another enterprise or company, the CO_2 emission factor thrown into the environment using fossil fuels of that area is prevented.

References

[1] Gary L. Johnson. Wind Energy Systems Manhattan, KS, May 19,2005- 449 s.

[2] Jenny Hayward, Peter Osman. The potential of wave energy. Canberra Australia published by CSIRO, mart 2011, - 18 s.

[3] HydroPower report – A guide for Developers and Investors by Internatioanl Finance Corporation. Stuttgart, Germany, 2017- 120 s.

[4] Merve Gültuna. Simulation of photovoltaic power plan; Techno-economic and environmental optimization – Bursa, 2015, 121 s.

[5] Muhammet Kayfeci. Alternatif Enerji Kaynakları. İstanbul, 2011- 57 s.

[6] Rethinking energy 2017 by IRENA. Abu Dhabi, 2017- 130 s.

[7] Rik DeGunther. Alternative Energy For Dummies. Wiley Publishing, Inc. Indianapolis, Indiana, 2009- 388 s.

[8] Sebahattin Ünalan. Alternatif Enerji Kaynakları. İstanbul, 2010- 66 s.

MUDFLOW HAZARD IN THE ARGUN RIVER BASIN: ASSESSMENT AND MAPPING

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Abstract

Mudslides, as well as the manifestation of landslides, rockfalls, desertification of the territory, seasonal floods, hail, are one of the negative natural processes that manifest themselves in the mountainous regions of the republic, damaging communications. Villages are also formed in parts of areas that economically represent only areas of mountain grazing, are poorly populated or not populated at all, but nevertheless do not lose their relevance and, like other inhabited areas, require studying the manifestations of natural processes. The amount of precipitation and the level of moisture in the mountainous part of the republic are the highest, so the influence of moisture on the surface shapes is the most significant here. The territory of the Argun River basin is located in a zone of 5-7-point seismicity, which increases from north to south. The most populated Chechen inclined plain and the northern slopes of the Greater Caucasus are located in a zone of increased seismic activity. An assessment of the possible activation of mudflow processes as a result of climate change is given. The conducted qualitative analysis of changes in meteorological factors influencing the formation of mudflows (precipitation, temperature regime) in the region according to data from various weather stations. An increase in air temperature and an increase in the amount of precipitation — both average annual values and values for the warm and cold period - have been revealed; the tendency of glaciers to retreat is clearly observed. A study of climate change over a long period shows that mudflow activity in the Argun River basin has increased significantly.

Keywords: mudflow processes, climatic changes, precipitation, temperature regime.

I. Introduction

The borderline natural and geographical position of the republic at the junction of the large European plains and the powerful mountain system of the Greater Caucasus determines many of its features. All elements of the natural landscapes here are formed under the influence, on the one hand, of the barrier role of the mountain system from the south, as a result, subtropical warm air masses do not penetrate into the territory of the republic, moisture intake to the flat part from the air basins of the Black and Mediterranean Seas decreases. On the other hand, the complete openness from the north, north—west and east to the penetration of Arctic, Atlantic and continental Siberian, Central Asian air masses in different periods of the year determines the aridity of the northern and moisture-sufficiency of the foothill plains of the republic with a generally high level of solar insolation.

The combination of all these factors determines the vegetation cover and fauna and, with their participation, the formation of landscapes over the previous millennia, which we see in the republic from north to south today. The variety of natural landscapes and, accordingly, soil-climatic, orographic and other conditions in the republic, from the northern lowlands to the snow-covered highlands in the south, create favorable conditions for human activity. Within the republic, he can choose a place of residence in a wide variety of natural conditions, which in many places have unique properties that contribute to health, its restoration and longevity. Tectonically— it is a large monocline complicated by anticline folds, the largest of which are the Benoy in the east and the Dattykh between the Fortanga and Assa rivers in the west. Reaching a width of up to 30 km in the western part, the Black Mountains noticeably narrow to the east, where their width does not exceed 12-15 km. The system of low-mountain ranges of the Black Mountains is composed of Cretaceous and Paleogene limestones, marls and sandstones, which are easily exposed to surface (exogenous) destruction. As a result, the Black Mountains have soft, rounded outlines. The ridges are low, the prevailing heights are 1000-1100 meters, they represent a series of mountain folds gradually descending to the north. Transverse valleys formed by numerous rivers and longitudinal depressions divide the Black Mountains into a number of separate mountain ranges. River valleys often expand, and the mountains surrounding them seem to recede, forming vast basins in places. The largest of these basins in the Black Mountains is located at the confluence of the Chanta-Argun and Sharo-Argun rivers, near the village of Chishki. From the foot to the peaks, the Black Mountains are covered with forest, which gives them a dark color from afar. Hence their name. The Black Mountains represent a zone of foothills. The actual mountainous part of the republic is located on the northern slope of the Greater Caucasus.

In the sedimentary thickness of the Caucasian Ridge, strong and easily destructible rocks alternate, which led to their division into a number of longitudinal ridges. Ridges were formed where resistant rocks were exposed, and valleys separating them arose in places where less durable rocks spread. The pasture Ridge (next to the south of the Black Mountains) has a complex structure. In the western part, it forms two, and in some places three parallel ridges. Strata of Upper Cretaceous limestones, dolomites, marls are exposed to the south by a steep cliff, and in the north they fall gently at a slight angle (up to 140). Many peaks of the Pasture Range rise to a height above 2000 meters. The next one to the south is a Rocky ridge, which is especially distinguished by its asymmetry: the southern slopes are steep, almost vertical in many areas, and the northern ones are gentle. In the valleys of the rivers crossing the limestone ridges, narrow and extended sections alternate.

In places where the river cuts into the solid limestone rocks composing the ridges, its valley has the appearance of a deep narrow gorge with steep rocky slopes. Even on a hot, sunny day, twilight and coolness reign in the gloomy gorges of such a gorge. The river valleys in the gaps between the ridges are completely transformed. Here, the mountains form vast light basins, elongated, as a rule, along the course of the river. Mountain villages and villages are usually located in such places convenient for settlement. Along the southern border of the republic stretches a chain of silvery-white snow-capped peaks of the Lateral Ridge, which in this area is a thousand meters higher than the Main Caucasian Ridge.

Between the Lateral Ridge and the Rocky One (to the north) is the North Jurassic intermountain basin, which reaches its greatest width to the west, within the Central Caucasus (up to 35 km) and within the republic is manifested by a number of separate basins: Galanchozhskaya, Itum-Kalinskaya, Sharoyskaya, Makazhoyevskaya. The lateral and Watershed (Main) ridges are composed of lower — Middle Jurassic Mesozoic clay shales. In the Chechen Republic, the links of the Lateral Ridge are the Pirikitelsky ridge with the peaks of Tembolt-Lam (Tebulos-Mta), Kamito-Dattakh-Kort (4271m), Donos-Mta (4178m) and the Snow Ridge, the highest point of which is Mount Diklos—Mta (4274 meters). Eleven peaks in Chechnya have a height of more than 4,000 meters. Tembolt Lam peak (4494 m above sea level) is the highest not only in Chechnya, but also in the entire Eastern Caucasus. Exogenous (external) factors that form the morphological appearance of the relief include: water, climate, fauna and flora, human activity, and the nature of rocks on the surface. Their influence is complex, zonal or altitudinal. In the Chechen Republic, the relief of the highest mountains in the south is directly determined by eternal snow and ice. The formation of mudflows in the Chechen Republic is due to a combination of geological, climatic and geomorphological conditions: the presence of seleforming soils, sources of intensive watering of these soils, as well as geological forms contributing to the formation of sufficiently steep slopes and channels.

II. Methods and material

Maecenas sedultriciesfelis [1].Sedimperdiet dictum arcu a egestas [2].

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III. Results and discussion

The Argun River basin is characterized by the complexity of the surface structure, which is associated with the tectonic structure and geological history of development. This has a decisive effect on orohydrography, climatic conditions, in particular precipitation and temperature conditions, which naturally contributes to a high probability of mudflow processes. The abundance of precipitation contributes to an increase in the moisture content of rocks, significantly increasing their mass and increasing the effects of gravitational forces on soil masses, this leads to the rupture of strong structural bonds in rocks, changing the consistency of soils to plastic and even fluid. Reduction of structural bonds in rocks on slopes, forming dynamic changes in slope landscapes.

In various regions of the republic, with abundant precipitation, only a small part of the moisture is infiltrated, and most of it quickly flows down the slope. In the areas of permafrost, rapid and deep thawing of frozen rocks in spring and summer favours the development of mudflows: on the slopes of the northern exposure to solifluction phenomena, on the southern ones — outflows, which, with abundant precipitation, can turn into active mudflows. Argun Gorge is one of the most dangerous mudslides in the Chechen Republic. The zone of occurrence of mudflow processes here are both the channels of numerous tributaries of the Argun themselves, as well as the channels of temporary watercourses, which, with prolonged precipitation, often turn into violent water-mud flows (Figure 1).

The physical and mechanical properties of the constituent territories of the Argun Gorge determine the features of their destruction during the active regime of atmospheric precipitation, the nature of which undergoes significant changes under the influence of ongoing changes in the planet's climate. Geological and geomorphological processes of exogenous origin depend on the resistance of rocks with different strengths to external influences. Our research has shown that over the past decade, there has been a significant intensification of mudflow processes in the study area due to ongoing climate changes.

The study area is composed of loose rocks of Neogene age that are easily susceptible to destruction, therefore even slopes and hollows with a small slope are potential zones of mudflow generation. The Argun River basin belongs to the zone of significant waterlogging, where the annual amount of precipitation is 700-1100 mm or more. Mudflows arising in the upper reaches of the Argun River basin consist of a mixture of water, clay and pebbles.

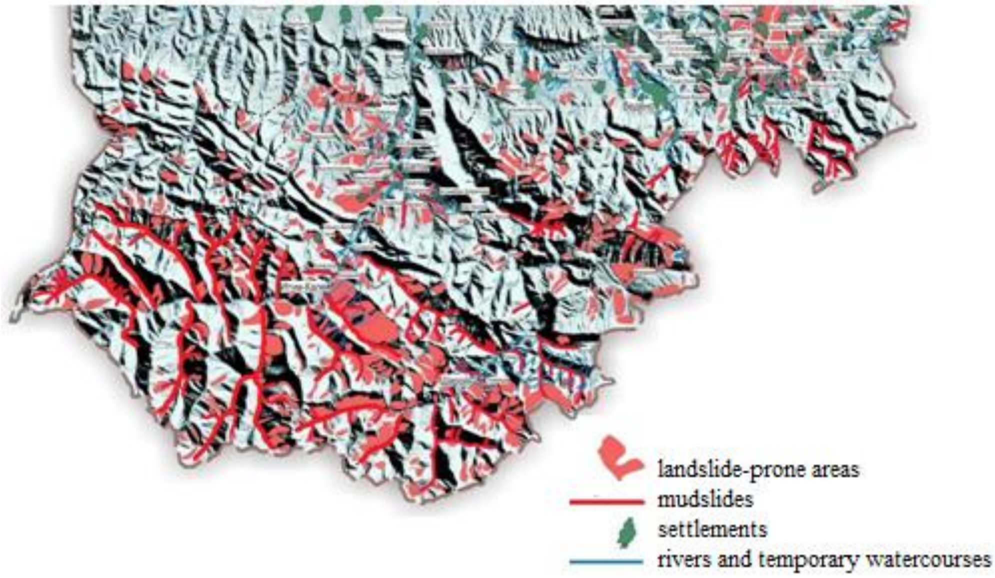

Figure 1: Map of catastrophic natural processes in the Chechen Republic

The ongoing mudflow processes in the Argun River basin belong to the rain by their genesis. The snow and glacial type of mudflow processes in the basin are manifested in the high-altitude part.

Sources of solid nutrition of mudflows can be: glacial moraines with or without loose filling; riverbed blockages and clutter formed by previous mudflows; woody and vegetative material. Sources of water supply for mudslides are: rains and downpours; glaciers and seasonal snow cover (during the melting period); waters of mountain lakes. Glacial mudflows are also characteristic of high-altitude basins with developed modern glaciers and glacial deposits, such as the upper part of the Sharo-Argun and Chanta-Argun rivers and their tributaries.

The main source of their solid nutrition are moraines, which are involved in the process of mudflow formation during the intensive melting of glaciers. The immediate causes of mudslides are also the intense melting of snow and ice, less often earthquakes. For the formation of mudflows, it is necessary to have: a sufficient number of products of rock destruction on the slopes of the basin; a sufficient volume of water to flush or demolish loose solid material from the slopes and its subsequent movement along the channels; a steep slope of the slopes and watercourse. The manifestation of mudflows forms the dynamics of the landscapes of the upper Chanta-Argun. The stability of subalpine and mountain-steppe landscapes is disrupted, the underlying rock is exposed, vegetation and a fertile layer flow down together with the mud mass, transferring subalpine and mountain-steppe landscapes into mudslides.

The prediction of glacial mudflow hazard is based on the identification of abnormal deviations in the characteristics of water and thermal regimes. For this purpose, information from hydrometeorological stations and posts located in this mountainous area is used. The forecast of glacial mudflow hazard consists in predicting in advance the possibility of a breakthrough of moraine and dammed lakes, as well as intraglacial reservoirs. According to the composition of the transferred solid material, mudflows are usually distinguished as follows: mudflows, which are a mixture of water and fine earth with a small concentration of stones (volume weight of the stream is 1.5–2.0 t/ m3); mudstone flows, which are a mixture of water, fine earth, pebbles, gravel, small stones; large stones are also found, but there are few of them, they sometimes fall out of the stream, then begin to move with it again (the volume weight of the stream is 2.1–2.5 t/m3); water-stone streams, which are a mixture of water with mostly large stones, including boulders and rock fragments.

The area of the upper reaches of the Sharo-Argun River basin is characterized by a fairly high mudflow activity. The area belongs to the waterlogging zones. Two factors affect the mode and amount of precipitation here: atmospheric circulation and the presence of high ridges of the Caucasus Mountains, which increase precipitation in its mountainous part.

Precipitation by season is characterized by great unevenness, due primarily to the intrusion of moist air masses into its limits, which are brought by the Atlantic cyclone. Since the influence of the Atlantic cyclone is manifested in the North Caucasus mainly in summer, the highest humidity and maximum precipitation are observed in May — July. At the same time, there is a sharp decrease in their annual number in the direction from south to north — from the mountains to the plains.

The amount of precipitation in the mudflow-prone zone of the Chechen Republic per year is 800-1000 mm or more. Mudflows arising in the upper reaches of the Sharo-Argun River basin consist of a mixture of water, clay and sand particles. The solution has the properties of a plastic substance. The stream seems to represent a single whole. Unlike a water stream, it does not follow the bends of the riverbed, but destroys and straightens them or passes over an obstacle. In places where there are significant riverbed slopes, the presence of loose material or clay, easily collapsing rocks, small sedimentary mudflows are formed caused by heavy rainfall of high intensity.

For the development of mudflow manifestations, in general, in the Argun River valley, hemorphological features contribute: a direct erosive-tectonic relief with a clear morphological reflection of the structural elements of the Montenegrin monocline, disturbed by the latest Neogene folding (anticline protrusions and flexures); the relief of the territory is relatively young, actively forming in the confrontation of intense modern uplifts and progressive erosion. increased precipitation from 800 to 1000 mm or more. per year. Moistening of rocks increases their mass and, accordingly, the effect of gravitational forces on them, which is accompanied by a weakening of the strength of structural bonds in them, a change in the consistency of soils to plastic and even fluid.

All this leads to a decrease in the strength (friction and adhesion) of rocks on the slope. With the stormy nature of precipitation, only a small part of the moisture is infiltrated, and most of it quickly flows down the slope. Also, the formation of mudflows is associated with anthropogenic activities in mountainous areas, construction and excessive grazing of livestock. According to the genesis, three main genetic types of mudflows are distinguished: rain, snow and glacial, which have a zonal distribution and significant differences in the mudflow regime.

The genetic type of mudflows characterizing the area means the dominance of this type of mudflows here and does not deny the presence of rare mudflows of a different genesis. In the mudflow basins of the Argun River, all three genetic types of mudflows are formed, but most of them belong to the rain type. Sedimentary mudflows are formed here with the transformation of mudstone flows as they move along the main channels. Spring activation of slope processes is possible during the cold autumn-winter season, when precipitation accumulates in the form of snow, initially falling on the unfrozen ground. In this case, during the spring snowmelt, almost all the meltwater will be filtered into the ground.

The precipitation of snow on the frozen ground will cause the predominance of surface runoff over infiltration during its spring melting. The nature of the influence of waterlogging is largely determined by the physical and mechanical properties of rocks, the peculiarities of their change when changing the regime of climatic indicators. Thus, under the same weather, the development of exogenous geological processes occurs differently in rocks of different genesis, with different strength properties, weathering rate, water resistance, etc.

IV. Conclusion

Mudflow processes are widely developed in the territory of the Argun River basin in the Chechen Republic in the medium- low-mountain and high-mountain terrain. With active climate change, it is possible to predict a high degree of mudflow activity in the high-mountain and medium-low-mountain parts of the Argun River basin.

The main factors of the predicted mudflow activity are climatic, to a lesser extent anthropogenic and technogenic. When abnormally heavy heavy rains fall, high activity of mudflow processes is possible in the middle-low mountains, in the middle and upper reaches of the Argun River and its tributaries. Mudflow activity is highly likely to occur in mudflow-prone areas in the middle and upper reaches of the rivers of the Argun River basin. Linear infrastructure objects (highways, communication lines, power lines, gas pipelines), parts of settlements fall into the impact zone of landslides. Climatic changes that have led to a change in meteorological indicators to an increase in atmospheric precipitation will lead to an increase in the number of mudflow processes in the Argun River basin.

References

[1] Bajrakov I. A., Gakaev R. A., Idrisova R. A. (2007) Vliyanie sovremennyj ehkzogennykh processov na landshafty Chechenskoj Respubliki. V sbornike: Materialy po izucheniyu Chechenskoj Respubliki Mezhvuzovskij sbornik nauchnykh trudov.. Bajrakov I. A., k.b.n., docent CHGU (otv. redaktor), Bolotkhanov EH. B., k.t.n., docent CHGU (zam. otv. redaktora), Avtaeva T. A., k.b.n., docent CHGPI, Idrisova R. A. st. prerod. kafedry fizicheskoj geografii CHGU. Nazran', 2007. S. 14–34.

[2] Gakaev R. A., Gacaeva L. S., Kerimov I. A. Geomorfologicheskie osobennosti vozniknoveniya selej v gornoj chasti Chechenskoj Respublike. V sbornike: Mezhdunarodnaya nauchnaya konferenciya, posvyashchennaya 500-letiyu armyanskogo knigopechataniya i 65-letiyu osnovaniya SNO EGU Materialy Mezhdunarodnoj nauchnoj konferencii, posvyashchennoj 500-letiyu armyanskogo knigopechataniya i 65-letiyu osnovaniya SNO EGU. 2013. S. 93–96.

[3] Kerimov I. A., Gakaev R. A., Daukaev A. A., Gacaeva L. S. Seli i ikh proyavlenie v Chechenskoj respublike. V sbornike: Sovremennye problemy geologii, geofiziki i geoehkologii Severnogo Kavkaza. Materialy Vserossijskoj nauchno-tekhnicheskoj konferencii. otvetstvennyj redaktor Matishov G. G.. Groznyj, 2011. S. 433–434.

[4] Perov V. F. Selevedenie : ucheb. pos. / V. F. Perov. – Moskva : MGU, 2012. – S. 274

[5] Panov V.D., Bazelyuk A.A., Lur'e P.M. Reka Terek. Gidrografiya i rezhim stoka. — Rostov-na-Donu: Donskoj izdatel'skij dom, 2015 607 s.

[6] Chernomorec S. S. Selevye ochagi do i posle katastrof : monografiya / S. S. Chernomorec. – Moskva : Nauchnyj mir, 2005. – 184 s.

NATURAL DISASTERS, ECOSYSTEMS AND POLLUTION: PROBLEM ANALYSIS AND DECISION-MAKING FOR SUSTAINABLE DEVELOPMENT

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Abstract

This article presents a systematic approach to the study of the relationship between natural disasters, ecosystems, pollution and sustainable development. The study is based on an analysis of the available data, as well as the latest scientific research in this area.

The main focus is on identifying the main causes of natural disasters and their impact on ecosystems, which, in turn, leads to environmental pollution and disruption of sustainable development. The authors of the study propose a number of recommendations and measures that can be used to make informed decisions and move towards sustainable development in a disaster risk environment.

In particular, the study focuses on the importance of taking environmental and social factors into account when developing disaster risk management strategies and ensuring sustainable development. This includes the development and implementation of effective measures to reduce the environmental impact on the environment, ensuring social justice and equality, as well as strengthening institutional mechanisms and structures for risk management.

In order to achieve sustainable development, it is necessary not only to eliminate the consequences of natural disasters, but also to prevent their occurrence in the future. This requires an integrated approach that will take into account the interrelationships between various factors such as climate change, environmental processes and socio-economic conditions.

Keywords: natural disasters, ecosystems, pollution, sustainable development

I. Introduction

The page of human history is filled with numerous natural disasters such as earthquakes, floods, hurricanes and fires. These natural disasters not only threaten people's lives, but also have a serious impact on the environment and ecosystems. In recent years, the frequency and intensity of natural disasters have increased significantly, which poses serious challenges to sustainable development.

One of the main problems associated with natural disasters is the destruction of ecosystems. As a result of strong earthquakes or floods, natural habitats of animals and plants can be completely destroyed. This leads to loss of biodiversity and imbalance in ecosystems. Many species of animals and plants that are important links in food chains and perform important functions in ecosystems may be completely extinct. This can have serious consequences for other species and for the ecosystem as a whole [1].

Another problem associated with natural disasters is environmental pollution. Chemical emissions such as oil spills or emissions of hazardous substances from factories can occur during natural disasters. This pollutes the soil and water, which can lead to poisoning of animals and plants. In addition, environmental pollution can cause long-term consequences, such as deterioration of soil and water quality, which leads to limited resources and complication of ecosystem restoration processes.

The impact of natural disasters on ecosystems can also lead to disruption of the cycles of nutrition and processing of organic matter. Natural processes, such as the decomposition of plant waste, contribute to the formation of nutrients for plants and further enrich the soil. However, as a result of natural disasters, these processes can be disrupted. For example, flooding can erode soil, carry away plant residues and deprive ecosystems of the necessary resources for restoration.

For sustainable development, it is necessary to develop strategies and take measures to adapt ecosystems to natural disasters. Important steps are the creation of nature reserves and nature reserves to preserve unique ecosystems in which species that require special attention for conservation can develop. It is also necessary to strengthen natural barriers, such as forest belts or reef systems, to mitigate the effects of floods and hurricanes.

However, it must be borne in mind that natural disasters cannot be completely prevented. Therefore, it is equally important to develop strategies for ecosystem restoration after natural disasters. Not only agriculture, but also forestry, fishing and other economic activities must take into account the long-term effects of natural disasters and their impact on ecosystems. [6,7].

Solving the problem of the impact of natural disasters on ecosystems requires an integrated approach and concerted efforts by States, international organizations and the public. It is necessary to conduct scientific research and develop new technologies to adapt ecosystems to changes caused by natural disasters [1]. In addition, the general public should be aware of the importance of ecosystem conservation and the need to take decisive steps for sustainable development. If we don't do this today, the consequences will be catastrophic for our planet and future generations.

II. Methods

One of the important methods that researchers can use is modeling. Using computer models, it is possible to study various scenarios of the impact of natural disasters on ecosystems, as well as to assess the effects of pollution on various components of the environment. Modeling makes it possible to predict the possible effects of climate change carry out risk calculations and develop appropriate strategies.

When studying this issue, a key aspect is the analysis of the impact of natural disasters and pollution on ecosystems. Various types of ecosystems are used for research - polar and temperate, oceans, forests, water resources and other elements of the natural environment. The assessment of the devastating impact of natural disasters makes it possible to determine the vulnerability of various ecosystems and develop effective measures for their conservation and restoration. An important aspect of the article is also the analysis of environmental pollution and its impact on ecosystems.

The study of various sources of pollution, including industrial emissions, vehicle emissions, as well as agriculture, allows us to identify priority areas in the fight against this problem. The main goal is to develop innovative and environmentally friendly technologies, as well as to take measures to reduce emissions and improve energy efficiency.

III. Results

Natural disasters such as hurricanes and floods are one of the main threats to ecosystems and sustainable development. In recent years, the number of such disasters has increased, which has led to serious environmental pollution and destruction of ecosystems. Pollution is also a serious problem, as it is caused by various sources such as industrial enterprises and transport. For many centuries, people have had the most negative impact on the state of the environment around us.

To date, the ecological state of the planet has forced humanity to begin taking active actions to maintain the current state and gradual recovery.

Table 1 shows us the dynamics of greenhouse gas emissions by sector from 2005 to 2021.

Table 1: *Greenhouse gas emissions by sector (million tons of CO2 equivalent per year).*

The name of the indicator	2005	2010	2015	2016	2017	2018	2019	2020	2021
Energy industry	1590,2	1639,3	1611,3	1606,1	1637,0	1688,7	1682,3	1593,8	1679,1
Industrial processes and the use of industrial products	212,4	204,4	228,0	228,2	243,0	252,3	246,3	254,4	259,5
Agricultural industry	106,8	105,4	110,5	114,3	115,2	114,8	116,4	118,8	121,3
Land use, land-use change and forestry	-539,7	-698,1	-583,3	-615,3	-602,9	-577,3	-550,5	-557,6	-506,6
Wastes	61,2	70,3	83,4	85,5	87,5	89,5	91,4	94,1	96,7
Total, excluding land use, land use change and forestry	**1970,6**	**2019,4**	**2033,3**	**2034,0**	**2082,6**	**2145,2**	**2136,5**	**2061,1**	**2156,6**
Total, taking into account land use, land use change and forestry	**1430,9**	**1321,3**	**1450,1**	**1418,7**	**1479,7**	**1568,0**	**1586,0**	**1503,5**	**1650,0**

A source: https://rosstat.gov.ru [5]

Greenhouse gas emissions are one of the main factors affecting climate change and ecosystem disruption. They lead to global warming, which, in turn, causes many negative consequences for the environment and sustainable development of countries.

Sectoral analysis of greenhouse gas emissions shows that the most significant sources are energy, industry and transport. Each of these sectors contributes to the disruption of the ecosystem and ultimately affects the sustainable development of the country.

Energy - Greenhouse gas emissions from energy account for approximately 73-77% of total emissions. This is mainly caused by the use of fossil fuels - coal, oil and natural gas. This leads to atmospheric pollution and disruption of climatic conditions.

Industry - Emissions from industry account for about 12-16% of total emissions. Atmospheric pollution occurs due to the use of fuel in the production process, as well as due to emissions from industrial enterprises.

Transport - The transport sector is the third largest source of greenhouse gas emissions. This is due to the use of cars, airplanes and other modes of transport that emit carbon dioxide and other harmful substances into the atmosphere.

The impact of greenhouse gas emissions on the sustainable development of countries is manifested in the following aspects:

Climate change - greenhouse gas emissions cause global warming, which, in turn, leads to negative consequences such as sea level rise, droughts, floods, hurricanes, etc. These climate changes disrupt the ecosystem and make it less habitable.

Economic losses - greenhouse gas emissions also have a negative impact on the economy. For example, they can lead to lower crop yields, which in turn can cause food shortages and economic problems. In addition, climate change can lead to damage to infrastructure such as roads and bridges, which can also affect the country's economy.

In order to minimize the impact of greenhouse gas emissions and ensure the sustainable development of countries, it is necessary to take measures to reduce emissions and adapt to climate change. This may include switching to cleaner energy sources, improving energy efficiency, developing public transport, etc.

Table 2: *Total number of natural emergencies that occurred in the territory the Russian Federation for 2010-2021.*

		among them:											the number of deaths as a result of emergencies, people
	total,ed	earthquakes and volcanic eruptions	dangerous geological phenomena	storms, hurricanes, tornadoes, squalls	snow avalanches	heavy rain, snowfall, large hail	frost, drought	marine hydrological hazards	separation of coastal ice	dangerous hydrological phenomena	major wild fires	ground water level rise	
2010	118	8	-	3	1	6	20	-	14	8	58	-	37
2011	65	4	-	2	-	2	2	-	13	17	25	-	2
2012	148	2	1	9	-	12	18	-	8	21	77	-	185
2013	116	5	2	6	1	22	48	1	4	16	11	-	6
2014	44	-	1	10	-	16	3	-	2	7	5	-	11
2015	45	-	-	4	-	11	16	-	-	4	7	3	43
2016	54	-	2	6	-	21	7	-	1	15	2	-	3
2017	42	-	2	3	1	14	4	-	-	13	5	-	33
2018	44	-	-	1	-	11	14	-	1	12	5	-	8
2019	49	-	2	2	1	9	12	-	-	17	6	-	34
2020	104	2	1	20	-	6	13	7	1	29	25	-	4
2021	110	-	2	27	3	10	14	-	2	28	24	-	24

A source: https://rosstat.gov.ru [5]

Table 2 shows us the dynamics of the number of natural disasters that occurred on the territory of the Russian Federation in 2010-2021.

In 2023, the number of dangerous weather events in Russia increased by 22%. Experts define such phenomena as a threat to human health or significant economic damage. Among them are abnormally high or low temperatures, heavy rains, hurricanes, floods, droughts and forest fires. Last year, 1,191 natural disasters were recorded, compared with 976 in the previous year. The year 2023 took the second place in this indicator in the history of observations of the Hydrometeorological Center, second only to 2021, when 1,205 dangerous phenomena were registered. During this period, only the number of days with abnormal heat decreased by 48% [5].

Any natural disaster brings with it significant losses both in material and human terms.

Let's discuss the Kashmir earthquake that occurred on October 8, 2005 at about 8:50 a.m. local time. This earthquake was rated at 7.6 on the Richter scale and led to the destruction of many buildings. The capital of Kashmir was severely damaged, killing more than 10,000 residents of the city. As a result of the disaster, the main minaret of the mosque was also destroyed.

This earthquake is considered one of the most severe in South Asia. About 4 million people were left homeless, and more than 30,000 buildings were destroyed. Pakistan has suffered huge financial losses estimated at 12 billion US dollars [3].

Let's also consider the flood that occurred in the Irkutsk region in 2019. The Oka River in the city of Tulun has reached its maximum level of 14 meters (with an acceptable value of 700 cm). Scientists called the cause of the flood the heavy rains that have recently fallen in the region. The only highway connecting Moscow with Siberia and the Far East was damaged, and more than

6,000 houses were flooded. The financial damage to the region was estimated at more than 27 billion rubles. The authorities of the Irkutsk region announced the day of remembrance of the victims of the flood on July 12, 2019.

Terrible floods have occurred in the Sochi region and some areas of the Krasnodar Territory. Due to the prolonged rains, as much precipitation fell in a day as usually falls in a whole month. Rivers overflowed their banks, flooding residential buildings and boarding houses, roads and highways in villages were seriously damaged. Three weeks later, the scenario was repeated: another month's rainfall, new floods and people died.

In regions with extremely high levels of environmental stress, a significant part of the territories already exceed the permissible limits of the economic capacity of ecosystems. In areas with a high level of environmental stress, these limits have not yet been reached, but they are approaching. Continuing to increase production in these conditions at current levels of technology and economic structure will lead to complete degradation of natural systems, complete exhaustion of resource opportunities, and the formation of sustainable sources of diseases among the population.

In areas with a relatively high level of environmental stress, the economic capacity of ecosystems is mostly exhausted. Changes in the economic structure are needed, taking into account the use of new technologies, the construction of wastewater treatment plants and the restoration and reclamation of landscapes.

Areas with an average level of environmental stress retain the economic capacity of ecosystems. It is possible to maintain the current economic structure, provided that new technologies are introduced and treatment facilities are created.

Regions with a relatively low level of environmental stress make it possible to continue increasing production and partially develop new territories that are not included in the system of specially protected natural zones.

In regions with low or very low levels of environmental stress, the full economic capacity of ecosystems is maintained according to the Concept of Sustainable Development of the Russian Federation.

The National Security Strategy of Russia until 2020 (Strategy 2020) was approved by Decree of the President of the Russian Federation dated 05/12/2009 No. 537 and includes section IV "Ensuring national security", where there is a special subsection 8 "Ecology of living systems and effective use of natural resources".

The 2020 Strategy focuses on the fact that national security in the environmental sphere is influenced by such negative factors as the depletion of world reserves of mineral, aquatic and biological resources and the presence of ecologically unfavorable regions in Russia. In addition, national security in this area is complicated by the presence of a large number of hazardous industries that violate the ecological balance, including non-compliance with sanitary, epidemiological and sanitary standards for drinking water. Radioactive waste from the non-nuclear fuel cycle remains outside regulatory regulation and control. All this leads to an increase in the strategic risk of depletion of the country's most important mineral reserves and a decrease in the production of many key minerals.

IV. Discussion

The Russian Federation is actively working to reduce the negative impact of natural disasters and pollution on the sustainable development of the country. The measures taken to do this include:

• Creation and implementation of programs to prevent and minimize the consequences of natural disasters, as well as to restore territories after them. Within the framework of these programs, measures are being taken to strengthen infrastructure, prepare the population for action in extreme situations, organize timely notification and evacuation.

• Improvement of the system of monitoring and forecasting of natural disasters. Modern technologies and tools are used to track natural disasters and provide early warning about them. This makes it possible to take measures to protect the population and reduce possible losses [3].

• Implementation of environmentally friendly and energy efficient technologies. This includes the development and use of renewable energy sources, reducing emissions of pollutants into the atmosphere and water bodies, as well as waste disposal.

• Development of the system of environmental protection and control over compliance with environmental legislation. This includes conducting regular inspections at enterprises and organizations, as well as imposing fines and other sanctions for violations of environmental norms and rules. Conducting educational and awareness-raising programs aimed at improving the ecological culture of the population. This includes environmental lessons in schools and universities, thematic events and actions, as well as information through the media.

• Cooperation with international organizations and countries to share experience and knowledge in the field of prevention and elimination of consequences of natural disasters and environmental pollution. All these measures are aimed at ensuring the sustainable development of the country, preventing the negative consequences of natural disasters and protecting the environment from pollution.

In addition, other actions are being taken:

Firstly, programs are being developed and implemented to prevent and minimize the consequences of natural disasters, as well as to restore territories after their impact. Measures are being taken to strengthen infrastructure and prepare the population for action in extreme conditions.

Secondly, the system of monitoring and forecasting of natural disasters is being improved using modern technologies and tools. This allows you to warn in advance about possible natural disasters and take measures to protect the population.

Thirdly, environmentally friendly and energy-efficient technologies are being introduced, including the development and use of renewable energy sources, and the reduction of pollutant emissions.

The system of environmental protection, monitoring compliance with environmental legislation and conducting educational programs to improve the ecological culture of the population is also being developed.

Finally, cooperation is being carried out with international organizations to share experience in the field of prevention and elimination of consequences of natural disasters and protection of the environment from pollution.

References

[1] Jan M. Qasim, Muazim Khazima, Ashraf Arshad Global warming, climate change and its threats to sustainable agriculture // Regional issues. 2018. No 3-1.

[2] Danilov-Danilyan V.I. Global environmental problem and sustainable development // Bulletin of the Moscow University. Series 6. Economics. 2019. No 4.

[3] Musostov Z., Berkaeva A., Basnukaev I. Natural hazards and environmental decision-making // RT & A. 2022. №SI 4

[4] Skubri D. V. Natural disasters and their impact on the economies of countries // Actual problems of management, economics and economic security // Proceedings of the IV International Scientific Conference, Kostanay, November 10-11, 2022. – Cheboksary: Publishing House "Wednesday" LLC, 2022. – P.268-270. – EDN IEJHYZ.

[5] https://rosstat.gov.ru

[6] Aguzarova F.S., Kornaeva K.T. Natural resources of the Russian Federation: tax aspect // Taxes and taxation. 2015. No 8. P. 597-604.

[7] Aguzarova L.A., Aguzarova F.S., Burnatseva A.A. Taxes and fees in the environmental management system. - Nalchik, 2021.

RISK MANAGEMENT USING ARTIFICIAL INTELLIGENCE IN THE ORGANIZATION OF CONSTRUCTION AND ERECTION OF MONOLITHIC REINFORCED CONCRETE STRUCTURES IN THE FAR NORTH AND ARCTIC ZONE CONDITIONS

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Abstract

The study is focused on the application of artificial intelligence (AI) in the construction and erection of monolithic reinforced concrete structures in the Far North and Arctic zone, with the aim of managing potential risks. The topic deals with various ways required to mitigate risks associated with the unique climatic and weather conditions of these regions. The objective of this study is to develop a methodology for forecasting and risk management using AI.
In this study, data on construction processes and potential risks in Far North and Arctic zone conditions was utilised. The methodology is based on the application of artificial intelligence algorithms for data processing and analysis.
The study resulted in the proposal of an AI-based risk management methodology. This methodology enables the prediction of potential issues and comprehensive risk management at all stages of construction and erection of monolithic reinforced concrete structures.
The application of AI in construction risk management in the Far North and Arctic zone increases the efficiency and safety of construction processes. The use of the developed model is recommended for risk minimization and optimization of construction in complex climatic conditions.

Keywords: Risk management, artificial intelligence, monolithic reinforced concrete structures, Far North, Arctic zone, risk forecasting

I. Introduction

The construction and erection of monolithic reinforced concrete structures in the Far North and Arctic zone presents a number of significant risks, including those associated with harsh climatic conditions, limited availability of resources, and complex logistics [1-6]. It is of the utmost importance to manage these risks in order to guarantee the safety, quality, and efficiency of construction projects in these regions.

The organization of construction and erection of monolithic reinforced concrete structures in the Far North and Arctic zone presents a unique set of risks, largely due to the harsh climate, limited access to resources, and specific reliability and durability requirements. [7,8] Further discussions will be undertaken to evaluate all types of risk.

1. Climate risks:

- Low temperatures: Paving concrete at sub-zero temperatures requires specific steps such as heating the concrete mix placed in the formwork, using anti-freeze additives, and insulating the formwork. Failure to comply with these technical requirements may result in failure to achieve the design strength of the concrete, cracking and other defects.

- Strong winds: Strong winds can impede the operation of construction equipment, prevent concrete from gaining strength, damage building structures, and increase the risk of accidents.

- Snow drifts: Snow drifts can impede access to the construction site and delay delivery of materials and equipment.

- Polar Night: Limited visibility during polar night can impede work and increase the risk of accidents.

2. Logistical Risks:

- Remoteness from suppliers: Delivery of materials and equipment can be difficult and expensive in remote areas of the Arctic. [9,10]

- Limited access to transportation infrastructure: Lack of roads, ports and airfields can make it difficult to deliver supplies and move personnel. [11,12]

- Dependence on weather conditions: Transportation of cargo on snow-covered roads may be difficult during winter.

3. Technical Risks:

- Permafrost: Construction requires the use of special foundation solutions to prevent subsidence and deformation of structures. This issue requires particular attention in light of the current global warming trend.

- Seismic activity: Some areas of the Arctic are subject to seismic activity, therefore seismic loads in the design of structures shall be taken into consideration [13-15].

- Corrosion: The presence of salty seawater and corrosive atmospheres can accelerate the corrosion of metal structures.

4. Personnel-related risks:

- Extreme conditions: Working in the Far North and Arctic zone can be physically and psychologically challenging, as such can lead to decreased productivity and increased risk of accidents.

- Lack of qualified specialists: It can be challenging to identify, recruit and retain qualified professionals willing to work in extreme conditions.

5. Economic Risks:

- Significant construction costs: Projects pertaining to the construction of facilities in the Arctic is associated with significant coast implications related to logistics, materials, equipment, and labor.

- Price instability: It is possible that prices for construction materials and other related services fluctuate, which could result in budget overruns.

- Potential for delays: Delays in deliveries, weather and other factors can result in construction delays, which in turn can increase costs.

It is of ~~the~~ utmost importance to manage these risks effectively in order to ensure successful construction in the Far North and Arctic zone. The use of AI can help identify, analyze, and manage risks, thereby improving construction efficiency and safety.

Traditional risk management methods are not always effective in addressing the increasing complexity and uncertainty of factors in extreme conditions in the North. The application of advanced technologies, such as artificial intelligence (AI), can be regarded as an invaluable opportunity to enhance the effectiveness of risk management in construction projects. [16-20]

While there is growing interest in the use of AI in construction, there is still a lack of research on its application in extreme conditions, such as those found in the Far North and the Arctic. Implementation of AI in construction can resolve problems in the following key areas:

- **Improving construction efficiency:** Artificial intelligence (AI) can optimize planning, logistics, resource management, and quality control, thereby reducing construction time and costs.

- **Improving structural quality:** AI systems can analyze data on weather conditions, material properties, and manufacturing processes to assist in decision-making, thereby improving the reliability and durability of structures.

- **Workplace safety:** AI can be utilized to monitor the condition of construction projects, predict potential risks, and automate hazardous operations, thereby enhancing worker safety.

The objective of this article is twofold: firstly, to assess the potential of AI in the organisation of construction and erection of monolithic reinforced concrete structures in the Far North and Arctic zone; secondly, to identify key problems and areas for further research. The research will propose a risk management methodology and methods for implementing it in the process of erecting monolithic reinforced concrete structures in the Far North and Arctic zone. [21-24]

II. Materials and methods

The scientific literature was analyzed as part of a study on the application of AI in construction. Additionally, case studies were conducted on the use of AI in other industries operating in extreme environments.

The following aspects were considered in order to evaluate the potential of AI in construction in the Arctic:

- **Planning and design:** The use of AI to optimize construction site selection, site-specific structural design, and cost forecasting.
- **Logistics and resource management:** The use of AI to optimize material delivery routes, manage inventory, and forecast demand.
- **Quality Control:** The application of AI to the analysis of data from sensors on construction projects enables the monitoring of structural health and the determination, identification and troubleshooting of defects.
- **Workplace safety:** By leveraging AI, we can predict potential risks, automate hazardous operations, and monitor the condition of personnel.

It is essential that risk management methodology be comprehensive and take into account both traditional approaches and the specific features of AI use in the context of AI application in the organization of construction and erection of monolithic reinforced concrete structures in the Far North and Arctic zone [24-28].

III. Results

The result of the research is the methodology of risk management when using AI in the construction of monolithic reinforced concrete structures in the Far North and Arctic zone, as presented below. This is an algorithm of step-by-step actions. Please refer to Table 1 for details.

Table 1: *Methodology of risk management when using AI*

№	Stage	Actions
1	Project Initialization	• Define project objectives and requirements. • Form a project team, including AI and construction specialists.
2	Data Collection	• Obtain data from completed projects in similar environments. • Analyze the available information on climatic conditions, logistics, material supply, and technical aspects.
3	Risk Identification	• Conduct brainstorming sessions with all stakeholders. • Utilize AI to analyze the collected data and identify potential risks.
4	Risk Assessment:	• Evaluate the likelihood and impact of each identified risk. • Apply an AI model to predict potential scenarios and their consequences.
5	Risk Mitigation Planning	• Develop a risk management strategy (avoidance, mitigation, transfer, acceptability). • Identify specific actions for each risk, including the reservation of necessary resources.
6	Implement the risk management	• Implement the risk management plan. • Assigning responsibility for monitoring and controlling risks.

	plan.	
7	Monitoring and Control:	• It is essential to regularly track the status of the project and any associated risks. • Use AI for continuous monitoring and early warning of problems.
8	Risk Response	• In the event of a risk, the implementation of response plans is to be initiated without delay. • Adjusting actions according to the current situation.
9	Analyze and adapt	• Analyze the effectiveness of risk management measures. • Modify risk management plans as needed.
10	Reporting and Communication	• Regular reporting of risk status and management actions. • Maintaining open communication about risks and risk management actions.
11	Project Completion and Learning	• After project completion, analyze the project with a focus on risk management. • Leveraging the insights gained to enhance the training of staff and optimize risk management processes in future projects.
12	Repeat the cycle.	• Apply the updated risk management methodology to future projects, taking into account lessons learned and new AI capabilities.

The process of collecting data on implemented projects begins with the identification of key indicators and risks that warrant analysis. Subsequently, questionnaires, interviews, and document analysis can be employed to procure data on previous projects. It is crucial to ensure anonymity of responses and to analyze the collected data in order to reveal trends and findings that will help in planning future projects.

Table 2: *Risk matrix*

№	Risk Description	Probability (P)	Impact (I)	Risk Class	Risk Indicator (R)	Management Measures
1	Delay in delivery of materials	High (0.8)	Medium (50,000 rubles)	High	40,000	•Close standby contracts •Create a stock of materials
2	Inconsistency in material quality	Medium (0.5)	High (100 000 rubles)	High	50 000	•Careful quality control at acceptance
3	Shortage of qualified personnel	Low (0.2)	Medium (20 000 rubles.)	Средний	4 000	•Contracting back-up contracts
4	Changes in legislation	Low (0.1)	High (200 000 rubles)	Medium	20 000	•Monitoring changes in legislation •Consultation with lawyers
5	Unexpected force majeure	Low (0.1)	Very high (500 000 rubles.)	very high	50 000	•Development of a plan of action in case of force majeure •Insurance against force majeure risks

The risk identification phase commences with the definition of project goals and objectives, followed by brainstorming sessions with the project team and stakeholders. It is also important to analyze past projects in order to identify potential problems and consider external factors that may affect the project. The next step is to generate a comprehensive list of all potential risks. This list will then be analyzed and classified according to the level of threat posed.

The risk assessment phase commences with the categorization of identified risks according to their level of likelihood and potential impact. A risk matrix can be utilized for this purpose, with each risk rated on a scale from low to high. For each risk, specific impact indicators are identified, such as financial loss, project delivery time, or reputational risks. A risk score is calculated for each element based on these scores, which allows the risks to be ranked in order of hazard.

The probability (P) is calculated using historical data, expert opinion, and an analysis of the current situation as presented in the table. Impact is estimated in monetary terms, in days of delay, or as a percentage of the planned outcome. The risk class is determined by combining probability and impact. The risk score (R) is calculated by multiplying the probability and impact factors together (P * I). Management measures have been defined for each risk, with the objective of minimizing or preventing it.

In the Monitoring and Control phase, AI is leveraged to facilitate continuous tracking and risk management. This encompasses a range of activities, including continuous data analysis, prediction and warning, decision optimization, automation, and data visualization.

In the seventh and eighth phases, the methodologies are employed to actively manage risks throughout the project lifecycle. The project team employs AI systems to monitor the situation continuously, analyzing large volumes of data in real time during the monitoring and control phase.

This allows for the timely identification of any deviations from the plan and potential threats. The risk response stage requires the ability to make quick and flexible decisions. In the event of an issue, the team promptly assesses the situation, activates pre-prepared response plans, and, if necessary, adapts them to the current circumstances. The AI's ability to rapidly simulate a range of potential scenarios is a crucial factor in enabling optimal decision-making in the challenging conditions of the Far North.

IV. Conclusions

The use of artificial intelligence in risk management may prove to be effective tool for managing risks in the construction of monolithic reinforced concrete structures in the Far North and Arctic zone. The use of AI enhances the precision of risk identification and assessment, optimizes decision-making, and facilitates real-time risk monitoring.

Further research could focus on improving data processing and analysis methods, developing AI models, and exploring specific aspects of risk management in different types of Arctic projects. The successful implementation of AI in construction in the Arctic requires:

- Create databases of construction in these environments that can be used to train AI models.
- Develop AI systems that are tailored to the specific operational conditions in the Arctic.
- It is essential to provide adequate training to qualified professionals who are capable of developing, implementing, and maintaining AI systems.

The set up of AI in construction in the Arctic is a complex system, but nevertheless a positive undertaking given the fact that it has the potential to drive significant progress in this field. We anticipate active development of AI in construction over the coming years. It is anticipated that AI development will include the Arctic. The advent of new AI technologies and tools, coupled with the growing accessibility of construction data in challenging environments, will drive the broader adoption of AI in this sector.

References

[1] Tsygankova A.A., Romanchenko O. V., Shemetkova O. L. Infrastructure of the Arctic zone of the Russian Federation: state, economic instruments of development and priority projects. Regional Economics and Management: electronic scientific journal. - 2016. - №. 4 (48). - p. 181-193.

[2] Savinova V., M.M. Brodach, Features of design and construction in the Arctic region. High Technology Buildings. - 2018. - № 4.

[3] Kalinina N.S., N.V. Morozov, Architectural, technical and design features of designing residential and public buildings in the Far North. System Technologies. - 2019. - № 3(32).

[4] Khubaev, A.O. Improvement of the production process of winter concreting on the basis of the potential of organizational and technical solutions: specialty 05.02.22 "Production organization (by branches) »: dissertation for the degree of Candidate of Technical Sciences /2022. - 178 p.

[5] Akshov E.A. Use of computational design and artificial intelligence in modeling architectural objects. Architecture and Modern Information Technologies. - 2023. - №. 2 (63). - p. 298-315.

[6] Abioye S. O., L. O. Oyedele, L. Akanbi, Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. Journal of Building Engineering. – 2021. – Vol. 44. – P. 103299. – DOI 10.1016/j.jobe.2021.103299.

[7] Koshelev V. A. Risk management mechanism in construction. Voprosy ekonomiki i prava. - 2014. - №. 74. - p. 122-127.

[8] Korabelnikova S.S., S.K. Korabelnikova, Digital technologies as an element of risk reduction in construction. Discussion. - 2019. - № 2(93). - p. 18-27. - DOI 10.24411/2077-7639-2018-10002.

[9] Lapidus A.A., I.L. Abramov, T.K. Kuzmina, A.I. Abramova, Sustainability of the activity of construction organizations under the conditions of risk factors. Industrial and Civil Engineering. - 2023. - № 11. - p. 97-104. - DOI 10.33622/0869-7019.2023.11.97-104.

[10] Abramov I., AlZaidi Z. A. K., Evaluation of the Effective Functioning of Construction Enterprises in the Conditions of Occurrence of Diverse Risk Factors. Buildings. – 2023. – T. 13. – №. 4. – p. 995. – DOI 10.3390/buildings13040995.

[11] Lapidus A.A., I. Abramov, T. Kuzmina, Abramova A., Alzaidi Z.A.K. Study of the Sustainable Functioning of Construction Companies in the Conditions of Risk Factors. Buildings. – 2023. – Vol. 13, No. 9. – P. 2282. – DOI 10.3390/buildings13092282

[12] Schreiber, I. Abramov, Z. Al-Zaidi, Assessment of risk-forming factors of construction production in conditions of uncertainty. E3S Web of Conferences. – EDP Sciences, 2021. – T. 258. – p. 09052. – DOI 10.1051/e3sconf/202125809052

[13] Makarov A. "Organization of Construction Quality Control based on a Priori Risks of Works," International Journal of Engineering Trends and Technology, vol. 71, no. 1, pp. 134-140, 2023. Crossref, https://doi.org/10.14445/22315381/IJETT-V71I1P212

[14] Szymanski P., "Risk management in construction projects", Procedia Engineering 208, 174–182 (2017). https://doi.org/10.1016/j.proeng.2017.11.036

[15] Wang T., et al, "A meta-network-based risk evaluation and control method for industrialized building construction projects", Journal of Cleaner Production 205, 552–564 (2018). https://doi.org/10.1016/j.jclepro.2018.09.127

[16] Hwang B.G. , X. Zhao and L. P. Toh, "Risk management in small construction projects in Singapore: Status, barriers and impact", International Journal of Project Management 32(1), 116–124 (2014). https://doi.org/10.1016/j.ijproman.2013.01.007

[17] Zhou H. , et al, "Risk assessment and management via multi-source information fusion for undersea tunnel construction", Automation in Construction 111, 103050 (2020).

[18] Dziadosz A. , A. Tomczyk and O. Kaplinski, "Financial risk estimation in construction contracts", Procedia Engineering 122, 120–128 (2015). https://doi.org/10.1016/j.proeng.2015.10.015

[19] Mohamed M. and D. Q. Tran, "Risk-based inspection for concrete pavement construction using fuzzy sets and bayesian networks", Automation in Construction 128, 103761 (2021). https://doi.org/10.1016/j.autcon.2021.103761

[20] Zheng X.-W. , H.-N. Li and P. Gardoni, "Life-cycle probabilistic seismic risk assessment of high-rise buildings considering carbonation induced deterioration", Engineering Structures 231, 111752 (2021).https://doi.org/10.1016/j.engstruct.2020.111752

[21] Ilyin, A.V., N.V. Vladimirov, The use of artificial intelligence in construction. Bulletin of the Master's degree program. - 2022. - № 4-2(127). - p. 5-7.

[22] Zavgorodniy A. M., Vakurov A. E. Use of Artificial Intelligence in Construction. Description and advantages of smartvid. io to ensure safety at the construction site. BST: Bulletin of construction technology. - 2018. - №. 12. - p. 52-53.

[23] Topchiy D. V., Tokarskiy A. Ya. The concept of quality control of the organization of construction processes during construction supervision based on the use of information technology. Vestnik Eurasian Science. - 2019. - T. 11. - №. 3. - p. 49.

[24] Khubaev A. O., Sahakyan S. S. Increasing the efficiency of monolithic construction with the use of virtual and augmented reality technology. Proceedings of Tula State University. Technical Sciences. - 2019. - №. 12. - p. 492-495.

[25] Bidov T.H., A.O. Khubaev, A.A. Shabanova, Organizational and technical modeling of the complex system of concrete works production in winter period during the construction of residential buildings. Construction and Geotechnics. - 2021. - T. 12, № 2. - p. 15-25. - DOI 10.15593/2224-9826/2021.2.02.

[26] Khubaev A.O., Determination of the efficiency of the production process of winter concreting based on field studies. E3S Web of Conferences: Ural Environmental Science Forum "Sustainable Development of Industrial Region" (UENF-2023), Chelyabinsk, April 25-28, 2023. Vol. 389. - Chelyabinsk: EDP-Nauka, 2023. - P. 06012. - DOI 10.1051/e3sconf/202338906012.

[27] Lapidus A., A. Khubaev, T. Bidov, A. Regression analysis of the calculation of organizational and technological potential for the production of cold-weather concreting. IOP Conference Series: Materials Science and Engineering: 23, Construction - The Formation of Living Environment, 55 Giai Phong Road, Hanoi, September 23-26, 2020. - 55 Giai Phong Road, Hanoi, 2020. - P. 072033. - DOI 10.1088/1757-899X/869/7/072033.

[28] Lapidus A.A., A.O. Khubaev, Increasing the efficiency of winter concreting production through the use of software "potential-cwc". // Izvestiya Tula State University. Technical Sciences. - 2020. - № 5. - p. 18-26.

PERSPECTIVES OF USE OF MINERAL AND THERMAL WATERS FORMED IN TALISH TERRITORY

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Abstract

The risk of depletion of oil and gas resources, which the countries of the world have been using for many years, is increasing over time. Also, considering that the oil and gas sector is one of the main causes of climate change, it is necessary to move away from this type of fuel. In this case, there is a need to use alternative and renewable energy sources in the world. The research area is located in the southeastern part of Azerbaijan, where mineral-thermal water deposits have formed. Mineral-thermal water deposits of the region are divided into 3 groups (Masalli, Lankaran and Astara). The northern zone (Masalli group mineral waters) was mainly formed in the section consisting of the alternation of Paleogene cracked sandstones - siltstone and argillite. These waters belong to the chlorinated-sodium-calcium chemical composition and the degree of mineralization in the amount of 17 g/l. The water temperature reaches 64-66 ^{0}C. The central zone (Lankaran zone) is mainly formed in the intersection of Eocene cracked tuff-sandstones, argillite and siltstones, it has a chlorine-sodium-calcium chemical composition, the degree of mineralization is 5-6 g/l, the temperature is within the limits of 50 ^{0}C, it is completely nitrogenous, hydrogen-sulphide. has a gas content. The southern zone (Astara zone) has high mineralization (20 g/l), chlorine-sodium-calcium chemical composition, nitrogen, methane and hydrogen-sulfide gas content, water temperature is within 50 ^{0}C. The mineral waters discovered in the research area can be used for therapeutic purposes. The thermal waters formed in the research area can be used as a source of renewable energy.

Keywords: geothermal, natural hazards, climate change, renewable energy, consumption

I. İntroduction

The Talish area of Azerbaijan is characterized by a mountainous terrain that descends sharply towards the Caspian Sea in the north-eastern direction. Astara passes through the southern part of the territory, and Alashar-Burovar anticlinorium passes through the northern part, and they are separated from each other by the North-West oriented synclinorium. These tectonic elements are overthrusts, faults, etc. as a result, it has become more complicated [1].

There are more than 50 mountain rivers in the study area, relatively large rivers are Vilashchay, Lankaranchay, Tangeruchay, Boladichay, Astarachay and others. In the summer months, the waters of the rivers are completely used for irrigation, only Vilashchay, Lankaranchay and Astarachay go back to the Caspian Sea.

In 1964-1970, geological exploration works were carried out to study thermal waters in Talish zone (Astara, Lankaran and Masalli), for this purpose, 17 exploratory wells were dug and thermal waters with a temperature of 38-64 ^{0}C were discovered in all of these wells.

In the eastern part of the territory, mineral waters belong to the chlorinated type, in the northern part they are accompanied by hydrogen-sulfide and methane, and in the southern part they are accompanied by nitrogen gases [2].

The Talish wrinkle system consists of 3 zones stretching from the north-west to the south-east at a distance of 100 km in the general direction of the Caucasus and is located on the border with the Islamic Republic of Iran. The peaks of Giz Yurdu (2438 m), Kamyurkey (2477 m) are located here. Parallel to this zone and older than them, the 2nd zone passes the Peshtasar mountain system. The 3rd Alasha-Burovar range runs parallel to the 2 zones mentioned above.

River valleys and terraces with a complex structure, various formation features and an ancient history of development have further complicated the relief of the Talish horst-anticlinal uplift and caused their sharp division. Tectonic fractures and faults are formed along the river valleys and play a leading role in the natural outflow of mineral waters.

The Talish zone is separated from the Little Caucasus by the Araz depression. From the tectonic point of view, Talish zone consists of Astara, Burovar anticlinories, Lerik, Yardimli, Jalilabad synclinors. These tectonic elements are further complicated by uplifts and faults. They are composed of Paleogene and Neogene sediments.

Volcanic eruptions occurred in Talish in the early Eocene, and pyroclastic materials were brought here in the Oligocene and early Miocene.

The Talish fold area is the immediate eastern continuation of the central part of the Lesser Caucasus. It is composed of thin carbonate of the Upper Cretaceous and flysch sediments of the Paleogene - Lower Eocene. The small intrusive masses of the area are located in the Paleogene and belong to the alkaline basalt, diabase-diorite and gabbro-monsonite-syenite formations and form a single magmatic complex together with the underlying volcanic rocks.

Tectonically, the Talish mountain system is included in the northern wing of the Elburus megaanticlinorium as a first-order anticlinorium. The Talish mountain system is bordered by the Kura depression in the north, and extends towards the Caspian Sea in the east [3].

Based on the analysis of electro and seismological geophysical materials, it was determined that the thickness of the Quaternary sediments is related to the deep tectonics of the area, the thickness of the structures increases in the synclines and decreases in the anticlinal parts.

The main structures of the area are in the Transcaucasian direction, it is bordered by the Kura megasyncline in the north, and the Lankaran plain in the east.

In general, the structures formed in the area differ from each other according to their metallogenicity, geotectonic development, and seismicity. Between the settlements of Goytepe and Masalli, there are two Goytepe-Masalli anticlines, stretched in the direction of latitude, at a depth of 2000-2700 m, and they alternate with the Gizilagac anticline. Lankaran anticline, which is 28 km long and 500 m deep, is located in the anticline zone indicated above from the southwest side.

II. Methods

According to the research carried out in the research area, two groups of mineral water are distinguished here:

1. Masalli-Lenkoran-Astara mineral water group;
2. Assisted mineral water group

Masalli-Lenkoran-Astara mineral water group is spread in the confluence zone of mountainous and plain areas. Here, mineral water sources are hot, and highly profitable [4,5].

To the north, highly mineralized (17 g/l) hypothermal (64 ^{0}C) waters were found in Masalli (Arkivan) mineral water sources. These waters are carbonated and hydrogen sulphide. This indicates that they are likely to be in contact with oil-bearing rocks. Masalli-Lankaran-Astara mineral-thermal water deposits are spread at the junction of mountainous area and plain areas. Here, in particular, thermal water deposits are located (Fig. 1) [6,7,8].

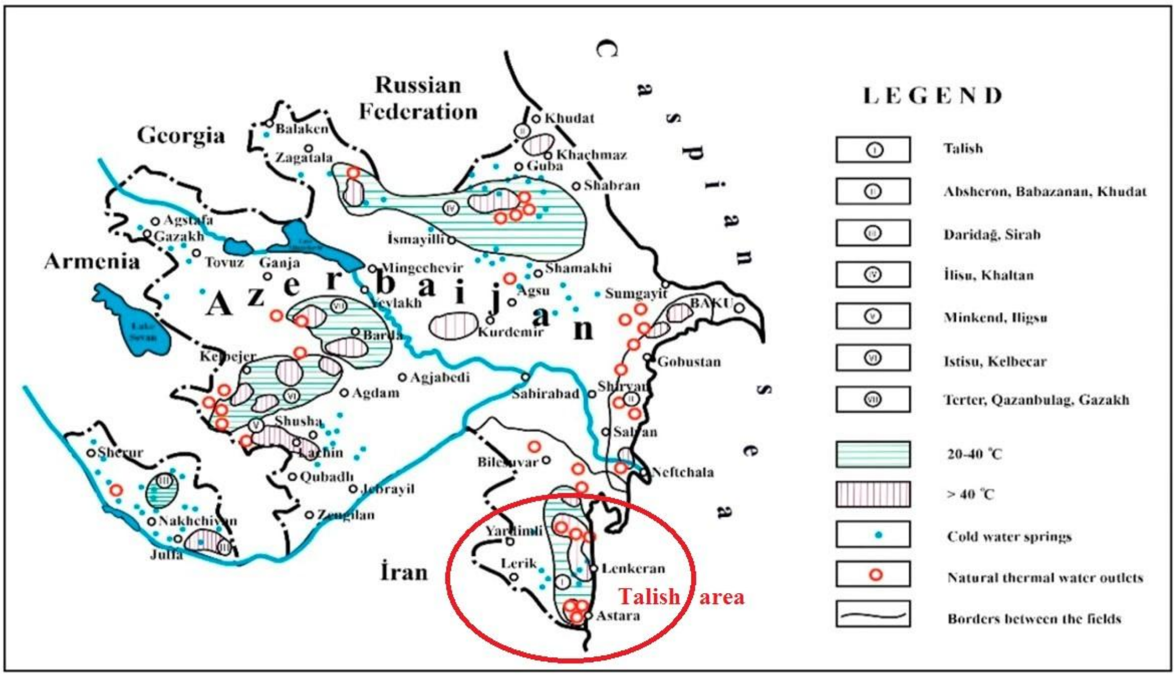

Figure 1: *Mineral-thermal waters map of Azerbaijan*

I. Masalli, (Arkivan) mineral water deposits are spread in the northern part of the territory. The degree of mineralization is 17 g/l, T-64 ^{0}C, carbon dioxide and hydrogen sulfide. This indicates that they are in contact with oil rocks [9,10].

II. There are Lankaran mineral-thermal water deposits in the central part of the area. The water temperature is 42-43 ^{0}C. The degree of mineralization is within 3 g/l. Waters contain nitrogen, sometimes accompanied by CO_2.

III. The temperature of thermal water deposits in the south of the area is 38-50 ^{0}C, the degree of mineralization is within 20 g/l. It is mainly accompanied by nitrogen gas.

Below is information about natural outlets and exploratory wells drilled in these areas:

1. Alasha area (Astara region), nitrogenous, mineralization rate 22 g/l, chemical composition Cl-HCO_3-Na-Ca. Among the specific components, H_2S, J elements can be mentioned. Its temperature is 46.2 ^{0}C, consumption is 1 million l/day. Of course, there are 3 exits. Wells with a depth of 500 m have been dug here. Total consumption is estimated at 2500 thousand l/day. In addition to the Alasha area, there are 6 natural water outlets in the Astara region. The chemical composition is mainly HCO_3-Cl-Na type. Total consumption is 2000 thousand l/day.

2. There are dozens of natural water outlets in Lankaran region. These are the following:

Meshesu thermal water field is nitrogen gas, the degree of mineralization is 3.9-5.9 g/l, and the temperature is 15.5-42.8 ^{0}C. The chemical composition is Cl-Na-Ca type. Among the specific components, H_2S is found in the trace of those waters. The total consumption is 1300 thousand l/day.

Ibadsu deposit - chemical composition is Cl-Na, mineralization rate is 3.6 g/l, temperature is 43-47 ^{0}C, consumption is 1 million l/day.

Gavzavua field - the degree of mineralization is 3.9-6.0 g/l, the chemical composition is Cl-Na type. Its temperature is 28 ^{0}C, consumption is 120 thousand l/day.

Khovt-Khaki deposit is an alternation of middle Oligocene siltstones and sandstones, chemical composition is Cl-Na type, methane (CH_4) gas. An exploration well with a depth of 1013 m was dug in this field. Temperature 22.5-37.4 ^{0}C, consumption 700 thousand l/day.

Sapnakaran area - for the first time, the location of the exploration well was chosen as a result of geophysical research, 10-15 m away from the natural outlets of mineral-thermal waters.

At a depth of 882 m, from the tuff sandstones of the Arkivan formation, the well produced a fountain (40 l/s), the temperature was 39 ^{0}C (the well was drilled with water, clay solution was used). Apart from those mentioned above, there are up to 20 natural outlets of mineral waters in Lankaran region; their temperature is 14-15 ^{0}C; the degree of mineralization was in the range of 0.6-8.8 g/l; chemical compositions are HCO_3-Cl-Na, Cl-HCO_3-Na-Ca.

Masalli district. Arkivan natural water outlet is characterized by alternation of upper Eocene siltstone, tuff sandstones and argillites.

H_2S from specific components; methane gas (CH_4); chemical composition – Cl-HCO_3-Na-Ca; mineralization rate 16.7 g/l; temperature - 41-50 ^{0}C; consumption is 1 million l/day.

Douzutan - natural water outlet - alternation of argillite, tuff sandstones and siltstones of the Upper Eocene; methane gas (CH_4); chemical composition is Cl-Na-Ca type; mineralization rate 17 g/l, temperature 63-64 ^{0}C, consumption 1.5 million l/day.

Itchy natural water outlet - alternation of Upper Eocene argillite, tuff sandstones and siltstones; chemical composition is Cl-Na-Ca type; spending 4 million l/day, its temperature is 66.1 ^{0}C (Table 1).

In addition, there are 7 natural water outlets in Masalli region. Their temperature is 15-52 ^{0}C. Mineralization rates are 0.9-17 g/l. Total consumption 1700 thousand l/day.

Table 1: *Physico-chemical and gas composition of mineral and thermal waters opened by search and exploration wells in Talish area*

Spring, wells	Depth, m	T, °C	pH	Degree of mineralization, g/l	Microelements	Gas composition
Alasha, 7	33-240	49	7,1	21,33	Mn, Mg, Si, Al, Ti, Cu, Cr, Be, Zn	-
Alasha, 4	245-310	50	7,3	21,97	Ba, Mn, Ti, St	N_2, He, Ar, O_2, CO_2, H_2
Alasha, 15-T	28-35	49	6,9	19,49	Mn, Mg, Si,Ti	-
Alaşa, 16-T	29-33	51	6,9	19,70	-	-
Alasha, 17-T	37-60	49	7,0	16,62	-	-
Alasha	spring	48	6,8	19,25	Mn, Si, Al, Mo, Ba, Ti	N_2, He, Ar, H_2, CO_2, O_2
Sapnakaran, 16	518-1000	36	7,6	36,33	Mn, Ti, Cu, Mo, Si	-
Moshkhan, 13	240-450	22	7,0	35,05	-	N_2, C_2H_4, He, Ar, H_2, O_2, C_2H_6
Meshasu, 1	431-1000	39	6,8	7,26	Mn, Al, Ba, Si	N_2, CH_4, Ar, He, C_2H_6, CO_2-H_2
Meshasu	spring	38	7,1	4,40	Mn, Al, Ba, Si	-
Ibadsu	spring	44	8,2	3,50	-	-
Havthoni	117-985	35	8,8	8,63	Mn, Al, Ba	N_2, CH_4, He, Ar, O_2, CO_2-H_2
Shaklyakudca, 15	859-886	37	7,3	13,63	Mn, Fe, Mg, Ti, Si, Al, Jr, Sr, Ba	-
Arkivan-2	73-489	50	6,8	14,10	Mn, Ti, Ag, St	-
Arkivan-3	390-430	44	6,8	9,66	Ba, Mn, Ti, Ag	CH_4, N_2, He, Ar, H_2, CO_2, C_2H_2
Donuzuten	spring	50	7,9	20,24	-	-
Gotursu	spring	64	7,8	14,16	Mn, Mg, Si, Al, Ti, Cu, Sr, Be	CH_4, N_2, He, Ar, O_2,CO_2, H_2, C_2H_6
Misharsu	spring	43	7,2	1240	-	CH_4, N_2, He, Ar, O_2,CO_2, H_2, C_2H_6

In the central part of the territory, the Lankaran group of mineral waters are found, which have a slightly lower temperature (42-43 ^{0}C) at the water outlets and a low degree of mineralization (3 g/l). These waters are mainly accompanied by nitrogen and sometimes carbon dioxide.

The South Astara mineral water group is hot (38-50 ^{0}C) and highly mineralized (20 g/l) and is mainly accompanied by atmospheric nitrogen (Table 2).

The eastern thermal-mineral waters of the area are chlorine-sodium-calcium, typical for oil regions. Here, the excess water in the north-west direction is cold, hydrocarbonate-calcium-magnesium-sodium type (Ag Korpu) and is accompanied by nitrogen gas.

Table 2: *Temperature parameters of the main natural thermal water springs of Talish area*

Springs	Consumption, m^3/day	Water temperature, ^0C	The amount of heat in the water coming to the surface of the earth	
			kkal.	mVt
Gotursu	3974	64	$1{,}53x10^{12}$	$6{,}4x10^{10}$
Donuzuten	1555	64	$5{,}98x10^{11}$	$2{,}5x10^{10}$
Misharchay	121	43	$2{,}44x10^{10}$	$10{,}2x10^{8}$
Bash Arkivan	302	50	$7{,}92x10^{10}$	$3{,}3x10^{9}$
Meshesu	112	38	$1{,}75x10^{10}$	$7{,}3x10^{8}$
Ibadsu	1123	42	$2{,}05x10^{11}$	$8{,}5x10^{9}$
Havzavua	259	38	$4{,}09x10^{10}$	$1{,}7x10^{9}$
Alasha	285	50	$7{,}48x10^{10}$	$3{,}1x10^{9}$
Total	7731	-	$2{,}56x10^{12}$	$10{,}7x10^{10}$

Thermal waters widely spread in the research area have scientific and practical importance for the use in agriculture and many fields of industry. Unfortunately, nowadays, except for a few primitive cases, it has not been possible to use these waters widely.

III. Results

As a result of the tectonic movements in Talish area, the uplifts, faults, horses and disjunctive dislocations played a major role in the formation of mineral-thermal water deposits.

Mineral waters are widespread in the mountainous Talish area. Mineral waters are dominated by N_2 and CH_4 gases. In addition, CO_2, He, Ar and other gases are also found. Also, the composition of the waters is rich in minerals. These mineral water deposits are considered important for treatment.

Thermal waters are widespread in Talish territory. So, the temperature of these thermal waters reaches up to 65 ^0C. It is believed that if deeper wells are drilled, the temperature may be even higher.

The relatively widespread distribution of thermal waters in the Talish zone can be used as a renewable energy source in our modern times, taking into account its high thermal energy capacity.

References

[1] Tagiev, I. I., Tagiev, A. Sh. (2016). Current state and general objectives of the use of mineral and thermal waters in Azerbaijan. Eurasian Scientific Association, 2(10), 177-178. (in Russian)

[2] Geology of Azerbaijan. 2008. Vol. VIII. Hydrogeology. Baku, Nafta-Press. 380 p.

[3] Israfilov, Yu.H, Israfilov, R.H., Guliyev, H.H., Efendiyev, G.M. 2016. Risk assessment of the water resources losses of the Azerbaijan republic due to climate changes. news of ANAS, Earth Sciences, № 3-4. 37-47.

[4] Taghiyev A.Sh. Climate change and water resources management. İnternational Scientific Cenference on Sustainable Development. Baku, 24-25 november, 2017. 55-61.

[5] Taghiyev A.Sh. Hydrogeological conditions of the Ganykh-Ayrichay basin and prospects for the use of groundwater. Proceedings of the conference, PART II, pp.201-203.

[6] Tagiyev, I.I., Ismailova, M.M., Karimov, V.M., Sharifov, J.J. (2022). Prospects for using thermal water in Kalbajar district and other regions (Azerbaijan) as an alternative energy. // Reliability: Theory & Applications, 17(SI 3 (66)), 76-81. DOI: https://doi.org/10.24412/1932-2321-2022-366-76-81

[7] Tagiev I.I. 2001. Status and problems of protection of the environment and nature use in the Republic of Azerbaijan, Ministry of Science and Technology of the USSR, Moscow.

[8] Tagiev, I.I., Kerimov, V.M. 2021. Prospects for the development of alternative energy and the use of thermal waters in Azerbaijan. // Ural Geolog. Journal. 3 (141). 51-57.

[9] Mustafayeva, E.M., Tagiyev, A.Sh. (2023). Perspective of using groundwater in the Ganikh-Ayrichay foothills. // Reliability: Theory & Applications, 18. DOI: https://doi.org/10.24412/1932-2321-2023-575-136-141

[10] Rzaeva, S.M., Tagiyev A.Sh. and Zeynalova S.A. Impact of climate change on the groundwater of the Ganikh-Ayrichay foothills. // Reliability: Theory & Applications 17.SI 4 (70) (2022): 180-187. DOI: https://doi.org/10.24412/1932-2321-2022-470-180-187

RESEARCH OF THERMAL AND MINERAL WATERS FORMATION CONDITIONS IN THE AZERBAIJAN PART (KARABAKH AND NAKHCHIVAN) OF THE SOUTH CAUCASUS

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Abstract

The risk of exhausting the oil and gas resources used by the countries of the world for many years is increasing over time. Also, considering that the oil and gas sector is one of the main causes of climate change, it is necessary to move away from this type of fuel. In this case, there is a need to use alternative and renewable energy sources in the world. Addressing climate change requires a shift away from fuels such as hydrocarbons to renewable energy sources such as solar, wind, hydro and geothermal. Renewable energy sources are carbon-free and produce fewer emissions, making them an important component in reducing greenhouse gas emissions. Overall, the transition to renewable energy sources is critical to addressing climate change and ensuring a sustainable future for the planet. The favorable geographical position and climatic conditions of the Azerbaijani part of the Lesser Caucasus allow the wide use of ecologically clean alternative (renewable) energy sources. The article describes the perspective of using the thermal water deposits in the Azerbaijani part of the Lesser Caucasus as an alternative energy source. The analysis of fund and printed materials on thermal water deposits of the research area shows that the energy resources collected in this area can be considered as alternative energy and are of great importance for the future economy of the region. Studies show that the water temperature is high in the zones where the tectonic faults spread directly. As you move away from these zones, the water temperature decreases and the zones without lavas are characterized by natural outlets of cold mineral waters. Mineral water resources are also considered useful for the development of balneological, sanatorium-health complexes.

Keywords: geothermal, percent of mineralization, natural hazards, climate change, renewable energy

I. İntroduction

The Azerbaijani part of the Lesser Caucasus occupies the territory between the Kura in the northeast and the Araks rivers in the southeast and borders with the Republic of Armenia in the southwest.

The rift consists of separate blocks bounded by micro- and macro-tectonic faults with a very complex geological-tectonic structure, mineral and thermal water deposits are widespread on the micro-macro-tectonic faults at the contacts of separate rock masses [1]. There are numerous natural outlets of mineral and thermal water deposits in carbonate sandstones and clayey rocks, which are products of intrusive and effusive magmatism and have a special layering structure. For example, river valleys and terraces with complex structure, different formation features and ancient geological development history have caused the formation of fault and fault lines that have caused the fragmentation of separate geological blocks along the Lesser Caucasus megaanticlinorium. Carbon dioxide, hydrocarbonate, chloride-hydrocarbonate-sodium type sediments are found in the Devonian, Upper Jurassic (Oxford-Kimmerian-Tithonian), Upper Cretaceous (Campanian-Maastrichtian) and Paleogene (Middle Eocene) sediments in the central part of the Lesser Caucasus, especially in the area of Nakhchivan MR, where thick carbonate rocks are accumulated mineral waters are widespread [2] (Fig. 1).

As a whole, Quaternary lavas are characterized by high-temperature thermal waters. Studies show that the water temperature is high in the zones where the tectonic faults spread directly. As you move away from these zones, the water temperature decreases and the zones without lavas are characterized by natural outlets of cold mineral waters. For example, the total discharge of natural thermal water outlets in Yukhari Istisu, Ashagi Istisu, Bagirsag and Tutkhun areas in Kalbajar region, which is characterized by volcanic eruptions that occurred in Paleogene-Neogene (Upper Eocene and Miocene) Pliocene and Anthropogenic periods in the Lesser Caucasus, is more than 100 m^3/day [3]. The consumption of individual wells dug here at a depth of 300-400 m was 300-1000 m^3/day (temperature 28-700C). It is estimated that there is a great possibility of obtaining thermal water with a temperature of 100^{0}C through wells with a depth of 900-1000 in these areas.

A very famous sanatorium-health complex operated during the USSR in an area rich in Istisu springs in Kalbajar region. This field is considered analogous to Karlovy Vary in Czech Republic.

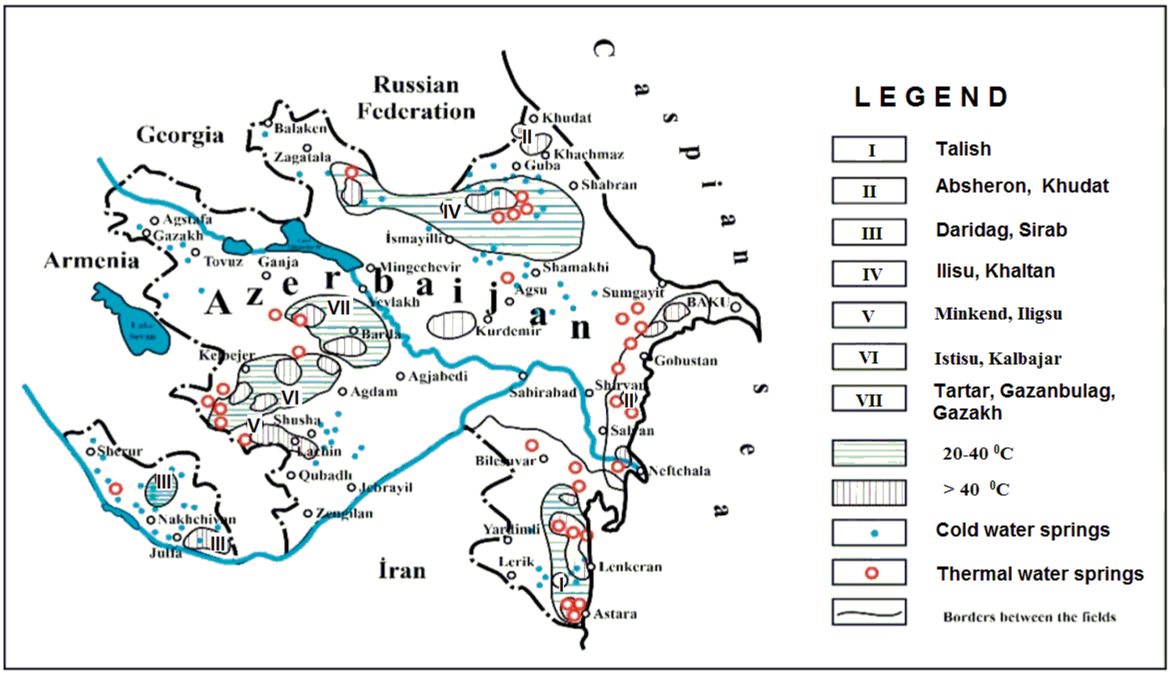

Figure 1: *Mineral-thermal waters map of Azerbaijan*

II. Methods

The amount of mineral salts contained in the mineral and thermal water deposits distributed throughout the territory of the Lesser Caucasus is much higher than that of ordinary drinking water, and these waters are rich in active chemical and specific components and gases (Table 1).

Carbon dioxide waters have great industrial and economic importance. In the territory of Azerbaijan, these waters are widespread only in the regions of the Lesser Caucasus mountain ranges and in the territory of Nakhchivan AR (Nakhajir, Istisu, Badamli, Turshsu, Daridag, etc.).

Along with Istisu and Tutkhun deposits, the Minkend-Ahmadli and Turshsu-Shirlan hydrochemical zones were studied in Kalbajar region (Fig. 2).

Table 1: *Some indicators of the main mineral and thermal water deposits distributed in the Kalbajar fold area of the Lesser Caucasus*

Name of field	Degree of mineralization, g/l	The formula of the ionic composition	Specific components	Water temperature, ^0C	pH	Consumption, 10^3 l/day
Gashtak	3,6-7,6	$\frac{HCO_3 70(SO_4 18)}{Na86(Ca10)}$	Ba, Cu, Sr	21,0-52	7,1	50
Shaplar	2,2-2,6	$\frac{HCO_3 79(SO_4 13)}{Na71Ca21}$	Ba, Cu, Sr	11,0-21,5	8,7	30
Kalbajar	4,2-6,7	$\frac{HCO_3 78(SO_4 16)}{Na80(Ca15)}$	Ba, F, Cr	12,0-25,0	6,6	25
Tutkhun	4,8	$\frac{HCO_3 85(SO_4 9)}{Na64Ca27}$	Ba, F, Cr	33,0	6,3	120
Turshsu	2,1	$\frac{HCO_3 86(Cl12)}{Mg45Ca37}$	Fe^{2+}, Cu, Ni	9,5	7,0	40
Shirlan	1,3-3,3	$\frac{HCO_3 93(Cl7)}{Mg68Ca29}$	Fe^{2+}, Zi, Ba	10,0	7,2	600
Agbulaq	3,6	$\frac{HCO_3 88(SO_4 11)}{Ca68\ Mg26}$	Ba, Sr	10,0	6,2	90
Ahmadli	1,6	$\frac{HCO_3 72Cl21}{Na39Ca31\ Mg30}$	Pb, Ag, Ti	47,0	5,6	300
Gushlu gaya	1,9	$\frac{HCO_3 52Cl41}{Na65Mg22}$	Cr, Ba	16,0	5,6	30
Iligsu	1,6	$\frac{HCO_3 67Cl25}{Na40Mg34Ca26}$	Ag, Sr	28,5	6,2	200
Nuraddin	3,6	$\frac{HCO_3 87(SO_4 13)}{Ca65\ Mg29}$	Fe^{2+}, Ag	18,0	6,2	150
Minkand	5,0	$\frac{HCO_3 66Cl27}{Na40Mg34Ca26}$	Fe^{2+}, Ag	43,0	5,8	300
Saloglu	4,4	$\frac{HCO_3 54SO_4 37}{Ca45Na37}$	Ba, Mn, Cr	14,0	8,2	10
Salahli	5,9	$\frac{Cl79HCO_3 21}{Ca45Na33Mg22}$	Ba, Pb, Cu	50,0	8,1	21
Kazımli	1,2	$\frac{HCO_3 91(SO_4 9)}{Na46Ca40}$	Ba, Ti, Ni	12,5	5,6	11
Shinikh	1,1	$\frac{HCO_3 97(SO_4 3)}{Na47Ca48}$	Ba, Ti, Sr	7,0	5,8	10
Slavyanka	2,7	$\frac{HCO_3 79(SO_4 18)}{Na45Ca32Mg23}$	Fe^{2+}, Br, J, HBO_2	12,5	7,6	30

Since the mineral water group of the intestinal area comes out through the granitoids, their contents are enriched with radium element, and their radioactivity gradually decreases as they move away from the dykes [4].

The above-mentioned Tutkhun mineral water field is characterized by a large amount of carbon dioxide mineral water outlets in the Tutkhun river valley (Gotursu, Garasu, Mozchay, Galatalig, Zulfugarli, Oruclu water groups) [5,6,7].

In general, in this zone, the Cenomanian tuffogenic-clastic rocks, characterized by conglomerate and tuffaceous sandstones, are considered more watery. Limestones and andesites (Eocene age) with vertical cracks, which create infiltration conditions, play the main role in ensuring the hydration of these rocks [8,9,10].

Turshsu-Shirlan zone is one of the most interesting mineral water deposits in the Lesser Caucasus. These deposits were discovered in the deep valleys of Gargarchay River (Turshsu) and Khalfalichai River (Shirlan) 16 km from Shusha region. Here, as a result of the Middle Jurassic volcanogenic layer sliding over the sediments characterized by lower Cretaceous shaly sandstones and crushing them, it created conditions for the formation and movement of mineral waters.

Figure 2: *Mineral-thermal water outlet in Kalbajar*

The mineral water deposits distributed in the Nakhchivan fold area of the Lesser Caucasus are divided into hydrochemical zones along 3 lines.

A number of mineral water deposits (Badamli, Vaykhir, Sirab, etc.) were studied along the 1st line. Badamli and Sirab mineral water sources are closely related to rocks characterized by Upper Cretaceous, Paleocene and Eocene age marls, sandstones, conglomerates, andesite and their tuffs and tufobreccias. The chemical composition of mineral waters is hydrocarbonate-chlorine-sodium.

The 2nd line of mineral waters of the territory passes through the border zone with Armenia in the southwest direction of Nakhchivan. In this zone, there is a zone of tectonic tension accompanied by fractures, cracks and disjunctive dislocations.

The 3rd line of mineral water sources of the area passes through Daridag water sources. These water sources are collected in a large anticlinal fold zone extending in the northwest direction in connection with the Upper Cretaceous and Eocene marly-sandstone rocks. The mineral waters of this zone are chlorinated-hydrocarbonate-sodium based on their chemical composition.

In total, there are more than 200 natural mineral water springs in the area of Nakhchivan folds. The mineral water deposits of this area resemble a hydrochemical museum with their diversity (Table 2).

When the mineral waters of the Lesser Caucasus come to the surface, they form many sediments in various forms (argonite, stalatite, stamite, etc.). For example, argonites formed in the area of Sirab village in Babak district of Nakhchivan are used as an excellent type of marble.

"Daridag" mineral water deposits in Julfa region are used to buy CO_2.

There are 2 types of mineral water in the "Sirab" mineral water field:

1. "Barjomi" type waters; operational reserve is more than 200000 l/day.
2. "Narzan" type waters; operational reserve is more than 500000 l/day.

Table 2: *Some indicators of natural water outlets of the main mineral and thermal water deposits distributed in the Nakhchivan fold area of the Lesser Caucasus*

Name of field	Gas composition	Degree of mineralization, g/l	The formula of the ionic composition	Specific components	Water T, ^0C	pH	Consumption, 10^3 l/day
Shakhtakhti	H_2S	2,8	$\frac{SO_4 67(HCO_3 10)}{Ca58Na30}$	H_2S+HS	21,0	6,2	70
Bakharsu	CO_2	3,9	$\frac{HCO_3 86(Cl11)}{Mg62Na36}$	H_2SiO_3	18,0	6,9	150
Sharur	CO_2	4,4	$\underline{HCO_3 75Cl21}$	-	18,0	7,5	900

			Mg58Na41				
Bashnorashen	H_2S	5,8	$SO_4$79Cl21 Ca66Na32	H_2S+HS	19,5	6,3	500
Gushchu	CO_2	4,1	$HCO_3$58Cl37 Mg65Na29	-	16,8	6,7	300
Dahna	CO_2	6,9	$SO_4$50Cl29$HCO_3$21 Na47Ca31Mg22	H_2SiO_3	17,5	6,9	150
Gomur	CO_2	3,2	$HCO_3$76($SO_4$17) Ca45Na33Mg22	H_2SiO_3	16,0	6,4	150
Badamlı	CO_2	2,1-3,2	$HCO_3$74(Cl17) Na23Ca37Mg21	As, Cu, Zn, F, Br, J, Pb	16,0- 20,5	6,4	50
Sirab I	CO_2	6,6	$HCO_3$72(Cl18) (Na+K)60Ca32	As, Cu, Ni, Fe^{2+}, Br, J	24,2	6,4	1330
Sirab II	CO_2	29,0	Cl54$HCO_3$45 (Na+K)94(Mg3)	Cu, As, Cd, Ni, Br, J, Fe^{2+}	28,0	6,9	150
Sirab III	CO_2	2,6	$HCO_3$78($SO_4$17) Ca56(Na+K)25	Ni, Cu, Br	20,0	6,4	180
Vaykhir I	CO_2	6,1	$HCO_3$53Cl39 (Na+K)60Ca30	As, Br, J, Fe^{2+}	22,0	6,5	125
Vaykhir II	CO_2	31,8	Cl63$HCO_3$32 (Na+K)93(Mg5)	As, Cu, Zn, Fe^{2+}, Br, J	20,4	6,5	175
Vaykhir III	CO_2	4,6	$HCO_3$75($SO_4$14) (Na+K)61	As, Cu, Fe^{2+}, Br, J	30,1	6,5	280
Kalbagil	CO_2	3,4	$HCO_3$80($SO_4$15) Ca48Na37	Cu, Fe^{2+}, Br, J	20,0	6,4	2000
Gakhab	CO_2	6,2	$HCO_3$35$SO_4$33Cl32 Na61Ca26	Cu, Zn, Rn, Br	22,0	6,8	900
Gizilvank	CO_2	5,7	$SO_4$71Cl22 Na40Mg31Ca29	Fe^{2+}, Br, J	16,0	7,7	300
Ahangagil	CO_2	3,9	$HCO_3$46Cl41 Na76(Ca15)	Fe^{2+}, Br, J	20,0	6,3	110
Daridag	Co_2	21,1	Cl64$HCO_3$29 (Na+K)92(Ca5)	As, Ni, Pb, Zn, Br	40,0	6,6	922
Daridag	CO_2	19,5	$SO_4$58Cl30 (Na+K)69Mg30	As, Pb, Br, J, Zn, Cu	42,0	6,4	2800
Daridag	CO_2	1,5	$HCO_3$42$SO_4$35Cl23 (Na+K)45Mg29Ca25	As, Pb, Br, J, Zn	52,0	6,5	835
Nakhajir	CO_2	5,5	Cl56$HCO_3$38 Na91(Ca8)	Fe^{2+}, Br	17,0	6,5	200
Cuga	CO_2	4,2	$HCO_3$57$SO_4$36 Ca47Mg28Na25	Fe^{2+}, Br, Ni	14,0	6,1	300
Lokotak	CO_2	1,6	$HCO_3$92($SO_4$6) Ca76Mg21	Cu, Co, Ni	13,0	6,5	700
Aravsa	CO_2	4,3	$HCO_3$87($SO_4$11) Na57Ca22Mg21	Mn, Cu, Br	14,5	6,3	250
Bashkand	CO_2	2,9	$HCO_3$85($SO_4$11) Ca50 Na26Mg24	Ni, Cu, Br	16,0	7,6	100
Gevi	CO_2	2,6	$HCO_3$79($SO_4$11) Ca58Na38	Ni, Pb, Zn	11,5	6,6	90
Darasham	CO_2	3,3	Cl41$SO_4$38$HCO_3$21 Na40Ca38Mg22	Pb, Br, J	23,0	6,6	55
Coshgun	CO_2	3,4	$HCO_3$76($SO_4$16) Na45Ca41	J, Br, Zn	18,0	6,4	75
Teyvaz	CO_2	7,6	$HCO_3$67Cl21 Na65Ca22	Ni, Pb, Br	21,0	6,2	50

Khoshkeshen	CO_2	5,6	$\frac{Cl38HCO_335\ SO_427}{Na78(Mg15)}$	Pb, Zn. J, Br	29,0	6,1	35
Saldash	CO_2	4,1	$\frac{HCO_384(SO_410)}{Ca36Na35Mg29}$	Ni, Pb, Zn	14,8	6,4	50
Gulustan	CO_2	3,4	$\frac{HCO_377(Cl16)}{Na38Ca37Mg25}$	Ni, Zn, Br	21,0	6,4	28
Nasirvaz	CO_2	1,5	$\frac{HCO_368SO_424}{Ca36Na35Mg29}$	Ni, Fe	14,3	6,1	350
Katam	CO_2	1,9	$\frac{HCO_391(SO_46)}{Ca85(Mg9)}$	Cu, Ca, Ni	14,5	7,7	250
Tivi	CO_2	4,4	$\frac{HCO_376(SO_415)}{Ca55Mg33}$	Ni, Mn, Br	10,0	5,7	200
Paraga	CO_2	1,7	$\frac{SO_487(HCO_311)}{Ca77Mg22}$	Ni, Cu, Br	16,5	6,6	120

In the Ordubad region of Nakhchivan, the Ordubad-Araz hydrochemical zone passes along the axis of the anticlinal uplift, around the fault zone and through the outer part of the intrusive.

The main mineral water deposits are:

1. The natural mineral water outlet in the Dasta area comes out of the gravel and gravel sediments on the ground. These waters belong to the Narzan type, the chemical composition belongs to the hydrocarbonate-sulfate-calcium type. Water discharge is 5000 l/day, water temperature is 19 ^{0}C, mineralization rate is 1.4 g/l, carbon dioxide (CO_2). Among the specific components – Ni, Pb, Zn were determined in the water. An exploratory exploitation well with a depth of 395 m was dug in this area. Mineral water-bearing rocks consist of fissured sandstones. The flow rate of the well is 300000 l/water, the degree of mineralization is 18.2 g/l, the chemical composition is chlorinated-hydrocarbonate-sodium, Fe (iron) and Br (bromine) have been determined in the water as specific components.

2. The Nasirvaz area spring emerges from small-grained Cognac-Sectonian sandstones. The discharge of the spring is 350,000 l/day, the degree of mineralization is 1.5 g/l, the water temperature is 14.3 0C, specific components Ni and Fe are determined in its content, it is carbon dioxide.

3. The Ketam area has a natural mineral water outlet, which comes out of the Cretaceous sandy-marly, calcareous sediments. The flow rate of the water is 250 thousand l/day, the degree of mineralization is 1.9 g/l, the chemical composition of the water is hydrocarbonate-sulfate-calcium, it contains Cu, Ni.

4. The Tivi area consists of an alternation of chalky marly, sandy, and limestone rocks. The flow of water is 200,000 l/day, the temperature is 100C, it belongs to carbon dioxide, hydrocarbonate-sulphate-calcium type.

5. Paraga emerges from the delluvial sediments to the earth's surface. Water discharge is 120 thousand l/day, mineralization rate is 1.7 g/l, water temperature is 16.5 ^{0}C. It contains specific components such as nickel, copper, and bromine. The chemical composition is sulfate-hydrocarbonate-calcium.

6. The flow of water in Alyagi area is 80000 l/day, it comes from delluvial sediments, the degree of mineralization of water is 3.6 g/l, the temperature is 19.5^{0}C with carbon dioxide, and the chemical composition belongs to the hydrocarbonate-sulfate-sodium type. Specific components of water include iron and bromine.

7. The flow of water in the Belav area is 40 thousand l/day, the temperature is 18.5 ^{0}C, the degree of mineralization is 2 g/l, and the chemical composition belongs to the hydrocarbonate-sulfate-sodium type. Among the specific components, water contains copper, bromine, iodine and carbon dioxide.

8. Bist area - delluvial sediments, water discharge 25 thousand l/day, water temperature 180C, mineralization rate 3.9 g/l, chemical composition belongs to hydrocarbonate-sulfate-calcium type. Carbon is gaseous, it contains copper, bromine and iodine as specific components.

9. Specimen area - delluvial sediments, water discharge 10 thousand l/water, mineralization rate 0.8 g/l, refers to carbon dioxide, hydrocarbonate-sulphate-calcium waters. Specific components of water include nickel, copper, and bromine.

10. Geyenza area - delluvial sediments, water discharge 12 thousand l/day, mineralization rate 5.6 g/l, carbon dioxide, water temperature 15 ^{0}C. Specific components of water include nickel and bromine.

III. Results

During the long geological period, mountain folding of the Lesser Caucasus, which continued with varying intensity in connection with the Alpine folding in the Caucasus, occupied a large area and participated in the formation of geochemical and geothermal characteristics of the geostructural zones on the right bank of the Kura basin. The Lesser Caucasus mega-anticlinorium has complex geological-tectonic conditions characterized by alternation of carbonate, sandstone and clayey rocks and tectonic faults, which are products of intrusive and effusive magmatism.

Analysis of geological materials shows that carbonic acid (H_2CO_3) acts on layers above magma, turning them into carbonate rocks. Free sulfuric acid is formed when sulfides, especially pyrite, are oxidized. That acid chemically reacts with limestone and other rocks to convert carbonates into sulfates. Carbon dioxide (CO_2) is compressed and remains free, and in some cases dissolved in water.

Due to the constant interaction with the mountain rocks in the research object, the degree of mineralization of the waters increases as a result of the dissolution of the rocks and the reaction of individual particles. The degree of mineralization is formed depending on the lithological composition of the rocks, the temperature and pressure of the substance in which the water moves.

Effective use of mineral and thermal water deposits of the Lesser Caucasus has been highly appreciated, especially in the Istisu, Tutkhun, Minkend, Ahmadli hydrothermal zones, according to the results of the search and exploration works conducted in these regions. The temperature of thermal waters in these zones is 54-74 ^{0}C, the total mineralization rate ranges from 4.2-7.9 g/l, and their chemical composition belongs to the hydrocarbonate-chlorine-sulfate type.

IV. FUNDİNG

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References

[1] Tagiev, I. I., Tagiev, A. Sh. (2016). Current state and general objectives of the use of mineral and thermal waters in Azerbaijan. // Eurasian Scientific Association, 2(10), 177-178. (in Russian)

[2] Geology of Azerbaijan. 2008. Vol. VIII. Hydrogeology. Baku, Nafta-Press. 380 p.

[3] Israfilov, Yu.H, Israfilov, R.H., Guliyev, H.H., Efendiyev, G.M. 2016. Risk assessment of the water resources losses of the Azerbaijan republic due to climate changes // News of ANAS, Earth Sciences, № 3-4. 37-47.

[4] Taghiyev A.Sh. Climate change and water resources management. İnternational Scientific Cenference on Sustainable Development. Baku, 24-25 November, 2017. 55-61.

[5] Taghiyev A.Sh. Hydrogeological conditions of the Ganykh-Ayrichay basin and prospects for the use of groundwater. Proceedings of the conference, PART II, pp.201-203.

[6] Tagiyev, I.I., Ismailova, M.M., Karimov, V.M., Sharifov, J.J. (2022). Prospects for using thermal water in Kalbajar district and other regions (Azerbaijan) as an alternative energy

// Reliability: Theory & Applications, 17(SI 3 (66)), 76-81. DOI: https://doi.org/10.24412/1932-2321-2022-366-76-81

[7] Tagiev I.I. 2001. Status and problems of protection of the environment and nature use in the Republic of Azerbaijan, Ministry of Science and Technology of the USSR, Moscow.

[8] Tagiev, I.I., Kerimov, V.M. 2021. Prospects for the development of alternative energy and the use of thermal waters in Azerbaijan // Ural Geolog. Journal. 3 (141). 51-57.

[9] Mustafayeva, E.M., Tagiyev, A.Sh. (2023). Perspective of using groundwater in the Ganikh-Ayrichay foothills. Reliability: Theory & Applications, 18. DOI: https://doi.org/10.24412/1932-2321-2023-575-136-141

[10] Rzaeva, S.M., Tagiyev A.Sh. and Zeynalova S.A. "Impact of climate change on the groundwater of the Ganikh-Ayrichay foothills." Reliability: Theory & Applications 17.SI 4 (70) (2022): 180-187.

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PREDICTION OF THE AMOUNT OF PRINTING INKS CAUSING ENVIRONMENTAL POLLUTION

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Abstract

The article examines the impact of the printing industry on environmental pollution. It was determined that the environmental problem is particularly relevant in this industry due to the high concentration of printing facilities in residential areas. The printing industry releases various harmful substances into the environment. Pollutants entering the atmosphere and wastewater entering the soil and groundwater are dangerous for humans, animals and plants. In the printing process, the printing ink breaks down, which causes the effect of ink dusting. This paper proposes a method to determine the amount of ink involved in dusting, taking into account the surface roughness of the printing plate. For this purpose, profilograms of the surface roughness of the printing form were taken. It was determined that an increase in the surface roughness of the printing form leads to an increase in the amount of ink involved in the dusting process, which, according to the results of theoretical studies, is 16.6% of the total amount of ink applied to the printing form. the surface of the printing form. It was also determined that the variation scheme of the amount of ink involved in the formation of dust in all sections of the printing machine is the same. The amount of paint involved in the formation of dust also increases many times with the increase in circulation. In order to experimentally confirm the theoretical results, the amount of ink applied to the surface of the printing plate was determined by the gravimetric method and the amount of ink involved in the formation of dust was calculated. The obtained results can be important information to ensure the cleanliness of the environment. The proposed method for determining the amount of ink involved in dust formation may be useful for professionals dealing with environmental problems in the printing industry. Also, the results of calculations can be used to solve environmental problems.

Keywords: Printing industry, pollutants, paint dusting, offset printing, roughness

I. Introduction

In recent years, climate change on our planet has worried society more. Environmental pollution has become one of the most urgent global problems. The current environmental situation has led to an increase in the interest of state institutions in the issues of environmental cleanliness. Government agencies, in turn, are tightening the requirements for the industry. Energy-saving technologies have become the highest priority in society, along with environmentally friendly products. With the use of these technologies, the complete disposal or recycling of production waste has become possible.

Consider the printing industry in terms of its impact on environmental pollution. Polygraphy is one of the most developed fields. It is characterized by a high concentration in residential areas, which makes its impact on the environment more noticeable. Therefore, the issue of ecology is particularly relevant in this industry. At present, printing houses are spreading in any country in a chaotic manner and without considering environmental safety. Modern printers produce many different products: packaging, labels, books, magazines and promotions. Typically, this industry is dominated by small businesses [1, 2]. Often, its representatives are focused on making a profit. Entrepreneurs are rarely interested in the environmental damage caused to the environment by their production. Some works [3, 4, 5] noted that the printing industry emits a relatively small amount of harmful substances into the environment. However, pollutants entering the atmosphere and wastewater entering the soil and groundwater are very dangerous for people, animals and plants. It is also necessary to take into account that most printing enterprises are located within the city limits, in residential areas and there are virtually no sanitary protection zones in them. Environmental protection at these enterprises is a necessary and important problem. Also, one of the important factors in printing is energy consumption. Printing makes a significant contribution to air pollution and the consumption of non-renewable energy sources. Improving technological processes in this direction is considered the most promising way to solve the problem of environmental protection.

Each printed publication goes through three stages of the printing process during its production: prepress preparation, printing and postpress finishing works. To fully understand the impact of printing on environmental pollution, each stage should be considered separately.

The work [4] shows that the pre-press stage does not have a negative impact on the environment, as the amount of technical waste is minimized.

This work also shows that post-printing processes do not have a significant impact on the environment. The analysis of the study shows that most of the emissions that have a negative impact on the environment are created directly during the printing process. According to Makarov [3], the main environmental threat of printed products is related to the printed material, as it constitutes more than 90% of the mass of the entire product. Currently, there is no clear vision of environmental problems in the printing and publishing industry. There is also no unified development program and proper management. Printing production was traditionally considered harmful to the environment.

II. Ink dusting in the printing process

Humanity uses a large number of paints and varnishes. The most common of them are construction and household, occupying more than half of the entire market. According to Makarov [3] the consumption of printing varnishes and paints is much less, i.e. 1-5 grams per square meter. In other industries, the application layer is tens of times larger. However, one kilogram of printing paint contacts the environment as well as several dozen kilograms of ordinary paint.

The printing industry uses different methods of applying paints and drying them. Almost all printing houses are faced with air pollution. This is due to the use of organic solvents. However, this is not the only air pollutant. The authors of a number of works [3, 5, 6, 7] also found that high printing speeds cause dusting, which leads to additional air pollution with paint and paper particles.

As the printing ink breaks down, ink filaments are formed and individual droplets are formed due to the rapid expansion of the ink, which creates a "dusting" effect. The authors of the work [6] show that the dusting is the result of the fragmentation of paint threads into many small particles and intensive scattering of these particles into the surrounding space under the influence of centrifugal forces. There are various reasons that cause dusting of paint. As noted by the authors of the works [5, 7, 8], the level of dusting is affected by the roughness of the paint-bearing surfaces and the thickness of the paint. film, paint properties and cavitation. The proportion of dust increases at high speed and higher ink viscosity, which affects not only print quality but also health and safety.

The authors of the works [5, 7] simulated the process of transfer and splitting of printing ink at the exit from the printing contact zone, with specifically specified components of the printing system, to predict and quantify the printing ink that has transferred to ink strands and is involved in the formation of "ink dusting". In the work of Khalilov et al. [8], the influence of the mechanics of a friction printing pair on ink dusting in the printing process was studied, taking into account the roughness of the surface of the printing plate.

Thus, it can be concluded that a printing house can cause significant air pollution, and it is necessary to carry out a set of measures to reduce risks.

III. Methodology for quantitative assessment of printing ink involved in the formation of "ink dusting"

In the printing process, printing ink is transferred from the inking unit to the printing plate and from the plate to the printed material [9, 10, 11].

In offset printing, separation of the ink layer occurs in two zones of the three-cylinder printing press (Figure 1), that is, between the plate and blanket cylinders, and between the blanket and printing cylinders.

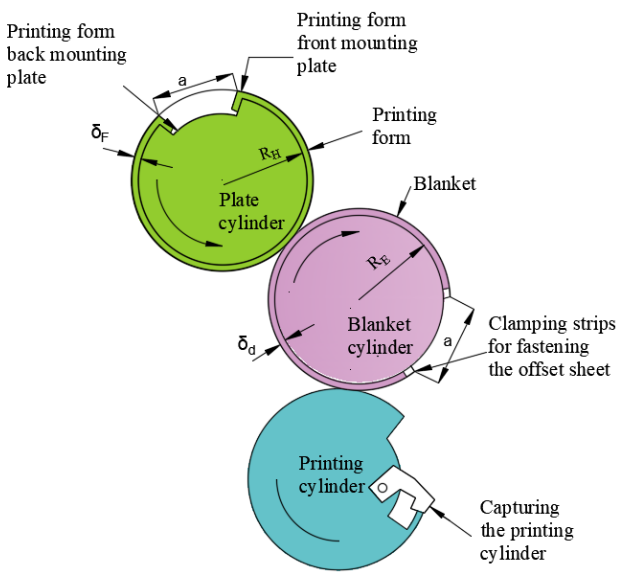

Figure 1: *Three-cylinder printing apparatus*

To standardize the offset printing process, it is necessary to select the correct printing system components [12]. According to Panichkin et al. [13], offset printing involves the transfer of a viscous incompressible fluid (ink). In the work of Aliyev [14], ink transfer to the printing plate was theoretically studied, taking into account the surface roughness of the printing plate. According to the scheme proposed by the authors of some works [14, 15], the effect of the surface roughness of the printing plate on ink separation in the indirect printing method was studied. Also, to determine the amount of ink on the printing plate on the contact strip, taking into account the microgeometry of the surface of the printing plate, the contact scheme of the printing pair (Figure 2) proposed by Khalilov et al. [8] was used.

In the work of Aliev [15], the amount of ink m on the printing form in the contact strip before printing is defined as follows

$$m = m_f + m_k \tag{1}$$

where m_f – is the amount of paint lying freely on the surface of the printing form in the contact strip, without taking into account the roughness; m_k –is the amount of paint that is in the free space of the roughness of the surface of the printing form in the contact strip

$$m_k = \frac{\rho \pi R'_H L}{180^\circ} \gamma_1 \left[\frac{R_{\max}\left(2R'_H - R_{\max}\right)}{2R'_H} - R_a \right] \tag{2}$$

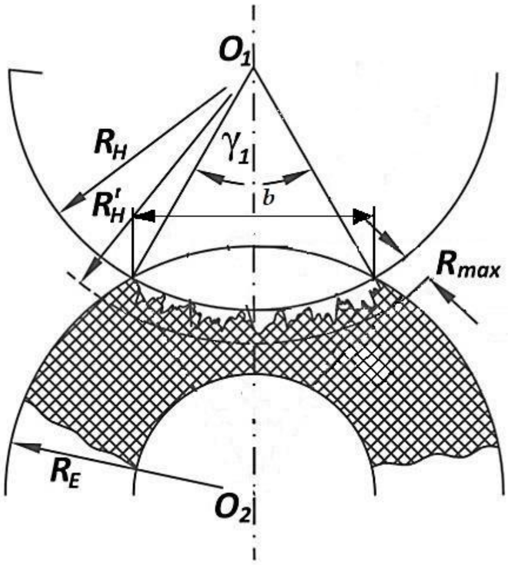

Figure 2: *Printed pair contact diagram, taking into account the surface roughness of the printing form*

Where L is the contact length along the generatrix of the contacting cylinders; R'_H – is the radius of the plate cylinder taking into account the thickness and surface roughness of the printing plate, $R'_H = R_H + \delta_F$, R_H –is the radius of the plate cylinder excluding the thickness and surface roughness of the printing plate; δ_F –is the thickness of the printing plate, taking into account the surface roughness of the printing plate; γ_1 – is the central angle of the contact zone sector; $R_{\max}$ – is the maximum height of the surface microroughness of the printing plate; R_a –is the arithmetic mean height of the surface microroughness of the printing plate; ρ –is the specific gravity of the ink;

Also, the amount of ink M_F –on the entire surface of the printing plate during one cycle of the printing machine, taking into account the roughness, before printing is determined in the following form

$$M_F = kk_1 \left\{ m_f + \frac{\rho \pi R'_H L}{180^\circ} \gamma_1 \left[\frac{R_{\max}\left(2R'_H - R_{\max}\right)}{2R'_H} - R_a \right] \right\} \tag{3}$$

Where $k-$ is the coefficient of filling the form with printing elements - for line images and text $k=0{,}13\div 0{,}15$, for raster $k=0{,}4\div 0{,}6$, for solid $k=1$ [16]; $k_1-$is the number of contact strips that can be located across the width of the nominal surface area of the printing form $k_1 = B/b$, where B is the width of the nominal area of the printing form and b is the width of the contact strip.
With a known value of the weight M of the printing form, without applying paint, M_F can be determined in the following form

$$M_F = M_1 - M \tag{4}$$

where M_1 – is the weight of the printing plate together with the applied paint before printing, taking into account the roughness. The values of M and M_1 can be determined gravimetrically.

When the paint layer is separated, the printing paint also splits and dusts. To determine the total amount of paint that has passed to dusting M_d in the contact strip, for one printing section, we write the following expression

$$M_d = M_{d1} + M_{d2} \tag{5}$$

where $M_{d1}-$ is the amount of paint transferred to dusting in the contact strip between the plate and blanket cylinders; M_{d2} – is the amount of paint transferred to dusting in the contact strip between the blanket and printing cylinders.

According to the results of the research by the authors of the work [17], it was found that after the separation of the ink layer, its thickness on the blanket cylinder of the printing apparatus is estimated at up to 38% of the total amount of paint applied to the printing form. This differs significantly from the results of similar studies, in which the division of the ink layer between the cylinders is usually estimated at 50%. Based on this, for one cycle of the printing machine, the expression can be written

$$M_{D1} = 0.5M_F - M_b \tag{6}$$

where M_{D1} – is the amount of paint transferred to dusting for one printing machine cycle between the plate and blanket cylinders; M_b – is the amount of paint lying on the blanket surface after contact between the plate and blanket cylinders after one cycle.
Similarly, the following expression can be written

$$M_{D2} = 0.5M_b - M_p \tag{7}$$

where M_{D2} – is the amount of paint transferred to dusting for one printing machine cycle between the blanket and printing cylinders; M_p is the amount of paint lying on the surface of the substrate after contact between the blanket and printing cylinders.

Taking into account the above information, the following expressions can also be written

$$M_b = 0.38M_F \tag{8}$$

$$M_p = 0.38M_b \tag{9}$$

Taking into account (8), we write formula (9) in the form

$$M_p = 0.144 M_F \tag{10}$$

Substituting values (8) and (10), we write expressions (6) and (7) in the following form

$$M_{D1} = 0.5M_F - 0.38M_F = 0.12M_F \tag{11}$$

$$M_{D2} = 0.19M_F - 0.144M_F = 0.046M_F \tag{12}$$

Taking into account formulas (4), (11) and (12), we write formula (5) for one cycle of the printing machine in the form

$$M_D = 0.166(M_1 - M) \tag{13}$$

Based on expression (13), we can conclude that the amount of paint transferred to dusting as a percentage is 16.6% of the total amount of M_F paint on the entire surface of the printing form. Considering that in multi-color printing, the printing machine has several printing sections, their number is equal to $i = 1, 2, .., N_S$, and the number of printing cycles of the machine is equal to circulation. N_T (print circulation), we write formula (13) in the following form:

$$M_{DT} = N_T \sum_{i=1}^{N_S} (M_D)_i \tag{14}$$

where M_{DT} – is the total amount of paint transferred to dust during the printing of the entire print run.

IV. Research results

For the study, the Rapida KBA 105 offset printing machine (Germany) was selected, which has $N_s = 4$ printing sections, with a form cylinder radius $R_H = 0.1494m$ and a blanket cylinder radius $R_E = 0.1468m$. A rubber-fabric blanket with a thickness of $0.95mm \pm 0.01mm$ was selected. A metal (aluminum) printing form of the PRO-V brand from Fujifilm (Japan) with a thickness of $\delta_F = 0.3mm$ was also selected. The contact length of the cylinders *L=0.104 m.*. The density of the printing ink used in the experiment is $-\rho = 1800\, kg/m^3$. When calculating the amount of ink, the surface roughness parameters of the printing plate were determined for each printing unit used in the studies. To determine the roughness parameters, surface profilograms of these printing plates were taken using a model 130 profilometer. A sample profilogram is shown in Figure 3.

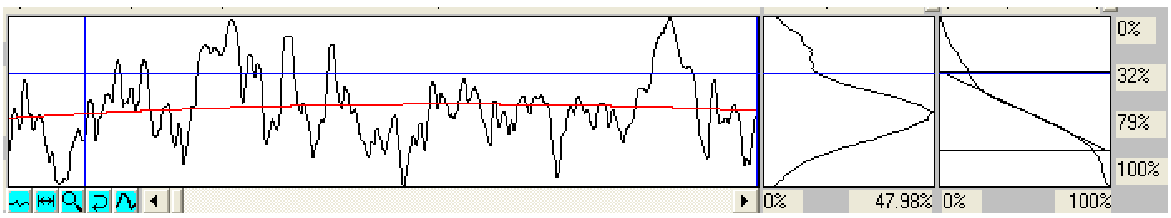

Figure 3: *Profilogram of the printing plate surface roughness*

During the study, these printing plates were installed in the cyan (C), magenta (M), yellow (Y) and black (K) printing units of the Rapida KBA 105 machine. The roughness parameters for each plate from the profilograms were determined as follows:

1. (C) $R_{\max} = 2.5\mu m$; $R_a = 0.396\mu m$

2. (M) $R_{\max} = 1.03\mu m$; $R_{\max} = 1.03\mu m$
3. (Y) $R_{\max} = 1.85\mu m$; $R_{\max} = 0.375\mu m$
4. (K) $R_{\max} = 0.644\mu m$; $R_{\max} = 0.0615\mu m$

The amount of paint on the printing form was determined by the gravimetric method. The mass of the printing form was weighed before and after rolling the paint onto the surface of the printing form. After that, the difference in the masses of the printing form before and after rolling the paint onto the surface of the printing form was calculated. To determine the masses, analytical electronic scales of the KERN FTB 3Ko.1 model were used. The experimental data of gravimetric measurements and the results of calculations for raster images $(k = 0.5)$, at $k_1 = 224$ for one cycle of the Rapida KBA 105 printing machine are given in Table 1. It was found that an increase in the roughness of the surface of the printing form leads to an increase in the amount of paint on the printing form, which contributes to an increase in the amount of paint participating in dusting.

Table 1: *Experimental data of gravimetric measurements and calculation results for printing sections for one cycle of the Rapida KBA 105 machine*

№	Printing plate in matching color	Experimentally determined weight of the printing form without applying paint	Experimentally determined weight of a printing plate with ink applied	Maximum height of surface roughness of the printing form	The arithmetic mean height of the surface roughness of the printing form	The amount of ink on the surface of the printing plate	The amount of paint involved in dusting
		M, g	M_1, g	$R_{\max}$, μm	R_a, μm	M_F, g	$(M_D)_i$, g
1	C	600.88	600.97	0,644	0,0615	0.09	0.015
2	M	600.95	601.16	2,5	0,396	0.21	0.035
3	Y	600.87	601.05	1,85	0,375	0.18	0.030
4	K	600.92	601.07	1,03	0,127	0.15	0.025

Table 2 shows the results of the calculation of the amount of paint involved in dusting, depending on the print run for the printing sections corresponding to cyan (C), magenta (M), yellow (Y) and black (K) colors of the Rapida KBA 105 machine and the calculation of the total amount of paint involved in dusting.

Table 2: *Results of calculation of the amount of paint involved in dusting, depending on the print run.*

№	Print section, matching color	The amount of paint involved in dusting per cycle $(M_D)_i$, g	Circulation of printed copies (thousand copies)				
			1	5	10	50	100
			Depending on the circulation, the amount of paint involved in dusting, $N_T \times (M_D)_i$, g				

1	C	0.015	15	75	150	750	1500
2	M	0.035	35	175	350	1750	3500
3	Y	0.030	30	150	300	1500	3000
4	K	0.025	25	125	250	1250	2500
The total amount of paint involved in dusting, $M_{DT} = N_T \sum_{i=1}^{N_S} (M_D)_i$, g			105	525	1050	5250	10500

V. The discussion of the results

To determine the amount of paint M_D, involved in dust formation during the printing process, the effect of the printing plate surface roughness on paint dusting was investigated. The amount of paint M_D, involved in dusting was theoretically calculated and found to be 16.6% of the total amount of paint M_F, applied to the surface of the printing plate. To experimentally confirm the theoretical results, the amount of paint applied to the surface of the printing plate was determined by the gravimetric method. Using the data obtained, the amount of paint involved in dusting was calculated, which is an important factor for ensuring a clean environment. The experimental results show that the change in the amount of paint involved in dusting depends on the surface roughness of the printing plate. Since at the maximum roughness height $R_{\max} = 0.644\mu$m the amount of paint involved in dust formation for one machine cycle in the cyan (C) color section is $M_D = 0.015g$. And at $R_{\max} = 2.5\mu$m in the magenta (M) color section this value increases to $M_D = 0.035g$. (Table 1.) Corresponding changes are also observed in the yellow (Y) and black (K) color sections of the printing machine.

Fig. 4 shows the dependence of the amount of M_D, ink involved in the dusting process on N_T by printing sections corresponding to the cyan (C), magenta (M), yellow (Y) and black (K) colors of N_T . Rapida KBA 105 machine From the graphs shown in Figure 4, it is clear that the scheme of change of the amount of paint involved in the formation of dust is the same in all sections.

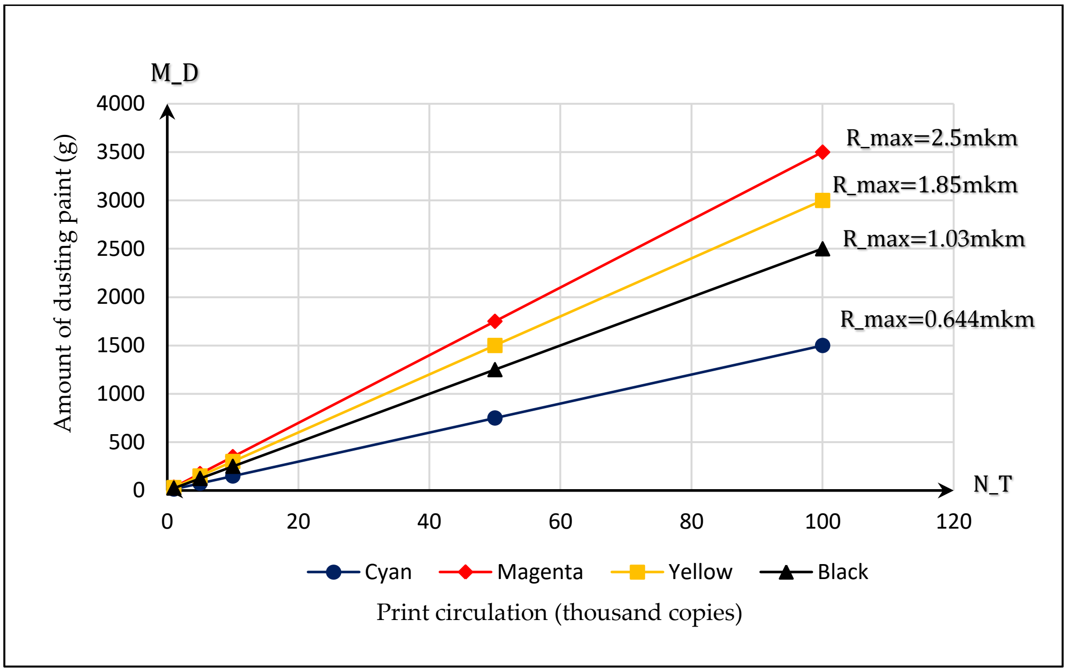

Figure 4: *Dependences of the amount of M_D paint involved in dusting on the print run N_T, by printing sections of the corresponding colors of the Rapida KBA 105 machine*

With an increase in the print run, a several-fold increase in the amount of paint involved in dust formation is observed. As an example, calculations were made for print runs from 1,000 copies to 100,000 copies of prints. Since for the cyan (C) section with a print run of 1,000 copies, the amount of paint involved in dust formation was $M_{DT} = 15g$,and with an increase in the print run to 100,000 copies, the amount of paint involved in dust formation reached $M_{DT} = 1500g$. Also, for the magenta (M) section, these values were similarly $M_{DT} = 35g$ and $M_{DT} = 3500g$. Similar changes in the increase in the amount of paint involved in dust formation, when printing the corresponding print runs, are also observed in the yellow (Y) and black (K) sections of the printing machine (Figure 4.). It has been established that the obtained difference in the amount of paint involved in dust formation during printing of the corresponding print runs depends on the roughness of the surface of the printing form. Since an increase in the roughness of the surface of the printing form leads to an increase in the amount of paint involved in dust formation. Also, with an increase in the print run, a multiple increase in the amount of paint involved in dust formation is observed.

The graph of the dependence of the total amount of M_{DT} paint involved in dusting on the print run N_T for all sections of the printing machine is shown in Figure 5.

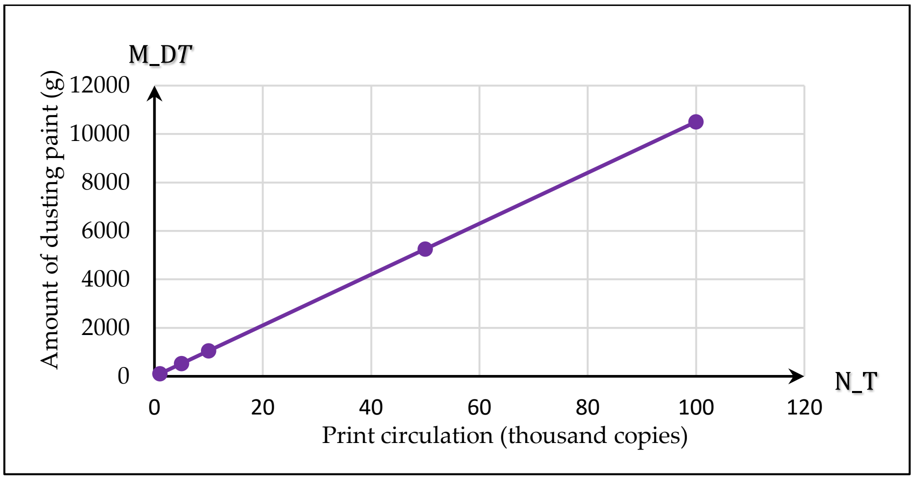

Figure 5: *Dependence of the total amount of* M_{DT} *paint involved in pollination on the print run* N_T

The graph shows that with an increase in the N_T circulation from 1,000 copies to 100,000 copies, the total amount of paint involved in dust formation during the printing process increases from $M_{DT} = 105g$ to $M_{DT} = 10500g$, which leads to environmental pollution. Based on the results of the studies, it can be concluded that when designing printing processes, it is necessary to take into account the amount of paint involved in dust formation, which pollutes the environment and significantly affects the quality of the products. The advantages of this study in comparison with analogues are the following: for the first time, the amount of paint involved in dust formation during the printing process is determined as a percentage of the total amount of paint applied to the surface of the printing plate. Also, knowing the geometric characteristics of the surface of the printing plate, it is possible to determine the amount of paint polluting the environment, which is very important in solving environmental problems. Therefore, before the printing process begins, it is recommended to select printing forms with optimal values of surface roughness parameters.

This method for determining the amount of paint involved in dust formation can be useful for specialists dealing with environmental issues in the printing industry.

References

[1] Buletova, N.E. (2013). Ecological and economic security: nature, content and problems of diagnostics in the regions of Russia. - Volgograd, Scientific magazine "Kontsep, Jan 15, 2013 - 220 p, https://books.google.az/books/about

[2] Rogachev, A.F. (2014). Modeling of ecological-economic systems / A.F. Rogachev, Y.V. Fedorova. Drukerovskij vestnik 2014; 1: http://dx.doi.org/

[3] Makarov, A. (2013). Environmental Challenge and Printing. Italics, No. 4, p. 2-6. [Electronic resource], https://tanzor.ru/upload/kursiv4_Ximzavod5.pdf

[4] Printing and ecology. (2024). [Electronic resource]. https://printland.kiev.ua/blog/ecologiya.html

[5] Varepo, L.G., Trapeznikova, O.V., Panichkin. A.V., Bobrov, V.I., Nagornova, I.V. (2024). Algorithm for quantitative assessment of the paint dusting process at the exit from the printing contact zone. [Electronic resource]. https://cyberleninka.ru/article/n/algoritm-kolichestvennoy-otsenki-protsessa pyleniya-kraski-na-vyhode-iz-zony-pechatnogo-kontakta/viewer

[6] Technology of printing processes. (1989). /A.N. Raskin et al. M.: Kniga, p.432.

[7] Varepo, L.G., Panichkin, A.V., Bobrov, V.I. (2013). Splitting of paint at the exit from the printing contact zone. Bulletin of Tula State University. Technical sciences. Issue 3.-p. 189-193.

https://cyberleninka.ru/article/n/rasscheplenie-kraski-na-vyhode-iz-zony-pechatnogo-kontakta/viewer

[8] Khalilov, I., Aliyev, E., Huseynzade, E. (2021). The phenomenon of paint dusting taking into account the surface roughness of the offset printing plate. Problems of labor protection in Ukraine, 37(2), 16–24. DOI: 10.36804/nndipbop.37-2.2021. 16-24

[9] Tyurin, A.A. (1980). Printing machines – automatic machines. Moscow, "Kniga" – 416 p. https://www.studmed.ru/tyurin-aa-pechatnye-mashinavtomaty_49b4554e49d.html

[10] Germanies, E. (1982). Handbook of a printing technologist. Moscow, "Kniga" – 336 p.

[11] Helmut Kipphan. (2003). Encyclopedia of Printed Media. Technologies and Production Methods/Helmut Kipphan; Translated from German. – Moscow: Moscow State University of Printing Arts. – 1280 p. c.c.214-226. https://www.twirpx.com/file/78238/

[12] Varepo, L.G., Trapeznikova, O.V., Panichkin, A.V., Roev, B.A., Kulikov, G.B. (2017). Software for Quantitative Estimation of Coefficients of Ink Transfer on the Printed Substrate in Offset Printing. Metrology, Standardization, Quality: Theory and Practice, (MSQ -2017) International Scientific and Technical Conference on Metrology, Standardization, Quality - Theory and Practice (MSQ) Omsk, Russia Nov 14-16, 2017 Vol. 998. 2018. UNSP 012041. https://doi.org/10.1088/1742-6596/998/1/012041.

[13] Panichkin, A.V., Varepo, L.G. (2013). The Numerical Calculation of the Viscous Incompressible Fluid Transfer onto Porous Surface Between Rotating Cylinders. 1st International Multidisciplinary Microscopy Congress (INTERM). Springer Proceedings in Physics. Antalya, TURKEY. Vol: 154. Oct.10-13, 2013. P. 79-83. 2014. https://doi.org/10.1007/978-3-319-04639-6_11

[14] Aliyev, E.A. (2017). Influence microgeometry offset printing plates for transfer ink from the printing form on dekel. Proceedings of the International Symposium of Mechanism and Machine Science, AzCIFToMM-Azerbaijan Technical University, Baku, Azerbaijan, 201-202. http://web.iyte.edu.tr/~gokhankiper/ ISMMS/ISMMS2017_Proceedings.pdf

[15] Aliyev, E.A., Khalilov, I.A, Ismailova, Sh.V. (2022). Indirect ink transfer for offset printing, taking into account the roughness of the offset printing plate surface./ Machine Science. International scientific-technical journal. Volume 11, Number 2, p. 71-79.

[16] Litunov, S.N. (2017). Fundamentals of printing processes [Electronic resource]. https: // bstudy.Net/858705/tehnika/ponyatie_pechatnogo_protsessa#257.https://bstudy.net/858714/tehnika/fiziko_mehanicheskie_yavleniya_zone_pechatnogo_kontakta#700

[17] Aliyev, E.A., Ismayilova, Sh. V. (2024). Determination of the Ink Layer Thickness, Taking into Account the Surface Roughness of the Printing Forum. Advances in Science and Technology. Vol.148, No. 2. https://www.scientific.net/AST.148/2

TECHNOLOGY FOR PRODUCING GREEN ENERGY FROM POLLUTED LAKES ON THE APSHERON PENINSULA AND ITS ECO-ECONOMIC JUSTIFICATION

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Abstract

This technological development is aimed at using renewable energy sources to provide electricity to oil wells on the Apsheron Peninsula, which contributes to improving the environmental situation and justifying the economic efficiency of this approach. The technology for producing green energy from polluted lakes on the Apsheron Peninsula has enormous potential for solving two main problems: environmental pollution and energy shortage. This project represents an innovative approach to utilizing polluted water resources, combining it with electricity production to support the energy needs of oil wells and the population.

Keywords: hydrogen production, electricity, renewable energy sources, water electrolysis, thermal power station, sustainable energy solution

I. Introduction

The Apsheron Peninsula, located on the shores of the Caspian Sea, is one of the key regions of Azerbaijan. It is rich in natural resources, including lakes and water bodies, which play an important role in the region's ecosystem. However, in recent decades, due to various anthropogenic and natural factors, many of these water bodies have become polluted, posing a serious threat to both the environment and the health of local residents [1-3].

One of the key challenges facing the region is not only the cleaning of polluted water bodies but also the use of their potential for green energy production. In this context, the technology for producing green energy from polluted lakes on the Apsheron Peninsula represents an important and promising direction for development.

The aim of this work is to study and analyze the possibility of using technology for producing green energy based on the purification of polluted lakes on the Apsheron Peninsula to achieve ecological and economic benefits. Within the framework of this work, the main aspects of the technology, its potential in the context of the region, as well as the ecological and economic benefits that can be obtained through its implementation will be considered [4-6].

This study is not only important in terms of improving the region's ecology but also has the potential to stimulate economic development through the creation of new jobs, increasing investments in infrastructure, and reducing dependence on traditional energy sources [7; 8].

II. Methods

Key aspects of this technology:

- Installation of wind turbines on the surface of polluted lakes: wind turbines will be placed on the surface of polluted lakes to harness wind energy for electricity production. This is an efficient way of utilizing available natural resources for generating clean energy.

- Hydrogen production: using electrolysis powered by the electricity generated from wind turbines, hydrogen will be produced. This process involves splitting water into hydrogen and oxygen, with hydrogen being utilized as a green fuel.

- Provision for oil wells: hydrogen can be used as a clean energy source to power oil wells, reducing dependence on traditional energy sources such as oil or natural gas, and decreasing emissions of greenhouse gases and other harmful substances.

- Providing energy to the population: the generated electricity and hydrogen can be used to meet the energy needs of the population in nearby areas, contributing to improving the quality of life and reducing environmental pollution from oil operations.

Thus, this technology represents an integrated approach to addressing multiple issues simultaneously, including energy security, reducing environmental pollution, and supporting the oil industry.

Overall, the technology for producing green energy from polluted lakes on the Apsheron Peninsula presents an effective and sustainable solution for reducing environmental pollution and providing a sustainable energy source for the region.

1. Investigation of Polluted Lakes on the Apsheron Peninsula

An analysis is conducted to identify contamination with oil products. Water samples are collected, then gas chromatography-mass spectrometry (GC-MS) is used to determine the types and concentrations of hydrocarbons in the water. Additionally, analysis of heavy metals is performed using atomic absorption spectrometry (AAS) [9].

For the chemical analysis of the polluted water bodies of "Boyuk Shor" on the Apsheron Peninsula, various apparatuses and methods were used depending on the specific analysis objectives and types of pollutants. The table below includes the main stages of analysis, equipment, and methods employed: 12 water sample bottles were collected from 12 different local sites and depths of Lake "Boyuk Shor."The results of the chemical analysis of the polluted waters of "Boyuk Shor" indicate significant contamination of water bodies on the Apsheron Peninsula with heavy metals, especially lead (Table 1).

Problems with the presence of oil products and coliform bacteria are also identified, posing a risk to public health. Urgent measures are needed to reduce emissions of pollutants and restore water quality in the region.

Despite the identified contamination of water bodies on the Apsheron Peninsula with heavy metals, oil products, and the presence of coliform bacteria, hydrogen in this context can be identified as a potential resource that can be used for clean and sustainable energy [10].

The specific gravity of lead (Pb) is 11.34 g/cm^3, mercury (Hg) is 13.55 g/cm^3, and cadmium (Cd) is 8.65 g/cm^3. The specific gravity of these metals is significantly higher than that of water, and they are concentrated at the bottom, with the rest located in the upper layer. Based on our measurements, the average depth of the lake in different locations is about 5 meters, so considering the presence of heavy metals in the bottom layer of the lake and other lighter impurities in the upper layer, the analysis should be taken at a depth of 2.5 meters using filters for electrolysis.

Table 1: *Results of the analysis of water pollution in "Boyuk Shor" of the Apsheron Peninsula*

Materials	Unit of Measurement	Standard	Actual	Analytical Instruments
Heavy Metal Content:				
Lead	Mg\L	0,05	0,15	Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
Mercury	Mg\L	0,05	0,02	-«-
Cadmium		0,03	0,01	-«-
Organic compounds				
Sum of pesticides	Mg\L	0,1	0,02	Liquid chromatographymass spectrometry (LC-MS)
Content of petroleum products	Mg\L	0,1	0,5	: Gas chromatographymass spectrometry (GC-MS) - conducted according to the USEPA standard.
Water quality parameters	pH	6,5-8,5	7,2	ASTM D 1293
Oxygen solvents	Mg\L	5-10	8,5	Oxygen Meter (DO sensor)
Water temperature	^0C	20	-	Thermometer
Microbiological analysis				
Number of coliform bacteria	CFU/ml	10	100	Filtration methods
Escherichia	E.coli		within the norm	The method of membrane filtration

2. Renewable Energy Sources

The Apsheron Peninsula in Azerbaijan has the potential to utilize several renewable energy sources. Some of these include: wind energy, solar energy, hydro energy, geothermal energy, biomass.

Each of these sources has its advantages and limitations, and a combination of various renewable sources can ensure sustainable and efficient energy production on the Apsheron Peninsula.

In the case of wind turbines on the Apsheron Peninsula, the height of installation plays a critical role in determining their effectiveness. It is important to place wind turbines at a sufficient height to ensure maximum capture of wind flow with minimal turbulent effects (Fig.1) [11-13].

The power of the power station depends on several factors, including the quantity and characteristics of the installed wind turbines, the efficiency of the electrolysis system for hydrogen production, and the overall electricity demand for oil wells. Let's assume several parameters to specify the answer.

Wind turbine power: according to our calculation, it is necessary to install a wind power station with wind turbines of 2 megawatts (MW) each. With the installation of 5 wind generators, the total required power will be 10 MW.

Electrolysis power: assuming an electrolyzer with an efficiency of 80%, meaning 80% of the wind turbine's electricity is used for hydrogen production. In this case, the electrolysis power will be 0.8 * 10 MW = 8 MW.

Hydrogen power station capacity: if hydrogen is used in hydrogen fuel cells with an efficiency of 60%, the hydrogen power station capacity will be 0.6 * 8 MW = 4.8 MW. Thus, in this scenario, the total power of the power station, including the wind farm, electrolysis system, and hydrogen power station, will be approximately 4.8 MW. Let's conduct a comprehensive analysis of the economic and environmental efficiency for the proposed project, which includes the use of electrolysis for hydrogen production and the purification of polluted water bodies on the

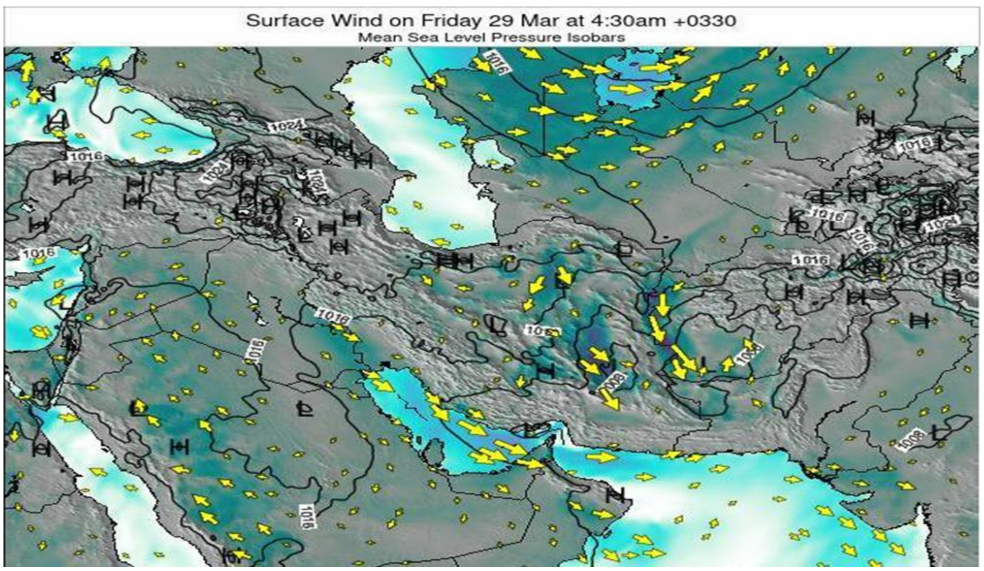

Figure 1: *Wind Map of Azerbaijan*

3. Energy Efficiency and Energy Consumption of Water Electrolysis Apsheron Peninsula.

Water electrolysis is a process in which water is decomposed into oxygen and hydrogen using an electric current passing through an electrolyte. There are several different types of water electrolysis, including alkaline (potassium-sodium) electrolysis, acidic electrolysis, variable electrolysis, and photoelectrolysis [14;15].

The energy efficiency and energy consumption of water electrolysis depend on several factors, including the technology used, operating conditions, and the efficiency of the electricity source. Here are the key aspects: There are several methods of water electrolysis, such as alkaline electrolysis (Fig. 2), PEM (polymer electrolyte membrane) electrolysis (Fig. 3), and high-temperature electrolysis (Fig. 4). Each has its energy consumption characteristics. For example, PEM electrolysis is typically more energy-efficient compared to alkaline electrolysis [16].

4. Electrolysis Technology

The hydrogen production processes discussed in this article are processes where water is the only input material, and hydrogen and oxygen are the only output materials. Moreover, the required energy expenditure should mainly consist of heat rather than useful work, such as electricity. As mentioned above, these processes can be represented as a series of chemical reactions summing up the decomposition of water [17].

Hydrogen production through water electrolysis is one of the most promising methods for obtaining "green" hydrogen that does not produce greenhouse gases when used. However, as noted, the high energy consumption of this process is a serious concern.

Advantages of Different Methods: The advantages of various methods depends on production conditions, raw material availability, energy costs, and environmental considerations. The development and diversity of hydrogen production methods play a crucial role in providing a sustainable and environmentally friendly energy source for the future [18].
In Azerbaijan, the development of these hydrogen production methods will depend on specific production conditions: raw material availability, energy costs, and environmental characteristics. Let's consider several methods of hydrogen production and their potential benefits for Azerbaijan: steam methane reforming (SMR), water electrolysis, thermochemical water splitting, and photocatalytic water splitting.

Water Electrolysis: If Azerbaijan has available renewable energy sources such as solar or wind, water electrolysis can be an effective and environmentally friendly method of hydrogen production. This may be particularly relevant in areas where there is potential for deploying renewable energy sources.

The use of platinum coating on a steel electrode can increase the efficiency of water electrolysis. Platinum is a well-known catalyst for water electrolysis, as it possesses high catalytic activity and corrosion resistance in aggressive electrolysis conditions.

Steel can be an inexpensive and sturdy material for electrodes. However, without a catalyst like platinum, water electrolysis may require higher voltage for an efficient process. Coating the steel electrode with a thin layer of platinum can significantly reduce this potential and provide more efficient water electrolysis.

However, it is worth noting that the use of platinum can make the process more expensive due to the high cost of this precious metal. In this regard, researchers are working on finding more affordable and efficient catalysts for water electrolysis.

Therefore, the use of nanostructured catalysts, such as metal nanoparticles or their compounds, can increase activity and enhance catalyst efficiency.

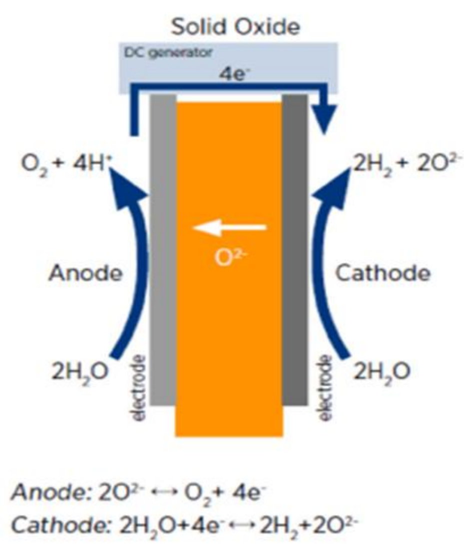

Figure 2: *SOEC reaction mechanism [16].*

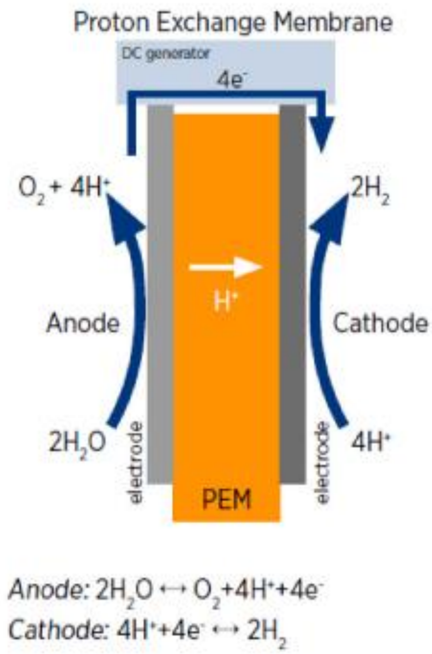

Figure 3: *PEM water electrolyzer schematic diagram and reaction mechanism [16].*

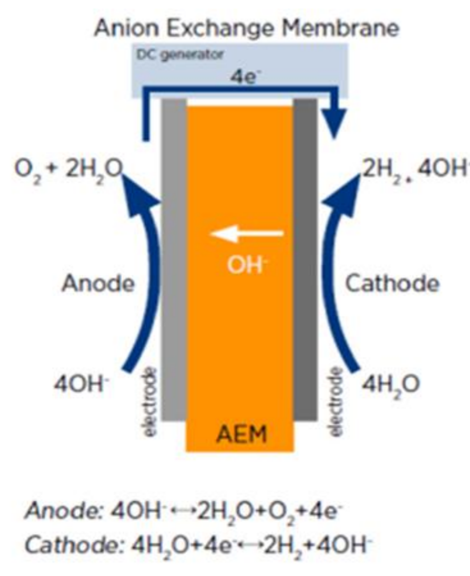

Figure 4: *Alkaline water electrolysis technology [16].*

Scientific research in the field of water electrocatalysis using metal nanoparticles is actively being pursued, and numerous metals have been tested for their catalytic properties. Some of the materials include [19]:

- Platinum nanoparticles (Pt): Although platinum is an expensive metal, platinum nanoparticles exhibit high electrocatalytic activity in water electrolysis.

– Iridium nanoparticles (Ir): Iridium can be used as a catalyst for efficient water electrolysis, especially in combination with other materials.

– Rhodium nanoparticles (Rh): Rhodium has also been investigated as a catalyst for water electrolysis.

- Nickel nanoparticles (Ni): Some research focuses on the use of nickel nanoparticles and their alloys, which may be more affordable compared to precious metals.

– Iron nanoparticles (Fe): Iron and its alloys are also considered as catalysts, especially in combination with other materials.

Nanoparticles provide a larger surface area for interaction with reactants, which can enhance process efficiency. However, besides the material itself, the architecture and structure of nanoparticles also play an important role in determining their catalytic properties [17].

In an experiment conducted by us under laboratory conditions, the coating applied to the metal surface using iron (Fe) method exhibited high operational characteristics, low cost, and a very short and simple production process duration compared to other coatings.

Each method has its unique advantages and limitations, and their application in Azerbaijan will depend on available resources, technical capabilities, and the country's energy and environmental strategy goals. Developing a balanced and sustainable hydrogen production strategy can help Azerbaijan utilize its potential for producing and using this clean energy source.

Let's assume that wind energy is used for water electrolysis to produce hydrogen. In this case, wind turbines generate electric current, which is then used in the electrolyzer to split water into hydrogen and oxygen. The process of producing hydrogen from water (H_2O) using electrolysis looks as follows:

$$2H_2O(l) + \text{electric current} \rightarrow 2H_2(g) + O_2(g)$$

At the anode, water oxidation occurs, forming oxygen (O_2), and at the cathode, hydrogen (H_2) is formed [18].

The advantages of such an approach include:

1. Use of renewable energy: Wind energy is a renewable energy source, allowing hydrogen production with minimal environmental impact and without greenhouse gas emissions.

2. Reduction of dependence on fossil fuels: Producing hydrogen using wind energy helps reduce dependence on fossil fuels and ensures a more sustainable energy system.

However, it should be noted that implementing such a system requires appropriate infrastructure for wind energy generation, hydrogen storage, and utilization. The efficiency and economic viability of this approach should also be considered based on specific conditions and regional characteristics.

The technology for obtaining hydrogen from water is called water electrolysis. This process involves splitting water into hydrogen and oxygen under the action of an electric current. This requires the use of an electrolyzer - a device containing electrodes and electrolyte through which the electric current passes (Fig. 5).

Brief outline of water electrolysis technology:

Step 1: Preparation of the electrolyzer.

The electrolyzer consists of an anode and a cathode separated by an electrolyte, which allows for the passage of ion current between the electrodes. The electrolyzer is filled with water or a solution of alkali or acid to create a conducting medium. These solutions provide the presence of ions in the water, allowing the passage of electric current through the water, causing the decomposition of water into hydrogen and oxygen [19].

The electricity consumption for producing one cubic meter (m^3) of hydrogen can vary significantly depending on the technology used, type of electrolyzer, system efficiency, energy source, and environmental conditions. Additionally, it is important to consider the temperature and pressure at which hydrogen production occurs, as these factors can also affect process efficiency (Fig.6).

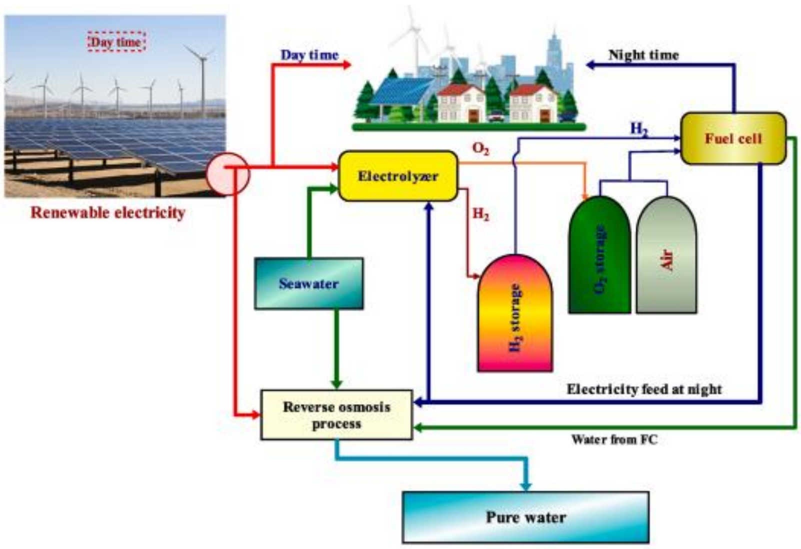

Figure 5: *Proposed integrated system for meeting energy and clean water needs using seawater [17].*

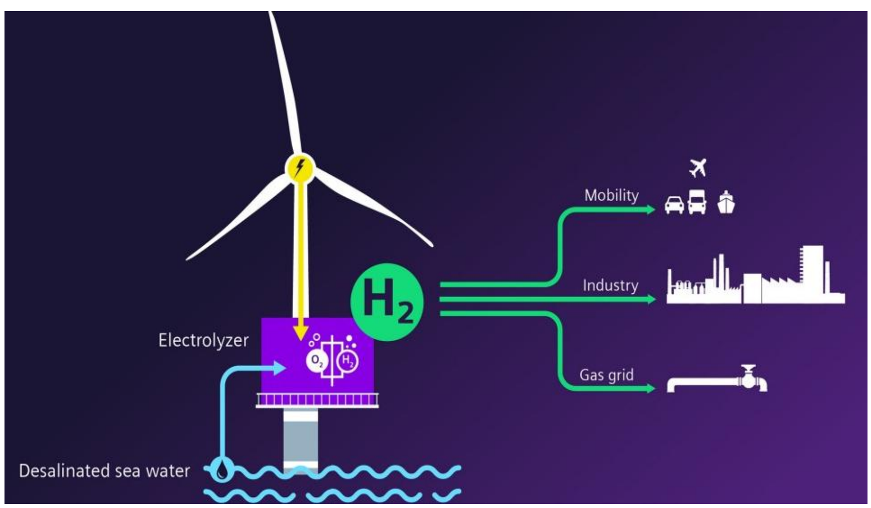

Figure 6: *Schematic structure of the electrolysis-polluted lake - H2Mare [20].*

An approximate estimate of the electricity consumption for producing one cubic meter of hydrogen by water electrolysis is about 4-6 kilowatt-hours (kWh). This value may vary in different systems and conditions, and precise values require more detailed data.

The cost of the electricity source, as well as the efficiency of the production process, will impact the overall energy expenditure of hydrogen production. Producing hydrogen using renewable energy sources such as solar or wind power can reduce environmental impact and make the process more sustainable in terms of climate aspects.

The water consumption for obtaining one cubic meter (m^3) of hydrogen via electrolysis depends on the chemical reactions that occur in the process of water decomposition into hydrogen and oxygen [21].

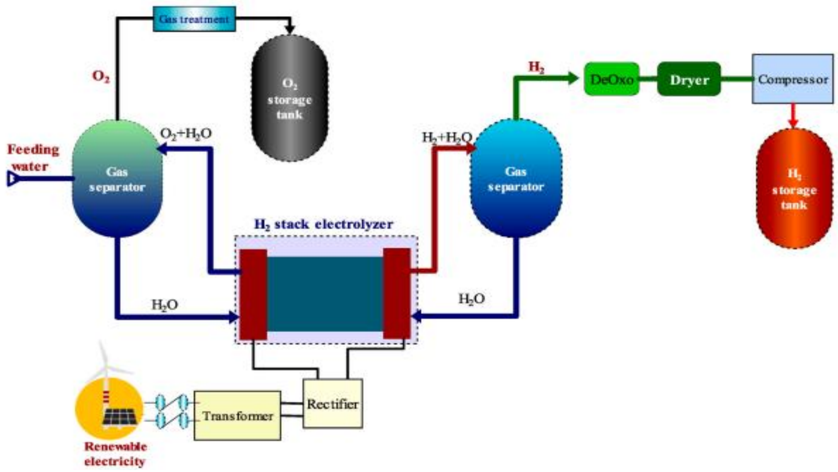

Figure 7: *Basic scheme of H2 and O2 production, including an electrolyzer [17].*

5. Heat Release of Hydrogen

1. Hydrogen has high heat release upon combustion, making it an efficient energy source. The primary reaction during hydrogen combustion is the combination of hydrogen with oxygen, forming water and releasing a significant amount of heat [22]:

Heat release of hydrocarbons (e.g., gasoline or diesel fuel):

$$2H_2+O_2\rightarrow 2H_2O+\text{heat}$$

2. Hydrocarbons also have high heat release upon combustion. The primary components of hydrocarbon fuels are carbon and hydrogen, and the combustion reaction is similar to that of hydrogen:

$$CnHm + (n + m/4)O_2 \text{->} nCO_2 + m/2H_2O + \text{heat}$$

3. Heat Release of Biomass: Biomass, such as wood or agricultural residues, is also an energy source. Its heat release is associated with the combustion process of organic materials, such as cellulose and lipids:

$$C6H10O5+6O2\rightarrow 6CO2+5H2O+\text{heat}$$

6. Environmental Consequences of Renewable Energy Production from Polluted Lakes

While producing green energy from polluted lakes on the Apsheron Peninsula may have significant environmental benefits, such as improving water quality and restoring ecosystems, it may also have certain environmental consequences that need to be considered and minimized. Below are some potential environmental consequences of renewable energy production from polluted lakes:

- Ecosystem Alteration: Infrastructure construction for green energy production may lead to changes in lake ecosystems and surrounding areas. This can affect local plant and animal species, as well as the region's biodiversity [23].

- Loss of Natural Areas: Building hydroelectric power stations or other infrastructure for green energy production may require the allocation of natural land areas, potentially resulting in the loss of ecologically important territories or biological corridors for animal migration.
- Hydrological Regime Alteration: Operating hydroelectric systems may alter the hydrological regime of lakes and water bodies, which can impact their ecological condition as well as plants and animals dependent on this regime.
- Potential Increase in Water Consumption: Large amounts of water may be required to cool hydroelectric power station equipment, leading to decreased water levels in lakes and water bodies. This could negatively affect local flora and fauna, as well as water availability for the local population.
- Risk of Harmful Substance Emissions: While producing green energy from water is considered environmentally cleaner compared to traditional energy sources, there is a risk of emitting harmful substances into the environment due to accidents or improper equipment operation [24].

To minimize these environmental consequences, a comprehensive analysis of potential impacts is necessary. Furthermore, appropriate environmental protection measures should be developed and implemented, along with effective project management for green energy production projects considering environmental aspects.

7. Economic Justifications

The economic efficiency and payback period of capital investments in green energy production technology from polluted lakes on the Apsheron Peninsula may depend on various factors such as construction and maintenance costs, electricity prices, government support, and others.

To do this, it is necessary to take into account not only capital investments but also operating expenses, taxes, inflation, discount rate, and other factors. However, for simplification of calculations, let's focus only on capital investments and assume that all project revenues go towards repaying capital investments [25].

First, let's determine the annual income from hydrogen and oxygen production using windmill electricity:

Annual income = (electricity = 4800 kWh * $0.0388 * 8760 h) + (hydrogen 84.096 x 0.49 x 8760 h) = $1.632 + $360.974 = $1.993 thousand.

Payback period = Capital investments / Annual income

Payback period = $12,000 / $1,993 = 6 years

Conducting comprehensive economic analysis and developing a business plan for the project will help accurately determine its economic efficiency and payback period. Considering the potential environmental benefits and incentives for using renewable energy, as well as the growing demand for green energy worldwide, projects of this kind can have significant potential for successful implementation and economic success.

III. Results

Despite the identified pollution of water bodies in the Apsheron Peninsula with heavy metals, oil products, and the presence of coliform bacteria, hydrogen in this context can be identified as a potential resource that can be used for clean and sustainable energy.

The heat release of hydrogen is an important parameter when considering it as an energy carrier. Hydrogen has high potential as a clean energy source, and its use becomes increasingly relevant with the growing interest in alternative energy sources.

The developed technology for hydrogen production from polluted lakes on the Apsheron Peninsula represents an innovative and sustainable solution capable of contributing to the efficient generation of electricity to operate oil wells. The main stages of the process include electrolysis of water using renewable energy sources, purification of polluted lake water, and obtaining high-quality hydrogen. After that, hydrogen can be integrated into the energy system, providing stable and clean energy supply to oil wells.

This technology has significant advantages, such as sustainable use of local resources, including polluted lakes, for energy production, reduction of greenhouse gas emissions, and improvement of the environmental situation in the region. At the same time, it contributes to strengthening energy independence and increasing the efficiency of the oil industry.

It is important to note that successful implementation of this technology requires joint efforts from scientific and engineering teams, government agencies, investors, and the business community. However, the potential benefits in the form of sustainable energy, reduced environmental pollution, and improved economic efficiency make this approach highly attractive and promising for further research and practical implementation.

Reference

[1] Abe J.O., Popoola A.P.I., Ajenifuja E., Popoola O.M., Hydrogen energy, economy and storage: review and recommendation. // Int. J. Hydrogen Energy 44 (2019), pp.15072–15086.

[2] Midilli A., Kucuk H., Topal M.E., Akbulut U., Dincer I., A comprehensive review on hydrogen production from coal gasification: challenges and Opportunities. // Int. J. Hydrogen Energy 46 (2021) 25385–25412.

[3] Roeb M., Monnerie N., Houaijia A., Thomey D., Sattler C., Solar Thermal Water splitting, in: Renewable Hydrogen Technologies, Elsevier, Amsterdam. The Netherlands, 2013, pp. 63–86.

[4] Kazim A., Veziroglu T.N. Utilization of solar hydrogen energy in the UAE to maintain its share in the world energy market for the 21st century. // Renew. Energy 24 (2001) 259–274.

[5] Jun Chi, Yu Hongmei, Water electrolysis based on renewable energy for hydrogen production. // Chin. J. Catal. 39 (2018) 390–394.

[6] Balat M., Potential important of hydrogen as a future solution to environmental and transportation problems. // Int. J. Hydrogen Energy 33 (2008) 4013–4029.

[7] M. El-Shafie, S. Kambara, Y. Hayakawa, Hydrogen production technologies overview. // J. Power Energy Eng. 7 (2019) 107–154.

[8] https://area.gov.az/az/page/layiheler/yasil-enerji-zonasi/yasil

[9] Mirzoev R.K. Prospects for the development of alternative and renewable energy in Azerbaijan. International Scientific Journal "Bulletin of Science" No. 11 (56) Vol.1 2022, pp. 292-303.

[10] Gurbanaliev A.I., Ismailova G.F. "Green Economy" in the Republic of Azerbaijan: Prerequisites and Directions for Development. // Moscow Economic Journal No.1 2017. Ecology and Nature Use.

[11] Prospects for the development of "green" energy in Azerbaijan May 16, 2023. Russian Council. https://russiancouncil.ru/analytics-and-comments/analytics/perspektivy-razvitiya-zelenoy-energetiki-v-azerbaydzhane/

[12] https://www.nkpi.az/?page=addread&id=13584 Renewable energy sources in Azerbaijan. May 24, 2021 — One of the alternative energy sources is wind energy.

[13] April 4, 2022 — The Absheron Peninsula and the Caspian region create favorable conditions for wind energy production. https://ahik.org/ru/2022/04/азербайджан-обладает-большим-потенц/

[14] Bobylev, S.V., Malkin, V.A., Mushtari, M.S., et al. "Hydrogen Energy and Its Development Prospects."// Bulletin of St. Petersburg University. Series 3. Physics, Astronomy. 2021. Vol. 29. No. 2. pp. 119-128.

[15] Leroy R.L., Industrial water electrolysis-present and future. // Int. J. Hydrogen Energy 8 (1983) 401–417.

[16] IRENA, Green Hydrogen Cost Reduction: Scaling up Electrolyzers to Meet the 1.5^{0}C Climate Goal, International Renewable Energy Agency, Abu Dhabi, 2020.

[17] Mostafa El-Shafie. Hydrogen production by water electrolysis technologies: A review. // Results in Engineering 20 (2023) 101426) pp.7-11

[18] Funk J.E., Thermochemical hydrogen production: past and present. // Int. J.Hydrogen Energy 26 (2001) 185–190)

[19] Hydrogen Energy: Challenges and Prospects / Ibrahim Dincer, Can Ozgur Colpan, Calin Zamfirescu. - Springer, 2016.

[20] https://ua-electro.com/ru/siemens-gamesa-i-siemens-energy-otkroyut-novuyu-eru-morskogo-proizvodstva-zelenogo-vodoroda/

[21] Hydrogen as a Future Energy Carrier / Andreas Züttel. - Wiley-VCH, 2008.

[22] Sustainable Hydrogen Production: Processes, Energy Systems and Technologies / Nicolaos Lymberopoulos, Angelo Basile. - Woodhead Publishing, 2019.

[23] Hydrogen and Fuel Cells: Emerging Technologies and Applications / Bent Sørensen. - Academic Press, 2019.

[24] Zhang, X., Li, S., Qi, T., & Zhang, C. (2020). Electrochemical removal of pollutants and hydrogen production from wastewater: A review. Journal of Hazardous Materials, 384, 121507.

[25] He, C., He, Y., Gao, B., & Zhang, Y. (2020). Green hydrogen production from polluted water by electrocatalysis. Journal of Cleaner Production, 258, 120669.

FREE OSCILLATIONS OF EARTHQUAKE SOURCE

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Abstract

The purpose of the work is to establish the peculiarities of ground vibrations in the near-field zone. The fact is that the existing ideas about generation and propagation of seismic waves in this zone poorly agree with empirical data. The ground vibrations in this zone during explosions and earthquakes are compared. A method of plotting the level of the day surface as a function of time after the moment of explosion is proposed. As a result of ground motion analysis, it is concluded that stresses in rocks during explosion are released in the form of damped standing waves. The amplitude of such oscillations far exceeds the level of generated volumetric seismic waves. And since the mass of oscillating rocks is much greater than the mass of the near-surface layer of ground, the latter have practically no effect on the spectrum and duration of oscillations. Similar processes in earthquakes differ only in the fact that the stresses in rocks exist before the beginning of movement along the fault. The verification showed that in contrast to the ideas about wave generation and propagation used in normative documents of earthquake-resistant construction, the parameters of vibrations in the near-fault zone do not depend on ground conditions. This fact is noted by many researchers. Consequently, many provisions of building codes should be revised. For example, the ground models used in NERA, STRATA, etc. programs are based on the assumption of passing waves and therefore the use of these programs is inappropriate.

Keywords: magnitude, source, fault, near-field and far-field zones of the earthquake, parameters of seismic ground motion, increment of seismic intensity

I. Introduction

Sometimes, the source of an earthquake is often defined as a rupture in rocks or a system of ruptures that occurred in the Earth and led to an earthquake. This definition corresponds to the fault plane as a model for the source of seismic waves. But energy cannot exist outside a certain volume.

Closer to the truth is the definition of an earthquake source as an area in which part of the deformation energy of rocks is converted into the energy of seismic waves. Even such a definition is too simplified. The processes of wave generation and propagation in the source zone remain unknown. There are no estimates of the shape and size of the source zone. The assumption of the source as a realized accumulated strain energy in some area corresponds to small sizes compared to the estimates of such areas from seismotectonic data.

The same applies to the size of aftershock regions. As early as 1935, Charles Richter spoke about the existence of primary and secondary aftershock zones [1]. It is quite probable that secondary aftershocks occur outside the origin and their appearance is the result of stress relief in the origin zone of the main shock. But how to separate primary and secondary aftershocks is still unknown.

Finally, the empirical data do not correspond to the characteristics of known types of seismic waves. According to empirical data, near the fault the amplitudes on soft ground are no higher than on hard ground [2 - 9].

II. Methods

Observations of explosions provide great assistance in studying the processes of generation and propagation of seismic waves. This method has the following advantages. The relative energy of the source is known. The exact time and location of the source are known. This makes it possible to organize a dense network of geophones near the epicenter.

Employees of the Schmidt Institute of Physics of the Earth (IPE) have studied the records of strong ground motions due to explosions, and came to the conclusion that it is impossible to explain the wave field using known types of seismic waves.

The author tried to consider on the field observations materials, obtained by IPE employees, not the level of oscillations at the geophone locations, as usual, but the levels of the day surface at different moments of time [10].

It was shown that the stresses arising in the environment cause, in addition to the known waves, free oscillations of a certain volume of rocks, surrounding the epicenter. The levels of the day surface at different moments of time for one of the explosions, taken from the above-mentioned work, are shown in Figure 1.

There is shown the vibrations of the day surface (vertical component) during an ejection explosion using dispersed charges with a total weight of one thousand tons. The distance between geophones is 100 m.

The first construction was made 0.35 sec after the explosion. The first arrival of shock waves corresponds to a distance of about 650 m. An oscillatory motion is observed with a maximum at a distance of 400 m and a minimum at a distance of 300 m.

After 0.45 s, we can talk about a formed P-wave with the first entry at approximately 820 m. The speed of this wave is about 2 km/sec. The amplitude of the minimum, which was observed after 0.35 sec at a distance of 300 m, took on a negative value (under the previously level).

After approximately 0.75 sec, the ground surface becomes close to the original one. Seismic body waves disappear beyond the considered range of distances. Fluctuations at distances of 600 m and 700 m have practically ceased. But the free vibrations of rocks do not stop.

After 0.9 sec, the amplitude at the same distance of 300 m takes on a maximal positive value.

After 1.5 sec, the amplitude again takes on a maximal negative value.

It can be concluded that the stress resulting from the explosion in the surrounding rocks is "reset" in the form of standing damped oscillations of the medium. Moreover, the amplitude of these oscillations is much higher than the generated traveling seismic waves.

Similar phenomena should occur during earthquakes. The only difference is that during earthquakes, stress in the rocks exists even before movement along the fault begins. The characteristics of seismic vibrations that confirm this hypothesis are considered.

Using empirical material, it is shown that other parameters of oscillations in the focal zone of earthquakes - the predominant period and the duration of oscillations - do not depend on ground conditions. However, seismic intensity on soft ground increases due to a decrease in the bearing capacity of the ground. Previously, only soil liquefaction was usually considered such a factor. However, there is a method for vibrating piles to significant depths (up to 70 m) without the liquefaction process. At acceleration amplitudes on the vertical component PGA > 0.1 g, the shear strength of soft ground in the horizontal plane can decrease several times. This phenomenon is also observed for hard ground, but to a weaker extent [11 - 13].

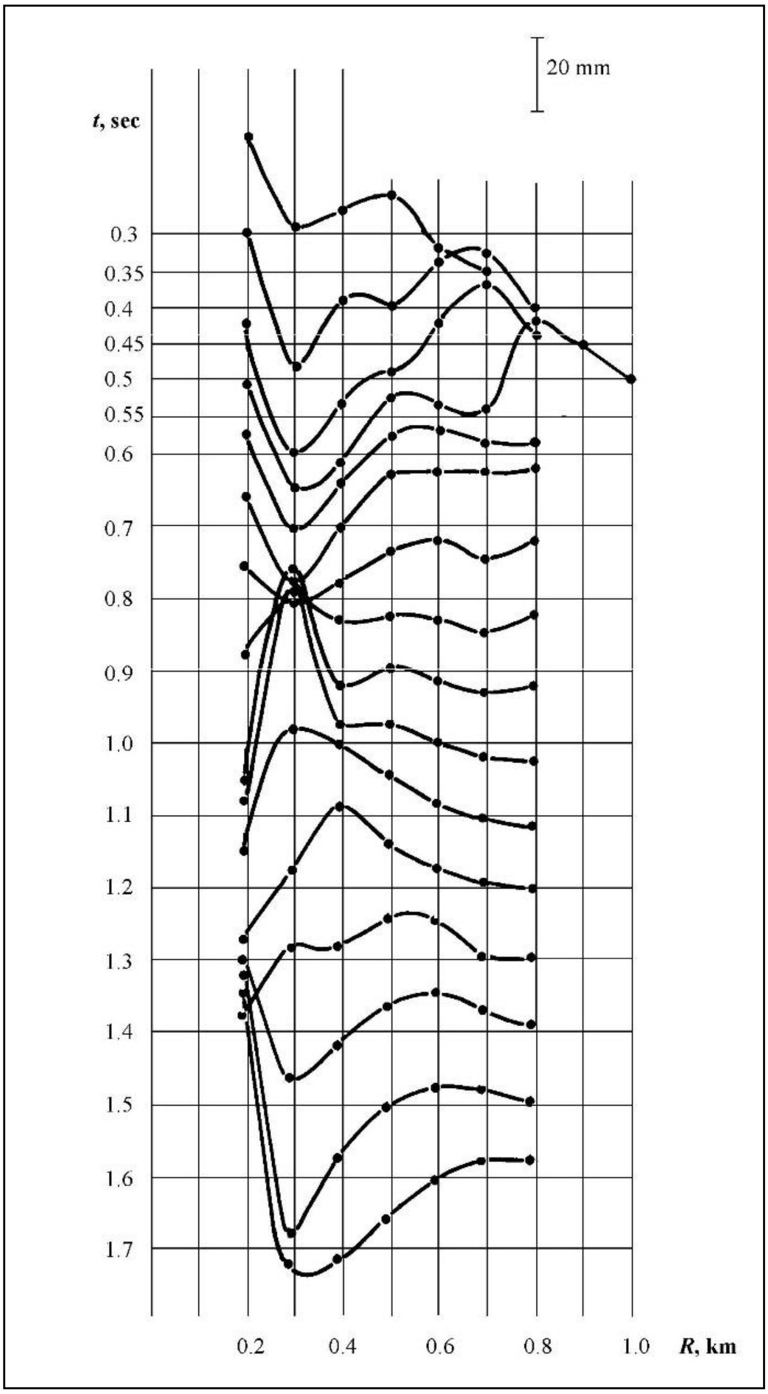

Figure 1: *The levels of day surface for different times for explosion of 1 kt (from [10])*

III. Results

It turned out that the influence of movement along the fault is limited in space. In the engineering range (intensities of 7 – 9 points), three zones were identified in which not only the attenuation laws, but also the dependences of the parameters of seismic ground motion on focal mechanism and ground conditions are different [14].

In the near-field zone the attenuation coefficient is noticeably lower than unity, and in the far-field zone it is much greater than unity. Consequently, seismic wave energy is released in the near-field zone, and this energy is absorbed in the far-field zone. The boundary of the source corresponds to the distance

$$\log R_g = -0.77 + M / 3, \quad (1)$$

where R_g is the shortest distance to the rupture surface,
M – magnitude based on surface waves.

Accordingly, the seismic source has the shape of a parallelepiped with smoothed edges.

Often the natural vibrations of the source are mistaken for a S - wave. In this case, estimates of the hypocentral distance from the difference in arrivals of S- and P - waves will be incorrect.

For some reason, the resonant properties of ground according to the building code is usually determined not on the basis of statistical processing of records obtained on various ground types, but on the basis of models of ground strata such as NERA, STRATA and others. Errors in using such programs are associated with the assumption of passing waves.

Empirical data indicate that the parameters of ground motion in the near-field zone are virtually independent of ground conditions [9, 15]. Thus, the seismic intensity increment in the near-field zone is related to the bearing capacity of the ground.

From the theoretical point of view, the parameters of natural oscillations do not depend on the ground conditions because of the mass of the source rocks is much greater than one of the 30-meter layer on one of the source surfaces. Consequently, seismic intensity increments can be related only to the bearing capacity of the ground. There are known cases when practically undamaged buildings plunged into the ground and tilted strongly. This was attributed to liquefaction of the ground. However, significant ground subsidence can occur without liquefaction. There is a method of vibropiling piles to considerable depths (up to 70 m) and without the liquefaction process.

The influence of ground conditions on the parameters of seismic ground motion is valid only in the far-field zone. Moreover, only half of the increase in seismic intensity is associated with a change in amplitude, and the second half is associated with a change in the duration of oscillations. The last factor, according to empirical data, has the same effect on the damageability of construction objects as the acceleration amplitude. Unfortunately, this factor is not yet taken into account in Russian building codes. In other countries the influence of the duration of oscillations on seismic intensity is accounted for by Arias' formula [16].

Since instrumental estimates of seismic intensity based on accelerations, velocities and displacements generally do not coincide, one can think that the spectral composition of vibrations also affects seismic intensity.

IV. Discussion

Damage to construction objects in the source zone (fault and near-field zones) is related to the free vibrations of the source and is determined only by the magnitude of the earthquake. Parameters of ground motions are independent on ground conditions. Accordingly, it is necessary to develop a system of ground parameters to which the seismic intensity increment refers.

In the far-field zone not amplitude of acceleration only, but all the parameters of ground motion (predominant period and duration of oscillations) depend on ground conditions.

Since instrumental estimates of seismic intensity based on accelerations, velocities and displacements generally do not coincide, one can think that the spectral composition of vibrations also affects seismic intensity [17].

References

[1] Richter C.F. (1958) Elementary seismology.

[2] Neuman R. Earthquake Intensity and related ground motion. Seattle Univ., Wash. Press, 1954.

[3] Duke C.M. et al. Effects of site classification and distance on instrumental indices in the San Fernando earthquake. Rpt. UCLA-ENG-7247, Los Angeles, 1972.

[4] Trifunac M.D. (1976) Preliminary analysis of the peaks of strong earthquake ground motion-dependence of peaks on earthquake magnitude, epicentral distance, and recording site conditions // *Bulletin of the Seismological Society of America*, 66 (1): 132-162.

[5] Mc Guire R.K. and Barnhard T.P. The usefulness of ground motion duration in predicting the severity of seismic shaking. Preprint, 1979.

[6] Joyner W.B., Boore D.M. (1981) Peak horizontal acceleration and velocity from strong-motion records including records from the 1979 Imperial Valley, California, earthquake. *Bulletin of the Seismological Society of America*, 71 (6): 2011-2058.

[7] Campbell K.W. (1981) Near-source attenuation of peak horizontal acceleration. *Bulletin of the Seismological Society of America*, 71 (6): 2039-2070.

[8] Chiaruttini C., Siro L. (1981) The correlation of peak ground horizontal acceleration with magnitude, distance, and seismic intensity for Friuli and Ancona, Italy, and the Alpine belt. *Bulletin of the Seismological Society of America*, 71 (6): 1993-2009.

[9] Aptikaev, F.F.; Erteleva, O.O. (2023) Perfection of the normative base of the earthquake-resistant construction. *Natural and technogenic risks. Safety of constructions,* 5 (66): 129-127 (In Russian).

[10] Aptikaev F.F. Standing waves in the epicentral region. *Seismic wave fields*. Moscow, 1992: 101-103. ISBN 5-02-002304-3. (In Russian).

[11] Okamoto Sh. Bearing capacity of sandy ground and horizontal earth pressure during an earthquake. *International Conference on Earthquake Engineering*. Moscow: Gosstroyizdat, 1961. (In Russian).

[12] Pyke R., Chan C.K., Seed H.B. Settlement and liquefaction of sands under multi-directional shaking. EERC-74-2, Berkeley, 1974.

[13] Ross G.A., Seed H.B., Migliaccio R.R. (1975) Bridge foundation behavior in the Alaska Earthquake. *J. of the Soil Mech. and Found. Div., Proc ASCE (JSMF),* 9B: SM4.

[14] Aptikaev F.F. Instrumental seismic intensity scale. Moscow: Nauka i obrazovanie, 2012. (In Russian).

[15] SP 286.1325800.2016. Construction objects of increased responsibility. Rules of detailed seismic zoning. (In Russian).

[16] Arias A. A Measure of Earthquake Intensity. *Seismic Design for Nuclear Power Plants* / R.J. Hansen, ed. MIT Press, Cambridge, Massachusetts, 1970: 438 - 483.

[17] GOST R14.13330.2018. Earthquakes. Seismic intensity scale. (In Russian).

NATURAL AND MAN-MADE CLIMATE CHANGES IN THE HOLOCENE

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Abstract

The article provides a comprehensive analysis of both natural and anthropogenic climate variations over the Holocene epoch, spanning the last 11,700 years. It begins by exploring the natural drivers of climate change, including Milankovitch cycles, which influence Earth's orbital parameters and contribute to long-term climatic shifts, volcanic eruptions that inject aerosols into the atmosphere, and changes in solar irradiance. These factors played a critical role in shaping early Holocene climate patterns, leading to periods of warming and cooling, such as the Medieval Warm Period and the Little Ice Age. As the article progresses, it shifts focus to the growing impact of human activities, particularly from the advent of agriculture and urbanization to the present-day industrial era. The study discusses how early human practices like deforestation, large-scale farming, and the domestication of animals gradually began to influence local and regional climates. However, it is in the post-industrial era that human influence on the climate has dramatically accelerated, primarily due to the combustion of fossil fuels, mass deforestation, and the significant rise in greenhouse gas emissions. This shift marks a transition from predominantly natural climate drivers to an era increasingly dominated by human-induced climate forcing.

Keywords: Holocene, natural climate variability, anthropogenic climate change, volcanic activity, solar insolation, greenhouse gas emissions, deforestation, industrial

I. Introduction

Climate changes have taken place throughout nearly all geological eras and are documented through paleontological discoveries, shifts in archaeological cultures, and other forms of evidence. However, the use of archaeological data for stratigraphic analysis and other studies is limited to the Quaternary period, as it was during this time that a key event occurred: the emergence of humans. Consequently, this period is also known as the Anthropogenic. Fossil remains and artifacts from human material culture serve as the primary paleontological markers for the subdivisions of the Quaternary period. The archaeological method, alongside paleontological research, is applied in various disciplines, including climatology. The Anthropogenic (Quaternary) period is divided into the Pleistocene and Holocene epochs. The Pleistocene is further subdivided into a series of glacial and interglacial stages, including the Günz, Mindel, Riss, and Wurm glaciations, and the Günz-Mindel, Mindel-Riss, and Riss-Wurm interglacial stages.

The Holocene epoch, the focus of this article, represents the second and current epoch of the Quaternary period. In July 2018, the International Union of Geological Sciences (IUGS) officially divided the Holocene into three distinct ages, each marked by climatic shifts: the Greenlandian (11,700 to 8,200 years ago), the Northgrippian (8,200 to 4,200 years ago), and the Meghalayan (from 4,200 years ago to the present), as classified by the International Commission on Stratigraphy. The Greenlandian is characterized by warming after the last ice age. The

Northgrippian is notable for a significant cooling event triggered by the disruption of ocean circulation due to glacial melt. The current age, the Meghalayan, began with a severe drought lasting around 200 years [Fagan, 2021].

The Holocene epoch began around 11,700 years ago, following the Pleistocene, and is the shortest geological epoch, except for the debated Anthropocene, which some scholars argue started in the 1950s. This epoch is marked by significant global warming, the extinction of Pleistocene megafauna, and the broader Holocene extinction, as well as the spread and social evolution of Homo sapiens.

Due to its distinctive climatic characteristics, the Holocene is generally considered an interglacial epoch, showing many similarities to previous interglacial periods. The primary trend in Holocene climate change was the shift from the cold conditions of the late Pleistocene to a warmer climate, with the peak of warming occurring approximately 6,000 years ago. Although the overall climate during the Holocene was relatively stable, researchers have noted considerable variability.

Roughly 14,000 years ago, the Earth's temperature began to rise, initiating the melting of glaciers and the breakup of ice sheets. This warming was global in scope and led to the degradation of the Wurm ice sheets in Europe and the Wisconsin ice sheets in North America. During this process, there were notable fluctuations in temperature, periodic glacier advances, changes in sea levels, the altitude of snow lines in mountain regions, and the extent of valley glaciers and vegetation zones. The Scandinavian ice sheet disappeared about 9,000 years ago, while the North American ice sheet followed around 7,000 years ago.

II. Methods

Based on paleobotanical data, the Holocene is divided into the following climatic periods: Arctic and Subarctic (end of glaciations and beginning of the postglacial period); Boreal (9,000–7,000 years ago) — cool and dry; Atlantic — warm and humid; Subboreal — warm and dry (xerothermic); and Subatlantic — cool and humid [Holocene climate..].

In the Arctic and Subarctic period (11,000–10,000 years ago), warming not only led to the retreat of ice sheets in North America and Europe, but also to the significant reduction of tundra in Europe. Birch-pine and taiga forests began to expand once again.

During the Boreal period, taiga forests continued to spread northward, replacing the tundra, while broad-leaved forests began to dominate southern and central Europe. The melting of glaciers contributed to a rise in sea levels. This period coincided with the Mesolithic (Middle Stone Age), characterized by the increasing settlement of permanent locations, marking a shift toward a more sedentary lifestyle. People still relied on hunting and gathering, although agriculture began to emerge in some regions, and the clan community was the basic social unit.

Around 6,000 years ago, the Holocene climatic optimum began, which is associated with the Atlantic period. According to the Blytt-Cernander classification, the Atlantic was the warmest and wettest phase of the Holocene in Northern Europe. During this time, temperatures were generally higher than today, and half of Iceland was covered in birch forests, compared to just 1% today. The vegetation in Europe was more diverse and included more heat-loving species. The temperate forest zone extended about 5° further north than its current location, and the average annual temperature in Europe was 1-2°C higher than today. In tropical regions, the climatic optimum brought increased humidity and a slight rise in temperature. The Sahara was a savanna, and Lake Chad’s water level was 40 meters higher than its current level (11 m). Evidence from different regions in both hemispheres indicates that the Holocene optimum was marked by a warm, humid climate on a global scale.

The Subboreal period (5,000–2,500 years ago) was characterized by cooling, which caused a southward shift of landscape zones toward the equator. This period saw the advance of mountain

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glaciers in Alaska, Spitsbergen, Iceland, and the Alps, as well as increased ice cover in higher latitudes and greater aridity in already dry regions.

The Subatlantic period, which began about 2,500 years ago (500 BCE) and continues to the present day, brought cooler and wetter conditions. During this time, the climate deteriorated, becoming cooler with increased precipitation, particularly in parts of Europe where precipitation rose by 1.5 times. Peat bogs began to form, and the tundra expanded into forest areas, while forests encroached upon the steppe. Gradually, the climate shifted toward modern conditions, characterized by higher oceanicity. In the early centuries CE, temperature and humidity were similar to today's levels, but by the 4th–5th centuries CE, the climate became dry and warm until the 8th century, during which time peatlands contracted, and lake levels dropped.

III. Results

Khotinsky N.A. and Savina S.S. conducted a detailed analysis of the ancient climate of the former USSR during the Holocene period [1985]. Earlier, N.A. Khotinsky, using paleobotanical research and radiocarbon dating data, identified three major warm phases of the Holocene within the USSR: the Boreal phase (8,300–8,900 years ago or the 7th millennium BCE), the Late Atlantic phase (the climatic optimum, 4,700–6,000 years ago or the 3rd millennium BCE), and the Mid-Subboreal phase (3,200–4,200 years ago or the 2nd millennium BCE). He also determined that the Boreal warming was most prominent in the Northeast and Far East of the USSR, the Late Atlantic phase was widespread across most of Eurasia, and the Mid-Subboreal phase was particularly significant on the northern Russian Plain.

Several researchers, based on paleoclimatic studies, observed that the warm, humid climate of the 4th millennium BCE transitioned into a hot and dry (arid) climate during the 3rd millennium BCE [Idrisov, 2010]. By the middle of the 3rd millennium BCE, the sedentary Kura-Araxes agricultural society was replaced by a population with a radically different economic system [Kornienko, 2013]. Numerous scholars have similarly linked shifts in archaeological cultures to corresponding climate changes [Munchaev et al., 2012].

In the first centuries CE, temperature and humidity levels were comparable to modern conditions. However, between the 4th and 8th centuries CE, the climate in Europe became drier and warmer, leading to the shrinking of peatlands and falling lake levels. During the Medieval Warm Period (7th to 14th centuries CE), the climate in the Northern Hemisphere became notably milder and warmer, causing a sharp reduction in the ice cover of the northern seas. This period, also known as the Medieval Climatic Optimum, featured mild winters, expanded agricultural land, and a notable increase in both food production and population. Some American researchers suggest that the classical Mayan civilization collapsed during this time due to prolonged droughts [Medieval Climatic Optimum]. In the Caucasus, there was a significant retreat of glaciers in the Greater Caucasus, increased river flows from glacial melt, a drop in the Caspian Sea level, and the formation of deflation basins, all indicative of a warmer climate [Phys. geog. CR, 2006].

By the 14th century, a new phase of cooling had begun. Ice cover in the northern seas increased, and intra-seasonal climate variability also grew, marking the onset of the Little Ice Age. Some sources date the beginning of this period to the 14th century, while others place it in the 17th century, with its effects lasting until the mid-19th century. Key characteristics of the Little Ice Age include the expansion of mountain glaciers and a decline in arable and pasture land. This period is discussed in detail in B. Fagan's book published in 2021 [Fagan, 2021]. However, some researchers, such as A.S. Monin and colleagues, argue that the term "Little Ice Age" is inappropriate, as there was no continuous cooling over the entire period [Monin et al., 1979].

In the Caucasus, the Little Ice Age manifested through a rise in the Caspian Sea level, a weakening of continental climate patterns, increased precipitation, and other features [Phys. geog.

CR, 2006].

IV. Discussion

In the 16th century, the Alpine glaciers began to advance noticeably, but by around 1700, some retreat was observed. However, at the same time, glacier growth was recorded in Iceland and Norway, with a maximum in Sweden occurring around 1710. Significant glacier movements occurred again in the 1720s in the Alps, Scandinavia, the USA, and Alaska. In Alaska, glaciers had already started advancing into the valleys from the 14th century. After some stabilization in the late 16th century, Alaskan glaciers resumed their advance. In the 1740s-1750s, particularly strong glacier advances occurred in Northern Europe, Iceland, and Alaska. Glacier expansion in the Alps continued through the 1760s-1790s, reaching a maximum in 1820. A global peak in mountain glaciation in regions such as the Alps, Iceland, Norway, North America, and the Patagonian Andes was noted in 1850. The last significant global glacier movement occurred between 1850-1860, marking the end of the Little Ice Age.

The timing of climatic changes during the Little Climatic Optimum and the Little Ice Age varied between different regions of the Earth. The exact causes remain unclear, but some hypotheses suggest increased volcanic activity and a decrease in atmospheric CO_2 concentrations as potential factors behind the Little Ice Age.

After the Little Ice Age, a warming period began in the late 19th century, with particularly pronounced warming during the 1920s and 1930s. Climate fluctuations in the late 19th and 20th centuries were measured directly through meteorological observations. In many parts of the world, such as the Caucasus, Pamir, Tien Shan, Altai, and the Himalayas, glaciers retreated during this period, leading to a reduction in their overall area. For instance, the glacier area in the Caucasus shrank by 8.5% between 1890 and 1946 [Modern climate, Internet resource]. Other data, including long-term monitoring from the High-Mountain Geophysical Institute in Nalchik, indicate that glacier coverage in the Greater Caucasus decreased by 40% over the last century.

By the 1940s, this warming trend reversed, leading to a cooling period that peaked in the mid-1960s. Glacier expansion occurred in the early 1960s as a result. However, since the 1970s, a new phase of warming began, which persists today [Monin, 1979]. Since the 1990s, there has been an increase in precipitation, a rise in the Caspian Sea and groundwater levels, and a continued reduction in glacier areas.

There is substantial evidence that the warming following the Little Ice Age extended into the late 19th and early 20th centuries. Instrumental observations show that the average global temperature increased by 0.5°C during this period. Rising global temperatures impact the ocean, causing thermal expansion and, consequently, sea level rise. Changes in precipitation distribution over land have also been observed. Since the early 20th century, sea level measurements show a consistent rise, with an average increase of 4-5 cm per century. Therefore, the past 100 years have been characterized by a period of climate warming.

Since the 1970s, a new phase of global warming has prompted widespread attention to the future of Earth's climate. Various explanations for the causes and consequences of climate change have emerged. The first theory attributes climate change to human activities, particularly the industrial use of hydrocarbon fuels, which has intensified the greenhouse effect. The second theory suggests that global warming is driven by cosmogenic factors, unrelated to human activity. A third theory posits that climate change is a result of the synergy between both anthropogenic (greenhouse effect) and natural processes [Global climate change].

Academician V.M. Kotlyakov acknowledges the greenhouse effect's existence but highlights the difficulty in determining its exact contribution to global climate change. Carbon dioxide is the primary contributor to the greenhouse effect, and efforts to reduce its emissions include transitioning from traditional fossil fuels to renewable energy sources. The Kyoto Protocol (1997) and the Paris Agreement (2015) have been pivotal in setting international standards for reducing CO_2 emissions. In response, renewable energy has gained increasing attention, with the share of renewables in the global energy mix growing to 14% over the past 50 years [Degtyarev, 2022]. Looking forward, population growth and economic expansion will shape global energy demand, with projections indicating a decrease in the use of oil and coal and an increase in gas and renewable energy. According to the World Energy Council, renewable energy sources could surpass 40% of the global energy balance [Salygin, 2021].

Thus, climate change in the Holocene, as in earlier geological epochs, is largely a natural historical process. Following the glacial and interglacial periods of the Pleistocene, the Holocene has witnessed alternating periods of warming and cooling, punctuated by shorter episodic climate shifts. The current warming phase, which began in the 1970s, continues today. However, the industrial revolutions and the increasing consumption of fossil fuels have introduced a significant anthropogenic factor into this natural process.

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References

[1] Daukaev, A. Main trends in climate change in the Holocene epoch of the antropogenic period in the world and in the Caucasus / A. Daukaev, R. Gakaev, T. Bachaeva // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 387-390. – DOI 10.24412/1932-2321-2023-575-387-390.

[2] Gakaev, R. Features of Landslide Manifestations in the Mountainous Parts of the Chechen Republic / R. Gakaev, R. Ahmieva, L. Dzhandarova // BIO Web of Conferences. – 2023. – Vol. 63. – P. 03004. – DOI 10.1051/bioconf/20236303004.

[3] Kornienko T.V. Questions of linguistic kinship, 2013. No. 9. P. 155-162.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Gakaev , R. Carbon sequestration in landscapes of the Chechen Republic / R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 193-196. – DOI 10.24412/1932-2321-2022-366-193-196. – EDN KHSSVY.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

[11] Gunya , A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

THE FEATURES OF AROMATIC HYDROCARBONS IN LIQUID PRODUCTS OF CATALYTIC OXYCRACKING OF VACUUM GAS OIL

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Abstract

While studying the structural and group composition of aromatic hydrocarbons in liquid fractions of the products of catalytic oxycracking of vacuum gas oil, as well as their molecular weight distribution, it was revealed that monocyclic aromatic hydrocarbons predominate in their composition. Their concentration is lower than in the traditional catalytic cracking sample and decreases in 1% OCC > CC > 2% OCC. Among the identified polyaromatic hydrocarbons, naphthalene and its homologs dominate at 1% oxycracking, and phenanthrene and its homologs dominate at 2% oxycracking; at a 1% degree of oxidation, the amount of naphthalene exceeds the indicators of traditional catalytic cracking by almost 2 times, while at a 2% degree of oxidation, this figure decreases by 4 times, which is the smallest among the studied samples. The cresol content also increased significantly. The concentration of fluorene, phenanthrene, and anthracene decreases, but only slightly. In oxycracking products at a 2% degree of oxidation, the content of all PAH groups is the lowest among the samples under consideration. The trend towards a drop in benzo-containing PAHs, noted for traditional catalytic cracking products, is also true for this sample.

Keywords: catalytic oxycracking, vacuum gas oil, aromatic hydrocarbons, naphthalene, cresol, phenanthrene

I. Introduction

The concentration of aromatic hydrocarbons (AHC) is successfully used instead of individual lower homologs of benzene (toluene, xylenes) as solvents for varnishes, enamels, and paints [1-4]. Aromatic solvents are produced: light with the content of C9-C10 arenes - 98% (wt.), medium with 97.3% (wt.) arenes of the naphtha fraction and heavy, containing 87.6% (wt.) of the arenes of the kerosene fraction. Various areas of use of arenes and aromatic solvents correspond to the boiling limits of gasoline-naphtha fractions. The authors noted that one of the most large-scale areas of use of aromatic hydrocarbons (except for the organic synthesis industry) and their mixtures are solvents, primarily for paints and varnishes. The global solvent market consumes about 15 million tons/year for these purposes, of which 36%, i.e. 5.4 million tons/year, are hydrocarbons [1]. According to Hildebrand solubility parameters, aromatic solvents occupy an intermediate position between paraffin-naphthenic and polar solvents [1]. Therefore, aromatic solvents exhibit high dissolving ability towards both non-polar and polar compounds and polymers.

Another large-scale area for the use of aromatic solvents is the oil production industry - mainly in drilling and cementing wells, stimulating oil flow. Aromatic hydrocarbon solvents are used to displace oil, influence the bottom hole formation zone, and inhibit and remove asphaltene-resin-paraffin deposits.

Aromatic solvents increase the effectiveness of de-emulsifiers during dehydration and desalting of oils. Increasing the concentration of arenes in the absorbent of hydrocarbons from natural gas, for example, replacing the hydrocarbon fraction with a boiling point of about 238 °C and an average molar mass of 180 with mesitylene, led to an increase in the degree of propane extraction from 37.1 to 60.2% [1]. The introduction of arenes (0.01-0.04 mol/l) helps to accelerate radical copolymerization processes, for example, methyl methacrylate with vinyl butyl ether, and increases the proportion of vinyl butyl ether units in the copolymer.

One of the most important areas of use of arenes of middle distillate petroleum fractions is the production of detergents based on both linear alkylbenzenes - n-alkyl-benzenesulfonates, characterized by high biodegradability - and alkylbenzenes with branched alkyl chains. Extracts of aromatic hydrocarbons are used as a softener for rubber compounds, to produce carbon black, etc.

Of interest is the method of intensifying the process of distillation of petroleum residues in the presence of aromatic concentrates [5-8]. Thus, adding 3% (wt.) of the extract of the oil fraction 350-420°C to the vacuum residue of West Siberian oil leads to an increase in the distillate yield by 11.5% (wt.). Various explanations for this effect have been proposed: an increase in the degree of dispersion of the oil system, a change in the degree of solvation of dispersed particles; and increasing the thermal stability of the system, which allows increasing the final temperature of the rectification process. Arene derivatives - alkyl arylsulfonates, Petrov's contact, alkylbenzene synthetic oils, sulfonate additives, and antioxidants - are also widely used.

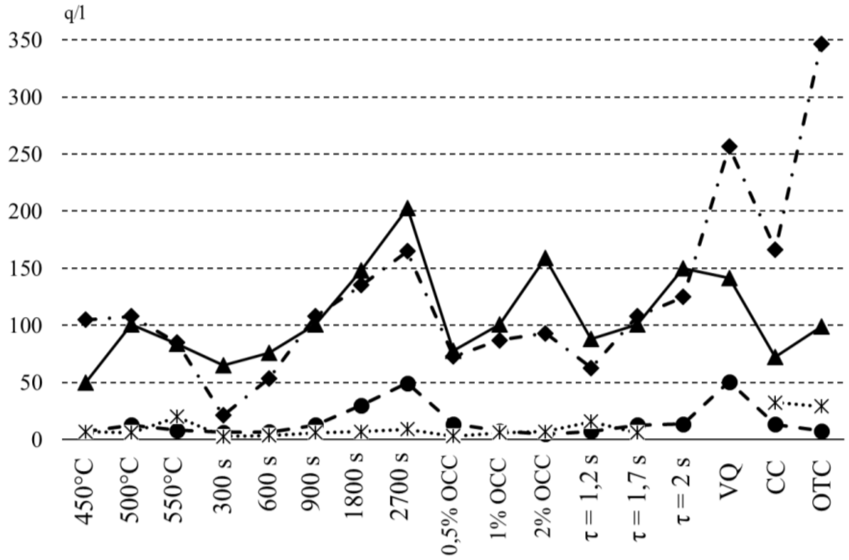
During our previous studies [9-11] of the process of catalytic oxycracking of vacuum gas oil (OCC VG), it was found that increased temperature conditions and high duration and contact time contribute to the formation of a product of a heavy fractional composition. In this regard, studies of the distribution and nature of ArHc are of particular interest for understanding the characteristics of the progression of OCC of VG.

II. Methods

Studies of the oxycracking process [9-11] were carried out in a flow-through installation at atmospheric pressure, at temperatures of 450, 500, and 550°C, with a catalyst volume of 5 cm3. To obtain data on the dependence of quantitative and qualitative indicators of the oxycracking process on technological parameters, it was carried out at 500°C with varying contact time (1.2, 1.7 and 2 s), process duration (300, 600, 900, 1800 and 2700 s), and 0.5, 1 and 2.0% degree of oxidation of the raw material - vacuum gas oil (VG). During the research, experiments of three types were carried out: catalytic oxycracking (OCC) itself, to determine the contribution of the catalyst-non-catalytic oxidative thermal cracking (OTC), as well as a series of experiments of traditional catalytic cracking (CC) under conditions identical to OCC and OTC. The VG OCC process was carried out in the presence of an industrial microspherical cracking catalyst OMNIKAT-210P (manufactured by Grace). The catalyst formed during the experiments was a mixture of both target fractions and unconverted raw materials. Quantitative analysis of hydrocarbons was carried out in a complex consisting of an Agilent 6890N gas chromatograph equipped with a skin with a highly efficient mass selective detector Agilent 5975. Correlation analysis was carried out by calibration with standard reference solutions. A mixture of deuterated polycyclic aromatic hydrocarbons was used as an internal standard: naphthalene-d8, phenanthrene-d10, pyrene-d10, cresol-d12 and perylene-d12 (Cambridge Isotope Laboratories, Inc., Andover, USA). The calculation was carried out based on an external calibration curve. A mixture of 16 polycyclic aromatic hydrocarbons (TCL PAH MIX, Supelco, USA) was used as a standard reference solution.

III. Results

Based on the corresponding characteristic masses of ions, mass fragmentograms of mono-, bi-, and poly ArHc were obtained and the content of the corresponding classes of compounds in VG oxycracking catalysates was determined depending on the process conditions (Fig. 1). The quality of the initial oil fraction, as well as the catalyzer obtained at 500°C for 900 s with a contact time of 1.7 s under conditions during traditional QC and the liquid QC product, is also shown in Fig. 1 and Table 1.



Picture 1: *The influence of OCC process conditions on the individual content in fraction 1 (alkyl-ArH (dotted line)) and fraction 2 (mono-ArHc (dashed line), alkyl-ArHc (solid line) and PaHc (dot-dash)).*

Based on the ArHc content in fraction I (standard gasoline), the catalysates selected at temperatures of 450 and 500°C, OCC duration up to 30 minutes, oxidation degree of 0.5 and 1%, contact time 1.7 s can be classified as types of gasoline with an average ArHc content (3-9%); and under conditions of elevated temperatures - 550°C, durations of 30 and 45 minutes, and contact time of 1.2 seconds - to gasoline with a high ArHc content (>9%). Comparative results of the group hydrocarbon composition of fractions I obtained under the conditions of traditional catalytic and oxidative thermal cracking, presented in the figure, indicate that these gasoline components also belong to highly aromatic products.

In the composition of fraction II of oxycracking samples, a relatively high content of aromatic hydrocarbons is observed (from 24.6 to 59.6% relative to 17.8% in CC), represented by mono-, bi-, and polycyclic structures.

We studied in detail the influence of the OCC process parameters on their nature and distribution due to the high content of ARC in this fraction. Due to the influence of a large number of factors on the content of aromatic hydrocarbons in the oxycracking catalyst, it is almost impossible to unambiguously predict any trend in their formation without describing experimental studies. The highest ArHc content is characteristic of samples obtained under conditions of maximum temperature, oxycracking duration, and contact time. In contrast to these parameters, the degree of oxidation does not have such a significant impact on this indicator. The data obtained indicate the contribution of the catalyst to the formation of ARC under OCC conditions, partly as a result of the same reactions as during traditional catalytic cracking (hydrogen transfer, dehydrogenation of naphthenes and dealkylation of alkyl aromatic hydrocarbons, dehydrogenation and cyclization of olefin hydrocarbons, decomposition of naphthenoaromatic hydrocarbons [12-14]), but mainly due to oxidative dehydrogenation and oxidative dehydrocyclization.

Table 1: *Influence of technological parameters of the oxycracking process on the content of ArHc groups*

Nomination	ВГ	Content in catalyst, %															
		[1]Degree oxidation%			Temperature °C			[3]Duration, s					Contact time , s			[5] OTK	[6]KK
		0,5	1,0	2,0	450	*	550	300	600	*	1800	2700	1,2	*	2,0		
Aromatic hydrocarbons, incl.	35,70	30,89	27,44	27,85	24,58		35,69	36,12	28,12		45,14	59,58	30,05		42,34	46,03	17,84
mono-, alkyl-ArU	11,26	11,50	11,06	16,63	6,17		10,78	14,49	9,61		21,71	25,05	21,19		10,82	10,05	5,13
ind PAH	4,03	2,19	1,30	0,57	0,88		0,99	0,96	0,92		3,98	5,88	1,94		0,92	0,78	0,94
2-6 ring alkyl PAHs	20,40	17,21	15,07	10,65	17,53		23,91	20,67	17,59		19,45	28,66	19,20		18,32	35,20	11,77
ΣPAH/mono-	2,17	1,69	1,48	0,67	2,99		2,31	1,49	1,93		1,08	1,38	0,99		1,78	3,58	2,48

[1] process conditions: duration 900 s; temperature 500°C; contact time 1.7 s.

[2] process conditions: duration 900 s; oxidation degree 1%; contact time 1.7 s.

[3] process conditions: temperature 500°C; oxidation degree 1%; contact time 1.7 s.

[4] process conditions: duration 900 s; temperature 500°C; oxidation degree 1%.

[5] thermal oxidative cracking, process conditions: duration 900 s; temperature 500°C; oxidation degree 1%.

[6] traditional catalytic cracking, process conditions: duration 900 s; temperature 500°C; contact time 1.7 s.

* Experimental conditions: duration 900 s; temperature 500°C; contact time 1.7 s, oxidation degree 1%.

When comparing the data obtained, it is also clear that each of the technological parameters individually has a specific effect on the nature of the distribution of mono- and poly-ArHc: with an increase in the degree of oxidation, the content of mono increases against the background of a decrease in poly- ArHc; at 2% the TCC of mono-ArK is absolute majority; with increasing temperature, both types of compounds gradually increase; the process duration of 600-900 s is the interval in which the resulting catalyst has a minimum content of ArHc of both types; An increase in contact time mainly promotes the formation of mono-ArK ArHc

The ratio of the total content of poly-ArHc as products of condensation and the addition of mono ArHc to the content of the latter can indirectly indicate the nature of the ongoing reactions: condensation, addition on the one hand, or isomerization reactions, hydrogen transfer, transalkylation of aromatic hydrocarbons and cyclization, on the other. For comparison, OTK products, being the most aromatized, in which this ratio is 3.58, are probably formed as a result of addition reactions of fused rings, while KK products, in which the poly-/mono- ratio is 2.58, are cyclization, alkylation [13, 14] .

The results obtained indicate that OCC conditions generally favor isomerization, hydrogen transfer, transalkylation, and cyclization reactions. Whereas low-temperature conditions and large oxycracking contacts slightly increase the contribution of condensation reactions of aromatic hydrocarbons.

Chromato-mass spectrometric analysis, which showed the presence of valuable petrochemical products, such as: acenaphthalene, phenanthrene, fluoranthene, etc., determined the concentrations of individual PAHc in oxycracking catalysts (Table 2). A detailed analysis of the distribution of individual PAHc indicates that in the raw materials, the following 5 components dominate: fluorene, phenanthrene, anthracene, benzo(a)anthracene, and cresol. In traditional CC products, the amount of fluorene and anthracene increased by 40% and 17%, respectively, cresol decreased by 60%, and phenanthracene remained virtually unchanged. The main difference was a more than 6-fold increase in the concentration of naphthalene and a decrease in all benzo-containing PAHs without exception.

Table 2: *The influence of technological parameters of the oxycracking process on the concentration of individual PAHc*

PAH	Concentration depending on process parameters, μg																	
	VG	[1]Oxidation state, %			[2]Temperature, °C			[3]Duration, s					[4]Time contact with, s			[5]OTK	[6]KK
		0,5	1,0	2,0	450	*	550	300	600	1800	*	2700	1,2	*	2,0		
Naftalin	12.4	13.0	148.8	34.4	24.5		38.9	49.7	74.9	50.3		17.7	53.3		15.4	14.9	79.6
Acenaftilen	6.9	1.4	5.5	2.0	3.2		3.4	1.8	3.5	3.9		1.8	2.2		3.3	1.5	6.3
Acenaften	16.5	3.5	26.7	9.1	9.8		10.9	10.3	12.9	12.3		10.3	12.1		10.5	7.6	21.8
Fluoren	128.2	30.1	143.0	84.3	96.0		103.3	99.9	103.3	108.4		107.	113.6		106.7	78.8	179.5
Fenantren	737.8	96.1	654.5	389.2	511.5		533.3	468.4	490.8	570.7		539.5	549.7		543.9	417.1	743.2
Antrasen	58.3	13.4	63.3	37.0	38.4		39.7	36.9	32.7	43.5		42.5	39.0		40.3	32.0	68.2
Fluoranten	22.7	8.5	22.3	12.2	18.6		18.6	14.8	16.4	17.2		19.2	17.8		16.4	16.4	26.9
Piren	48.2	21.3	41.0	23.2	38.4		32.5	27.9	35.7	38.0		36.1	34.4		34.5	31.2	44.5
Benzantrasen	53.4	30.4	47.2	21.1	32.8		32.2	29.1	30.9	35.6		38.2	27.7		28.9	32.4	44.7
Krizen	239.6	100	178.3	72.6	106.5		97.1	85.8	96.4	98.5		104.9	99.6		97.6	107.2	97.9
Benzfluonten	20.3	15.7	16.1	5.4	11.8		9.9	8.72	10.2	9.6		9.7	10.5		9.1	14.6	12.2
Benz(a)piren	13.4	7.7	4.1	1.3	3.1		3.8	2.61	3.1	2.8		2.6	3.0		2.6	4.0	4.1
Indenpiren	5.2	3.1	2.5	0.2	2.2		1.2	0.98	1.2	0.8		1.5	1.5		1.2	2.2	1.1
Benzperilen	2.9	5.2	0.9	0.7	2.1		1.3	1.19	1.4	1.1		1.6	1.6		1.4	3.4	1.7
Dibenzatrcen	2.9	7.3	6.0	1.3	3.1		3.6	2.4	3.1	3.6		3.1	2.4		2.7	6.2	1.7

[1] process conditions: duration 900 s; temperature 500°C; contact time 1.7 s.
[2] process conditions: duration 900 s; oxidation degree 1%; contact time 1.7 s.
[3] process conditions: temperature 500°C; oxidation degree 1%; contact time 1.7 s.
[4] process conditions: duration 900 s; temperature 500°C; oxidation degree 1%.
[5] thermal oxidative cracking, process conditions: duration 900 s; temperature 500°C; oxidation degree 1%.
[6] traditional catalytic cracking, process conditions: duration 900 s; temperature 500°C; contact time 1.7 s.
* Experimental conditions: duration 900 s; temperature 500°C; contact time 1.7 s, oxidation degree 1%.

IV. Discussion

Consideration of the results of the distribution of individual PAHc in oxycracking products made it possible to identify several distinctive features in comparison with the indicators of traditional catalytic cracking. The composition of raw materials - VG, as well as liquid products of its oxycracking and traditional catalytic cracking, includes the same homologous series of aromatic hydrocarbons, monocyclic aromatic hydrocarbons predominate; concentration changes of monocyclic aromatic hydrocarbons: 1% OCC > CC > 2% OCC ; Among the identified polyaromatic hydrocarbons, naphthalene and its homologues dominate at 1% oxycracking, and phenanthrene and its homologs dominate at 2% oxycracking; in oxycracking samples the concentration of ArHc is lower than in traditional catalytic cracking.

References

[1] Gaile A.A., Somov V.E., Varshavsky O.M. Aromatic hydrocarbons: Isolation, application, market Directory. - St. Petersburg: Khimizdat, 2000. - 544 p.

[2] Sokolov V.Z., Kharlampovich G.D. Production and use of aromatic hydrocarbons. M.: Chemistry. 1980. P. 336

[3] Tym de Wild, Tamas Nemeth, Pascal Becker, Detlef Günther, Thomas Nauser, Thomas J. Schmidt, Lorenz Gubler, Repair of aromatic hydrocarbon-based membranes tested under accelerated fuel cell conditions, Journal of Power Sources, Volume 560, 2023, 232525

[4] Ming Chen, Piao Xu, Guangming Zeng, Chunping Yang, Danlian Huang, Jiachao Zhang, Bioremediation of soils contaminated with polycyclic aromatic hydrocarbons, petroleum, pesticides, chlorophenols and heavy metals by composting: Applications, microbes and future research needs, Biotechnology Advances, Volume 33, Issue 6, Part 1, 2015, Pages 745-755,

[5] Syunyaev Z.I., Safieva R.Z., Syunyaev R.Z. Oil disperse systems. M.: Khimiya, 1990. 226 p.

Petrochemistry, 2020, T. 60, No. 1, pp. 3-19

[6] Increasing the efficiency of the oil distillation process at refineries by preliminary optimal mixing of raw materials (review) E. A. Chernysheva, I. V. Piskunov, V M. Kapustin

[7] Yuhe Tian, Salih Emre Demirel, M.M. FArHcque Hasan, Efstratios N. Pistikopoulos,An overview of process systems engineering approaches for process intensification: State of the art,Chemical Engineering and Processing - Process Intensification,Volume 133,2018,Pages 160-210

[8] Luning Chai, Bin Lou, Jun Li, Yanjun Liu, Zhichao Wang, Xiaoguang Pei, Liekui Cai, Dong Liu, Insight into the reactivity of aromatic-rich fractions co-carbonized with polyethylene glycol for preparation of isotropic pitch with superior spinnability, Fuel Processing Technology,Volume 237,2022,107433

[9] Guseinova E.A., Mursalova L.A., Bagirova N.N., Adzhamov K.Yu. Calculation determination of the conditions for the oxycracking process of vacuum gas oil // Journal "Petrochemistry", 2019, volume 59, No. 2, s. 172-177

[10] Hydrocarbon composition of liquid products of catalytic oxy-cracking of vacuum gasoil // 2023BIO Web of Conferences 67(20)

[11] Elvira Guseinova, Alakbar Hasanov, and Rashad Shikhiyev

Influence of catalytic oxycracking conditions on the concentration of hydrocarbon groups in the catalyst // Science. Technology. Production - 2023: materials of the All-Russian Scientific and Technical Conference. Part 1 / editorial board: N.G. Evdokimova and others - Ufa: UPTS "Publishing House USNTU", 2023. - 495 p. P. 232-234 E.A. Guseinova

[12] Kruglova, L.E. Quality assessment of gas oils obtained from catalytic cracking of mixed feedstocks / L.E. Kruglova, S.N. Khadzhiev // Petrochemistry, - 2004. v. 44. No. 1, - pp. 11-15.

[13] Potapenko, O.V. Intermolecular hydrogen transfer reactions as key stages in catalytic cracking processes: achievements and prospects / Potapenko, O.V. Doronin V.P., Sorokina T.P. [and others] // Uspekhi khimii, - 2023. v. 92. No. 1, – pp. 1-31.

[14] Obryadchikov, S.N. Oil technology. Part 23, – Moscow; Leningrad: Gostoptekhizdat, - 1952. - 408 p.

MINIMIZING CLIMATIC FLOOD RISKS OF THE CURONIAN SPIT (BALTIC COAST)

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Abstract

The article is devoted to the application of nature-compatible solutions for minimizing climate risks and adapting to climate change. The article presents the results of a study on surface runoff in Curonian Spit area using models of the InVEST Urban Stormwater Retention software package. The modeling results identified the most vulnerable area in the Curonian Spit (Baltic Coast) in terms of potential flooding in the context of increasing climate change - specifically, the village of Rybachy. To minimize the climatic risks of flooding and to modernize the rainwater drainage and collection, nature-compatible solutions have been proposed for integration into the existing infrastructure.

Keywords: nature-compatible solutions, adaptation to climate change, risks

I. Introduction

Nowadays, significant attention is devoted to mitigating and adapting to the impacts of climate change. The 2024 Global Risks Report by the World Economic Forum identifies three key climate-related challenges as primary risks facing humanity: extreme weather events, critical changes in Earth's systems, and the loss of biodiversity and ecosystem degradation. Solutions aimed at minimizing risks and adapting to climate change are essential to reduce the effects of rising temperatures, intense storms, water pollution and eutrophication.

Anthropo-natural systems (APS), created through natural processes and human intervention, are particularly sensitive to climate change [1]. One such system is the Curonian Spit - a narrow, elongated, crescent-shaped sandspit separating the Curonian Lagoon from the Baltic Sea. The Curonian Spit has been shaped by the sea, wind, and human activity and continues to be influenced by these factors. After catastrophic human interventions that threatened its existence, the spit was restored through extensive protection and stabilization efforts beginning in the 19th century and continuing to this day. The contemporary cultural landscape of the Curonian Spit has been formed under the influence of both both human and natural forces.

The Curonian Spit is constantly affected by waves and storms, experiencing erosion and flooding, which pose threats to the population and infrastructure of the settlements within its territory. Under changing climate conditions, the frequency and intensity of such events are increasing. Additionally, the rising population and tourist numbers on the Curonian Spit, and the consequent increase in anthropogenic pressure, may lead to the loss and degradation of coastal ecosystems and their ability to protect people during storms. Thus, this topic is particularly relevant; it is crucial to understand the roles of various biological and geophysical factors that can enhance or mitigate the threat of coastal erosion and flooding to better plan future development of the territories [2].

To minimize the climate-related flood risks on in the Curonian Spit area, it is necessary to adopt technologies that can take into account climate change. In these conditions, nature-compatible solutions are most effective, using sustainable management principles and natural properties and processes to solve social and environmental problems. International experience shows that nature-compatible solutions are economically viable and sustainable, offering long-term effectiveness compared to technological investments or the construction and maintenance of infrastructure [3]. In the Russian Federation, nature-compatible solutions are rarely implemented, yet local residents of the Curonian Spit have long adapted to environmental changes, creating favorable living conditions. That is why it is particularly important to apply nature-compatible solutions for climate adaptation in the Curonian Spit area.

II. Research methods

The study employed field observations, modeling, and a monographic method. The InVEST Urban Stormwater Retention Model from the InVEST software suite was used to assess the annual volume and quality of stormwater. This model evaluates potential groundwater recharge and the amount of pollutants in surface runoff. [4]. The InVEST Urban Stormwater Retention Model primarily addresses surface runoff and is designed for implementation in urban watersheds. It calculates the annual volume and quality of retained stormwater, thus showing the prevention of pollutant transfer to water bodies. Retention, groundwater recharge, and surface runoff are evaluated on an annual scale rather than for individual adverse events. [2]. The model calculates the annual retention volume of runoff for the Curonian Spit National Park over an area of 0.1 hectares. Categorization of the results into three groups is used for clarity.

The initial data processing was carried out in two Geographic Information Systems – QGIS version 3.24.3 and ArcGIS ArcMap version 10.3. Maps and diagrams were developed in GIS ArcGIS ArcMap version 10.3.

III. Results

To identify areas on the Curonian Spit susceptible to climatic flood risks, a study on runoff retention was conducted. Runoff modeling identified critical areas for flow retention (marked in red in Figure 1). These critical areas are characterized by a low annual volume of flow retention, resulting in high flood risks. The study revealed that the village of Rybachy faces the greatest flood risk, with a retention volume of less than 220 m^3/year from an area of 0.1 hectares, while the annual runoff volume exceeds 276 m^3/year with a soil filtration coefficient of up to 44 m^3/year. The village predominantly consists of soils with high runoff potential, comprising 20-40% clay and 50% sand [5]. Based on these results, Rybachy is identified as the most flood-prone area, with a population of about 1,000 residents. The location of Rybachy is detailed in the Figure 2.

To modernize the drainage and rainwater collection system and minimize the climatic flood risks in Rybachy, nature-compatible solutions are proposed for integration into the existing infrastructure. Given the soil and climate conditions in Rybachy, bioswales and permeable parking lots are recommended for rainwater collection. Bioswales are vegetative stormwater systems that form part of a sustainable drainage system. They consist of specialized soil layers, gravel, drainage systems with perforated pipelines, and overflow mechanisms to manage substantial stormwater volumes. Bioswales will be placed in adjacent areas to collect water from roads, pedestrian surfaces, and roofs.

For flood protection, the use of wetlands is proposed. Treated water will flow through linear bioswales and drainage pipes to the wetland, which will serve as a site for wastewater accumulation and treatment. Artificial wetlands are engineered systems that enhance the physical, biological, and chemical processes of water purification. They are widely used for treating municipal wastewater, landfill leachate, urban stormwater, and industrial wastewater. Wetlands not only purify water (removing fine sediments and pesticides) but are also provide habitats for wildlife, enhance aesthetics, reduce flood risks, and facilitate water reuse. Artificial wetlands can be established in areas with high stormwater volumes.

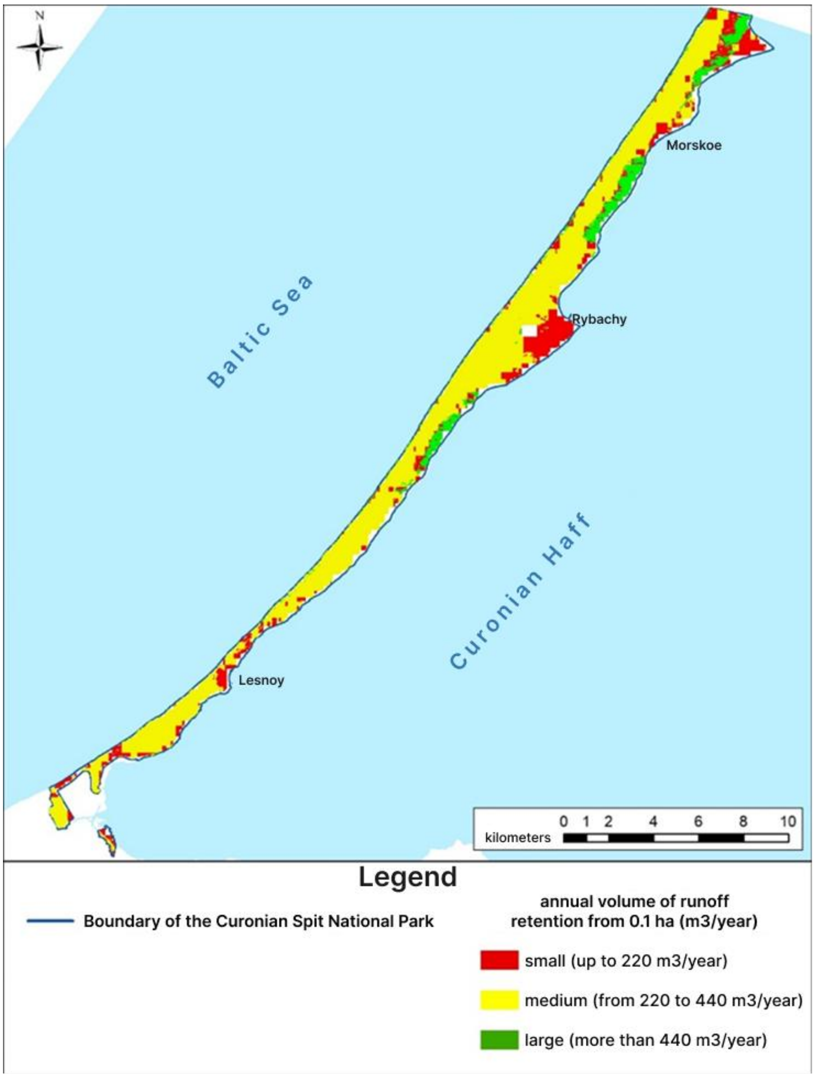

Figure 1: *Annual volume of runoff retention in the Curonian Spit territory*

Figure 2: *Area of the village of Rybachy*

Based on the studies in Rybachy, proposals were developed for the placement of bioswales, wetlands, and permeable parking lots (Figure 3).

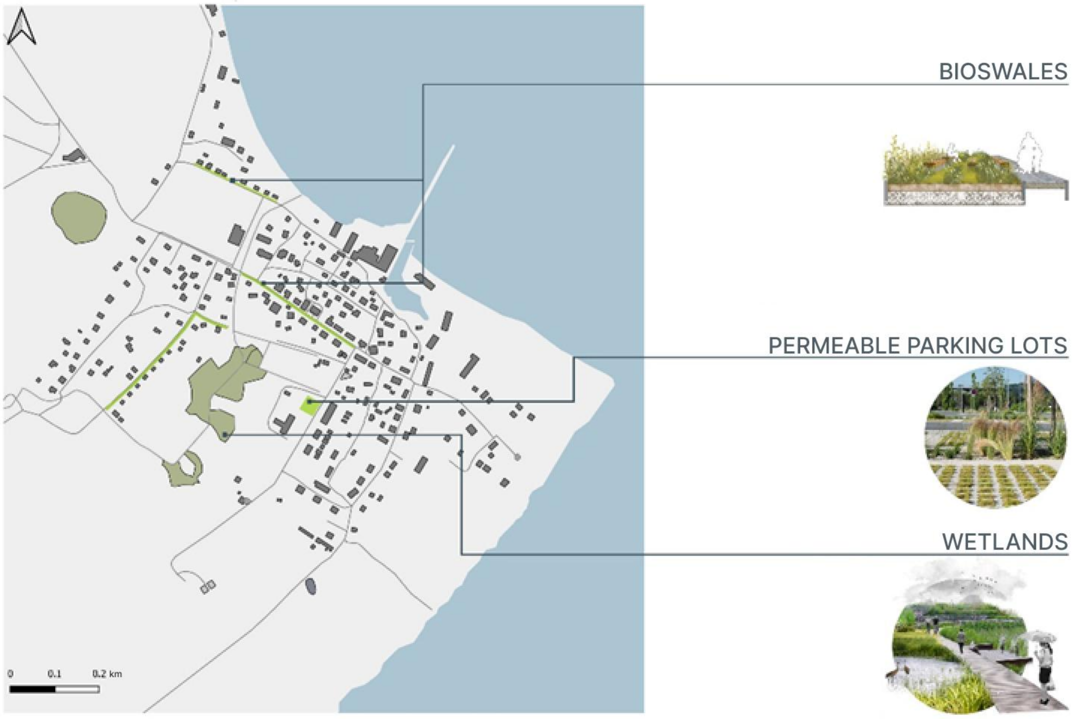

Figure 3: *Location of proposed nature-compatible technologies*

Modeling and international experience indicate that the most effective natural solution for the study site is the establishment of wetlands (Figure 4).

Figure 4: *Location of the proposed wetlands*

Bioswales are to be created along roads. These bioswales will be installed along the transition zone, with the covering made at an incline for natural water drainage into green islands At the same time, water entering the bioswale undergoes natural purification due to the vegetation layer, with sand acting as an absorbent and layers of gravel and geotextiles providing filtration. In other words, bioswales are multifunctional stormwater transport systems capable of retaining excess water and filtering out dirt and pollutants. The proposed locations for bioswales are shown in Figure 5.

Figure 5: *Location of the proposed bioswales*

The implementation of these nature-compatible solutions in Rybachy is expected to reduce climatic flood risks due to water retention in the wetlands. The volume of filtration directly in the wetlands and bioswales is projected to be more than 440 m^3/year, with more than 220 m^3/year retained in the village (Figure 6).

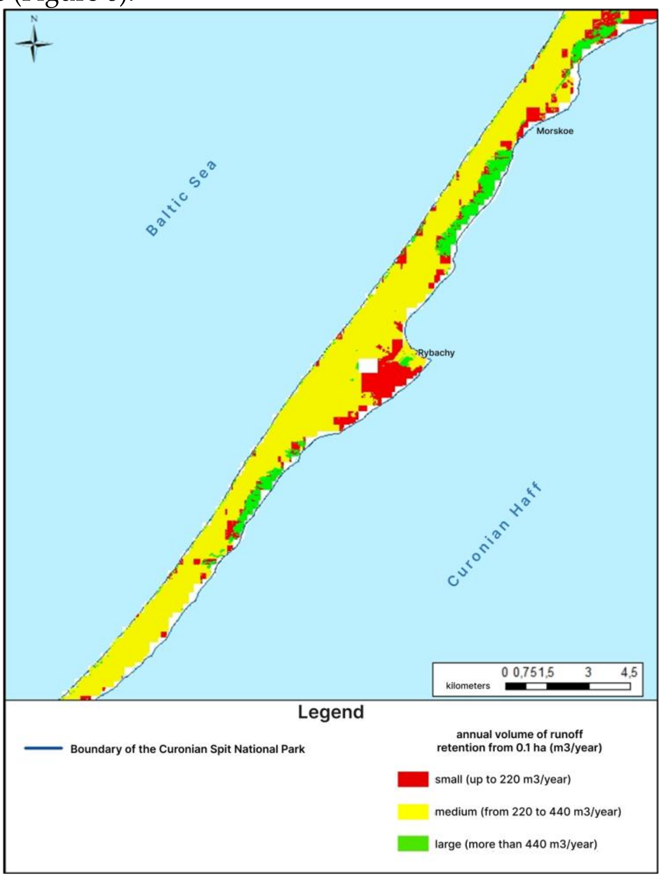

Figure 6: *Annual volume of flow retention in the Curonian Spit after the implementation of nature-compatible solutions*

IV. Discussion

The effectiveness of such solutions is well-documented internationally. In New York, there are over 5000 wetlands that provide wildlife habitats, absorb atmospheric carbon dioxide, enhance settlement resilience to climate change, reduce flood risks, and collect, retain, and filter stormwater.

V. Conclusions

Research conducted in Rybachy highlights the importance of nature-compatible solutions in minimizing climatic flood risks on the Curonian Spit. The arrangement of bioswales, permeable parking lots, ha and artificial wetlands will mitigate flood risks and modernize the rainwater drainage and collection system in Rybachy.

Modeling results show that the introduction of nature-compatible solutions reduces the flood risk by 50%, and double the volume of retained runoff. The implementation of the proposed solutions will increase the filtration volume in the wetland site from 44 m^3/year to 86 m^3/year per 0.1 hectare and raise the volume of retained stormwater to 440 m^3/year per 0.1 hectare.

In addition, the creation of artificial wetlands plays a crucial role in restoration ecology. Many wetlands are among the most productive natural ecosystems, often surpassing the best farmland and rivaling the productivity of tropical rainforests. They provide habitats for a rich diversity of native species, thereby preserving biodiversity and minimizing the risk of ecosystem destruction. Bioswales effectively treat rainwater, reducing pollutants, providing attractive wildlife habitats, and naturally replenishing groundwater reserves.

References

[1] Fomenko G.A. Ustoychivyy ekspelitel'nyy dizayn: osnovnye cherty i osobennosti: uchebno-metodicheskoe posobie [Sustainable ecosystem design: main features and features]. Yaroslavl: ANO NIPI "Cadaster", 2021. 136 p. (In Russian) (Series "Planning and Design of Spatial Development").

[2] Sustainable ecosystem design: GIS-technologies and modeling: a textbook / Scientific editor: G.A. Fomenko. Yaroslavl: ANO NIPI "Cadaster", 2023. 192 p. (In Russian)

[3] IUCN French Committee (2019) Nature-based Solutions for climate change adaptation and disaster risk reduction

[4] Beck, N. G., Conley, G., Kanner, L., & Mathias, M. (2017). An urban runoff model designed to inform stormwater management decisions. Journal of Environmental Management, 193, 257-269.

[5] State report "On the ecological situation in the Kaliningrad region in 2021" / Ministry of Natural Resources and Ecology of the Kaliningrad region. Kaliningrad, 2022. 200 p.

ADAPTATION OF THE HOUSING AND UTILITIES SECTOR OF BELARUS TO CLIMATE CHANGE

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Abstract

The article is devoted to assessment of impact of climate change on activity of housing and communal services sector in the Republic of Belarus. Assessment of climate change impact, risks and opportunities of housing and communal services sector was carried out on the basis of qualitative and quantitative analysis of sectoral «impact chains». Climate change impact assessments were carried out for water supply and sanitation (sewerage), rainwater sanitation. Heat waves, intense heat, droughts will have a significant negative impact. Warming in winter will have a positive impact on wastewater treatment. Based on the findings, a strategy for adapting the housing and utilities sector to climate change is currently being developed.

Keywords: housing and utilities sector of Belarus, climate change, adaptation measures

I. Introduction

In accordance with the National Strategy for Sustainable Socio-economic Development of the Republic of Belarus until 2030 [1], the main measures to reduce the impact of climate change on socio-economic development are:

- increase the ecological security of the territories by optimizing the location of production facilities and the organization of territories of settlements;
- modernization in the main industries;
- establishment of a natural risk management system;
- introduction of water-saving technologies;
- creation of reliable hydrometeorological monitoring and others.

The development of the «green» economy in Belarus implies solving environmental problems while ensuring economic security, social stability and creating additional conditions for the resumption of sustainable economic growth.

In many sectors of the economy there are real needs for the modernization of technological processes, the introduction of innovative «green» technologies that allow to increase the ecological sustainability of the economy and increase employment of the population by improving working conditions, and ample opportunity to do so.

Taking into account socio-economic conditions, prospects, expediency, international obligations, priority directions of development of «green» economy in the Republic of Belarus [2] include the following:

- implementation of sustainable consumption and production;
- development of the closed cycle economy (circular economy);
- formation of smart and energy efficient cities;
- development of electric transport (infrastructure) and urban mobility;
- climate change mitigation and adaptation.

These areas of development of the country’s economy in the context of climate change are directly related to the living conditions of the population, which supporting by housing and communal services.

Therefore, assessing the impact of climate change, vulnerability and climate risks in the housing and communal services sector in order to strengthen the planning system for adaptation to climate change in the Republic of Belarus is an important task at the present stage. The research was carried out within the framework of the project «EU for climate» in 2021-2022 with the financial support of the European Union (EU) and is implemented by the UN Development Programme (UNDP).

II. Methods

For the purposes of this study, the following activities of the housing and communal services are considered: drinking water supply and sanitation (sewerage), rainwater sewerage. The objects of the study are elements of engineering infrastructure and provided services of water supply and sanitation. The assessment also took into account the conditions of water supply and sanitation for urban and rural settlements, including water supply and the collection and treatment of domestic and surface wastewater from industrial plants.

Assessment of climate change impact, risks and opportunities of housing and communal services industry was carried out on the basis of qualitative and quantitative analysis of sectoral «impact chains». To identify the focus of priority adaptation measures to climate risks, information is needed on the difference in the magnitude of such risks in the spatial (e.g., regional/district) or temporal (current - future) dimensions. The standardized risk assessment methodology of the German Society for International Cooperation (GIZ) [3] was used for this purpose.

According to the GIZ methodology, the risk is divided into three main components: «exposure», «vulnerability» and «hazard», each of which is assigned its own weight and a set of indicators with their thresholds and its own weights. A numerical value is then calculated for each risk component, taking into account rationing of indicators. On the basis of the values of the risk components, the integral risk indicator for the examined system is calculated.

For example, the forecasting of future risks of disturbance of treatment facilities and risk of contamination of surface water bodies was carried out taking into account information about climate change and parameters of the system. The «exposure chain» for the risk of disruption of the operation of treatment plants with a set of indicators for each component of the given risk is presented in Fig. 1.

The «Hazard» component includes an increase in hot and very hot days, average annual rainfall and the duration of winter.

For the component «Exposure», two indicators have been selected: the number of cases of excess pollution of water bodies by wastewater and the coverage of the population by water treatment and wastewater treatment systems.

For the risk component «Vulnerability» four indicators were selected: two describe sensitivity («deterioration of water treatment infrastructure and facilities», «number of water bodies with poor and very poor ecological status»), and two describe adaptive capacity («developed national documents and technical standards» and «percentage of biological treatment plants»).

Analysis of sectoral «impact chains» allowed to determine the main risks, necessary measures and resources for adaptation of housing and communal services industry.

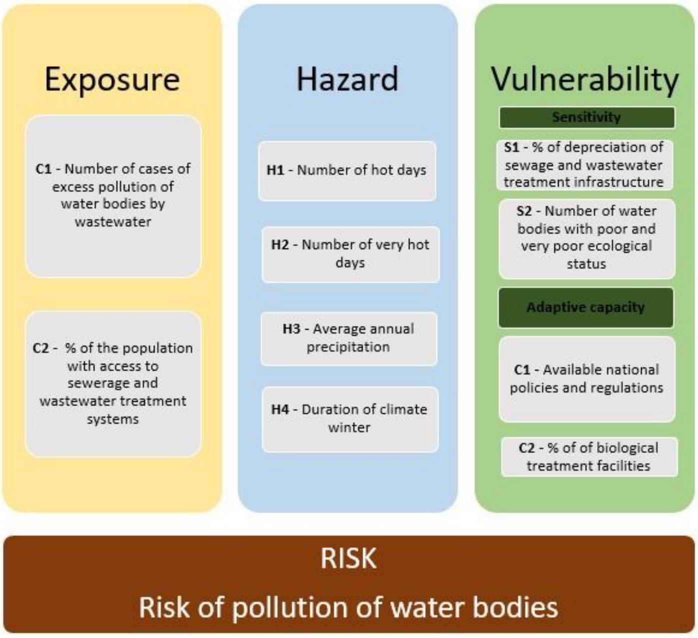

Figure 1: *«Exposure chain» for risk of disruption of treatment plants*

III. Results

The low impact of climate change on water supply is due to the use of groundwater for drinking water supply - the central water supply uses deep aquifers that are less susceptible to weather conditions. However, additional water will be required during hot periods, increasing pressure on infrastructure. The impact of climate change is most significant for areas not covered by central water supply, due to the reduction of water availability in the first aquifers from the surface during hot periods, especially during long heat waves. For regions where water is supplied from surface water bodies, the probability of not only decreasing water supplies but also polluting water sources increases during hot periods. Additional resources will be required to compensate for water shortages (water supply) and water treatment. In the case of heavy rains, there is a possibility of flooding and flooding of the water treatment and water supply infrastructure, especially in flood plains. Additional problems may arise due to the use of infrastructure with an excessive service life under increased loads during hot and heavy rains.

The impact of climate change on sanitation (sewerage) is both positive and negative. On the one hand, it is possible to reduce the cost of pumping, maintaining the required wastewater temperature, treating wastewater by increasing the length of the warm period and reducing the number of cold days. On the other hand, additional efforts will be needed during hot days and «heat waves» to maintain biological wastewater treatment processes. In addition, increased wastewater treatment costs will be required during a period of reduced water consumption and dilution capacity in watercourses. Additional problems may arise due to the use of infrastructure with an excessive service time under increased loads during hot and heavy rains. Higher temperatures lead to increased fermentation of solids in mud, resulting in an unpleasant odor. Harzards can lead to additional costs to eliminate leaks from municipal liquid waste storage systems in regions without a central sewerage system, additional costs for the export of sewage by special vehicles.

Treatment of wastewater to bring it up to the required quality parameters becomes technologically more complex and expensive due to higher temperatures, increasing and changing pollutant concentrations in the effluent. Heavy rains can cause flooding and disruption of sewage treatment plants through sewage maintenance.

Table 1: *Expected impact of climate change on processes and systems in housing and communal services in Belarus*

Parameter	Trend	Industry Processes and Systems			
		water intake	water treatment	water and sewerage system	wastewater treatment and collection
slow changes					
Temperature	↗1,2	● moderate, negative		● moderate, negative	● moderate, mixed
Hot days / «Heat waves»	↗3	● strong, negative	● strong, negative	● strong, negative	● strong, negative
Summer length	↗4	● moderate, mixed	● moderate, mixed	● moderate, mixed	● moderate, mixed
Duration of winter	↘4	● strong, mixed		● moderate, negative	
Cold days	↘4	● moderate, mixed	● moderate, mixed	● moderate, mixed	● moderate, positive
Sediments	↗2,4				
Droughts	↗	● strong, negative	● moderate, negative	● moderate, negative	● strong, negative
hazards					
Heavy rains	↗	● moderate, negative	● moderate, negative	● moderate, negative	● strong, negative
Intense heat	↗	● strong, negative	● strong, negative	● strong, negative	● strong, negative
Hard frost	↘			● moderate, mixed	● moderate, positive
Strong wind	[↘4]				● moderate, positive

Expected impact of these climate trends: ● strong ● moderate
direction of the impact: ● negative ● mixed ● positive

[ ] No forecast due to significant variability, analysis based on current trends
1 Above world average, especially fast in the summer-autumn period
2 Especially winter time
3 Uneven between seasons and areas, particularly vulnerable south-east of Belarus
4 Uneven across regions

The distribution of rainfall is the determining factor for rainfall. The main condition for the operation of rainwater is the intensity (supply) of rain and fluctuation of water level in water bodies. The most problematic are heavy rains in summer, causing flooding and flooding, destruction of water supply infrastructure and wastewater treatment.

The risk to the housing and utilities subsystems is due to changes in precipitation patterns (frequency and intensity of rainfall) and temperature factors (high air temperatures, frequency, duration).

In general, slow climate change may have a positive impact in terms of reducing the costs of certain winter processes (pumping and treatment of wastewater)However, droughts and long periods of heat will require additional efforts and costs to provide consumers with additional water, water treatment, water transport, etc. Extreme events, such as heat waves and heavy rains, can be particularly damaging.

IV. Discussion

Adaptation measures to climate change (Table 3) can be divided into:

- “soft” (including institutional and behavioural (related to educational processes, behavioural change), regulatory (i.e., in terms of law-making, regulatory legal framework, including technical normative legal acts, etc.), planning (related to the collection and use of climate information, territorial development, sectoral development programmes),
- “grey” (infrastructure) (related to the operation and construction of infrastructure, technological

processes and services),
- "green" (related to the use of natural solutions and the development of water-green infrastructure).

Table 2: *Expected impact of climate change on housing and communal services in general*

Parameter	Time horizon today	2040	2100	Housing impact
		slow changes		
Temperature	↗1	↗1,2	↗1,2	🔵
Hot days / «Heat waves»	↗3	↗3	↗3	🔴
Summer length	↗4	↗4	↗4	🔵
Duration of winter	↘4	↘4	↘4	🟢
Cold days	↘4	↘4	↘4	🔵
Sediments	↗2,4	↗2,4	↗2,4	🔵
Droughts	↗	↗	↗	🔴
		hazards		
Heavy rains	↗	↗	↗	🔴
Intense heat	↗	↗	↗	🔴
Hard frost	↘	↘	↘	🔵
Strong wind	↘4	[↘4]	[↘4]	🟢

Expected impact of these climate trends: ⬤ strong ● moderate
direction of the impact: 🔴 negative 🔵 mixed 🟢 positive

[ ] No forecast due to significant variability, analysis based on current trends
1 Above world average, especially fast in the summer-autumn period
2 Especially winter time
3 Uneven between seasons and areas, particularly vulnerable south-east of Belarus
4 Uneven across regions

Belarus has a system for monitoring surface and groundwater quality. However, additional measures are needed to strengthen the monitoring system for groundwater and surface water bodies. Monitoring may also include modelling aspects to predict the availability of groundwater and changes in groundwater and surface water quality.

Studies to quantify the impact of climate change on groundwater and surface water, as well as on components of the water supply and sanitation system, taking into account the current infrastructure situation and projected climate change indicators, are relevant.

Information and education activities will raise awareness of stakeholders on the impact of climate change on water supply and sanitation. In addition, timely clarification of adaptation to climate change at different levels will increase the motivation of both residents and decision makers to apply adequate measures for the industry in response to climate change. The concept of improvement and development of housing and communal services until 2025 includes measures to improve the quality of training, retraining and advanced training of specialists in housing and communal services. Cooperation with citizens and organizations should also be strengthened. Outreach activities may also include information on problem areas, pollution prevention, flood and flooding prevention, operational telephones and others.

Planning the development of the industry taking into account expected climatic changes will reduce risks to the normal functioning of water supply and sanitation networks and services. Long- and medium-term planning involving all stakeholders to ensure a balance between demand and supply of quality water.

Table 3: *Analysis of needs and possibilities of industry adaptation*

Climate change impacts on housing and communal services in Belarus under the «impact chains» and adaptation measures reviewed	Water quality monitoring	Climate risk modelling for sectoral aspects	Informing and engaging stakeholders	Planning the development of the industry in view of expected climatic changes	Improvement of legal and technical requirements	Surveys of the technical condition of networks and structures, maintenance	Technical re-equipment of infrastructure facilities, increasing their efficiency	Water demand management	Land use regulation
Activity category	**M**	**M**	**M**	**M**	**M**	**C**	**C**	**M/C**	**3/M**
Shallowing of wells and disappearance of springs	✓	✓	✓	✓	✓	✓			
Increased contamination of wells and springs (nitrates, iron, heavy metals)	✓	✓	✓	✓	✓	✓			✓
Increasing average water demand	✓	✓	✓	✓	✓			✓	
Rising peak demand for water	✓	✓	✓	✓	✓			✓	
Reduction of water availability	✓	✓	✓	✓	✓	✓		✓	✓
Risks of water-borne diseases	✓	✓	✓	✓	✓	✓			✓
Increased costs and electricity consumption for water treatment	✓	✓	✓	✓	✓	✓	✓	✓	
Interruption of service provision	✓	✓	✓	✓	✓	✓	✓	✓	✓
Deterioration of filtration and cleaning systems by increasing the amount of suspended particles in water	✓	✓	✓		✓	✓	✓		✓
Increase in pathogens, smell in networks	✓	✓	✓			✓	✓		
Flooding of the network	✓	✓	✓		✓	✓			✓
Risk of flooding and flooding of urban areas, intensive erosion, erosion and damage to infrastructure	✓	✓	✓	✓		✓	✓		✓
Additional costs of sewage treatment for diversion to water	✓	✓	✓	✓	✓	✓	✓	✓	✓

Resources and capacity to develop and implement adaptation measures	🟡	🟡	🟢	🟡	🟢	🟢	🟡	🟢	🟡

◎ Adaptation measures are needed
🟢 Sufficient resources and capacity to develop and implement measures
🟡 Limited resources and capacity to develop and implement measures
🔴 Resources and capacity to develop and implement measures are scarce
C - "grey" activities; 3 - "green" activities; M - "soft" activities

Improvement of regulatory legal framework, including technical regulations, in terms of design standards (especially for «long-lived» facilities), ensuring the capacity of new networks, The improvement of requirements for the design and construction of treatment plants, technologies and cleaning methods, taking into account modern technologies and changing climatic conditions, will increase the efficiency of the system.

Surveys of the technical condition of networks and structures, maintenance allows to maintain maintained networks and installations in proper technical condition. However, the funds for repairs and replacement of equipment are only for minimal activities. As temperatures rise, extreme weather events (showers, heat waves, flooding) the cost of maintaining networks increases. Network maintenance programmes may need to be adjusted, including increasing the frequency of maintenance, additional provisions for wastewater treatment, etc.

Technical re-equipment of infrastructure facilities and improvement of their efficiency includes construction of new infrastructure, modernization of structures to increase efficiency and level of treatment of raw water and wastewater, to reduce their impact on the environment and public health.

Water demand management and conservation measures aim to strengthen and support existing mechanisms and practices to reduce water use. These measures may include both information and education and infrastructural measures aimed at the reuse of water.

The land management system provides for the restoration of ecosystems, the establishment and maintenance of borehole sanitary zones, the restoration of green vegetation, etc.

The implementation of programmes and strategies for the development of housing and communal services and related industries, aimed at the development of the industry, will reduce vulnerability and dependence on climate change.

Based on the findings, a strategy for adapting the housing and utilities sector to climate change is currently being developed.

References

[1] The national strategy for sustainable socio-economic development of the republic of Belarus until 2030: Protocol of Presidium of the Council of Ministers of the Republic of Belarus, May, 2017, №10 - 148 p.

[2] The national action plan for the development of a "green" economy in the republic of Belarus for 2021 – 2025: Resolution of the Council of Ministers of the Republic of Belarus, Dec. 2021 N 710

[3] GIZ, EURAC и UNU-EHS (2018): Climate risk assessment for ecosystem-based adaptation - A Guide for Planners and Practitioners. Bonn: GIZ.

WATER RESERVOIR LIFE EXTENSION AND METHODS SPECIFY WATER BALANCE

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Abstract

A phenomenon triggered by modern global warming is a change in the freshwater balance between the land and the ocean in favor of the latter. Centuries-old reserves of mountain glaciers, ice sheets, and groundwater are moving into the oceans. The consequences of this event are particularly severe for regions with limited water resources, where the most optimal ways of solving the problem are designing new methods to calculate water balance and water consumption, modernizing and rationalizing the existing methods, and essentially prolonging the period of operation of water reservoirs. For this purpose, this study proposes a new method that makes it possible to extend the service life of a reservoir, significantly increase the accuracy of water balance operations, and efficiently use the accumulated sediments as a natural resource. This method was made possible through the use of the results of natural experiments on small mountain reservoirs, the generalization of research data on the dynamics of silting prisms of operational reservoirs, and the use of monitoring materials of river sediment. Methods of mathematical statistics (least squares, mathematical expectation, analogy), as well as methods to calculate the basic hydrological characteristics and the water balance of the reservoir, were used to generalize the information and analyze the research data.

Keywords: water balance, silting prism, mead reservoir, Colorado River

I. Introduction

Ongoing climate fluctuations are changing the freshwater balance between the land and the ocean in favor of the latter. Centuries-old reserves of mountain glaciers, ice sheets, and groundwater are moving into the oceans. The flow of glacier-fed rivers is increasing, while the flow of the rivers with basins in areas lacking moisture is decreasing [1]. The results of monitoring the runoff of the Colorado and Rioni rivers in 1960-1990 [2-4] offer clear evidence of this fact (Fig. 1, 2).

The growing demand for regulated water and the tendency to decrease runoff has increased the importance of water reservoirs, which has led to a focus of scientists on studies related to the siltation of reservoirs and related problems [5-13].

The unfavorable trend of the spatial and temporal distribution of water resources leads to severe problems, an effective means of adaptation and solution to which is spatial and temporal regulation of river flow by reservoirs. However, besides offering numerous advantages, reservoirs also have disadvantages, including silting with sediments (sand, pebbles, gravel, etc.) and solid residues of coastal deformation, which is an irreversible process. The accumulation of these products in a reservoir forms a "silting prism," which reduces the reservoir conservation zone and causes progressing errors in the W=f(H) curve of water registration and distribution. This feature is particularly dangerous for large urban conglomerates and irrigation facilities located in regions with insufficient water supply. In the southern arid region of the United States, the Colorado River flow is used almost entirely for irrigation and municipal water supply. The waters of the Amu Darya and Syr Darya Rivers in Central Asia are distributed among users in such a way that the

Aral Sea, a lake fed by these rivers, has almost completely dried up and the region itself has become an ecological disaster zone. The main reason for this ecological disaster was the incorrect water-balance inventory of river flow and users' ignorance of the climatic decline of the flow.

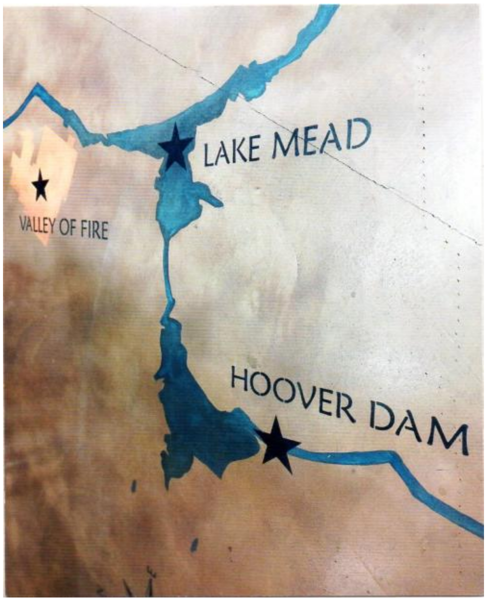
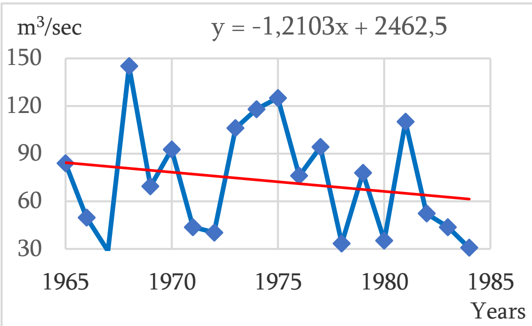


Figure 1: *Made reservoir on River Colorado*



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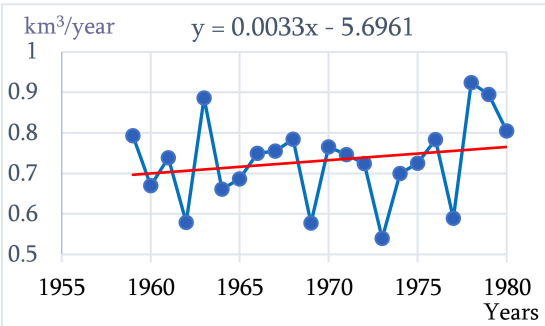

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Figure 2: *The trend of multi-year flow variability of (a) the Colorado River (North America) and (b) - the Rioni (Caucasus) in terms of current climatic conditions*

The economy of many regions of the planet is limited by the lack of regulated water volumes in the reservoirs, as the volumes decrease inversely proportionally to the increase of a silting prism. This factor clearly indicates that improving reservoirs' inventory and rational use is vital in the nearest future. The lack of regulated water resources hinders economic development in in many African countries and Australia. Consequently, improving the regulation and balancing of river flow is an important task for them as well.

Accordingly, the primary purpose of this research was to conduct studies of water balance, improve the accounting of balance elements, and design and modernize the calculation formulas. The objective of the study was formulated as follows after summarizing results: assessing the reduction of a reservoir conservation zone caused by a silting prism and designing methods for periodically correcting the curve *W=f(H)* and extending the service life of the reservoir.

II. Methods

The research employed mathematical statistics methods (least squares, mathematical expectation, analogy), as well as methods to calculate the basic hydrological characteristics and the water balance of the reservoir. For this purpose, field, and natural studies were conducted on reservoirs of different regulations and types in Georgia to study the silting processes in operating reservoirs, especially when the silting prisms were in the last phase of development. The studies were also conducted on small mountain rivers, where natural experiments to study the features of silting processes are highly efficient.

III. Results and discussion

Siltation of a reservoir is an ongoing, irreversible process that reflects the accumulation process of sediment in it, specifically of material resulting from bank formation and anthropogenic activity. The deposited material forms what is known as a silting prism, a body originating at the mouths of tributaries and constantly growing in all directions. It increases most rapidly forward, to the dam, and backward, and to the mouths of the tributaries. The main feature of the prism growth rate is its permanent increase at a decreasing rate. This value is maximum in the initial phase of reservoir operation and is minimum at the end of the third phase of operation when the silting prism reaches its maximum volume. In this phase, the surface of the silting prism is plain inclined toward the dam, whose gradient and other morphometric parameters are such that any tributary can completely carry the sediment to the tailrace. In this phase, the siltation process practically stops, and the volume of the silting prism significantly (1.3-1.5 times) exceeds the size of the reservoir, fills it completely, and emerges in the estuaries above it as a “tail” of the silting prism [14, 15].

The main feature of the reservoir is the movement of the water level between the dead volume level and the normal filling level. Due to this peculiarity, during the filling and emptying phases of the reservoir, the mouths of the tributaries constantly displace and distribute the sediment within the reservoir depending on such motion. Accordingly, the river-regulating reservoir is an object functioning for a certain time (T, year), whose efficiency is maximum in the first phase of operation, and minimum in the third, when it is filled and covered with sediment and has completely lost the ability to regulate the flow.

According to the field studies, the reservoir continually losses its volume, and the multi-year regulating reservoir is reduced first to a seasonally regulating reservoir, and then to one controlling only the daily flow.

During the silting process, sediment constantly accumulates at the mouths of tributaries and in areas surrounding their channels. As a result, the bed rises, the water conductivity of the tributaries decreases, and the probability of catastrophic floods increases drastically. In this state, the silting prism expands in the tributaries at a distance L_i determined by the initial slope of the river (I_0) and the diameter of the largest sediment (*dm*).

The volume of water accumulated in a reservoir is measured and regulated by type *W=f(H)*, the so-called working curve, reflecting the dependence between the water level (*H*, cm) and the volume (*W*, m^3) accumulated in the reservoir. The drawback of such a dependence is that if it is not periodically corrected, an error that equals this prism value (W_0) and increases proportionately to it emerges in the operation of any hydraulic facility. This property of a prism necessitates periodic correction in the working curve according to the data of geodetic planning of the prism or results of the water-balance survey. This peculiarity of the reservoir should be considered during its design, that is, in the selection of the site and morphometric parameters, and the realization of the working curve *W=f(H)*.

Water supply in the reservoir is measured by the curve of dependence of water levels and volumes, which in practice is known as water balance or working curve *W=f(H)*. The volume of flooded water (*W*) depends on the water content of tributaries and the water consumption value (*P*), which vary from year to year and from season to season. The reservoir water balance is used, which is mathematically expressed by the following equations, to study spatial and temporal variability:

$$\Sigma G - \Sigma P = \Sigma A \pm H \quad \text{(filling phase), and}$$
$$\Sigma P - \Sigma G = \Sigma A \pm H \quad \text{(discharge phase)} \qquad (1)$$

Here: *G* represents the components of the inflowing portion of the water balance (flow of tributaries, sediments on the water level, groundwater, etc.); *P* denotes the components of the outflowing portion of the water balance: water consumption for electrical power, irrigation, utilities, and evaporation; A is the change in water volume in the reservoir, which is calculated by the water working curve; and *H* is the balance error.

The component *H* in Equation 1 is a random variable called the balance accuracy index. It is a random variable as long as all balance components in Equation 1 are written with acceptable accuracy. Its value varies from years to years and seasons to seasons; that is, it is sometimes positive (H≥0), and other times negative (H≤0). The balance accuracy for any period is satisfactory if

$$\frac{\Sigma G}{H} \leq 15\% \text{ (filling phase)} \quad \text{and} \quad \frac{\Sigma P}{H} \leq 15\% \text{ (discharge phase)} \qquad (2)$$

H maintains this property until new factors turn it into a constant, increasing value. A similar permanently increasing factor is the volume of a silting prism, which increases in proportion to the accumulated solid sediment. This process stops only when the volume reaches a limited and the tributaries produce stable hydrographic curves.

Accordingly, the transformation of the component *H* into a constant value occurs as a result of the annual accumulation of sediment of volume R_i and product in the amount of N_i formed during the deformation of the reservoir banks. Hence, in the first phase of reservoir operation, that is, after *n* years, it does not exceed the permissible error of water balance (2), when their volume is

$$M = \sum_i^n (Ri + Ni) \qquad (3)$$

In the second phase of reservoir operation, after *m* years (mn) the accumulated solid material forms a prism of volume W_m. After that, the component *H* becomes an explicitly increasing value, and the curve *W=f(H)* changes its position and shape (Fig. 3).

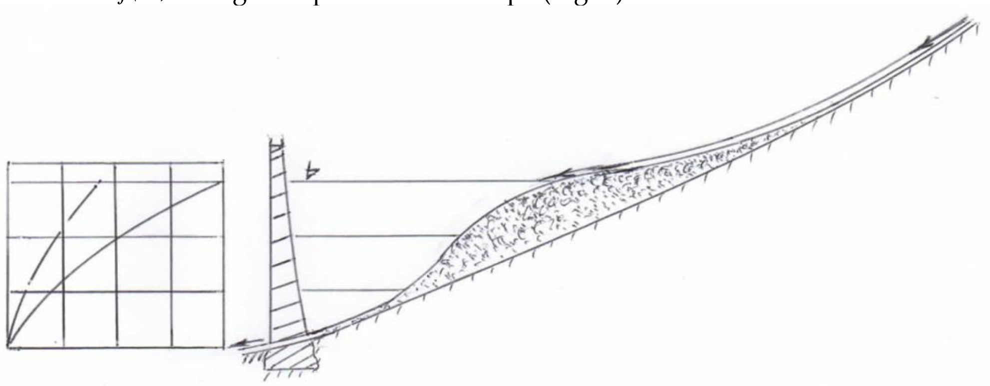

Figure 3: *Longitudinal sections of the silting prism of a reservoir in different phases of prism formation and the corresponding state of the curve W=f(H)*

In the third phase, the tributaries consume most of the sediment to form their bed slope and other morphological parameters and carry an increasing amount of sediment from the reservoir to the tailrace. At the end of this phase, the reservoi's conservation zone is almost completely covered with silting prism material, and the tributaries have transported all the sediment to the tailrace. In this phase, the *H* member of the balance exceeds the reservoir conservation zone, and the working curve has the corresponding shape.

Any operation aimed at managing the accumulated water requires an appropriate monitoring system. If there is no such system provided for a reservoir, an approximate correction of the curve W=*f*(H) is possible by the average volume of solid sediment in the tributaries ($\frac{1}{n}\sum_{I}^{n} Pi$). Such information is a necessary component of the reservoir design parameters and is not difficult to obtain. The corrected, that is, the approximate value of accumulated water volume A_i, can be calculated using the following expression:

$$A_i = \sum\nolimits^{n}_{j} A - \sum\nolimits^{n}_{jPi}, \qquad i = 1,2,..n \qquad (4)$$

A geodetic-bathymetric survey method is designed to avoid gross errors in water balance accounting and planning and in, related losses. With its program, a grid of reference points should be constructed, which includes a reservoir basin at the normal flooding level. The grid density depends on the morphometric and terrain peculiarities of the basin. It is advisable to conduct the survey in the season of the year when the water level is the lowest, as the land survey data are more accurate than the bathymetric data.

For the cross-sections fixed by the reference points, the cross-sections of the reservoir must be plotted with the hypsometric data taken from the design map of the reservoir basin (Fig. 5) showing the state of the terrain of the basin before flooding. Land and bathymetric surveys must be plotted in each section. The portions of each two bordering sections covered with sediment will form a geometric figure, the approximate shape of which is a prism or pyramid. The volume of such figures is calculated using well-known mathematical expressions:

$$V_i = sh \quad \text{(prism)} \qquad (5)$$

Here, w_i is the volume of portions between the silting prism sections, m^3; h is the distance between the bordering sections, m; and *s* is the area of the silted figures, m^3

$$V_j = \frac{1}{3}\left(s + \sqrt{sp} + p\right)h, \quad \text{(truncated pyramid)} \qquad (6)$$

Here, V_j is the volume of the portion between the silting prism sections $\{V_j\}^{m}_{j=1}$, (in m^3), and ; *s* and *p* are the areas of the lower and upper bases of the pyramid (in m^2). The areas of silted areas with complex geometry, not resembling any known geometrical figures, can be calculated with a planimeter.

The values *Vi* and *Vj* of *n* sections of the silting prism form three information groups. One of them unites the discrete volumes of prismatic bodies (V_i). The second contains the values of pyramidal bodies (V_j), and the third contains the results of planimetry (V_f):

$$\{V_i\}^{k}_{i=1}, \ \{V_j\}^{m}_{j=1}, \text{and } \{V_f)^{p}_{f=1}\}, \text{ where } i=1,2\,3,\dots k;\ j=1,2,3,\dots m, \text{ and } k+j=n \qquad (7)$$

The total volume of the silting prism is the algebraic sum of the values calculated above:

$$W = \{V_i\}^{k}_{i=1} + \{V_j\}^{m}_{j=1} + \{V_f)^{p}_{f=1}, \text{ where } k+j+f=n \qquad (8)$$

According to Equation 8, $W_1 = f(H)$, *a* corrected version of the curve *W=f(H)* will be constructed.

The frequency *τ* of such operations is determined by the relation of reservoir volume (*W*) to the annual volume of solid matter deposited in it (*ω*), that is, the frequency of curve correction is proportional to the folowung ratio.

$$\varepsilon = \frac{W}{\omega} \quad (9)$$

Generalizing the study results during the critical low-water period of Colorado reservoirs (1970-1990) for analysis and efficient recommendations is an urgent task. It is also interesting as such critical situations are numerous and their number is increasing in the arid regions of the world (Fig. 4).

Figure 4: *The water level of Mead Reservoir (Lake) in 2023*

The Colorado River flow (Table 1) is regulated by three large and several small reservoirs (Table 2). These reservoirs supply irrigation and municipal water to the states of California, Arizona, and Nevada, as well as the cities of Las Vegas, Los Angeles, and San Diego [7]. These cities consume ~1.0 km^3 of water per year, while the states are much heavier and more extensive (21.6 km^3) consumers of irrigation water. The average volume of annual sediment of this river is ~145 million tons. With water flooding in the reservoir starting in the spring of 1935, the volume of the silting prism produced in the reservoir is expected to have reached 12.6 billion tons by 2020.

Consequently, due to siltation, the reservoir had already lost 34% of its volume by 2020, most of which (80-85%) was useful volume. During this period, the volume of the Mead Reservoir decreased to 23 km^3. If, based on this information, the curve W=f(H) of the reservoir were not corrected periodically, the measurement and consumption of the accumulated flow would be recorded with incremental errors, the size of which has reached ~12.6 km^3 at present. These studies show that when the silting prism ignores the permanent reduction of useful water volume and this process develops against the background of flow reduction caused by current climate change (Fig. 1), the water balance of the regulated flow and water consumption proceeds with ever-increasing errors.

Table 1: *Colorado River Basin Water Balance*

Basin area, thous. km^2	Atmospheric precipitation, P		Runoff, Q		Evaporation, E		Balance mismatch H=P-Q-E		Runoff coefficient $k=\frac{Q}{P}$
	mm	km^3	mm	km^3	mm	km^3	mm	km^3	
635	377	239	$\frac{36}{0.24}$	$\frac{23}{0.15}$	$\frac{258}{294}$	$\frac{164}{187}$	83	22	0.10 0.0

Numerator: flow balance before the construction of the reservoirs;
Denominator: flow balance during the operation of the reservoirs

Table 2: *Morphometry of Colorado River reservoirs*

Water reservoir	Start filling, year	Normal inflow level, m asl	Morphometry					
			Volume W, km^3	Area F, km^2	Depth, m	Length, m	Regu-lation	Usage
Powel, Australia	1964	1174	33.3 25.7*	658	179.5	300	Multiyear	Flood; Irrigation; Communal supply; Energy sector; Navigation.
Mead, US	1935	368.7	36.8 33.5*	640	162	185	Multiyear	Flood; Irrigation; Communal supply; Energy sector.
Mohave, USA	1951	214	0.25	10.7	197	74.1	Annual	Irrigation; Energy sector; Communal supply.

(* Useful water volume)

It is impossible to prevent the process of silting of reservoirs, especially of those regulating river flows. However, it is possible to considerably increase their service life. For this purpose, a system of sediment collection quarries should be provided in the area of displacement of the curve of reservoir flooding and in the mouths of tributaries.

The sediment collection system captures most and the largest fractions of sediment during floods and flash floods. Sediments from these quarries can be used for construction, to fill degraded coastal beaches, to increase the service life of reservoirs, and for other purposes. The operation of such quarries will greatly reduce the heavy burden on nature caused by the extraction of inert material (sand, pebbles, and gravel).

IV. Conclusions

- Permanently decreasing flow regulation capacity of reservoirs is inevitable due to the growth of the silting prism and modern climate warming.
- The operations using the $W = f(H)$ curve, if the curve is not periodically corrected according to the silting prism size, contain increasing errors, which is particularly problematic in arid regions with great water consumption.
- In case of a shortage of regulated water resources, the accuracy of water balance and water consumption operations in the reservoirs must be improved significantly.
- The proposed method is the first attempt to increase the safety of the population in the mouths of tributaries, reduce the pressure on nature caused by sediment removal from river beds, and increase the volume and reliability of inert material supply.
- Water consumption problems in the near future make it urgent to extend the lives of reservoirs and launch sediment collection quarries.

References

[1] Tielidze L.G., Gennady A. Nosenko, T.E. Khromova, Paul, F. (2022). Strong acceleration of glacier area loss in the Greater Caucasus between 2000 and 2020. // The Cryosphere, 16, 489–504.

[2] Metreveli, G., Matchavariani, L., Gulashvili, Z. (2022). Positives and Negatives of Water Reservoirs. Samshoblo, ISBN: 978-9941-9784-6-3, 200 p. (in Georgian).

[3] Wescoat Jr, J.L. (2023). Institutional levels of water management in the Colorado River basin region: A macro-historical geographic review. // Frontiers in Water, *4*, 1024055.

[4] Metreveli G., Matchavariani L., Svanadze D., Alaverdashvili M., Metreveli A. The Genesis Transportation and Accumulation of the Bed Drift of Mountain Rivers. // Bulletin of Georgian National Academy Sciences. Vol.11, №3, 2017, 112-118.

[5] Metreveli G., Matchavariani L. Research Methods of Silting the Mountain Reservoirs Under the Current Climate Change. // Journal of Water Resources and Ocean Science. Science Publishing Groupe, 2016, 5(2), 22-27.

[6] Matchavariani, L., Metreveli, G., Gulashvili, Z. Positive and Negative Aspects of Water Reservoirs. Proceedings of 22nd International Multidisciplinary Scientific GeoConference SGEM2022, Vol. 22, Issue 3.1, Bulgaria, 2022, 145-152

[7] Owen D. (2018). Where the Water Goes. Life and Death Along the Colorado River. Riverbed Books. New York., 274 p.

[8] Daus, M., Koberger, K., Koca, K., Beckers, F., Encinas Fernández, J., Weisbrod, B., Dietrich, D., Gerbersdorf, S.U., Glaser, R., Haun, S., Hofmann, H. (2021). Interdisciplinary reservoir management—a tool for sustainable water resources management. Sustainability, 13(8), 4498.

[9] Batuca, D. G., & Jordaan Jr, J. M. (2000). Silting and desilting of reservoirs. CRC Press.

[10] Yao, F., Livneh, B., Rajagopalan, B., Wang, J., Crétaux, J. F., Wada, Y., Berge-Nguyen, M. (2023). Satellites reveal widespread decline in global lake water storage. // Science, 380(6646), 743-749.

[11] Bianchini, A., Cento, F., Guzzini, A., Pellegrini, M., Saccani, C. (2019). Sediment management in coastal infrastructures: Techno-economic and environmental impact assessment of alternative technologies to dredging. // Journal of environmental management, 248, 109332.

[12] Huguet, J. R., Brenon, I., Coulombier, T., & Hamani, V. (2020). Dynamics and management of siltation in a macro-tidal marina: The case of La rochelle marina, France. // Ocean & Coastal Management, 198, 105371

[13] Manzolli, R. P., Portz, L., Villate-Daza, D., Pulido-Nossa, D., García-Becerra, D., & Alcántara-Carrió, J. (2022). Recent geomorphological evolution of channel bar in Magdalena River (Colombia) due to natural and anthropogenic interferences. Estuarine, // Coastal and Shelf Science, 275, 107959.

[14] Metreveli G., Matchavariani L., Gulashvili Z. Method for Hydrological Parameters Definition of Silting Prism and Equilibrium Bed in Water Reservoirs. Proceedings of the 19th Intern. Multidisciplinary Scientific GeoConference SGEM, Bulgaria, 2019, vol. 19(3.1), 363-368.

[15] Matchavariani, L., Metreveli, G., Gulashvili, Z. (2021). Role of Water Reservoirs in the Seashore Dynamics. Proceedings of the 21th Intern. Multidisciplinary Scientific GeoConference SGEM2021, 3(3.1), Albena, Bulgaria, 285-292.

CLIMATE AGENDA: THE ROLE OF INTERNATIONAL AGREEMENTS IN COMBATING GLOBAL WARMING

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Abstract

The article examines the importance of international agreements and treaties in addressing climate change. Global warming is a transboundary problem and no country can address it alone, which highlights the need for cooperation through international frameworks. The article covers key agreements such as the Paris Agreement, the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC). These initiatives aim to reduce greenhouse gas emissions, increase resilience to climate change and promote sustainable development. The author focuses on the difficulties of achieving international consensus due to differences in economic status, national interests and political conflicts between countries. Important considerations include mechanisms for monitoring the implementation of commitments, financing climate programs and technology transfer to developing countries, which helps them adapt to changes and reduce their own emissions. Particular emphasis is placed on the need to increase ambitions for emission reductions to keep global warming within 1.5°C. The article also notes the role of civil society, non-governmental organizations and the private sector in promoting and supporting the implementation of international climate commitments, as well as the need for their active involvement in decision-making and the implementation of climate policy.

Keywords: climate change, global warming, international agreements, greenhouse gas emissions, sustainable development, climate resilience

I. Introduction

Over the past few decades, the center of gravity in environmental diplomacy has confidently shifted towards the issue of climate change. The visible effects of climate change are apparent: familiar weather patterns are changing across various parts of the world, glaciers and snow caps are melting, sea levels are rising, and the frequency of extreme weather events is increasing. "This is not surprising," scientists say, "because climate change is a natural cyclical process influenced by numerous natural and geophysical factors. It has been this way for billions of years and will continue to be in the future." However, it is alarming that, according to a fairly widespread opinion within the scientific community, the main cause of climate change, specifically global warming, over the past 50 to 100 years has been the increase in the concentration of greenhouse gases (GHGs) in the atmosphere due to the growing volumes of human economic activity.

At the turn of the 1980s and 1990s, when ecology made a significant breakthrough into mainstream politics, the issue of climate change began to gain increasing international resonance. It was actively embraced by international organizations, and in 1988, the Intergovernmental Panel on Climate Change (IPCC) was established under the auspices of the UN. The IPCC started to release assessment reports on the state of the planet's climate approximately every four to five years. With each report, experts' conclusions became more confident: the trend of warming on Earth is occurring and has been largely explained by anthropogenic causes over the past century. According to the latest IPCC report in 2007, if current economic development scenarios remain unchanged, the climate could warm by more than 6°C by 2100, and sea levels could rise by nearly 60 cm. The world is threatened with an increase in natural disasters and extreme weather events, shifts in traditional agricultural and fishing zones, loss of biodiversity, and the flooding of entire cities and even countries.

In 1992, the UN Framework Convention on Climate Change (UNFCCC) was signed at the UN Conference on Environment and Development in Rio de Janeiro. In 1997, the Kyoto Protocol to this Convention was adopted in Kyoto, Japan, obligating 39 countries (from the category of industrialized nations and economies in transition) to reduce their GHG emissions by a total of 5.2% during the first commitment period (2008-2012) compared to 1990 levels. The Protocol entered into force in February 2005, thanks to its ratification by Russia.

In the second half of the 2000s, the intensity of discussions surrounding climate change in global politics reached its peak. Authoritative analytical centers recognized climate change as the number one threat to international security, surpassing even the threat of terrorism. In 2007, the UN Security Council devoted a special meeting to climate change for the first time. UN Secretary-General Ban Ki-moon began the practice of holding UN climate summits in the lead-up to the annual sessions of the UN General Assembly starting in 2007. Additionally, the IPCC, along with prominent American environmental politician Al Gore, was awarded the Nobel Peace Prize in 2007.

However, the rise of climate change as a global issue had its downsides. Over the past 20 to 30 years, the discussion surrounding global climate change has become excessively politicized, increasingly moving away from its scientific basis and often falling prey to political interests and speculation. Disagreements persist among scientists regarding, firstly, the extent of the influence of anthropogenic factors on climate change, and secondly, the optimal strategies for humanity to respond to this process. The scientific community has split into "alarmists," who emphasize anthropogenic causes of climate change, and "skeptics," who do not consider these causes to be decisive. Both camps include authoritative scientists with substantial scientific arguments and many reasons to criticize their opponents. Meanwhile, amidst such scientific confrontation, deliberately fueled by the media, politicians face the challenging task of choosing the only correct solution. Are these scientific disagreements not the root cause of the slow progress in international climate negotiations?

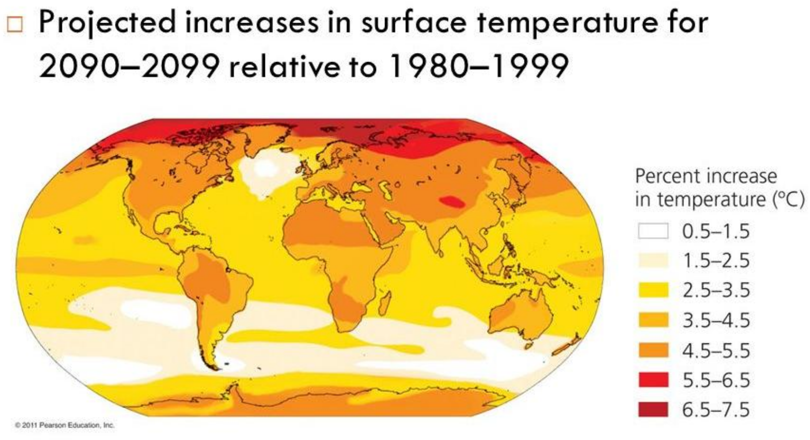

Figure 1: *The Earth's climate system*

Climate change has become one of the most pressing global challenges of the 21st century (fig.1). Rising temperatures, extreme weather events, sea-level rise, and shifting ecosystems are increasingly threatening human life, natural systems, and global economies (fig.2). The scientific consensus is clear: human activities, particularly the burning of fossil fuels and deforestation, are driving unprecedented levels of greenhouse gas emissions, leading to global warming. This issue, however, transcends national borders, making it impossible for any single country to tackle the problem in isolation. Addressing climate change requires collective action and a coordinated response from the international community.

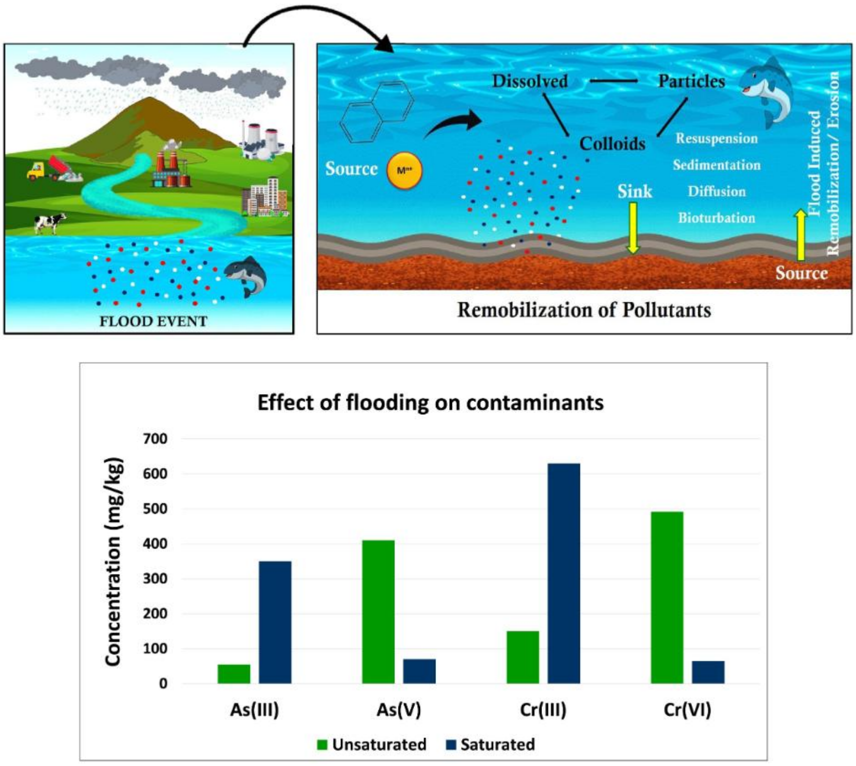

Figure 2: *Remobilization of contaminants during extreme flood events. While arsenic is more mobile and bioavailable under reduced conditions, chromium biomes less mobile and bioavailable*

Climate change significantly exacerbates the severity and frequency of wildfires, leading to a cascade of effects on soil properties and the broader ecosystem. These wildfires alter biological, chemical, and physical aspects of the soil, impacting soil organic matter and its structure, which in turn influences processes like soil erosion and metal transport. Increased temperatures can change the composition of organic matter, with destruction occurring at temperatures between 600°C and 700°C. This degradation of organic matter can further impact soil health and its ability to support vegetation. Climate change-induced erosion increases the transportation and migration of metals within the soil, leading to the loss of metals that are bound to humic materials and facilitating their release into the environment. Research by Frogner-Kockum et al. (2020) highlights how erosion exacerbates this issue. Furthermore, climate change can remobilize legacy metals, such as mercury, altering their release and conversion processes. For instance, mercury can be transformed into methylmercury, a more toxic form that is readily absorbed by organisms. Changes in the redox state of the soil due to flooding can significantly affect the mobility of various metals. Under unsaturated conditions, arsenic (As) exists primarily as the less mobile As(V) species, while chromium (Cr) exists as the more mobile Cr(VI) species. However, flooding can reduce As(V) to the more mobile As(III) and convert Cr(VI) to the less mobile Cr(III). These transformations impact the bioavailability, toxicity, and transport of these elements in soil and aquatic environments, leading to potential environmental contamination. Additionally, altered rainfall patterns due to climate change can significantly affect net carbon release from the soil. Low rainfall conditions lead to droughts, causing increased release of nitrous oxide (N_2O) from natural soils and inorganic carbon from carbonates and bicarbonates. Moreover, methane (CH_4) and carbon monoxide (CO) can be released from acidic soils (IPCC, 2019). The interplay between climate change, wildfires, and soil dynamics presents a complex web of environmental challenges. Increased wildfire frequency not only alters soil properties but also enhances the mobility and toxicity of metals, contributing to environmental contamination. Changing rainfall patterns further complicate the carbon cycle, highlighting the urgent need for comprehensive strategies to mitigate these impacts and protect soil health and ecosystems.

International agreements play a crucial role in forming a unified approach to combating global warming. These agreements, such as the Kyoto Protocol and the Paris Agreement, provide a framework for countries to set emissions reduction targets, share technology, and cooperate on adaptation strategies. By fostering collaboration among governments, they create a platform for nations to commit to ambitious climate goals, while also addressing the varying capacities and responsibilities of developed and developing countries.

The evolution of these agreements reflects the growing recognition that a global response is needed to limit temperature rise to below 2°C, and ideally 1.5°C, above pre-industrial levels. However, despite these efforts, there remain significant challenges, such as ensuring compliance, financing climate initiatives, and balancing economic development with environmental protection. This introduction sets the stage for an exploration of how international agreements serve as the cornerstone in the fight against global warming, and the challenges they face in driving meaningful change across the globe.

II. Methods

To analyze the role of international agreements in combating global warming, the following methods were used in this paper:

1. Analysis of documents and international agreements:

The main method is a detailed analysis of the texts of key international climate agreements, such as the Kyoto Protocol (1997), the Paris Agreement (2015), and the documents of the United Nations Framework Convention on Climate Change (UNFCCC). These documents are considered in the context of their role in global carbon regulation, reducing greenhouse gas emissions and adapting to climate change. The analysis assesses the legal obligations assumed by the participating countries and the mechanisms for their implementation.

2. Comparative analysis:

To identify differences in approaches to solving climate issues, a comparative analysis of the Kyoto Protocol and the Paris Agreement was used. This analysis examines their principles, mechanisms and results in order to identify changes in the global climate agenda and the impact of these agreements on countries with different levels of economic development.

3. Methods of statistical analysis:

We used data from international organizations such as the Intergovernmental Panel on Climate Change (IPCC) and the World Meteorological Organization (WMO) to analyze the dynamics of greenhouse gas emissions, Earth's temperature, and other climate indicators. These data made it possible to assess the extent to which countries-parties to international agreements are fulfilling their obligations.

4. Qualitative interviews and expert assessments:

We collected opinions from climate policy experts, representatives of international organizations, and non-governmental organizations. Qualitative interviews provided additional information on the challenges that countries face in fulfilling their climate commitments and on opportunities to improve existing regulatory mechanisms.

5. Content analysis of media and public demand:

We also conducted a content analysis of publications in the global media and social networks reflecting public sentiment and demands for stronger climate action. This method made it possible to study the influence of civil society and the private sector on the formation of climate policy at the international level.

The use of these methods made it possible to conduct a comprehensive analysis of international climate agreements, assess their effectiveness and identify areas for further improvement of global climate policy.

III. Results

The global climate agenda today occupies a central place in the formation of a strategic vision for the future of civilization. It promotes the integration of the efforts of countries to achieve sustainable development goals and the creation of an international institutional framework for the analysis and development of joint solutions. Over the past decades, the climate agenda has become an integral part of global politics, despite the current economic crises and growing contradictions between countries on economic development issues.

One of the reasons for the continued relevance of climate issues is the public demand for action aimed at preventing climate change. Citizens demand that governments take more decisive measures to protect the environment and preserve the planet for future generations. In addition, increasing competition between countries and corporations for leadership in the creation of new "green" infrastructure and technologies stimulates the transition to more sustainable economic models. It is important to note the formation of a new worldview that rejects the old economic principles of making a profit at any cost in favor of the concept of sustainable development.

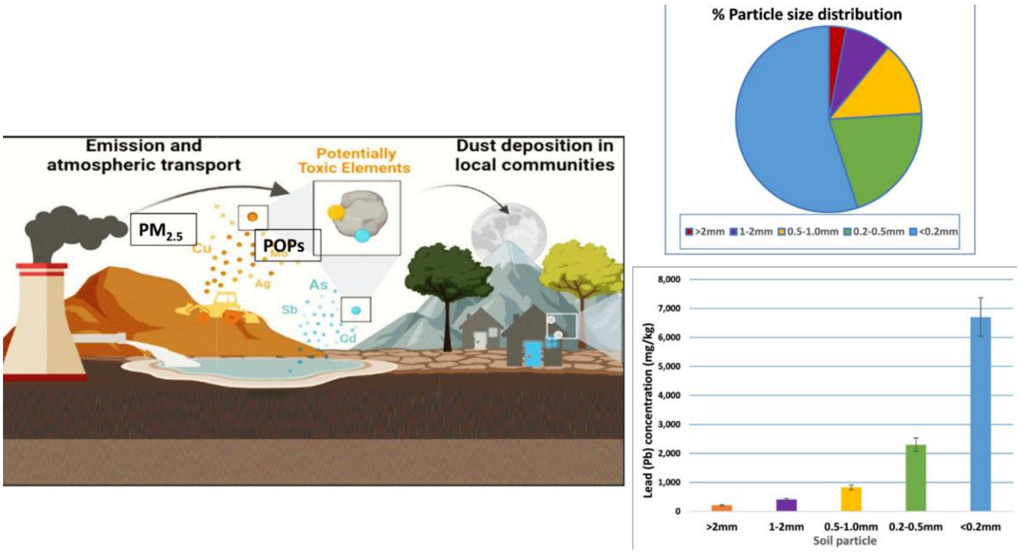

Figure 3: *Dust dispersion of contaminants. Wind erosion carries finer particles (<0.2 mm) with enriched concentration of contaminants including lead (Pb), resulting in off-site contamination*

Global climate changes, driven by both natural and anthropogenic factors, significantly impact the transportation and transformation of toxicants. Extreme weather events, such as floods induced by heavy rainfall, facilitate the movement of metals, dioxins, and hydrocarbons from contaminated to non-contaminated areas, exacerbating pollution issues (Lake et al., 2005). Additionally, wind erosion contributes to off-site heavy metal contamination, further spreading pollutants beyond their original locations (Fig. 3). In response to these challenges, enhancing remediation strategies through green technologies becomes essential, requiring precise steps for remediating contaminated lands. One effective approach is phytoremediation, which utilizes plants to absorb and detoxify contaminants. Elevated atmospheric CO_2 levels can enhance this process by improving plant growth and increasing their capacity for metal detoxification. This not only aids in remediating contaminated soils but also contributes to CO_2 fixation and emission reduction, creating a dual benefit in addressing environmental concerns.

Recognition of climate change as a global threat requires decision-making at the international level. The 2015 Paris Agreement was a milestone in the development of carbon regulation, setting priorities for reducing greenhouse gas emissions, developing technologies for their accumulation and absorption, and implementing adaptation measures. Unlike the Kyoto Protocol, the Paris Agreement transfers the initiative to the level of individual countries and regions, which creates an opportunity for a flexible approach to solving the problem. The world's leading economies have recognized the need to transition to a low-carbon development model based on the use of cleaner and more affordable energy sources.

However, many unresolved issues remain, including the speed and scale of the necessary changes, as well as their consequences for the economy and society. World leaders must not only take into account all aspects of the climate problem, but also coordinate their actions in accordance with scientific data and the international climate agenda. Including climate change issues on the agenda of global summits contributes to progress and allows for harmonizing decisions in areas such as the environment, health and the economy.

This multilateral approach provides an opportunity for a comprehensive solution to the problem of climate change, making international agreements a key tool in the fight against global warming.

The close connection between the issue of climate change and development strategies is critical, particularly regarding traditional energy, which is the primary source of greenhouse gas emissions due to fossil fuel combustion. According to the International Energy Agency (IEA), to maintain atmospheric CO_2 concentrations at a safe level (450 parts per million), countries must undergo a significant environmental and energy revolution. This transformation requires reaching the peak of hydrocarbon use no later than 2020 and transitioning towards predominantly low-emission and renewable energy sources, including natural gas, clean coal, nuclear, hydropower, wind, solar, wave, geothermal, and tidal energy.

Experts argue that a radical increase in energy efficiency is essential to achieving these revolutionary changes. By 2050, it is projected that each dollar of GDP should be produced using only half the energy that was required in 2002. The IEA estimates that by 2030, the share of renewable energy sources and nuclear energy should increase from the current 18% to 33%. Furthermore, from 2007 to 2020, carbon intensity of energy—the average CO_2 emissions per kilowatt-hour of electricity produced—should decrease by 23%, and the carbon intensity of GDP should drop by 37%. By 2020, the proportion of new cars with internal combustion engines should fall from 95% to 40%. Achieving these goals may require up to $430 billion per year in additional investments.

One of the breakthrough solutions in reducing greenhouse gas emissions from hydrocarbon energy is the development of technologies for capturing CO_2 from the atmosphere and storing it underground, known as Carbon Capture and Storage (CCS). However, the commercial implementation of such technologies is still far off, even in technologically advanced Western countries, due to their high costs.

The concept of low-emission development is central to the "New Green Deal" in the global economy, proclaimed by the UN in late 2008. This initiative aims to reorient global economic development towards a new technological base, addressing the dual challenge of reviving economic growth while combating climate change. The promotion of low-carbon energy and enhanced energy efficiency aligns well with the long-term strategic goals of leading economies worldwide—to reduce reliance on imported fossil fuels while meeting increasing energy demands. As a result, the "green" agenda has become the foundation of anti-crisis strategies in the United States, Europe, and large developing nations, gaining popularity globally. Currently, environmental investments represent a significant portion of the budget plans of countries like the USA, Germany, France, South Korea, and China, with experts estimating that approximately $436 billion has been allocated for these purposes worldwide.

The necessity of stimulating low-emission economic development strategies, especially in developing countries, was also emphasized in the "Copenhagen Accord." This highlights the growing recognition of the need for global cooperation and investment in sustainable development practices to effectively address the challenges posed by climate change.

IV. Discussion

Russia has set a goal — transition to a low-carbon development model with the prospect of achieving carbon neutrality by 2060. The consequences of climate change are included in the challenges of the Strategy for Environmental Security of the Russian Federation for the period up to 2025 (Decree of the President of the Russian Federation of 19.04.2017 No. 176), the National Plan for Adaptation of Industries and Regions to Climate Change is being implemented, the Law on Limiting Greenhouse Gas Emissions has been adopted, mandatory carbon reporting for large emitters has been introduced, and conditions have been created for initiating climate projects. Russia declares the need for the most complete consideration of the absorptive capacity of ecosystems. In the low-carbon development strategy of Russia, adopted in 2021, the main emphasis is placed on this mitigation method (mitigation measures): when implementing the target scenario, by 2050 it is expected to reduce GHG emissions by 289 million tons, and increase absorption by 665 million tons of CO_2 equivalent compared to the baseline level of 2019, that is, priority is given to absorption measures [4]. Russia's experience in developing national climate legislation and carbon regulation can become the basis for determining environmental and/or climate benchmarks for the EAEU, SCO, and BRICS. The government has adopted basic regulatory documents defining the volumes of greenhouse gas emissions reduction, the methodology for accounting for them, market, financial and legal measures stimulating low-carbon development, and much more. Russia pays great attention to taxonomy issues and is systematically working to create a Unified National System for Monitoring Climate-Active Substances [5]. The development of a national methodology will enhance the status of Russian expertise at the international level, including in negotiations on measures to adapt the economy and population to climate change.

An achievement was the signing of a protocol of intent at the SPIEF between the Federal Accreditation Service and the Global Carbon Council on the recognition of the accreditation of Russian bodies in the validation and verification of greenhouse gas emissions. This opens up new prospects for expanding cooperation with foreign countries in the field of carbon unit trading. For Russia, joint work with the Global Carbon Council is important for the development of common approaches to climate issues as part of friendly multilateral formats.

Thus, Russia today is among the countries capable of determining the vector of development of the climate agenda at the global level, forming an idea of effective ways of transition to a low-carbon economy, and also actively participating in determining the basic development strategies of the world's leading regions, based on scientific data. Russia, occupying a leading position in a number of areas of technological development, is able to offer partner countries environmental or climate benchmarks with the prospect of their subsequent possible dissemination to the EAEU, SCO, BRICS, etc.

The modern understanding of climate change is associated with a global phenomenon that has manifested itself as a result of the accumulation of greenhouse gases in the atmosphere. The peculiarity of greenhouse gases is that they are evenly distributed in the Earth's atmosphere, i.e. they do not have a local nature of influence. The problem of the greenhouse effect has not only become the subject of scientific discussions on the formation of the climate, but has also attracted wide public interest. The novelty of the climate agenda of the 21st century is associated with the identification of the limits of potential anthropogenic impact on the planet's biosphere, in contrast to the resource limitations in the understanding of R. Malthus in the 17th century [6] or in the report to the Club of Rome in 1972 "The Limits to Growth" [7].

In order to achieve the goals of reducing greenhouse gas emissions, it is important to take into account the positions of different countries and adhere to the principle of common but differentiated responsibility. Climate negotiations, as a rule, take into account the position of the participants in relation to both actions to mitigate the effects of global warming by reducing the anthropogenic impact on the environment by reducing or limiting greenhouse gas emissions, and actions to adapt to the effects of climate change. In the first case, the basis is collective agreements at the level of entities, such as countries or subnational associations, on joint principles and approaches to solving priority problems in the field of climate. The Paris Agreement (2015) points to the importance of adaptation measures, including ensuring direct financing of adaptation activities. In the second case, we are talking about the development of specific actions and events at the level of specific stakeholder groups (regions, enterprises, population and others) to increase their ability to cope with such consequences, reduce their vulnerability to climate risks. In this regard, it is extremely important to show the equal importance of mitigation and adaptation issues.

According to UN forecasts, the main population growth, and therefore sales markets, occurs in developing countries, so the main resources will be “attracted” by these regions. Developing countries in most cases follow the development trajectory of more developed countries (urbanization, industrialization, priority development of personal transport in relation to public transport, etc.).

The expected growth in energy and other resource consumption in developing countries has increased the concerns of developed countries and prompted them to form protective mechanisms, declare the need to restructure the energy system and reduce anthropogenic emissions by abandoning the consumption of fossil fuels. Developed countries have formed a coalition to form a global system of restrictive mechanisms for the use of hydrocarbons, including directive support for renewable technologies, based on a solid ideological foundation and the popularization of climate ideas to form a loyal public opinion. At the level of the OECD (2009) and ASEAN (2010), competing concepts of a "green economy" and "green growth" were presented. The demand for "green" policy in developed countries during this period is largely due to the lack of alternative concepts of economic growth and the conviction of political elites in the correct choice of a method for a rapid transition to a new technological order in order to maintain leading positions in the world economy. More and more economists, based on empirical data on resource use and greenhouse gas emissions, reject the concept of green growth, concluding that green growth is likely to be a mistaken goal and that alternative development strategies should be sought [8]. In addition, accounting for greenhouse gas emissions and absorption in the world does not fully reflect the objective picture; the methods used need to be improved, given that climate data are increasingly used for international comparisons, including as a factor in the competitiveness of producers from different countries [9].

Thus, at the present stage, the climate discourse projects the influence of two basic ideas — ensuring energy security and searching for a new model of intensive development. The EAEU, BRICS and SCO, uniting countries with rapidly developing economies, act as a counterweight to coalitions of developed countries. The potential for pooling resources and cooperation between participating countries.

References

[1] Daukaev, A. Main trends in climate change in the Holocene epoch of the antropogenic period in the world and in the Caucasus / A. Daukaev, R. Gakaev, T. Bachaeva // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 387-390. – DOI 10.24412/1932-2321-2023-575-387-390.

[2] Podkolzina, I.M., Gladilin, A.V., Reshetov, K.Y., Taranova, I.V., Gladilin, V.A. Building a Financial Security System to Ensure Russia's Food Security // Lecture Notes in Networks and Systems, 2021, 205, страницы 539–548

[3] Gakaev , R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. С. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[12] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 2137-2144

ANALYSING THE FUNCTIONALITY OF OIL WELL REHABILITATION EQUIPMENT FROM A SAFETY AND ENVIRONMENTAL PERSPECTIVE

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Abstract

One of the main directions of environmental protection and pollution prevention is the improvement of technological processes. The drilling of deep oil and gas wells is a very complex technological process, the violation of which can lead to various emergencies that pollute the environment. Therefore, well rehabilitation is becoming an increasingly important aspect of ensuring the sustainability and efficiency of the production process. This paper analyses the performance of equipment used in oil well rehabilitation. For this purpose, a classification of accidents in production and drilling wells is presented and a qualitative evaluation of the main oil well rehabilitation methods and the equipment used in this process (milling, capture, flushing tools and raisers) is carried out in order to determine their advantages and disadvantages.

Keywords: acid mudding, hydraulic fracturing, milling tools, trapping tools, plugging tools, reiber

I. Introduction

One of the reasons that reduce the efficiency of drilling and well operations is accidents. In oil and gas wells, an accident is an interruption of technological processes caused by the seizure or breakage of downhole tools and equipment, as well as the fall of individual parts and components downhole. Modern drilling is characterised by continuous increase of well depths, reduction of well diameter in the lower intervals, increase of complications. As a result, the likelihood of accidents in the operation of the above-mentioned wells (both producing and drilling wells) increases.

An important measure to reduce the accident rate is the prevention of accidents and complications, as well as systematic preventive maintenance. In order to inform the strategy of these measures, it is necessary to study the experience of accidents in the production and drilling of wells. This should be done by analysing accidents in wells:

- the location and depth of the emergency object in the well;
- the shape, size and diameter of the emergency object;
- the condition of the borehole walls,
- the physical and mechanical properties of the material of the emergency object and the degree of its adhesion;
- the degree of risk of gas and oil spillage, etc.

All of this is a sine qua non for the improvement of existing methods and the development of new methods and technical means to speed up the commissioning of idle wells at minimum cost. For this purpose, it is necessary to establish a classification of accidents in production and drilling wells, which is presented below:

1. downhole pipe accidents
2. accidents involving downhole motors, instruments (devices), packers and drill string threads;
3. accidents associated with geophysical surveys;
4. accidents involving rock destruction tools;
4. accidents involving cables, ropes, wires;
5. accidents related to foreign objects falling into the well;
6. fire and explosion accidents;
7. other.

However, the classification which groups objects into classes mainly on the basis of the type of emergency object is conditional and only acceptable for simple accidents, i.e. cases where there is a single type of emergency object in the well. For combined accidents, i.e. when a combination of accident objects is present in the well, this classification loses all meaning. Therefore, the classification should be based on a formal basis. Nevertheless, the proposed simple accident classification [1] is a guideline for the development, maintenance and improvement of the reliability, operational characteristics of downhole tools to prevent accidents. According to this classification, the data on the oil industry of the Commonwealth countries on the distribution of accidents, the corresponding volume of repairs and tripping operations are given in the form of a diagram in Fig. 1.

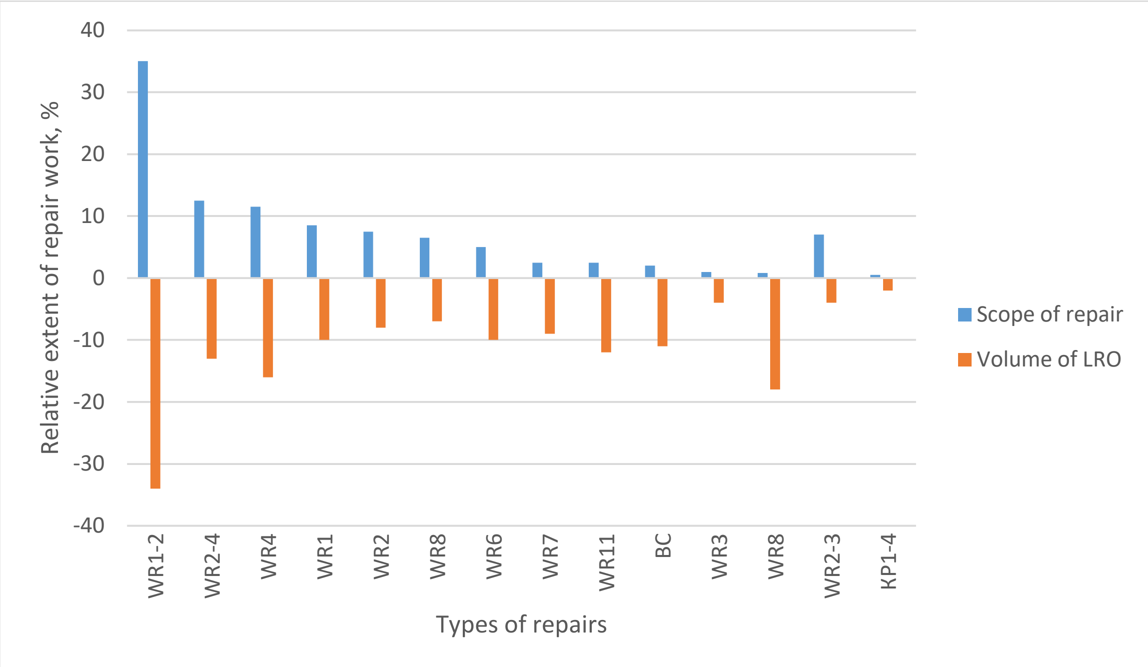


Figure 1: *Diagram of repair volumes and corresponding of repairs and corresponding launch and recovery operations (LRO):*

WR1-2 - separation of separate formations; WR2-4 - elimination of leakage by partial replacement of the production string; WR4 - transition to other horizons and connection of formations; WR1 - repair and insulation works; WR2 - elimination of leakage of the production string; WR8 - well exploration; WR6 - Complex of underground works for restoration of well performance using technical elements of drilling, including cabling of horizontal sections of the well; WR7 - Treatment of the formation zone at the bottom of the well and induction of flow; WR11 - preservation and re-conservation of the well; WR13 - other types of works; WR2-3 - elimination of leakages by running additional casing of smaller diameter; WR1-4 - cement ring construction behind production, intermediate casing, conductor.

In addition, oil wells are subject to a number of unfavourable factors such as clogging, corrosion and fouling. These problems can significantly reduce well performance. To overcome these problems, specialised equipment is used to restore well performance.

II. Methods

The following are the main methods of restoring the operability of oil wells and the equipment used.

I. Well flushing method.

Flushing an oil well involves:

- Transfer of hydraulic energy from pump to turbo or electric drill, bit, downhole motor;

- Cooling, lubrication and corrosion protection of the bit as the mud passes through the wellbore. Oxidative destruction of metal parts of the equipment occurs due to the action of oxygen dissolved in the mud, hydrogen sulphide and rock salts. Anticorrosive properties are imparted to the working drilling fluid by the addition of inhibitors:

- flushing of oil wells during drilling allows the reduction of abrasive wear during drilling by timely and proper cleaning of drilling fluid from solid particles of cuttings;

- facilitating the drilling process through the kinetic energy of the fluid as it leaves the drill bit and reducing the coefficient of friction. This is particularly effective when working in loose soils;

- pressurising the borehole to prevent gas and oil spillage and collapse of the borehole walls when working in unstable rock;

- temporarily maintaining the suspended state of the mud particles during pump shutdown (in an emergency situation). For this purpose, the drilling mud is given thixotropic properties by additives that allow it to transform from ash to gel;

- prevention of technological difficulties in the drilling process, including differential seizure of the drill string;

- strengthening the wellbore channel when working in weak and fractured rock by creating a reinforced clay crust;

- preserving reservoir productivity in the downhole zone.

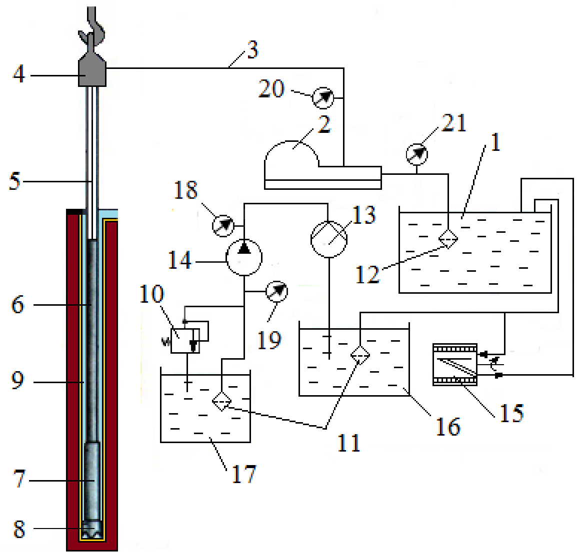


Figure 2: *Direct well flushing scheme:*
1 - mud tank; 2 - pump; 3 - flexible hose; 4 - swivel; 5 - drive pipe; 6 - drill string; 7 - hydraulic motor; 8 - drill bit; 9 - annular duct; 10 - safety valve; 11, 12 - filters; 13 - hydrocyclone; 14 - auxiliary pump; 15 - centrifuge; 16, 17 - sumps; 18-21 - pressure gauges.

The disadvantage is that sand plugs form during the drilling process as a result of the thermal effect on the reservoirs. As a result, additional time is spent flushing the well to "clean water" before reaming the casing. It is also important to note that the direct circulation method requires a large amount of working fluid, especially when drilling with a maximum diameter bit.

2. Acid dissolution - used to remove sediments and increase formation permeability. Analyses include evaluation of the concentration of acids used, depth of penetration and changes in well productivity.

Acid dissolution plays an important role in the oil and gas industry and is used to remove deposits and clean up wells. Specialist equipment is required to carry out this process effectively. Below is a list of equipment that can be used for acid dissolution in the oil and gas industry:

1. Acid pumps - must be corrosion resistant and capable of handling corrosive media.
2. Acid supply tanks - these are acid tanks and reservoirs for the storage and supply of acid solutions and metering systems for accurate and uniform acid distribution (Table 1).
3. Instrumentation - this includes instrumentation to monitor pH, temperature and acid concentration, as well as pressure and flow monitoring equipment: to ensure process safety and efficiency.
4. Acid resistant tubing and casing to ensure well longevity and safety.
5. Waste treatment equipment as part of the decontamination system to neutralise spent acid solutions.
6. Corrosion monitoring equipment to assess the effects of acid on equipment.

Table 1: *Volume of acid injected (m^3) per 1 m of uncovered formation thickness*

Number of treatments	Type of collector	
	Low permeable	Highly permeable
1	0,4 ÷ 0,6	0,7 ÷ 1,1
2 or more	0,6 ÷ 1,7	1,1-1,6

It is important to comply with safety and environmental standards when using acids in the oil and gas industry. Exact equipment requirements may vary depending on the specific process and field characteristics.

3. Hydraulic fracturing - used to increase permeability and improve production. This technique creates fractures in the rock to allow increased fluid (oil and gas) flow to the wellbore. When using this technique, it is necessary to determine the effect of pressure and volume of water used on the change in well production rate.

Here are some basic aspects of this technique:

- Fluid preparation. A special fluid known as "hydraulic fluid" is prepared at the surface. This fluid usually consists of water, additives to improve properties and, importantly, proppants (small particles that help prevent cracks from closing after flushing).
- Fluid injection. A hydraulic fluid under pressure is injected into the well. This creates fractures in the rock and increases the permeability of the formation.
- Proppant into the fractures. When fractures are created, proppant (particles such as sand or ceramics) is injected into the fractures to prevent them from closing after the fracturing process is complete.

The equipment used in hydraulic fracturing includes

- Hydraulic pumps to generate sufficient water pressure to overcome rock resistance.
- Special pumps to inject proppant into the fractures.
- Monitoring equipment, i.e. various tools such as seismic and sonic monitoring systems are used to control and optimise the process.

Drawbacks. Hydraulic fracturing is a complex and controversial technology, and its use requires a balanced approach that considers both economic benefits and environmental risks. There are concerns about potential negative environmental impacts such as groundwater contamination, seismic activity and others. Different countries and regions have different laws and regulations governing the use of fracking technology. The technology is a matter of public concern because of the environmental risks associated with it. Potential negative impacts must be considered when implementing this technology.

Depending on the type and degree of complexity of the accident, well repair and recovery operations are carried out mainly by destroying emergency equipment and by containment operations, which also include tackling operations.

The most common destruction methods are chemical, mechanical and thermal destruction of emergency objects in the well. The analysis of these methods shows the efficiency of the mechanical destruction method as the most economical and easy to use. Various types of milling cutters are widely used for this purpose.

At present, some experience has been gained in various oil regions of the country with the use of downhole cutters with a cutting part in the form of a reinforcement made of composite material [5.59]. However, the capacities of the country's machine-building industry are not sufficient. to meet the oil industry's ever-increasing demand for these tools. The situation is further aggravated by the low performance indicators of the tools produced by the machine-building industry of the CIS countries. This indicates that the process of interaction between the tools and the object to be destroyed is insufficiently studied, despite the fact that the milling process is similar to the well-studied processes of rock destruction by chisels and metal processing by cutting [7, 4].

Reserves for improving and increasing the efficiency of the milling process should be sought in the following directions

1. Research of composite materials, which are coated on the body of tools and form their cutting part;

2. Reliable theoretical and experimental modelling of the process of their interaction with the emergency object;

3. Synthesis of wear-resistant materials as armament with given properties, compatible constructive and technological parameters of their functioning; in borehole conditions.

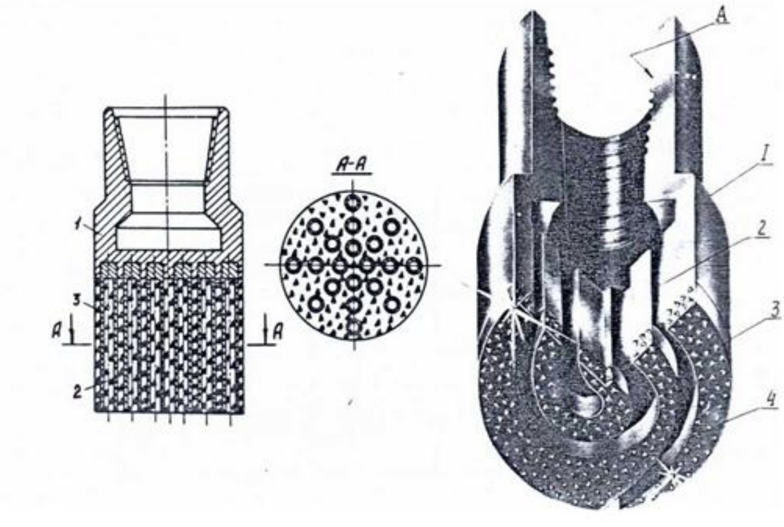
A number of works [2] are devoted to the study of various aspects of the production and operation of composite materials and the serviceability of composite products.

A significant increase in the cutting properties and wear resistance of tools can be achieved by proper orientation of shape-classified grains of solid filler material [6].

Ensuring and improving the cutting properties of milling tools in general is a complex set of different problems involving the implementation of a number of design, technological and operational measures [5]. The milling tools shown in (Fig.3) are the result of attempts to solve the problem of intensification of the milling process by appropriate design changes. The operational measures should include the prevention of thermal shock in the heating-cooling cycle (Fig.4) and thermal fatigue on the cutting surface of the tool, scattering [8] the values of mode-technological factors.

The kinetics of the wear processes of working bodies of tools such as downhole milling cutters and its interrelationship with the thermophysical processes accompanying tool operation are very complex and multifactorial. The study of this relationship in the thermal formulation is to solve contact thermodynamic problems with the phenomenon of wear. The solution of such a problem is ultimately reduced to the differentiation of complex integral equations with moving natural boundary conditions. Obviously, the complexity of both the formulation and the solution explains the absence of such studies. The authors [9] have attempted to solve such a problem in an experimental formulation, and their work differs favourably from previous studies in this direction.

It was found that, depending on the energy supplied to the bottom hole, pre-critical (moderate wear) and sub-critical (catastrophic wear) modes of tool wear are possible. The transition from one wear mode to the other is explained by the change in cooling conditions; at the transition there is a temperature jump (Fig.4) at the tool face, which in turn contributes to the change in the character of the wear process. Simultaneously with a sharp increase in temperature, there is a jump in power consumption (N ~ Fu, where N - power consumption, F - axial load, u - tool speed) at the transition to subcritical operation. Processing of the experimental results showed that in the subcritical mode the wear of the matrix of the cutting part of the tool increases 3-4 times. As a result, it was concluded that it is possible to solve the problem of automatic maintenance of the operating mode in the subcritical range without burns and catastrophic wear.



a *b*

Figure 3: *Downhole milling tools:*
a - with inserted metal tubes (I - casing, 2 - cutting: element, 3 - metal tubes);
b - with moulded cooling system (A - fixing thread, I - body, 2 - flushing hole
3 - cutting section, 4 - Archimedean spiral channel).

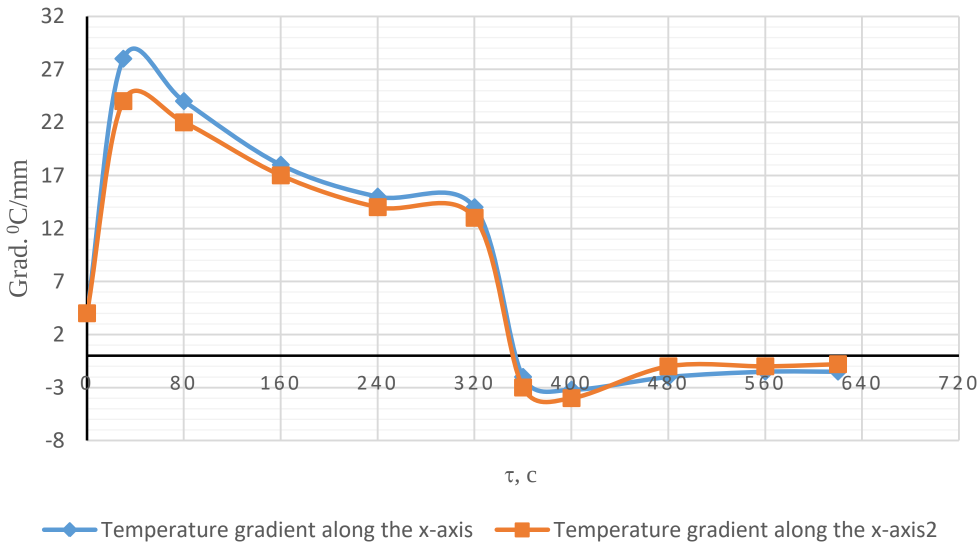


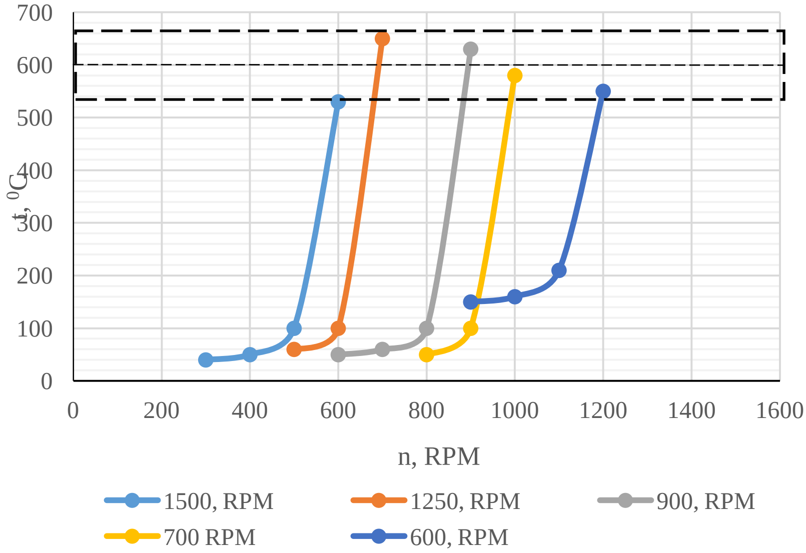
Figure 4: *Variation of temperature gradients in the heating/cooling cycle*

The disadvantage of this work is that the investigated factors do not include the flow rate of the flushing fluid, the flushing scheme and a number of other factors that significantly influence the intensity of the thermophysical process that develops during the destruction of an emergency object. However, the rheology of the flushing fluid, its composition and flow regime is one of the most accessible, universal and, in most cases, economical means of increasing the thermomechanical stability and wear resistance of cutting tools [3-5].

One of the most complex and labour-intensive types of work performed during overhaul is catching work [8,9]. The tools used for catching work are divided into three groups according to the principle of pipe gripping (Fiq.5):

- Tools with pay and wedge gripping devices;

- Tools with thread-cutting gripping devices;
- Other gripping tools.



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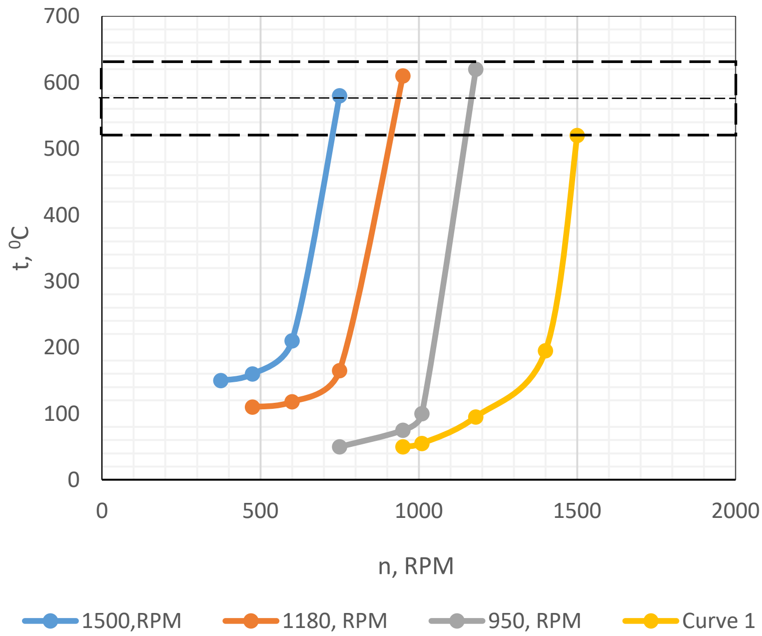

b

Figure 5: *Bit temperature as a function of axial load (a) and drill speed (b)*

The efficiency of slotted tools, which are the most widely used in practice, is determined by the perfection of the design and kinematic characteristics of the gripping device, which determine the reliability of the adhesion of the slots to the surface of the pipe body for successful unscrewing. The main load-bearing node of the jaws is also the node of the gripping device, the reliability of which determines the operability of the tool design as a whole.

It should be noted that a number of theoretical and experimental works [3-7] are devoted to the study of the force and kinematic interaction of the gripping device with the surface of the pipe to be gripped. Due to a significant simplification of the force and geometrical relations of the interaction process, these works do not fully reflect the actual deformed state of the gripper elements and the surface of the catching pipe.

The main factors that determine the design characteristics of the gripper are the reduction of the specific pressure generated by the movement of the dies on the inclined support surface and the prevention of changes in the shape of the catching tube in the gripping zone. In addition, the requirements of the specified tool should be met without compromising the tool's load-bearing capacity.

One of such technical solutions in the specified direction is a downhole tool with a gripping device in the form of a spiral, developed in SOCAR. Such a design of the gripping device with optimum design parameters allows to increase the working area of contact with the pipe and thus to make full use of the rated load capacity of catching tools when eliminating complex accidents by applying maximum axial loads (Fig.6).

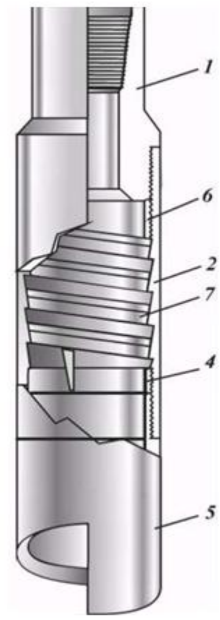

Figure 6: *Catch tool with spiral gripping device:*
1 – upper guide; 2 – housing; 3 – plate grid; 4 – limiting ring;
5 – guiding funnel; 6 – paker; 7 – spiral grid

The problem of increasing the load capacity of catchers with payload gripping devices should be solved by perfecting the process of interaction with the object to be caught. This interaction should not reduce the load-bearing capacity of the caught object in the gripping zone. As a result, the possibilities for increasing the load capacity of flame arresters, which is particularly important for preventing accidents in deep wells, are limited. Therefore, in order to increase the efficiency of catching operations in deep wells together with mechanical flame gripping devices, it is necessary to develop designs of catchers whose gripping devices do not deform their surface when interacting with the trapped pipe.

According to the existing classification of accidents [4], unlike the first (accidents with downhole pipes) and second (accidents with downhole motors, tools, packers and drill string bottoms) groups of accidents, other types of accidents are possible (third group - accidents with cables, ropes, wires, fourth group - other accidents), for the elimination of which downhole cleaning tools are used [6, 8].

This class of equipment includes tools that use the effect of physical fields (magnetic catchers, magnetic milling machines, etc.) to clean the borehole from small metal objects. Despite the fact that the performance of these tools has been studied by a number of authors [4, 5], the efficiency of their use in field practice is comparatively low.

In [5] the reasons for the unsatisfactory operation of magnetic cutters in connection with the increase of the borehole depth are considered, among which a special place is given to the breakaway force arising in the process of technological operation at the cleaning of the borehole from small metal objects.

In order to improve the efficiency of operation, it is considered necessary to make changes in the design of magnetic milling machines produced by the industry of the CIS countries. For this purpose, it is necessary, first of all, to study various factors that determine the design of magnetic milling machines and predetermine the efficiency of their application in deep boreholes. This problem is addressed in the paper [4.49], in which the results of studies on the dependence of the magnetic cutter attraction force on metal objects at different distances from the pole, the influence of the type of washing liquids and temperature on the tool traction characteristics are given.

It is expedient to continue research in this direction in order to meet the requirements of the practice of cleaning the borehole from metal objects.

Accident-free drilling is the main direction of the solution to the problem of improving the quality of drilling and is determined both by the perfection of accident prevention methods and by the adaptation of the measures adopted for this purpose to specific conditions. Among the accidents, the most common in practice (especially in deep wells) and requiring the application of very labour-intensive measures is the seizure of downhole equipment. Because of the time-consuming nature of stuck wells, the means and methods of both preventing and remedying this class of phenomena are constantly being improved [4]. A wide variety of methods are currently used to clear stuck wells. Depending on the situation in the well when a stuck well occurs, any one of these methods, or a particular sequential set of them, may be effective. This is usually the case when the choice of action or set of actions is appropriate to the conditions under which the seizure occurs and the nature of the process. As a rule, the technology of eliminating the seizure is based on the sequential application of means and methods, as well as on their alternation (especially in complex geological and technical conditions). In this case, in order to reduce both material and time costs, it is necessary to have a (theoretical) tool for choosing a rational strategy of tackling.

The use of special technical means (percussors, yasses, vibrators, etc.), the classification of which is given in Fig.7, is no less widespread among the methods of tackling liquidation. These technical means are mainly divided into surface and submersible ones. Surface equipment is not widely used because the depth at which it is effective does not exceed 200 metres. Submersible devices, both mechanical and hydraulic, are mainly used in deep drilling. The main requirements for submersible impact devices to ensure their effectiveness in tackling are

- simplicity of design;
- simple and accident-free application technology;
- the ability to apply shock impulses in the immediate vicinity of the tacking zone.
- possibility to regulate the impact force at the wellhead;
- possibility to apply repeated directional blows the required number of times both from top to bottom and from bottom to top to unseat the seized pipe string;
- reusability, etc.

At present both in domestic [7] and foreign field practice [3, 5] of liquidation of seizure phenomena various shock devices are used, satisfying to some extent the above-mentioned requirements. The main design characteristic of these devices is the dynamic load imparted to the seized part of the string. The application of dynamic load to the pipe string during attempts to release it contributes to the occurrence of significant stresses in it, which may lead to failure. Therefore, the study of the stress state of a tacked pipe string is of great practical interest [4, 6, 7].

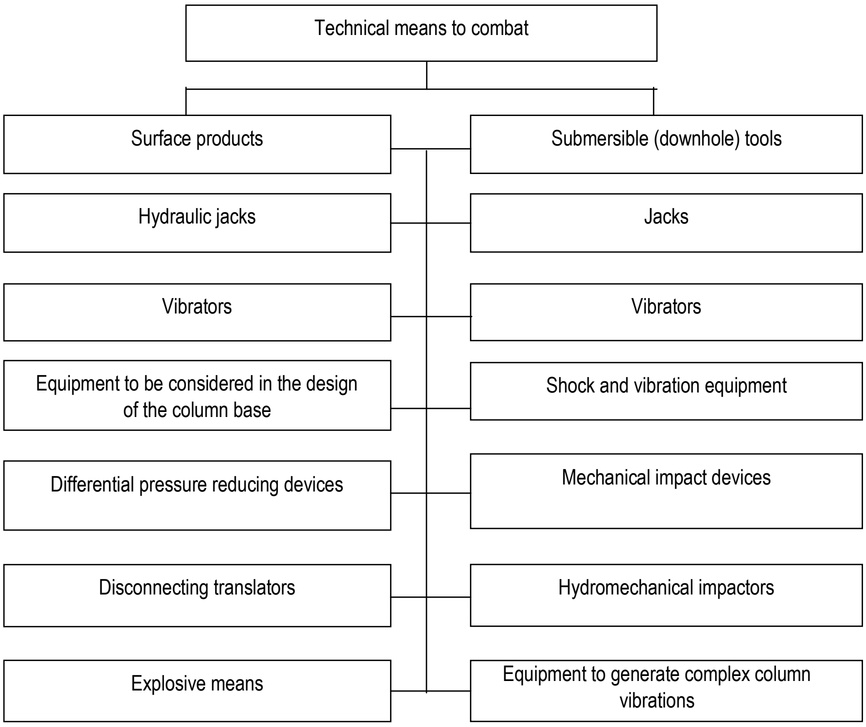

Figure 7: *Classification of technical means of removing tackle*

As a result of a certain class of theoretical and practical calculations, the authors [1-3] found that the dynamic coefficient decreases significantly with increasing well depth. This is explained by the fact that the static component of the total load absorbed by the string increases with increasing well depth. Furthermore, the determining parameters of the dynamic component are the speed of the drill string movement and the number of blows applied to the stuck part of the string. The disadvantage of this work is that it investigates the wave process induced by the application of impulse loads to the stuck part of the string in one direction (from top to bottom) and does not determine the number of blows required to complete the release without damage. However, the conclusions drawn from the results of the work, which consist in the need to impart a large variation in the amount of movement to the gripped part of the string in each test, within the limits allowed by the strength of the pipe, are very valuable and can be a starting point for the development of effective impact devices.

Wave processes in longitudinal elastoplastic impacts are also studied in [1-5]. The efficiency of impact devices used for tacking is also assessed by the possibility of disengagement of the tacked pipe string by impact in opposite directions. Therefore, modelling the tacking process by wave processes developed in one direction does not correspond to the physical model of the interaction between the impactor and the tacked part of the pipe string. This circumstance does not allow to use the models proposed by the above mentioned works to describe the dynamics of the interaction between the impactor and the seized part of the string. In order to accurately reproduce this interaction, it is necessary to develop and study its mathematical model, which provides for the excitation of wave processes developed in opposite directions.

Wells that are technically impossible or economically unviable to rehabilitate using the above methods are rehabilitated by sidetracking and drilling a second well. The rehabilitation of shut-in wells by sidetracking and drilling a second well is an important part of the package of measures aimed at stabilizing the level of oil production in long-developed areas. This method allows wells to be reworked in areas where the conditions and state of reservoir development make it difficult and unprofitable to drill new wells. Sidetracking and drilling a second well increases the number of producing wells at the expense of inactive and previously abandoned wells. This also allows the disturbed development network to be reestablished, corrections to be made to the previous development to be made and previously missed oil targets to be identified, ultimately increasing the oil recovery factor of old reservoirs. The issue of maximizing oil recovery in the late stages of field development has recently become of great national economic importance.

Since the development and introduction of the method of sidetracking and drilling of the second well into the practice of rehabilitation works, both the technology of the works and the technical means for their implementation have been significantly improved. This contributed to the wide application of the method in the oil fields of the North Caucasus and Azerbaijan and some other areas of the CIS countries [1-5], as well as abroad [6]. Recently, however, the volume of well rehabilitation using this method has decreased significantly due to the increase in well depths and the complexity of the operations. The complexity of the sidetracking process in deep wells places special demands on the development of technical means and technological measures for this purpose. It should be noted that the efficiency of sidetracking, in addition to the use of high-performance equipment and technology, is also significantly influenced by the correct choice of the object to be targeted [5.7]. This means that it is first necessary to assess the economic feasibility of this operation in accordance with the geological and technical characteristics of the wells. In studying this issue, criteria should be established for assessing the technical and economic feasibility in each individual case of workover or reworking of a well.

The problem of choosing the shape of the deflection surface of the deflection wedge is very controversial, and it should be solved not independently for the deflection wedge, but in the complex of problems related to obtaining a "window" of the required dimensions in the production line from the point of view of tool permeability. This means that, in order to obtain a "window" of the required dimensions with good permeability, it is necessary to develop compatible conditions "well design - deflector - ripple - technological factors". In [3], "tentative" attempts were made to develop these conditions, which would allow the shape and size of the deflector surface to be designed according to the "window" permeability criterion. According to the results of experimental studies with the design of the developed rayber, it was found that the most acceptable is the flat shape of the deflection surface, and the design of such a deflector was developed [4]. However, when flat wedges are used, the specific pressure generated during the operation of the rayber is greater on the wedge surface than on the pipe surface [8]. As a result, a strip of metal is cut from the wedge body rather than from the pipe wall, as was the case with the "window" cuts in the production string at Khydyzhenneft Oil and Gas Production Department.

After the deflector has been lowered and landed, a window is cut in the production string. Opening the "window" in the string is a very important operation. The degree of perfection of the working technology and structures, the equipment used for this purpose determine the configuration and dimensions of the "window" to be cut in the column. Conformity of the configuration and dimensions of the "window" to the further conditions of the second borehole conduction is estimated by the character of possibility of drilling tools and geophysical instruments used for various purposes during drilling.

Otherwise, as practice shows, the results of works are reduced to obtaining a "window" with wrong dimensions, which considerably complicates further work, obtaining a "window" with wrong dimensions can be promoted by such constructive features of cutting tools and deflectors.

In spite of the significant improvement of the second hole cutting process in recent years, it is not always possible to avoid additional time and costs due to possible complications [1-3].

The most common accidents and complications are 1) jamming of the cutting tool; 2) premature exit of the cutting tool behind the string; 3) breakage of drill pipes or breakage of the threaded connection; 4) displacement from the landing place or rotation of the deflector around the axis; 5) strong absorption of the mud.

In some cases, in order to obtain a high mechanical speed, the established rules for the technology of opening the "window" in the string are not respected. The mechanical opening speed depends on the load axis, the number of rotor revolutions, the steel grade and the condition of the production column, the pump capacity and the design features of the tool and the deflector. When designing the conditions for cutting a "window" in the string, it is necessary to provide such a combination of the above factors that would allow obtaining a "window" of the required configuration and dimensions and satisfy the criterion of absence of complications such as "tool jamming". In addition to the jamming of the tool with a full stop, there is often an instantaneous jamming and release of the tool. In this case, the tool works by jolts, as a result of which there is a phenomenon of torque impact, accompanied by the emergence in the drill pipes, reaching quite high values of stresses that can lead to the breakage of drill pipes [3].

Summarising the above phenomena, it can be concluded that the cause of complications and accidents when opening a "window" in the production string are design deficiencies of cutting tools and deflectors, their incompatibility with each other and with the well conditions, the lack of a reasonable process technology and of appropriate criteria for assessing the quality of the cut "window". A vector combining the design parameters of the borehole, cutting tool and deflector, as well as the technological parameters of window cutting, can serve as a state vector for the development of such criteria. Depending on the degree of compatibility of these parameters, the cut "window" can be of three classes: 1) "window" good - passable; 2) "window" satisfactory - passable, but with a risk of jamming; 3) "window" unsatisfactory - not passable for the cutting tool. Naturally, this poses the task of developing the necessary algorithm, in the state vector space for the possibility of designing the conditions of cutting through the "window" of good quality.

The main drawback of previous work in this area is that it has focused on the study of local problems in isolation, which has not allowed us to develop a set of measures to improve the quality of the "window". In particular, the design of the deflector [5] and the window cutting device [9] have been improved in order to obtain a full profile window equal to the line of the deflector chamfer and to prevent premature tool exit behind the column. The design of the deflector (although the degree of its manufacturability is relatively low) and the design of the device are both highly original.

However, the unconditional efficiency of their use together (or in combination with other designs) cannot be claimed. In order to assess the effectiveness of the interaction between the deflector and the cutting tool, [7.3] presents the results of experimental studies of five variants of their combinations. The aim of the experiments was to study the influence of the design of the applied technique on the length and shape of the "window" and to develop measures for selecting the most effective design of the cutting tool and deflector, as well as to determine the optimum mode of opening the "window".

Due to the fact that the designs and shapes of the cutting tools (Fig.8) and deflectors used are different, it is of great practical importance to determine the value of the areas where friction occurs. The area of friction where both the string and the deflector of cutting tools of different design rub against the wall of the production string in the process of opening the "window" determines "the value of the specific pressure at the points of contact between the interacting bodies.

Perfect are the designs of cutting tools that do not wipe the deflector, cut through the column to the end of the deflector bevel and create a high specific pressure on the friction surface at a relatively low load. The magnitude of this pressure is determined both by the geometric shape of the cutting part of the tool and the direction of the main vector of the forces acting on it as it cuts through the "window".

In order to ensure trouble-free operation of the drill string and avoid premature cutting tool exit, the authors [9] developed and tested a Drill Pipe Bending Straightener (DPBS) on a number of SOCAR wells. The use of the Drill Pipe Bending Rectifier (DPBR) when opening the "window" in cased wells prevents the premature exit of the cutting tool from the string, regardless of the axial loads, and makes it possible to reduce the resulting bending stresses in the drill pipe by about 10 times. It is recommended that the first drill pipe bending straightener be installed at a distance of (1.5-3) m from the cutting tool, and subsequent ones at a distance of 6 m from each other. However, these recommendations are not confirmed theoretically, which does not allow to adapt the arrangement of drill pipe straighteners to specific conditions of their operation in the process of opening the "window" in the production string.

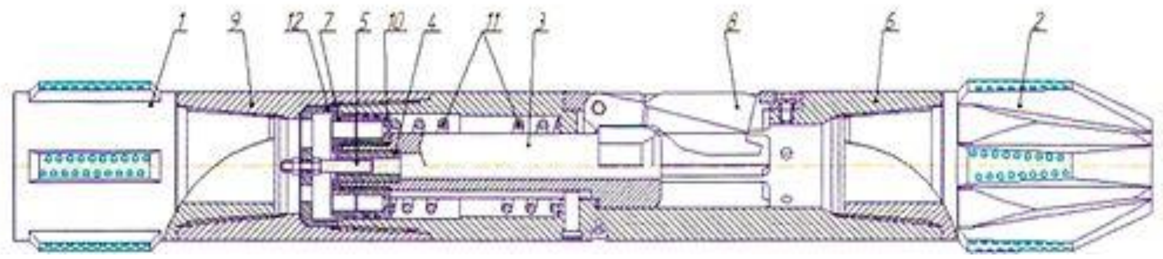

Figure 8: *Milling cutter with cutting centring direction:*
1 – upper centering device; 2 – lower centering device; 3 – shaft; 4 – shaft bushing; 5 – needle; 6 – housing; 7 – cover; 8 – blade; 9 – guide; 10 – piston; 11 – spring; 12 – grid

III. Results

The result of the analysis of the serviceability of tools used for carrying out repair and recovery operations in oil and gas wells will allow to determine the main directions of improvement of repair techniques and technology. Formation of a set of tasks to solve the problem of improving the efficiency of production of repair and recovery operations at emergency oil and gas wells.

Analysis of the performance of oil well rehabilitation equipment is a key element in improving the efficiency of production and ensuring stable operation of oil companies. The analysis includes the change in daily and annual production after the introduction of new equipment. It should be noted that efficient equipment also reduces well maintenance and workover costs.

The introduction of new technologies and the continuous improvement of equipment play a crucial role in achieving this goal. In the future, we can expect to see further development and innovation in well rehabilitation technology, leading to more efficient and sustainable oil production.

References

[1] Grudz, Volodymyr, Grudz, Yaroslav, Bevz, Volodymyr, Chernetsky, Mykhailo. Dynamic analysis of well equipment to produce oil. // J. Mining of Mineral Deposits. – 2020, Vol.14, N1. – Pp.82-89. DOI:10.33271/mining14.04.082.

[2] Bozorgian, Alireza. Investigation of Well Equipment in Oil Industry. // International Journal of Advanced Studies in Humanities and Social Science. 2020, Vol.9. – Pp.205-218. DOI: 10.22034/ijashss.2020.255356.1019.

[3] Abdollahbeigi M., Choobineh M.J., Nasrollahzadeh B., Nano Catalyst, Operation Mechanism and Their Application in Industry. // Australian Journal of International Social Research, 1(5) (2015), pp.1-6

[4] Mullakaev M.S., Abramov V.O., Abramova A.V.. Development of ultrasonic equipment and technology for well stimulation and enhanced oil recovery. // Journal of Petroleum Science and Engineering 125 (2019) 201–208.

[5] Guluyev G.A., Pashayev F.H., Jafarov J.M. Some Methods and Algoriths for Evaluation of Well Equipment and Regime Parameters in Rod, Depth Pump Oil Wells. // International Journal of Latest Engineering Research and Applications. – Volume – 08, Issue – 09, September 2023, Pp.8-18.

[6] Mukeshimana C. Application of the Model of Fuzzy Logic to Evaluate the Quality of Data Transfer in Networks of the Industrial Internet of Things. Computertoolsineducation, 2019, N 1, Pp.29–42.

[7] Meiyi Jiang. Discussion on the countermeasure of improving the development effect of oil well dynamic analysis. // E3S Web of Conferences 375, 2023 https://doi.org/10.1051/e3sconf/202337501037 ESAT 2023.

[8] Yang Haiwei. Application of oil-well dynamic monitoring data in oilfield development dynamic analysis [J]. Chemical Engineering and Equipment,2020 (04):58-59.

[9] Yang Lei. Application of oil-well dynamic monitoring data in oilfield development dynamic analysis. // [J]. China Petroleum and Chemical Standards and Quality, 2021, 41(20). – Pp.57-58.

HUMAN HEALTH AND THE ECOSYSTEM: THE RELATIONSHIP BETWEEN ECOLOGICAL STATUS AND QUALITY OF LIFE

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Abstract

This paper explores the intricate relationship between human health, ecological status, and quality of life, emphasizing the significance of ecosystem health as a determinant of overall well-being. The degradation of ecosystems due to human activities poses a substantial threat to public health, affecting not only physical well-being but also mental health and social cohesion. We analyze various ecological factors, including air and water quality, biodiversity, and green spaces, which directly influence health outcomes and quality of life. By synthesizing existing literature and empirical data, this study underscores the importance of sustainable environmental practices and policies in promoting human health. The findings highlight the need for integrated approaches that encompass ecological conservation, public health initiatives, and community engagement to foster a healthier population and environment. Ultimately, this paper advocates for a holistic understanding of the interconnectedness of human health and ecosystem vitality, calling for collaborative efforts among stakeholders to enhance both ecological and human well-being.

Keywords: human health, ecosystem health, quality of life, environmental sustainability, public health, biodiversity, air quality, water quality, green spaces, social cohesion.

I. Introduction

The relationship between human health and ecological status has garnered increasing attention in recent years, driven by a growing awareness of how environmental factors significantly influence overall well-being. As populations expand and industrialization intensifies, the degradation of natural ecosystems has escalated, leading to adverse health outcomes. The degradation of the environment—manifested through pollution, loss of biodiversity, and climate change—poses considerable risks not only to physical health but also to mental well-being and social cohesion.

Ecosystems provide vital services that directly support human health, including clean air, safe drinking water, nutritious food, and spaces for recreation and mental relaxation. The Millennium Ecosystem Assessment (2005) underscored the importance of these ecosystem services in sustaining human life, highlighting that the health of ecosystems directly correlates with the quality of life experienced by communities. For instance, polluted air and water sources have been linked to a range of health issues, including respiratory diseases, cardiovascular conditions, and even mental health disorders. Furthermore, the loss of biodiversity can disrupt the balance of natural systems, reducing their resilience and ability to adapt to changing conditions, which can further exacerbate health risks.

Despite this clear interconnection, traditional public health approaches often fail to incorporate ecological perspectives, resulting in fragmented strategies that overlook the broader environmental determinants of health. As such, there is a pressing need for integrated approaches that recognize the intricate links between ecological integrity and human health. This includes not only the need to address immediate health concerns but also to engage in proactive ecological conservation efforts that safeguard the health of ecosystems and, by extension, the populations that depend on them.

In this paper, we will explore the multidimensional relationship between human health, ecological status, and quality of life. We will examine key factors influencing this relationship, including air and water quality, biodiversity, and the availability of green spaces, while emphasizing the implications for public health policies and practices. By synthesizing existing literature and empirical research, we aim to highlight the critical need for collaborative efforts among various stakeholders, including policymakers, public health officials, and environmental organizations, to foster a healthier population and environment. Ultimately, this work advocates for a holistic understanding of the interconnectedness of human health and ecosystem vitality, emphasizing the importance of sustainable practices and community engagement in enhancing both ecological and human well-being.

II. Methods

To explore the relationship between human health and ecological status, this study employs three primary research methods: literature review, empirical analysis, and case studies. Each method offers unique insights into how ecological factors influence health outcomes and quality of life.

1. Literature Review

The literature review involves a comprehensive analysis of existing research related to human health and ecosystem interactions. This method encompasses studies published in peer-reviewed journals, reports from international organizations (such as the World Health Organization and the United Nations), and relevant grey literature. The review will focus on identifying key themes, such as the impact of air and water quality on health, the role of green spaces in promoting mental well-being, and the effects of biodiversity loss on disease prevalence. By synthesizing findings from multiple sources, the literature review aims to provide a holistic understanding of the current state of knowledge on the subject, highlight gaps in the literature, and inform future research directions.

2. Empirical Analysis

Empirical analysis will involve the collection and statistical examination of quantitative data to assess the relationships between ecological indicators and health outcomes. This method will utilize existing datasets from national health surveys, environmental monitoring agencies, and public health databases. Key ecological indicators may include air and water quality measurements, biodiversity indices, and green space availability. Health outcomes of interest could encompass rates of respiratory diseases, cardiovascular conditions, and mental health disorders. By employing statistical techniques such as regression analysis and correlation studies, this method will aim to quantify the strength and significance of associations between ecological factors and health outcomes, offering empirical evidence to support the hypotheses derived from the literature review.

3. Case Studies

The case study method involves an in-depth examination of specific geographic locations or communities to illustrate the practical implications of the relationship between human health and ecological status. Selected case studies may focus on areas experiencing notable environmental challenges, such as urban pollution hotspots, regions facing water scarcity, or communities with rich biodiversity that have seen health benefits. Through qualitative data collection methods, including interviews, surveys, and participant observations, this approach will provide insights into local experiences, perceptions, and behaviors related to health and the environment. Case studies will also allow for the exploration of community-level interventions and policies that have successfully linked ecological preservation with improved health outcomes, thereby offering valuable lessons for broader application.

By employing these three methods—literature review, empirical analysis, and case studies—this study aims to provide a comprehensive understanding of the complex interplay between human health, ecological status, and quality of life. This multifaceted approach ensures that both theoretical insights and practical applications are considered, ultimately informing public health strategies and environmental policies.

III. Results

Human health plays a crucial role in the overall well-being of populations and is closely linked to the state and functionality of ecosystems, particularly their capacity to deliver healthy and adequate ecosystem services, as emphasized by the Millennium Ecosystem Assessment (MEA). This paper aims to review existing literature that explores the connections between ecosystem services and human well-being, beginning with a reinterpretation of the MEA framework. In this exploration, we underscore the importance of considering exposure mechanisms through passive, consumptive, and active behaviors, along with contextual factors such as socio-economic status, demographics, and climate conditions. In this framework, elements like tourism, recreation, and leisure are associated with active participation.

Current literature employs various metrics to measure health and well-being, highlighting the necessity for standardized approaches and new methodologies to evaluate how study design affects outcomes. In conclusion, the studies reviewed indicate moderate evidence supporting a positive relationship between green environments and well-being, although significant positive effects are not consistently observed across all cases.

Ecosystem services play a vital role in enhancing human well-being through various pathways. The Millennium Ecosystem Assessment (MEA, 2005) identifies five key elements contributing to well-being: security, basic materials for a good life, health, good social relations, and freedom of choice and action. The concept of security encompasses not only the physical safety of individuals and their properties but also the broader assurance of access to essential resources and the ability to avert human-induced disasters. Basic materials for a good life include essentials like shelter, food, water, energy, income, assets, and access to goods.

Health is a central component of human well-being and is fundamentally dependent on the ecosystem's capacity to deliver healthy and adequate ecosystem services, such as clean water, nutritious food, and good air quality. The MEA framework categorizes ecosystem services into four groups: provisioning, regulating, cultural, and supporting services. Supporting services underpin the functioning of the other ecosystem services, facilitating essential processes like nutrient cycling and soil formation. Ecosystems also provide direct provisioning of goods, including food, water, and medicinal plants. Regulating services contribute to human well-being by controlling climate and flood dynamics. Cultural services impact health by offering opportunities for recreational activities and fostering aesthetic and spiritual connections, which enhance both physical and mental well-being. Engaging in recreational activities promotes active lifestyles, reducing the risk of diseases such as cardiovascular issues and obesity, while also supporting mental health, community cohesion, and a sense of identity.

The quality of the environment significantly influences human health; for instance, air pollution can exacerbate existing cardiovascular and respiratory conditions, particularly in older adults. Conversely, improvements in air quality and reductions in extreme temperatures can yield positive health outcomes. Direct interaction with nature has been shown to benefit health by enhancing cardiovascular and respiratory functions, decreasing the prevalence of diabetes and obesity, and improving psychological well-being. Access to green spaces, such as urban parks, fosters social interactions, thereby strengthening community bonds and positively affecting social relations.

This paper examines the health benefits provided by green and blue spaces, including urban parks, green areas, freshwater systems, and coastal zones. To achieve this, a literature review was conducted to explore how the natural environment influences various dimensions of well-being, with a specific focus on health and its determinants.

IV. Discussion

The passage you've shared provides a detailed analysis of the ecosystem services provided by freshwater ecosystems, particularly wetlands, and the challenges associated with their management in both developing and developed countries. It highlights the importance of these ecosystems for a wide range of cultural, commercial, and ecological functions, while also addressing the negative impacts of industrial agriculture, pollution, and urbanization. Several key themes and strategies emerge from the discussion on how to balance human needs with the preservation of natural systems.

First, freshwater ecosystems provide critical services, including water purification, flood regulation, habitat provision, and cultural benefits. The value of these services is substantial, as evidenced by studies that quantify their economic worth. While agriculture is seen as a provider of ecosystem services, industrialized farming often leads to environmental degradation. Practices associated with large-scale agriculture can diminish soil health, reduce biodiversity, and pollute water sources. There is a growing recognition of agroecology as a means to promote sustainable agricultural practices that work in harmony with natural ecosystems. This approach emphasizes soil health, recycling of materials, and the empowerment of local communities.

Wetland management is crucial, and the concept of "wise use" encourages sustainable practices that protect and restore these environments, ensuring they continue to provide their valuable services. The passage questions the effectiveness of investing in cleanup efforts for polluted water bodies while the root causes of pollution remain unaddressed, advocating for proactive measures to eliminate pollution drivers. Rapid growth of global populations and industrial activity poses challenges to the conservation of natural ecosystems. Balancing these demands with the need for environmental protection is crucial for sustainable development.

To address these challenges, integrated water resource management (IWRM) can help balance the demands of various sectors—agriculture, industry, and domestic use—while prioritizing the health of freshwater ecosystems. Promoting agroecology and organic farming can enhance soil health and biodiversity, reduce reliance on chemical inputs, and increase resilience to climate change. Education and support for farmers can facilitate this transition. Ecosystem-based adaptation strategies, such as restoring wetlands and reforesting, can mitigate flooding and protect communities in a cost-effective manner. Finally, strengthening regulations on industrial discharges and agricultural runoff can significantly reduce the nutrient loading that harms freshwater systems, ultimately leading to healthier ecosystems that can continue to support both human populations and biodiversity.

Schumacher's observation about the alienation of modern man from nature encapsulates a critical challenge in contemporary society: the prevailing view of nature as an adversary rather than an integral part of human existence. This mindset drives a relentless push to dominate and control the natural world, often leading to environmental degradation in the pursuit of short-term economic gains. The passage outlines the consequences of this approach, particularly through the examples of infrastructure development and industrial agriculture, and raises the question of whether viable alternatives to purely technological solutions exist. The emphasis on technological solutions often overlooks the inherent value of natural ecosystems. For example, while concrete structures can provide flood protection, they typically come with higher costs and fail to replicate the multifaceted benefits provided by healthy ecosystems, such as wetlands and mangroves. The ecological services these natural barriers provide—like storm surge protection and nursery habitats for marine life—are not easily quantifiable but are critical for community resilience.

Moreover, the conversion of natural environments for industrial use frequently benefits a small number of individuals or corporations at the expense of local communities. In the case of shrimp aquaculture in Sri Lanka, the socioeconomic impacts disproportionately affected traditional livelihoods while offering minimal benefits. This pattern is evident globally, where the costs associated with ecosystem destruction often fall on the poorest populations and future generations, who rely on these ecosystems for their survival. The issue of 'non-tradable public benefits,' which are essential ecosystem services that do not enter the market economy, is particularly concerning. Politicians and businesses typically operate on short time scales, failing to account for the long-term consequences of ecosystem degradation. This shortsightedness allows for continued exploitation of natural resources, transferring economic benefits from many to a privileged few.

In light of these challenges, viable alternatives to technological responses can be explored. Ecosystem-based management integrates ecological health into resource management decisions. By prioritizing the conservation and restoration of ecosystems, communities can benefit from the natural services these systems provide, such as clean water, flood protection, and biodiversity. Community-led conservation engages local populations in the stewardship of their natural resources, fostering a sense of ownership and responsibility that often results in more effective conservation outcomes. Payment for ecosystem services (PES) incentivizes the protection of ecosystem services by compensating landowners and communities for maintaining or restoring natural habitats. PES schemes help align economic incentives with environmental health, ensuring that the benefits of healthy ecosystems are recognized and rewarded.

Integrated water resource management (IWRM) promotes a holistic approach to managing water resources, considering the interdependencies between water, land, and ecosystems. By balancing the needs of different sectors and ensuring sustainable use of water resources, IWRM can help protect vital ecosystems while meeting human demands. Transitioning to agroecological practices can enhance food production while preserving ecosystem health. By focusing on ecological principles, such as crop diversity and soil health, agroecology aims to create resilient agricultural systems that support local communities without degrading the environment. Incorporating natural elements into urban planning—such as green roofs, permeable pavements, and urban forests—can mitigate the impacts of climate change and reduce reliance on traditional engineering solutions. These practices enhance urban resilience while providing ecological benefits.

In conclusion, the challenges posed by modern society's disconnection from nature require a paradigm shift in how we view and interact with the natural world. Viable alternatives to technological responses exist and often prioritize ecological health, social equity, and community resilience. By recognizing the intrinsic value of ecosystems and incorporating their services into economic and developmental frameworks, societies can move toward a more sustainable future that respects both people and nature. This approach not only mitigates the adverse effects of environmental degradation but also fosters a deeper connection between humans and the natural world, ultimately leading to a more balanced and sustainable coexistence.

References

[1] Mendoza, J.M.F. (2020). Self-perceived action competence for sustainability: the theoretical grounding and empirical validation of a novel research instrument. Environmental Education Research, 26(5), 742-760. https:// doi.org/10.1080/13504622.2020.1736991

[2] Mapar, M., Jafari, M. J., Mansouri, N., Arjmandi, R., Azizinezhad, R., & Ramos, T. B. (2020). A composite index for sustainability assessment of health, safety and environmental performance in municipalities of megacities. Sustainable Cities and Society, 60, 102164. http://doi.org/10.1016/j.scs.2020.102164

[3] Caeiro, S., Sandoval Hamón, L.A., Martins, R., Bayas Aldaz, C.E. (2020). Sustainability Assessment and Benchmarking in Higher Education Institutions: A Critical Reflection. Sustainability 2020, 12, 543.

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes’ impact on China’s green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

THE INFLUENCE OF CIRCULATION PROCESSES ON THE ECOLOGICAL CONDITION OF TBILISI CITY IN THE BACKGROUND OF CLIMATE CHANGE

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Abstract

Since the second half of the twentieth century, the atmosphere, as the main component of the environment, has undergone significant changes due to the impact of anthropogenic factors, which have resulted in global climate change and its impact on humans and ecosystems. The consequences of climate change are often complex in nature, which makes it particularly difficult to determine the cause-and-effect relationship between them. The paper presents the results of the monitoring of atmospheric polluting components for Tbilisi City territory (period of March 2023), when there was observed smog, accompanied by a sharp worsening of visibility and the synoptic situation, causing the mentioned condition was determined. The main aim of the study is detection of atmospheric pollution level in Tbilisi, and assessment of anthropogenic sources. Studies have revealed, that the main synoptic situation for Tbilisi, during which the total pollution increases, is a "high-pressure trough", which is mainly associated with the stationary anticyclone of Kazakhstan, Western Siberia, or Eastern Siberia. During the mentioned situation, the concentration of polluting substances in the atmosphere (for Tbilisi city) increases. In almost every related case: Wind speed at the surface of the earth is less than 5 m/s; The influence of the front and stream currents is not observed, and the wind speed is also reduced at the height; Turbulent mixing is weak at 1-3 m/s; Cases of inversion and isotherms are common. Under these conditions, the level of pollution in the ground layer increases as a result. In the paper, the dynamics of quantitative change of individual pollutant sources, and aerosols in the atmosphere is revealed. Research has established, that the ecological condition of the atmosphere depends on the specificity and intensity of the pollution source, on physical-geographical and meteorological conditions (inversion, isothermy), and synoptic situations, typical for Tbilisi.

Keywords: Climate change, smog, synoptic situation, Tbilisi, pollution

I. Introduction

Starting with the second part of the 20th century, atmosphere, as a main component of the environment underwent substantial changes due to impact of anthropogenic factors that as a consequence caused global climate changes and its influence on human and ecosystem [1].

Polluting agents emitted in the troposphere not only impact on human and ecosystem, but also generate harmful substances. There are two factors of atmosphere pollution, namely natural and anthropogenic-technogenic factors.

One of biggest problems of the modern world is a global environmental pollution that causes climate changes [2]. Following civilization development, a human modifies environment and ecosystem, in general. All this is resulted in deterioration of social environment, human health status that is already of global nature and covers the entire planet [3, 4, 5].

Elemental processes become more frequent and intense along with climate changes. Intensification of some of these events is related to the change of global climate system.

During the past century, in parallel with upcoming of so-called "era of industrialization", the problem of atmosphere pollution became relevant in the entire world, including Georgia. Alongside with technological progress, the number of harmful emissions has continuously increased that caused surpass of maximum permissible concentrations of separate components entering the atmospheric air [6, 7].

The last decade clearly showed that under conditions of demographic explosion and intense development of manpower the tomorrow of the Earth and its future in general, mostly depends on the fact how we can protect the natural environment from anthropogenic impact. That is why the environmental protection problem got an extremely actual role among the most acute problems facing the mankind today [8].

Climate change results are frequently of integrated nature that especially complicates establishment of cause-and-effect relationship between them [9]. The scientific literature has repeatedly studied the issues of atmospheric circulation and dispersion of air pollution [10], effects of atmospheric processes on smog formation [11], impact of meteorological parameters of atmospheric pollution [12], etc.

The article represents the research results of monitoring of Tbilisi atmosphere polluting ingredients (2022-2023, March), when a smog accompanied by rapid deterioration in visibility was recorded at the territory of city. Synoptic situation causing the mentioned state was established.

The research **goal** is a qualitative and quantitative assessment of anthropogenic sources of Tbilisi city atmosphere pollution; establishment of quality conditions of atmospheric air; quantitative assessment of main atmosphere polluting ingredients: solid suspended particles (PM10 and PM2.5), sulfur dioxide (SO_2) and carbon oxide (CO) with the use of monitoring data, identification of atmosphere pollution level and its impact on human health under Tbilisi conditions.

It was established by studies that so-called high-pressure baric field, which is mainly related with stationary anticyclone of Kazakhstan, western Siberia or eastern Siberia is the most characteristic synoptic situation for Tbilisi, during which the total pollution increase occurs. During the mentioned situation, atmospheric concentrations of polluting substances (Tbilisi city) increase almost in all cases. Wind velocity near the Earth surface is less than 5 m/sec; front and stream flow effect is not observed, wind velocity is decreased at a height, as well; turbulent mixing is weak and equals to 1-3 m/sec; there are frequent cases of inversion and isothermy. Under the mentioned conditions, pollution level in the surface layer increases.

Dynamics of quantitative changes of aerosols emitted in the atmosphere from separate polluting sources is revealed in the work.

It is established by the study that ecological state of the atmosphere depends on peculiarity and intensity of pollution source, physical-geographic and meteorological conditions (inversion, isothermy), and synoptic situations under complex microclimate and physical-geographic conditions of Tbilisi city. The mentioned state results in increase of surface layer pollution level.

Meteorological conditions of atmosphere pollution

Tbilisi is located in the eastern Georgia, in the Tbilisi hollow, and is spread on both embankments of Mtkvari (Kura) River, at 380-600 meters height from the sea level.

Complex terrain of Tbilisi territory predetermines peculiarities of its natural environment. It is generally represented in the form of hollow. Terrace system of Mtkvari River, the nature of its horizontal and vertical dissection puts the city-planning measures within narrow bounds, complex topographic conditions established thereof hinders proportional territorial growth of the city. City expansion put its relief form under influence of anthropogenic factors, and as a consequence drastically changed its morphometrical characteristics. Terrace forms of city building modified original form of water-dividing ridges and slopes [13, 14].

Aerosols are non-uniformly distributed in Tbilisi that depends not only on distribution of the pollution focuses, but also on meteorological conditions (inversion, isothermy). The main among meteorological processes is an atmosphere circulation, when aerosols are spread in both, vertical and horizontal directions. Aerosols transfer intensity depends on relief, meteorological conditions and wind regime.

Dissipation or diffusion of aerosols generated by the different sources occurs very intensely by means of turbulent mixing peculiar for surface air. In this case aerosols are dissipated and their concentration is getting smaller, that depends on atmosphere stratification [4, 5].

It is obvious that duration and repetition of meteorological conditions cause severe pollution of Tbilisi air compared to those cities, which are characterized by relatively less duration and repetition of elemental meteorological events [13].

Complex terrain and meteorological conditions of Tbilisi substantially change characteristics of general circulation of atmosphere that causes peculiar character of aerosols distribution, for which sustainable condition of atmosphere is especially important. Duration of aerosols availability in the atmosphere is considerably influenced by character of the vertical profile of meteorological elements (temperature, wind, humidity).

Wind velocity is reduced by 20-30% in the city, compared to suburban areas, that is caused by air flow inhibition between buildings. Above buildings the wind velocity rapidly increases (approximately according to logarithmic law). In the cases, when temperature inversion is not recorded in Tbilisi, wind velocity at heights may increase up to the value, which exceeds velocity peculiar for open places and jet flow may originate at heights. Wind direction and velocity are changeable enough, especially during strong winds.

Convection development, which in the surface layers is accompanied by air mass shift towards city center, may be associated with a "heat island". The observations show that in case of light wind, there are originated air flows routed to the city center with 2-3 m/sec velocity, and ascending vertical flows headed to the central part. These factors promote water steam condensation and precipitation enhancement in the city [14, 15].

Water steam content in the city center is reduced in comparison to its suburban areas that become especially noticeable in summer, since evaporation from asphalt and stone surface is low. Relative humidity is 10-15% less in summer in the central parts than in outskirts. Decrease of wind, increased cases of inversion, shift to the center of an air bringing admixtures from suburban areas, promotes admixture concentrations growth in the central part of the city. Extremely hazardous cases of air pollution in the city are observed during formation of fog and its variety – smog.

II. Methods

In order to evaluate atmospheric pollution in Tbilisi city, there have been used the materials of atmospheric air pollution monitoring of the National Environmental Agency, who carries out observation on air background pollution and measurements of aerosol and harmful substance concentrations in automatic mode. The work also makes use of indicatory measurement results for Tbilisi city.

The following polluting agent concentrations are measured citywide, namely: solid suspended particles PM10 and PM2,5, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO2) and ozone (O_3).

Standard statistical, climatological and graphical analysis research methods are used for study. Data processing is based on the methods of multifactorial statistical analysis [16].

III. Results and Discussion

The research makes use of research results of the following polluting ingredients monitoring data (2022-2023, March) conducted at the atmospheric air observation automatic station located at Tsereteli Avenue, namely: solid suspended particles PM10 and PM2,5, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2).

Tbilisi city environmental pollution degree was assessed based on atmospheric air observation and results of automatic station monitoring materials study. We made comparison and graphical analysis of materials of polluting ingredients ($PM_{2.5}$, PM_{10}, SO_2, O_3, NO_2 and CO) monitoring carried out in 2022-2023, March (Fig. 1, 2, 3, 4, 5); qualitative and quantitative comparison of anthropogenic sources of atmosphere pollution and identification of atmospheric air quality state.

We have established synoptical and meteorological conditions which caused smog registered in March 2023.

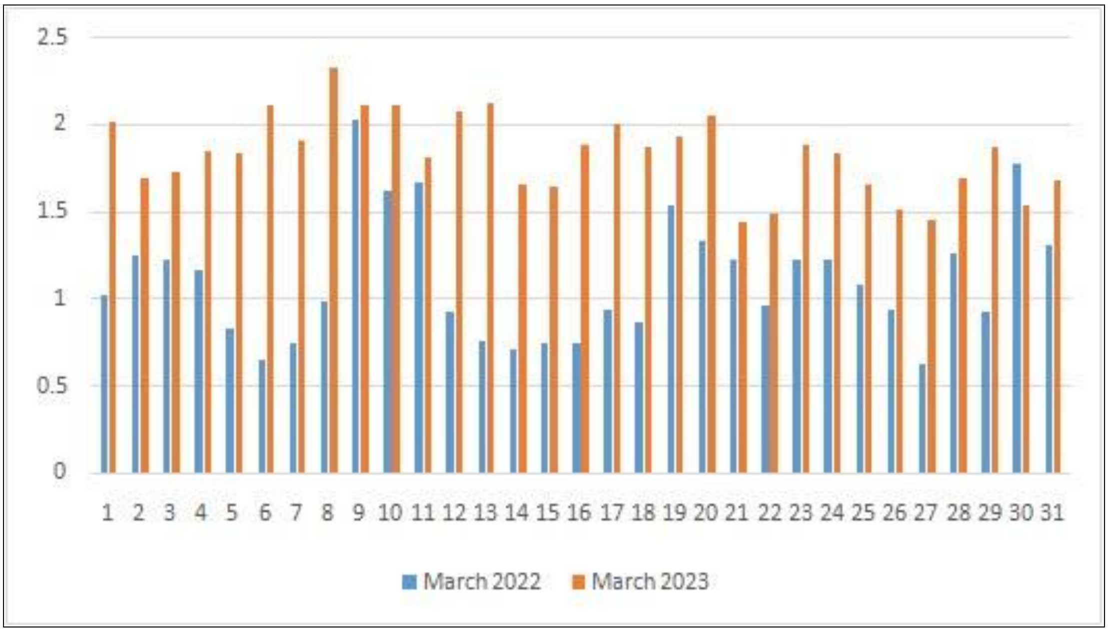

Figure 1: *Carbon Monoxide (CO) dynamics (March 2022 and March 2023)*

As is seen from the diagram, according to March 2023 data, carbon monoxide (CO) concentration over the course of a month surpassed the data of March 2022, though exceedance of the maximum permissible concentration was never recorded in any case. Main sources of CO entering into atmosphere are exactly vehicle emissions and natural gas consumption. Such concentration of carbon monoxide is presumably caused by city motor park upgrading and control over vehicles carried out by technical inspection. CO has a substantial impact on human health, in particular causes cardiovascular diseases, fetal development delay, while in case of inhalation in large amount a lethal outcome may come (Fig. 1).

Solid particles (PM10) dynamics is not stable. There are days, when March 2022 data prevail over March 2023 data and vice versa (Fig. 2). In both cases the situation is complicated enough. Taking into account that PM10 maximum permissible concentration is 40 mkg/m^3, it is clearly seen that in March 2022 concentration of solid particles (PM10) exceeded a limit. However, much more complicated situation was in March 2023, since concentration of solid particles was sharply increased and far exceeded the previous year level, in particular during 17 days. Especially should be noted the period from 8^{th} to 21^{st} of March, when solid particles concentration exceeded maximum permissible norms that was caused by frequent penetration of air masses from Kara-Kum desert to Georgia during the eastern process and as a consequence a smog was recorded in the period from $10^{th}$to 17^{th} of March. This is an emergency situation, since such a high content causes severe diseases in humans like eye irritation, asthma, bronchitis, tumors, intoxication etc.

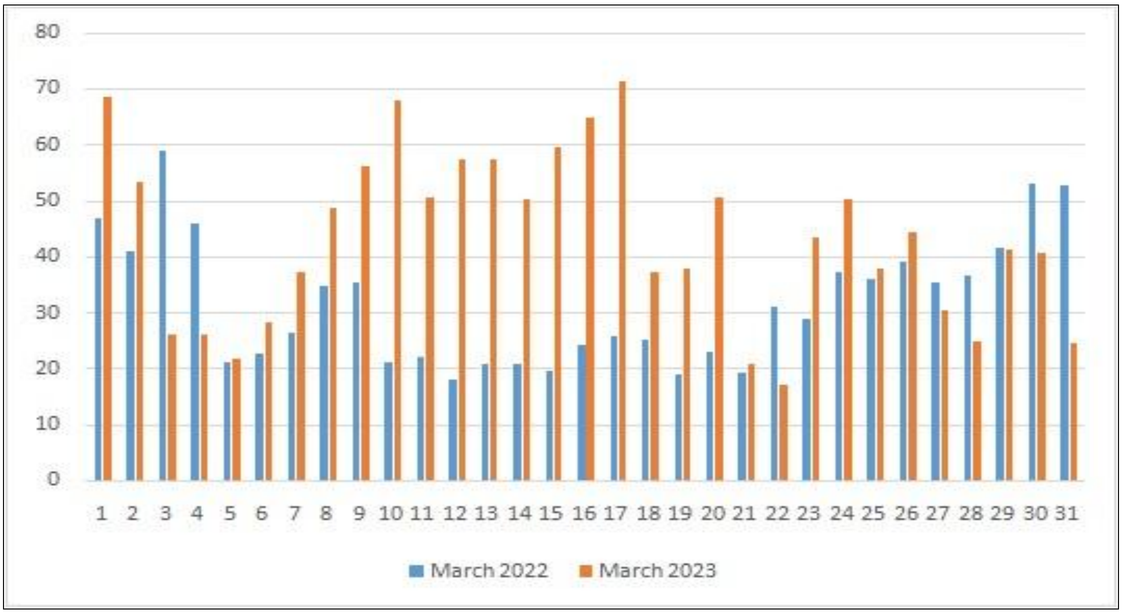

Figure 2: *Solid particles (PM10) dynamics (March 2022 and March 2023)*

Similar to PM10 particles, PM2.5 concentration exceeded MPC (Fig. 3). In both cases (2022-2023 March) the cases of exceedance of maximum permissible concentration were recorded. Maximum permissible concentration for PM2.5 is 25 mkg/m^3. In March 2022, PM2.5 concentration during 7 days surpassed the maximum permissible concentration (basically in the beginning of the month), while in 2023 – in the course of 22 days, mainly in the middle of month, from 10th to 20th March (that was caused by air mass entrance from Kara-Kum desert during the eastern process).

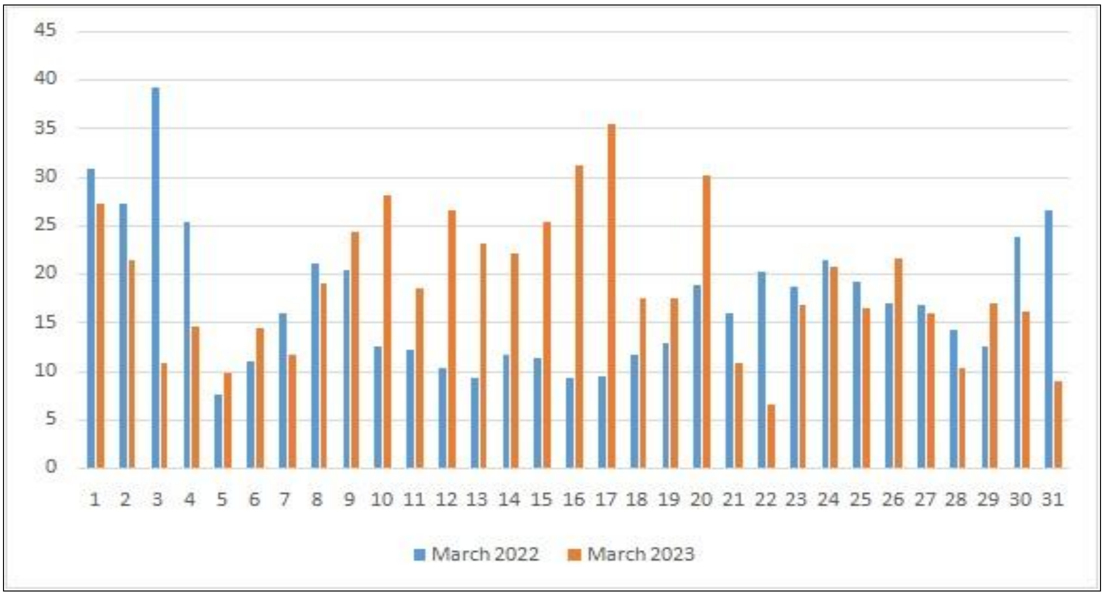

Figure 3: *Solid particles (PM2.5) dynamics (March 2022 and March 2023)*

Here one has to take into account the circumstance that PM2.5 particles are of very small size and respectively they are very light. As a consequence, they present in suspended state in the atmospheric air (due to very low sedimentation rate, since PM2.5 particle deposition rate is 10-time lower compared to PM10 particles). Small dispersive PM2.5 particles available in the air due to their small mass and size easily penetrate human lungs through respiratory passages; these particles are discovered even in the blood composition. Proceeding from this fact they can likely cause different types of diseases and, therefore, pose a threat to human health.

96% of urban population live in the environment of high concentrations of solid dust particles (PM2.5), which excesses WHO recommendations (5 mkg/m^3), while less than 1% - in the medium of such concentrations of PM2.5 particles, which surpass annual permissible level of 20 mkg/m^3 established by European Union.

The sulfur dioxide (SO_2) concentration decrease trend, not counting several days, is clearly seen from the diagram (Fig. 4). Maximum value 58.68 mkg/m^3 was recorded on 21st of March, 2022, while in 2023 the maximum was registered on 6th of March and was equal to 53.06 mkg/m^3. This state may be considered as satisfactory, since maximum concentration of sulfur dioxide according to these data approximately approaches (not exceeds) the maximum values. The mentioned circumstance is caused by the strict control over motor transport and by fuel quality check performed in recent years.

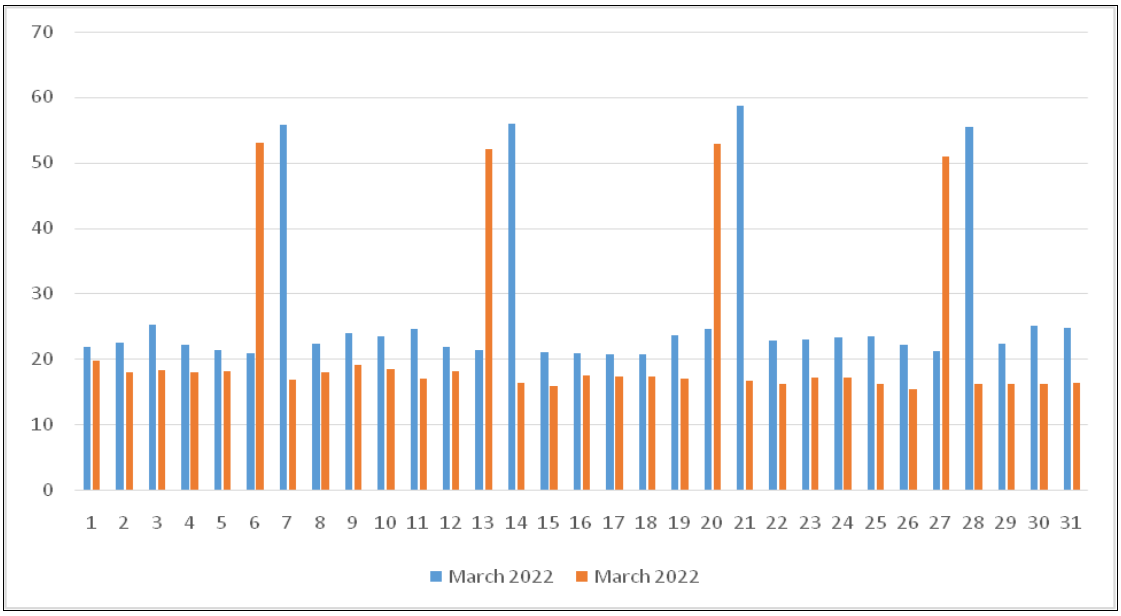

Figure 4: *The sulfur dioxide (SO_2) dynamics (March 2022 and March 2023)*

Nitrogen dioxide (NO_2) MPC equals to 40 mkg/m^3. It is well seen from the diagram (Fig. 5) that according to March data nitrogen dioxide concentration in both cases is more than 40 mkg/m^3 in the majority of days and approximately varies between 40 and 100 mkg/m^3, that 1.5-times exceeds maximum permissible concentration. The mentioned circumstance may be caused, as it was already mentioned, by features of circulation processes peculiar for the region and by frequent cases of inversion and isothermy. Pollution level in the surface layer increases under mentioned conditions. It is also important that aerosol concentrations growth under these conditions leads to ozone concentration increase and formation of photochemical smog, as a result.

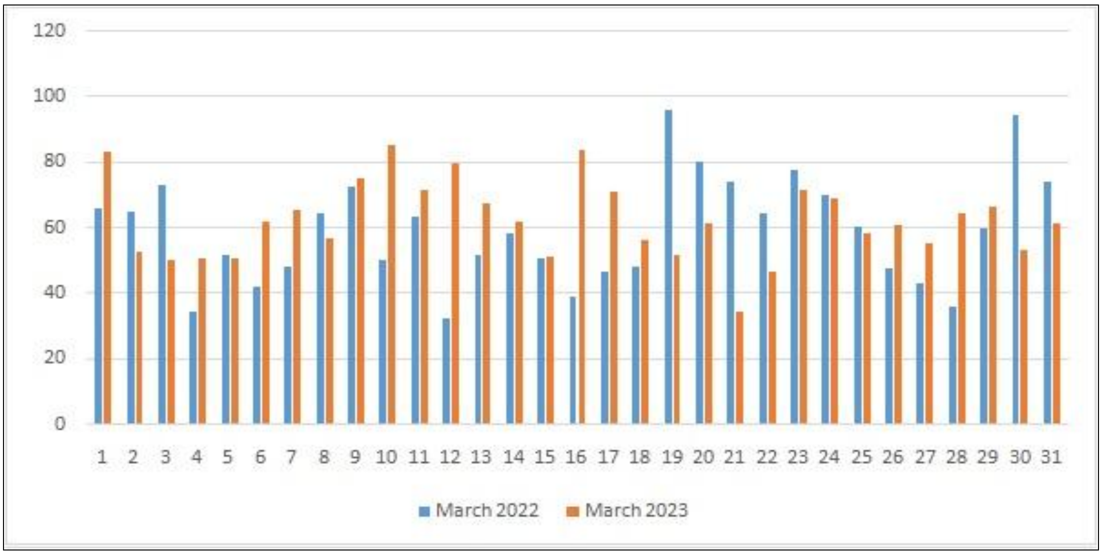

Figure 5: *Nitrogen dioxide (NO_2) dynamics (March 2022 and March 2023)*

IV. Conclusions

- Ecological state of the atmosphere depends on pollution source specificity and power, as well as on microclimatic, physical-geographical, and meteorological conditions peculiar for this place, and the most important, on the level of economic development and environmental awareness of the country.
- Maximum concentration (78%) of atmosphere polluting substances under Tbilisi conditions is caused by high intensity of motor transport use, and by physical-geographical, microclimatic and meteorological conditions.
- Solid particle concentrations were rapidly increased in March 2023 that was stipulated by the frequent penetration of air masses from Kara-Kum desert to Georgia, as a consequence of which a smog was recorded for several days.
- According to National Environmental Agency data, due to air masses (desert dust) invasion, a daily rate of PM10 particles at the Tsereteli Avenue was exceeded 47-times in 2022, and 78-times – in 2023.
- According to National Environmental Agency data, in some cases nitrogen dioxide (SO2) content at the Tsereteli Avenueis 10-times higher compared to other territories.
- Under conditions of Georgia, there is established a negative impact of atmosphere pollution on human health, and meteotropic diseases, malignant tumors, mutation etc are revealed.
- It was established by the studies that a synoptic situation the most peculiar for Tbilisi, during which a total pollution increases, is a high-pressure baric field (anticyclone), which is mainly associated with stationary cyclone of Kazakhstan, Western Siberia or Eastern Siberia. During the mentioned situations, concentrations of polluting agents in the atmosphere of Tbilisi increase almost in all cases. Wind velocity near the Earth surface is less than 5 m/sec; front and stream flow effect is not observed, and wind velocity is decreased at a height, as well; turbulent mixing is weak and equals to 1-3 m/sec; there are frequent cases of inversion and isothermy. Under the mentioned conditions, pollution level in the surface layer increases.
- Air quality deterioration in March, 2023 in Tbilisi was caused by increase in solid particles content. The World Health Organization considers that the smallest dust particles present in the air, concentration of which at this moment in Tbilisi exceeds maximum permissible level, more than other pollutants do damage to human health. Their inhalation heightens the risk of cardio-vascular and respiratory diseases, as well as lung cancer.

References

[1] World Atlas of Atmospheric Pollution. Ranjeet S.Sokhi, (2011), 144 p.

[2] Seinfeld JH, Pandis SN. Atmospheric chemistry and physics: from air pollution to climate change. John Wiley & Sons; 2016.

[3] Lagidze, L., Matchavariani, L., Tsivtsivadze, N., Khidasheli, N., Paichadze, N. and Motsonelidze N., (2015). Medical Aspects of Atmosphere Pollution. J. Environ. Biol., 36, 101-107.

[4] Lagidze L, Matchavariani L, Kereselidze D, Tsivtsivadze N, Paichadze N, Motsonelidze N, Vakhtangishvili M. (2015) The Influence of Meteorological Conditions on Atmospheric Pollution in Georgia. American Journal of Environmental Protection, 12(3), 67-71.

[5] Lagidze L, Matchavariani L, Svanadze D, Khomasuridze G. (2020). Influence of meteorological factors on ecological conditions of the atmosphere in Tbilisi, Georgia. J. Environ. Biol., 1, 41, 391-395.

[6] Bhola, R., Gurjar L. T., Molina Chandra and Ojha S.P., (2010) Air Pollution (Health and Environmental Impacts). CRC Press, New York, 544 p.

[7] Rani B, Singh U, Chuhan AK, Sharma D, Maheshwari R. Photochemical smog pollution and its mitigation measures. Journal of Advanced Scientific Research, 2011, 2(04), 28-33.

[8] Jacob D.J., Winner D.A. (2009). Atmospheric Environment (2009). Effect of climate change on air quality. Vol. 43, Issue 1 51-63.

[9] Fenger J. (2009). Atmospheric Environment. Air pollution in the last 50 years – From local to global. Vpl. 43, Issue 1 (13-22.

[10] Bilal M, Hassan M, Tahir DB, Iqbal MS, Shahid I. Understanding the role of atmospheric circulations and dispersion of air pollution associated with extreme smog events over South Asian megacity. Environmental monitoring and assessment, Springer, 2022, 194, 1-7.

[11] Mohammadi H, Cohen D, Babazadeh M, Rokni L. The effects of atmospheric processes on Tehran smog forming. Iranian journal of public health, 2012, 41(5), 1.

[12] Zacharis E, Sempos I. Effect of Meteorological Parameters of Atmospheric Pollution and Possible Correlation with Climate Change. 1st International Conference on Environmental Design (ICED2020), 24-25 October 2020, Athens, Greece, 417-421.

[13] Amiranashvili A., Bliadze T., Chikhladze V. (2012). Photochemical Smog in Tbilisi. Universal, Tbilisi, 160 p.

[14] Paolini R., Santamouris, M. (2022). Urban Climate Change and Heat Islands Characterization, Impacts, and Mitigation. 1st Edition, 144 p.

[15] Adi Wibowo, Nadira Retno Abisha, Revi Hernina, Eko Kusratmoko, Ratna Saraswati. Urban Heat Hazard Model Based on Local Climate Zones. International Journal of GEOMATE, 2023, Vol.24, Issue 103, 96-103.

[16] Nikolaishvili D. Geographical research methods. Tbilisi, TSU (2014), 94 p.

ECOLOGICAL CULTURE AS A CONDITION FOR THE FORMATION OF HUMAN POTENTIAL

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Abstract

This article is devoted to the study of the essence of environmental education, which plays a very important role in the formation of an individual's ecological culture, as well as a person's caring attitude towards nature and the environment. The main goals and tasks of the category under consideration are aimed at the development of environmental thinking, and a better understanding of the relationship between nature and man, which affects the formation of an individual's ecological behavior. In addition, to achieve these goals and tasks, the basic principles of ecological behavior come to the rescue, in particular, a practical orientation, a systematic approach and the conditions of the local environment.

Undoubtedly, the availability of qualified personnel to train both the younger and older generations plays a very important role in the formation of a cult of personality, responsible for his/her actions and benefiting nature. But, unfortunately, at the present stage of human development, environmental education faces a number of problems, in particular, the lack of an adequate level of funding, appropriate personnel, the absence of merging ecology with other sciences, etc., which require prompt intervention and solutions. In our opinion, in the near future it is necessary to make environmental education a priority in order to achieve sustainable development and protect natural resources for future generations.

Keywords: ecology, environmental education, environmental training, ecological culture, ecological thinking, environment, natural management

I. Introduction

The emergence of such a science as ecology dates usually back to 19th century, during which the considered category served as a certain component of such a broad concept as zoology and studied the relationships within the environment.

But, as practice shows, with the development of civilization, the main direction of ecology also changes, to a greater extent, flowing into the social aspect.

Now the role of ecology is being studied in the context of science that helps people survive under environmental conditions and make this environment as "comfortable" as possible for existence.

Unfortunately, human resources and the importance of clean ecology were realized only after an obvious conflict with the negative consequences of people's careless attitude towards nature, which, first of all, had a negative impact on people's health.

Accordingly, in modern conditions of development of society and the entire civilization, there is much concern about improving the quality of education, covering issues of the ecological environment, which is called environmental education.

In our opinion, before studying this term, it is important to focus our attention on the four well-known laws of ecology, which were put forward by the American scientist B. Commoner in the early 70s and became known under the slogan of the following aphorisms [1, 4].

So, let's consider the basic laws of ecology proposed by him:

1. "Everything is connected to everything else." The essence of the first law of ecology is interpreted in the context that all phenomena and processes in nature are closely interconnected. That is, this law "teaches" people to live without injudicious actions on individual parts of the ecological system, which can lead to global consequences.

2. "Everything must go somewhere." The second law states that any waste from economic activities must either be minimal or must go through a secondary usage cycle.

3. "Nature knows best." The third law of ecology focuses on the reasonable and conscious use of available natural resources. This law teaches people to cooperate with nature, instead of trying to completely transform it, and reminds us that we, humans, serve as an integral part of nature itself, but not its conqueror.

4. "There is no such thing as a free lunch." This is exactly what the latest Commoner Law says. After all, everything that we take from nature, we are obliged to compensate

For clarity, we would like to demonstrate the main 4 laws of ecology using by Barry Commoner 1917–2012, American biologist and ecologist:

1. Everything is connected to everything else.
2. Everything must go somewhere.
3. There is no such thing as a free lunch.
4. Nature knows best.

Undoubtedly, these laws play a key role in our life, although many of us are not even aware of it.

II. Materials and methods

We have to deal with environmental information almost every day in such areas as medicine, culture, education, etc.

But, unfortunately, the population usually doesn`t know how to correctly assess this or that emerging problem, due to the fact that it doesn`t have the proper qualifications and competence.

In this connection, the introduction of environmental education in people's lives is becoming highly relevant.

Thus, the main aim of environmental education is to create the most conscious, reasonable, positive attitude of a person towards nature and the environment, as well as the establishment of various interrelations between them.

The following tasks can be considered as the main tasks of environmental education [12, 15]:

- ✓ Extension of knowledge in the field of ecology for better understanding various environmental terms and concepts;
- ✓ Increasing the level of interest in environmental conservation among the population;
- ✓ The introduction of knowledge and skills for a proper attitude to nature;
- ✓ An increase in the level of environmental literacy among both the younger and older generations;
- ✓ Fostering a humane attitude towards nature;
- ✓ Increasing the level of competence in the study of various objects and phenomena;
- ✓ Upgrading the existing skills in helping the environment;

✓ Development of the qualities of competent analysis of all consequences of the environmental environment.

That is, for the formation of environmental education it is important to have environmental consciousness, because these terms are interrelated.

As for the methodology of environmental education, it is necessary to consider the complex of methods that are used to achieve the set goals and objectives.

The methods of environmental education are chosen depending on pedagogic and educational tasks, as well as the age criteria of students.

So, it is customary to distinguish the following methods of environmental education [5]:

✓ Visual methods, the essence of which is to study natural objects in real life or using images. Various types of observations, both live and with the help of illustrations, serve as vivid examples of this method. For example, observing the growth of plants or the behavior of animals;

✓ Verbal methods, including conversations, stories, reading information about ecology. Here, in our opinion, an important role is given to works of art, which clearly describe those processes of nature that become impossible to see;

✓ Practical methods covering various practical tasks and exercises. These methods usually include modeling, design, experiments, games, etc.

The terminology of environmental education was first discussed at a conference in the USA in the 70s of the XX century.

At that time, the following definition of this term was put forward: "Environmental education is the process of a person's awareness of the value of the environment and clarification of the basic regulations necessary to obtain the knowledge and skills necessary to understand and recognize the mutual dependence between man, his culture and his biophysical environment. Environmental education also includes the development of practical skills in solving problems related to interaction with the environment, developing behavior that contributes to improving the quality of the environment" [11].

According to Yu.L. Khotuntsev, the main goal of introducing environmental education in schools is to form in individuals the correct views and beliefs, covering the norms of moral responsibility of individuals for the state of the environment and for its improvement.

In other words, the main significance of environmental education is to teach people to make the most rational and effective decisions to protect the environment, based on moral norms and values [7].

A well-known expert in the environmental field I.D. Zverev offers a similar interpretation of this category, defining it as "... a continuous process of education, training, and personal development, aimed at forming a system of knowledge and skills, value orientations, moral, ethical and aesthetic relations, that ensure the environmental responsibility of an individual for the condition and improvement of socio-natural environment..." [9].

In his opinion, the main pedagogical tasks of environmental education include the following stages:

✓ Training is acquiring new knowledge about the environment;

✓ Education is introduction of moral qualities, guidelines, habits for environmental protection;

✓ Development is the ability to competently analyze the resulting environmental situation.

That is, as we see it, there is a fairly close relationship between environmental education and environmental training, which is a certain mechanism that ensures the presence of certain fundamentals of caring for nature and the environment in individuals, as well as the most rational use of natural resources.

Accordingly, in turn, the key component of environmental training is environmental consciousness, which is a complex phenomenon and evolves through the development of the intellect, emotions and desires of students.

So, as for environmental consciousness, the following factors take place [2]:

✓ Having an interest in problematic aspects of the environment

- ✓ Having a sense of responsibility towards nature;
- ✓ Willingness and readiness to participate in environmental activities;
- ✓ Concern about the environmental views of the population.

In turn, the structure of consciousness includes a number of environmental values that play a key role in the formation of certain norms of ecological behavior of people.

Accordingly, as we see it, ecological behavior is formed on the basis of various actions and views of a person on certain actions, which are directly related to the goals and motives of the individual [10].

We`d like to note that, according to A.A. Pavlov, the modern younger generation, unfortunately, does not particularly have environmental values in matters of careful natural management and preservation of the entire environment.

Thus, to sum up all the mentioned above, we can conclude that environmental education acts as an important tool in the pedagogical process for the formation of certain knowledge and skills that help to form in the individual the most important qualities necessary for a responsible and careful attitude towards nature.

In other words, an important task of environmental education and training is the creation of a developed ecological culture.

Some scientists identify these terms with each other. Others, on the contrary, believe that environmental education is formed only through the presence of ecological culture.

For example, V.A. Yasvin considers ecological culture in the context of people's abilities to use personal knowledge and skills in the field of ecology at a practical level.

After all, many people, even having a lot of knowledge, do not have the ability to use it competently due to the lack of the necessary level of ecological culture.

In this regard, environmental education of the population is becoming more relevant. It consists in disseminating knowledge about environmental safety, healthy lifestyle, the state of the environment, etc. [16].

III. Discussions

Thus, as we see it, the role of environmental education in the modern world is constantly increasing. But, unfortunately, in the process of development it faces a variety of problems that require prompt solutions to increase the effectiveness of the entire educational cycle.

We`d like to note several main problems of environmental education.

First of all, we`d like to start with the factor of insufficient awareness of existing environmental problems. Indeed, very often people do not realize the scale and seriousness of certain environmental situations, which undoubtedly have a direct or indirect impact on our lives.

In our opinion, this phenomenon may be connected with the fact that the population does not adequately own the entire information base and does not have a correct understanding of nature and the environment.

And the task of environmental education is to instill knowledge about careful attitude towards nature, as well as a sense of responsibility for its well-being, in people's minds.

As for education, in our opinion, the absence of merging ecology with other disciplines is also an important problem.

After all, environmental education is most often considered as a completely separate discipline, without showing the connection between it and other subjects, which is the wrong decision [13, 14].

Therefore, it is necessary to integrate the object of our research at all levels of education, in order to explain to students the close relationship between ecology and other sciences [8].

A negative factor is the absence of appropriate personnel who could teach the younger generation to environmental friendliness.

To do this, in our opinion, additional classes and trainings are needed to prepare the best specialists in environmental education.

And finally, another acute problem is the lack of funding, which is necessary for conducting excursions, purchasing equipment and materials, etc. [3].

In this regard, it is important to ensure the appropriate level of funding for the object of our research for its further development and prosperity [17].

IV. Results

Thus, having considered the main problems of environmental education, we would like to dwell on promising directions for its development.

First of all, we`d like to start with the formation of ecological thinking, the essence of which lies in the ability of students to see the connection between certain components of nature and understand their interrelation.

With the help of ecological thinking, an individual gets the opportunity to make the most effective management decisions and function in defense of the interests of the environment.

Also, as a perspective, we would like to note the formation of sustainable behavior skills, which consist in the most rational use of available natural resources, in particular, production waste sorting, reducing energy costs, etc.

These actions will serve as a certain incentive for students in matters of preserving the environment and increasing the level of responsibility for their actions.

Careful attitude to the conservation of various living organisms also serves as a perspective for the development of environmental education.

And finally, the development of environmental education is accompanied by the development of ecological culture among the population, which plays a key role in environmental protection due to various norms and values.

That is, there is an increase in the level and quality of people's knowledge about environmental ethics, a fair and careful attitude towards natural values.

V. Conclusions

Thus, based on the above-mentioned, we can conclude that environmental education has quite a serious development potential in order to solve various global environmental problems and ensure a decent future.

But, unfortunately, at the present stage of development of society and the economy, environmental education faces a number of problems in matters of training appropriate personnel, financing and absence of its merging with other disciplines that require prompt solutions.

After all, only by solving at least the basic problems of environmental education we will be able to see the potential of environmental education and its benefits for all humankind.

References

[1] N.A. Nazarbaev, Vzglyad v budushchee: modernizatsiya obshchestvennogo soznaniya [Looking into the Future: Modernization of Public Consciousness]. Accessed on: August 04, 2021. [Online]. Available: https://www.akorda.kz/ru/events/akorda_news/press_conferences/statya-glavy-gosudarstva-vzglyad-v-budushchee-modernizaciya-obshchestvennogo-soznaniya

[2] Alekseeva E.V., Gorbenko N.V. Main directions of environmental education implementation in the Nizhny Novgorod region. // Nizhny Novgorod Institute of the Education Development. Nizhny Novgorod education. – No. 4. – 2009. – pp. 48-54. – URL: https://elibrary.ru/item.asp?id=14751310.

[3] Anchukova S.N. Creativity and the ecology of personal culture // Trends in the

development of science and education. 2023. No. 97-1. pp. 95-98.

[4] Bondarenko M.A. Implementation of state policy to protect the environment by the example of the Murmansk region // Trends in the development of science and education. 2023. No. 96-10. pp. 138-141.

[5] Zimnenko V.A. Environmental education: a new aspect. // The project "National Strategy for. Environmental Education in the Russian. Federation". – URL: http://samson-corp.ru/Developments/MM23/mm23-02.pdf.

[6] Klubnikina A.V., Musatova O.V. Educational program as a means of environmental education for younger schoolchildren. – URL: http://files.scienceforum.ru/pdf/2012/1939.pdf.

[7] Lykova I.A. Integration of aesthetic and environmental education in kindergarten / I.A. Lykova. – M.: Tsvetnoy mir, 2018. – 828 P.

[8] Maryin E.V. Sustainable development as a way to achieve a compromise between ecology and economics // Scientific aspect. 2022. V. 5. No. 3. pp. 554-558.

[9] Nikolaeva S.N. Theory and methodology of environmental education for children. – M.: Publishing Center "Academy", 2002. – 336 P.

[10] Kuptsov, M.I., Yablochnikova, I.O., Yablochnikov, S.L., Dzobelova, V.B. & Mineev, V.I. (2020). Modeling Internet Business Optimization Processes, 2020 International Conference on Engineering Management of Communication and Technology (EMCTECH), Vienna, Austria, 2020, pp. 1-5, doi: 10.1109/EMCTECH49634.2020.9261507.

[11] Petrova E.V. Ecology as a methodological principle // The problem of the relationship between the natural and the social in society and man. 2023. No. 14. pp. 56-65.

[12] The program "Continuing environmental education in St. Petersburg". – URL: https://flatik.ru/programma-neprerivnoe-ekologicheskoe-obrazovanie-v-sankt-peter.

[13] Savvateeva O.A., Spiridonova A.B., Lebedeva E.G. Modern environmental education: Russian and international experience // Modern problems of science and education. – 2019. – Issue No. 5. – URL: https://science-education.ru/ru/article/view?id=29188.

[14] Radoushinsky D. A. , Radushinskaya A. I., Khaykin M. M. Improving the quality of implementation of the container transportation project along the NSR based on the environmental and energy transition agenda Polar Science. 2023. №35. pp. 100923-100923. https://doi.org/10.1016/j.polar.2022.100923

[15] Radoushinsky, D.; Gogolinskiy, K.; Dellal, Y.; Sytko, I.; Joshi, A. Actual Quality Changes in Natural Resource and Gas Grid Use in Prospective Hydrogen Technology Roll-Out in the World and Russia. Sustainability 2023, 15, 15059. https://doi.org/10.3390/su152015059

[16] Digitalization of the Social Sphere in Russia During the COVID-19 Pandemic: Analysis, Risks, Prospects / V. Dzobelova, N. Davletbayeva, O. Tegetaeva [et al.] // Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East (AFE-2022) : Agricultural Cyber-Physical Systems, Tashkent, 25–28 января 2023 года. Vol. 733-1. – Zug: Springer Cham, 2024. – P. 323-332. – DOI 10.1007/978-3-031-37978-9_31. – EDN CIFHRE.

[17] Digitalization and Industry 4.0-Changes Caused by COVID-19 / M. S. Rysalieva, V. B. Dzobelova, A. V. Olisaeva [et al.] // Strategies and Trends in Organizational and Project Management, Rostov-on-Don, 19–20 мая 2021 года / Editors: Pavel V. Trifonov, Marina V. Charaeva. – Rostov-on-Don: Springer Nature, 2022. – P. 12-20. – DOI 10.1007/978-3-030-94245-8_2. – EDN ZVSEKQ.

A COMPARATIVE STUDY OF ATTITUDES TOWARDS ENVIRONMENTAL ISSUES IN THE DIGITAL ENVIRONMENT AND REALITY

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Abstract

The article presents a comparative analysis of attitudes towards environmental issues in real life and in the digital environment. The authors attempted to evaluate 10,000 statements regarding environmental issues by VK users not only from the point of view of content analysis, but also from the point of view of the psychological characteristics of this digital trace of individuality. On the other hand, when analyzing attitudes towards environmental issues in real life, we applied traditional methods of psychological personality diagnostics, which were taken by 80 VK users. To compare the results obtained, we used data from the diagnostics of emotional attitudes - positive, negative and neutral. The results obtained in this study allow us to evaluate and compare attitudes towards environmental issues in real life and the digital environment, which contributes to understanding and identifying ways to solve problems of the ecosystem as a whole.

Keywords: digital trace of individuality, environmental issues, digital environment, VK users, emotional attitude

I. Introduction

Currently, one of the most burning topics in public discussion is the topic of ecology. In some aspects, these problems sometimes act as triggers to draw attention to the risks and real threats to the entire ecosystem. However, there are also "excesses" in assessing problems. An example is the problem of global warming, which environmentalists talk about as a fact that has happened more than once in the history of the earth, and is practically not related to environmental pollution.

Psychologists are particularly interested in the attitude of society (both real and digital) to environmental issues. The relevance of studying attitudes to environmental aspects of life is that it is necessary to know and control the degree of an individual's emotional reaction to pressing issues related to changes in the living environment of a modern person. Starting with the problems of the thinning of the ozone layer and ending with people's dissatisfaction with the proximity of settlements to landfills or the fact that neighbors have too many pets and do not take care of them. The modern educational and upbringing system provides many courses to improve environmental literacy. However, in real life, and even more so in digital reality, society actively and emotionally reacts to problems on the one hand, and, on the other hand, shows its attitude to the world around it. At the same time, people's reactions can indicate both a healthy and constructive attitude, and a destructive and harmful attitude to the environment. In this paper, we examined the psychological characteristics of attitudes to environmental problems, both in the real world and in the digital environment.

II. Methods

The study was conducted in September 2024 at the Pyatigorsk State University. In our study, we used two different approaches, since it is impossible to apply the same diagnostic methods to the real world and the digital environment.

So, to assess the attitude towards environmental issues in the digital environment, we received an unload of 10,000 statements by VK users on this topic. We processed these statements on the Polyanalyst platform [1], which provides the technical ability to identify the tone of statements, determine keywords, terms and establish connections between them [2; 3]. Such a technique allows us to characterize the digital trace of individuality, to characterize it in the digital environment. [4] This opportunity was provided to us by the developer of the Polyanalyst platform - Data - Diving Academy , the University Consortium of Big Data Researchers at Tomsk State University.

To diagnose attitudes towards environmental issues in the real world, we used valid diagnostic methods – the Method of Diagnosing Motivation for Interacting with Nature "Alternative"; the Scale of Environmental Concern and the Method of "Differential Emotions Scale"[5]. VK users took this diagnostic. We used statistical data analysis to process the data obtained.

In the third stage of our research, we conducted a comparative analysis of the obtained data.

III. Results

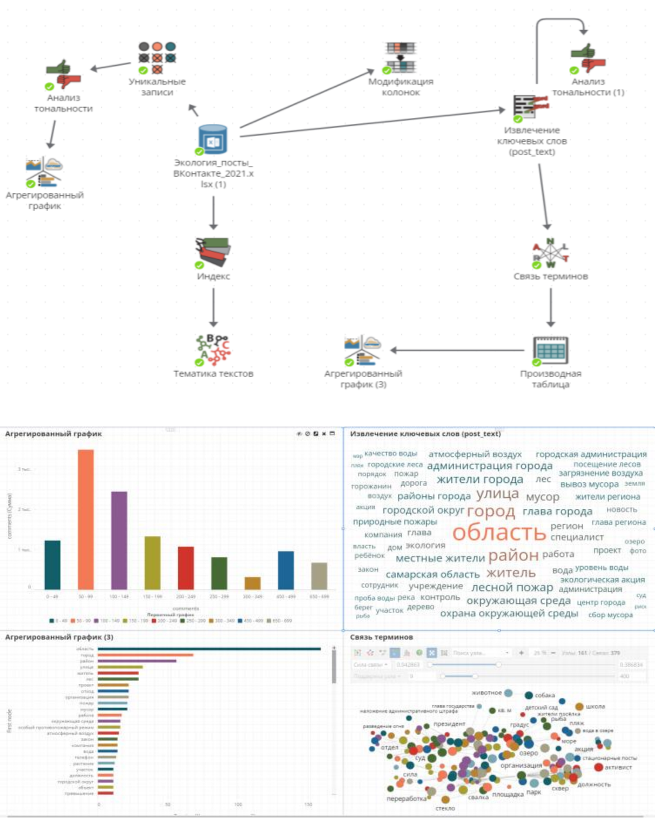

Figure 1: *Project and dashboard for analyzing environmental statements in VK*

Fig. 1 shows the results of the analysis of 10,000 statements by VK users. Working on the Polyanalyst platform and using the functionality of various nodes, we identified a number of features that can be interpreted from a psychological point of view. Thus, analyzing the data of the "Keyword Extraction" node, we define the following as the main keywords: "region", "mayor", "city", "district"; and secondary keywords - "garbage", "environmental protection", "forest fires", etc. This fact indicates that VK users, speaking out about environmental problems, more often define the priority for government representatives in responsibility for solving problems. These data are confirmed by the data of the "Aggregated Graph" node.

By defining the features of the connection of terms in the corresponding node, and relying on the indicators of the number of connections and the strength of connections, we identified the following priority connections - waste-landfill-site-plastic; atmospheric air-pollution-maximum permissible concentration; citizen-fine-waste incineration; recycling-processing-glass. These chains define the main topics in the discussion, they can be considered as the main triggers.

Particular attention should be paid to the data of the "Sentiment Analysis" node. For our study, it is necessary to determine the emotional background - positive or negative - of the statements of network users. The tonality of the statements was determined automatically and it turned out that there are 1.8 times more negative statements than positive ones.

In the second stage of our research, we present an analysis of a block of methods that were completed by 69 real respondents – VK users.

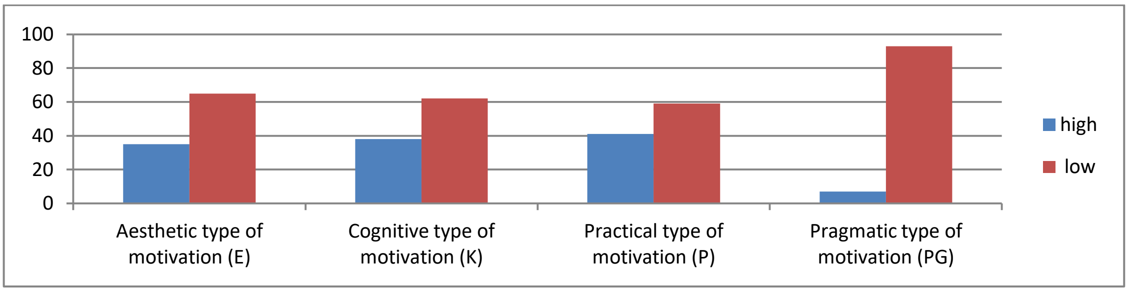

Figure 2: *Results of the Methodology for Diagnosing Motivation for Interaction with Nature "Alternative" (%)*

According to the data presented in Fig. 2, we see that the overwhelming majority of respondents showed a low level of motivation for their attitude towards the environment and its problems, which indicates that respondents are not inclined to be interested in nature, enjoy it, and try to solve environmental pollution problems. The overwhelming majority of respondents are more concerned with themselves and their concerns. In comparison with the results of the analysis of statements, we can trace the coincidence of attitudes towards the environment. VK users tend to consider the administration and officials to be the main ones responsible for the state of the environment. The users themselves are not inclined to admire or learn about the environment around us.

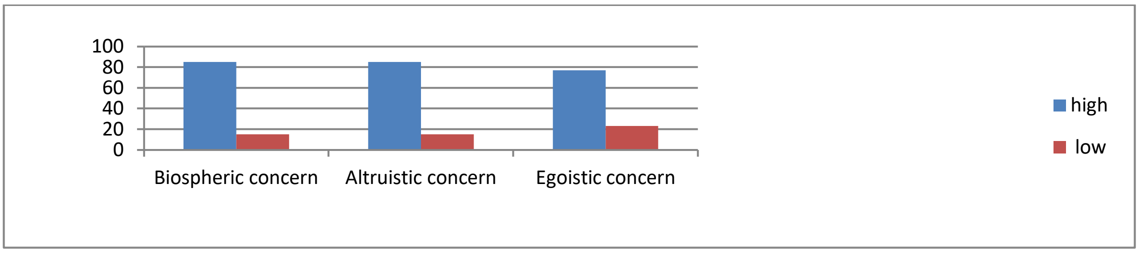

Figure 3: *Results for the Environmental Concern Scale Methodology (%)*

Fig. 3 shows the results of the "Scale of Environmental Concern" Methodology. It is obvious that high scores were obtained for all scales , which indicates concern about the fate of animals, birds and the ecosystem as a whole, as well as concern about the impact of environmental problems on children, people who live in the same region with me. A lower level is observed for the "Egoistic Concern" indicator - everything that concerns the consequences of environmental problems for one's own health, one's own lifestyle and future. Such scores indicate a high level of involvement in understanding the consequences of environmental problems in real life. In the digital environment, we can state an identical attitude and concern.

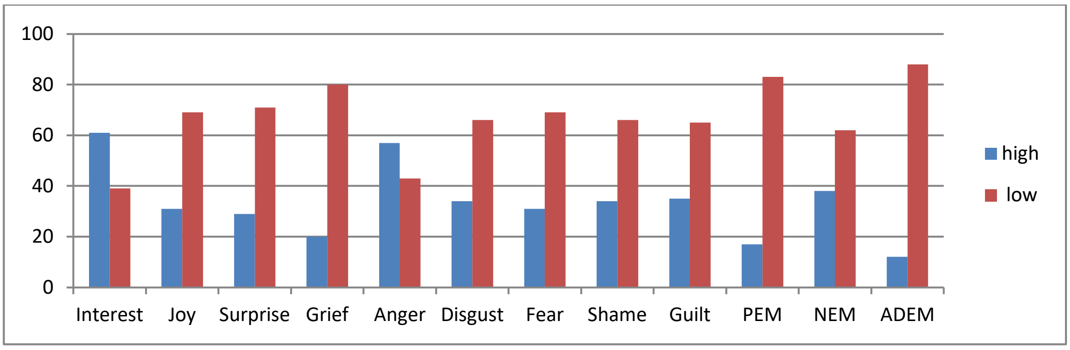

Figure 4: *Results for the "Differential Emotions Scale" method (%)*

Characterizing the data presented in Fig. 4, we determine the level of emotion that respondents showed regarding the current situation. In the block of positive emotions, "Interest" prevails, which is confirmed by the "Cognitive motivation" indicator regarding environmental problems. In the block of negative emotions, the data on the "Anger " indicator prevails, which is approximately half the results for the "Disgust" and "Fear" indicators. In general, the overall index of positive emotions is extremely low - about 19%, while the level of negative emotions is about 40%. This picture is also observed in the digital environment, where the level of positive tonality of statements is 1.8 times lower than the level of negative tonality of statements.

IV. Discussion

Modern studies of environmental problems affect various spheres of human activity and the whole society as a whole. In the work of E.A. Kharcheva the level of awareness of the population about the existence of various kinds of environmental problems is studied, and the level of environmental culture of the population of Russia and Europe is determined [6]. In the study of N.V. Kochetkov the components of the subjective attitude of young students to environmental problems are determined [7]. The scientist notes that if for the overwhelming majority of the population the determining component of the subjective attitude to environmental problems is the emotional component, then for students connected with environmental problems within the framework of their educational and cognitive activities, the components of a practical and cognitive nature act as key and decisive. In the study of O. Ogarkov the influence of environmental crises on the individual was revealed [8]. The study showed that the psychological consequences of environmental crises can be varied and include the following aspects: stress and anxiety, deterioration of physical and mental health, feelings of helplessness and fatigue, and changes in attitudes toward nature. The study shows that overcoming these negative psychological consequences of environmental crises is possible with the help of psychological, educational, personal strategies, and strategies to reduce the negative impact on the environment [8]. Social and psychological research abroad also raises the issue of the relationship and mutual influence of environmental and personal problems [9].

However, in modern research there has not yet been an attempt to study the digital trace of individuality in relation to the holistic structure of individuality in its relation to environmental issues. The authors of the article plan further research in the direction described in this study

References

[1] Petrov E. Yu., Sarkisova A. Yu. The resource of the analytical platform PolyAnalyst in social and humanitarian scientific research // Open data - 2021. Forum materials / edited by A. Yu. Sarkisova. Tomsk: Publishing house of Tomsk State University, 2021. Pp. 94–104.

[2] Markowetz A., Błaszkiewicz K., Montag C., Switala C., Schlaepfer TE Psycho-informatics: Big data shaping modern psychometrics // Medical Hypotheses. 2014. V. 82. P. 405–411

[3] Matz S., Kosinski M., Nave G., Stillwell D. Psychological targeting as an effective approach to digital mass persuasion // Proceedings of the National Academy of Sciences USA 2017. V . 114.P. 12714–12719.

[4] Marcinkowska, T. D. New methodology of digital everyday life / T. D. Marcinkowska // Questions of Psychology. - 2023. - Vol. 69, No. 2. - P. 3-13. - EDN NNHYYG.

[5] Ivanova Alexandra Andreevna, Shevel Tatyana Maksimovna, Agisova Fatiha, & Patrakova Natalia Alekseevna (2023). SCHULTZ'S ENVIRONMENTAL CONCERN SCALE: ADAPTATION AND VALIDATION. Psychology. Journal of the Higher School of Economics, 20 (4), 699-717. doi: 10.17323/1813-8918-2023-4-699-717

[6] Kharcheva E. A. (2021). Population attitude towards environmental problems. Digital Science, (5), 65-69.

[7] Kochetkov N.V. On the comparative importance of the main priorities of environmental policy for students // United Scientific Journal, No. 26 (84). - M., 2003. - P. 41-43

[8] https :// www . researchgate . net / publication /376081109_ Psychological _ consequences _ of _ environmental _ crises _ for _ the _ individual

[9] Steg L, Gifford R. Social psychology and environmental problems. In: Steg L, Buunk AP, Rothengatter T, eds. Applied Social Psychology: Understanding and Managing Social Problems . Cambridge University Press; 2008:184-205.

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ASSESSMENT OF BUILDING VULNERABILITY DURING THE THAWING OF PERMAFROST SOILS

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Abstract

The development of new Arctic regions in the context of global and local thawing of permafrost soils caused by both local man-made and global natural thermal impacts on the ground necessitates the use of new engineering solutions for the timely prediction and prevention of dangerous uneven deformations in buildings. Uneven building deformations occur due to the reduced stiffness of the soil mass beneath the foundation, caused by the uneven thawing of the soil. It is proposed to assess the stiffness of the "soil-building" system using the dynamic-geophysical testing method.

Keywords: "soil-building" system, dynamic-geophysical testing, natural vibration frequencies of soils, vulnerability of the "soil-building" system, technical condition of the "soil-building" system

I. Introduction

In the Far North, modern multi-story construction has been employed for many years, and it is in no way different from construction in regions without permafrost. However, the use of modern engineering life support systems creates a significant thermal load on the soil mass beneath the buildings, which can lead to uneven thawing of permafrost soils, causing uneven settlement and deformation of the structural framework of buildings (see Figure 1). To prevent potential damage to buildings caused by uneven thawing of the soil, additional diagnostic and monitoring methods are required. These methods should allow for the timely identification of hazardous zones in the soil mass during the investigation, construction, and operational stages, which could lead to deformations in the "soil-building" system [1].

Due to the influence of possible heterogeneities in the soil mass, there is a loss of equilibrium and stability, leading to subsidence, landslides, disruption of hydrological regimes, suffosion, karst phenomena, increased deformation of the "soil-building" system, and a heightened risk of building and structure collapse. To detect potential geological hazards beneath the foundation of a building, investigative methods capable of assessing the soil mass up to depths of 50-100 meters are required [2].

Known geological and geophysical methods do not allow for the quick and reliable determination of the location and magnitude of geological heterogeneities (see Table 1). Geological drilling with soil sampling is a point-based investigation, and to obtain accurate data on the structure, physical and mechanical characteristics, and potential geological hazard zones, the number of boreholes must be maximized, which is impractical in reality. The use of geophysical methods, such as seismic exploration, improves the quality of geological surveys; however, these studies are limited to two-dimensional linear profiles of up to 50 meters in length and 20 meters in depth. The depth of research can be increased by extending the wave source, but this requires additional time and financial resources. The greatest challenge, however, lies in the interpretation of geophysical data and identifying potential geological hazards, which depend solely on the expertise of the geophysicist [3].

Figure 1: *deformation of a building in arctic conditions due to uneven settlement of the "soil-building" system*

Table 1: *comparison of geological and geophysical methods for investigating the physical-mechanical and dynamic parameters of the soil mass beneath buildings and identifying potential geological hazards.*

Criteria	Geological Methods (Drilling and Sampling)	Geophysical Methods (e.g., Seismic Exploration)
Depth of Investigation	Limited to specific borehole depth (can reach 50-100m)	Typically up to 20m, but can be extended with additional efforts
Data Accuracy	High at specific borehole locations	Moderate; relies on interpolation between points
Coverage	Point-based, requires multiple boreholes for broader coverage	Provides continuous profiles along a line, but limited in area
Physical-Mechanical Data	Direct sampling allows precise measurement of soil properties	Indirect; requires interpretation of wave propagation data
Dynamic Soil Properties	Limited, usually not assessed directly	Provides information on soil stiffness, natural frequencies
Geological Hazard Detection	High precision at the borehole location, but limited coverage	Identifies anomalies, but exact nature requires interpretation
Cost	Expensive (especially with a high number of boreholes)	More cost-effective for larger areas, but requires specialized equipment
Time Required	Time-consuming due to drilling and sample analysis	Faster than drilling for shallow studies, slower for deeper studies

Applicability in Complex Terrains	Limited by access for drilling equipment	More flexible; can cover larger and more difficult terrain
Interpretation Dependence	Minimal; results are based on direct soil properties	High; depends on the expertise of the geophysicist
Hazard Detection at Depth	High, but localized to borehole	Moderate, dependent on the depth capability of the equipment

It is proposed to use the dynamic-geophysical testing method for assessing the stiffness parameters of the "soil-building" system.

II. Methods

The experience of applying the dynamic-geophysical testing method shows that, by considering the soil mass as a vibrating body with specific dimensions and depth, one can roughly determine its structure and physical-mechanical characteristics depending on the predominant soil composition and the natural vibrations of the mass.

The technology of dynamic-geophysical monitoring of the "soil-building" system has been widely tested on various objects. This technology allows detecting possible changes in the system's condition. It has been successfully applied for diagnosing "soil-building" systems to identify the risk of building collapse in locations such as Novy Urengoy, Muravlenko, Nizhnevartovsk, the Bryansk region, Yakutia, Altai, the Kamchatka region, Sakhalin, the Ulyanovsk region, and others.[4]

The proposed comprehensive dynamic-geophysical monitoring technology is an integrated measurement and analytical system installed in areas with potential geological hazards. The system consists of a computer with specialized software that collects, analyzes, and processes digital data from sensors placed in the monitored zone according to specific criteria. The system includes a multi-channel analog-to-digital converter (ADC), three-component accelerometers, tilt sensors, water level and pore pressure sensors in the soil, temperature sensors, and others, along with a cable or radio data transmission system from the sensors to the ADC. The composition and number of necessary monitoring system elements are determined based on the monitoring goals.[5]

The criteria developed with the participation of the authors for assessing the stability of the soil mass using the results of dynamic-geophysical observations allow the early detection of unstable equilibrium states of the soil (within hours to days). A sensitive stiffness parameter of structural systems is vibrations. Vibrations of the soil mass, like those of structures, depend on their mass and stiffness. For the soil mass, the equation linking its vibrations to its geometrical and physical-mechanical parameters can be expressed as follows:

$$T_1 = 2{,}63 \times \mathrm{H}\sqrt{\frac{\rho}{G}}, \ (1)$$

where:

ρ is the density of the considered block of the soil mass,

G is the shear modulus of the soil mass,

H is the height of the block of the soil mass.

The most convenient parameter for measurements and calculations is the natural frequency of vibrations, which is the inverse of the vibration period. Each type of soil with uniform thickness is characterized by a certain level of weighted average period or frequency of vibrations. The values of fsv vary depending on the thickness, size of the soil mass, and type of soil. For example, for soil with a thickness of 8-10 meters,Tpr = 4H/vs Table 2 provides the physical-mechanical and dynamic parameters of soils.

Thus, by monitoring the period (frequency) of vibrations of the object or the soil mass, it is possible to control their stiffness, including the degree of soil saturation. The stiffness of the soil mass and the building is directly proportional to the squares of the frequencies in the monitored directions.

Table 2: *physical-mechanical and dynamic parameters of soils.*

Soil Type	Density (ϱ), t/m³	Shear Modulus (G), MPa	Elastic Modulus (E), MPa	P-Wave Velocity (Vp), m/s	S-Wave Velocity (Vs), m/s	Natural Frequency of the Soil Mass (f), Hz
Sand	1.6	33.54	15.9	200-500	150-300	2.86
Sandy Loam	1.6	60.38		250-550	120-280	0.7
Loam	1.7-1.75	26.71	5.06	300-600	100-250	1.25
Clay	1.8-2.05	48.16	7.1	1400-2500	400-600	2.1
Wet Clays	Less than 1.5	3-6	1.5	1400	100	1

Thus, to assess the stiffness of the "soil-building" system, it is necessary to:

1. Select locations for sensor placement and perform tests on the "soil-building" system.
2. Obtain the natural frequencies of the "soil-building" system.
3. Calculate the normative values of the natural frequencies of the soil mass beneath the building and the building itself.
4. Calculate the normative values of the natural frequencies of the monitored load-bearing structures.
5. Compare the squares of the natural frequencies of the soil mass and the building, and determine the stiffness deficits by direction.
6. Using the criteria, evaluate the technical condition of the soil mass and the building.

III. Results

In a kindergarten building constructed with a precast reinforced concrete frame and located in Arctic conditions, structural deformations began to appear during its operation due to soil weakening in the foundation caused by thermal exposure. To assess the stiffness of the "soil-building" system, the dynamic-geophysical testing method was applied. For soil assessment, three-component accelerometers of type A1638 were used. By sequentially placing the sensors on the pile cap foundations in the building's basement, as well as on the floors and roof of the building, the natural vibration frequencies of the "soil-building" system were obtained. [5]

Figure 2: *Kindergarten Building Tested Using the Dynamic-Geophysical Method.*

To assess the technical condition category of the building, a comparison was made between the normative values of the building's natural vibration frequencies and the experimentally obtained values.

The potential reduction in the building's stiffness is determined by comparing the normative and experimentally obtained natural vibration frequencies.

Stiffness deficiency is assessed using the following dependencies [4–8]:

$$\Delta fx = ([fx]^2 - fx^2) \times 100 / [fx]^2, \quad (1)$$

$$\Delta fy = ([fy]^2 - fy^2) \times 100 / [fy]^2, \quad (2)$$

$$\Delta fz = ([fz]^2 - fz^2) \times 100 / [fz]^2, \quad (3)$$

where fx, fy, fz are the values of the building's natural vibration frequencies obtained from dynamic tests.
[fx], [fy], [fz] are the standard natural vibration frequencies obtained from the design or calculated values.
Δfx, Δfy, Δfz are the stiffness deficiencies in percentages along the X, Y, Z axes (see Table 2).

Table 3: *Percentage of stiffness reduction (square of the building's natural vibration frequency), depending on the category of technical condition.*

Type of Structure	Percentage of Relative Stiffness Reduction of a Structure in Various Conditions				
	Very good	good	fair	poor	very poor
Reinforced Concrete Frame	0–25	25–43	43–57	57–71,4	71,4–100
Steel Frame	0–16,7	16,7–33	33–50	50–67	67–100
Brick	0–16,7	16,7–33	33–50	50–75	75–100
Wooden	0–20	20–27	27–40	40–67	67–100
For Other Types of Buildings and Structures, Soil Masses Beneath Buildings	0-10	11-30	31-60	61-90	

Based on the test results, the following conclusions were made: The building is in operational condition; however, resonance frequencies between the soil and the building were detected, which may lead to increased vibration amplitudes and the development of structural damage.

To assess possible heterogeneities, loosened areas, and likely zones with reduced soil stiffness, dynamic-geophysical testing was conducted in the building's basement. In Figure 3, the zoning of the soil mass beneath the building is shown. In red zones, stiffness reduction can reach up to 50%, while in yellow zones, it can reach up to 30%. At least two high-frequency anomalies are recorded in the red zones along the axes, while one anomaly is recorded in the yellow zone.

The example considered demonstrates that timely detection of potential zones of stiffness reduction in the soil can be ensured by:[6]

1. Monitoring the soil mass condition to promptly determine its dynamic-geophysical parameters and prevent resonance phenomena from dynamic impacts;
2. Comprehensive monitoring of the "soil-structure" system (parallel control of water levels in boreholes, monitoring the building's geometry and soil surface, etc.);
3. Timely implementation of protective engineering measures, such as installing drainage and stormwater systems to effectively divert groundwater, strengthening the soil, and other measures to enhance the stiffness of the soil mass.

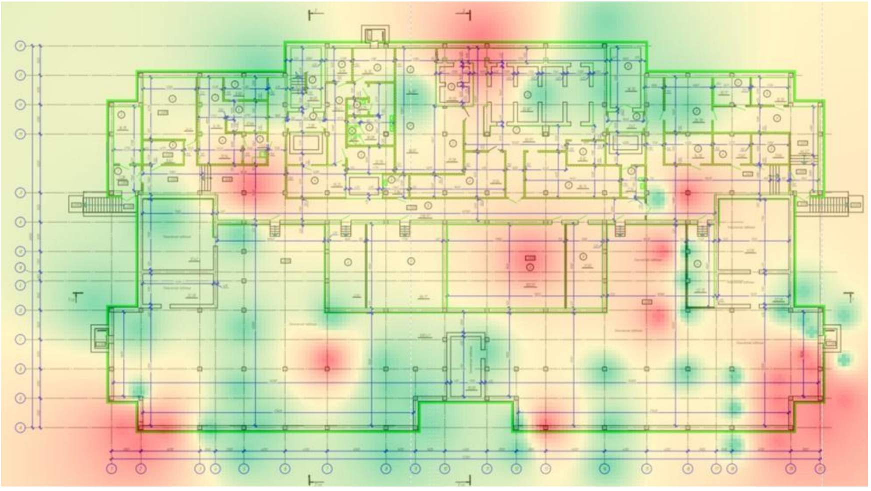

Figure 3: *Zoning of the Soil Mass Beneath the Building Based on Bearing Capacity. In Red Zones, Soil Stiffness Reduction Can Reach Up to 50%*

IV. Discussion

The dynamic-geophysical comprehensive monitoring technology for the "soil-structure" system can ensure the timely detection of geological hazards and assess the potential probability of catastrophic building and structure failures. At the investigation and design stages, it enables the selection of rational engineering measures to enhance the stability of "soil-structure" systems, and during the operational stage, it allows for the control of the effectiveness of these measures.[7]

References

[1] Guidelines on Safety "Methodological Foundations for Hazard Analysis and Risk Assessment of Accidents at Hazardous Production Facilities". Moscow: ZAO NTU PB, 2016.

[2] Nigmetov, G.M., Chubakov, M.Zh. Problems of Monitoring Buildings and Structures. Seismic-Resistant Construction and Safety of Structures, No. 4, 2011, pp. 51-55.

[3] Larionov, V.I., Nigmetov, G.M., Shakhramanyan, M.A., Suschev, S.P., Ugarov, A.N., Frolova, N.I. Application of GIS Technologies for Assessing Individual Seismic Risk. Seismic-Resistant Construction, No. 2, 1999.

[4] Methodology for Comprehensive Individual Risk Assessment in Emergencies of Natural and Technogenic Origin. Moscow: 2002, VNII GOChS (FC) of the Ministry of Emergency Situations of Russia.

[5] Nigmetov, G.M., Savinov, A.M., Savin, S.N., Nigmetov, T.G., Simonyan, A.R. Dynamic-Geophysical Tests of the Technical Condition and Earthquake-Resistance of Historical Buildings. AlfaBuild, Vol. 21/1, ISSN: 2658-5553, pp. 2101.

[6] Savinov, A., Nigmetov, G., Nigmetov, T., Galliulin, R. The Possibility of Vibrodynamic Data from Phone Accelerometers for the Rapid Assessment of the Technical Condition of Buildings and Structures. Proceedings of STCCE. International Scientific Conference on Socio-Technical Construction and Civil Engineering 2022: Lecture Notes in Civil Engineering, Switzerland, 2022, pp. 371-379.

[7] Nigmetov, G., Savinov, A., Nigmetov, T. Assessment of Individual Seismic Risk for the Population, Taking into Account the Actual Seismic Resistance of Buildings and the Seismicity of Soils. Reliability: Theory & Applications, 2022, Vol. 4, No. 70, p. 172.

DIAGNOSIS OF OIL SPILLS FROM SUBSEA PIPELINES

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Abstract

Taking into account the importance of quick detection of oil leaks from submarine pipelines in sea conditions, and the importance of eliminating their consequences, the issues of diagnostics for the determination of leaks and oil losses are discussed in the article. The possibility of determining the location of the leak depending on the degree of leakage is shown. Since the diameter of the pipeline and the physico-chemical properties of oil are assumed in the calculations, the development and application of the mentioned method for the purpose of detecting leaks in specific subsea oil pipelines operated in practice does not require additional costs, as it is based on a known software set and field data.

Keywords: Caspian Sea, subsea pipelines, leak, flow rate, pressure

I. Introduction

One of the factors affecting the ecological environment of the Caspian Sea is the occurrence of oil leaks into the sea as a result of accidents during the operation of offshore pipelines.

Since the products are mainly supplied under wellhead pressure to the subsea pipelines used for the collection and transportation of well products from offshore fields, it is inevitable that new wells start up, stop working, and change their operating modes due to operational challenges. On the other hand, since these pipelines are laid along the bottom of the sea, they are under different hydrostatic pressure depending on the water depth. In deep water basins, it is also possible that this pressure exceeds the working pressure of the pipelines. In such cases, if the subsea pipeline is damaged or punctured, oil will not leak into the sea, but seawater will be absorbed into the pipeline. Once leaks are confirmed, an important issue that arises is the location of leaks and the assessment of oil losses. Detection of small oil spills in marine conditions is associated with many challenges. For the accurate detection and identification of a leak, it is necessary to know the behavior of the fluids inside the pipeline, which allows to determine the pressure drop along the pipeline and the total amount of fluid released, to stop the pumps and control valves to prevent or minimize the damage to the environment [1-4].

II. Methods

Methodology. If we assume that the pipeline is laid along the bottom of the sea with a depth Hd and the internal pressure Px at the point of leakage, the amount of oil flowing into the environment (q) and the condition of oil flowing into the sea can be determined according to the following expressions:

$$q = c_0 \cdot a\sqrt{\frac{2(P_x - P_e}{\rho_n}} \quad (1)$$

$$X_{l.l} < \frac{\left(\frac{P_1}{P_e}-1\right)H_d}{\frac{\rho_o}{\rho_w}\cdot K\cdot Q_1^{2-m}} \quad (2)$$

where: $P_e = \rho_w g H_d$ - hydrostatic pressure exerted by seawater; c0-flowrate factor for the stream (for calculation c0=0.61 can be accepted); a-area of the leakage location (m2); ϱo - oil density (kq/m3); Xl.l - distance to the location of the oil spill; P1 - pressure at the beginning of the pipeline; Q1 - flowrate of oil in the pipeline after the occurrence of a leak; m və k - are indicators that characterize the oil flow regimes in the pipeline.

As can be seen from statement 1, in order to determine the amount of leaking oil, the pressure inside the pipe at the location of the leak must be known.

The pressure inside the pipe at the point of leakage can be determined as follows, depending on the inlet pressure of the pipeline:

$$P_{\tilde{o}} = P_1 - K\cdot\rho_o g Q_1^{2-m}\cdot X_{l.l} \quad (3)$$

If we consider expression 3 in 1, we get:

$$q = c_0\cdot a\sqrt{\frac{2}{\rho_o}\left(P_1 - K\cdot\rho_o\cdot gQ_1^{2-m}\cdot X - P_e\right)} \quad (4)$$

Since the difference between the oil flow rate at the inlet and the outlet of pipeline is taken equal to the oil loss due to leakage, it can be assumed that the leakage amount (q) is known. Then from expression 4 we obtain the following expression to determine the location of the oil leak:

$$X_{l.l} = \frac{\left(\frac{P_1}{P_e}-1\right)H_d}{\frac{\rho_o}{\rho_w}\cdot K\cdot Q_1^{2-m}} - \frac{q^2}{2c_0 a^2 K\cdot gQ_1^{2-m}} \quad (5)$$

Thus, as it can be seen from the statement (5), if a leak has occurred in the subsea oil pipeline, the location of the leak can be determined based on the parameters q, P1/Pe and Q1, taking into account the flow regime and the depth of the sea.

In order to diagnose various cases of oil leakage in submarine oil pipelines, calculations were made for oil with density kg/m3 and viscosity ν = 5*10-6 m2/s in different flow regimes based on expression (5). In order to correspond to real situations, the calculations are based on the depths of the sea Hd = 10, 30, 50, 100, 150, 200, 250 m, the initial pressure in the pipelines P1=1.0-6.0 MPa, and the flow rate Q=0.1-0.8 m3/s. performed for pipelines. The location of leakage (Xl.l) was determined for values of q=1,2,3,4,5,6,7% of different leakage cases. Based on the results of the calculations, the dependences between the Xl.l, Q1 and P1/Pe parameters in 3-dimensional space were graphically depicted in the Delphi environment using a special program for Windows. Those images are shown in Fig. 1 and 2, respectively, for values of q=1 and 7% of leakage cases in Xl.l - Q - P1/Pe coordinate system.

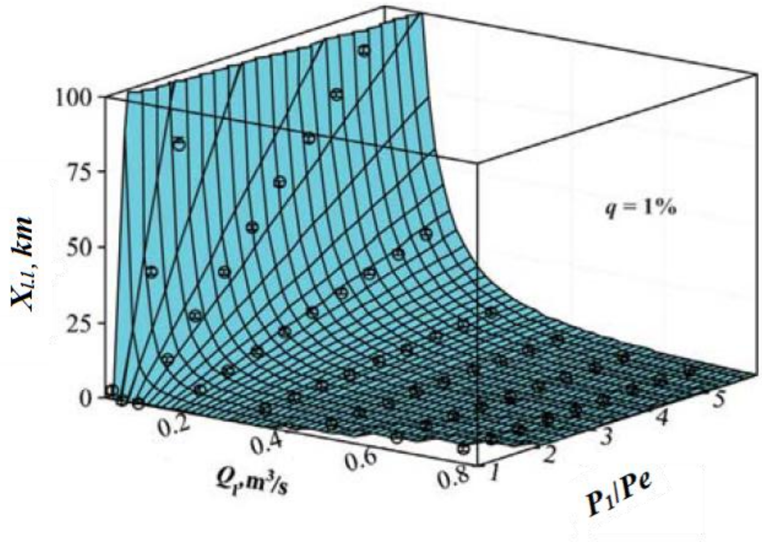

Figure 1: *Dependence of the distance to the leak point in subsea pipelines on the flowrate and pressure ratio (q=1%)*

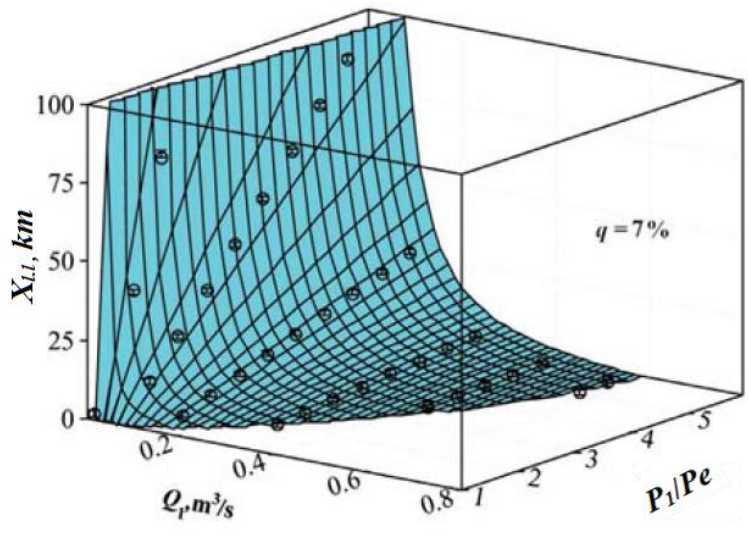

Figure 2: *Dependence of the distance to the leak point in subsea pipelines on the flowrate and pressure ratio (q=7%)*

It was determined that the location of the leak can be indirectly determined with an accuracy of up to 1%, depending on the Q1 and P1/Pe parameters, based on the following regression equation-empirical expression with a very high correlation coefficient (R2=0.999):

$$X_{1.1} = a + \frac{b}{Q_1} + c\frac{P_1}{P_e} + \frac{d}{Q_1^2} + e\left(\frac{P_1}{P_e}\right)^2 + f\frac{P_1}{Q_1 P_e} + \frac{g}{Q_1^3} + h\left(\frac{P_1}{P_e}\right)^3 + \frac{i}{Q_1}\left(\frac{P_1}{P_e}\right)^2 + \frac{j}{Q_1^2}\left(\frac{P_1}{P_e}\right) \quad (6)$$

Here, a, b, c, d, e, f, g, h, i, j are coefficients and are determined by the depth of the sea, the amount of leaks and the flow regimes of oil (Table 1).

III. Results

Table 1: *The values of the coefficients included in the empirical expression*

For various leakage conditions								
	Hd = 150 m				Hd = 200 m			
q, %	1	3	5	7	1	3	5	7
a	-0,204	-1,006	-2,185	-4,821	-0,060	-0,927	-1,781	-4,0362
b	-0,302	-0,191	0,232	0,198	-0,438	-0,312	0,174	0,170
c	-0,396	-0,210	-0,994	0,733	-0,650	-0,398	-1,964	-0,797
d	-0,1399	-0,1434	-0,1574	-0,1623	-0,1836	-0,1874	-0,2030	-0,2007
e	0,1166	0,1124	0,6537	-0,1068	0,2833	0,2828	1,3870	0,8646
f	0,4274	0,3838	0,2034	0,3302	0,5300	0,4672	0,2100	0,2932
g	0,0001	0,0001	0,0002	0,0003	0,0001	0,0001	0,0002	0,0002
h	-0,0427	-0,0467	-0,1259	-0,0223	-0,1011	-0,1107	-0,2980	-0,2291
i	0,0441	0,0490	0,0679	0,0432	0,0785	0,0872	0,1210	0,1130
j	0,1311	0,1318	0,1355	0,1357	0,1748	0,1758	0,1810	0,1773
	Hd = 250 m				Hd = 300 m			
a	0,096	-0,813	-1,203	-3,789	0.311	-0.655	-0.423	-3.399
b	-0,563	-0,421	0,132	0,106	-0.679	-0.519	0.1064	0.0543
c	-0,981	-0,698	-3,393	-1,158	-1.463	-1.139	-5.367	-2.754
d	-0,2274	-0,2314	-0,2478	-0,2451	-0.2711	-0.2754	-0.2930	-0.2898
e	0,5465	0,5717	2,5189	1,6199	0.9543	10.101	41.335	27.221
f	0,6116	0,5283	0,1847	0,2941	0.6736	0.5667	0.1287	0.2675
g	0,0001	0,0001	0,0002	0,0002	0.0001	0.0001	0.0002	0.0002
h	-0,1952	-0,2163	-0,5830	-0,4475	-0.3371	-0.3737	-10.076	-0.7732
i	0,1230	0,1364	0,1891	0,1768	0.1772	0.1966	0.2725	0.2546
j	0,2185	0,2198	0,2258	0,2217	0.2622	0.2638	0.2710	0.2660

IV. Discussion

According to expression 6, in order to determine the locations of oil leaks from subsea pipelines based on the values of Q1 and parameters as soon as the fact of leakage is confirmed, the coefficients included in that expression should be selected according to the known depth of the sea and the accepted leakage rate, and then appropriate calculations should be made. It should be noted that the proposed diagnostic method is not universal and should not be applied to all pipelines. Since the diameter of the pipeline and the physico-chemical properties of oil are assumed in the calculations, the development and application of the mentioned method for the purpose of detecting leaks in specific subsea oil pipelines operated in practice does not require additional costs, as it is based on a known software set and field data.

References

[1] Colombaroli, P.L. (2008) Acoustic Leakage Detection in Oil Pipelines. Federal University of Itajubá/MG. http://www.anp.gov.br/site/extras/prh/docs/ANP_10 anos/PRH_16.pdf

[2] Tavares, D.P.S.A. (2016) Fluid Dynamics of Oil Dispersion from Leakage in a Catenary Submarine Riser: Analysis of Multiphase Plumes. Doctoral Thesis Post Graduation in Chemical Engineering, Federal University of Campina Grande, Campina Grande.

[3] Zhu, H. and Lin, Q.A. (2014) A CFD (Computational Fluid Dynamic) Simulation for Oil Leakage from Damaged Submarine Pipeline. Energy, 64, 887-899. https://doi.org/10.1016/j.energy.2013.10.037

[4] Falcão, M.V.S. (2015) Analysis of Oil Leakage in Waters at Great Depths: A Study with Computational Fluid Dynamics. Course Conclusion Depart, Graduation in Chemical Engineering, Federal University

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NEW ENVIRONMENTALLY SAFE COMPOSIT

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Abstract

The aim of the work is to obtain composite materials on the basis of pine needles and investigation the properties of composite materials: water absorption, physical-mechanical investigations: (hardness, flexural and stretching and thermal properties, Vicat, FTIR, SEM, energy dispersive X-ray microanalysis and optical microscopic studies. Study of resistance of composites to microorganisms. The pine is one of the more extensively used types of wood used as lumber. The composites were prepared by hot pressing of highly dispersed (20-30 μm) dry pine needles sawdust with triethoxysilylated styrene (in the presence of 1% benzoyl peroxide).Fourier transform infrared spectroscopy (FTIR) confirmed the composition of composites. Optical microscopic examinations showed amorphous clusters on the micrographs, and concentration heterogeneity is also observed. Mostly obtained composites are anisotropic and are characterized by the fibrous structure of supramolecular structures.The surface morphology of the composites was studied by scanning electron microscopy (SEM).

Keywords: ecology, composite, filler, binder, property

I. Introduction

Agro-industrial waste removal is a serious issue of concerning in developing countries. Cellulose is a polysaccharide polymer. This present review [1] explores cellulose history, structure, worldwide production, and extraction of cellulose from agro-waste. A wide spectrum of researches in the arena of properties of cellulose, hemicellulose and lignin; their degradation; sources and composition of cellulosic and its derivatives from agro-industrial wastes; present status of converting them into value-added products of food and pharmaceutical applications. Cellulose is a tremendous product due to its abundance and characteristic structural properties. The major industrial source of cellulose is vascular plants. The lignocellulosic materials, especially agro-industrial residues, are important as reinforcement products for building construction material industry, in terms of environmental preferences of the modern society. Most paper products generate from wood pulp, while textile fibers are commonly not isolated from woody fibers. The materials based on cellulose and its derivatives have been used for a wide variety of applications, such as food additives, paper manufacturing, pharmaceuticals, or other chemical engineering uses, such as chromatography, paints, and explosives.

Waste is defined as any material, which has not yet been fully utilized, i.e., the leftovers from production and utilization. The waste contains three main constituents: Cellulose, hemicellulose, and lignin, and it can contain various compounds [2]. Cellulose and hemicellulose are carbohydrates that can be broken down by enzymes and acids and then fermented to produce ethanol renewable electricity, fuels, and biomass-based products [3, 4]. However, waste is an expensive and generally unavoidable result of human activity. It includes plant materials, agricultural, industrial and municipal wastes, and residues [5]. Food processing wastes food in spillage, spoilage, discarding substandard edible materials, or removing edible food parts in inefficient processing [6]. Waste significantly impacts environmental, economic, and community health [7]. Plants produce about 180 billion tons of cellulose manufacture annually, and it is the largest reservoir of organic carbon on the earth. Cellulose constitutes the most abundant, renewable polymer resource available today worldwide. It has been expected that by photosynthesis, 10^{12} tons are synthesized annually in a rather pure form, for example, in the seed hairs of the cotton plant but mostly are common with lignin and other polysaccharides in the cell wall of woody plants. Cellulose is the structural part of the primary cell wall of green plants, many forms of algae, and the oomycetes. Cellulose is the most common organic compound on the earth. About 33% of all plant material is cellulose (cotton is 90% and wood is 40–50%). For industrial use, cellulose is mainly obtained from wood pulp and cotton. It is mainly used to manufacture paperboard and paper [8] and it is transformed into a wide variety of derivative products such as cellophane and rayon. Converting cellulose from energy crops into biofuels such as cellulosic ethanol is under exploration as an alternative fuel source.

In recent years great interest in the development of new composites is derived from thermoplastic polymer matrices reinforced with wood filler, because of their environmental and economic benefits [1, 2]. Their renewability, biodegradability, low density, high stiffness and relatively low price are established [3]. Among of these various thermoplastic matrices mainly used in the manufacture of plastic / wood composites was polystyrene [4], which is very popular because of its inapparency, fluidity and good electrical insulating properties [5].

The use of lignocellulosic fibers has certain disadvantages such as degradation at low temperatures with poor compatibility between the polar lignocellulose filler and the non-polar polymer matrix [6]. Due to the strong intermolecular hydrogen bonding between the lignocellulose fibbers, which tend to agglomerate during mixing with the polymer matrix in the compounding process, resulting composites with low mechanical and thermal properties [7].

The improving of the interface compatibility between thermoplastic polymers and lignocellulosic filler has attracted much attention from researchers [8]. Several modifications of the fiber surface such as reaction with acid compounds [9, 10], alkali treatment [11, 12] and the incorporation of compatibilizer, such as malleated polymer [13, 14] or treatment with coupling agents [15, 16] are reported in the literature.

Among the different coupling agents, functional organosilanes [$RSi(OR')_3$)] are often used. These bifunctional molecules with their alkoxylsilane groups are used to modify the surfaces of natural fibers. After hydrolysis reactions of the fibers, surfaces rich in OH groups can be created. Chemical bonds on the surfaces of the fibers through a siloxane bridges, organofunctional groups bond to the polymer matrix. These groups improve the compatibilization between the fibers and the polymer matrix by formation of covalent bonds. The silane coupling agents provide bridges between the fibers and the matrix [17-19].

II. Experimental part

Processing. The composites were prepared by hot pressing of highly dispersed (50 μm) components under pressures up to 15 MPa and temperatures up to 100^0C in molds for 15 min. We have created two types of samples: cylindrical (for investigation of water absorption) and rectangular (for mechanical testing).

Fourier transform infrared spectra were determined with a Varian 660-IR FT-IR Spectrometer. The KBr pellets of samples were prepared by mixing (1.5–2.0) mg of samples, finely grounded, with 200 mg KBr (FTIR grade) in a vibratory ball mixer for 20 s.

Microstructure of the samples was studied by NMM-800RF/TRF type of optical microscope SEM and EDS observations were conducted. Measurements were performed under a microscope - Tescan Vega 3, LMU, LaB 6 cathode. Maximum accelerating voltage was 30 kV, resolution 2.0 nm. The microscope was also equipped with an energy dispersive spectrometer of X-ray-induced electron beam specimens (EDS, Oxford Systems). EDS was used to analyze the sample compositions.

Bending testing also known as flexural testing, was performed on parallelepipeds with the length of 10 cm and the vertical square cross-section of 1 cm^2. Each specimen was placed on two prisms, with the distance of 8.0 cm between the prisms. The indenter was a metal cylinder with the diameter of 10 mm applied from above to the midpoint of the specimen. Bending strength (or flexural strength) is defined as the stress needed to create a breaking point (a crack) in the outer surface of the test specimen .

Impact viscosity determination, also called *shock viscosity* determination, is a technique applied to soft solids and is essentially a drop impact test. The drop height h is the vertical distance between the upper surface of the tested material (h_1) and the bottom surface of the drop hammer at the end of the impact event (h_2). With the sample mass m and the acceleration g, the work performed by the falling hammer is mg ($h_1 – h_2$), anormalized with respect to the horizontal cross-section of the specimen.

Vicat softening depth consists in the determination of the depth of the indentation with respect to the top surface caused by a flat ended indenter with the cross-section of 1 mm^2. The load applied is 10 or 50 N and the cross-section of the indenter end is circular. The term *Vicat hardness* is also in use – really confusing since larger values correspond to lower hardness.

Water absorption is determined simply as the percentage weight change of the sample after submersion in water. We have performed such measurements after 3 hours and 24 hours exposition to water.

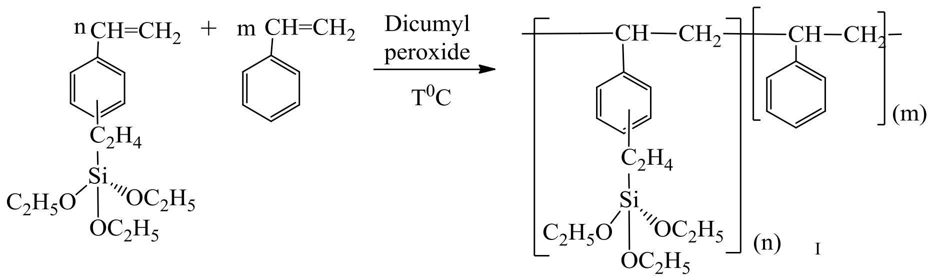
III. Results and discussions

Wood has been an essential material for human survival since the primitive state, for its wide abundance, renewable and environmentally benign nature, relative ease of working it, and outstanding mechanical properties. With the development of technology, wood came to be used for shelter, fuel, tools, boats, vehicles, bridges, furniture, engineering materials, weapons, and even raw materials for energy. Now, wood is widely used in various corners of human life. The wood-polymer composites (WPC) are materials of relatively new generation, in which the role of the binder performs such thermo-plastics polymers as polyethylene, polypropylene, polyvinyl chloride, polystyrene and others. These materials sometimes are called as liquid wood. There are known rather wide assortment of the products made from WPC. Using such methods as extrusion, hot pressing, rotation formatting one obtained such goods as terraces, floor desks, wall panels, roofs coatings, pipes and so on. WPC are distinguished from analogs by high stability to atmospheric influences, mechanical and chemical sustainability, water proofing, which allows to use these materials as coatings of washing rooms, sauna, terraces, and docks and so on. Wood-polymer composites (WPC) are substances or items made up of one or more natural materials or flours but one or a mixture of polymers, such as polyamide, rayon, or latex. Their cheap and superior efficiency, as well as their elevated sustainable development, low moisture absorption, sturdiness against ecological impact such as insects and fungi when compared to timber, high-dimensional data stability over their entire life, and high relative stiffness, have attracted the attention of manufacturers and researchers in recent decades [5].Introduction inorganic nanoparticles have found numerous applications in fields such as medicine, design of electronic devices, catalysis, and polymers reinforcement. Grafting polymer chains endow them with unique functional properties and allow tailoring of their surface characteristics to obtain materials with novel properties and applications. The wood polymer composite on the basis of triethoxy (vinylphenethyl) silane and sawdust via in-situ polymerization has been obtained earlier. The aim of the work was to obtain and research new environmentally safe wood polymer composites (WPC) - based on a new environmentally safe binder and reinforcing agent triethoxy- (vinylphenethyl) silane and styrene and in the presence of antioxidant aluminum hydroxide, study physical-mechanical, thermal properties, and water absorption.

Composites based on dry sawdust on the basis of pine with triethoxy (vinylphenethyl) silane and styrene as a binder and reinforcement agent which was obtained via hydrosilylation reaction of divinylbenzene with triethoxyvinylsilane according to the have been created.The pine is one of the more extensively used types of wood used as lumber**.** The composites were prepared by hot pressing of highly dispersed (20-30 μm) dry sawdust on the basis of pine with agent. The composites have been created under pressures up to 15 MPa and in the temperature range 140-220^{0}C in samples for 5 min. Two types of samples have been created: cylindrical (for investigation of water absorption) and rectangular (for mechanical testing).

It is known that the wood sawdust contains cellulose, hemicellulose derivatives, and lignin structural rings with hydroxyl groups. In our binder triethoxy(vinylphenylethyl) silane we also have ethoxyl groups as well as a vinyl group. Those groups were expected to participate in the etherification reaction with a binder through inter-molecular and intra-molecular reactions and the vinyl group may polymerize. So, used a coupling agent.

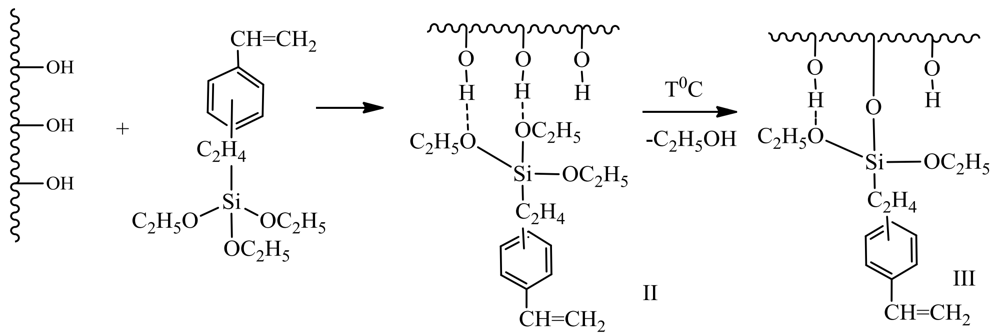
Composites were prepared in the following ratio: 3% triethoxy(vinylphenylthyl)silane, 27% styrene, and dicumyl peroxide, 60% pine sawdust. As filler two types of wood sawdust have been obtained sifted sawdust medium size particle 0.614 mm and unsifted sawdust particle size 1.615 mm The triethoxy(vinylphenethyl)silane (TEVPES) and styrene were stirred with dicumyl peroxide (DP) (1% by weight) and this homogeneous mixture (3-5% (TEVPES) - 27-25 %) was added to a predefined weight ratio of pine sawdust. Then the mixture was stirred for 5 minutes until it became homogeneous, placed in a press form, and pressed at several temperatures. During hot-pressing, the initiator existing in the mixture may initiate the polymerization reaction of vinyl groups of TEVPES and styrene. Wood sawdust impregnated with TEVPES and styrene, at the moment of hot pressing, forms chemical bonds with the hydroxyl groups of a wood surface. Active filler is likely formed, then etherification and in-situ polymerization reactions take place. In the case of dicumyl peroxide during hot pressing, in situ polymerization and copolymerization by the formation of different ring polymers (Structure I) is possible according to the following Scheme 1:



Scheme 1: *Co-polymerization of triethoxy(vinylphenethyl)silane and styrene*

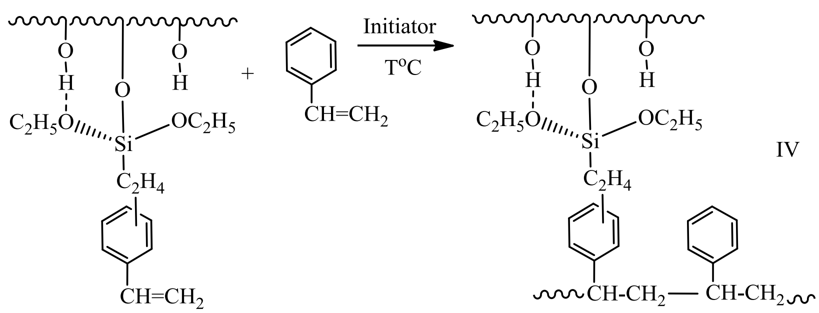
It is not excluded that triethoxy(vinylphenethyl)silane can form hydrogen bonds with or after the polymerization reaction with silane sawdust (Structure II) by etherification at high temperatures to form a chemical bond (Structure III) according to Scheme 2:

In particular, one expects the formation of hydrogen bonds before the onset of the etherification reaction with triethoxysilylated styrene and also the formation of ethyl alcohol.



Scheme 2: *Formation hydrogen bonds and etherification reactions of triethoxy(vinylphenethyl)silane with sawdust surface.*

It is possible that the product of the interaction of triethoxy(vinylphenethyl)silane with cellulose will undergo a polymerization reaction with styrene (Structure IV) according to Scheme 3:



Scheme 3: *Co-polymerization reaction of TEVPES and cellulose interaction product II with* styrene

For obtaining composite materials were performed Fourier transform infrared spectra investigation, likewise, optical microscopic examinations, scanning electron microscopy and energy dispersive X-ray spectral analysis.

In the FTIR spectra of composite materials, one can see the adsorption bands for the asymmetric valence oscillations characteristic of the ≡Si-O-Si≡ bond, up to a maximum of 1026 cm^{-1}, corresponding to siloxane bonds. The absorption band at 1150 cm^{-1} area corresponds to the asymmetric absorption bands characteristic of the Si-O-C and C-O-C bonds, where the absorption bands overlap. Absorption bands at 1262, 1370, 1419, 1507, 1600-1650, 1720, 2800-2950, and 3346 cm^{-1} correspond to the methyl groups, CH bond absorption in (-C / C- /CH_3), CH_2 cellulose - lignin, C=C aromatic, C=C alkene, (C=O ester bonds), phenyl groups and -OH groups.

Mostly obtained composites are anisotropic with different sizes of particles. Cracks and dividing lines are also observed. Whose dimensions can be easily determined using the scale bar.

The surface morphology of the composites was studied by scanning electron microscopy (SEM). In Fig. 1 one can observe indicate pores, indentations, and inserts with the sizes in the range of 0.01-0.5 mm.

For composites, physical-mechanical investigations have been performed. In particular, the determination of the bending strength and impact viscosity with respect to temperature and triethoxy(vinylphenethyl)slane and styrene concentrations has been studied.

As have shown investigation results, with increasing temperature from 140 to 220^{o} C, at 20-degree intervals, the values of bending strength decrease from 10.6 up to 20.9 MPa. With an increase in the TEVPES concentration the values of bending strength increase from 23.6 up to 29.6 MPa. With an increase in temperature, the impact viscosity slightly increases.

The thermal properties of composites have been studied via the Vicat method. The Vicat softening temperature is the temperature at which a flat-ended needle penetrates the specimen to the depth of 1 mm under a specific load. The temperature reflects the point of softening to be expected when a material is used in an elevated temperature application.

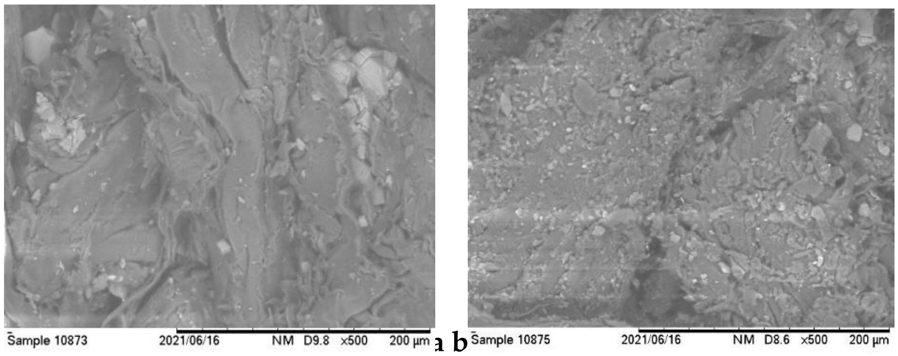


Figure 1: *Scanning electron microscope micrograph of a composites: Sawdust (sifted)-60%+TEVPES -5%+ St -25% +Al(OH)₃ -10%, 160 ⁰C (a), Sawdust (sifted) 60%+TEVPES-5%+ St -25% +Al(OH)₃ -10% (220⁰C) (b).*

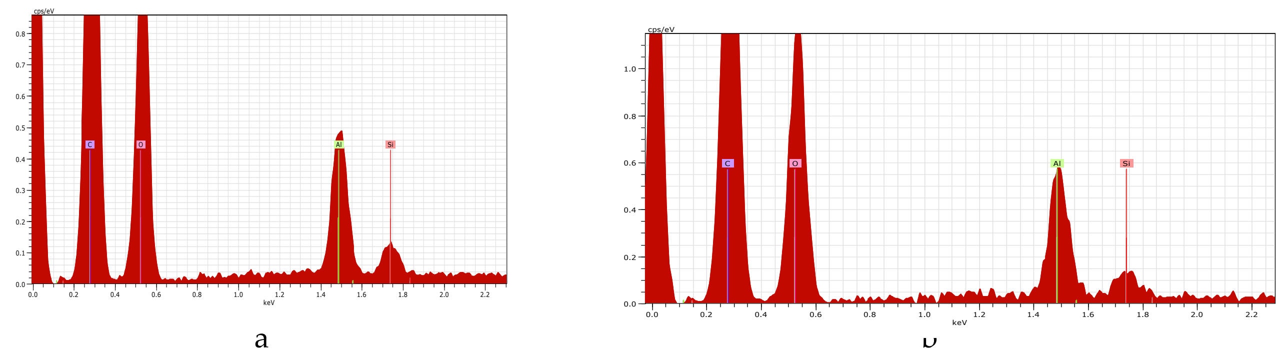


Figure 2: *Energy dispersive X-ray microanalysis of composites: Sawdust (sifted)-60%+TEVPES -5%+ St -25% +Al(OH)₃ -10%, 160 ⁰C (a), Sawdust (sifted) 60%+TEVPES-5%+ St -25% +Al(OH)₃ -10% (220⁰C) (b).*

The composites based on TEVPES, styrene, and Al $(OH)_3$ with sawdust are characterized by improved thermal stability with increasing temperature. This result is expected for two reasons. The total volume of connected empty micro spaces distributed randomly in the composite has been reduced by the pressure application. Consequently, the rigidity and thermal stability of the WPC material increase, and the density of micro-structure increases again TEVPES creates new heterogeneous chemical bonds in the composites via etherification reaction at high temperatures not only with sawdust surface but with used antioxidant Al $(OH)_3$. In parallel, TEVPES reinforce composite materials, by in–situ copolymerization reactions with styrene. The higher this pressure, the higher is thermal stability compositions.

Water-absorption test is a test to determine the moisture content of the soil as a percentage of its dry weight Water absorption is one of the significant magnitudes used to determine the amount of water absorbed under specified conditions.

The results of investigations were shown, that with an increase in pressing temperature from 140^o up to 220^{o}C the water absorption decreases from 54-60% up to 0.95-1.07 %. It must be noted that the WPC obtained from sifted sawdust is characterized by less water absorption. WPC prepared from unsifted sawdust is characterized by increased density compared with sifted sawdust. Both phenomena may be explained with relatively low values in the last column show low volumes of the empty intermolecular spaces.

During the current study composition of composite materials, as well of composition plant materials, used for the preparation of these materials were determined. Specifically, content of Calcium, Magnesium, Sulfur and Silicon were determined. Quantitative analysis were performed using ISO methods. Experimental results comply with theoretically expected results.

References

[1] Sundarraj A.A., Ranganathan Th.V. A review on cellulose and its utilization from agro-industrial waste. // Drug Invention Today, 2018: 10 (1), 89-94,

[2] Puri VP. Effect of crystallinity and degree of polymerization of cellulose on enzymatic saccharification. // Biotechnol Bioeng 1984; 26: 1219-22.

[3] Wyman CE, Goodman BJ. Biotechnology for production of fuels, chemicals and materials from biomass. // J Appl Biochem Biotechnol 1993; 39:39-59.

[5] van Wyk JP. Biotechnology and the utilization of biowaste as a resource for bioproduct development. // Trends Biotechnol 2001; 19:172-7.

[6] Okonko IO, Adeola OT, Aloysius FE, Damilola AO, Adewale OA. Utilization of food wastes for sustainable development, electronic. J Environ Agric Food Chem 2007; 8:263-86.

[7] Kosseva MR. Chapter 3 processing of food wastes. // Adv Food Nutr Res 2009; 58:57-136.

[8] Kumar S. Conversion of Food Waste to useful Chemicals/Products Bachelor of Technology (Chemical Engineering) Thesis, National Institute of Technology, Rourkela, India; 2010.

[9] David GB, Ray LW. Cellulose. In: Access Science. Cellulose: McGraw-Hill; 2008. p. 419.

[10] Ichazo M.N., Albano C., Gonzalez J., Perera R., Candal M.V. Polypropylene/wood flour composites: Treatments and properties, // Composite Structures, 54 (2001), (2-3): 207-214.
https://doi.org/10.1016/S0263-8223(01)00089-7

[11] I. Seung-Hwan, O. Tsutomu, Mechanical and thermal flow properties of wood flour –biodegradable polymer composites, // Journal of Applied Polymer Science, 90, **(2003),** 1900-1905.
https://doi.org/10.1002/app.12864

[12] Torres F.G., Cubillas M.I., Study of the interfacial properties of natural fibre reinforced polyethylene, // Polymer Testing, 24, (2005), (6), 694-698.
http://dx.doi.org/10.1016/j.polymertesting.2005.05.004

[13] Arrakhiz F.Z., Elachaby M., Bouhfid R., Vaudreuil S., M. Essassi, A. Qaiss, Mechanical and thermal properties of polypropylene reinforced with Alfa fiber under different chemical treatment. // Materials and Design, 35, (2012), 318-322. http://dx.doi.org/10.1016/j.matdes.2011.09.023

[14] Rosa S.M.L.R., Santos E.F., Ferreira C.A., Nachtigall S.M.B., Studies on the properties of rice-husk filled PP composites: Effect of maleated PP. // Materials Research, 12, (2009), 333-338. http://dx.doi.org/10.1590/S1516-14392009000300014

[15] Poletto M., Dettenborn J., Pistor V., Zeni M., Zattera A.J. Materials produced from plant biomass. Part I: Evaluation of thermal stability and pyrolysis of wood. // Materials Research, 13, (2010), 375-379. http://dx.doi.org/10.1590/S1516-14392010000300016

[16] H.S. Kim, B.H. Lee, S.W. Choi, S. Kim, H.J. Kim, The effect of types of maleic anhydride grafted polypropylene (MAPP) on the interfacial adhesion properties of bio-flour filled polypropylene composites. // Composites Part A: Applied Science and Manufacturing, 38, **(2007)** 6: 1473-1482. https://doi.org/10.1016/j.compositesa.2007.01.004

[17] M. Sain, P. Suhara, S. Law, A. Bouilloux, Interface modification and mechanical properties of natural fiber polyolef in composite products, // Journal of Reinforced Plastics and Composites, 24, (2005), 121-130. https://doi.org/10.1177/0731684405041717

[18] Özmen N.,, A study of the effect of acetylation on hemp fibres with vinyl acetate. // BioResources, 7, (2012) 3, 3800-3809.

[19] Manikandan N.K.C., Sabu T., G. Groeninckx, Thermal and dynamic mechanical analysis of Polystyrene composites reinforced with short sisal fibres. // Composites Science and Technology, 61, (2001), 2519-2529. https://doi.org/10.1016/S0266-3538(01)00170-1

SUSTAINABLE DEVELOPMENT OF RURAL AREAS IN SIBERIA IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

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Abstract

The article is devoted to determining the prospects for long-term development of rural areas of the Siberian Federal District in the context of global climate change. The study is based on the predicted calculation of changes in hydrothermal conditions within the boundaries of natural and climatic zones of Siberia. It was revealed that by 2050 the predicted shift of natural and climatic zones will be on average 50-100 km depending on the region in the direction from south to north. In some regions (Krasnoyarsk Krai, Novosibirsk, Tomsk and Kemerovo Oblasts) by 2050 there will be a significant improvement in natural and climatic conditions that have a favorable effect on agriculture. Scenarios for the long-term development of rural areas of the Siberian Federal District in the context of global climate change have been developed: "Climate Adaptation", "Climate Mitigation" and "Climate Crisis". Sustainable development of rural areas in Siberia is possible within the framework of the "Climate Mitigation" scenario, which implies mitigating the risks of global climate change through the development of fallow lands, agroforestry, crop rotation, organic farming, etc.

Keywords: rural areas, global climate change, scenarios, climate adaptation, climate mitigation, climate crisis

I. Introduction

Modern challenges affecting the issues of global climate change and its predicted impact both on the agro-industrial complex (hereinafter referred to as the AIC) and on the rural areas that provide it, require the formation of an adequate technological, social and economic response now. That is, this problem can be considered exclusively in the context of the paradigm of sustainable development, which combines these three areas. It is a comprehensive response, implying the development and implementation of innovative AIC technologies adapted to climate change, the creation of new types of organizational forms of rural settlements, the emergence of new types of rural employment, and ultimately the likely expansion of the geography of settlement of the rural population to the north of Russia, that will reduce the risks of global climate change for the AIC and rural areas. This issue is especially relevant for the rural areas of the Siberian Federal District, which are located above the 55th parallel, where, according to climatologists, the greatest consequences of climate change will be observed.

The purpose of this study is to identify promising areas for the sustainable development of rural areas of the Siberian Federal District in the context of global climate change.

II. Methods

The following methods were used as the methodological basis for the study: methods of analysis and synthesis, scenario forecasting, calculation and design and cartographic methods.

The territory of the study is the Siberian Federal District (SFD), which includes 10 subjects (the Altai Republic, the Republic of Tyva, the Republic of Khakassia, Altai Krai, Krasnoyarsk Krai, Irkutsk, Kemerovo, Novosibirsk, Omsk and Tomsk regions). As part of the study, a predicted change in the boundaries of natural and climatic zones in the SFD by 2050 was constructed based on the calculation of hydrothermal conditions. To assess the change in hydrothermal conditions in the SFD, the Selyaninov hydrothermal coefficient, HTC [1], was used, which is currently widely used in the practice of Roshydromet as the main quantitative indicator of the ratio of heat and moisture. The distribution of HTC is in good agreement with geobotanical zones and, in fact, reflects the differentiation of landscapes. To construct the climate projections of the Selyaninov GTC up to 2050, climate projections of air temperature and precipitation amounts obtained from CMIP6 data (scenarios SSP1-2.6 and SSP5-8.5) and adjusted similarly to [2] were used. Previously developed software modules [3] were used to calculate values for individual years and average long-term values in the reanalysis grid nodes and CMIP6. The result of the modules' work is files in the netCDF format.

III. Results

Previous studies [2,4,5] have shown that there is already a shift in the boundaries of natural and climatic zones in the Siberian Federal District, mainly from south to north. It is less noticeable in the steppe zone of the district and quite obvious in other natural and climatic zones. Depending on the generally accepted socio-economic scenarios of the Intergovernmental Panel on Climate Change (IPCC) - SSP1-2.6 and SSP5-8.5, the shift in boundaries can be from 50 to 150 km by 2050 [6]. It should be taken into account that in this study, the shift in zones is understood as a change in the boundaries of zones with a certain heat and moisture supply (certain values of the HTC). That is, in the next 30 years, favorable climatic conditions will be created for changing the areas of vegetation corresponding to certain natural zones. It is also worth noting that the SSP1-2.6 scenario is a sustainable development scenario, i.e. the most optimistic option (shift by 50-70 km), and the SSP5-8.5 scenario is an unfavorable option, assuming further development of the country's economy on fossil fuels (shift by 100-150 km). Within the framework of the second scenario, according to the Sixth Assessment Report, very high greenhouse gas emissions are predicted: by 2075, CO_2 emissions will triple threefold. Each of the listed SSPs provides a future forecast of greenhouse gas emissions and land use changes in accordance with its baseline. In most cases, development according to the SSP5-8.5 scenario will lead to more rapid changes and the advancement of zone boundaries will occur at a distance twice as large as in the SSP1-2.6 scenario [7, 8].

Figure 1 shows a cartographic representation of the predicted change in the boundaries of natural and climatic zones in the territory of the Siberian Federal District subjects. By 2050, the predicted shift of natural and climatic zones will average 50-100 km, depending on the region. During this period, a statistically significant increase in the duration of periods with average air temperatures above 0, +5, +10 °C is predicted, which will have a positive effect on extending the growing season in most of the district.

In addition, there will be an increase in areas with hydrothermal conditions that characterize steppe and forest-steppe landscapes suitable for agricultural production.

Thus, the shift in natural and climatic zones in the Siberian Federal District will become a key factor in the possible change in the structure and directions of economic activity in rural areas. In some regions (Krasnoyarsk Region, Novosibirsk, Tomsk and Kemerovo Region), by 2050 there will be a significant improvement in natural and climatic conditions that have a favorable effect on agriculture. Here it will be possible to expand the area of crops, including by introducing fallow lands into agricultural circulation and growing new types of crops. At the same time, in the republics of Altai, Khakassia and Tyva, in the Irkutsk Region, an increase in aridity of the territory is predicted, which will lead to a decrease in the share of agriculture in the gross municipal product.

Novosibirsk Region (expansion of the northern boundaries of the zones of provided and excessive moisture up to 100 km, the arid zone in the south of the region - up to 75 km) - expansion of the area under grain and leguminous crops, oilseeds by reducing the area of swamps. Involvement of fallow lands in agricultural circulation, development of organic agriculture. Creation of new eco-settlements.

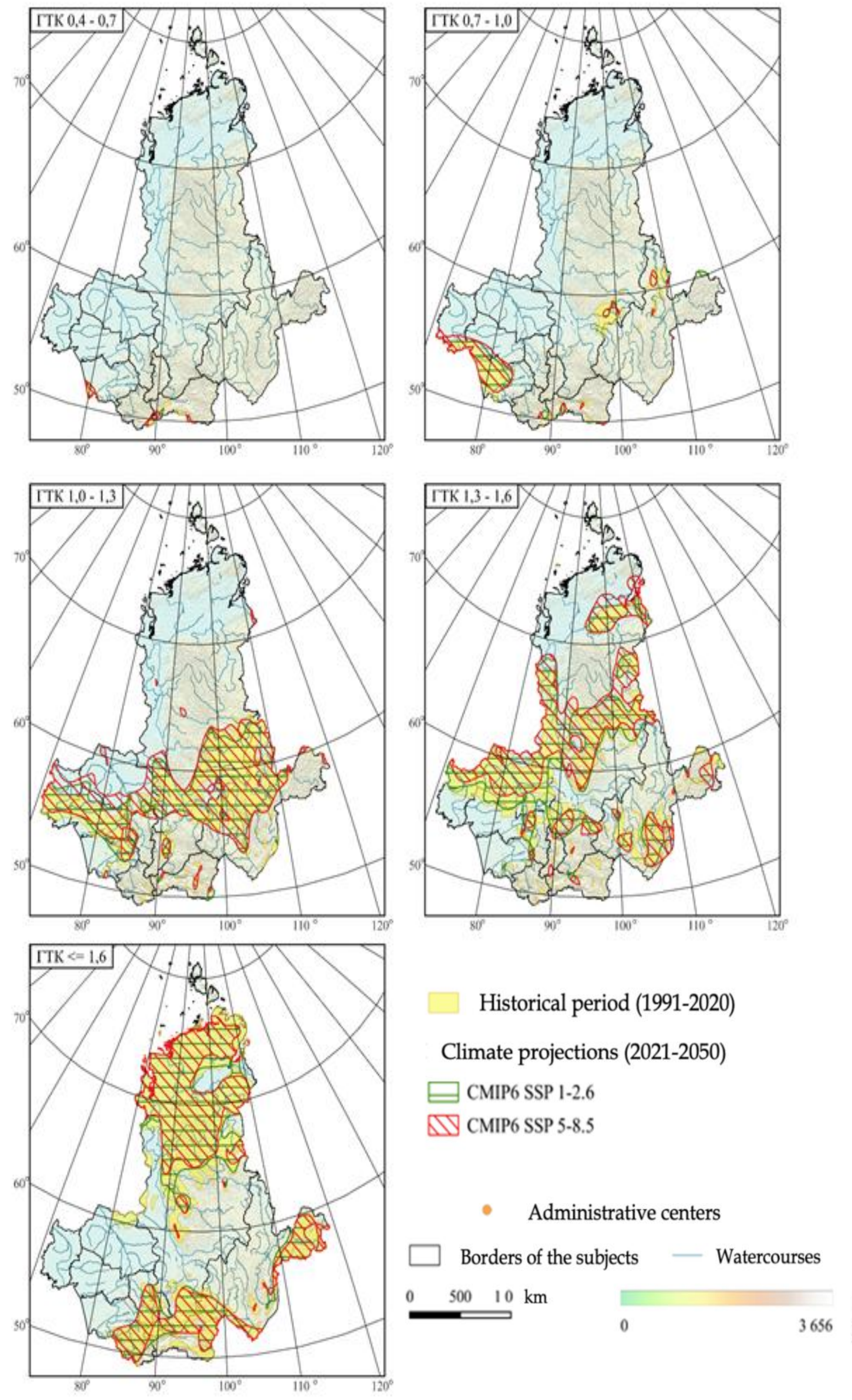

Figure 1: *Forecast zones of humidification by the values of hydrothermal coefficient. Siberian Federal District*

Altai Republic (southeast - semi-desert, shift of the moisture zone to the north) - reduction of sown areas and pastures. Diversification of the rural economy, moving away from agriculture. Development of rural tourism, cultivation of medicinal plants. Development of organic livestock farming. Creation of new eco-settlements.

Krasnoyarsk Region (reduction of the area of excess moisture zones, expansion of the zone of provided moisture. In the east - the appearance of forest-steppe landscapes) - expansion of spring wheat, oilseeds and legumes. Growing winter crops. Possibility of using late-ripening varieties in the south of the region. Creation of new rural settlements and shift camps to provide food for oil production facilities.

Republic of Tyva (predominant zone of excessive waterlogging. Southwest – semi-desert. In the central regions, the zones shift up to 200 km) – strong negative impact of climate change on the rural economy will lead to a reduction in agricultural production.

Republic of Khakassia (no significant natural and climatic changes are observed) – introduction of new areas into agricultural circulation, including fallow lands for organic farming. However, the use of drought-resistant varieties is required due to the increasing aridity of the climate.

Altai Region (expansion of the steppe zone, reduction of the forest-steppe. Shift of zones up to 150 km to the northeast) – cultivation of drought-resistant crops, reduction in grain production. Development of rural tourism.

Omsk Region (decrease in humidity of the territory, with the advancement of zone boundaries to the north) – adverse impact of global warming on the rural economy, reduction in agricultural production. Tomsk Region (shift of excess moisture zone to the north – up to 150 km. The entire territory of the region is an excess moisture zone) – possible increase in crop production due to reduction of swamp areas. Creation of shift camps to provide food for oil production facilities.

Irkutsk Region (increase in the area of arid zones by 40-60 km to the south. In the central regions – over-moistening) – adverse impact of global climate change on crop production. Development of rural tourism.

Kemerovo Region (predominant zones of provided and excess moisture) – diversification of crop production, cultivation of oil crops, development of organic agriculture.

It has been revealed that the natural and climatic zones of Eastern Siberia are "moving north" faster than those of Western Siberia. This is especially true for Krasnoyarsk Region, where as a result of such changes, more and more zones are emerging that are favorable for agricultural production. In this region, the zone of provided moisture is expanding, and new forest-steppe landscapes are appearing. In the Irkutsk Region, opposite trends will be observed: an increase in the area of arid zones in the south and over-moistening in the central part of the region.

IV. Discussion

The study revealed that in the southern regions of the Siberian Federal District (the Republics of Tyva, Khakassia and Altai, Altai Krai), an increase in the average annual temperature leads to a decrease in the yield of grain and leguminous crops, while in more northern regions (Krasnoyarsk Krai, Tomsk and Novosibirsk Oblasts) - on the contrary, to an increase, which is confirmed by the correlation coefficients. The contribution of temperature growth to the change in yield is on average 10-20% [2]. That is, it can be concluded that global warming will have the most favorable effect on the subjects of the Siberian Federal District located in the north of the macroregion. Global warming here will be accompanied by an increase in the growing season, a longer frost-free period, etc. It will be possible to grow new varieties of crops, including late-ripening ones. Improved natural and climatic conditions will allow the introduction of fallow lands into agricultural circulation, which can be used, among other things, for growing organic agricultural products. In the southern regions, the increase in climate aridity will lead to an increase in the number of droughts and, accordingly, a reduction in crop yields. In these regions, it is necessary to use drought-resistant varieties of agricultural crops, introduce pre-sowing seed treatment technologies and apply mineral fertilizers.

The author proposes three scenarios for the long-term development of rural areas in the Siberian Federal District in the context of global climate change: "Climate Adaptation", "Climate Mitigation" and "Climate Crisis". The basic scenario condition for all three scenarios is the shift of natural and climatic zones from the south to the north of the macroregion.

Within the framework of the "Climate Adaptation" scenario, the rural economy will adapt to the predicted natural and climatic changes. It is necessary to use drought-resistant plant varieties, change the timing of agro-technological work, increase the use of mineral fertilizers and chemical plant protection products, and irrigation systems to preserve crops. The main measures to adapt to climate change will be the implementation of hydromelioration and other reclamation measures, coastal protection and clearing of river beds, and the restoration of degraded lands [9].

As a result of the implementation of these measures, the impact of climate change on agricultural production will be minimized (reduction of losses from natural disasters - droughts and floods) [10]. An example of adaptation measures in Russia is the restoration of 7 km of the historical Ural River bed in the Orenburg Region as part of the national project "Ecology".

In regions where the efficiency of agricultural production continues to decline, the rural economy will be reoriented to new sources of growth, as mentioned above. "Climate adaptation" is a basic scenario for the long-term development of rural areas in Siberia, which assumes the extrapolation of existing trends.

The "Climate mitigation" scenario involves the development of measures aimed at eliminating or reducing the long-term risks of climate change. This scenario should be based on sustainable development of agriculture and rural areas, integrating economic growth, social well-being and ecological balance. This is an optimistic option for long-term rural development, implying a reduction in greenhouse gas emissions from agricultural production.

The following natural climate solutions should be implemented within the framework of the "Climate Mitigation" scenario:

1) agroforestry, sanitary felling, optimization of logging operations;

2) accumulation of organic matter in the soil and reduction of soil carbon losses in arable land and meadows;

3) crop rotations;

4) reclamation of degraded lands and reduction of nitrogen losses when applying mineral and organic fertilizers;

5) agrotechnical measures to prevent salinization and soil degradation;

6) cultivation of perennial plants;

7) pasture management.

In addition, "Climate Mitigation" requires the development of measures to significantly reduce forest fires, which is extremely important for the territory of Siberia.

Thus, the condition of this scenario should be the introduction of resource-saving technologies both in agriculture and in land use.

The result of this scenario will be the introduction of new areas of agricultural land into circulation, diversification of agricultural crops, growth in crop yields and animal productivity, and the creation of new rural settlements. For example, in the Altai Territory, the ANO "Center for Environmental Innovations" leased agricultural land in the Zalesovsky District with an area of 10 thousand hectares for 49 years. Where forests were planted to absorb greenhouse gases.

The "Climate Crisis" scenario assumes the absence of any measures on the part of local, regional and federal authorities and the population to adapt and/or mitigate economic activity to natural and climatic changes. This will lead to the extinction of villages and an increased outflow of the rural population to the city. Agriculture, as one of the main sources of income for the rural population, will be exposed to increasingly frequent extreme natural and climatic conditions, which will lead to the loss of sustainability of rural households. The absence of measures to prevent the consequences of global climate change will further accelerate the warming process due to increasing greenhouse gas emissions. "Climate Crisis" is a negative scenario for the long-term future of rural areas of Siberia, threatening Russia's food security. According to the authors, the most optimal direction for long-term development of rural areas of the Siberian Federal District in the context of climate change will be the integration of two scenarios: "Climate Adaptation" and "Climate Mitigation", within the framework of which adaptation measures will be jointly implemented, as well as the prevention and mitigation of the risks of global climate change.

The authors identified the following as key technologies for mitigating rural development to climate change:

1. Agricultural land management, which consists of improving agricultural technologies in terms of increasing crop resistance to unfavorable natural and climatic conditions and pests (biotechnology), precise application of fertilizers and plant protection products, organizing optimal crop rotations, agro-improvement, and introducing methods of minimum crop cultivation (No-Till, Mini-Till).

2. Livestock management as one of the main sources of methane emissions - improving the feed base for farm animals and improving their well-being (keeping conditions and selection). Here, it is necessary to find a balance between reducing the number of animals and increasing their productivity.

3. Management of organic fertilizers/solid biological waste, which is the basis of closed-loop agricultural production, when livestock waste is used as organic fertilizer in crop production.

4. Bioenergy – production of solid, liquid and gaseous fuels for energy supply of agricultural production from grown biomass. Corn, soybeans, sorghum, crop residues, millet, etc. can be used as raw materials for processing.

5. Organic agriculture is a concept that can make the industry carbon neutral. According to estimates, greenhouse gas emissions from the use of mineral fertilizers annually worldwide amount to about 1000 million tons. With organic farming, their use is completely excluded.

The following can be attributed to the technological areas of adaptation of the rural economy to climate change:

1. Development of new technologies and plant varieties resistant to climate change, adapted to the conditions of areas with a difficult climatic situation.

2. Increasing the efficiency of the irrigation and moistening system of crops, including through the rational use of alternative water sources.

3. Intensification of the use of organic methods of raising livestock and poultry, increasing the importance of practices to ensure the welfare of farm animals (better feeding and housing conditions).

4. Expanding and improving measures for the prudent use of natural resources, including measures to preserve highly fertile soils, reduce the amount of degrading land, and eliminate ineffective forest management practices.

5. Training and supporting the rural population in the field of sustainable agriculture and environmental practices, including consultations, trainings, and public educational events.

At the same time, a mandatory condition for the introduction of adaptation technologies should be taking into account the risks to the country's food security; a balance is needed between economic efficiency and the impact on surrounding ecosystems.

Sustainable development of rural areas in Siberia is possible within the framework of the "Climate Mitigation" scenario, which implies mitigating the risks of global climate change through the development of fallow lands, agroforestry, crop rotation, organic agriculture, etc. [11] The implementation of this scenario will create the preconditions for the emergence of new organizational forms of rural settlements in Siberia:

1) eco-settlements - rural settlements whose main activity is organic production of agricultural products;

2) tourist settlements - concentration of various types of rural tourism within one rural settlement;

3) rotational settlements, the purpose of which is to manage remote robotic agricultural production in new territories;

4) water and forest protection settlements - specialized rural settlements implementing mitigation measures for agroforestry and hydromelioration;

5) agrotowns - low-rise settlements of landscape-estate type in places of concentration of agricultural production;

6) smart villages - comfortable settlements with highly developed digital infrastructure.

As the conducted studies have shown, the most favorable region for the creation of new rural settlements may be Krasnoyarsk Krai, where the most rapid change in natural zones is predicted towards an increase in the area of more favorable conditions for agriculture and rural population (steppe and forest-steppe landscapes). In addition, increasing the duration of periods with average air temperatures above 0, +5, +10 °C will create comfortable conditions for the development of various types of tourism in the region.

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References

[1] Selyaninov G.T. On agricultural climate assessment. *Proceedings on agricultural Meteorology*, issue 20. L.: Hydrometeoizdat, 1928. pp. 165-177.

[2] Petukhova M.S., Voropai N.N. (2024). On the issue of the influence of natural and climatic factors on agriculture in the Siberian Federal District. *Economics of Agriculture of Russia*, No. 1, pp. 10-15.

[3] Voropai N.N., Ryazanova A.A. (2020). Droughts in the Tomsk region. *Meteorology and Hydrology*, No. 12, pp. 39-51.

[4] Petukhova M. and Kondratyev M. (2024). Technological steps towards adaptation and mitigation of the rural economy of Siberia to climate change. *BIO WEB OF CONFERENCES. XVII International Scientific and Practical Conference "State and Development Prospects of Agribusiness" (INTERAGROMASH 2024).* EDP Sciences, 05026.

[5] Petukhova M.S., Kondratiev M.V. (2023). Climate change, rural areas and agriculture in Siberia: foresight forecast. *ECO*, No. 8 (590), pp. 155-171.

[6] The third assessment report on climate change and its consequences on the territory of the Russian Federation (2022). *Roshydromet – St. Petersburg: High-tech technologies*, 676 p.

[7] IPCC, 2013.Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental. Panel on Climate Change. Stocker, T. F., D. Qin, G.-K.Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 1535 pp.

[8] Vicente-Serrano S.M., Beguería S., López-Moreno J.I. et al. (2012) Performance of drought indices for ecological, agricultural, and hydrological applications. *Earth Interactions*, Vol. 16. № 10. P. 1-27. DOI: https://doi.org/10.1175/2012EI000434.1

[9] World Meteorological Organization (WMO) and Global Water Partnership (GWP), 2016: Handbook of Drought Indicators and Indices (M. Svoboda and B.A. Fuchs). *Integrated Drought Management Programme (IDMP), Integrated Drought Management Tools and Guidelines*, Series 2.

Geneva.

[10] Utkuzova D.N., Vilfand R.M., Khan V.M., Ganieva E.S. (2015). Synoptic analysis of extreme aridity and moisture content in the territory of the Russian Federation. *Interdisciplinary Scientific and Applied Journal "Biosphere*, vol. 7, No. 1. pp.50-60.

[11] Petukhova M.S., Orlova N.V. (2024). Assessment of the potential for sustainable development of rural areas in Siberia. *Innovation and Food Security*, No. 2 (44), pp. 102-112.

PROTECTION OF WATER RESOURCES BY USING ENVIRONMENTALLY-FRIENDLY BIOADSORBENTS

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Abstract

The current study built and characterized modified sorbents and then tested their ability to absorb the waste products in a lab setting. This work investigated the physicochemical properties and structure of enhanced environmentally friendly sorbents based on alginates, bentonite, and nanoparticles using spectroscopic techniques (SEM, FTIR, X-ray diffraction, and XRD analytical methods). Because the alginate core contains active COOH and OH groups, it may be chemically and physically changed and used in a range of phosphate anion adsorption techniques. We determined the sorption efficiency of a modified Fe3O4NPs@AlgBT. Using biofilters to lessen nutrient loading is an easy substitute for this. Thus, in a lab setting, the capacity of the Fe3O4NPs@AlgBT (biosorbent) to absorb nutrients and heavy metals at various starting concentrations and contact times was examined. It has also undergone testing for uses of nutrients other than growth in wastewater. Fe3O4NPs@AlgBT conducted a nutrient uptake experiment that revealed substantial nutrient uptake in all time intervals (7, 13, 19, and 25 hours) sustained at various pH levels (3–11). From all of these, the maximum amount of nutrients removed was demonstrated by 25-hour biosorption at pH 7,5. A pH of 7,5 and 25 hours later showed the maximum zinc absorption, with an ideal in vitro seaweed content of 0.5 g. The enhanced capacity of Fe3O4NPs@AlgBT to absorb nutrients and consequently stimulate development was demonstrated in an experimental investigation conducted using wastewater.

Keywords: alginate, bentonite, nanoparticles, adsorbents, waste products

I. Introduction

The excessive rise in nutrient content in water bodies, particularly in nitrogen and phosphorus, is a result of aquaculture's quick expansion. The standard method for obtaining these nutrients is to fertilize the pond with food and animal metabolic waste from raised animals. Thus, creating ecologically friendly plans that reduce these activities' detrimental effects has been the major problem [1-4]. The most pragmatic and economical method of lowering aquaculture nutrient concentrations is to treat wastewater before to its discharge into the ocean. Biological wastewater treatment with macroalgae for nutrient removal is a possibly workable substitute. It has been stated that heavy metals including Fe, Zn, Ca, and Mg have biological importance in humans and can be taken on a regular basis for medical purposes [5-7]

Even for those of biological importance, food intake must be maintained within regulatory limits, as excess will result in poisoning or toxicity, as evidenced by some reported drug symptoms that are clinically pronounced. Methods for removing metal ions from aqueous solutions mainly consist of physical, chemical and biological technologies. The advantages and disadvantages of traditional metal removal technologies are summarized. In recent years, the application of biotechnology for the control and removal of metal pollution has received much attention and is gradually becoming a hot topic in the world. Areas of metal pollution control due to its potential applications [8-12].

An alternative process is biosorption, which uses various natural materials of biological origin, including bacteria, fungi, yeast, algae, etc. These biosorbents have the property of binding metals and can be used to reduce the concentration of heavy metal ions in solution. It can effectively and quickly isolate dissolved metal ions from dilute complex solutions, so it is an ideal candidate for treating complex wastewaters of large volume and low concentration [13-15].

II. Methods

Preparation of biosorbent - Laminariaceae algae samples from several locations in the Caspian Sea were gathered in order to prepare alginates. The alginate extraction method includes numerous phases. Alginate that is water-soluble is created by first converting the alginic acid ions in the algae into pure alginic acid, which is subsequently reduced by sodium carbonate/hydroxide. In order to recover the soluble alginate, calcium chloride precipitation is used to create calcium alginate, which is then processed with sodium carbonate to create sodium alginate. Bentonite – is obtained from a clay deposit located in the village of Dash Salakhly, Gazakh region of the Republic of Azerbaijan (AzRosPromInvest LLC). This deposit is one of the highest quality natural deposits in the world. Nanoparticles of iron oxide Fe_3O_4 with superparamagnetic properties were obtained by chemical coprecipitation from aqueous solutions of ferrous and ferric salts in an alkaline medium created with NH_4OH in a nitrogen gas atmosphere. Following separation using a permanent NdFeB magnet, the resultant Fe_3O_4 nanoparticles (NPs) were periodically rinsed with distilled water before being disseminated in ethanol. An ethanolic solution of Fe_3O_4 nanoparticles was added to an ethanolic solution of the macro heterocycle taken in excess with vigorous stirring. After stirring for 8 hours at ambient temperature, the resulting nanostructures were isolated by applying a constant magnetic field and washed repeatedly with distilled water [16].

A particular amount of bentonite was dissolved in 30 mL of a 2% (v/v) acetic acid solution for 50 minutes. Addition of 0.03 g of Fe_3O_4 to the bentonite solution and three hours of stirring produced the same mixture. After adding a certain quantity of bentonite clay to the homogenous mixture, the combination was stirred for 60 minutes at 65 °C before alginate was added. The Fe_3O_4@AlBT mixture was, in the end, washed with 100% ethanol and dried at 50 °C in a furnace.

XRD - Using a Rigaku Mini Flex 600 XRD diffractometer at room temperature, XRD (X-ray diffraction) examination was carried out. Cu K α radiation from a Cu X-ray tube operating at 15 mA and 30 kV was utilized in each example. The samples underwent scanning within the 20–70 ° Bragg angle 2 h range.

FT-IR - (FTIR) spectroscopy, were investigated. Using a Varian 3600 FTIR spectrophotometer, FTIR spectra were captured in KBr tablets. At room temperature, the spectra was recorded in the 4000-400 cm^{-1} range.

Analysis using the Energy-Dispersive Spectrum (EDS) and a scanning electron microscope (SEM)- Prepared samples were subjected to SEM and EDS examination using a Field Emission Scanning Electron Microscope (JEOL JSM-7600F) operating in the SEI domain at an accelerating voltage of 15.0 kV [18].

III. Results

Using spectroscopic techniques (SEM, FTIR, X-ray diffraction, and XRD analytical methods), researchers examined the physicochemical characteristics and structure of enhanced ecologically friendly sorbents based on alginates, bentonite, and nanoparticles [17].

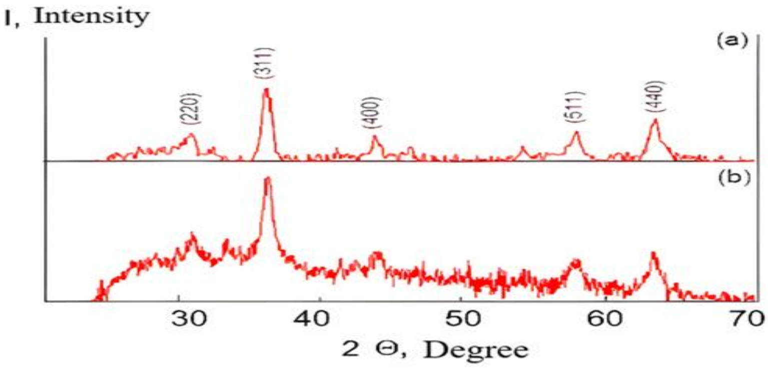

Figure 1: *XRD-Pattern of the obtained nanosized samples*

Data from the X-ray examination of samples of MC@Fe_3O_4 NPs are shown. Visualization of all the diffraction peaks of the acquired samples indicates that they are cubic-shaped Fe_3O_4 nanoparticles.

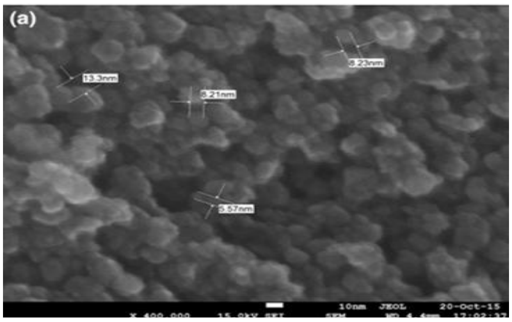

Figure 2: *Scanning electron microscope image of Fe_3O_4 NPs sample*

According to the SEM analysis it was investigated that the resulting nanostructures have a homogeneous structure and they are nanosized.

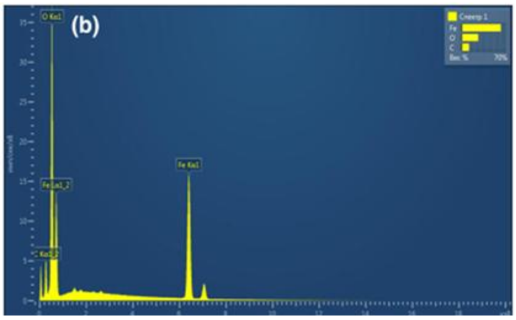

Figure 3: *Electron dispersion spectrum of the Fe_3O_4 NPs sample*

The samples indicate EDS analysis verifies the synthesis of magnetite nanoparticles by identifying Fe and O as the primary components present in the sample composition of the produced nanostructures.

Effect of pH and Time on Nutrient Absorption

In this study, maximum phosphate removal was achieved at pH 7,5, with an initial phosphate concentration of 0.5 μmol/L eventually decreasing to 0.05 μmol/L over 25 hours and a final value of 0.08 μmol/L at pH 7 was the second best (Figure 4).), pH 6 had the lowest phosphate removal at 25 hours at 0.18 μmol/L. Ammonia concentration decreased significantly in the pH range 3-11. The lowest ammonia removal (88.83 μmol/L) was recorded at pH 4 after 12 hours; the highest removal was recorded (67.55 μmol/L) at pH 7,5 and duration 25 h. Nitrate concentrations decreased significantly at pH 3 and 13. The lowest nitrate removal occurred at pH 6 - 0.07 µmol/L, and at pH 11 - 0.06 µmol/L. The greatest nitrate removal was recorded at pH 7,5, where it decreased from 0.07 µmol/L to 0.05 µmol/L. Nitrite concentration decreased markedly at pH 3 and pH 11. A gradual decrease in nitrite concentration was observed at all pH values. The maximum nitrite removal was 4.88 µmol/L at pH 7,5, while the lowest nitrite removal of 28.30 µmol/L was observed at pH 5. From the results presented, it is clear that pH has a significant effect on the reduction of nutrient concentrations . A pH of 7,5 was found to be at which nutrient concentrations were significantly reduced, although significant nutrient removal was also observed at both acidic and basic pH concentrations. Stirring the nutrient solution also improved nutrient adsorption by the seaweed. Similarly, increasing the duration of the experiment was found to enhance the adsorption process. This is evident from the fact that maximum nutrient removal was achieved after 24 hours.

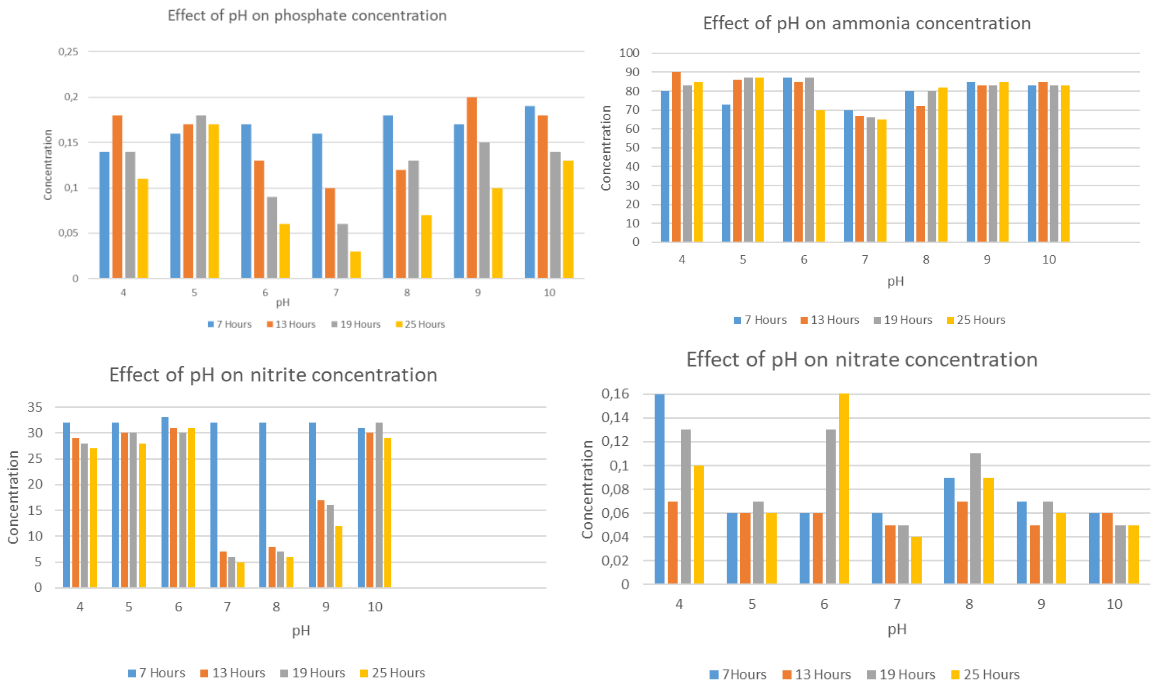

Figure 4: *Effect of pH and time on nutrient removal*

The effect of pH of aqueous solution is a key controlling parameter for the biosorption of heavy metals. pH levels ranging from 3 to 11 have been tested for the uptake of heavy metals by seaweed. The results showed that the removal of heavy metals was directly proportional to pH (Fig. 4). This experiment was carried out at three different concentrations at two different time intervals. The maximum removal (17.4 µg/L) of zinc was observed at a concentration of 0.1 g of seaweed at pH 10 in 24 hours, and the minimum removal (87 µg/L) at pH 6 in 13 hours. At pH 11, maximum zinc removal was achieved at a seaweed concentration of 0.5 g in 24 hours, the zinc concentration was 0.4 µg/L. 0.5 µg/L was the second best maximum zinc removal rate at the same seaweed concentration observed after 13 hours. 1 g concentration of seaweed significantly reduces zinc content. Minimal zinc removal was observed after 13 hours at pH 3 (73.66 µg/L). Maximum zinc removal was observed at pH 11 at 24 hours (3.4 µg/L). Metal uptake increased with increasing pH. A gradual increase in the biosorption of heavy metals was observed as the pH transitioned from acidic to basic. Although heavy metal biosorption was recorded at both acidic and basic pH, heavy metal removal was unsatisfactory under acidic conditions. Thus, it is clear from the present study that pH above neutral conditions is capable of improving the removal of heavy metals. This may be due to the presence of more free binding sites on the biomass that absorb heavy metals from solution at these pH concentrations. In the phenomenon of biosorption, the pH value affects two aspects: the solubility of metal ions and the overall charge of the biosorbent, since protons can be adsorbed or released. This behavior will depend on the functional groups present on the algal cell wall, which in turn determine the acidity constant.

The increase in the level of biosorption with increasing pH can be explained by the influence of the number of negative charges, which depends on the dissociation of functional groups. At low pH values, the concentration of hydrogen protons in the solution significantly exceeds the concentration of zinc ions and, therefore, the protons compete with metal ions to form bonds with active sites (functional groups) on the surface of the algae, leaving metal ions free in the solution. These bound active sites subsequently become saturated and inaccessible to other cations. As pH increased, the competing influence of hydrogen protons decreased.

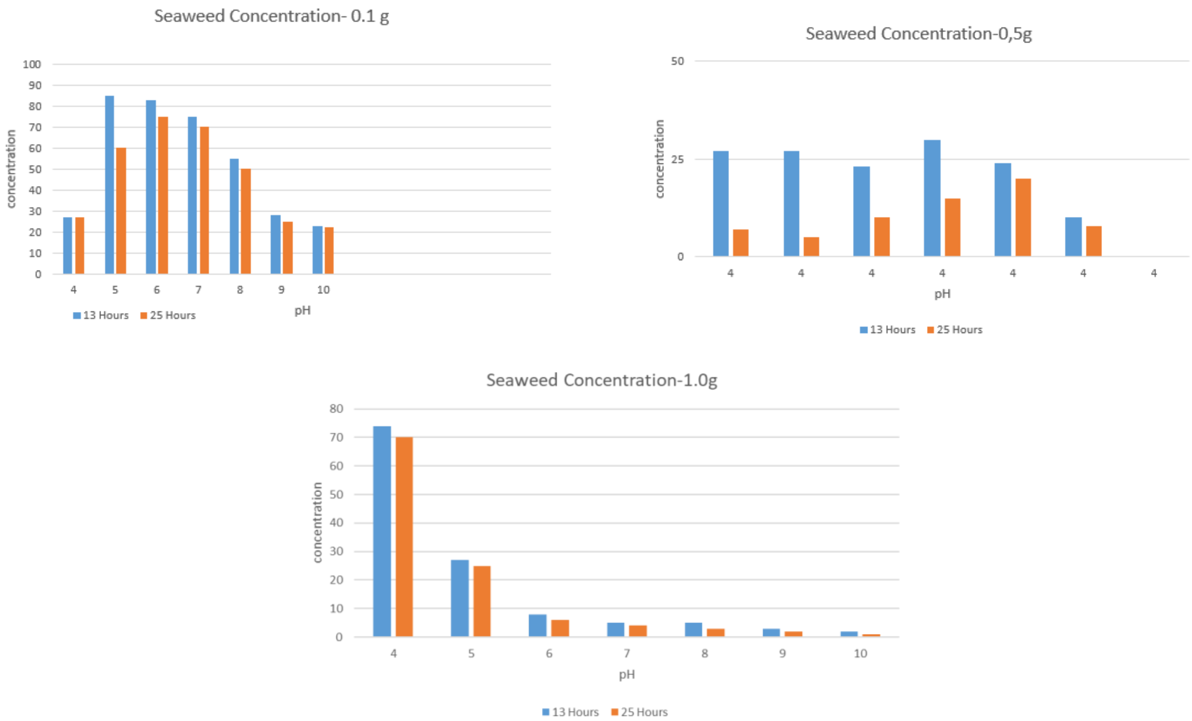

Figure 5: *Effect of pH, time and concentration of seaweed on the adsorption of heavy metals*

Therefore, an increase in sorption capacity or removal efficiency can be observed. Contact time is also rated as one of the most important factors affecting biosorption efficiency. The efficiency of biosorption increases with increasing contact time. As a result of these experiments, it was found that the efficiency of biomass biosorption reaches a maximum after 24 hours.

Biomass concentration is another important variable during metal uptake. The effect of biomass concentration on the biosorption of zinc ions was studied using different dosage ranges (0.1, 0.5 and 1 g), respectively. High concentrations of biomass can have a sheathing effect, protecting active sites from metal occupation. But the uptake of metals can also decrease with increasing biosorbent dosage, which may be due to the complex interaction of several factors. This may be due to partial cell aggregation, which occurs at high biosorbent concentrations and leads to a decrease in the number of active sites; we also observed this trend in our biosorption experiments. It has been suggested that electrostatic interactions between cells may be a significant factor in the relationship between biomass concentration and metal sorption. Because of this, for a given metal concentration, the lower the biomass concentration in the suspension, the higher will be the metal/biosorbent ratio and the metal retained by the sorbent unit until the biomass reaches saturation.

Concentrations of the four nutrients tested

The concentrations of the four nutrients tested (NO_2-N, PO_4-P, NO_3-N, and NH_3-N) decreased significantly during the experimental period indicating that adsorbents have a strong ability to remove nutrients (Figure 6) . PO_4^{3-} concentrations decreased from 0.038 μmol/L to 0.003 μmol/L, corresponding to approximately 95.6% of the nutrients being eliminated over the five days of the study. A significant reduction in NO_3 concentration was observed in the present study. The greatest reduction occurred from the fourth (20.585 μmol/L) to the fifth days (13.392 μmol/L), corresponding to the removal of approximately 49% of nutrients.

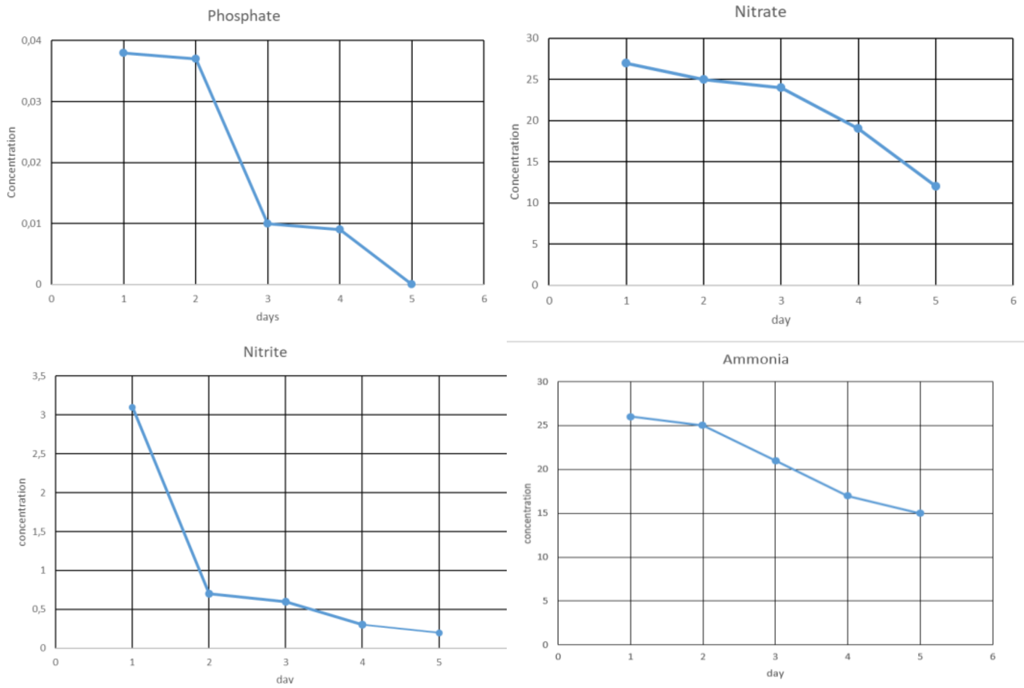

Figure 6: *Rate of removal of nutrients from wastewater*

The nutrient removal capacity for the entire period was approximately 55.55%. At the end of the experiment (fifth day), most of the NO_2 was absorbed, which is consistent. Removal efficiency 93.4%. There was also significant. Removal of NH_3^+ (43%) during the experiment. Significant decrease in NO_3 (13.392 μmol/L) during the culture period. This decrease may be due to the mineralization of organic matter. Previous studies have also shown that seaweed is capable of removing high concentrations of PO_4^{3-}. However, only the studies carried out found higher than in our present study. Removal of NH_4^+ from wastewater by seaweed occurred gradually between the beginning and end of the experiment (27.123–15.976 μmol/L). The biofiltration capacity of NO_3 obtained in this experiment was significantly higher. Because nitrate has a secondary source in nitrification processes. In addition, all other aspects must be taken into account changes in seaweed removal efficiency.

IV. Conclusion

In conclusion, ecologically friendly Fe_3O_4NPs@AlgBT sorbents have been obtained and has huge adsorption capacity in the incorporation of layered double hydroxides and the alginate matrix significantly improved the adsorption capacity of the developed toward water treatment.

The study showed that Fe_3O_4@AlgBT showed significant removal of nutrients and heavy metals. Therefore, it is considered for bioremediation of domestic and industrial wastewater that may cause environmental pollution.

It was concluded that Fe_3O_4@AlgBT can be used as a bioremediant in wastewater treatment plants to preserve nature and natural resources.

In addition, waste from cultivated seaweed can be used as feedstock to produce biofuels, biofertilizers and animal feed additives, reducing the cost of the wastewater treatment process.

References

[1] Solomon, W. (1995) Environmental Impact of Metals Derived from Mining Activi-ties: Processes, Predictions, Prevention. Journal of Geochemical Exploration, 52,5-23
(2) (PDF) Selected Adsorbents for Removal of Contaminants from Wastewater: Towards Engineering Clay Minerals. Available from:
https://www.researchgate.net/publication/327315818_Selected_Adsorbents_for_Removal_of_Contaminants_from_Wastewater_Towards_Engineering_Clay_Minerals#fullTextFileContent

[2] Gang S, Weixing S (1998) Sunflower stalks as Adsorbents for the removal of metal ions from wastewater. // Ind Eng Chem Res 37: 1324-1328.

[3] Bueno, P.D.L.C.; Gillerman, L.; Gehr, R.; Oron, G. Nanotechnology for sustainable wastewater treatment and use for agricultural production: A comparative long-term study. // Water Res. 2017, 110, 66–73.

[4] Chowdhary, P.; Raj, A.; Bharagava, R.N. Environmental pollution and health hazards from distillery wastewater and treatment approaches to combat the environmental threats: A review. // Chemosphere 2018, 194, 229–246.

[5] Inyinbor, A.A.; Bello, O.S.; Oluyori, A.P.; Inyinbor, H.E.; Fadiji, A.E. Wastewater conservation and reuse in quality vegetable cultivation: Overview, challenges and future prospects. // Food Control 2019, 98, 489–500.

[6] Sunil Rajoniya,Balpreet Kaur,"Adsorptive removal of zinc from wastewater by natural biosorbents", // International Journal of Engineering Science Invention Vol 3 (2014) pp 60-80

[7] Senthilkumar P., Ramalingam S., Sathyaselvabala V., Dinesh Kirupha S., Sivanesan S. "Removal of copper (II) ions from aqueous solution by adsorption using cashew net shell", // Desalination Vol 266 (2010) pp 63- 71

[8] Yaneva, S. L.; Koumanova, B. K. and Georgieva, N. K. (2013). Linear and Nonlinear Regression Methods for Equilibrium modelling of p-Nitrophenol Biosorption by Rhizopus 61 oryzae: Comparison of Error Analysis Criteria. // Journal of Chemistry: Article ID 517631, pp 10. http://dx.doi.org/10.1155/2013/517631

[9] Martı´nez-Ara´gon, J.F., Herna´ndez, I., Pe´rez-Llore´ns, J.L., Va´squez,, R., and Vergara, J.J. 2002. Biofiltering efficiency in removal of dissolved nutrients by three species of estuarine macroalgae cultivated with sea bass (Dicentrarchus labrax) waste waters 1. Phosphate. // J. Appl. Phycol. 14: 365–374

[10] Romera, E., Gonza´lez, F., Ballester, A., Bla´zquez, M.L., and Mun˜oz, J.A. 2007. Comparative study of biosorption of heavy metals using different types of algae. // Bioresource Technology 98: 3344–3353.

[11] C. Y. Yin, Emerging usage of plant-based coagulants for water and wastewater treatment, // Process Biochem., 45, 9, 1437–1444 (2010)

[12] B. C. Cao, B. Y. Gao, C. H. Xu, Y. Fu, X. Liu, Effects of pH on coagulation behavior and floc properties in Yellow River water treatment using ferric based coagulants, Chinese Sci. Bull., 55, 14, 1382–1387 (2010)

[13] Agahuseynova M.M, Synthesis and properties of supramolecular catalyst based on metal oil porphyrins for alkens oxygenation. PPOR, 2023, Vol. 24, No. 3, pp.390-396, DOI: https://doi.org/10.36719/1726-4685/95/390-396

[14] Kassem, Kh. O., Hussein, M. A. T., Motawea, M. M., Gomaa, H., Alrowaili, Z. A., Ezzeldien, M. (2021). Design of mesoporous ZnO @ silica fume-derived SiO2 nanocomposite as photocatalyst for efficient crystal violet removal: Effective route to recycle industrial waste. Journal of Cleaner Production, 326, 129416. doi: https://doi.org/10.1016/j.jclepro.2021.129416

[15] Mithra, R., Sivaramakrishnan, S., Santhanam, P., Dinesh Kumar, S., Nandakumar, R. (2012). Investigation on nutrients and heavy metal removal efficacy of seaweeds, caulerpa taxifolia and kappaphycus alvarezii for wastewater remediation. Journal of Algal Biomass Utilization, 3 (1), 21–27.

https://www.researchgate.net/publication/221675802_Investigation_on_nutrients_and_heavy_metal_removal_efficacy_of_seaweeds_Caulerpa_taxifolia_and_Kappaphycus_alvarezii_for_wastewater_remediation

[16] Hasanova U.A., Ramazanov M.A., Maharramov A.M., Gakhramanova Z., Hajiyeva S.F., Vezirova L., Eyvazova G.M., Hajiyeva F.V., Huseynova P., Agamaliyev Z., The functionalization of magnetite nanoparticles by hydroxyl substututed diazacrown ether, able to mimic natural siderophores and investigation of their antimicrobial activity // Journal of Inclusion phenomena and Macrocyclic Chemistry, 2016. v. 86, pp. 19-25 https://link.springer.com/article/10.1007/s10847-016-0636-x

[17] Development of environmentally-friendly modified bioadsorbents for water treatment, Minira M. Aghahuseynova, Leyla Z.Vazirova , // EUREKA: Physics and Engineering N.10, 2023

[18] Hasanova U., Ramazanov M., Maharramov A., Gakhramanova Z., Hajiyeva S., Eyvazova Q., L.Vezirova, F.Hajiyeva, M.Hasanova, N.Guliyeva, Synthesis of Macrocycle (MC) – Mimics the Properties of Natural Siderophores and Preparation the Nanostructures on the Basis of MC and Magnetite Nanoparticles, // Chemical Engineering Transactions, 47 (2016) pp.109-114.

DIVERSITY OF NATURALLY REGENERATED FOREST ECOSYSTEMS AND EVALUATION OF THE ECOLOGICAL (SOIL COVER) CONDITION ON THE LANDSLIDE SLOPES OF THE SKHALTA RIVER

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Abstract

Adjara is located in a mountainous, exceptionally small region, noted for its diverse and unique natural landscapes. In this area, intense land exploitation disrupts the already delicate balance of the geological environment, leading to the active advancement of natural geological processes. Consequently, the natural regeneration of forest ecosystems following a disaster is understood to be a complex successional process. Over35 years, the regenerated forest ecosystems on the landslide-affected slopes of the valley have been extensively studied. For this research, the systematic arrangement of the flora was analyzed, phytocoenology surveys were conducted, and assessments of soil fertility were completed. The flora of the naturally regenerated vegetation comprises 101 species, which are organized into 32 families and 84 genera. Species-rich families such as Asteraceae, Borraginaceae, Lamiaceae, Poaceae, Brassicaceae, Umbelliferae, Scrophulariaceae, Caryophyllaceae, and Leguminosae are identified. In the research site, as woody plants developed, cenotic relationships gradually emerged among species within the phytocenoses of the pine forest (Pineta; Pinus sosnovskyi), including Pinetum Ramnosum, Alnetum Pinetozum, Alnetum Ramnosum, and Alnetum Salixsosum. Consequently, tiered differentiation occurred, a tree canopy was established, and a specific system for natural regeneration was formed. The chestnut, oak, mixed (polydominant), and beech sub-zones within broad-leaved forests are primarily characterized by typical forest soils. It has been demonstrated through studies that the pH (KCl) of soil samples obtained from regenerated forests is 5.8, indicating a weakly acidic soil reaction. The strong buffering properties of the soil absorption complex are indicated by its high calcium content (336 mg/100g) and magnesium content (43.8 mg/100g). Low levels of total humus and nitrogen content are observed in the soil. The natural forest soil, with a neutral reaction (pH 7.1), is characterized by richness in calcium (378.7 mg/100g) and magnesium (50 mg/100g). Both soils possess a significant reserve of mobile phosphorus and potassium content. In comparison to the regenerated forest soil, the natural forest soil contains 1.65% more humus and 0.132% more total nitrogen. In the vicinity of the surveyed slopes, amid the presence of the derivative-type cascade Skhalta hydroelectric power station, an investigation was conducted on the soil's multi-elemental composition to evaluate the current ecological conditions and identify any toxic elements. Nickel (Ni), mercury (Hg), lithium (Li), antimony (Sb), selenium (Se), thallium (Tl), and vanadium (V) were detected below the detection limit in the 0–40 cm layer of soils. The concentrations of manganese (Mn), cadmium (Cd), lead (Pb), and molybdenum (Mo) in both soil samples exceed the permissible limits. This could be attributed to the proximity of the Skhalta Hydroelectric Power Plant (HPP) to the slopes, where its reservoir is fed by water from the Chirukhi River discharged through the derivation tunnel. Crushed rocks were deposited and spread on the surrounding slopes during the construction of the tunnel, potentially increasing the levels of heavy metals in the soil.

Keywords: secondary ecosystems, forest, variety, soil fertility, multi-element analysis

I. Introduction

Adjara is situated in the Caucasus, a region renowned for its biodiversity and recognized by the International Union for Conservation of Nature (IUCN) as one of the world's 36 biodiversity hotspots. This designation highlights regions with the highest biological diversity and a significant number of endangered terrestrial ecosystems. Additionally, the Adjara floristic region is part of the list of 200 ecoregions globally recognized, located in the southwestern corridor of the Lesser Caucasus. This area is notable for its species richness, high endemism, taxonomic uniqueness, distinctive origins, and rare habitats. Our region is also among the 25 regions worldwide with a uniquely high level of biological diversity, emphasizing the urgent need for its protection.

Adjara, with its diverse natural landscapes, stands out as one of the unique regions in Georgia. This uniqueness arises from its varied natural conditions and the complex history of its flora and vegetation development. According to numerous researchers, Adjara boasts the richest relict flora of Kolkheti in Georgia. Within this relatively small area, a wide range of ecosystems has evolved, from the wetland habitats of the Kolkheti plain to the distinctive ecosystems of the high mountains, where relict and endemic species still thrive. During the Ice Age, South Kolkheti, including Adjara, served as a refugium for ancient plant species (relicts).

The diversity and distinctiveness of Adjara's vegetation are evident in the Acharistskali River valley and its surrounding areas. The natural ecosystems here exhibit regular variation based on vertical zonation, slope exposure and steepness. Forest ecosystems are systematically distributed throughout the area, each occupying its unique eco-topological zone characterized by distinct ecological conditions.

Active human intervention in nature has triggered natural processes everywhere, and the mountain region of Adjara is no exception. Adjara is situated in a vulnerable zone and is considered one of the most challenging regions in the country in terms of natural processes. Unplanned and excessive consumption of local natural resources has led to landslides, destroying forests around villages, causing slope deformation, and resulting in the fragmentation, degradation, and destruction of vegetation. The natural renewal of ecosystems in these areas is a long and difficult process.

The most critical factor for slope stability and landslide development in mountainous Adjara is the saturation of slope rocks with excess atmospheric precipitation. This wetting disturbs the already weak static balance and triggers gravity processes [4]. There is limited information on the natural renewal of ecosystems in Adjara that have been damaged by these natural processes [5,6]. Therefore, studying the naturally regenerated forest phytocenoses on the slopes of mountainous Adjara, as well as the natural forests on adjacent slopes, is essential. This is especially relevant in the context of the derivation-type hydro power plant being constructed in the valley. Such studies are crucial for assessing the current ecological situation and for timely and competently determining preventive measures to address existing and anticipated ecological problems [12].

The purpose of the research was to examine the current ecological condition of natural and regenerated phytocenoses, determine the systematic structure of the flora, and conduct a geobotanical diagnosis of the phytocenoses. Additionally, the research aimed to evaluate soil fertility at the study locations and analyze it using multi-element analysis.

The study focused on the renewed forest ecosystems following the natural disaster in the Skhalta River valley (Khulo municipality), the natural forests on the surrounding slopes, and the soils developed under them. The Skhalta River, a left tributary of the Acharistskali, originates on the western slope of the Arsiani ridge at an altitude of 2220 meters above sea level. It has a length of 29 kilometers and a basin area of 223 m^2, and is fed by snow, rain, and underground water.

II. Methods

The main research method was traditional route expeditions. We conducted numerous floristic and geobotanical descriptions and performed a reconnaissance survey of the study area to understand the vegetation background. Using phytocenological diagnostics, we identified xenotypes through the Relevé method. Traditional method sofphytocenological research were employed for geobotanical descriptions [8, 10, 11].

We determined some agrochemical indicators of natural and regenerated forests oils that would allo wus to judge the level of soil fertility. Agrochemical analysis of soils were carried using classic, widely tested methods: Soil Ph was determined potentiometrically with a laboratory pH meter (Metter Toledo) in both aqueousand salt (KCl) extracts; Mobile P_2O_5 and K_2O were measured photometrically by Oniani's method in a single extract obtained by adding 0.1N H_2SO_4 to the soil; exchangeable CaO and MgO were analyzed titrimetrically using the trilonometric method; total Humus was determined by the Turin method, which involves oxidizing soil organic matter (containing carbon) with 0.4N $K_2Cr_2O_7$ in H_2SO_4, followed by titrationof the remaining bichromate with 0.1N Mori'ssalt $(NH_4)_2Fe(SO_4)\cdot 6H_2O$ using diphenylamine - $C_{12}H_{11}$ Nasan indicator; total Nitrogen was measured by the Kjeldahl method, which involves oxidizing humus carbon to carbon dioxide and converting amine (NH_2) nitrogen to anammoniacal form during soil digestionin concentrated H_2SO_4. To completely separate ammonia, the solution is made alkaline with 40% NaOH, causing the formed NH_3 to be transferred to 0.1N H_2SO_4 under boiling conditions. At this point, NH_3 combines with H_2SO_4 toform $(NH_4)_2SO_4$. The remaining free H_2SO_4 is then titrated with a 0.1N NaOH solution using Congo redasan indicator until a weak pink coloris achieved [1, 2].

Multi-element analysis of the soil was conducted using the modern method of instrumental research known as plasma atomic emission spectrometry (on instrument ICPE-9820). For this analysis, we prepared comparison (standard) solutions in advance, including on esolution that represented the internal standard, ytrium (Y):

I – ytrium standard solution - concentration 0,1ppm;

II standard solution - concentrations 5ppb and 25ppb;

III standard solution - concentrations - 2ppm ans 5 ppm.

The multi element standard solutions include: $Al, Sb, Ba, Pb, B, Ca, Cd, Cr, Co, Fe, K, Cu, Mg, Li, Mn, Mo, Na, Ni, P, Si, Ti, V, Zn, As, Be, Se, Tl$

Inductively coupled plasma spectrometryis a method of atomic emission spectrometry that uses inductively coupled argon plasmaas a source of atomic excitation. The method works by causing excitationan dionization, where each element emits a quantum of light at a specific wave length. Quantitative analysis involves measuring the amount of electromagnetic radiation, while qualitative analysis is based on the wavelength of the radiation. This method allows for simultaneous qualitative and quantitative analysis. Currently, it is the most widely used high-sensitivity method for element alanalysis of liquid and solid substances, with a correlation coefficient of at least 0.99 [9, 14].

III. Results

The wild flora of the regenerated forest comprises 105 species, grouped into 36 familie sand 88 genera [7]. In contrast, the wild flora of the boreal forests developed on the slopes suffered from landslide consists of 202 species, organized into 61 families and 152 genera.

The distribution of species into major taxonomic units is clearly illustrated in the diagrams.

The species diversity of the regenerated forest flora is significantly lower compared to the natural forests on the surrounding slopes (Table 1). In natural forests, the families distinguished by species richness are:*Asteraceae* - 32; *Lamiaceae*- 15; *Brassicaceae* - 9; *Rosaceae* - 9; *Dryopteridaceae* - 9;

Borraginaceae - 8; *Caryophyllaceae* - 8; *Scrophulariaceae* - 7; *Apiaceae*– 7. In regenerated forests, the families distinguished by species richness are: *Asteraceae*- 23; *Lamiaceae* - 8; Borraginaceae - 8; Brassicaceae - 7; Poaceae - 7; Scrophulariaceae - 4; Leguminosae - 4; Caryophyllaceae – 3. A significant portion of the wild flora consists of perennial herbaceous species, accounting for 69.5%, while annual herbaceous species make up 16%. Woody plants comprise 9.5% of the total.

highest taxa	Family	Genus
Pteridophyta	5	4
gimnospermae	3	3
Angiospermae	26	81
Dicotyledones	24	73
Monocotyledones	2	8
all	34	88

Для изменения диапазон

Diagram 1: *Regenerated forest wild flora*

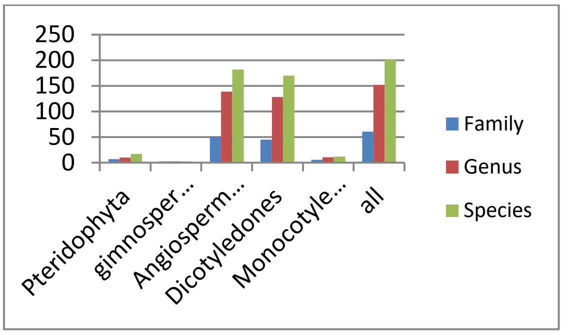

Diagram 2: *Natural forests wild flora*

Table 1: *Flora species of natural and regenerated forests*

	The families distinguished by species richness in natural forests		The families distinguished by species richness in regenerated forests	
	family	Number of species	family	Number of species
1	Asteraceae	32	Asteraceae	23
2	Lamiaceae	15	Lamiaceae	8
3	Brassicaceae	9	Borraginaceae	8
4	Dryopteridaceae	9	Brassicaceae	7
5	Rosaceae	9	Poacaea	7
6	Borraginaceae	8	Umbelliferae	6
7	Caryophyllaceae	8	Scrophulariaceae	4
8	Scrophulariaceae	7	Leguminosae	4
9	Umbelliferae	7	Caryophyllaceae	3
10	*Poaceae*	6	Rosaceae	3

The natural forests of the valley are polydominant and broad-leaved, with chestnut, oak, and beech as the dominant species. Typical phytocenoses include beech-larch-chestnut-leafy forests Fageto-Carpineto-Castanetumlaurocerasosum (Castanea sativa + Fagus orientalis + Carpinus caucasica – Laurocerasusofficinalis), hornbeam-chestnut-Cherry-laurel, Castaneto - Carpinetumlaurocerasosum (Castanea sativa + Carpinus caucasica - Laurocerasus officinalis), chestnut rhododendron, Castanetumrhododendronosum (Castanea sativa – Rhododendron ponticum), oak forest with rhododendron-Cherry-laurel, Quercetumrhododendronoso - laurocerasosum (Quercus hartwissiana + Rhododendron ponticum - Laurocerasus officinalis), beech forest with rhododendron, Fagetumrhododendrosum (Fagus orientalis – Rhododendron ponticum), chestnut-hornbeam-beech forest with blackberry, Castaneto-Carpineto-Fagetumrubosum (Fagus orientalis + Carpinus caucasica + Castanea sativa – Rubus caucasicus), Alder-grove with blackberry, Alnetumrubosum (Alnus barbata– Rubus caucasicus), Alder-grove braken blackberry, Alnetummatteuccioso-rubosum (Alnus barbata, Matteucciastruthiopteris, Rubus caucasicus). Natural regeneration of dominant species in forests is satisfactory in low-frequency groves (0,5-0,6), but weak in high-frequency groves (0,7-0,8).

Figure 1: *Natural vegetation of the valley*

Figure 2: *Naturally regenerated vegetation of the valley*

Naturally regenerated forests are pine forests (Pineta; Pinus sosnovskyi). Coenoses featuring alder grove on well-moistened soils in *the relatively leveled areas of the slope.* In pine groves, individual occurrences of Spruce, Silver-fir, hornbeam and Yew-tree can be found. We have described typical phytocenoses: *the pine grove with buckthorn sub forest Pinetum Ramnosum (Pinus Sosnovski-Ramnusimeretina); Alder-grove-pine forest, Alnetum Pinetozum (Pinus Sosnovski+Alnusbarbata); Alder-grove with buckthorn sub forest Alnetumramnosum (Alnus barbata+Ramnusimeretika); Alder-willow grove Alnetumsalixsosum* (Alnus barbata+Salix alba); In pine forests with low regeneration frequency, the natural regeneration of pine is satisfactory. However, the following species exhibit weak natural regeneration: *Piceaorientalis, Abies mordmaniana, Taxus bacatta, Alnus barbata, Ramnusimeretina.*

The soils of broad-leaved forests, including chestnut, oak, mixed (polydominant), and beech forests, represented by typical fulvous forests oils. In contrast, regenerated forest soils are characterized by being loamy, stony, and low inhumus.

Soil samples were collected from the surface at a depth of 0-20 cm for agrochemical analysis and to assess fertility levels. Upon arrival at the laboratory, the samples were spread on dense paper and allowed to air dry for 3-5 days. The soil was then cleaned of impurities, ground, sieved through a 1 mm diameter sieve, and stored in a hermetically sealed labeled container for analysis. The agrochemical indicators of the soils are detailed in Table 2. It is evident from these indicators that the main quality parameters of the regenerated forest soil (sample No. 1) are inferior to those of the natural forest soil. This includes its active reaction and the quality of basic nutrients, humus and nitrogen. The regenerated forest soil has average or below-average concentrations of essential plant nutrients, including phosphorus, potassium, calcium, and magnesium.

Table 2: *Some agrochemical indicators of natural and regenerated forest soils*

№	Samplinglocation	sampling depth, cm	pH		mobileformsofnutrients, mg/100 ginthesoil				Total, %	
			H_2O	KCl	P_2O_5	K_2O	CaO	MgO	humus	nitrogen
1	soilfromtheregeneratedforest	0–20	4.85	3.47	59.10	29.4	21.56	11.90	3.68	0.13
2	naturalforestsoil	0–20	6.58	5.69	72,30	44.6	78.47	46.21	5.62	1.90

To perform the multi-element alanalysis, an aqueous extract of the soils was prepared with a soil-to-water ratio of 1:25. The analysis results were compared with the maximum allow able concentrations of heavy metals established by the environmental quality standards approved by the Republic of Georgia. This comparison was made to prevent adverse effects on the environment and human health due to environmental and anthropogenic factors [3].

The conducted studies allowed us to judge the content of microelements and some heavymetals in the research soils in relationt to their maximum permissible concentrations (MPC)

(Table 3). The content of copper and lead in the natural forest soil exceeded the permissible concentration. As for the soil of the regenerated forest, there was an excess of concentration of several elements in relation to MPC. The seelements are: copper; manganese; zinc; plumbum.

Table 3: *Multi-element analysis of aqueous extracts from soil Concentration of microelements, mg/kg*

№	Sampling location	As	B	Ba	Co	Cu	Mn	Mo	Zn	Cr	Cd	Pb
1	Soil from the regenerated forest	0.00086	0,320	0.00112	0.450	4.465	1.348	0.326	5.983	1.476	0.113	2.866
2	Natural forest soil	0.00079	0.292	0.00103	0.414	3.850	0.127	0.312	4.738	1.397	0.102	2.527
MPC		0,001	0,5	0,0025	0,5	3,0	0,2	0,35	5.0	3.0	0.2	2,5

IV. Discussion

I. Floristic and Coenological Analysis of Natural and Regenerated Forest Ecosystems

Forest phytocenoses on the slopes affected by landslides develop primarily in zones at an altitude of 750–1000 meters, mostly on slopes with an eastern exposure, where they in habit slightly moistened areas. The natural form at ion of secondary phytocenosesis quite dynamic, influenced by local climatic and soil conditions. Over the years, as woody plants grow on the baresubstrate, a tiered structure of phytocenosis gradually forms (see Fig. 3 and Fig. 4). The primary layer of secondary natural forest phytocenoses is predominantly composed of pine (Pinus Sosnovski), within dividual representations in some places of alder (Alnusbarbata), spruce (Piceaorientalis), sochi (Abiesnordmaniana), willow (Salixalba), and horn beam (Carpinus caucasica). Depending on the intensity of plant growth influenced by local climatic and soil conditions, the sub-tiersoft hemainlayer have naturally formed. The over all density of the groves in most phytocenoses ranges from 0,5 to 0,6. Typically, the main forest exhibits unevendensity, which significantly impacts the floristic composition and structure of the understory and herbaceous cover in the lower levels. The understory is unevenly developed, featuring species such as Ramnusimeretina, Ilexcolchica, Rhuscoriaria, and Swidaaustralis. The herbaceous cover is primarily composed of perennial species, with relatively high projected coverage in open areas and gaps: Athyriumfilix-femina, Crepisfaetida, C. foetida, Hieraciumpilosella, Echiumvulgare, Fragariavesca, Brachypodiumsilvatica, Trifoliumcampestra,T. pratese, T. arvense, Poaannua, Mycelismuralis, Sambucusebulus, Plantagolanceolata, Tunicasaxifraga,Circiumimeretina, Teucriumnuchense, Clematisvitalba, Hipericumperforiatum, Eupatoriumcannabinum and other.

The natural regeneration of pine on the slopes of the renewed forest is progressing satisfactorily. However, species such as Piceaorientalis, Abiesnordmaniana, Taxusbaccata, Alnusbarbata, and Ramnusimeret in a exhibit weak natural regeneration. This indicates that while a system of natural renewal existsin secondary natural phytocenoses, the development of monoclimax ecosystems in the near future seems unlikely.

Figure 3: *Slopes affected by landslides 1989 affectedbylandslides*

Figure 4: *Secondary natural forests on the places*

II. Agrochemical Indicators of Soil.

The experimental study of the soils revealed that the natural forest soil has significantly higher fertility compared to there generated forest soil. Specifically, the pH in KCl suspensionis 3.47, indicating a moderately acidic reaction. The levels of mobile phosphorus and potassium are average (59.10 and 29.4 mg/100g of soil respectively). However, the concentrations of mobile Caand Mg which are important for the soil's buffering capacity, are below average (21.56 and 11.90 mg/100g). Additionally, the soils are deficient in total humus (3.68%) and total nitrogen (0.13%), which are crucial indicators of soil quality and fertility (Table 2).

In the natural forest sample (sample №2), the pH in KCl suspension is 5.69, placing it in the weakly acidic range. The soil is well-supplied with essential nutrients, including calcium (78.47 mg/100g) and magnesium (46.21 mg/100g). The content of mobile phosphorus in the natural forest soil is higher by 13.2 mg, and the mobile potassium content is higher by 15.2 mg compared to the regenerated forest soil. Consequently, the natural forest soil is adequately provided with these nutrients. A similar pattern is observed for total humus and nitrogen content, with these indicators being 1.94% and 1.77% higher, respectively, in the 1st sample compared to the 2nd sample.

III. Multi-element Analysis of Soil.

The content of mercury, lithium, antimony, selenium, titanium, thallium, and vanadium is below the detection limitin both regenerated and natural forest soil samples. Additionally, the levels of arsenic, boron, barium, cobalt, molybdenum, chromium, and cadmium do not exceed the permissible concentration in any of the samples.

The content of Cu (3.850 mg/kg) and Pb (2.537 mg/kg) in natural forest soil was higher than maximal permissible concentration (MPC). As for the soil of the regenerated forest, there was an excess of concentration of several elements at the same time, in relation to MPC. These elements are: Cu-4.465mg/kg; Mn-1.348mg/kg; Zn-5.983mg/kg; Pb-2.866 mg/kg.

The elevated concentrations of the mentioned metals are likely attributed to the proximity of the Skhalta HPP to the slopes. The water reservoir of the HPP is fedby the Chirukhi River, whichdischargeswaterfromthederivationtunnel. During the tunnel's construction, crushed rocks were placed and spread over the surrounding slopes, potentially leading to increased levels of these heavy metals in the soil.

The current situation under scores the need for systematic research and monitoring of soil chemical composition. This will help assess the current state of the soil and enable timely preventive measures to improve soil quality.

References

[1] Kvesitadze, G., Urushadze, T. (2016). Field Soil Science, Georgian National Academy of Sciences: 145-160.

[2] Margvelashvili, G. Soil Chemical Analysis (2019). Tbilisi: 8-36. ISBN 978-9941-8-1511-9

[3] Order No. 297/M, issued on August 16, 2001, by the Minister of Labor, Health, and Social Protection of Georgia, on „Approval the norms for the qualitative state of the environment", Tbilsi, 16 August,2001. https://matsne.gov.ge/ka/document/view/52384?publication=

[4] Palavandishvili, S. Soil Geography (2002). Batumi: 270-293.

[5] Dzirkvadze, A. (2012). Impact of Cattle Grazing on the Natural Regeneration of Beech Forests In Adjara // Georgian Academy of Agricultural Sciences "Moambe", 30 (2012): 66-69.

[6] Shainidze, A., Dzirkvadze, A. Natural Regeneration of Forests in the Primary Subalpine Formations of Adjara // Collection of Scientific Papers, 3, (2010), Tbilisi: 55-57.

[7] Gvarishvili, N., A. Sharabidze, A. Peculiarities of Successive Processes of Naturally Renewed Forest on the Landslide Slopes // Internacional conference "Applied ekologe: problems, inovacions". Collected Papers. ISAE (2015). Tbilisi: 262-264. ISBN 878-9941-0-7644-2.

[8] ReleveMetod-handbookforCollectingVegetationPlotDatainMinesota. StateofMinesota (2013):4-60. https://files.dnr.state.mn.us/eco/mcbs/releve/releve_booklet.pdf

[9] Becker, Yu. Spectroscopy. Edition 1-e (2009): 376-394. ISBN 978-5-94836-220-5

[10] Mirkin, B.M., Naumova, L.G., Solomeshch, A.I. Modern Science of Vegetation. Textbook (2001): 145-177. ISBN 5-94010-040-6. https://reallib.org/reader?file=586064&pg=7

[11] The plantlist (a working list of all plant species). 2013. http://www.theplantlist.org/

[12] Kiknadze,N., Gvarishvili, N.,Mikeladze, Z., Lominadze, S., Tavdgiridze, G., Jashi, D., Shvydka, S. Study of phytiextraction at some locations of Ajaristskali river based of soils and plants analysis // Environment and Ecology Research, (2023), 11(1): 114-123. DOI: 10.13189/eer.2023.110108. ISSN: 2331-6268 (Online). https://www.hrpub.org/journals/article_info.php?aid=12911

[13] Nakashidze, N., Kiknadze, N., Alasania, N., Jashi, D., Lominadze S. The Concentration of Macro and Micro Elements in Open and Closed Ground Soils in the Territories of Adjara Region // 20th International Multidisciplinary Scientific Geo Conference Surveying, Geology and Mining, Ecology and Management, SGEM (2020). ISSUE 5.1.Albena, Bulgaria: 787-793. ISBN 978-619-7603-10-1. ISSN 1314-2704. https://doi.org/10.5593/sgem2020/5.1

[14] Simultaneous ICP Atomic Emission Spectrometer ICPETM-9820 Determination of Elemental Composition of Animal Feed by ICP-OES According to EN 15621 https://www.shimadzu.com/an/sites/shimadzu.com.an/files/pim/pim_document_file/applications/application_note/14064/an_04-ad-0238-en.pdf?fbclid=IwAR0cu6DEBot6nD5Z0tLutpxheNAewsLpmE89ObND5QpOSNIJxCMDrMJGGck

PROBLEMS IN ASSESSING THE VULNERABILITY OF BUILDINGS AND STRUCTURES IN THE CONTEXT OF CLIMATE CHANGE

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Abstract

Already, we are increasingly encountering the consequences of dangerous climate impacts on buildings and structures. These effects are particularly evident in the thawing of permafrost, geological hazards, floods, mudflows, as well as forest and landscape fires. Of course, climate change also influences seismic and tsunami risks.
To plan protective measures for populations in hazardous zones in a timely manner, it is necessary to be able to predict the parameters of these dangers, assess the vulnerability of buildings and structures, and evaluate the risks to the population. By understanding the hazards, vulnerabilities, and risks, appropriate measures to reduce risks can be developed.

Keywords: technical condition of buildings, vulnerability of buildings, vulnerability of soils beneath buildings, individual risk for the population, risk reduction

I. Introduction

The most effective way to protect buildings from hazards associated with climate change and the reduced bearing capacity of soils is a reliable structural design of buildings and structures that provides protection against dangerous changes. However, it is not always possible to design and build buildings that are immune to vulnerabilities. Therefore, in order to prevent possible accidents, it is important to be able to quickly and reliably assess the technical condition and vulnerability of the "soil-building" system.

If we analyze what is more dangerous for the "soil-building" system, it is obvious that the most hazardous aspect is the emergency technical condition of both the building and the soil mass, as elements of an interconnected system [2].

Unfortunately, traditional methods of design, construction, and operation do not account for the possibility of errors at these critical stages. At the investigation stage, errors arise due to the limited capabilities of point-based drilling, as soil properties between boreholes are interpolated. Soil samples sent to laboratories for testing often lose their natural physical and mechanical properties during transport. During the design stage, errors are amplified due to inaccuracies related to soil conditions, which can be further exacerbated by the lack of consideration for climate change. Fast-paced competitive construction leads to underestimation of the importance of adhering to all design conditions, such as incomplete driving of foundation piles, poor quality of expansion joints, and inadequate implementation of soil paving and drainage around the building [3].

Figure 1: *A new framed residential building that has undergone significant deformation due to the thawing of soils in permafrost conditions*

II. Methods

For timely diagnostics of the technical condition of the soil mass and its suitability for construction, effective and accurate methods are needed that provide three-dimensional data about the structure of the soil mass and potential hazard zones within it. Such three-dimensional data on the stiffness of the soil mass can be obtained through its natural vibration frequencies. Heterogeneous hazard zones within the soil mass emit high-frequency acoustic noise. When building vulnerability decreases, the frequency of its natural vibrations also decreases.

A technology is required that can capture the frequency characteristics of the "soil-building" system and determine its stiffness, potential hazards, technical condition, and vulnerability based on frequency data. By identifying hazards and vulnerabilities, it is possible to determine potential consequences and the individual risk to the population using the geographic information system (GIS) "Extremum" [3, 4].

III. Results

The calculation of potential consequences from repeated strong impacts must take into account the possible decline in the technical condition and vulnerability of buildings. Currently, such a procedure is not provided in the GIS "Extremum." For the prompt assessment of the technical condition and seismic resistance of buildings, it is proposed to use the method of dynamic testing [11,13]. Based on the results of dynamic tests, the building database in the GIS "Extremum" can be updated.

In the GIS "Extremum," the current classification system for building databases is based on the MSK-64 seismic scale, and buildings are categorized into type A (constructed from local materials), type B (stone and block structures), and type C (seismically resistant, categories C7, C8, and C9). The proportion of building types in the database used for assessing the consequences of major earthquakes in certain areas is represented as percentages (see Table 3.2). [5]

Figure 2: *An example of mixed, dense development in the city of Istanbul on hilly terrain*

Table 1: *Example of database entry for buildings classified by type (based on data from 1999-2000, from the GIS "Extremum" database).*

City name	A/ Height, m	B/ Height, m	C6/ Height, m	C7/ Height, m	C8/ Height, m	C9/ Height, m
Nalchik	0,2/3	0,21/6	0,2/15	0,39/3	0	0

As seen from the example (see Table 1), in the examined city, according to data from 1999-2000, there are no buildings with seismic resistance of categories C8 and C9. This example makes it clear that the seismic resistance database requires constant updating. The seismic resistance data are tied to the seismic scale and provide only discrete values of seismic resistance without considering operational wear, meaning they do not reflect the actual seismic performance of buildings. The GIS "Extremum" database needs adjustments, and it can be used for preliminary analysis. The database can be updated either by decreasing or increasing the share of buildings in categories A, B, C6, C7, C8, C9, or by dividing the city's territory into separate areas with predominant seismic resistance values.

To assess the technical condition, stiffness, and seismic resistance of buildings and structures, it is proposed to use the "Struna" technology [11]. The essence of the method is based on the fact that through oscillations, the stiffness of the structure can be evaluated, and through stiffness, the technical condition and seismic resistance of the buildings can be assessed.

For evaluating possible resonance between the ground and the building, sensors are installed on both the ground and the building.

Stiffness deficiency is assessed using the following dependencies [4–8]:

$$\Delta fx = ([fx]2-fx2)\times 100/ [fx]2, (1)$$

$$\Delta fy = ([fy]2-fy2)\times 100/ [fy]2 , (2)$$

$$\Delta fz = ([fz]2-fz2)\times 100/ [fz]2, (3)$$

where fx, fy, fz are the values of the building's natural vibration frequencies obtained from dynamic tests.

[fx], [fy], [fz] are the standard natural vibration frequencies obtained from the design or calculated values.

Δfx, Δfy, Δfz are the stiffness deficiencies in percentages along the X, Y, Z axes (see Table 2).

Based on the obtained data on stiffness deficiency, the technical condition and seismic resistance of the buildings are determined [6].

Table 2: *Percentage of stiffness reduction (square of the building's natural vibration frequency), depending on the category of technical condition*

Type of Structure	Percentage of Relative Stiffness Reduction of a Structure in Various Conditions				
	Very good	good	fair	poor	very poor
Reinforced Concrete Frame	0–25	25–43	43–57	57–71,4	71,4–100
Steel Frame	0–16,7	16,7–33	33–50	50–67	67–100
Brick	0–16,7	16,7–33	33–50	50–75	75–100
Wooden	0–20	20–27	27–40	40–67	67–100
For Other Types of Buildings and Structures, Soil Masses Beneath Buildings	0-10	11-30	31-60	61-90	

Dynamic testing is proposed to be conducted on characteristic typical elements of settlements with uniform building types. Data on seismic resistance (see Table 3) for each building element should be entered into the GIS database. The seismic resistance of buildings is proposed to be determined by the following formula:

$$A = \frac{4*\pi^2*\Delta d}{k_0*k_1*k_\varphi*\beta(T)*T^2} \quad (4)$$

where

Δd – the maximum allowable displacement of the building;

k_0 – coefficient accounting for the structural design features and its importance, K_0 [4];

k_1 – coefficient accounting for allowable damage, k_1;

$k\varphi$ – coefficient accounting for the dissipative properties of the structure, $k\varphi$;

$\beta(T)$ – coefficient of the building's dynamic response;

T – period of the building's natural vibrations.

Based on the results of dynamic testing, knowing the category of technical condition, the probability of human injury can be determined

The individual risk of people being in damaged buildings in the considered hazardous area over the projected time interval, taking into account possible repeated impacts, is proposed to be calculated using the following formula:

$$Re_i(t)=P_z\times\sum_i^n m_i/(N_i\times T) \leq [Re_i] \quad (5)$$

where

P_z - probability of the primary (or repeated) strong impact on the building;

m_i – estimated human losses in the event of failure of the "soil-building" system's bearing capacity in the considered i-th element of the area (building) after the impact [4, 10, 11];

N_i – number of people in the i-th element who fall into the danger zone leading to building damage;

T – the period during which the primary (or repeated) impact leading to building damage will occur;

$[Re_i]$ - risk norm of 10^{-5} .

The mathematical expectation of population losses is calculated using the "Extremum" geographic information system (GIS) [7].

Let us consider an example of assessing karst hazard for the soil mass in the area of a two-story building made of silicate brick. The building is two stories high.

Based on the results of dynamic-geophysical tests, the natural vibration frequencies of the soil and the building, as well as accelerations and damping decrements in the spatial coordinate system X, Y, Z, were obtained. Examples of measurements taken at the site in 2022-2023 are shown in Figures 3-4.

To assess the karst hazard of the construction site, the data on soil mass vibration frequencies in the low-frequency range (up to 20 Hz) and high-frequency range (from 0.1 to 400 Hz) were converted into a hazard parameter ranging from 0 to 10 points. The technical condition of the building blocks was evaluated by comparing the normative values and the squares of the natural vibration frequencies of the blocks obtained from the tests.

In Figures 3-4, the formation of karst hazards is visible in the form of high-frequency noises at frequencies of 60-120 Hz and periodic pulses, repeating every 0.5-1 second, with amplitudes exceeding the background microseismic vibrations by more than 10 times. To create maps of karst hazard for the site, dynamic-geophysical measurement data, depending on the values of the parameters and their level of "noise," were rated (Fig. 5).

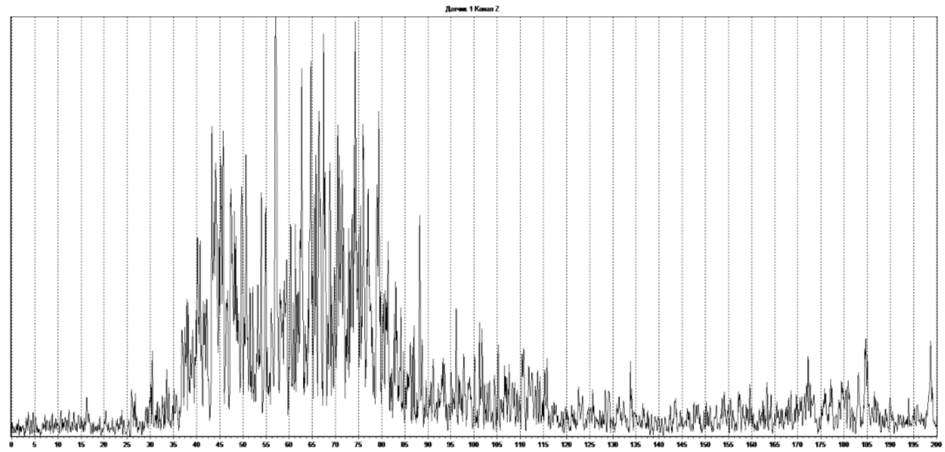

Figure 3: *Vibration spectrum of the "soil-building" system along the Z-axis, data from 2022*.

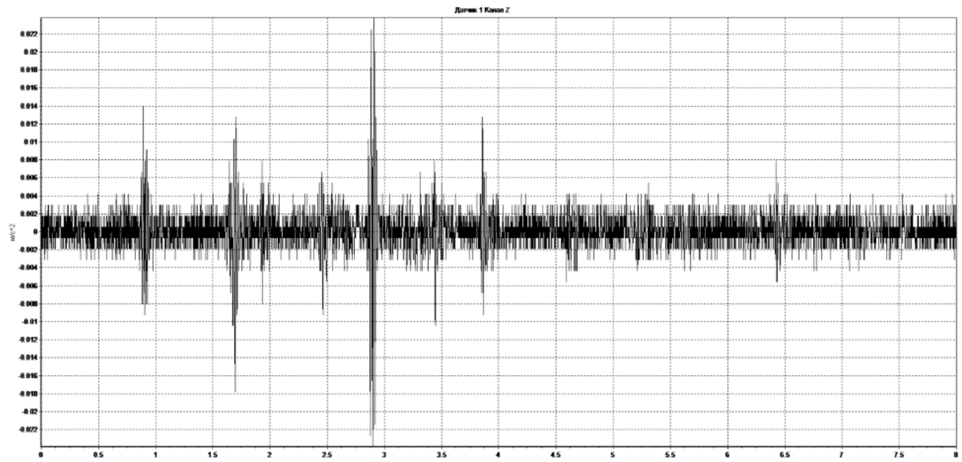

Figure 4: *Vibrations of the "soil-building" system along the Z-axis, data from 2022.*

Figure 5: *Zones of increased karst hazard (marked in red).*

IV. Discussion

The use of the dynamic-geophysical testing method allows for the rapid identification of stiffness deficiencies in the "soil-building" system and the assessment of building vulnerability. By knowing the vulnerability or technical condition of buildings, it is possible to determine the probability and expected losses, as well as calculate individual risk.

With the value of individual risk for the forecasted area, it becomes possible to plan risk reduction measures in a timely manner.

References

[1] Guidelines on Safety "Methodological Foundations for Hazard Analysis and Risk Assessment of Accidents at Hazardous Production Facilities". Moscow: ZAO NTU PB, 2016.

[2] Nigmetov, G.M., Chubakov, M.Zh. Problems of Monitoring Buildings and Structures. Seismic-Resistant Construction and Safety of Structures, No. 4, 2011, pp. 51-55.

[3] Larionov, V.I., Nigmetov, G.M., Shakhramanyan, M.A., Suschev, S.P., Ugarov, A.N., Frolova, N.I. Application of GIS Technologies for Assessing Individual Seismic Risk. Seismic-Resistant Construction, No. 2, 1999.

[4] Methodology for Comprehensive Individual Risk Assessment in Emergencies of Natural and Technogenic Origin. Moscow: 2002, VNII GOChS (FC) of the Ministry of Emergency Situations of Russia.

[5] Nigmetov, G.M., Savinov, A.M., Savin, S.N., Nigmetov, T.G., Simonyan, A.R. Dynamic-Geophysical Tests of the Technical Condition and Earthquake-Resistance of Historical Buildings. AlfaBuild, Vol. 21/1, ISSN: 2658-5553, pp. 2101.

[6] Savinov, A., Nigmetov, G., Nigmetov, T., Galliulin, R. The Possibility of Vibrodynamic Data from Phone Accelerometers for the Rapid Assessment of the Technical Condition of Buildings and Structures. Proceedings of STCCE. International Scientific Conference on Socio-Technical Construction and Civil Engineering 2022: Lecture Notes in Civil Engineering,

Switzerland, 2022, pp. 371-379.

[7] Nigmetov, G., Savinov, A., Nigmetov, T. Assessment of Individual Seismic Risk for the Population, Taking into Account the Actual Seismic Resistance of Buildings and the Seismicity of Soils. Reliability: Theory & Applications, 2022, Vol. 4, No. 70, p. 172.

USE OF SOLAR ENERGY RESOURCES IN THE TERRITORY OF THE REPUBLIC OF AZERBAIJAN

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Abstract

The article proposes a method for calculating the solar energy potential for the Republic of Azerbaijan and presents the obtained results. The annual amount of sunlight falling on the territory of the Republic of Azerbaijan has been scientifically analyzed. The results obtained on a sample solar collector on the use of solar thermal energy are presented. The experiments were carried out in the summer months and the results show that the highest temperature in the solar collector during the day is obtained in the second half of the day. Here, as a result of the experiments, the dependence of the temperature on the hours of the day is graphed.

Keywords: Solar energy, solar collector, solar energy potential, thermal energy, technical potential

I. Introduction

The development of green energy and the access of green energy to world markets are currently the priority of Azerbaijan's energy policy. Expanding the use of renewable energy sources in the field of energy in our country has been put forward as a priority task by our state, and the goal of increasing the share of renewable energy in the installed capacity of electricity to 30 percent by 2030 has been determined. Also, the 29th session of the Conference of the Parties to the UN Framework Convention on Climate Change (COP29), which will be held in our country, will create new approaches to climate change and promote cooperation between various stakeholders. Everyone in the world will once again see that our agenda is about green energy. To combat climate change, significantly reduce greenhouse gas emissions to reduce risks in this area, achieve technology transfer to achieve low-carbon development worldwide, finance renewable energy, as well as find other innovative solutions to reduce emissions and adapt to climate impacts, it is important to expand policies promoting the use of renewable energy, grid integration and energy efficiency measures. Expanding the use of solar energy is one of the important tasks in the direction of reducing greenhouse gases in our country. Huge projects are being implemented in our country in the direction of purchasing electricity from solar energy, but the production of thermal energy is just as important.

The Republic of Azerbaijan is rich in solar, wind and other renewable energy sources and has highly qualified specialists for their use. The use of ecologically and economically favorable solar energy is of great importance in our country. The values of insolation in cloudless air are 800÷1000 kW·h/m² during the year for the Absheron peninsula and the Caspian coastal strip. The number of sunny hours here is 2500 hours per year. For the Autonomous Republic of Nakhchivan, these figures are more appropriate, 1100÷1200 kWh/m² and 2900 hours, respectively.

Modern photovoltaic modules are solar installations available to provide industrial facilities, residential areas and commercial facilities with high technical characteristics. At the same time, these devices convert direct current energy into alternating current energy by means of an inverter and are used to create a reliable energy source.

Among the methods of using solar energy, two options of photothermal conversion are used more: heat supply of residential, communal and agricultural enterprises; obtaining electricity by means of steam and gas turbines.

The first option is used more often, there is little transition to the use of the second option.

The potential amount of solar energy of the region means the total amount of solar radiation falling on the territory of the region during one year and depends on the climatic conditions of this region (Eum, kWh/(m²·year)). The linear size of potentially measured zones is taken up to 200 km.

II. Methods

Cadastral data is used to determine solar energy potential. The displayed data should reflect the spatio-temporal dynamics of solar radiation fall and the characteristics of meteorological factors affecting it. The following information is usually included in the solar cadastre: average monthly and average annual total cloudiness; probability of clear and cloudy skies; clear air attendance coefficient; average monthly and average annual duration of solar radiation; average hourly values of the main elements of solar radiation incident on a horizontal surface under conditions of medium cloudiness. Usually 0.1% of the incident solar radiation is attributed to the technical potential. The annual duration (in hours) of the length of the day at the 38-42nd parallels of heliograph observations at the meteorological stations in the territory of the Republic of Azerbaijan was determined.

At the limit of the atmosphere, the solar radiation falling on the horizontal plane can be calculated analytically. Actinometric observations cannot be made at all locations, but analytically, it is possible to calculate the horizontal solar radiation falling on the surface at the upper boundary of the atmosphere at any latitude with great accuracy. The values of solar radiation were calculated in 1 degree increments for latitude circles covering the entire territory of the Republic of Azerbaijan, i.e. from the 38th latitude to the 42nd latitude, and are shown graphically in Figure 1. As can be seen from the graph, due to the small size of the area, solar radiation values are almost unchanged in the hot season, while in the cold season, small differences in latitude are observed.

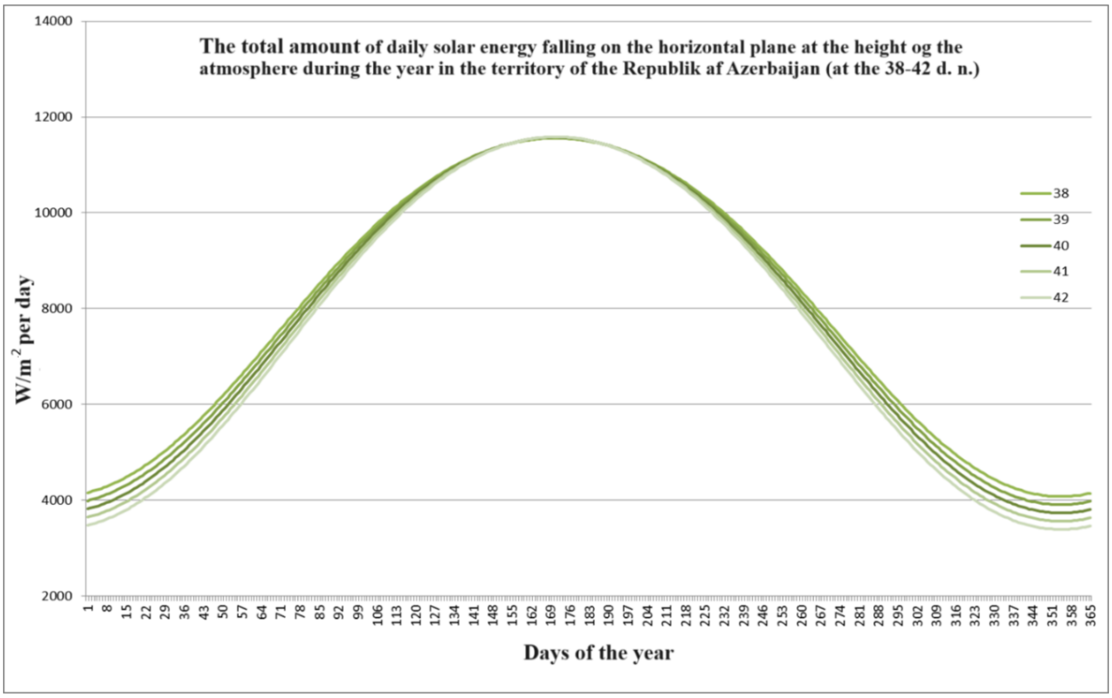

Figure 1: *The graph of changes in solar radiation values depending on the season*

The technical potential of heat and electric energy of the area is taken as the sum of heat and electric energy produced by the taken technical means. During the determination of thermal energy, the technical characteristics of the technical device, i.e. the solar collector, are taken. In the determination of electric power, the energy characteristics of photoelectric devices are considered as the basis.

III. Results

The technical potential of Solar Energy is calculated as follows:

$$E_{tex} = E_{tot} * S * \tau * \eta_{sp} * \eta_0 \quad (1)$$

$\boldsymbol{E_{tex}}$- technical potential of solar energy
$\boldsymbol{E_{tot}}$- solar energy total potential
$\boldsymbol{S}$ - solar panel area (m^2)
$\boldsymbol{\tau}$ – light emission capacity of the solar panel (0.85)
$\boldsymbol{\eta_{sp}}$- useful work coefficient of the solar panel (0.15)
$\boldsymbol{\eta_0}$- useful work coefficient of energy conversion and transmission to the consumer (0.83)
$\boldsymbol{\eta_0}$ - is calculated in the following manner

$$\eta_0 = K * \eta_{conv} * \eta_{tran} \quad (2)$$

here
η_{conv} – conversion – useful efficiency of conversion (0.9)
η_{tran} – transmission-is the useful efficiency of the transmission (0.95)
K – is the coefficient according to the angle of inclination of the panel.

When the inclination angle is equal to the width of the point, K=1.3, that is, the radiation increases by 30%.

Accepting the above coefficients, we can calculate the technical potential of solar energy in the following manner:

$$E_{tex} = E_{tot} * 1 * 0.85 * 0.12 * 0.83 = 0.085 * K * E_{tot} \quad (3)$$

Table 1 shows the potential of solar energy calculated in the above manner. For a given solar installation, the average annual technical potential of the area with horizontal panels is 121.23 kWh per square meter. At this time, the average technical potential of the area fluctuates between 100-160 kWh.

We find the average technical power of solar installations as follows:

$$\bar{P} = \frac{E_{tex}}{8760} \quad (4)$$

The power of technical potential is 8-15 W/m^2 in January, and 22-36 W/m^2 in July. Average annual prices are 15-23 W/m^2.

The solar energy potential of the Republic of Azerbaijan and its administrative regions was calculated separately using the above formulas, data from hydrometeorological stations and research results of ANAS institutes. Areas suitable for agriculture, areas of forest funds were not taken into account in the calculations (parameters for several cities and regions are presented in Table 1).

Table 1: *Solar energy potential of the administrative regions of the Republic of Azerbaijan*

№	The name of the areas	Common area, huh	K/t usable area, huh	K/t usable area, huh	Areas suitable for the use of solar energy, yes
1	Aghdam	137221	90376	1014	45831
2	Agdash	94720	52401	7568	34751
3	Agstafa	123996	76175	6489	41332
4	Nax.MR;	536300	157165	4158	374977
5	Nagorno-Karabakh	497951	220004	128769	149178
6	Baku general	187416	4973	0	182443
7	Sumgait general	10865	1056	0	9809
8	Ganja	8307	900	0	7407
9	total for Azerbaijan;	8641506	4514473	1063480	3063553

Using solar radiation parameters, the technical potential of administrative regions, large cities and the country as a whole was determined (Table 2).

As can be seen from the tables, the solar energy potential of the Republic of Azerbaijan is 47.5 billion kWh and the technical potential to be achieved with the solar panels to be installed is 43.2 thousand MW. Using this potential, it is possible to obtain a large amount of funds from the export of oil and gas resources of our country.

It is more efficient to use solar collectors in relatively warm areas of the country. Our newly designed solar collector is similar to the solar collector used for air heating with a number of changes.

Table 2: *The technical potential of administrative regions was determined by using parameters of solar radiation*

№	The name of the areas	Duration of solar radiation, hours	Total radiation of solar energy (kW*h/m2)	Potential power of annual total (flatly scattered) radiation (W/m2)	Technical potential of total solar radiation falling on areas suitable for use of solar energy, (GWh*h)	The power of solar panels installed in the purchase of technical potential, MW
1	Aghdam	2310	1499,51	160	687	595
2	Agdash	2400	1450	160	504	420
3	Agstafa	2350	1550	175	641	545
4	Nax.MR;	2760	1717	195	6438	4665
5	Nagorno-Karabakh	2200	1200	150	1790	1627
6	Baku general	2244	1455,99	165	2656	2368
7	Sumgait general	2200	1400	160	137	125
8	Ganja	2320	1504,78	160	111	96
9	total for Azerbaijan;	2200	1552	162	47546	43224

Stainless steel plates with a thickness of 0.5 - 2 mm are used in the preparation of the solar collector to increase the service life and reduce the cost (Fig. 2). As you can see, the lower part of the solar collector is made of a rectangular prism, and the upper part is made of a trapezoidal prism. In the lower part, the water is heated by the sun's rays, moves up and is put to use. In order to reduce heat losses, the lower part of the solar collector is covered with heat insulating material.

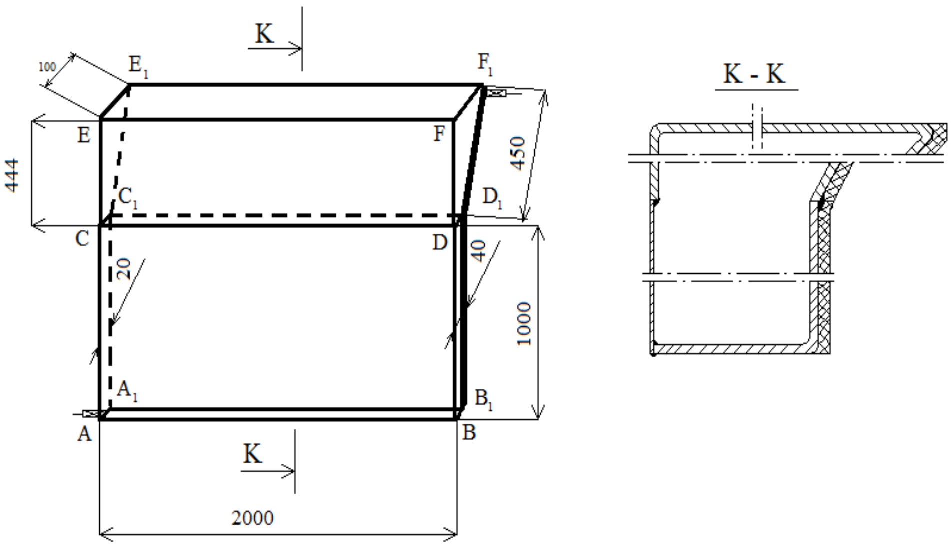

Figure 2: *Stainless steel plates*

Experiments were carried out in the middle of July on the Absheron Peninsula using the provided solar collector, and it was determined that the highest water temperature was obtained through the solar collector around 16:00.

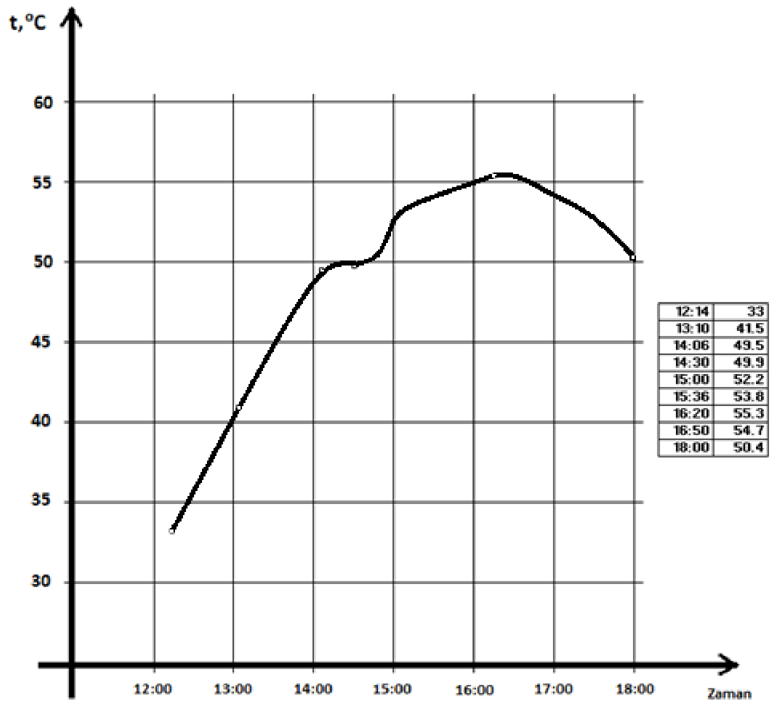

Figure 3: *Water temperature*

Our country has great resources for the production of both electricity and heat energy from solar energy. Investments by the public and private sector are essential for the utilization of these resources. With this, new jobs will be opened, energy security, environmental cleanliness and export potential of traditional energy resources will be achieved.

IV. Conclusion

Expanding the use of solar energy is one of the important tasks in the direction of reducing greenhouse gases in our country. Huge projects are being implemented in our country in the direction of purchasing electricity from solar energy, but the production of thermal energy is just as important.

The Republic of Azerbaijan is rich in solar, wind and other renewable energy sources and has highly qualified specialists for their use. The use of ecologically and economically favorable solar energy is of great importance in our country.

The solar energy potential of the Republic of Azerbaijan and its administrative regions was calculated separately using the above formulas, data from hydrometeorological stations and research results of ANAS institutes. Areas suitable for agriculture, areas of forest funds were not taken into account in the calculations

As can be seen from the tables, the solar energy potential of the Republic of Azerbaijan is 47.5 billion kWh and the technical potential to be achieved with the solar panels to be installed is 43.2 thousand MW. Using this potential, it is possible to obtain a large amount of funds from the export of oil and gas resources of our country.

It is more efficient to use solar collectors in relatively warm areas of the country.

References

[1] Yusifbayli N.A., Kalbiyev R.K. Solar energy potential of the Republic of Azerbaijan. İnternational Conference “Modern Trends in Physics”. 01-03 May 2019, Baku. Dedicated to the 100th anniversary BSU, p.122.

[2] Badalov A.B., Kalbiyev R.K., Barkhalov R.R., Kalbili N.R. Prospects for the Development of Renewable Energy in Azerbaijan. Moscow: "Energetik", 2015.

[3] Jalilov M.F. Alternative regenerative energy systems. Baku-2009.

[4] Mammadov F.F.. Use of solar energy and modern solar energy installations in Azerbaijan. Textbook. "Progres" publishing house, Baku-2011, 204 pages.

[5] Bekman U., Klein S., Duffy D., Calculation of systems of solar heat supply, M., Energoizdat, 1982.

[6] Duffy D.A., Bekman A. Thermal processes using solar energy. M., Mir, 1977- 429 p.

[7] Kazymov M. Calculation of the energy of solar rays on the territory of the Nakhchivan autonomous republic of Azerbaijan // Innovations in science: sb. Art. by mater. XLVIII international. conf. No. 8(45). – Novosibirsk: SibAK, 2015.

ASSESSMENT OF THE INFLUENCE OF RELIEF ON TERRACING OF THE SLOPES OF THE MAKAZHOY BASIN IN THE CHECHEN REPUBLIC (BASED ON THE MATERIALS OF AIR LASER SCANNING)

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Abstract

In September 2023, an unmanned aerial vehicle was used to conduct airborne laser scanning and aerial photography in the Makazhoy Basin, where the carbon testing ground of the A.A. Kadyrov Chechen State University is located. As a result, a highly accurate digital elevation model (DEM) was compiled for areas of about 170 hectares located on opposite macroslopes of the basin at comparable hypsometric levels (1700-2200 m). Subsequent processing of the DEM using ArcGis software allowed us to quantitatively characterize the microrelief of the test sites and identify, based on morphometric analysis and semi-automated interpretation, the terraces on the mountain slopes that were previously used for agriculture. It was found that the previously existing settlement and farming system in this area took into account the natural resource potential of the mountain slopes. In this regard, the northern macroslopes of the Makazhoy Basin are characterized by greater productivity of natural ecosystems compared to the southern ones. The consequence of these natural causes is that the terraces on the northern macroslope occupy 46% of the test site area, while on the southern one - 26%.

Keywords: Makazhos basin, carbon landfill, aerial laser scanning, unmanned aerial vehicles, digital terrain model, terraces

I. Introduction

Currently, the process of involving mountain territories in economic turnover is accelerating. If in the second half of the 20th century, depopulation of the mountains and a decrease in economic activity were noted here, now they are again attracting attention from the point of view of economic development. This is, not least, due to the fact that the quality of agricultural products produced in the mountains is often higher due to the lower level of pollution of these territories. However, the process of re-involving mountain territories in agricultural turnover should be based on the principles of sustainable development, implying the preservation of the habitat and the minimization of the negative impact on the environment. This is possible on the basis of comprehensive information about the area of economic development.

In the North Caucasus, including the territory of the Chechen Republic, mountainous territories were used for distant-pasture livestock farming. In the warm season, mainly small cattle were driven to high-mountain pastures, where they stayed for almost the entire warm period. In the cold period, they were driven to the flat part, where they wintered. However, within the mountain basins, it was possible to keep farm animals all year round, which was facilitated by natural conditions. Basins are closed territories to varying degrees, formed either by the main ridges or confined to the valleys of the largest rivers. This kind of isolation leads to the formation of a warmer and drier climate and a wider range of soil and plant groups, the spatial distribution of which is determined by local relief features. In this regard, mountain basins were populated and developed quite a long time ago throughout the entire territory of the North Caucasus. This is especially expressed in the largest and most clearly expressed tectonic depression, located to the south of the Rocky Ridge – the North-Jurassic. The basins in the Inner-Mountain Dagestan are also widely expressed.

In this regard, our research covered the Makazhoyskaya depression, located in the southeastern part of the Chechen Republic, on the border with Dagestan. The orographic boundaries of the depression are expressed differently and are represented by a number of ridges.

In the north, the border runs along the Kashekrlam ridge, which further northeast approaches Lake Kezenoy-Am. The eastern border is confined to the spurs of the Gagotytlyur ridge. The southeastern border extends along the local watershed with heights of up to 2500-2600 m. From it, in the Ansalty canyon, the orographic line extends to the south and is expressed by the Khindoy-lam ridge, extending strictly to the west, where at the extreme western point the orographic line extends strictly to the north, after which it turns east-southeast to the watershed between the Akhkete River basin (a tributary of the Ansalty) and the Keloy-akhk, which flows into the Sharo-Argun. The area of the basin within the specified boundaries is 144 km^2 (Fig. 1, 2).

Figure 1: *Chechen Republic. Physical map*

Interest in the Makazhoy depression is also associated with the fact that the carbon testing ground of the Chechen State University named after A.A. Kadyrov is located here, one of the tasks of which is to develop a methodology for regenerative livestock farming in mountainous conditions.

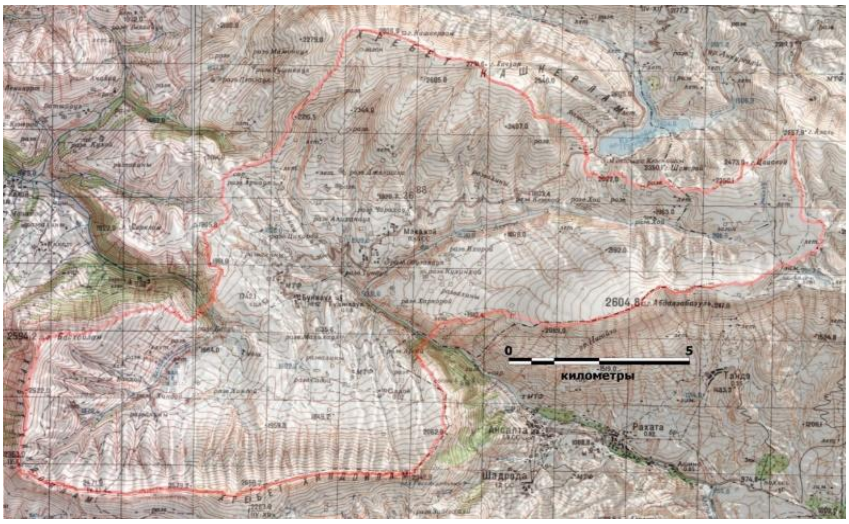


Figure 2: *Position and orographic features of the Makazhoy basin*

Previously, an analysis of the relief of the depression was carried out based on the digital elevation model of the average spatial resolution of the European Space Agency FABDEM V1-0 with a resolution in this part of about 27 m [3] using standard methods [4-6]. It was found that the depression is dominated by heights of 1600-2000 m, which account for 43.0% of the territory, the most common slopes are 10-15 ° (23.8%), 20-30 ° (23.5%) and 5-10 ° (19.7%). As for the exposure, the southern (16.6%) and northwestern (16.2%) slopes are most widely represented. These macro-exposure differences determined not only the distribution of the soil and vegetation cover across the basin, but also its economic development, which manifested itself in the terracing of the slopes. They are reflected in the modern microrelief, are clearly visible during a visual inspection of the territory and are its peculiarity. However, they are not revealed by the global digital elevation model due to its low spatial resolution. In this regard, detailed high-precision studies based on other methods are necessary.

Currently, unmanned aerial vehicles (UAVs) are actively used to obtain detailed information about the microrelief of a territory, which allows for prompt receipt of information at a local level [1, 2]. Aerial photography (AP) and airborne laser scanning (ALS) are used for these purposes. These high-tech methods of collecting geospatial data allow for obtaining detailed digital models of relief and terrain, as well as orthophoto plans, which are then used for geospatial analysis of mapped territories.

II. Methods

In the autumn of 2023, field studies and airborne geodetic works were carried out in the Makazhoy Basin, which included geodetic works, aerial photography and airborne laser scanning [7]. The survey sites were located in the eastern part of the basin in the altitude intervals of 1700-2200 m and covered 2 sites. Highly detailed AFS was carried out on 2 sites. The first of them is the territory of the carbon test site of the A.A. Kadyrov ChSU, where the regenerative livestock farming technology is being developed, located on the northern macroslope of the Makazhoy Basin. The area of this site is 168.0 hectares. The second site is located on the opposite, southern macroslope of the basin, and occupies an area of 169.4 hectares (Fig. 3).

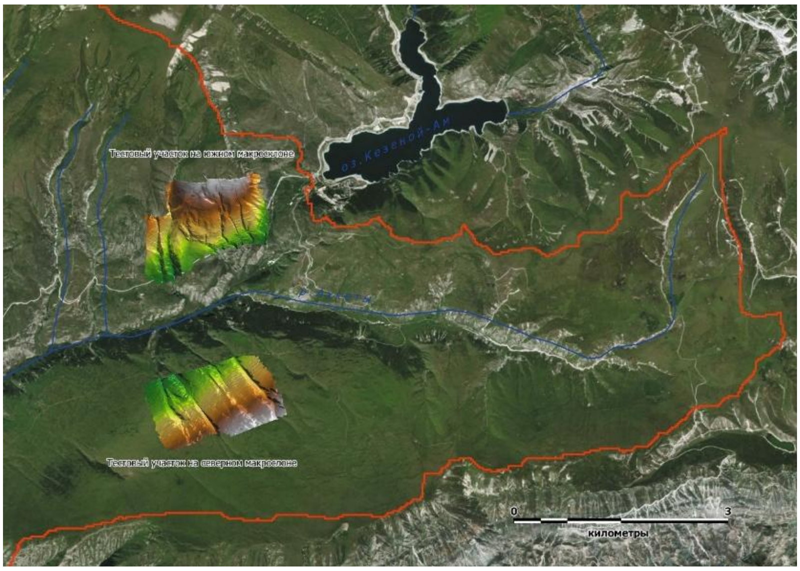


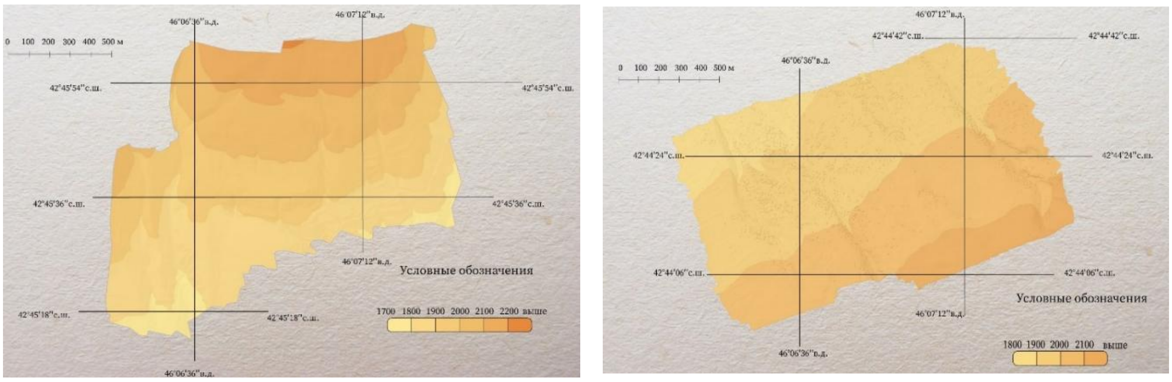
Figure 3: *Location of test sites within the Makazhoy basin*

Aerial photography and airborne laser scanning were carried out using the GEOSCAN 401 Lidar UAV by staff and students of the Moscow State University of Geodesy and Cartography and the A.A. Kadyrov Chechen State University. Photogrammetric processing of the aerial photography results was performed using Agisoft Metashape software. Point clouds obtained using the UAV were processed in Terrascan and Credo 3D SCAN software. As a result, it became possible to separate points into the "land" and "vegetation" classes, and highly accurate digital elevation models with a resolution of 0.1 m were compiled [7]. To remove information "noise" associated with the presence of different-height, mainly herbaceous vegetation, the original resolution was reduced to 0.5 m, which made it possible to more accurately identify the features of the microrelief itself.

Mapping and analysis of the DEM was carried out using ArcGis software. Maps of the areas were created at a standard scale (1:10,000). An individual projection was selected for the coordinate grid (PROJCRS ["ProjWiz_Custom_Lambert_Azimuthal", BASEGEOGCRS ["WGS 84", DATUM ["World Geodetic System 1984", ELLIPSOID ["WGS 84",6378137,298.257223563, LENGTHUNIT["metre",1]], ID ["EPSG",6326]]).

III. Results

The distribution of the test areas by elevation marks is illustrated in Fig. 4 and Table 1



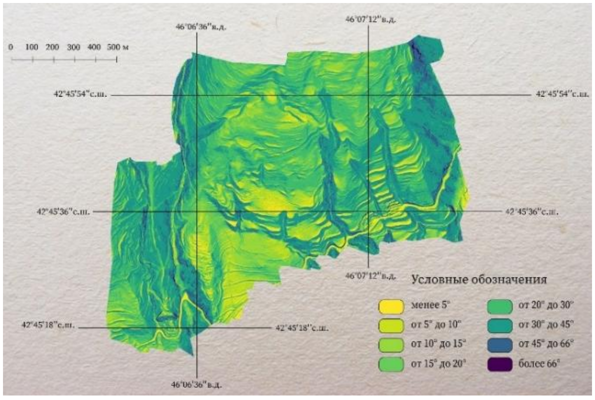
a) section of the southern macroslope *b) section of the northern macroslope*

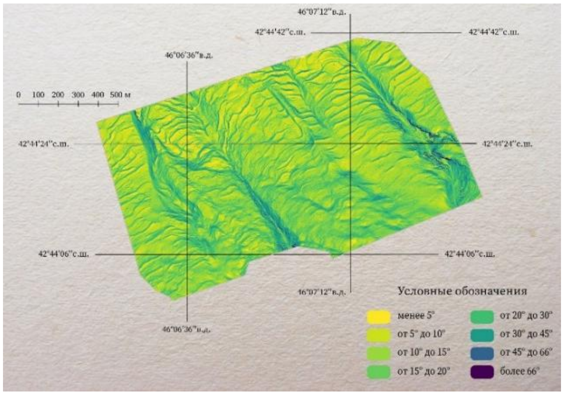
Figure 4: *Hypsometric map of the southern (a) and northern (b) macroslopes of the Makazhoy basin*

Table 1: *Distribution of the test site area by elevation marks*

Height, meters	Southern macroslope		Northern macroslope	
	hectare	%	hectare	%
1700-1750	0,7	0,4		
1750-1800	9,6	5,7		
1800-1850	22,1	13,1	0,4	0,2
1850-1900	27,2	16,0	17,0	10,1
1900-1950	22,8	13,5	35,3	21,0
1950-2000	24,4	14,4	37,5	22,3
2000-2050	20,7	12,2	36,9	22,0
2050-2100	18,5	10,9	25,8	15,4
2100-2150	14,3	8,4	14,7	8,8
2150-2200	9,2	5,4	0,3	0,2
TOTAL	169,4	100,0	168,0	100,0

As can be seen from the presented data, there is a well-defined asymmetry in terms of the distribution of areas by elevation marks. Thus, on the southern macroslope, where the range of elevations is almost 100 m greater than on the northern one, the main territories are confined to the heights of 1800-2000 m, after which the areas of territories located in the highlands begin to shrink. As for the northern macroslope, here the heights of 1900-2050 m account for more than 65% of the territory, and at the same time the most elevated areas are more widespread compared to those occupying the lowest hypsometric levels. It is also clearly visible that the northern macroslope is much more gentle than the southern one, which well illustrates the distribution of the territory by slope steepness. The change in steepness on the slopes of the Makazhoyskaya Depression test sites is illustrated by Fig. 5 and Table 2.





a) section of the southern macroslope *b) section of the northern macroslope*

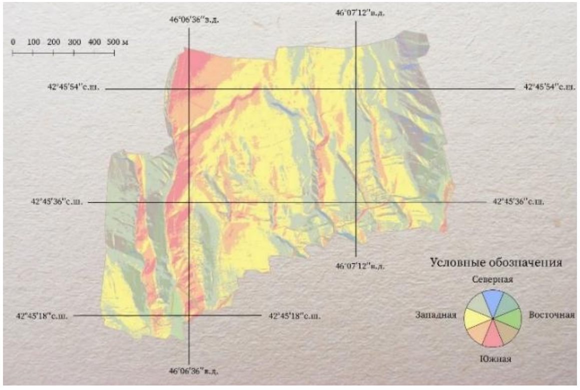
Figure 5: *Map of the steepness of the slopes of the southern and northern macroslopes of the Makazhoy basin*

The presented data indicate that the distribution pattern of steepness on the macroslopes is generally opposite. The steepest (more than 45°) and the most gentle (less than 5°) slopes occupy the smallest areas on both slopes. On the northern macroslope, where the regenerative livestock farming site is located, slopes with a steepness of 10-15◎ are most widely represented (29.2°), and steeper (15-20°) and gentler (5-10°) slopes are also quite widely represented (21.3 and 20.3%, respectively). As the steepness increases, the area of the slopes decreases. As for the southern macroslope, a gradual increase in the area of slopes up to a steepness of 30-45° is noted here, which account for 33.3%. The larger area of steep slopes on the southern macroslope is explained by the large amount of solar radiation coming here and contributing to more active geomorphological processes. In particular, here, compared to the area located on the northern macroslope, erosional relief forms are presented more widely, aerosional cuts, to which the steepest slopes are confined, have become more widespread.

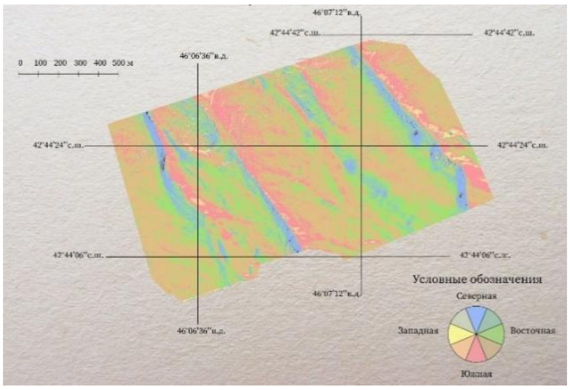
Table 2: *Distribution of the test site area depending on the steepness of the slopes*

Slope, degrees	Southern macroslope		Northern macroslope	
	km ^{2}	%	km ^{2}	%
0-5	4,2	2,5	8,0	4,7
5-10	11,2	6,6	34,1	20,3
10-15	17,0	10,0	49,0	29,2
15-20	23,3	13,8	35,7	21,3
20-30	46,5	27,4	31,5	18,8
30-45	56,4	33,3	8,6	5,1
45-66	10,3	6,1	0,9	0,5
66 и более	0,4	0,2	0,2	0,1
TOTAL	169,4	100,0	168,0	100,0

Distribution of slopes depending on their exposure on the test sites of the Makazhoyskaya depression is illustrated in Fig. 6 and Table 3.



a) section of the southern macroslope



b) section of the northern macroslope

Figure 6: *Map of the exposure of the slopes of the southern and northern macroslopes of the Makazhoy basin*

Table 3: *Distribution of the test site area depending on the slope exposure*

Exposition	Southern macroslope		Northern macroslope	
	га	%	га	%
North	0,4	0,2	37,1	22,1
Northeast	2,6	1,5	10,2	6,1
East	24,1	14,2	2,2	1,3
Southeast	44,8	26,4	1,7	1,0
South	60	35,4	2,2	1,3
Southwest	25,3	14,9	5,7	3,4
West	11	6,5	24,7	14,7
Northwest	1,2	0,7	84,2	50,1
TOTAL	169,4	100,0	168,0	100,0

As in the case of slope steepness, the opposite pattern of distribution of this parameter is generally observed. Thus, due to the fact that the carbon polygon area is confined to the northern macroslope of the Makazhoyskaya Basin, the slopes of the north-western (50.1%), northern (22.1%)

and western (14.7%) are most widely represented here, i.e. 86.9% of the entire area of the area. In the second test area, the southern (35.4%) and south-eastern (26.4%) are most widely represented, i.e. more than 60% of the territory. Nearby areas have north-western and eastern slopes (about 14%). That is, the test sites in these areas of the Makazhoyskaya Basin are located on its north-western and south-eastern mesoslopes.

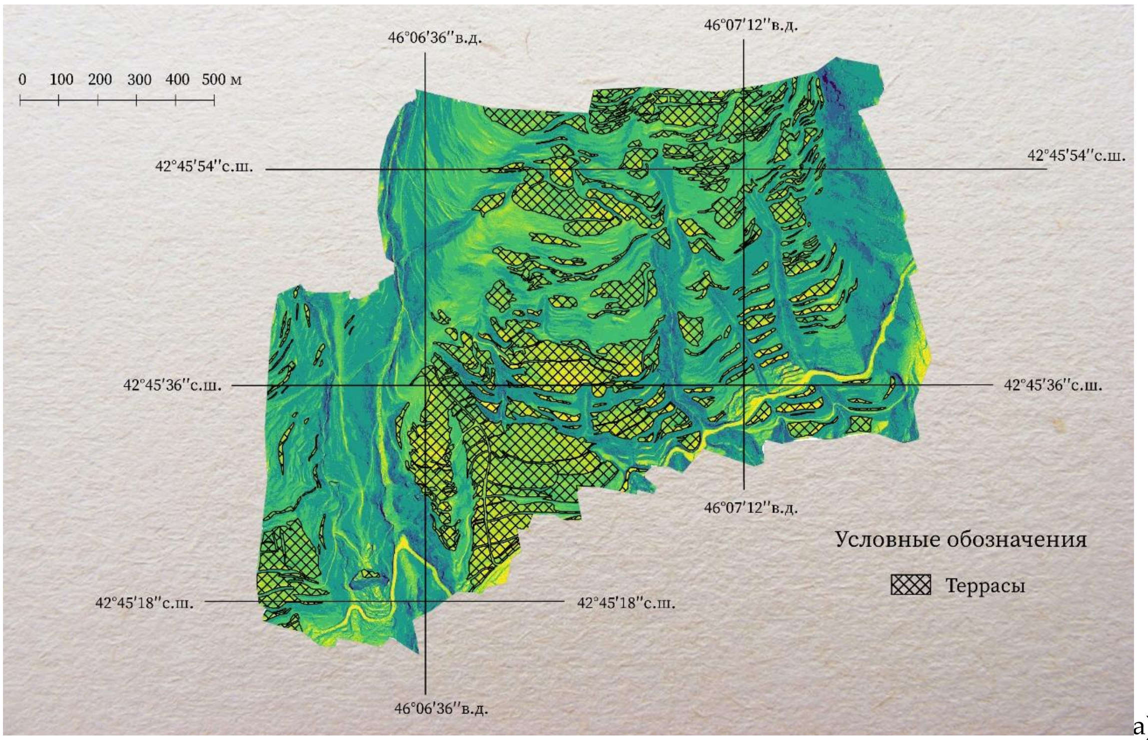
The provided maps, created on the basis of the DEM, also allowed to compile a map of terraces, which were created by the population to intensify mountain nature management. In terms of relief, terraces are sections of mountain slopes, the steepness of which is reduced by creating retaining walls. As a result, these flattened sections can be determined quite well on the basis of the digital elevation model.

Terrace mapping is based on 3 groups of methods: manual, semi-automatic and automatic. Preliminary analysis of the initial data showed that the most accurate result is obtained by combining manual and semi-automatic methods. During the preliminary analysis, the semi-automatic method with vectorization using preliminary selection of terraces using manual tracing was recognized as the most accurate. This method combines both the best accuracy and the time spent on vectorization with the supporting requirements for the data.

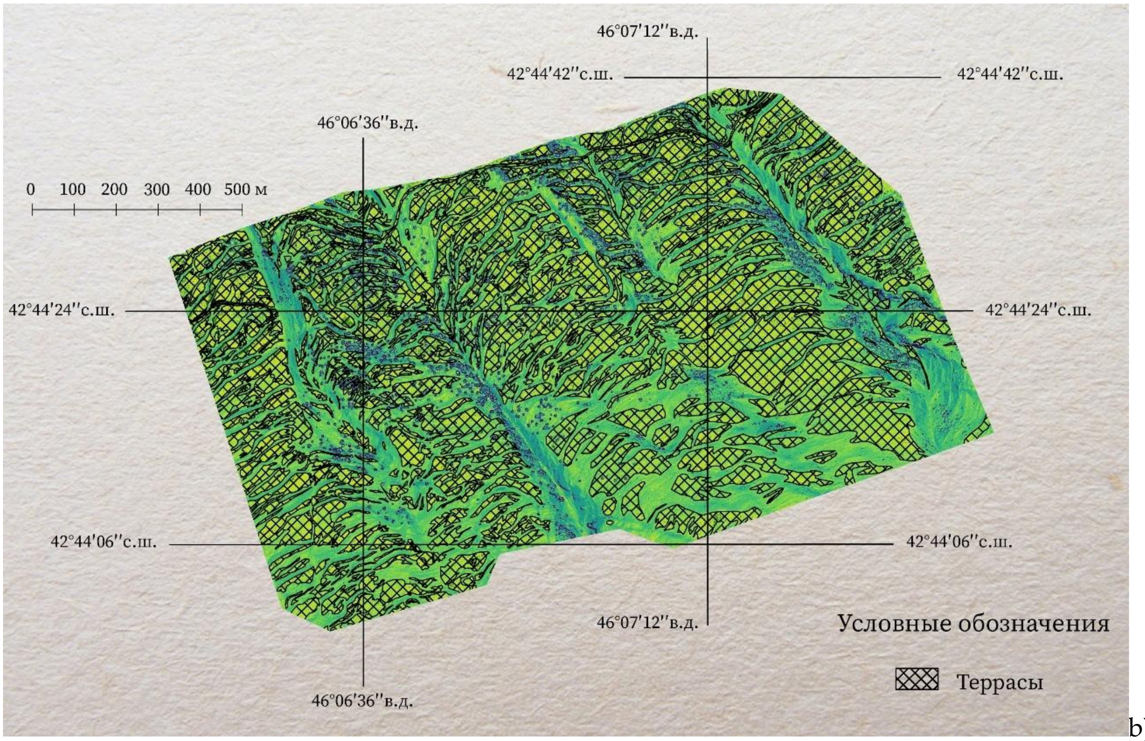
The results of terrace selection based on the DEM within the Makazhoy Basin are illustrated in Fig. 7.

The calculations showed that with a total area of the southern macroslope of the Makazhoy Basin of 169.4 hectares, the area of the terraces is 44.1 hectares, or 26% of the territory. The test site of the regenerative livestock farming site of the A.A. Kadyrov CheSU, confined to the northern macroslope of the Makazhoy Basin, has an area of 168.0 hectares, of which the terraces occupy 76.6 hectares, or 46%.

The maps clearly show that only slopes with minimal steepness were subjected to terracing. To increase the efficiency of agricultural management, it was necessary to create single, largest-area terrace sections, which was achieved to the maximum extent on the northern macroslope. As for the southern macroslope, the fragmentation and mosaic nature of the terraces is quite well expressed here, which is expressed in the presence of a fairly large number of small fragments, most widely represented in the eastern part of the test site. The high degree of agricultural development of the territory is confirmed by the presence of a large number of ruins reflected on late Soviet topographic maps (Fig. 8), reflecting the state of the area in the 1980s. They clearly show that all areas of the basin were intensively developed. The southern macroslope was used to the greatest extent for construction and residence, while the northern slope, apparently, was used for hayfields and pastures due to the better productivity of pastures, since the settlements here are confined to the part that adjoins the Akhket River.



a)



b)

Figure 7: *Map of the terraces of the southern (a) and northern (b) macroslopes of the Makazhoy basin*

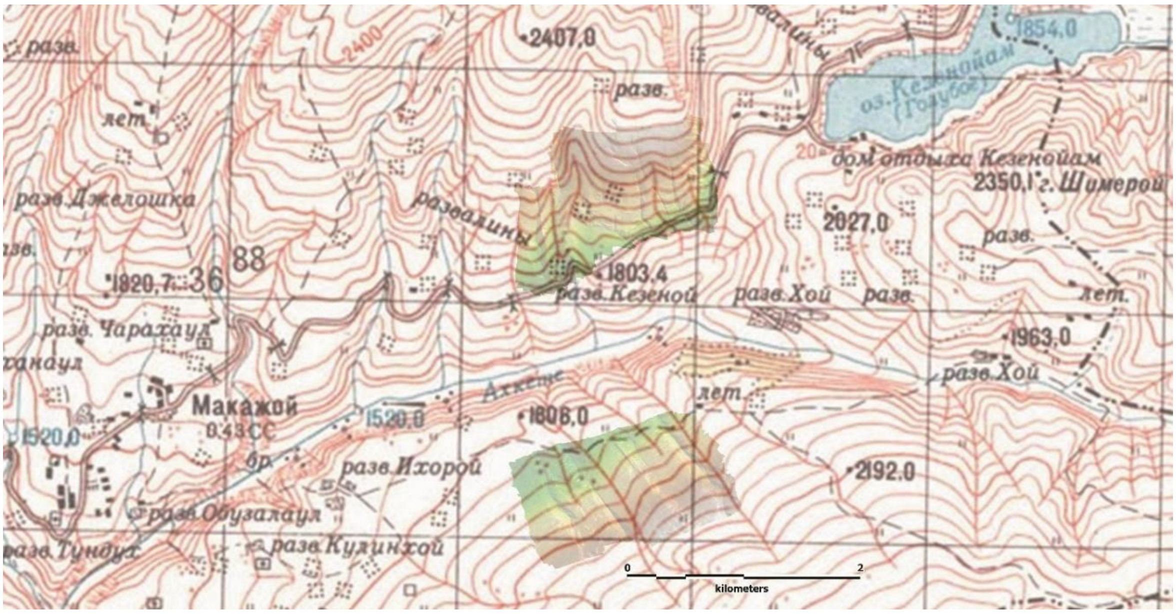


Figure 8: *Fragment of a topographic map illustrating the historical aspect of the degree of economic development of the territory*

IV. Discussion

The conducted study allowed to conduct a comparative analysis of the relief of the southern and northern macroslopes of the Makazhoy Basin based on a series of large-scale morphometric maps obtained on the basis of a digital elevation model. The latter was created by airborne laser scanning during the survey from a unmanned aerial vehicles.

A comparative analysis of the distribution of morphometric indicators (hypsometry, steepness and slope exposure) revealed that on test sites comparable in absolute height and occupied area, the northern macroslopes of the Makazhoy Basin are characterized by generally more gentle slopes. It is this fact that makes it possible to suggest that this parameter is decisive for their terracing in order to intensify economic use. This fact is confirmed by the fact that terraces on the northern macroslope occupy 46%, while on the southern one they are almost twice as small (26%). The created digital elevation models allow for a quantitative assessment of the processes of formation of phytomass reserves and its products at the local level, and in combination with microclimatic observation data, they can serve as a basis for GIS modeling of productivity and the possibility of developing optimal loads on pastures.

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References

[1] Wei Zhao, Meini Wang, V. T. Pham, and R. Mo. 2023. Unmanned Aerial Vehicle and Geospatial Analysis in Smart Irrigation and Crop Monitoring on IoT Platform. Mob. Inf. Syst. 2023 (2023). https://doi.org/10.1155/2023/42136454. 3

[2] White, C.T.; Reckling, W.; Petrasova, A.; Meentemeyer, R.K.; Mitasova, H. Rapid-DEM: Rapid Topographic Updates through Satellite Change Detection and UAS Data Fusion // Remote Sens. 2022, 14, 1718. https://doi.org/10.3390/ rs14071718 6

[3] Bekmurzaeva R.Kh., Skripitsyna T.N., Bratkov V.V., Bulaeva N.M. Morphometric characteristics of the relief of the Makazhoy depression (Chechen Republic) // Monitoring. Science and Technology. 2024. No. 1 (59). P. 47-54.

[4] Pogorelov A.V., Dumit Zh.A. Relief of the Kuban River basin: Morphological analysis.

Moscow: GEOS. 2009. 208 p.

[5] Simonov Yu. G. Morphometric analysis of the relief. - M.-Smolensk: Publishing House of Smolensk Humanitarian University, 1998. - 272 p.

[6] Simonov Yu. G. Explanatory morphometry of the relief. - M.: GEOS, 1999. 251 p.

[7] Skripitsyna T.N., Vorotylov A.G., Kochneva D.A., Smirnov E.A. Some results of the integrated expedition of MIIGAiK to the Chechen Republic // GEOPROFI, 2024, M: OOO Information Agency GROM No. 2. P. 10-17.

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THE IMPACT OF THE COVID-19 PANDEMIC ON GLOBAL ENVIRONMENTAL CHANGE AND ITS CONSEQUENCES FOR HUMAN HEALTH

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Abstract

The COVID-19 pandemic has had a significant impact on global environmental change, primarily through the reduction of greenhouse gas emissions and air pollution due to the sharp decline in economic activity, particularly in the transportation and industrial sectors. While these changes brought temporary environmental improvements, such as better air quality and reduced water pollution, they did not offset long-term environmental challenges. The pandemic's effects on human health have been mixed: on one hand, improved air quality may have reduced respiratory illness-related morbidity, while on the other hand, the economic downturn and disruptions in healthcare services negatively affected public health. The long-term implications of the pandemic highlight the need for a transition toward more sustainable economic activities and improved natural resource management to mitigate future health and environmental risks.

Keywords: greenhouse gas emissions, air pollution, human health, sustainable development, climate change, air quality, economic downturn

I. Introduction

The COVID-19 pandemic and the associated social restrictions such as isolation and travel restrictions have impacted various areas of society, as well as people's work and personal lives. The impact of the pandemic has varied depending on the sector of work, socio-economic situation and other factors. For example, depending on the requirements for physical presence in the workplace and the availability of remote working options, people have experienced different changes in their daily lives.

At the global level, the COVID-19 pandemic has exposed systemic weaknesses in infrastructures, supply chains, government preparedness and response, as well as human resources and public health systems. The pandemic has challenged public health officials and health system managers to maintain a coherent narrative of measures to control the spread of COVID-19. Among other challenges encountered in the fight against the virus, it became apparent that many health facilities were ill-equipped and unprepared for the influx of patients, and had insufficient medical and epidemiological training to adequately care for patients. Overall, public health systems were unprepared to deal with a new viral pathogen that was rapidly spreading across the world, as containment measures were not rigorous enough and were not effectively implemented at the most critical time.

More than two years after the emergence of SARS-CoV-2, it has become clear that collaboration in information sharing between governments and health care providers, as well as clear and timely communication with the public, are critical to slowing the spread of the disease and preventing a resurgence of the pandemic. However, it is still unclear whether health measures in any country have adapted to the possibility of another outbreak.

Part of the recovery from the pandemic requires reorganizing public health systems to be better prepared to manage new outbreaks of diseases that have overburdened the traditional hospital system and significantly reduced the quality and volume of health care. Thus, public health systems must be rebuilt to effectively and competently manage emerging infectious diseases and are framed around five key activities: (1) governance, (2) protection, (3) containment through transmission control and suppression, (4) information, and (5) support (see Figure 1).The COVID-19 pandemic has put immense pressure on global economic and healthcare systems, underscoring the extent of global interconnections and the critical need for preparedness against global health threats (fig.1). Current efforts are largely centered on pandemic response, including developing treatments and vaccines. However, other pressing health threats, driven by human activities—such as climate change, pollution, urbanization, and unsustainable consumption—may seem less urgent. These factors have caused significant environmental disruption and biodiversity loss. Addressing the pandemic in isolation from these issues, through measures like increased use of disposable materials, reduced public transport, or subsidizing polluting industries, may offer short-term economic and health benefits but would undermine long-term goals for human health and sustainability. Climate change and other environmental stressors, along with their impacts on human and ecosystem health, remain ongoing challenges. The COVID-19 crisis highlights the links between environmental changes and the emergence of infectious diseases, emphasizing the urgent need for prevention, as controlling pandemics in a globalized world has proven difficult. This situation calls for a planetary health perspective in governance and research, adopting interdisciplinary, transdisciplinary, and cross-sectoral approaches.

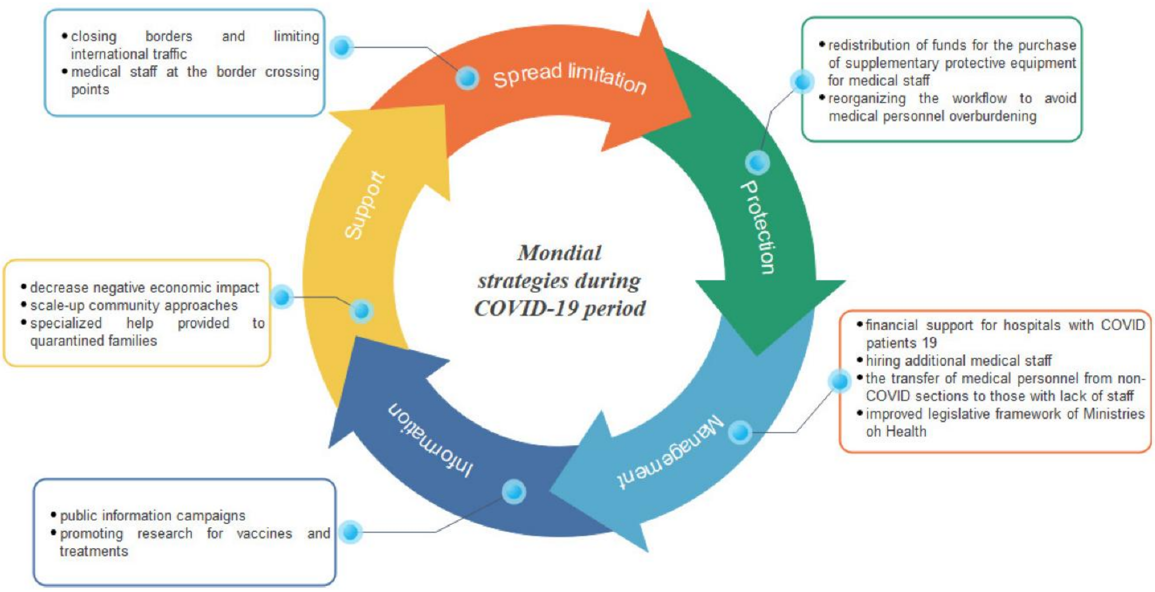

Figure 1: *Mondial strategies during C19, describing five measures that focus on redesigning public health care systems to better manage future pandemic events*

Compounding the response to COVID-19 are concurrent global challenges such as heat waves, wildfires, locust swarms in East Africa, droughts, and the severe 2020 cyclone season. Additionally, the pandemic itself is likely to impede optimal responses to these threats, overburdening under-resourced public health systems, complicating evacuations and emergency measures, and fostering the spread of misinformation and conspiracy theories. The pandemic and environmental health issues are deeply intertwined, and we argue that only an integrated global approach that simultaneously addresses infectious diseases and other environmental threats will lead to sustainable solutions and policies to safeguard both human and ecosystem health for current and future generations. In this paper, we outline the key findings of this work.

II. Methods

Improving our understanding of the ecological and behavioral drivers behind the emergence and spread of coronaviruses is crucial. While the zoonotic origin of SARS-CoV-2 has been well-established, a direct connection between the viral variants found in bats, pangolins, and humans remains unidentified, including the intermediary host(s) that transmitted the virus to humans. Understanding the ecology and epidemiology of COVID-19 also involves investigating the genetic basis of host susceptibility, whether in animal reservoirs or human populations. Key research questions include the impact of ecosystem changes—deforestation, land use, infrastructure development, and urbanization—on human-wildlife interactions, and the subsequent increased risk of zoonotic disease spillover. It is vital to determine the extent to which habitat destruction and human activities (such as farming, hunting, and wildlife trade) have contributed to recent zoonotic disease outbreaks, particularly SARS-CoV-2. In the context of climate change, the role of biodiversity loss in disease emergence also requires more in-depth investigation.

Advances in methods and tools are also necessary. For example, ecological health observatories could help analyze the social-ecological dynamics of SARS-CoV-2 and track its spatial and temporal patterns across different ecosystems (wild and domestic animals, air, and water) in both urban and rural environments. Viral genome screening of wildlife (through metagenomics) and the creation of open-access databases are needed to trace transmission pathways and viral evolution within the intermediary hosts of SARS-CoV-2. These efforts will also be critical for managing future emerging viruses. Pandemic modeling has proven essential for informed decision-making during COVID-19, and improving data integration and processing, as well as enhancing modeling capacities worldwide, is crucial. This includes models that account for climate conditions affecting viral transmissibility and models that describe human interactions to estimate effective contact rates. Thus, these models must incorporate epidemiological, demographic, ecological, evolutionary, climatic, social, and cultural data, as these are all key factors in disease evolution.

Research will require interdisciplinary collaboration across fields such as microbiology, medicine, epidemiology, ecology, environmental and evolutionary sciences, veterinary science, agriculture, social sciences, urban planning, mobility studies, anthropology, and behavioral economics. These data will be necessary to both build and validate models of disease emergence and transmission, and integrative approaches that encompass human activities and health status should be prioritized.

The combined effects of infectious diseases and environmental stressors are a major concern. COVID-19 severity has been strongly linked to age and comorbidities, including respiratory, cardiovascular, and metabolic diseases, as well as obesity, conditions partly caused by exposure to environmental stressors such as poor urban planning, unhealthy food environments, air pollution, and chemical toxicants. Better understanding of how pollutants impact immune and cardiometabolic health is essential for identifying population-level vulnerabilities and exacerbating factors. COVID-19 has disproportionately impacted low-income and minority groups, underscoring the role of socioeconomic factors in both exposure to and vulnerability to the virus.

Coordinating existing cohort studies across Europe is a key step, along with the Europe-wide development of tools and models to better assess and predict the health, social, and environmental determinants of COVID-19. The pandemic has highlighted the deep interconnections between infectious and non-communicable diseases, with the latter exacerbating the severity of the former.

It is therefore crucial to explore how viral infections interact with environmental factors of chronic diseases, such as chemical exposure, air pollution, climate change, and socioeconomic conditions.

For example, more research is needed on the dual role of indoor air quality in both environmental contamination and viral spread, as well as innovative solutions for mitigation, such as air purification technologies. Additionally, exposure to wood smoke at relatively low levels has been linked to suppressed respiratory immunity, increasing susceptibility to infections and lung diseases—a concern that is particularly relevant given the energy poverty exacerbated by recent financial crises. Similarly, the risks and benefits of spending time in parks, green spaces, and blue spaces (water bodies) need further investigation.

III. Results

The World Health Organization (WHO) officially declared COVID-19 a pandemic on March 11, 2020. In response, many countries implemented quarantine, isolation, and lockdown measures as part of public health strategies to limit the spread of the virus. While these actions were necessary to control the outbreak, they also led to severe economic downturns and significant changes in social behavior. However, this unprecedented global event also had unexpected positive effects on planetary health. The widespread shutdown of industries, travel restrictions, and lockdowns resulted in several environmental benefits, particularly due to the reduction of human-caused pollution.

The World Health Organization (WHO) reported that the SARS-CoV-2 virus can be transmitted through blood, stool, saliva, and respiration, making the availability of personal protective equipment (PPE) for healthcare workers a critical part of treatment, containment, and the health of the workers themselves. In the general public, where precautions were less strict, the disease spread widely. Testing laboratories were vital early in the pandemic and continue to play a crucial role in documenting the spread of COVID-19. While testing is a post hoc measure, it reveals the prevalence of infection, providing valuable epidemiological data and helping coordinate healthcare needs for infected individuals. Rapid identification and diagnosis of COVID-19 cases can lead to quick treatment for patients, with workflows adapting to evolving care procedures and standards for infection detection.

Generally, standard protocols for handling COVID-19 cases involved transferring patients to COVID-19 containment areas. However, the specifics of these protocols were not thoroughly investigated, making it challenging to assert the existence of a cohesive global protocol. Although public health authorities were typically notified of cases, tracking and tracing patient contacts with family members and others proved burdensome, limiting population-level containment approaches. While the majority of cases globally did not require hospitalization, patients treated at home still posed health risks, as individuals often came into contact with others due to the urban environments where most people live.

Asymptomatic individuals, who were often untested, presented a significant challenge during the pandemic; therefore, comprehensive testing strategies emerged as the best solution to mitigate the spread of the coronavirus. Asymptomatic transmission of SARS-CoV-2 is considered a major obstacle in controlling the COVID-19 pandemic. Consequently, continuous testing of staff who attend to vulnerable populations and those in need of care is essential. The use of rapid antigen tests for SARS-CoV-2 has streamlined emergency departments and facilitated public access to home-based testing methods, although false negatives are a possibility. Despite these minor drawbacks, the advantages of rapid tests and at-home testing kits are crucial in tracking the virus's spread.

According to globally established regulations, testing and metagenomics laboratories involved in the detection and sequencing of the SARS-CoV-2 virus must be managed by trained staff or experts, who are required to comply with established protocols (mainly separating input and output flows) and be equipped with nucleic acid extractors, RT-PCR devices, ultra-low freezers, UV lamps for decontamination, and other disinfection equipment, as well as automatic pipettes (robots) and contamination-free consumables.

Unfortunately, the COVID-19 pandemic has claimed many lives. However, it has also prompted a reevaluation of medical systems worldwide. The reorganization of emergency departments was beneficial, and many of the models implemented remain relevant even post-pandemic, allowing for better-organized workflows, quicker interventions, and increased medical advice sought by patients with minor needs via telephone or telemedicine.

More than any other ward, the emergency department was primarily engaged with COVID-19 cases. Most medical staff were reassigned to this department, receiving training and remaining on standby. Emergency rooms often experienced overcrowding. The organization of medical processes using a color-coded system helped alleviate the situation. For example, in Italy, a heavily impacted country, the emergency department was organized by color based on severity: white, green, yellow, and red. Red indicated immediate access, orange allowed access within 15 minutes, blue within 60 minutes, green within 120 minutes, and white within 240 minutes. This color-coding system was later adopted by hospitals in various parts of the world, representing a model of good practice.

Rapid detection of COVID-19 was crucial for patient treatment and minimizing the risk of transmission. In addition to continuous PCR testing, doctors discovered alternative methods for identifying the disease, such as ultrasound or symptom assessment. In all countries affected by the pandemic, emergency departments were supplemented with PCR equipment, CT scanners, and ICU units, either through redistribution from their own units or through donations from more developed hospitals or states assisting severely affected countries.

Funding from industry, academia, government agencies, and regulatory bodies has helped emergency departments worldwide, facilitating easier access for sick individuals to medical care and treatment. Protective equipment for emergency department staff was enhanced (including coveralls, high-protection masks, gloves, face shields, and goggles), and workflows were digitized to ensure immediate connections between reception areas and care and treatment zones. Critically ill patients were isolated in airborne infection isolation rooms or negative pressure isolation rooms with HEPA filtration of recirculated air.

IV. Discussion

Much of the work performed by dermatologists underwent significant reorganization during the COVID-19 pandemic. Many dermatologists were reassigned to COVID-19 treatment facilities, resulting in non-essential cases being sidelined to focus on critical patient care. Consequently, hospitalizations for non-medical emergencies ceased, and routine consultations transitioned to telemedicine. In instances where face-to-face consultations were essential, particularly for conditions like melanoma that require early surgical intervention, procedures were adjusted to protect staff from COVID-19 exposure. Unlike in some countries where workflow reorganization facilitated urgent dermatological treatments, many low- and middle-income countries faced challenges in addressing conditions requiring emergency care, such as solid tumors and metastatic diseases.

In dermatological emergencies, triage is essential. Dermatological consultations typically cannot occur from a distance of less than 25 cm, particularly for dermoscopies or other interventions. When patient interactions occurred, staff were required to wear PPE and adhere to strict decontamination protocols before and after contact, especially after handling contaminated surfaces or body fluids. The European Task Force on Atopic Dermatitis recommended the continuation of immune-modulating treatments, urging strict adherence to hygiene protocols, including the use of non-irritating cleansing agents and moisturizers after each application.

Similar to many hospital wards, orthopedic departments underwent complete restructuring. Non-emergency interventions were postponed to prioritize major emergency and oncological cases. Mild cases that would usually be treated in inpatient or outpatient settings were also deferred until safe conditions were restored following the pandemic. However, patients such as pregnant women, immunocompromised individuals, or those over 60 years of age continued to be classified as medical emergencies. Medical staff utilized PPE during patient intakes and procedures, with workflows adapted due to the challenges of accurately assessing patients' conditions following initial consultations. Continuous monitoring was necessary for health changes, considering potential COVID-19 symptoms like fever, loss of taste or smell, respiratory or gastrointestinal issues, and cardiac irregularities. Suspected nasopharyngeal samples were collected for PCR testing and processed in designated areas while awaiting results. Patients who tested positive for COVID-19 and presented as medical emergencies were transferred to specialized containment areas for surgical procedures.

The number of medical personnel allowed in operating rooms was limited, and procedures that could generate aerosols were avoided. Treatment equipment for COVID-19 patients, such as monitors and ultrasound devices, had to be protected from contamination and easily cleaned to minimize risks. Postoperative routines were adjusted to maximum capacities, and where possible, portable radiography equipment was used and disinfected immediately after use. Dressings and splints that could be easily changed were primarily utilized for postoperative care.

The COVID-19 pandemic posed significant risks for over 100 million pregnant women worldwide. Due to suppressed immunity, these women are at increased risk of moderate to severe infections that can also affect their fetuses. Pregnant women with COVID-19 face heightened risks of miscarriage, premature birth, and preeclampsia. Fetuses are also at increased risk of mortality and requiring intensive care. Routine screening for COVID-19 is crucial for this population. Pregnant women who contracted the virus but exhibited no respiratory symptoms were advised to quarantine at home while maintaining communication with their primary care providers.

Continuous health monitoring of pregnant women is vital, necessitating regular testing and blood tests for various important parameters. In heavily impacted areas, initial consultations were suggested to occur at home, with subsequent hospital visits to minimize unnecessary exposure to patients. Typically, patients would be hospitalized for 1-2 days before giving birth, but during the pandemic, contact with medical facilities was limited to ensure safety for both mother and fetus. This change posed scheduling challenges for hospitals and patients.

During cesarean sections, epidural anesthesia is typically administered, but the use of nitrous oxide was minimized due to the risk of aerosol generation, which could facilitate virus spread. Breastfeeding is encouraged for women infected with COVID-19, as studies indicate that both IgG and IgM antibodies can be transmitted through breast milk. Antibodies are present in breast milk as early as two weeks post-vaccination. To mitigate contamination risks, visits by outsiders were prohibited, and online communication became the primary means of connecting with family and friends. Before discharge, both mothers and newborns underwent COVID-19 testing, and they could only leave the hospital after receiving negative test results.

The pandemic also significantly impacted pediatric healthcare. Initially, the number of COVID-19 cases among children was relatively low; however, with the emergence of new SARS-CoV-2 variants, children became increasingly affected. Fortunately, symptoms in children tend to be milder, including fever, dry cough, nasal congestion, abdominal discomfort, or diarrhea, with many remaining asymptomatic. Nonetheless, there have been instances requiring pediatric emergency care. Hospitals prepared for pediatric emergencies, particularly in infectious disease wards.

Most children needing emergency care faced moderate to severe respiratory infections, such as influenza and bronchiolitis, meningitis, sepsis, osteomyelitis, and asthma. The Omicron variant, while more contagious among children, has resulted in less severe outcomes compared to the Delta variant, with lower rates of hospitalization, ICU utilization, and mechanical ventilation.

Although environmental and health professionals have an expert understanding of the spread of infectious pathogens and the potential for zoonotic pandemics, the shock of COVID-19 has been particularly profound. The confirmation of the zoonotic origin of the virus, its survivability in air, water, and surfaces, and its modes of transmission have clearly demonstrated that the COVID-19 pandemic is a global emergency based on the link between the environment and human health. The environment has played a key role in the emergence and spread of SARS-CoV-2, as well as in the societal response to this emergency.

National and subnational environmental and health structures have been affected in almost every aspect of their work. For experts who (at least in developed countries) have long focused on understanding and managing the environmental aspects of noncommunicable diseases, it has come as a surprise that infectious diseases have once again come to the fore. The pandemic has also demonstrated the importance of understanding the impact of the environment on mental health in the context of isolation and restrictions, and the need to adapt homes and public spaces to new conditions.

Before the pandemic, environmental and health professionals realized that their work transcends traditional understandings of space and time. Climate change and its impacts have shown that the key function of public authorities in this area - ensuring a safe and healthy environment - must take into account the impact of economic and social factors, as well as human activities, on ecological systems. Moreover, work at the national and subnational levels must now include concern for the environment and health of people beyond these territories. COVID-19 has once again confirmed this need.

It is important to note that climate factors and pandemics, although different phenomena, are interrelated in their origins and require the creation of societal resilience. The working hypothesis should take into account the possibility of the simultaneous occurrence of pandemics, climate events and disasters in the future. The COVID-19 pandemic has not only exposed societal resilience issues that will be exacerbated by climate change, but also exposed significant vulnerabilities across a range of sectors.

The pandemic has also exacerbated social inequalities. People with low incomes, chronic illnesses, the elderly, and other vulnerable groups were at greater risk of infection and severe consequences. One clear finding was that knowledge workers, who tend to have higher incomes, were able to work remotely, avoiding the risk of infection. At the same time, low-income workers often faced higher risks, as they were forced to be in the workplace and use public transport. This policy brief provides a high-level picture of the environmental and health impacts of the COVID-19 pandemic, without going into depth on specific issues or topics. Although WHO has declared the COVID-19 pandemic no longer a public health emergency of international concern, its impacts will be felt for a long time. Moreover, the COVID-19 literature is constantly evolving, expanding the evidence base.

The analysis presented here begins with a No COVID Base scenario representing expected development patterns in a world without the pandemic. To simulate this we rely on economic growth rates produced just prior to the pandemic in the World Economic Outlook (WEO). We apply growth rates from this report for 2019–2025 and then use IFs endogenous growth projections through 2050. For this scenario we maintain 2017 country Gini-index values through 2050. As noted previously, this scenario produces similar results to other medium-variant forecasts prior to the outbreak. We compare this No COVID Base scenario with the COVID Base scenario. This scenario simulates the effect of COVID-19 by including WEO growth projections published for the years 2021–2023. From 2023–2050 we also rely on IFs endogenous growth projections for this scenario and keep country-level income inequality values flat across time. We compare these two scenarios with six alternative scenarios that frame uncertainty by varying GDP growth and income inequality. We vary GDP growth by 1.5 percentage points for 2022 around the COVID-Base values and then converge these to the COVID Base growth trajectory by 2025. The 1.5 percentage points variation is a high-end assumption that falls within the standard variation across world GDP growth rates from the WEO during the COVID-19 period (~1.6%), and the mean difference across countries in GDP growth rates comparing the World Bank Global Economic Prospects [85] and the IMF WEO April 2021 release (~1.6%).

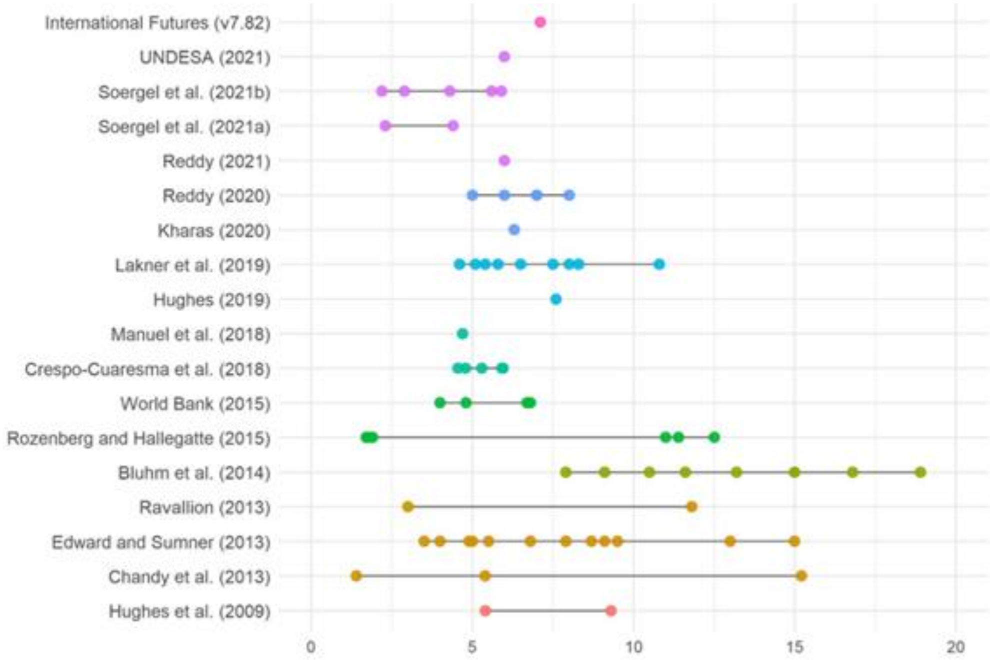

Figure 2: *Previous projections of extreme poverty levels summary that do not account for COVID-19*

This policy brief is based on a "rapid review of policy papers" (WHO Regional Office for Europe, 2023), which reviews high-quality studies published from early 2020 to early 2023. This review is structured similarly to this policy brief and provides more detailed information on the topics discussed. It also aims to facilitate access to policy papers and primary research.

The published and unpublished reviews highlight the desire for change and acknowledge the urgency of this change. The COVID-19 pandemic has caused significant disruption, and some survey results suggest that it has created a sense of urgency for change that goes beyond the academic and policy circles that provided the analyses discussed.

People are now more informed and have a better understanding of how their experiences of the pandemic and the impacts of climate change relate to their health, well-being, and ultimately the survival of humanity. Institutions and sectors of society have clearly demonstrated a lack of resilience.

References

[1] Gakaev, R. Assessing Carbon Dynamics in Diverse Ecosystems: The Role of Carbon Polygons / R. Gakaev , L. Gatsaeva // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03013. – DOI 10.1051/e3sconf/202453703013. – EDN OOIDOS.p.

[2] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities,

and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[3] Kornienko T.V. Questions of linguistic kinship, 2013. No. 9. P. 155-162.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A.S. Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

[11] Gunya, A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

PHYSIOGRAPHICAL CHALLENGES OF MOUNTAINOUS AREAS

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Abstract

The mountainous regions of the Earth have significant elevation differences even on small areas of the earth's surface, which is the main reason for the characteristic combination of natural conditions in these regions. This includes height as a leading factor, resulting in relief and a corresponding complex of natural components. All other components of development in these areas will be radically different from those in nearby plains, and the conditions of existence for the population will also be characteristic of these territories. These conditions affect lifestyle, occupation, and health. Altitude is most clearly traced in the variability of hydroclimatic, soil-biological, and landscape components vertically. As altitude and climatic components directly affect agricultural specialization, it is important to consider these factors when planning agricultural activities in mountainous areas. There is a change in the direction of reducing the duration of the vegetation period for plants. Agriculture is associated with growing cold-resistant plants, while heat-loving plants are grown on the plains and their growing season is shorter. The physical and geographical challenges of highlands involve determining the limits of disturbance or barrier that can cause instability, as well as forecasting the development of weak components. It is necessary to identify processes that affect the development of mountains. These include altitude, topography, climate, and weathering, which together determine the stability of natural complexes in highlands.

Keywords: mountainous areas, natural components, safety margin

I. Introduction

Mountainous countries are characterized by an unusually rich, diverse, and variegated vegetation cover. This is due to a variety of habitats and environmental conditions, including changes in temperature with altitude, lighting conditions depending on slope exposure, and humidification conditions depending on relief. Because of these factors, mountain biota surpasses lowland territories in terms of biodiversity. A person should be aware of the characteristics of the altitude zone because the natural nature of plains has been changed by agriculture. Mountains will remain in their natural state for a long time and their landscapes will influence nature management and development. These factors are necessary for the sustainable use of mountain resources. The study of mountain natural complexes and their patterns is important for understanding the ecological processes that occur there [1,2]. Distribution is impossible without a broad geological analysis, linking vegetation with the surrounding geographic landscape. Precisely because mountains with their rich plant, animal, aquatic, and fossil wealth, located in relatively small spaces, have been and remain, on an ever-increasing scale, suppliers of resources for lowland civilizations. Summer grazing, logging, mining, engineering, construction of dams, roads, and much more are areas of exploitation of mountains for the prosperity of the plains.

II. Methods

The 21st century, the century of mountains, is the United Nations' forecast for the future of humanity. It has been stated that in the near future, mountains will determine the quality of life for all of humanity. According to the prediction, in the near future, mountains will determine the quality of life for all mankind, despite the fact that they occupy only 1/5 of the Earth's surface and only 10% of the world's population lives in mountainous areas. Mountains contain a vast potential of natural resources, including hydropower, which is being almost untapped by humans. This makes them a storehouse of the Earth's interior that has been preserved from human interference. We can say that mountainous areas have a unique lifestyle, mentality, and cultural and biological diversity that seems to be frozen in time.

Only with a new approach to assessing mountains and their potential for providing natural and biological resources can we transition to a sustainable development policy for mountain ecosystems. this consideration of the issue will allow us to include the potential of mountain territories in the parameters of regional wealth. The degradation or destruction of mountains is still a major concern today [3, 4].

Despite this, mountains remain some of the most ecologically prosperous regions of the planet, where the STR (Scientific and Technical Revolution) has not taken over yet. Mountain regions are unique in many ways. They lack industrial enterprises with their harmful emissions and drains. Asphalt pavements have not sealed off the soil, allowing geochemical processes to continue. Vehicles are fewer, and the population is smaller than in nearby plains.

All of this does not imply that there are no challenges in mountainous regions. One of the issues is the expansion of grazing areas in the alpine meadow zone and the consequent depletion of flora and fauna in these areas.

Another, not less significant aspect, is the melting of glaciers in the snow zone due to a global warming.

If we talk about alpine meadows, this is a highly vulnerable ecosystem. In order to preserve this unique ecosystem, it is essential to immediately ban the grazing of domestic animals in this area. Domestic animals, such as hoofed mammals, can significantly affect the structure and productivity of plant communities in alpine meadows. It should be noted that the number of pets may increase. Wild animals also have an impact on the vegetation of mountain meadows.
Unregulated and haphazard use of pastures is prohibited by law given the current situation, which is one of the most pressing issues today [5,6].

One of the goals of comprehensive geographical research is to assess the natural resource potential of a territory, primarily in mountainous areas due to their vulnerability. Due to the potential resources of the territory the environment is not taken into account, and this leads to a deterioration in environmental conditions.

III. Results

The peculiarity of mountainous areas is the specific distribution and transformation of solar energy. The amount of solar radiation in the mountains increases in proportion to the increase in altitude, elevation difference, and steepness of the slopes.

The rugged terrain creates an absence of large flat areas in the mountains, leading to high activity of slope processes and a concentration of vegetation in particular local areas.

We can identify the main causes of the vulnerability and extreme instability of mountain geosystems:

1. The geosystems in the highlands have relatively simple, direct, and rigid connections. This is because natural complexes develop in rugged terrain, where parameters such as altitude and associated temperature are important. This means that they are dependent on external influences.

2. Ecological relations in mountainous areas are disproportionate. This is due to the dominance of abiotic environmental factors, such as light, temperature, and humidity. These external factors are more influential than internal factors in mountainous ecosystems.

An ecosystem is a system composed of interrelated and interdependent parts that interact through the exchange of materials, energy, and information. As a result, internal connections within the system are more stable and help maintain the overall structure of the ecosystem. This is due to the inherent dynamism of mountainous environments, which can lead to changes in the composition and function of an ecosystem over time.

3. Inclined surfaces in mountainous areas can support various types of life, including plants, animals, and microorganisms. Provided that the flow of matter and energy follows a downward gradient, the physical and energetic properties of natural systems are closely interrelated and cannot exist independently of each other in natural environments. These include talus and mudflow deposits, which have an oval shape. Consequently, it can be observed that the boundaries between ecological systems will be fluid and will depend largely on climate change and human activities [7,8].

IV. Discussion

The physiographical issues of highland areas are associated with the need to determine the limit of disturbance or barrier, beyond which their stability is compromised. This involves identifying problems in the landscapes of the mountainous meadow zone and forecasting the development of weaker components. It is essential to identify the processes that influence the development of mountain areas. These include, primarily, altitude, topography, climate, weathering, and solar radiation. Together, these factors determine the safety margin for natural complexes in highlands.

Physiographical issues related to high-altitude zones can be grouped according to their factors of occurrence:

1. The ones related to the distinct mountainous terrain and the inclination of the mountains include landslides, debris slides, rock falls, mudflows, and avalanches.

2. The ones caused by climate and natural conditions, such as fog, precipitation in the form of rain and snow, thunderstorms, and wind, may also contribute to physiographical issues.

3. The ones caused by the anthropogenic activities

As previously noted, mountains possess a significant potential for natural resources, contributing to a quarter of the total biological diversity on land. This diverse range of plant and animal species can be attributed to several factors, with the most prominent being the extensive variety of climatic conditions over short distances and a diverse array of habitats. Consequently, it is essential to recognize that the conservation of mountain biodiversity is becoming an essential component of the sustainable development agenda for mountainous regions. Addressing this pressing issue necessitates socio-economic development in mountainous areas.

Therefore, one of the most significant challenges in the sustainable development of mountainous regions continues to be the preservation of landscapes and biological diversity, as well as the establishment of a natural and ecological foundation.

The natural and ecological framework should encompass all types of specially protected natural areas, ranging from nature reserves to pastures and hayfields, as well as certain types of disturbed lands. The justification for including disturbed lands within this framework lies in their potential for inclusion in the land fund [9].

A key aspect of environmental management within the territories encompassed by the natural and ecological framework is the careful handling of these areas. When combined with environmental measures, this can help to reduce the anthropogenic pressure on natural ecosystems, thereby promoting sustainable development.

To enhance the effectiveness of the measures implemented, it is essential to define a set of actions aimed at establishing a special protection regime.

The mode of protection should vary depending on the specific natural landscape. For forested areas, deforestation should be prohibited, except for sanitary felling.

For leveled areas within protected areas, plowing, the use of mineral fertilizers, and pesticides should be banned [10].

Hunting and fishing are permitted only for species that are not protected. Water bodies should be protected from pollution.

It is necessary to impose a ban on land allocation for construction, horticulture, and other uses, including the construction of buildings and infrastructure that are not required for the needs of nearby communities.

All economic activities that may harm or endanger the functioning and preservation of the natural ecosystem should be prohibited. As representatives of the plant and animal kingdom, we should be protected by law. The attitude towards the natural environment, its components, increases the power of irrational pressure. In this case, it is necessary to talk about anthropogenic factors of influence on nature. In this case, it is necessary to separate two types of influence on nature and its components, in particular on the climate, unintentional - in the process of economic activity and intentional - with the aim of changing, in this case, the climate, according to certain parameters for certain purposes [11].

Caring for our natural environment is essential for sustainable development. This is why the Federal Law "On Environmental Protection" has been enacted to regulate relations between society and nature [12]. Any form of economic activity poses a threat to our natural surroundings, which provide us with natural conditions and resources. In this regard, the Federal Law aims to address the challenges of preserving our natural environment, prevent and eliminate the harmful effects of human activity on nature, and improve the quality of our environment as much as possible.

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References

[1] Abdurakhmanov G.M, Dudurkhanova L.A, and Gayrabekova R.H, "The North Caucasian Federal district needs a unified law for mountainous territories", South of Russia: Ecology, Development, vol. 10, no. 3, Moscow, Tuning Fork Publishing House, 2015, pp. 24-35.

[2] Avessalamova, I.A., Petrushina M.N., and Khoroshev A.V., Mountain landscapes: Structure and dynamics: A textbook. Moscow: Publishing House of the Moscow Unita, 2002, p. 158. pp. 67–68.

[3] Catastrophic Processes and Their Impact on the Natural Environment: Monograph in 2 Volumes. M.: General Organization of Scientists on Applied Geophysics Problems; Ministry of Industry, Science, and Technology of the Russian Federation, 2002 - Vol. 1: Volcanism - 435 pp.

[4] Krakhmal A.G., Specially Protected Natural Territories and Sustainable Development of the North Caucasian Ecological Region. Regional Problems of Geography and Geoecology. Issue 1 - Makhachkala, 2004.

[5] Koronovsky N.V., Bryantseva G.V. Dangerous Natural Processes: Textbook. Moscow: INFRA. M, 2021. 233 pp.

[6] Nabieva U.N. and Abdurakhmanov G.M. The country and the region need state policy for mountain region development, in Sustainable development of the mountainous regions of the North Caucasus in the context of global change: Research and practice", Proceedings of the International Conference, Grozny 2014, p. 121.

[7] Osipov V.I. Natural disasters at the turn of XXI century, Bulletin of Russian Academy of Science, vol. 71(4), pp. 291–302. 2001.

[8] Kasimov N. S., Klige R. K. Modern global changes in the natural environment.

Monograph. Vol. 1. M.: Scientific World, 2006. 696 p.

[9] Gunya A., Gakaev R. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic. Reliability: Theory & Applications. 2022. Vol. 17, No. S3(66). pp. 124-128. DOI 10.24412/1932-2321-2022-366-124-128.

[10] Daukaev A., Gakaev R., Bachaeva T. Main trends in climate change in the Holocene epoch of the antropogenic period in the world and in the Caucasus. Reliability: Theory & Applications. 2023. Vol. 18, No. S5(75). P. 387-390. DOI 10.24412/1932-2321-2023-575-387-390.

[11] Gakaev R., Gatsaeva L., Eskiev M. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies. E3S Web of Conferences. 2024. Vol. 537. P. 03009. DOI 10.1051/e3sconf/202453703009.

[12] Gakaev R. The world's forests are a stabilizing element of the climate system/ BIO Web of Conferences. I International Conference "Biotechnologies in the Context of Human Development" (BCHD - 2023). Les Ulis, 2023. C. 06003.

THE IMPACT OF ECOTOURISM ON THE DIVERSITY AND ECOLOGICAL CONDITION OF THE ECOSYSTEMS OF THE PROTECTED AREAS OF ADJARA

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Abstract

The impact of ecological tourism on the ecological conditions and ecosystem diversity within Adjara's protected areas has been thoroughly studied. The focus of these discussions encompasses the protected areas of Kobuleti, Kintrishi, Mtirala, and Machakhela, along with their existing infrastructure and the diverse services they offer.Moreover, a comprehensive analysis of plant diversity has been performed. This analysis indicates that the vegetation cover within these regions is marked by significant floristic diversity.It also highlights the presence of species with considerable conservation importance, particularly an abundance of endemic and relict species, as well as those listed on the Red List. The development of ecotourism has been observed to contribute to the preservation of natural beauty in unique areas, while simultaneously mitigating negative environmental impacts.Moreover, the threats posed by ecotourism to protected areas, including pollution, noise, fire, and the potential invasiveness of alien plant species, have been thoroughly examined. These threats significantly affect the protection and preservation of ecosystem diversity.A comprehensive analysis of the strengths and weaknesses associated with the development of ecotourism in the protected areas of Adjara, including its impact on the diversity of natural vegetation, has been provided. A statistical analysis of the visitor numbers to the protected areas of Adjara from 2018 to 2023 has been conducted.It has been observed that, despite Georgia's rich ecotourism resources, there is a current deficiency in marketable tourist products characterized by relevant properties. Moreover, it has been emphasized that ecotourism in protected areas not only cultivates new market segments and advances the tourism sector but also increases the efficiency of ecotourism and contributes to Georgia's economic development. An analysis of the development of ecological tourism in Adjara, identified as a crucial sector in the modern tourism industry, reveals that this area necessitates support at both the state and regional levels.This perspective is robustly corroborated by the 'Georgian Ecotourism Strategy 2020-2030,' collaboratively formulated by the Agency for Protected Areas of Georgia,the Austrian Development Agency (ADA), and the German Society for International Cooperation (GIZ). Within this strategy, it is acknowledged that ecotourism in Georgia notonly provides tourists with an authentic experience but also markedly boosts the economic well-being of the country. Furthermore, it plays a pivotal role in safeguarding naturaland cultural heritage and in elevating environmental awarenessamong both tourists and local inhabitants.

Keywords: ecotourism, protected areas, diversity, threats, statistical analysis

I. Introduction

Currently, the emphasis on developing ecotourism in protected areas worldwide is significant. Ecotourism in these areas respects ecosystem integrity and encourages nature-based travel. It serves as a pivotal economic driver for our region, fostering infrastructure growth, enhancing tourism-related businesses, thereby boosting local employment. Moreover, it plays a crucial role in preserving and promoting cultural heritage, traditional crafts and contributes to enhancing the country's international reputation.

Therefore, studying the challenges of ecotourism development in unprotected areas of Adjara is highly relevant, as it can generate substantial profits while maintaining ecological safety.

Given the growth of ecotourism in protected areas and its transformation into a significant socio-economic phenomenon, this research aims to address effective regulation issues in the organization of ecotourism. It also seeks to examine the impact of ecotourism on the ecological condition and biodiversity of Adjara's protected areas. The goal is to propose scientific and methodological recommendations that ensure ecological safety and preserve natural ecosystem diversity, as well as to coordinate the activities of economic entities at the regional level effectively.

To achieve this goal, the following tasks are set:

- Study the existing ecotourism infrastructure in the protected areas of Adjara;
- Investigate the diversity of ecosystems in the protected areas of Adjara;
- Examine the impact of ecotourism on the ecological condition of the protected areas of Adjara;
- Assess the impact of ecotourism on the biodiversity of the protected areas of Adjara.

The study focuses on four protected areas in the Adjara region: Kobuleti and Kintrishi protected areas, and Mtirala and Machakhela national parks.

II. Methods

The research methods used in this paper include:

- Route-expeditionary reconnaissance method
- Interview method: Engaging with visitor service specialists and rangers in the protected areas.
- Economic analysis and statistical methods (utilizing official statistical data for quantitative assessment)
- Analysis and synthesis methods
- Comparative analysis method: Comparing analytical and statistical data.

III. Results

The study examines the impact of ecotourism on the ecological condition and plant diversity of the protected areas in Kobuleti, Kintrishi, Mtirala and Machakhela. It also addresses the threats posed by ecotourism to these areas. Scientific and methodological recommendations have been developed, which, according to the authors, will aid in the formation and growth of the market for ecological tourism products, enhance ecological safety in protected areas, preserve vegetation diversity, and address the challenges hindering ecotourism development in the Adjara region.

In the process of implementing ecotourism activities in the unprotected areas of Adjara, the following observations were made:

- Ecotourism activities lead to both direct and indirect environmental changes, which can have positive and negative effects on wildlife.
- In the protected areas of Adjara, positive impact is reflected in responsible travel by visitors which promotes the protection and preservation of the natural environment.
- The adverse effects of ecotourism are most pronounced in the Kobuleti Nature Reserve and Mtirala National Park.
- Ecotourism negatively impacts the unique sphagnum habitat in Kobuleti Nature Reserve, causing artificial drainage and the introduction of invasive species. Rare species such as white moss (Sphagnum austinii) and globally red-listed species like the Colchian water-lilly (Nymphaea colchica) and water vine (Potamogeton natans) are at risk.
- Massive tourism in Mtirala National Park is endangering certain plant species listed on the

Red List of the Caucasus and Georgia.

- Visitor services in Kintrishi and Machakhela Protected Areas are managed with minimal negative impact on the environment, considering the capacity of natural ecosystems and national park zoning. Negative impacts include trampling of vegetation, pollution, noise, invasion of alien species, and, in rare cases, fires.

IV. Discussion

Ecotourism is emerging as a significant new sector in Georgia's tourism industry. Renowned for its natural beauty; diverse landscapes; Georgia offers attractions such as the Caucasus Range (with 668 glaciers); the subtropical Black Sea coastline (320 kilometers); rivers, lakes and waterfalls (25000 rivers and 860 lakes); mineral waters (1,400 mineral springs, most of them are thermal); cities carved into rocks, historical landmarks, traditional hospitality, and renowned Georgian cuisine, all contributing to its appeal as a tourist destination [1].

As of 2023, Georgia has designated 100 protected areas under six different categories based on IUCN criteria. These include 14 state reserves, 14 national parks, 40 natural monuments, 26 restricted areas, 5 protected landscapes, and one multi-use area. A total area of protected territory covers 912,862 hectares, which represents approximately 13% of Georgia's territory [2].

Today, Georgia faces the imperative of defining clear priority directions for regional development that ensure sustainable and stable regional growth. Concurrently, there is potential to cultivate new industries that can stimulate positive multiplier effects within the regions. One such priority direction identified is the development of ecotourism, seen as a pivotal component of Georgia's regional economic development strategy [3].

Considering that the Adjara region is one of the largest and most naturally diverse regions of Georgia, it is pertinent to examine the challenges and prospects of ecotourism development in Georgia today. Additionally, it is crucial to assess its impact on the ecosystem diversity and ecological condition of protected areas, using the Adjara region as a case study.

There are following protected areas in the A/R of Adjara [2]:

- Kintrishi Protected Areas (Kintrishi Nature Reserve 3 108 Ha; Kintrishi National Park with 20 406 Ha);
- Machakhela National Park, total area 7 333 Ha;
- Mtirala National Park, with total area 15 580 Ha;
- Kobuleti Protected Areas (Kobuleti Reserve with 316 Ha; Kobuleti Managed Reserve with 466 Ha).

The following table (Table 1) presents visitor statistics for the unprotected areas of Adjara from 2018 to 2023.

In recent years, (up to 2020 before the COVID-19 pandemic), Georgia experienced a consistent rise in both visitors and tourism revenue. The National Tourism Agency of Georgia identified 2019 as the peak year for the tourism industry’s growth. This trend was particularly evident in ecotourism, with a record (109,800) visitors reported in the protected areas of Adjara in 2019.

The COVID-19 pandemic has dramatically altered global lifestyles and triggered a crisis across all parts of life and sectors. In 2020, the tourism industry in Georgia, like worldwide, experienced a significant downturn. As shown in Table 1, the number of visitors to unprotected areas of Adjara dropped drastically by 81.8% compared to 2019, falling from 109.8 thousand to just 20.2 thousand.

Despite the disruptions caused by the pandemic, life and nature continue their cycles and everything has its begining and ending. From late 2021 into 2022, ecotourism began to rebound. By 2022, the number of visitors to unprotected areas of Adjara had risen to 85,700, marking an increase of 65,500 visitors (a 324.3% rise) compared to 2020. In 2023, ecotourism almost fully recovered, with visitor numbers reaching 104,300 in the protected areas of Adjara, which is 95.0% of the record high of 109,800 set in 2019 [2].

Table 1: *Number of visitor for the unprotected areas of Adjara 2018 – 2023*

Protected Areas		Number of visitor for the unprotected areas of Adjara 2018 – 2023, thousand persons					
		2018	2019	2020	2021	2022	2023
Total in Ajara A/R		88,8	109,8	20,2	56,3	85,7	104,3
Including	Kintrishi Reserve and National Park	6,6	7,0	1,2	1,8	2,9	3,1
	Machakhela National Park	10,1	11,3	0,8	0,5	0,9	1,4
	Mtirala National Park	57,8	77,3	15,4	51,1	78,1	95,3
	Kobuleti Reserve and Managed Reserve	14,3	14,2	2,8	2,9	3,8	4,5

Source: The table was created by the authors based on the reports from the Agency of Protected Areas of Georgia for the years 2018-2023

Today, as the COVID-19 pandemic subsides globally, many mass tourism destinations have implemented social distancing measures and established visitor thresholds based on the lessons learned during the pandemic. These practices may become a permanent aspect of tourism management, as ecotourism—particularly in protected areas—already required such restrictions to ensure sustainability and protect natural environments.

People are increasingly seeking destinations where they can feel safe and maintain social distancing, opting for less crowded places. Georgia's tourism sector faces the challenge of actively promoting ecotourism, which involves harmonizing tourism with natural resource conservation. Ecotourism can attract investment not only for environmental protection but also for the region's economic and socio-cultural development. Furthermore, advancing ecotourism provides local communities with the opportunity to generate additional income through tourism-related services.

Currently, Georgia possesses numerous ecotourism resources, but lacks a well-developed tourist product with defined market characteristics [4]. It is important to recognize that while ecotourism can create new market segments and expand the tourism sector, it also has the potential to significantly impact Georgian agriculture. By integrating ecotourism with agriculture, Georgia can enhance the efficiency of its ecotourism industry and contribute to overall economic growth.

A key factor for developing ecotourism in Adjara is its location within the Caucasus eco-region, known for its rich terrestrial biodiversity. The International Union for Conservation of Nature (IUCN) has listed this area as one of the world's biodiversity hotspots for its high levels of biological diversity and the presence of endangered terrestrial species. Adjara, with its varied ecosystems and unique geographical features, is recognized among the 200 global eco-regions for its species abundance, endemism, taxonomic uniqueness, and distinctive habitats in the southwestern corridor of the Lesser Caucasus [5].

Additionally, it is important to highlight that the World Wildlife Fund (WWF) initiative, "About 100 Hotspots of European Forests," which identifies approximately 100 critical protected forest areas in need of conservation, places a high priority on the unique Kolkheti forest ecosystems in Adjara [6].

Currently, Adjara's wild flora is estimated to consist of 1,837 species. According to literary sources, the endemic flora of Adjara includes 174 species, which belong to 43 families and 109 genera. This represents 9.47% of the total floristic composition of the region. These endemic species are distributed across the geographical regions of the Caucasus, Georgia, Kolkheti, Adjara-Lazeti, and Adjara [7].

The varied terrain and diverse climatic and soil conditions in the protected areas of Adjara contribute to a wide range of landscapes and ecosystems. In this relatively small region, one can find an array of ecosystems, from the lush mixed-leaved forests of the Kolkheti plain to the unique ecosystems of the high mountains with their more challenging climates. This results in a rich and intriguing vegetation profile [8].

In recent decades, Adjara's biodiversity has significantly declined due to various anthropogenic and natural factors, including habitat loss, fragmentation, degradation, illegal hunting and fishing, the introduction of alien species and unsustainable use of biological resources.

Protected areas in the Adjara region are crucial for tourism development. Kintrishi, Ispani, Machakhela Valley protected areas, Mtirala National Park, and the Botanical Garden have the most ecotourism potential. These areas offer exceptional and memorable experiences for ecotourism enthusiasts.

However, implementing ecotourism in these protected areas brings about changes in environmental conditions, influenced by both direct and indirect effects of tourism activities having positive and negative effect on wild nature as well. Studies have indicated that while ecotourism aims to offer nature-based tourism and recreation without harming natural ecosystems and promotes environmental protection, it inevitably impacts the environment. Research into protected areas has demonstrated that with effective management and well-defined planning, it is possible to mitigate negative environmental impacts and enhance the positive effects of ecotourism.

To evaluate the environmental damage caused by ecotourism in the protected areas of Adjara, interviews with visitor service specialists and rangers, along with observations on ecotourist routes, have revealed several issues. The pollution of both terrestrial areas and water bodies, such as rivers, ponds, and lakes, with food and household waste is a significant problem. Additionally, noise from entertainment facilities disrupts the ecological balance, frightening birds and other wildlife. There are also instances of visitors violating reserve regulations and causing damage to plants and animals. These issues represent only a portion of the negative impacts associated with ecotourism in these protected areas. It is crucial to recognize that preventing environmental damage is far easier than attempting to repair it once it has occurred.

Based on interviews with visitor service specialists and rangers in Adjara's protected areas, it is clear that those responsible for managing these areas are dedicated to organizing tourism activities while adhering to established rules and considerations. They have implemented measures such as creating ecological trails and installing informational boards. Additionally, they have developed designated walking and educational routes to enhance visitors' ecological awareness and improve recreational services.

Ecological trails have been established to manage tourist flow effectively in Adjara's protected areas. One significant issue is the trampling of these areas, which can damage important vegetation. Rangers focus on ensuring that tourists stay on designated routes to help preserve and protect these vital habitats. Currently, all four protected areas in Adjara have specialized routes for small groups, designed to avoid disrupting the integrity of natural environments while allowing for proper monitoring. These routes are carefully planned to prevent environmental damage. Additionally, the protected areas are equipped with facilities for travelers, including designated spots for resting, camping, lighting fires, and waste disposal. These amenities help minimize fire risks, maintain cleanliness in resting areas, and prevent uncontrolled trampling of the terrain.

The establishment of ecological paths in protected areas is crucial as it helps manage tourist traffic, reduces vegetation trampling, and thus aids in its preservation.

Informational stands with ecological content, including designated spots for resting and stopping, are strategically placed along tourist trails. These stands help minimize the creation of unauthorized parking areas and fire hazards, while also enhancing visitors' ecological education.

Ecotourism plays a vital role in protected areas by addressing various ecological challenges and contributing to their overall management and conservation.

Many plant species in the protected areas of Adjara are listed on international or Georgian red lists. The national park is notable for its rare diversity of endemic and relict plants. Among the rare relict endemics featured on Georgia's red list are the Pontic oak (*Quercus pontica*), Medvedevi birch

(*Betula medwedewii*), Ungern's rhododendron (*Rhododendron ungernii*), and Epigea (*Epigaea gaultherioides*). The latter two evergreen shrubs, along with Medvedevi birch, are found exclusively in Adjara and nearby regions of Turkey.

Although the tourist trails and ecotourism infrastructure in the protected areas of Adjara are generally well-maintained, there remain ongoing threats to the protection and preservation of biodiversity within these areas.

The main threats to the protection and preservation of biodiversity in the protected areas of Adjara, resulting from the development of ecotourism, are summarized in Table 2.

Table 2: *The main threats to the protection and preservation of biodiversity in the protected areas of Adjara*

Impact of ecotourism on the protected areas of Adjara						
	Threats to habitats and endemic relict species	**Reason**	**Impact level (assessment from 1 to 5)**	**Impact threat**	**Problem solution**	**Note**
1	Pollution	Household waste	3	Unaesthetic	Increase in awareness Fines	Negligence by visitors
2	Noise	Disruption of reserve's regimen by visitors	3	Disturbing birds		Rarely
3	Invasion of alien species	Habitat modification, degradation, drainage effect	4	Displacement of native species and dominance over their distribution	Ongoing monitoring and the development of proactive management strategies in alignment with the management plan.	Constantly

Source: The table was compiled using data from the 2023 report of the National Environmental Protection Agency and personal observations by the authors.

Contamination of protected areas, primarily due to visitor negligence, is largely attributed to solid waste pollution, which has been rated 3 out of 5 points in terms of impact. Addressing this issue could involve increasing visitor awareness and implementing fines. Noise pollution, resulting from visitors disregarding recommended guidelines and disturbing birds, is also rated 3 points for its environmental impact.

In the disturbed and degraded habitats within the protected areas and along adjacent paths, there have been instances of invasive plant species establishing themselves *(Spiraea japonica*, *Paspalum dilatatum*, and *Robinia pseudoacacia)*, particularly in Mtirala National Park and its vicinity. However, the Kolkhi forest remains relatively stable. This situation may represent an early stage of invasive species naturalization. Continuous monitoring and development of effective control measures are essential. The threat posed by invasive species to biodiversity is rated 4 points (see Table 3).

Additionally, the growth of ecological tourism in Georgia, particularly in the Adjara region, faces several challenges. These include inadequate legislation, as the legal status of ecological tourism remains unresolved (relevant laws and regulations are incomplete). There is also a need to define and clarify the concept of ecological tourism development. Furthermore, there is a lack of alignment between cooperation interests and the implementation of economic management mechanisms. Municipal bodies in the region are not fully leveraging their governance roles, which affects their ability to shape tourism policy and regulate tourism effectively [4].

Additionally, several factors hinder the development of tourism in Georgia, including:

- The seasonal nature of tourism, which results in significant periods of underutilization for a substantial portion of service personnel throughout the year;
- The risk of undermining the existing local cultural environment;
- Low awareness among the local population regarding the opportunities of ecological tourism;
- Underdeveloped road infrastructure;
- Lack of state support at both regional and local levels.

Regarding foreign investments, it is important to note that foreign investors have shown limited interest, largely because they do not view the Georgian market as a significant consumer base due to the relatively low income levels. Consequently, attracting foreign tourists to Georgia seems more promising. However, this also presents challenges: not only is there a lack of adequate infrastructure, but it is also crucial to create incentives to encourage their visit.

From our analysis of ecotourism within the contemporary tourism industry, it is clear that ecological tourism requires primary support at the regional level. Regional tourism business associations should take the lead in organizing the ecotourism sector. In our view, these associations need to address the following tasks to advance ecotourism in the Adjara region:

- Developing information systems to support regional ecotourism development programs and providing methodological guidance;
- Establishing effective mechanisms for creating new ecotourism attractions;
- Training skilled personnel to manage entrepreneurial activities within the tourism sector;
- Creating mechanisms for selecting and implementing promising investment projects aimed at advancing ecotourism.

Regional tourism business associations, alongside local administration, regional funds, labor exchanges, and other relevant organizations, should oversee the development of ecotourism infrastructure. This process should follow a state program designed to support ecotourism, which includes enhancing the legal and regulatory framework, improving methodological support and information networks, and building financial infrastructure through the involvement of funds, specialized banks, insurance companies, and investment institutions. Additionally, the program should engage technological, social and business sectors to ensure a comprehensive and effective development of ecotourism infrastructure.

Ecotourism has the potential to draw funds for enhancing the region's ecological security, as well as for its economic and socio-cultural development. Additionally, the growth of ecotourism helps increase public awareness of environmental issues and promotes ecological education.

References

[1] Devadze, A., Gvarishvili N. Ecology of Protected Areas of Georgia in the Context of Tourism Development. Journal of Innovative Economics and Management. No. 1, Volume V, pp. 112- 122. Batumi, 2018.[2] Margvelashvili, G. Soil Chemical Analysis (2019). Tbilisi: 8-36.

[2] Report of 2023, The Ministry of Environmental Protection and Agriculture of Georgia LEPL the Agency of Protected Areas. https://drive.google.com/file/d/1fhb_1Ud9yIGXsRiqzAFdGiMK0YYhFu_v/view

[3] Devadze, A., Devadze, L. COVID-19 pandemic and tourism in Georgia: challenges and development prospects. Participatory movement of science: additional abstracts. XII International Scientific and Practical Internet Conference, 1st-2nd quarter 2021 – Dnipro, Ukraine, 2021. – T.1. – 493 p.

[4] Devadze. A. Chaganaba, P. Challenges in the Development of Ecotourism in Georgia. Scientific Papers Collection. Kutaisi, November, 2017, pp.57-66.

[5] WWF & IUCN, 1974; Williams, Zazanashvil., Sanadiradze, Kandaurov 2006 (WWF)

http://www.wwf.org/; http://www.worldwildlife.org

[6] The map - ”100 European Forests We Should Protect Now”, 1997.

[7] Manvelidze, Z., Memiadze, N., Kharazishvili, D., Varshanidze, N. (2008). Specific Diversity of the Ajara Floristic Region (A List of Wild Juvenile Plant Species. Plant Science, Georgia). // ,,Plants Science”, Georgia, 86 pp.

[8] Gvarishvili, N. About the vertical zonation of Adjara's vegetation cover. "Current Scientific Issues". Sukhishvili University. Gori. Georgia, 2010. Pp.294–299.

VERTICAL COMPONENT LEVEL OF SEISMIC GROUND MOTION VELOCITY

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Abstract

Today it is considered proven that the vertical component of seismic ground motion makes a significant contribution to seismic loads on structures. For practical use in engineering calculations, it is necessary to assess the level of the vertical component. Taking into account growing interest to velocity of seismic oscillations, it is necessary to make such investigation and for vertical component of the seismic ground motion velocity. To solve this problem, the world empirical database of strong ground motions parameters of the earthquakes was used. Methods of statistical data processing were used. The first stage was the investigation of the ratio between the peak amplitudes of the maximal horizontal and vertical components of ground motion velocity, as well as the dependence of this ratio on the distance and magnitude of the seismic event It has been established that the dependence on magnitude is negligible. Taking into account the fact, that seismic oscillations in the near- and far- field zones of earthquakes have the different laws, further the dependence on distance was studied separately in each zone. As a result, correlation relationships for assessing the level of the vertical component of the velocity of expected seismic ground vibrations were developed, and the corresponding correlation coefficients and standard deviation values were computed. The obtained results can be used in calculating seismic treatments for the purposes of design and construction of seismic resistant structures.

Keywords: velocity, vertical component, amplitude, ratio, distance, seismic treatments

I. Introduction

One of the main tasks of providing comprehensive protection against earthquakes, which must be solved to reduce seismic risk, to decrease economic damage and human losses during earthquakes, is the seismic hazard assessment and the forecast of expected seismic treatments. In modern seismic resistant construction, seismic treatments are described by various quantitative parameters. The most commonly used one is acceleration; its characteristics have been studied in numerous works [1 – 7, etc.].

However, today in the practice of engineering calculations it is often necessary to take into account the velocity of seismic ground motions [8 – 11]. Nevertheless, this parameter has not yet been studied enough. In the scientific literature, one can mainly find only velocity attenuation equations [12 – 15, etc.]. Some authors propose the attenuation equations for vertical component of velocity [14, 16, 17, etc.]. The other characteristics are not practically researched. The vertical component of velocity also remains uninvestigated, although the need for such investigation is beyond doubt.

If special field observations are not carried out and the acceleration is used as the characteristics of seismic treatments, the level of the vertical component of acceleration is determined through the peak amplitude of the maximal horizontal component of ground motion. It was established that the relation between the accelerations on vertical and horizontal components significantly depend only on level of vibration [18].

Similar investigations for velocity of seismic ground motion have not been carried out.

The issue of the ratio of amplitudes on different components is very important, first of all, from a practical point of view. After all, if, as in the case of accelerations, there is a certain relationship between the levels of velocities on different components, then there is also the possibility of limiting research to studying only the maximal horizontal component of velocity of seismic ground motion.

II. Methods

To investigate the problem of assessing the level of vertical component of seismic ground motion velocity, the world empirical database of strong ground motions parameters of the earthquakes from different regions of the world with different tectonic settings was used. The interval of earthquake magnitude is $2 \le M_S \le 8$. The used distance was the shortest distance to the rupture surface. The interval of such distance is 0.01 km ≤ R ≤ 100 km. The soils were classified into 4 groups by seismic properties according to Russian building codes.

Used research method is statistical analysis of empirical data on strong ground motions.

The study contained several stages:

- firstly, the ratio between the vibration amplitude of the vertical component and the amplitude of the maximal horizontal component was considered;
- secondly, the influence of earthquake magnitude and distance on this ratio was considered;
- thirdly, mentioned above ratio was considered in both near- and far-field zone separately.

Finally, for each developed correlated relations the standard deviation and correlation coefficient were defined.

III. Results

So, let us consider the ratio of the oscillation amplitude of the vertical component PGV_{vert} and the maximal horizontal (or, what is the same, main) component PGV_{Hmax}. The ratio of the peak amplitudes of these components is presented in Figure 1.

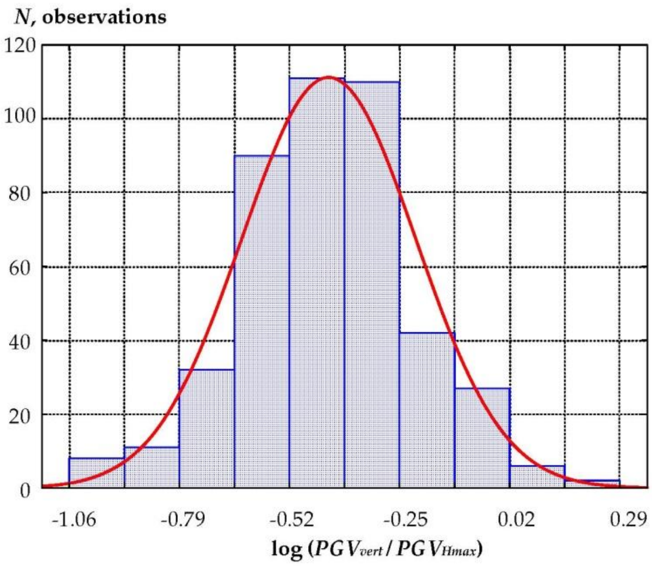

Figure 1: *Ratio of peak amplitudes of the vertical and maximal horizontal components (439 events). Red line is Gaussian distribution with parameters -0.43 ± 0.21.*

The average value of this ratio for a sample of 439 events is -0.43 units decimal logarithm, standard deviation σ = 0.21. The peak amplitude value of the vertical component is approximately 60% less than the peak value of the more intense horizontal component.

The dependence of the oscillation amplitude of the vertical component on the maximal horizontal one is graphically presented in Figure 2.

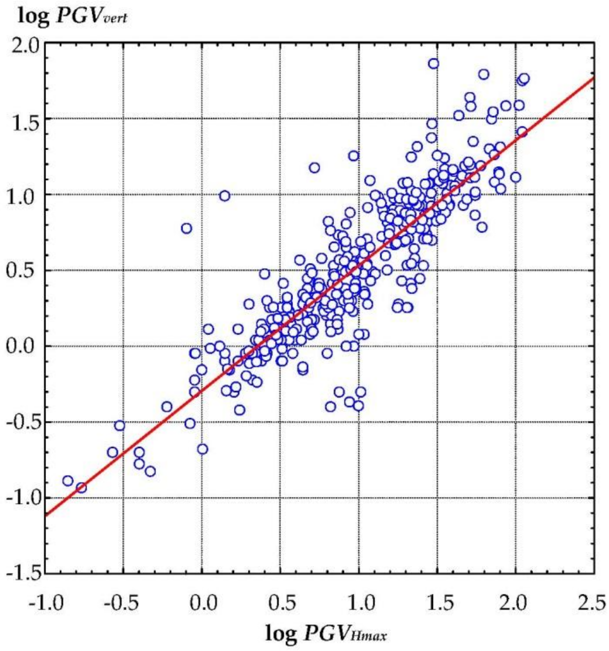

Figure 2: *Dependence of PGV_{vert} on PGV_{Hmax}.*
Circles are the empirical data (439 events); red line is approximating straight line

This relation is described by the equation:

$$\log PGV_{vert} = 0.82 \log PGV_{Hmax} - 0.29 \pm 0.29 \quad (1)$$

where PGV_{vert} - peak ground velocity (a maximal oscillation amplitude) of the vertical component, PGV_{Hmax} - peak ground velocity (a maximal oscillation amplitude) of maximal horizontal component (or, what is the same, main component).

The correlation coefficient in this case is $r = 0.87$.

With distance, the difference in levels between the vertical and maximal horizontal components increases, i.e. the vertical one grows faster, and with increasing magnitude, on the contrary, it decreases (Figure 3).

The corresponding formula for a sample of 159 events is:

$$\log (PGV_{vert} / PGV_{Hmax}) = 0.19 \log R - 0.06\, M_S - 0.38 \pm 0.33. \quad (2)$$

However, as can be seen from formula (2), the ratio of the levels of the vertical and maximal horizontal components to the magnitude is insignificant. The dependence on distance requires additional study.

Let us consider the dependence of the ratio of the amplitudes of the vertical and maximal horizontal components on distance separately for the near - and far – field zones. The relationship between far-field amplitudes ratio and distance is shown in Figure 4.

The equation of the approximating line has the form:

$$\log (PGV_{vert} / PGV_{Hmax}) = 0.08 \log R - 0.57 \pm 0.28. \quad (3)$$

As it is seen from equation (3,) the change in the value of log (PGV_{vert} / PGV_{Hmax}) over the entire considered range of distances does not exceed the standard deviation. So, the dependence on distance can also be neglected.

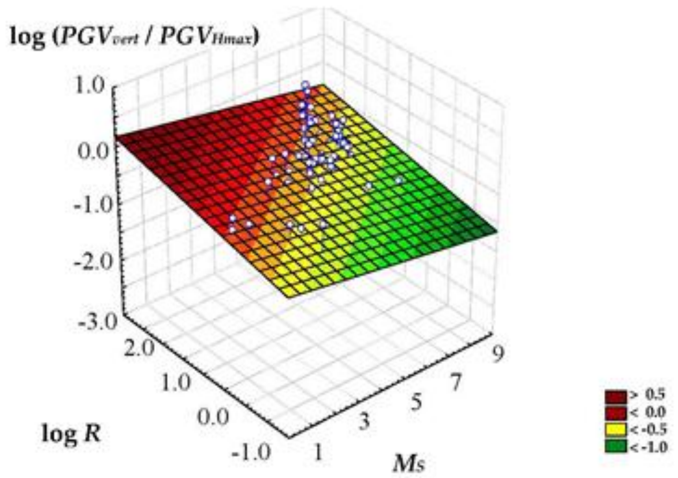

Figure 3: *Dependence of the ratio log (PGV_{vert} / PGV_{Hmax}) on the magnitude M_S and distance R. Circles are empirical data (159 events)*

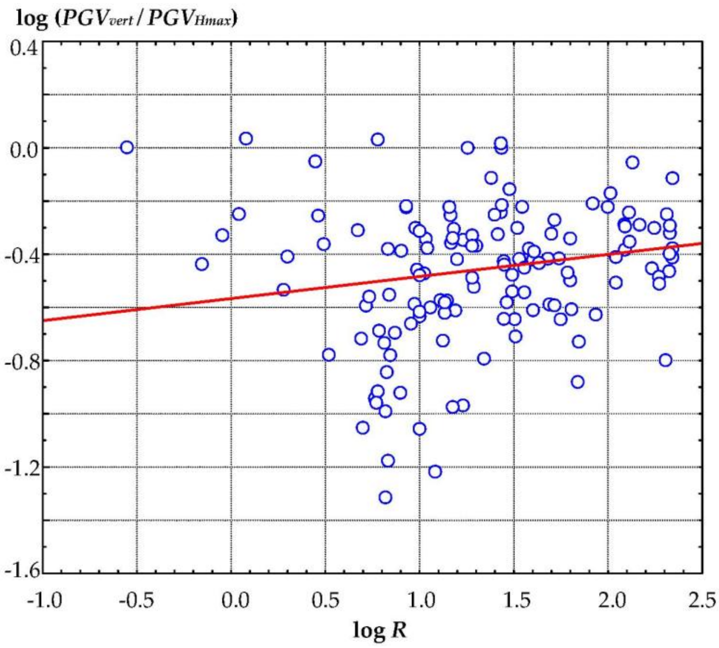

Figure 4: *Dependence of the value log (PGV_{vert} / PGV_{Hmax}) on the distance in the far-field zone. Circles are empirical data (144 events); red line is approximating straight line*

A similar picture is observed in the near - field zone.

Note, that magnitude and distance in equation (2) are correlated: small magnitudes are recorded only at short distances. As has been shown, the dependence of log (PGV_{vert} / PGV_{Hmax}) value on both distance and magnitude is insignificant. Therefore, equation (2) does not adequately describe the real dependencies. It is not for nothing that the distribution of the value log (PGV_{vert} / PGV_{Hmax}) without taking into account any factors (see Figure 1) has a lower standard deviation.

Let us consider the relationship between the levels of vertical and maximal horizontal components in the near - and far – field zones separately.

For the near -field zone (Figure 5)

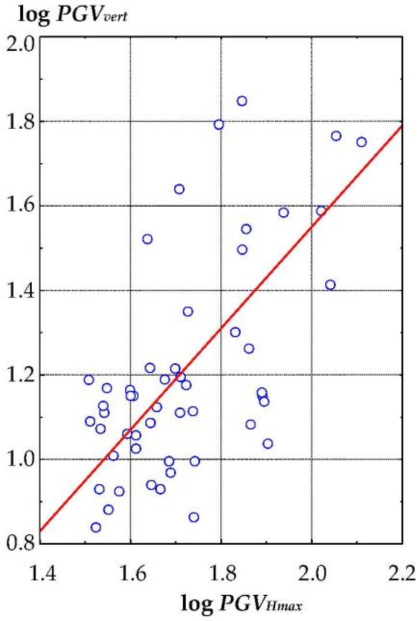

Figure 5: *Dependence of PGV_{vert} on PGV_{Hmax} in the near-field zone.*
Circles are empirical data (58 events); red line is approximating straight line

we have the next correlation relation:

$$\log PGV_{vert} = 1.20 \log PGV_{Hmax} - 0.85 \pm 0.14, \quad (4)$$

moreover, in the far-field zone (Figure 6)

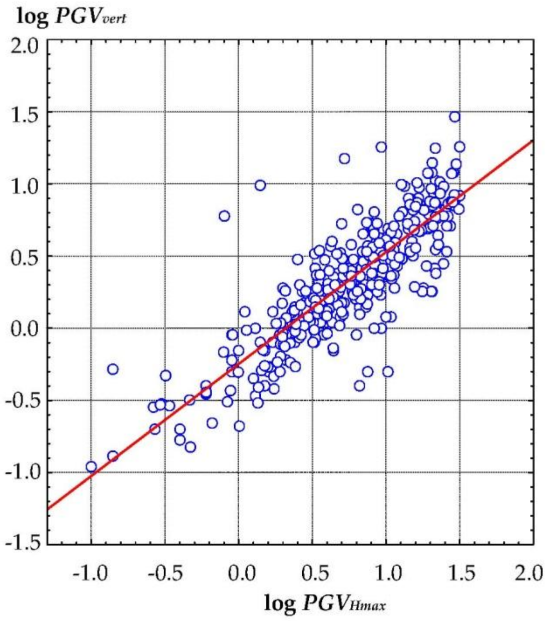

Figure 6: *Dependence of PGV_{vert} on PGV_{Hmax} in the far-field zone.*
Circles are empirical data (379 events); red line is approximating straight line

the relation was obtained

$$\log PGV_{vert} = 0.78 \log PGV_{Hmax} - 0.25 \pm 0.20. \quad (5)$$

The correlation coefficient of this relationship is high: $r = 0.87$.

IV. Discussion

Thus, as the empirical data analysis shows, the level of vertical component of seismic ground motion velocity is approximately in 1.7 times less than the peak value of the more intense horizontal component. It is the average estimation, without taking into account any factors as ground types at the observations point, the type of source mechanism, the distance and magnitude.

The influence of earthquake magnitude on the relation between the amplitudes of peak ground velocity of vertical component and the maximal horizontal component is insignificant. This relation is dimensionless value. In according the theory of dimension and similarity, the dimensionless quantity should not depend on the scale of the phenomenon.

As the result of research, the correlation relations for assessing the level of vertical velocity component were developed. These relations were obtained for near- and far-field zones of seismic wave field.

As in the case of accelerations, the relation between the velocities on vertical and horizontal components significantly depends on level of vibration. Therefore, the prediction of the amplitude level of the vertical velocity component of seismic ground motion is possible using data on the maximal horizontal component.

References

[1] Stafford P.J. (2019) Continuous integration of data into ground-motion models using Bayesian updating. *Journal of Seismology*, 23 (1):39–57, doi: 10.1007/s10950-018-9792-3.

[2] Sung C.-H., Lee C.-T. (2019) Improvement of the quantification of epistemic uncertainty using single-station ground-motion prediction equations. *Bull. Seism. Soc. Am.*, 109 (4):1358–1377, doi: 10.1785/0120180044.

[3] Hu J., Tan J., Zhao J. X. (2020) New gmpes for the Sagami Bay region in Japan for moderate magnitude events with emphasis on differences on site amplifications at the seafloor and land seismic stations of K-NET. *Bull. Seism. Soc. Am.*, 110 (5):2577–2597, doi: 10.1785/0120190305.

[4] Phung V.-B., Loh C. H., Chao S. H., Chiou B. S. J., Huang B.-S. (2020) Ground motion prediction equation for crustal earthquakes in Taiwan. *Earthquake Spectra,* 36(4):2129–2164, doi: 10.1177/ 8755293020919415.

[5] Boore D. M., Stewart J. P., Skarlatoudis A. A., Seyhan E., Margaris B., Theodoulidis N., Scordilis E., Kalogeras I., Klimis N., Melis N. S. (2021) A ground-motion prediction model for shallow crustal earthquakes in Greece. *Bull. Seism. Soc. Am.*, 111 (2):857–874, doi: 10.1785/0120200270.

[6] Bommer J.J., Stafford P.J.,·Ruigrok E.,·Rodriguez-Marek A.,·Ntinalexis M., Kruiver P.P., Edwards B., Dost B., van Elk J. (2022) Ground-motion prediction models for induced earthquakes in the Groningen gas field, the Netherlands. *Journal of Seismology*, 26:1157–1184, https://doi.org/10.1007/s10950-022-10120-w

[7] Keshri C. K., Mohanty W.K. (2023) Next generation ground-motion prediction equations for Indo-Gangetic Plains, India. *J. Earth System Science,* 132 (85):84–107, https://doi.org/10.1007/s12040-023-02092-3.

[8] Trombetti T., Silvestri S., Gasparini G., Righi M., Ceccoli C. (2008) Correlations between the displacement response spectra and the parameters characterizing the magnitude of the ground motion. *Proc. XIV World Conference on Earthquake Engineering (Beijing, October 12 – 17, 2008),* CD:Paper ID 02-0130.

[9] Dashti S., Bray J.D., Pestana J.S., Riemer M., Wilson D. (2010) Centrifuge testing to evaluate and mitigate liquefaction-induced building settlement mechanisms. *J. Geotech. Geoenv. Eng.*, 136 (7):918–929, doi: 10.1061/(ASCE)GT.1943-5606.0000306.

[10] Campbell K.W., Bozorgnia Y. (2012) Use of cumulative absolute velocity (CAV) in damage assessment // *Proc. XV World Conference on Earthquake Engineering (Lisbon, September 24 – 28, 2012),* 22:17370–17379.

[11] Lanzano G., Salzano E., Santucci F., Fabbrocino G. (2013) Performance Assessment of Continuous Buried Pipelines under Earthquakes Loading. *Chemical Engineering Transactions,* 31:631–636, doi: 10.3303/CET1331106.

[12] Chiou B., Youngs R., Abrahamson N., Addo K. (2010) Ground-motion attenuation model for small-to-moderate shallow crustal earthquakes in California and its implications on regionalization of ground-motion prediction models. *Earthquake Spectra,* 26 (4):907–926, DOI: 10.1193/1.347993.

[13] Akkar S., Bommer J.J. (2010) Empirical equations for the prediction of PGA, PGV and spectral accelerations in Europe, the Mediterranean region and the Middle East. *Seism. Res. Lett.,* 81(2):195–206, doi: 10.1785/gssrl.81.2.195.

[14] Bozorgnia Y., Campbell K.W. (2016) Vertical ground motion model for PGA, PGV, and linear response spectra using the NGA-West2 database. *Earthquake Spectra,* 32 (2):979–1004, doi: 10.1193/072814EQS121M

[15] Sedaghati F., Pezeshk S. (2017) Partially nonergodic empirical ground-motion models for predicting horizontal and vertical PGV, PGA, and 5% damped linear acceleration response spectra using data from the Iranian plateau. *Bull. Seism. Soc. Am.,* 107 (2):934–948, doi: 10.1785/0120160205

[16] Morikawa N., Fujiwara H. (2013) A new ground motion prediction equation for Japan applicable up to M9 mega-earthquake. *J. Disaster Research,* 8(5):878–888, doi: 10.20965/jdr.2013.p0878

[17] Stewart J.P., Boore D.M., Seyhan E., Atkinson G.M. (2016) NGA-West 2 equations for predicting vertical component PGA, PGV, and 5%-damped PSA from shallow crustal earthquakes. *Earthquake Spectra,* 32(2):1005–1031, doi: 10.1193/072114EQS116M

[18] Aptikaev Felix, Erteleva Olga (2009) Vertical component problem for seismic hazard analysis. *Seismology and Engineering seismology (ed. Mihailo D. Trifunac)*, Banja Luka, Republic of Srpska, Bosnia and Herzegovina: N.I.G.D. Nezavisne novine: 77–86.

STATISTICAL ANALYSIS OF PARAMETERIZED LANDSLIDE DATA IN GEORGIA FROM 1900 TO 2022

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Abstract

Some results of statistical analysis of parameterized landslide (LS) data (the number of landslides and their areas) for 11 regions of Georgia (Autonomous Republic of Adjara, Guria, Imereti, Kakheti, Kvemo Kartli, Mtskheta-Mtianeti, Samegrelo-Zemo Svaneti, Racha-Lechkhumi and Kvemo Svaneti, Samtskhe-Javakheti, Shida Kartli, Tbilisi) from 1900 to 2022 are presented. Landslides count for Georgia is 1325, total area - 526.3 km^2. The area of individual landslides varies in the range from 0.0005 km^2 (Imereti, Samegrelo-Zemo Svaneti, Samtskhe-Javakheti) to 12.0 km^2 (Shida Kartli). In particular, the following results were obtained. Map of distribution of landslides number and their areas for different regions of Georgia is presented. Repeatability of the number of landslides and also their total area for different ranges of LS areas is study; the highest frequency of landslides in the study area falls on the range of their areas 0.0005-0.05 km^2 (41.5%), the smallest - on the range 5.01-12.0 km^2 (0.38%); the highest frequency of the total area of landslides falls on the range of their areas 1.01-2.0 km^2 (26.1%), the smallest – on the range 0.0005-0.05 km^2 (1.8%). The average annual shares of the total area of landslides from the area of study regions is calculated; this share in Guria (0.288%) and Adjara (0.281%) is significantly higher than in other regions - respectively, 5.05-4.9 times more than in Shida Kartli and 28.8-28.1 times more than in Samegrelo-Zemo Svaneti. The relative coefficient of the total area of landslides (RC) for individual region is calculated. RC = (Landslides average area in region/Sum average landslides area in all regions)/(Region area/All regions area); the RC value for Guria and Adjara, respectively, is 6.26 and 6.13 and 3.6-3.5 times more than in Shida Kartli and 27.2-26.7 times more than in Kvemo Kartli and Samegrelo-Zemo Svaneti. The relative landslide risk ratio for the population of study regions (RLR) was calculated. RLR = RC·(Region population/All regions population). The highest RLR value is observed for Adjara (0.60); for Guria and Tbilisi - 0.17 each (approximately 3.5 times less). The lowest RLR values are observed for Racha-Lechkhumi and Kvemo Svaneti (0.007).

Keywords: natural disaster, dangerous geological processes, landslides, landslides area.

I. Introduction

Landslides are a type of natural disaster. Landslide processes are widespread almost everywhere, including in Georgia, and are dangerous due to damage to residential buildings, roads, infrastructure, etc., often accompanied by human casualties [1-4]. In particular, according to incomplete data [5,6], in Georgia in 1996-2020 the total number of reactivated and new cases of landslides was about 12000. Therefore, the study of landslide processes in this country has always been and is given special attention [7–9].

An analysis of extensive material on landslides in Georgia showed that there is not so much systematic data about this natural phenomenon. In connection with the above, we collected the most reliable values of the main parameters of landslides, determined on the basis of the totality of available information. These included the date of occurrence (year, month, day), time of occurrence (hour), location of occurrence (geographical coordinates), magnitude and intensity [7,10], where appropriate, affected area and associated losses (number of fatalities; casualties in economic terms). As a result of this work, the first systematic catalog in Georgia was created for this natural phenomenon, as one of the five natural disasters (landslides, debris flows, flash floods, windstorms and hailstorms) [11,12].

The Landslide Catalog contains 1636 events for the period from 1900 to 2022, including, in particular, data on their areas.

At this stage of research, the results of a statistical analysis of data on the number of landslides and their areas for 11 regions of Georgia in the period from 1990 to 2022 are presented.

II. Study area, material and methods

Study area is Georgia and their 11 regions (Autonomous Republic of Adjara, Guria, Imereti, Kakheti, Kvemo Kartli, Mtskheta-Mtianeti, Samegrelo-Zemo Svaneti, Racha-Lechkhumi and Kvemo Svaneti, Samtskhe-Javakheti, Shida Kartli and Tbilisi).

Table 1: *Study area, population, period of observations and height range on landslides emergence in Georgia.*

Region	Region, Abbr	Regional center	Area, km²	Population (thous.)	Period of observations	Number of years	LS height range (m,a.s.l.)
Autonomous Republic of Adjara	Adj	Batumi	2919	363	1968-2022	21	2-1846
Guria	Gur	Ozurgeti	2033	102	1979-2022	13	28-553
Imereti	Im	Kutaisi	6516	442	1940-2022	26	21-965
Kakheti	Kakh	Telavi	11310	300	1974-2022	10	440-1974
Kvemo Kartli	KK	Rustavi	6528	436	1977-2022	8	285-1361
Mtskheta-Mtianeti	M-M	Mtskheta	6785	93	1963-2022	28	497-3773
Samegrelo-Zemo Svaneti	S-ZS	Zugdidi	7441	288	1900-2017	28	33-2384
Racha-Lechkhumi and Kvemo Svaneti	R-L KS	Ambrolauri	4690	26	1966-2022	35	354-1838
Samtskhe-Javakheti	S-J	Akhaltsikhe	6413	142	1973-2022	14	797-2468
Shida Kartli	Sh K	Gori	3429	244	1971-2022	14	509-1000
Tbilisi	Tb	Tbilisi	504	1259	1973-2022	25	437-1376
Georgia	Geo	Tbilisi	58567	3695	1990-2022	60	2-3773

In Table 1 information on the above mentioned study area, population [https://en.wikipedia.org/wiki/Administrative_divisions_of_Georgia_(country)], period of observations and height range on landslides emergence in Georgia are presented. In particular, the area of the studied regions vary from 504 km² (Tbilisi) to 11310 km² (Kakheti); population vary from 26 thousand (Racha-Lechkhumi and Kvemo Svaneti) to 1259 thousand (Tbilisi) [https://www.geostat.ge/en]; period of observations - from 1990 to 2022; number of years of observations - from 8 (Kvemo Kartli) to 35 (Racha-Lechkhumi and Kvemo Svaneti). In general, in Georgia, the study area is 58567 km^2, population – 3695 thousand and the number of years of observations is 60. The height of landslides emergence in Georgia vary from 2 to 3773 meters.

The work used catalog data [12] on the landslides and their areas for 11 regions of Georgia in the period from 1990 to 2022 (1375 cases in total).

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods.

The following designations will be used below: Mean – average values; Max - maximal values; Min – minimal values; St Dev - standard deviation; St Err - standard error; Low and Upp – lower and upper levels of the confidence interval of the mean within standard error; LS – landslide. RC - relative coefficient of the total area of landslides in region; RC = (Landslides average area in region/Sum average landslides area in all regions)/(Region area/All regions area). RLR - relative landslide risk ratio for the population of study regions; RLR = RC·(Region population/All regions population).

III. Results

The results in Fig. 1-6 and Table 2 are represented.

In Fig. 1 map of distribution of landslides number and their areas for different regions of Georgia is presented. In Table 2 statistical characteristics of Fig. 1 data is represented.

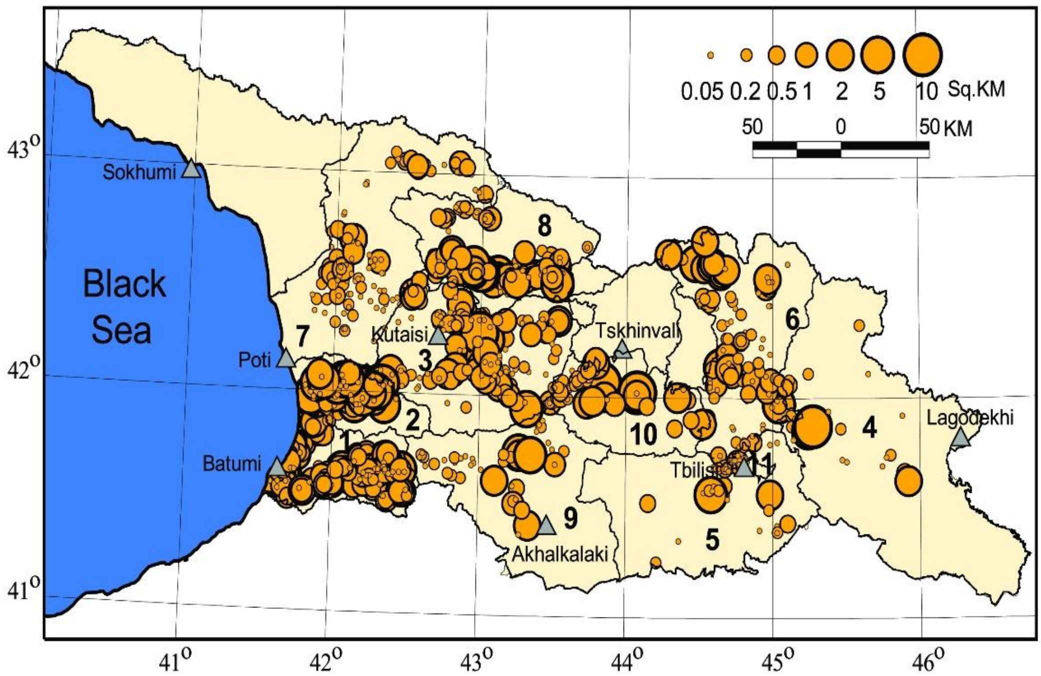


Figure 1: *Distribution of landslides area in Georgia*
1 – Autonomous Republic of Adjara, 2 – Guria, 3 – Imereti, 4 - Kakheti, 5 - Kvemo Kartli, 6 - Mtskheta-Mtianeti, 7 - Samegrelo-Zemo Svaneti, 8 - Racha-Lechkhumi and Kvemo Svaneti, 9 - Samtskhe-Javakheti, 10 - Shida Kartli, 11 - Tbilisi.

As follows from Fig. 1 and table 2, the distribution of the number of landslides and their areas on the territory of Georgia is extremely uneven. In particular, LS count vary from 23 (Kvemo Kartli) to 300 (Autonomous Republic of Adjara). LS count for Georgia is 1325. The area of individual landslides varies in the range from 0.0005 km^2 (Imereti, Samegrelo-Zemo Svaneti, Samtskhe-Javakheti) to 12.0 km^2 (Shida Kartli).

Table 2. *Statistical characteristics of landslide areas in different regions of Georgia (km²).*

Region	Adj	Gur	Im	Kakh	KK	M-M
Min	0.001	0.0007	0.0005	0.00132	0.0017	0.001
Max	2.7	3.7	8.4	6.0	2.2	4.1
Mean	0.57	0.97	0.35	0.49	0.24	0.32
St Dev	0.53	1.16	0.88	1.30	0.51	0.57
St Err	0.031	0.133	0.064	0.259	0.108	0.050
Total area	172.5	76.0	65.6	12.6	5.5	41.5
LS count	300	78	189	26	23	131
Region	S-ZS	R-L KS	S-J	Sh K	Tb	Geo
Min	0.0005	0.001	0.0005	0.001	0.001	0.0005
Max	2.0	4.0	3.0	12.0	0.8	12.0
Mean	0.16	0.28	0.32	0.50	0.05	0.40
St Dev	0.26	0.54	0.66	1.53	0.13	0.76
St Err	0.022	0.034	0.095	0.174	0.018	0.021
Total area	21.5	74.1	15.5	38.7	2.8	526.3
LS count	138	260	49	78	53	1325

The total landslides area changes from 2.8 km² (Tbilisi) to 172.5 km² (Autonomous Republic of Adjara). For Georgia the total landslides area is 526.3 km². On average, the area of landslides vary from 0.05 km² (Tbilisi) to 0.97 km² (Guria). In Georgia as a whole, this area is 0.40 km².

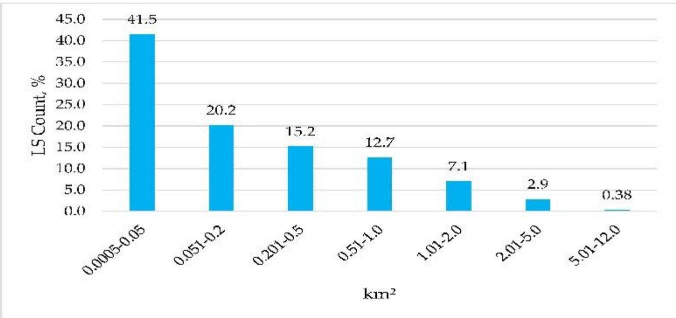


Figure 2: *Repeatability of the number of landslides at different ranges of their areas.*

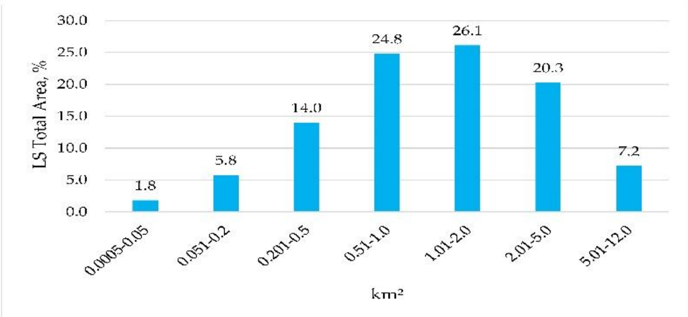
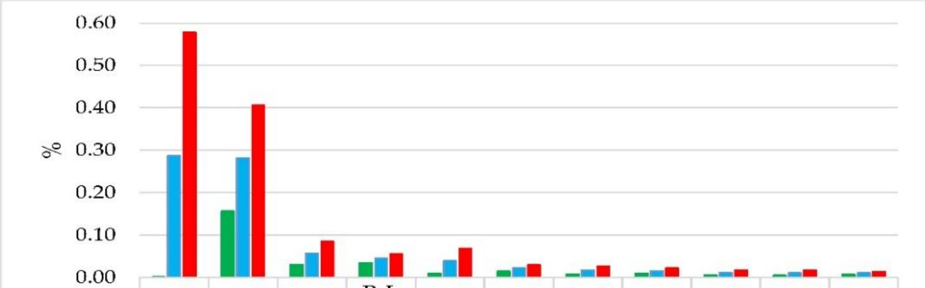


Figure 3: *Repeatability of the total area of landslides for different ranges of their areas.*

From Fig. 2 it follows that the highest frequency of landslides in the study area falls on the range of their areas 0.0005-0.05 km² (41.5%), the smallest - on the range 5.01-12.0 km² (0.38%). At the same time, as shown in Fig. 3, the highest frequency of the total area of landslides falls on the range of their areas 1.01-2.0 km² (26.1%), the smallest – on the range 0.0005-0.05 km² (1.8%).



	Gur	Adj	Sh K	R-L KS	Im	M-M	S-J	Tb	Kakh	KK	S-ZS
Low	0.001	0.156	0.030	0.035	0.009	0.014	0.008	0.010	0.005	0.005	0.007
Mean	0.288	0.281	0.057	0.045	0.039	0.022	0.017	0.016	0.011	0.011	0.010
Upp	0.578	0.406	0.084	0.056	0.068	0.029	0.026	0.022	0.017	0.017	0.014

Figure 4: *Mean annual share of the total area of landslides from the area of the region.*

Taking into account that the studied regions have different areas, we calculated the average annual shares of the total area of landslides from the area of these regions (Fig. 4). As follows from Fig. 4, this share in Guria (0.288%) and Adjara (0.281%) is significantly higher than in other regions: respectively, 5.05-4.9 times more than in Shida Kartli and 28.8-28.1 times more than in Samegrelo-Zemo Svaneti.

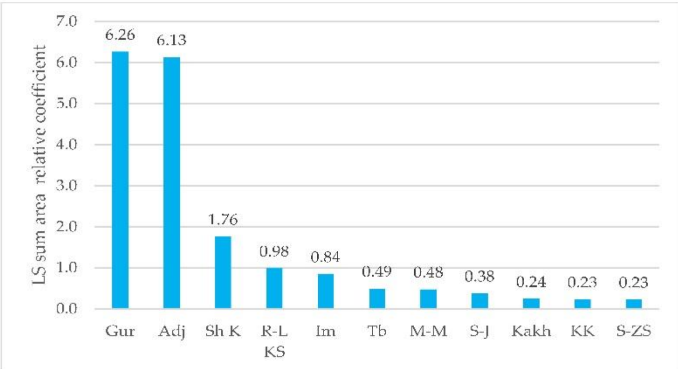


Figure 5: *Relative coefficient of the total area of landslides for different regions of Georgia.*

Taking into account that the amount of systematic data on landslides in Georgia is much lower than the total recorded amount (for example, about 5% in 1996-2020 [5,6,12]), we calculated the relative coefficient of the total area of landslides RC for individual regions (Fig. 5). As follows from this figure, the RC value for Guria and Adjara, respectively, is 6.26 and 6.13 and 3.6-3.5 times more than in Shida Kartli and 27.2-26.7 times more than in Kvemo Kartli and Samegrelo-Zemo Svaneti.

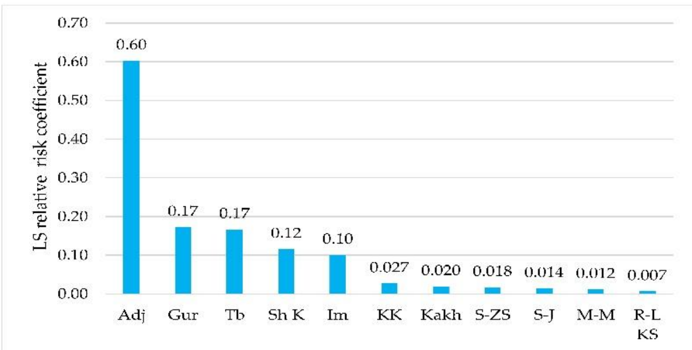


Figure 6: *Relative landslide risk ratio for populations of different regions of Georgia.*

Finally, taking into account the number of inhabitants in the study regions of Georgia, the relative landslide risk ratio (RLR) for the population of these regions was calculated (Fig. 6). As follows from Fig. 6, the highest RLR value is observed for Adjara (0.60); for Guria and Tbilisi - 0.17 each (approximately 3.5 times less). The lowest RLR values are observed for Racha-Lechkhumi and Kvemo Svaneti (0.007).

IV. Discussion

Landslide (LS) processes are widespread almost everywhere and are dangerous due to damage to residential buildings, roads, infrastructure, etc., often accompanied by human casualties. This problem is also very relevant for Georgia. According to incomplete data the total number of landslide on the territories of Georgia in 1996-2020 was near 12000 [5,6]. Therefore, the study of landslide processes in Georgia has always been and is given special attention.

An analysis of extensive material on landslides in Georgia showed that there is not so much parameterized data about this natural phenomenon. In connection with the above, by us made the first systematic catalog in Georgia was created for this natural phenomenon, as one of the five natural disasters (landslides, debris flows, flash floods, windstorms and hailstorms) [11,12].

The Landslide Catalog contains 1636 events for the period from 1900 to 2022, including, in particular, data on their areas. At this stage of research, a statistical analysis of data on the number of landslides and their areas for 11 regions of Georgia in the period from 1990 to 2022 carried out (1325 LS events).

In particular, it has been quantitatively confirmed that in terms of relative landslide-hazardous area, the most vulnerable regions are Guria and Adjara, significantly exceeding all other regions. In terms of the level of landslide risk for the population of these regions, Adjara is the most unfavorable, followed by Guria and Tbilisi.

V. Conclusion

In the near future, we plan to conduct a statistical analysis of such LS catalog parameters as magnitude, intensity, economic loss. In addition, it became possible to significantly improve the quality of mapping the territory of Georgia using parameterized data on landslides, to clarify the quantitative relationships of landslides with various geological, geophysical and atmospheric processes (in particular, with precipitation [13]). We also plan to continually update the catalog data as new information becomes available [14,15].

Acknowledgments

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References

[1] Aleotti P., Chowdhury R. (1999). Landslide hazard assessment: summary. Rev N Perspect. *Bull Eng. Geol. Env.* 58, pp. 21–44.

[2] Corominas J., Van Westen C., Frattini P., Cascini L., Malet J.-P., Fotopoulou S., Catani F., Van Den Eeckhaut M., Mavrouli O., Agliardi F., Pitilakis K., Winter M. G., Pastor M., Ferlisi S., Tofani V., Herva´s J., Smith J. T. (2014). Recommendations for the quantitative analysis of landslide risk. *Bull Eng Geol Environ*, 73, pp. 209–263. DOI: 10.1007/s10064-013-0538-8

[3] Froude M., Petley D. (2018). Global fatal landslide occurrence from 2004 to 2016. *Nat. Hazards Earth Syst. Sci.*, 18, pp. 2161–2181.

[4] Bondyrev I.V., Tsereteli E.D., Ali Uzun, Zaalishvili V.B. (2014). Landslides of the Southern

Caucasus. *Geologiya i geofizika Yuga Rossii*, № 4, tom 2, s. 105-123, (in Russian).

[5] Fourth National Communication of Georgia Under the United Nations Framework Convention on Climate Change. (2021). Chapter 4.9 Geological Hazards in Georgia, Tbilisi, pp. 278-286.

[6] Tsereteli E., Bolashvili N., Gaprindashvili G., Gaprindashvili M., Machavariani N. (2021). Risk of Natural Hazards in Georgia. *Journal of the Georgian Geophysical Society, Physics of Solid Earth, Atmosphere, Ocean and Space Plasma*, v. 24(2), pp. 22-29.

[7] Varazanashvili O., Tsereteli N., Amiranashvili A., Tsereteli E., Elizbarashvili E., Dolidze J., Qaldani L., Saluqvadze M., Adamia Sh., Arevadze N., Gventcadze A. (2012). Vulnerability, Hazards and Multiple Risk Assessment for Georgia. *Natural Hazards*. Vol. 64, pp. 2021-2056. DOI 10.1007/s11069-012-0374-3

[8] Gaprindashvili G., Cees J. Van Westen. (2016). Generation of a national landslide hazard and risk map for the country of Georgia. *Natural hazards*, vol.80, N 1, pp. 69-101.

[9] Gaprindashvili M., Tsereteli E., Gaprindashvili G., Kurtsikidze O. (2021). Landslide and Mudflow Hazard Assessment in Georgia. In: Bonali, F.L., Pasquaré Mariotto, F., Tsereteli, N. (eds) Building Knowledge for Geohazard Assessment and Management in the Caucasus and other Orogenic Regions. NATO Science for Peace and Security Series C: Environmental Security. Springer, Dordrecht. https://doi.org/10.1007/978-94-024-2046-3_14

[10] Varazanashvili O.Sh., Gaprindashvili G.M., Elizbarashvili E.Sh., Basilashvili Ts.Z., Amiranashvili A.G. (2022). Principles of Natural Hazards Catalogs Compiling and Magnitude Classification. *Journal of the Georgian Geophysical Society, Physics of Solid Earth, Atmosphere, Ocean and Space Plasma*, v. 25(1), pp. 5-11.

[11] Gaprindashvili G., Varazanashvili O., Elizbarashvili E., Basilashvili Ts., Amiranashvili A., Fuchs S. (2023). GeNHs: the First Natural Hazard Event Database for the Republic of Georgia. EGU General Assembly 2023, EGU23-1614.

[12] Varazanashvili O., Gaprindashvili G., Elizbarashvili E., Basilashvili, Ts., Amiranashvili A., Fuchs S. (2023). The First Natural Hazard Event Database for the Republic of Georgia (GeNHs). Catalog, 270 p. http://dspace.gela.org.ge/handle/123456789/10369; DOI: 10.13140/RG.2.2.12474.57286

[13] Chelidze T., Amiranashvili A., Svanadze D., Tsamalashvili T., Tvauri G. (2023). Terrestrial and Satellite-Based Assessment of Rainfall Triggered Landslides Activity in Georgia, Caucasus. *Bull. Georg. Nat. Acad. Sci.* vol. 17, no. 2, pp. 71-77.

[14] Koberidze R., Gaprindashvili G., Rikadze Z., Kurtsikidze O., Gaprindashvili M. (2024). Advancing Landslide Monitoring in Tbilisi city and Imereti Region (Georgia): Integrating Tiltmeters, Piezometers, GPS and Geospatial Technologies. EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-2523. https://doi.org/10.5194/egusphere-egu24-2523, 2024.

[15] Bakhsoliani D., Magalashvili A., Gaprindashvili, G. (2024). Landslide Inventory Mapping in Densely Populated and Forested Environments using UAV LiDAR Data: A Case Study in Zindisi, Surami District, Georgia, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-2467, https://doi.org/10.5194/egusphere-egu24-2467, 2024.

THE INCREASE IN THE INTENSITY OF DESERTIFICATION DUE TO CLIMATE CHANGE IN THE TERRITORY OF THE NORTH CHECHEN LOWLAND

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Abstract

Desertification processes that have covered significant areas in the North Chechen Lowland, caused by anthropogenic impact exceeding their stability, have intensified due to climate change. The temperature regime has changed significantly over the past 30 years, the temperature has increased by 1-1.5 degrees, and the amount of precipitation has decreased – less than 250 mm per year, evaporation has increased and in summer can reach up to 2500 mm or more. Under these conditions, degradation processes leading to the reduction of vegetation cover and to the destruction of soil cover, causing the activation of deflationary processes. Dust storms have become quite frequent. The areas exposed to desertification processes exceed more than 270,000 hectares, including more than 100,000 hectares of open sand masses overweighed by wind.

Keywords: desertification processes, climate change, deflation processes, arid landscapes, North Chechen Lowland

I. Introduction

Arid landscapes occupy the northern regions of the Chechen Republic. Within this type of landscapes, 1 subtype is distinguished — semi—desert and desert, which is divided into 1 genus - lowland-lowland accumulative with wormwood (with fragrant wormwood, Tauric and Lerkha), solyanka deserts and wormwood-cereal semi-deserts and 3 types of landscapes (Fig. 1.).

The relief is dominated by low-lying plains with absolute heights from 5 to 200 m, composed of Pleistocene marine rocks and loess-like loams. The climatic conditions are characterized by continentality and aridity. The temperature of the coldest month (January) ranges from -4.4 to 1.8° depending on the location. The hottest month is July, with a temperature of 23.5-25.2°. Accordingly, the annual temperature reaches 9.7-11.1 °. The sum of active temperatures reaches 3550-3600 °. The low amount of precipitation (300-350 mm) determined the "fragility" of the connections between the components of nature and the "vulnerability" of semi-desert landscapes. The soils here are sandy, chestnut and light chestnut with an abundance of salt marshes and salt marshes. They are not very fertile, so for a long time the main resource used in human economic activity was the wormwood-grass steppes adjacent to the floodplain of the Terek River. When moving to the northeast, with the increase in aridity of the climate, vegetation is thinned, sod cereals gradually disappear and pickles acquire an increasingly important role in the cover. At the same time, the influence of microrelief is increasingly beginning to affect the composition of vegetation cover. Even with minor changes in the surface, there is a sharp change in plant groupings: from grass-steppe associations of wormwood and solyanka.

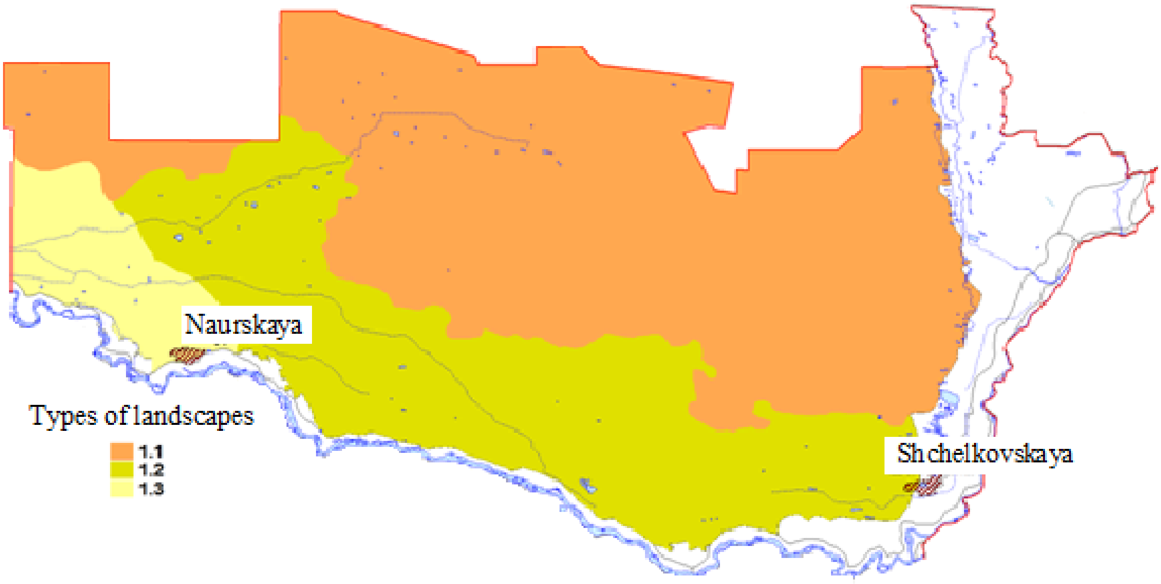

Figure 1: *Types of arid landscapes of the North Chechen lowland*
The legend of the map

1.1. A low-lying slightly inclined alluvial plain, composed of developed and intertwined sands, with a wide range of Aeolian relief forms, with semi—desert (Taurian wormwood, Marshall, Austrian) and sand-loving (erianthus Rowenna, impereta cylindrical, kendyr Sarmatian) vegetation on light chestnut soils - occupies the territory of the Tersk sandy massif, where typical Aeolian landforms with the most arid climate;

1.2. A low-lying, slightly inclined alluvial plain, composed of developed and intertwined sands with fragments of Aeolian relief, with grassy and grassy desert steppes and sand lovers on light chestnut soils, adjoins the Tersk sandy massif from the south, but the Aeolian landforms are not so widely represented here and mainly in the northern part, the climates are only slightly less drier than in the Tersk sand massif;

1.3. A low-lying slightly inclined alluvial plain composed of sands with fragments of Aeolian relief, with grassy semi-steppe and steppes (grassy-grassy, grassy—wormwood and borodachev) on dark chestnut soils is the least arid and somewhat more elevated part adjacent to the Tersk sandy massif from the southwest, Aeolian relief is extremely rare, The composition of the flora is influenced by the proximity of the real steppes.

The information currently available on the nature and distribution of the vegetation cover of the Zaverechye has accumulated as a result of research by a number of botanists. Of these, P.V. Novopokrovsky (1922, 1925, 1926), S.A. Vinogradov, G.A. Tolchin (1932), S.E. Rozhenits-Kucherovskaya (1925), A.D. Gozhev (1930), S.M. Borisov (1946) should be noted. Since the end of the 19th century, pastures of arid landscapes have been actively used year-round, which naturally led to their degradation and the manifestation of deflationary and Aeolian processes here. The anthropogenic factor intensified by climate change actively interfered with the natural course of evolution of these landscapes, which led to a significant transformation of natural components and the geosystem as a whole.

II. Methods

The North Chechen lowland has significant diversity of vegetation cover both in its genesis and species composition. Here we find plant associations of past eras, as well as modern formations and adjacent territories. In order to better understand the origin of the existing forms of plant associations, the history of their formation has been traced since the beginning of anthropogenic.

The territory of the North Chechen lowland in the modern era, three transgressions of the Caspian Sea have been traced: Baku, Khazar, Khvalyn, which alternated with periods of sea retreat - regressions. The territory of the North Chechen Lowland released after the Khvalyn transgression is exposed to climatic and anthropogenic factors. The main methods of our research of vegetation cover are the field route, which allowed us to establish the evolution and its patterns. Botanical methods are based on direct observation of the external appearance of forms and elements of plant associations, identification of their features and typical features, as well as the study of their spatial relationships.

In visual ground surveys, the main work is carried out at the reference points. They are chosen so that they can characterize one of the forms of plant associations, or a system of genetically related groupings. At the reference points of the study, a detailed botanical and geographical assessment of the studied plant associations is given: their appearance and spatial placement are described. The main method was field research by routes that ran from south to north, the reference points were located at the corners of squares with sides of 5 km. Dozens of photographs were taken. The basis has been laid for further studies of vegetation cover. The complex nature of our research has allowed us to determine that the main factor that provoked deflationary processes here is the anthropogenic factor. Since the second half of the last century, the process of intensive warming began, which naturally intensified deflationary processes.Our research covers a significant part of sandy landscapes that are subject to intense deflationary processes.

III. Results

A new type of landscape has been formed, where the anthropogenic factor of evolution plays a significant role. The Naursko-Shelkovskaya natural and anthropogenic landscape occupies the western part of the Priterskiy sand massif on the territory of the Naursky and Shelkosky districts. The natural functions of the landscape have been preserved over a significant area, they are weakened by forms of farming (watering and irrigation) and overgrazing of livestock. The coefficient of anthropogenic disturbance is 0.9.

The component subsystem is represented by a set of all natural components that have been modified by humans to varying degrees. The soil and plant components were particularly affected. Most of the landscape consists of upper quaternary alluvial-marine deposits (sands, sandy loams). Modern alluvial deposits (pebbles, sands, sandy loams) are common in the Terek Valley.

The terrain is dominated by alluvial-marine Late Pleistocene flat lowlands with fluctuations in relative heights of no more than 80 m. The maximum heights in the north-west of the landscape are up to 100 m. The alluvial-marine Holocene lowlands are widespread in the northeast. In the south, the landscape is bounded by the flood plain of the Terek River. The central position is occupied by the alluvial plain of Ak-Terek. The climate is harsh, the average temperatures in July are up to +25, in January – 4.0, -5.0 OC. A small amount of precipitation falls per year (250-300 mm) with an evaporation rate of 900-1000 mm. During the period of full vegetation of plants (from April to October), the amount of precipitation is even less — 120-150 mm. The transition through 0 C and the beginning of the frost-free period in the landscape takes place on average on March 6-10. The average daily temperatures exceed the threshold of +5.0 oC on March 27-30 and only by April 17-20 begins the period of full vegetation, lasting 185-190 days. During this time, the potential of active temperatures of 3540.0-3550.0 °C accumulates on the territory of the landscape. GTC = 0.4-0.5; the moisture coefficient rarely exceeds 0.3 per year. The summer months are the driest of the year (Cvl< 0.2), the number of days with relative humidity below 30% at 13 o'clock is about 11-18 (in some years more).

The river network is represented by the Terek transit River, which has no tributaries. Surface runoff is increased by a system of canals and irrigation systems. The Tersko-Kuma Canal, its Naursko-Shelkovskaya branch, begins its course here. The Burun Branch departs from these channels to the northeast. Groundwater aquifers are confined to the Akchagyl and Absheron rock layers. The zonal type of vegetation is cavill-grass communities in combination with soleros.

This is a typical vegetation of semi-deserts. In the east of the landscape, a significant area is occupied by vegetation of bumpy sands. In the lower reaches of the Terek, meadow-marsh and salt marsh vegetation of the floodplains and floodplains was widespread. The soil cover is dominated by light chestnut soils of sandy loam and light loamy mechanical composition. In the northern and northeastern regions of the landscape, salt marshes and salt marshes occupy from 10 to 40% of the area. Significant areas fall on the alluvial soils of the Terek River Valley.

The composition of material culture has been enriched with man-made components: roads, power lines and communications, canals, drilling rigs and oil storage facilities, artesian wells, farm buildings and rural settlements. The ploughing of the territory is large and exceeds 45%. The main arable lands are adjacent to irrigation systems.

The morphological subsystem has good pasture and soil resources. Areas with natural FABRICS prevail The biocenotic subsystem is represented by natural TCS, which occupy more than 60% of the area and are used as pastures: 1) oligodominant bioecosystems of cereal-wormwood communities; 2) oligodominant bioecosystems of wormwood communities, soleros. Geotopes with a quasi-natural environment include: 1) monocultural bioecosystems of irrigated lands (vineyards, fodder, melons, etc.); 2) monocultural bioecosystems of rainfed lands with a predominance of winter wheat; 3) rare forest belts in the northern regions of the landscape (Fig.2).

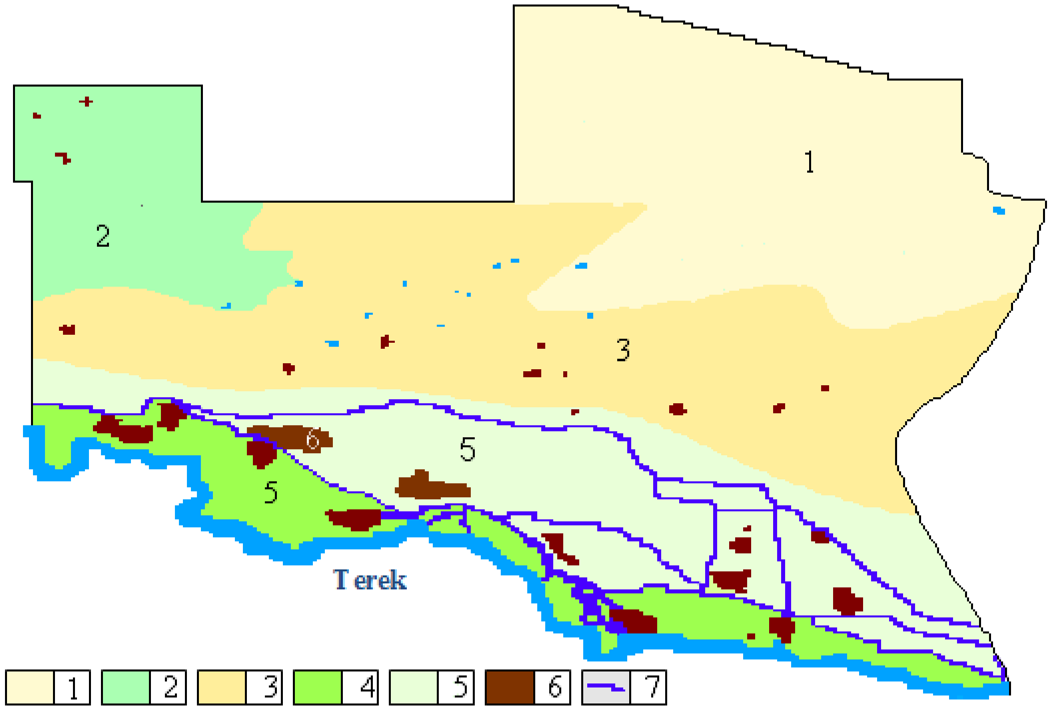

Figure 2: *Morphological structure of the Naursko-Alpatov natural and anthropogenic landscape of 1-5 localities (description in the text) Symbols:*

1).marine accumulative lowlands, composed of Khvalyn deposits (sands, clays), with sagebrush deserts and agrophytocenoses on light chestnut soils;

2) Aeolian deflationary-accumulative lowlands, composed of Aeolian deposits, which are overgrown with cereals; 3) alluvial-marine accumulative plains, composed of Khvalyn continental and marine deposits, with wormwoodgrassy desolate steppes on light chestnut soils;

4) floodplain modern alluvial plains with salt marshes and marsh-salt meadows and floodplains on alluvial saline meadow-marsh soils;

5) river terraces on alluvial deposits with chestnut and patches of dark chestnut soils;

6) residential complexes (Naur, Alpatovo, Ishgorskaya, etc.) mainly with cottage buildings, gardens and vegetable gardens, pasture pastures and irrigation canals. The population density is 10-18 people per km2;

7) irrigation canals

The functioning of modern landscapes still retains a natural character, but anthropogenic processes have made significant changes to their structure, especially component ones (water cycle, geochemical processes, growth of anthropophytes in vegetation, etc.). Dynamics occurs according to a semi-desert type in a continental climate (hot dry summers and moderately cold low-snow winters). The optimal ratio of heat and moisture is observed only from mid-April to mid-June. The evolution of landscapes is associated with their transition to the stage of natural-cultural (northern) and cultural-natural (southern parts). With the introduction of large masses of water into natural circulation by the Tersko-Kuma Canal, large areas of semi-deserts were plowed. Low soil fertility has determined the involvement of a large number of chemical elements, including toxic ones, in natural cycles. Currently, the semi-desert landscapes have begun to show the processes of their degradation (soil salinization, waterlogging, wind erosion, desertification, etc.). The territory of the North Chechen lowland belongs to the zone of insufficient moisture (aridity of the climate, lack of moisture, salinity of soils, soils of light mechanical composition), fragility and instability of natural ecosystems. Irrational and uncontrolled use of natural forage lands of the North Chechen lowland, high loads on natural pastures, often 2-5 times higher than their soil infertility, progressive desertification of the territory of the North Chechen Lowland. Thus, 50-70 years ago, an unsatisfactory economic condition was noted only on 8% of the area of natural pastures, and currently more than 80% of the area of pastures in the North Chechen lowland has been knocked down, degraded and subject to deflationary processes.

IV. Discussion

The methods of accelerated ecological restoration are based on the basic scientific principles of biogeocenology, physical geography, ecology and geoecology.

These are the principle of floristic and coenoptical completeness of communities, the concept of the types of adaptive strategies of plants, the principle of ecological differentiation of ecological niches and the interaction of species, and the principle of conformity of the design of restored pasture ecosystems with zonal types of biogeocenotic structures (Shamsutdinov, 1998). Lalymenko and Albukaev made a huge contribution to the study of the geoecological state of the arid territories of the Chechen Republic, 1997.

The region belongs to the southern tip of the agricultural belt of Russia with its arid, semiarid and dry semigumid zones - lands of varying degrees of vulnerability affected by desertification. Therefore, the development of a scientific basis for the organization of systematic actions to combat desertification of agricultural lands, using the example of this region, is extremely important to ensure the sustainable development of the entire North-Eastern Caucasus, and will be a guideline for carrying out similar work in other regions prone to desertification (Petrov, 1950,1973).

Sand dunes are found in relatively small areas in the northern and eastern parts (Lalymenko, Albukaev, 1978., Bayrakov, 1996, 1978, 2009).

V. Conclusion

One of the most important environmental problems of our time is anthropogenic desertification, which has covered significant areas of land on our planet. The predominant territory of the arid zone of the North-Eastern Caucasus is used extensively, mainly as natural pastures with unstable and unproductive vegetation cover. An attempt to intensify the economic use of natural pastures without carrying out the necessary agroforestry measures in a semi-desert zone leads to degradation and desertification of landscapes (Bayrakov, 1997, 2004).

According to its physical and geographical features and from the point of view of the direction of economic use, the Priterskiy sand massif is a sharply defined area. The uniqueness of its landscapes in comparison with the surrounding spaces is determined, first of all, by the hydrological conditions of the sands. Typical meadow phytocenoses are found in depressions with close groundwater occurrence. The properties of sands to accumulate and retain moisture throughout the growing season, to some extent neutralize and mitigate the effect of arid climate, create conditions approaching those of a more northern steppe zone.

When using semi-desert ecosystems as forage lands for year-round grazing, it is necessary to take into account the type of grazing cattle and the climatic conditions in which the ecosystem of pasture lands functions. The rate of the desertification process depends on their ecological state and degree of destruction, the threshold values are 0, 25, 50, 75 and 100% of the ecosystem area. If we trace the history of the development of the vegetation cover of the plain, then we can restore the course of restoration to its original state according to the following scheme:

• at the first stage, arable land is overgrown with associations of wormwood, which includes other species: porcine, roofing and spreading bonfire, larkspur, bunny, small-flowered milkweed and field bindweed. This group of plants in this composition develops within 5-10 years;

• at the second stage, the dominance gradually shifts to a plant association with roofing and spread-out bonfires, which includes wormwood, milkweed Seguer, tipchak, like sandy, larkspur, borage, carrot, whiteflower dubrovnik, blue alfalfa and a number of other plants;

• at the third stage, we notice an increase in the sod of piggery, when its rhizomes are closed, conditions of constraint are created and often the displacement of previously dominant plant species and piggery almost completely takes over. In addition to the above-mentioned plant species, this new association includes euphorbia, thyme, roofing and spreading bonfire, broom wormwood, hair-like feather grass, whitewater dubrovnik, bunny, larkspur, watermelons, broad-leaved cormac, bobberry, stinky and some others.

• the final stage of the restoration process creates a tipchak-kovyl steppe in the North Chechen lowland consisting of tipchak, hair-shaped kovyl, sea wormwood, prostrate kochia, combed wheatgrass, noble yarrow and tamarix.

References

[1] Bayrakov I.A. (2004). Sovremennaya dinamika antropogennoj transformacii pastbishchnykh resursov polupustynnykh ehkosistem Zaterech'ya. //«Nauchnaya mysl' Kavkaza» Prilozhenie №4. Rostov-na-Donu,.S.104-109.

[2] Gozhev A.D. (1930). Tipy peskov zapadnoj chasti Tersko-Dagestanskogo massiva i ikh khozyajstvennoe ispol'zovanie// Izv. GGO. T.52.Vyp.4. S.463-529.

[3] Kashin V.I. (1949). Rastitel'nost' Tersko-Kumskogo mezhdurech'ya Groznenskoj oblasti. (Rukopis').

[4] Petrov M.P. (1950). Podvizhnye peski pustyn' i bor'ba s nimi. M., Nauka.

[5] Petrov M.P. (1974). Mirovoj opyt obleseniya i zakrepleniya podvizhnykh peskov v pustynyakh zemnogo shara. L.: Izd-vo Leningr. Un-ta, , 48 s.

[6] Petrov K.M. (1973). Pustyni zemnogo shara. L.: Nauka,. 436 s.

[7] Rozhanec-Kucherovskaya S.E. (1925). Geobotanicheskie landshafty yuzhnoj chasti Tersko-Kumskogo massiva // Izv. RGO.. T.68. Vyp.4.

[8] Ryzhikov V.V. K (1960). K voprosu o genezise i morfologii peskov Kumsko-Kaspijskoj nizmennosti // Izv. Grozn. in-ta i muzeya kraevedeniya,. Vyp. 2-3.

A RESEARCH OF THE DIGITAL TRACE OF INDIVIDUALITY IN RELATION TO ENVIRONMENTALLY RESPONSIBLE BEHAVIOR

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Abstract

The article presents a study that attempts to investigate the features of students' environmental behavior. The peculiarity of this work is the inclusion of some indicators of the digital trace of individuality (openness/closedness of the profile and the color scheme of the profile) in the analysis of the results obtained using valid methods characterizing students' attitudes to environmental issues. The authors trace the relationship between the indicators characterizing environmental behavior and the studied indicators of the digital trace of students' individuality. Also, in the process of analyzing the results obtained, a relationship was revealed between the age characteristics of students and the features of their profile in VK.

Keywords: digital trace of individuality, integrated individuality, environmental issues, digital environment, VK users, environmental behavior, student age

I. Introduction

Trying to analyze the digital trace of individuality, or as we propose from the point of view of the theory of integrated individuality of V.S. Merlin and the theory of polymorphic individuality of V.V. Belous [1] - the supra-status (digital) level of individuality, it is necessary to evaluate its profile in the social network according to available open parameters. In this study, we attempted to analyze the characteristics of the attitude to environmental issues in the student environment, on the one hand, and, on the other hand, to link these characteristics with some parameters of the digital trace of individuality - the openness or closedness of the profile in the social network and the predominant colors in the photographs that are available in the profile. This approach is relevant, since the actively developing digital environment makes its own adjustments to the structure of individuality [2]. Not so long ago - in the early 2000s, psychologists considered this environment, the environment of the Internet space exclusively as a resource that negatively affects the psyche. In studies, the Internet environment was considered addictive.

II. Methods

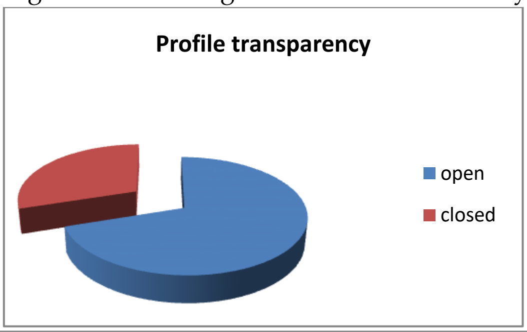
The study involved first-year students of the Institute of International Relations of the Federal State Budgetary Educational Institution of Higher Education "Pyatigorsk State University" - future journalists and specialists in international relations. The diagnostics were conducted in September 2024. We asked the respondents to provide a link to their profile on the social network during the diagnostic methods. Of the 123 students who passed the test, 98 provided this information. Another feature of this component of the study was that several students provided incorrect access to the profile. Thus, 86 people remained in the sample - 69 girls and 17 boys. The profile for analysis was characterized by 2 indicators - openness / closeness of the profile and the predominant color of photos, pictures, etc., which are available in the profile.

To diagnose attitudes towards environmental issues and manifestations of environmental behavior, we used valid diagnostic methods – the Method of Diagnosing Motivation for Interaction with Nature "Alternative"; the Scale of Environmental Concern and the Method of "Differential Emotions Scale" [3]. To process the obtained data, we used statistical data analysis.

At the final stage of the study, a comparative analysis of the obtained data and their interpretation was carried out.

III. Results

At the first stage, our goal was to characterize students' profiles on VK by two characteristics: openness or closedness of the profile and the predominant color scheme of the profile photo, which will indicate the emotional background of the digital trace of individuality.



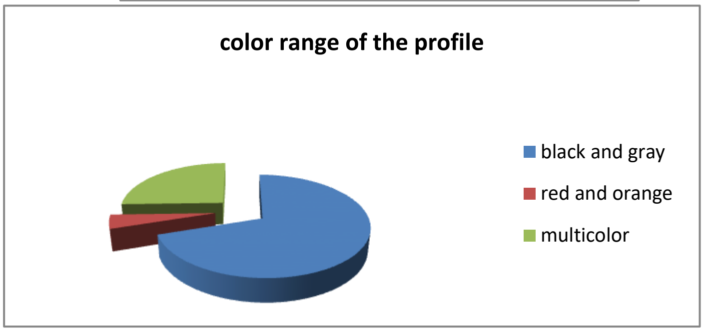


Figure 1: *Results of the analysis of profile openness/closedness and profile color scheme" (%)*

Of the provided VK profiles, 30% were closed. The remaining 70% are open and filled profiles. We assume that students exhibit extroverted behavior in the digital space - they are open to the digital environment and ready to interact. As for the color scheme, black or gray predominates in most profiles (77%). Red or orange predominates in 5% of cases, and in 28% of cases, there is a variety of colors and no dominance of any color. The predominance of black indicates an emotional state characteristic of the stage of adaptation to the university conditions, the presence of a certain stress characteristic of the transition from adolescence to young adulthood. Black in this situation is a desire for independence, resistance to external pressure and denial of any authorities. To this characteristic should be added the manifestation of aggression and depression.

In the further analysis, we will consider the results of diagnostics using methods that determine environmentally responsible behavior - the Method of Diagnostics of Motivation for Interaction with Nature "Alternative"; the Scale of Environmental Concern and the Method "Scale of Differential Emotions". In the analysis, we will trace the relationship between the obtained results and the features of the digital trace of individuality.

Fig. 2 shows the results of diagnostics using the Alternative method of diagnosing motivation for interaction with nature. In the sample under study, two types of motivation predominate:

aesthetic and cognitive. This fact indicates that respondents perceive nature as an object of beauty when actively interacting with it. High rates of this type of motivation are demonstrated by 68% of students with an open VK profile.

Also, high rates are presented in the cognitive type of motivation, which indicates the attitude to the environment as an object of knowledge in interaction with it. This type of motivation prevails in 30% of students with an open profile. It should be noted that 89% of students have a multi-color profile photo.

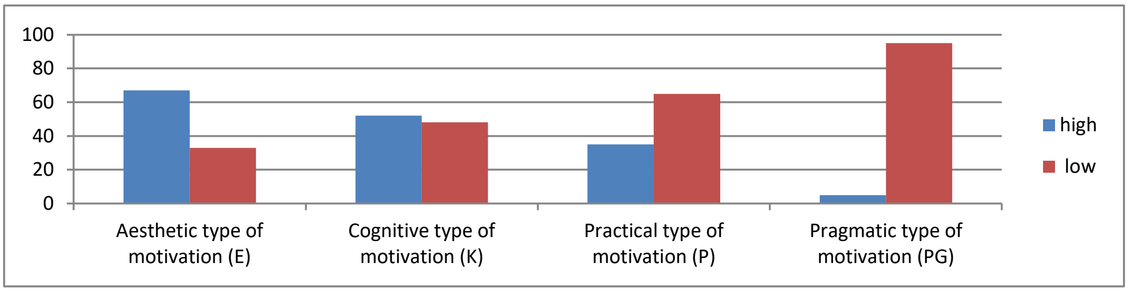


Figure 2: *Results of the Methodology for diagnosing motivation for interaction with nature "Alternative" (%)*

Fig. 3 shows the results of the "Scale of Environmental Concern" method. It is obvious that high scores were obtained for all scales, which indicates concern about the fate of animals, birds and the ecosystem as a whole, as well as concern about the impact of the consequences of environmental problems on children, people who live in the same region. A high level is also observed for the "Egoistic Concern" indicator - everything that concerns the consequences of environmental problems for one's own health, one's own lifestyle and future. Such scores indicate a high level of involvement in understanding the consequences of environmental problems in real life. Moreover, such data are shown by all representatives of this sample - students with open and closed profiles and with all types of color schemes in the profile.

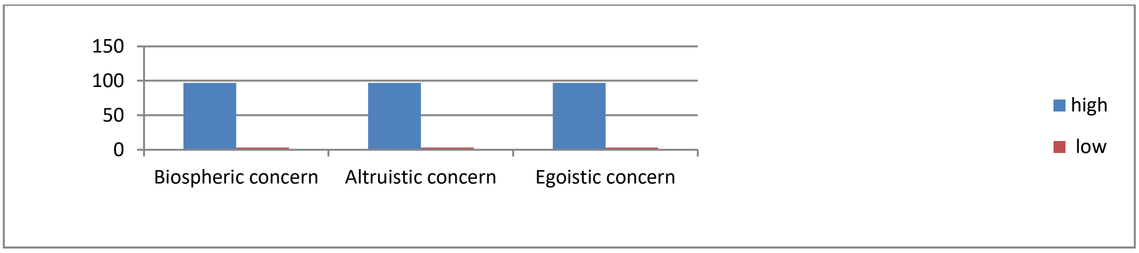


Figure 3: *Results for the Environmental Concern Scale Methodology (%)*

Based on the data obtained, we can state a high level of environmentally responsible behavior.

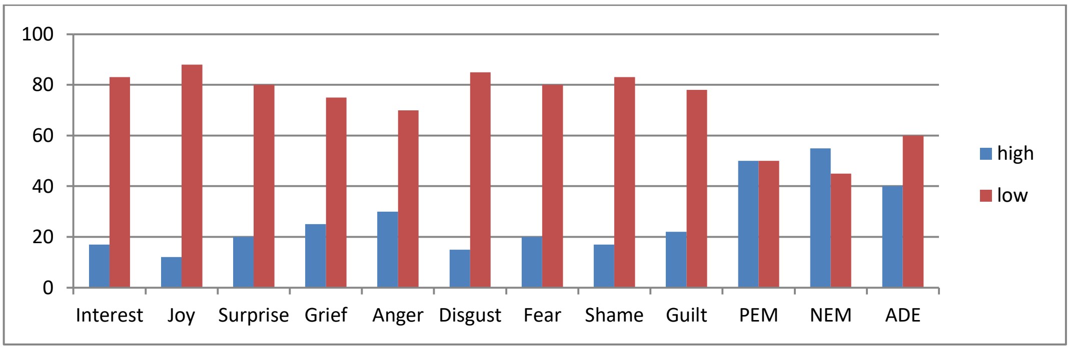


Figure 4: *Results for the "Differential Emotions Scale" method (%)*

The results presented in Fig. 4 determine the level of emotion that the subjects showed regarding the current situation. In the block of positive emotions, there is a predominance of low emotion in all indicators: "Interest", "Joy" and "Surprise". Comparing the data with the manifestation of the digital trace of individuality, and specifically in the prevailing color scheme - black and gray, there is a connection between the emotional state and the prevailing color of the profile. In the block of negative emotions, low values are recorded for all four indicators, which once again confirms the closeness and some emotional instability inherent in first-year students. In general, the general index of positive emotions and negative emotions are distributed approximately in equal shares between high and low indicators. At the same time, the picture is complemented by the predominance of the low level of the indicator " Anxious and depressive emotions ", which characterizes the predominance of environmental features over individual ones in the manifestation of emotions regarding the situation associated with the attitude to environmental problems.

IV. Discussion

The study by Ivanova I.V. and Konenkova N.V. examines the influence of the reflexive-value approach on the formation of environmentally responsible behavior of young people [4]. Scientists have proven the importance of interpersonal relationships and both general and environmental culture in the formation of environmentally responsible behavior. The study by Matovaya N.I and Shagarova L.M. highlights a very relevant and burning topic of our country's share - tourism and its development [5]. Their work examines the need for environmentally responsible behavior of tourists in nature conservation areas. This problem is considered within the framework of the contradiction between the need to develop domestic tourism and the need to preserve unique natural monuments of Russia. Demenshin V.N. in his "Review of Foreign Studies of Environmental Consciousness" [6] refers to the studies of I. Tilikidou and J. Zotos, who, based on the works of B. Schlegelmilch, developed an approach to describing environmental consciousness, in which they included all components of environmentally responsible consumer behavior, while the behavioral aspect includes pro-environmental purchasing behavior, pro-environmental behavior after purchase and environmental protection activities [7]. Summarizing the sources we have cited, we can state that environmentally responsible behavior in the student environment is not considered in psychological science.

In the aspect of the digital trace of individuality, Tulupyeva T.D. and Ivanova A.Yu. consider a psychological approach, which involves studying the manifestation of mental properties and characteristics of a person during communication and behavior on the network, taking into account that communication occurs within social groups, this approach is characterized as socio-psychological [8; 9; 10]. Gaidash O.V. in his study, describing modern approaches to the interpretation of the digital trace, states the fact that the features of these characteristics of individuality are used mainly by marketers [11].

From the point of view of the theory of integrated individuality by V.S. Merlin and polymorphic individuality by V.V. Belous [12], the digital trace of individuality (the data that can be openly available in the digital environment) has not yet been considered as a supra-status level of integrated individuality. In this paper, we postulate a new approach to the study of the holistic individuality of a modern person.

References

[1] Belous, V. V., & Boyazitova, I. V. (2008). Development of integrated individuality of a person in objective space. Bulletin of the Peoples' Friendship University of Russia. Series:

Psychology and Pedagogy, (1), 37-45.

[2] Marcinkowska, T. D. New methodology of digital everyday life / T. D. Marcinkowska // Questions of Psychology. - 2023. - Vol. 69, No. 2. - P. 3-13. - EDN NNHYYG.

[3] Ivanova Alexandra Andreevna, Shevel Tatyana Maksimovna, Agisova Fatiha, & Patrakova Natalia Alekseevna (2023). Schulz's environmental concern scale: adaptation and validation. Psychology. Journal of the Higher School of Economics, 20 (4), 699-717. doi: 10.17323/1813-8918-2023-4-699-717

[4] Irina Viktorovna Ivanova, & Natalia Viktorovna Konenkova (2023). Reflexive-value approach to the formation of environmentally responsible behavior of teenagers and youth. Innovative Scientific Modern Academic Research Trajectory, (3 (15)), 49-61. doi: 10.17853/2686-8970-2023-3-49-61

[5] Matova N.I., Shagarov L.M. Features of environmentally responsible behavior of tourists in protected natural areas // Modern problems of service and tourism. 2021. Vol. 15. No. 1. P. 93–106. DOI : 10.24412/1995-0411-2021-1-93-106.

[6] Demenshin V.N. Review of foreign studies of environmental consciousness // Internet journal "World of Science" 2017, Volume 5, Number 5 https :// mir - nauki . com / PDF / 18 PSMN 517.

[7] Tilikidou, I., Ecological consumer behavior: review and suggestions for future research / I. Tilikidou, Y. Zotos // Medit, 1999. – Vol 10. – No. 1. – P. 14-21.

[8] Flerov O.V. (2018). Human digital trace on the Internet: basic humanitarian approaches. Educational resources and technologies, (4 (25)), 79-82.

[9] Tulupyeva T.V., Tafintseva A.S., Tulupyev A.L. An approach to the analysis of the reflection of personality traits in digital traces // Bulletin of Psychotherapy. - 2016. - No. 60 (65). - P. 124-137.

[10] Ivanova A.Yu., Malyshkina M.V. Psychological problems of communication and activities of the digital technology generation // Scientific notes of P.F. Lesgaft University. - 2017. - No. 7 (149). - P. 221-228.

[11] Gaidash O.V. (2020). The phenomenon of digital trace in modern society. Bulletin of Magistracy, (6 (105)), 10-.

REGIONAL CLIMATE CHANGES IN AZERBAIJAN AND ASSESSMENT OF THEIR IMPACT ON WATER RESOURCES WITH A NEW METHOD

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Abstract

The article is devoted to regional climate changes in the territory of Azerbaijan and the study of water resources of the Karabakh region. Based on the actual multi-year temperature and precipitation data, the dynamics of changes of the specified parameters for the years 2007-2022 compared to the multi-year norm were evaluated by regions and different altitude intervals. An increase of 1.2^{0}C in the average multi-year temperatures across the republic, and a decrease of precipitation to 26 mm was determined.

The water resources of the rivers of the Karabakh region were assessed using the newly developed Complex Water Balance Method (CWBM). This method is based on the principle of estimating water resources, taking into account the complex flow-forming factors. For this purpose, satellite data, GIS and other multifunctional computing technology were used. In 1998, the water resources of the Karabakh region's rivers were 2.13 km^3, but in 2022 it was 1.80 km^3, or a decrease of 15.2% was observed.

Keywords: climate changes, temperature, precipitation, CWBM method, water balance, water resources

I. Introduction

Provision of water to the population and economy, purposeful and economical use of water resources have always been priority directions in water policy. The aggravation of water-related problems has made it necessary to pay more attention to this spher than before. Conducting relevant scientific research on water problems is considered one of the priority scientific researches, being one of the always relevant issues in hydrology. Because there is a big difference between the demand and supply of water in the Republic of Azerbaijan, where irrigation agriculture and the population's demand for water dominate. In recent times, due to the influence of global climate changes, there have been changes in the world's water resources, especially in surface and underground waters, in the annual flow and regime of rivers, which of course also manifests itself in the territorial rivers of Azerbaijan. Thus, in the annual flood and high flows period of the country's rivers, their maximum water consumption decreases, while in the winter low flows period flows, on the contrary, there is an increase. As a result of the reforms carried out in Azerbaijan, a strong socio-economic potential has been created in the country. However, the depletion of natural resources against the background of global climate change creates additional problems in the implementation of reforms. For this reason, scientific directions and methods should be determined so that research does not lag behind the general pace of development of reforms. Current conditions require the assessment of natural resources with more modern, sensitive and operational methods that can respond to any changes [1, 3, 9]. Our proposed CWBM method is one of these types of methods. CWBM was developed on the basis of the leading water balance methods available in the world, taking into account their synthesis and the specific characteristics of the nature of Azerbaijan [6, 8].

II. Materials and methods

Satellite images of territory, digital elevation model (DEM) and hydrometeorological observation data of different years were used as initial input data for conducting the research. The main source of climate data is the measurement-observation data of the Ministry of Natural Resources and Ecology of the Republic of Azerbaijan. To determine the types of landscape, land cover, and moisture levels, multispectral space images of the terrain from different periods were processed using normalized difference indices (NDI-Normalized Difference Indices). Considering the content of the research work, difference indices of vegetation (NDVI, SAVI), bare soil and bedlands (BSI), erosion (NDBal), soil salinization (NDSI), residential and build-up (NDBI), urban (UI) , water (NDWI), drought (NDDI) and moisture (NDMI) were preferred in the study. The elevation, slope and aspect values of the study area were determined using DEM, and the morphometric indicators of the rivers using the Hydrology, Surface and Density software of the ArcGIS program. To select similar data and get more reliable correlations between components, Modern Analogue method and Multiple linear regression equations were used.

III. Results and discussion

Since regional climate changes have a greater impact on the water balance elements and annual flow of rivers, in order to study the dynamics of temperature and precipitation changes in the territory of the country, their higher intervals than the multi-year norm and by regions were studied, and some results are given in tables 1, 2 and 3, respectively [4, 5].

Table 1: *Changes of temperatures in the territory of Azerbaijan in 2007-2022 at different height intervals relative to the multi-year norm (1961-1990), T°C*

Periods	Elevation intervals, m					By the republic
	≤ 0	1-200	201-500	501-1000	> 1000	
Multi-annual norm, 1961 -1990	14.6	14.3	13.3	11.9	7.8	12.3
Medium perennial, 2007-2022	15.5	15.7	14.5	12.9	9.2	13.5
Relatively increase to the perennial norm	+1.0	+1.4	+1.2	+1.0	+1.4	+1.2

As can be seen from Table 1, the temperature increase in the territory of the country compared to the multi-year norm is +1.2^{0}C in the period 2007-2022. The greatest increase in elevation intervals is at 1-200 m and >1000 m elevations (+1.4^{0}C). However, the high annual temperature increase for the period 2007-2021 was 2010 (+1.3^{0}C), 2012 (+1.3^{0}C), 2014 (+1.3^{0}C), 2015 (+1.5^{0}C) , 2018 (+1.8^{0}C), 2019 (+1.5^0 C) and 2021 (+2.1^{0}C). In general, the years 2018 and 2021 have gone down in history as the hottest years in the world during the entire observation period, and this has also shown itself in Azerbaijan.

Table 2: *Temperature changes in the years 2007-2022 compared to the 1961-1990 period in different regions of the Republic of Azerbaijan, T°C*

Periods	Regions						By the Republic
	Absheron-Kobustan	Lankaran-Astara	Greater Caucasus	Lesser Caucasus	Kur-Araz	Nakhchi-van AR	
Multi-annual norm, 1961 -1990	14.5	12.9	10.7	9.2	14.3	12.4	12.3
Medium perennial, 2007-2022	15.5	13.9	11.5	10.5	15..6	13..7	13..4
Relatively increase to the perennial norm	+1.0	+1.0	+0.8	+1..3	+1.3	+1.3	+1..2

As can be seen from Table 2, the largest temperature increase by region is in Kura-Araz and the Lesser Caucasus (+1.3^{0}C), in Nakhchivan AR, and the least in the Greater Caucasus is +0.8^{0}C. In 2018 and 2022, a sharp increase in temperature was observed in all regions. Thus, in 2018, +1.4^{0}C in Absheron-Kobustan, +1.7^{0}C in Lankaran-Astara, +1.1^{0}C in the Greater Caucasus, +1.6^{0}C in the Lesser Caucasus, 1.9^{0}C in Kur-Araz, +2.8^{0}C in Nakhchivan AR. But the air temperature has risen by +1.8^{0}degrees across the entire republic.

In 2021, the average annual temperature for the republic increased by 2.1^{0}C, in 2022 by 2.0^{0}C, and the largest increase occurred in the Lesser Caucasus by 2.5^{0}C.

This increase in regions reflects its regularity for the multi-year period (2007-2022). In the Nakhchivan region, which is distinguished by its warm continental climate, the temperature increase compared to the multi-year norm was observed at a record level: +2.8^{0}C. In precipitation (Table 3), a weak decrease was observed compared to the multi-year norm, and it is interesting that, although there was an increase or decrease in all altitude intervals during this period, only in the altitude interval of 200-500 m, a decrease in precipitation was recorded in all years. In 2014-2017, a decrease was observed in all height intervals, including precipitation across the country. In 2011 and 2016, a maximum increase in precipitation was observed at all altitudes (except 201-500 m altitude), including the republic.

The study of regional climate changes in Azerbaijan, including the evaluation of river water resources in the occupied Karabakh territory, where systematic hydrometeorological observations have not been carried out for nearly 30 years, is proposed as the main research goal in the article [2, 7, 10]. Thus, against the background of modern climate changes, the study of the water resources of the Karabakh territory, re-estimation and improvement of water demand are considered more important from the point of view of scientific-research directions.

Currently, water balance methods are preferred in estimating water resources [3, 6, 9]. New advanced methods are created by internal modification of leading hydrological models, called "base methods", or by their synthesis and hybridization. Based on the current trend, a new operational-interactive method–Complex Water Balance Method (CSBM) has been proposed to assess the water balance and water resources of regional rivers. With the new method, the research process is carried out entirely through satellite images and GIS technologies. The main scientific principle of CWBM is the assessment of water resources through runoff coefficients, which include the influence of complex factors that shape the river flow. It is known that the greater the participation of factors affecting the flow formation, the more accurate the results. The participation of complex flow-forming factors was taken into account in CWBM. Even for the first time, new predictors were added to the calculations, such as the vegetation density, slope degree, horizontal fragmentation of the territory, exposure of slopes, humidity level. Among the innovations of CWBM, the application of new and different scientific approaches such as acceptance of the soil-air-water environment as a single mechanism, Counter-approach technology and Analogue method are also included. As a result, it is possible to calculate water resources with high accuracy without space-time limitation and dependence on observational data.

Table 3: *Precipitation changes in different altitude ranges in Azerbaijan for the period 2007-2022, mm*

Years	Heights, m					By the republic territory
	≤ 0	1 - 200	201-500	501-1000	>1000	
Norm	334	327	478	534	639	476
2007	-21.0	-8.0	62.0	89.0	25.0	+16.0
2008	+5.9	-29.0	-171	147.0	+5.0	-31.0
2009	+38.0	+69.0	-7.0	+17.0	+11.0	+6.0
2010	+30.0	+69.0	-28.0	+232	-20.0	+51.0
2011	+178	+124	-19.0	+288	+143	+87
2012	+14,0	-29,0	-130	+94.0	+51,0	-23,0
2013	+29.0	- 44	- 186	+ 78.0	- 18.0	- 45.0
2014	-11.0	-60	-117	-11	-82.0	-70.5
2015	+10.0	+32.0	-55.0	+33.0	-31.0	-42.0
2016	+118	+108	-12	+151	+124	+110
2017	-40.3	-38.6	-260	-41.2	-125	-101
2018	+6	-32	-7	+172	+10	-21
2019	+34	+6.0	-22.0	+8.0	-95.0	-50.0
2020	+20.9	-63.5	-141	+55.7	-43.7	-51.2
2021	-119	-80	-90	49	-140	-134
2022	+16,0	-10	-80	+75	-25	-27
Changes from norms	+14.5	-7.5	-77.0	+67	-22.0	-26.5

Research in this type of methods covers 4 main principles: applicability, operativeness, interactivity and prognosticity. Applicability - characterizes the maximum practical orientation of scientific results. Operativeness - refers to the faster use of the results obtained in order for scientific research not to lag behind the pace of economic development. Interactivity - is the adequacy of research against variable factors, prognosticity - is the assessment of changes in terms of possible consequences that may occur in the future. In terms of ensuring flexibility and interactivity in hydrological research, the most important tool is obtaining the necessary information about the research area without physical contact. Expanding the use of satellite images of the area, giving preference to remote sensing and flexibility methods are presented as an important scientific necessity in modern approaches. On the other hand, since it takes a lot of time to restart measurement and monitoring works on climate and flow quantities, the obtained results can lead to delays from a practical point of view, and lose scientific-practical and economic importance. Therefore, the minimization of observations and experimental experiments is also an important factor in terms of flexibility and interactivity. Expanding the use of modern technologies in the process of research data processing and calculation is one of the aspects considered as the foundation of this process. In this type of scientific approaches, various calculation, comparison, probability and prioritization technologies are highlighted with GIS and other technical means.

Thus, the advantages of the new methods are the following important principles:

1. Conducting research through satellite images without physical contact;
2. Fast, interactive and accurate calculation mechanism;
3. Lack of dependence on observational data;

4. Not imposing time-space and size restrictions;
5. Consideration of the influence of complex factors;
6. The effect of each factor on the flow can be given separately and together in a quantitative expression;
7. In addition to climate factors, landscape and anthropogenic effects are calculated separately;
8. Multivariate prediction line through 3-stage (past, present, future) research;
9. Air, soil and water space are considered as a single environment.

Among the innovations that attract attention in the process of developing the CWBM, for the first time in the GIS environment, the selection of similar geo-spaces based on complex factors, several different interpolation methods and the application of Counter-approach technology, including the inclusion of scientific principles such as recovery of unknown factors.

The Analogue method, that is, the principle of finding similarities in terms of physical and geographical conditions between basins with data and those without observations, is one of the widely used methods in hydrology. The more similar conditions are between geo-spaces, the more successful it is to calculate river flow and water resources. Flow formation is a very complex process. Until now, due to the influence of several factors, the condition of flow formation and the assessment of water resources did not allow obtaining very accurate results. Long-term experiments conducted in river basins using basic methods have also shown that the more similar the physical-geographical conditions in which the flow is formed, the closer the flow coefficients are to each other. At present, scientific and technical achievements have created conditions for a more in-depth analysis of flow formation and precipitation-flow process. These results were obtained based on the data of numerous measuring stations with different natural conditions, as well as artificial experimental experiments carried out in the basins.

In the research process, the correction process of flow coefficients with CWBM was carried out according to the following algorithm:

1. Daily climate and flow data of hydrometeorological observation points located in river basins with different physical and geographical conditions are collected.
2. Data on other complex factors influencing flow in these river basins is obtained through satellite images.
3. Available hydrometeorological observation data and indicators of flow-forming factors are collected and processed together in the ArcGIS database.
4. Based on actual observation and space data, the regional representativeness of climate and flow data in river basins is investigated.
5. The specific physical and geographical conditions corresponding to the flow quantities are defined.
6. Possible situations involving the combined effect of complex climate, landscape and other factors are considered and different runoff coefficients are found for each situation.
7. Correspondence of runoff coefficients is determined, same (or close range) coefficients are grouped and corrected.
8. The applicability of the obtained coefficients to similar places without data is checked and the most reliable results are selected.

In the CWBM method, the influence of factors on the flow is evaluated both separately and together in a complex manner. Not only the factors themselves, but also their intraspecies diversity, different quantitative indicators are necessary when determining runoff coefficients. For example, the vegetation density, the degree of soil moisture, the population settlement level, different slope and height gradations, etc. runoff coefficients are also determined for indicators. Each different situation manifests itself as a new runoff coefficient. The multiplicity of runoff coefficients is due to the consideration of complex effects and each specific situation. In order to facilitate the use of the method, the runoff coefficients are given on the basis of more important and variable factors, which actually include the influence of other factors directly or indirectly.

The application of CWBM is suitable for areas with any physical-geographical conditions and where observations are not made, without time-space restrictions. The evaluation of the water resources of the Karabakh region, which is distinguished by its extreme conditions, through CWBM is the basis of the research work. Due to the fact that it is under occupation, measurement works and researches have not been carried out in the region for many years. However, the research process was carried out with high accuracy, since the advantages of the new method allowed to eliminate these and other shortcomings. The research period covers the years 1998-2022 (figure 1).

Figure 1: *Location of the study area*

The water balance elements and water resources of the Karabakh region for the years 1998-2022 were investigated with satellite images and multifunctional GIS processing. The results obtained using CWBM method are reflected in Table 4.

Table 4: *Comparison of changes in the water balance components and water resources for 1998-2022*

Components of the water balance	1998	2021
Atmospheric precipitation, mm	572	547
Air temperature, C°	8.28	8.51
Potential evaporation, mm	802	829
Factual evaporation, mm	415	423
Humidity coefficient,	0.71	0.66
Maximum soil water retention, mm	1163	1189
Initial abstraction, mm	313	331
Actual soil moisture, mm	196	217
Hydrologic losses, mm	495	478
Rational runoff coefficient	0.303	0.290
Total runoff, mm	158	143
Surface runoff, %	48.9	47.9
Baseflow, %	51.1	52.1
River discharge, m^3/sec	67.5	57.3
Water resources, km^3	2.13	1.80

During 1998-2022, the change of water resources of the administrative regions included in the Karabakh region and the role of climate and landscape changes in this process were also assessed separately (Table 5).

Table 5: *The role of climate and other factors in the change of water resources of the Karabakh region in 1998-2022*

Regions	Water resources changes		İmpact of factors			
			Role of climatic factors		Role of other factors	
	increase-decrease	%	increase-decrease	%	increase-decrease	%
Terter	⬆	+10.9	⬆	+1.15	⬆	+9.75
Agdam	⬇	–9.47	⬇	–14.6	⬆	+5.13
Fuzuli	⬇	–4.86	⬇	–9.54	⬆	+4.68
Xojavend	⬇	–26.7	⬇	–7.59	⬇	–19.1
Jebrayıl	⬇	–18.7	⬇	–9.05	⬇	–9.65
Shusha	⬇	–37.2	⬇	–6.82	⬇	–30.4
Khojali	⬇	–14.4	⬇	–1.11	⬇	–13.3
Kelbejer	⬇	–4.53	⬇	–3.02	⬇	-1.51
Lachin	⬇	–8.91	⬇	–6.04	⬇	–2.87
Kubadlı	⬆	+7.91	⬆	+4.37	⬆	+3.54
Zengilan	⓿	0.00	⬇	–9.33	⬆	+9.53
Karabag	⬇	–15.2	⬇	–9.54	⬇	–5.66

IV. Conclusions

1. A new hydrological method – CWBM (Complex Water Balance Method) was used to assess the water balance of the area and the water resources of the rivers. CWBM is an operative-interactive and highly accurate method. Through CWBM, the whole research process and assessment can be performed without physical contact with the area, time-space limitations, and dependence on observational data.

2. Water resources of the Karabakh region using of the CWBM, were estimated at 2.127 km^3 in 1998 and 1.804 km^3 in 2021. In total, over the specified period, water resources decreased by 15.2 %.

3. According to assessment, the average total runoff coefficient of the Karabakh rivers in the period up to 2022 was equal to 0.2625; that is, 73.75 % of precipitation did not participate in the runoff formation. The fraction of surface runoff was 47.9 %, and baseflow – 52.1 % in total feeding of regional rivers.

4. It was determined that out of this 9.54 % decrease in water resources in 1998-2022 accounts for climatic, and 5.66 % - for the role of human activities and other factors.

5. Serious regime variability is observed in the rivers of the research area. Thus, due to the influence of regional climate changes, the annual runoff decreases, and the runoff of the winter low-water period increases. Due to the decrease in the volume of flood and torrential flows, their maximum water discharge (Q_{max}, m^3/sec.) also decreases.

References

[1] Amir Aieb, et. al. (2022). A hybrid water balance machine learning model to estimate inter-annual rainfall-runoff. Sensors 22 (9). 3241.

[2] Gerald A. Meehl, et al. Climate Change: Chapter 10: Global Climate Projections. 2007, pp. 842.

[3] Junfang Liu., et.al. Water balance changes in response to climate change in the upper Hailar River Basin, China. Hydrology Research. 2020. 51 (5): 1023–1035.

[4] Makhmudov R.N. Regional climatic changes in Azerbaıjan and its impact on hydrometeorological condıtıons. Slovak international scientifıc journal. N-63, 2022 s.48-55.
https://doi.zenodo.org/records/6535054

[5] Makhmudov R.N. Regional climate change and river runoff in Azerbaijan. Meteorology and Hydrology, No. 9, Moscow, 2016., pp. 63-69.

[6] Rza Makhmudov, Vugar Aliyev, Movlud Teymurov, Emil Gafarov. Assessment of the water balance of the territory and rivers water resources using a new operational-interactive method. // RT&A, Special Issue No 5 (75) Volume 18, November 2023, https://doi.org/10.24412/1932-2321-2023-575-500-509

[7] Mammadov R.M., Teymurov M.A. Assessment of water resources and risk of water losses due to climate changes and human activities. The Scientific Heritage Journal. Budapest, Hungary. 2019.

[8] Movlud A.Teymurov. The value of ınıtıal abstractıon and estımatıon of run-off formıng raınfall rate at a specıfıc geographıcal locatıon. Journal Science, Education and Innovation in the context of modern problems, Vol. 5; Issue 4, 2022. DOI:10.56334/sei/6.1.4.

[9] Rebeca Martinez, et.al. Influence of climate and land cover/use change on water balance: An approach to individual and combined effects. Journal Water: 2022, 14(15), 2304. DOI: 10.3390/w14152304

[10] Regional Climate Change Impacts Study for the South Caucasus Region.Tbilisi, Georgia. 2011, pp. 61.

THE INFLUENCE OF CLIMATIC CONDITIONS ON THE ADAPTATION OF THE CARDIOVASCULAR SYSTEM OF STUDENTS TO PHYSICAL ACTIVITY: ASPECTS OF SUSTAINABLE DEVELOPMENT IN EDUCATION

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Abstract

This study explores the influence of climatic conditions on the adaptation of the cardiovascular system of students to physical activity, emphasizing the implications for sustainable development in education. As climate change continues to alter environmental conditions, understanding how these factors affect students' physiological responses to physical exercise becomes crucial. The research highlights the importance of incorporating climate-responsive training programs in educational institutions to enhance students' cardiovascular health and overall well-being. By addressing the interconnection between climatic influences and cardiovascular adaptation, the study aims to provide insights into developing sustainable educational practices that promote physical fitness and health resilience among students in varying climatic contexts. The work studied the functional state and assessed the functional reserves of the cardiovascular system in university students at rest and during adaptation to muscle load. Male and female students of the higher educational institution participated in the study of the functional reserves of the cardiovascular system. Blood pressure, heart rate and a number of indices characterizing the functional state of the cardiovascular system were examined. The study of these hemodynamic parameters was carried out at rest and after a functional motor test. It was found that the type of response to dynamic muscle load in male and female students is normotonic. According to the Ruffier index, male and female students have a satisfactory functional state of the cardiovascular system. The values of the adaptation potential indicate the tension of the adaptation mechanisms and some decrease in the physiological reserves of the cardiovascular system. Minor differences were noted between the sexes in adaptation to muscular load (Ruffier test): females had average performance, while males had good performance.

Keywords: cardiovascular system, blood pressure, heart rate, adaptation, muscle load, hypoxia, hypokinesia, student, climatic conditions, cardiovascular adaptation

I. Introduction

In recent years, the impact of climatic conditions on human health has gained increasing attention, particularly in the context of physical activity and exercise. As students represent a vital segment of society engaged in physical education, understanding how environmental factors influence their cardiovascular adaptation to exercise is essential. The cardiovascular system plays a pivotal role in regulating physical performance, and its efficiency is significantly affected by external conditions such as temperature, humidity, and altitude.

Climatic variations can alter how the body responds to physical exertion. For instance, extreme heat can lead to dehydration and heat-related illnesses, while cold conditions may affect circulation and increase the risk of hypothermia. As climate change progresses, educational institutions must consider these factors to foster a safe and effective environment for student athletes and physically active individuals.

This study aims to examine the intricate relationship between climatic conditions and the cardiovascular responses of students during physical activity. By focusing on these dynamics, we can better understand the importance of developing adaptive strategies that align with the principles of sustainable development in education. Incorporating climate-aware practices in physical education can not only enhance students' health outcomes but also promote awareness of environmental issues, ultimately contributing to a more sustainable future for communities.

The findings of this research will serve as a foundation for educators, policymakers, and health professionals to create more effective physical education programs that prioritize cardiovascular health while adapting to changing climatic conditions. By acknowledging the interplay between climate and health, we can work towards fostering resilience among students in the face of environmental challenges, ensuring their well-being and capacity to thrive in diverse settings. Studying at a higher educational institution causes certain functional and structural changes in the body of young people studying. Long-term physical inactivity in higher educational institutions has a significant impact on the functional state of the cardiovascular system in male and female students. The functional state of the cardiovascular system can act as a key factor in assessing the adaptive reactions of the human body [5]. It is believed that its functional indicators are a universal indicator of the adaptive activity of the human body to environmental factors [11, 12].

The functional state of the cardiovascular system is assessed by studying the parameters of hemodynamics at rest [7]. Assessment of the cardiovascular system at rest does not allow for a full characterization of the functional state. Functional tests are used for this purpose . Functional tests with physical activity lead to activation of neurohumoral mechanisms of regulation of the cardiovascular system, increased oxygen transport, increased respiration rate, and the occurrence of tissue hypoxia in the cardiac and skeletal muscles [4]. In poorly adapted and untrained people, adaptation to muscle activity occurs mainly due to an increase in cardiac output. Cardiac output in such people increases due to an increase in heart rate [4].

When studying the work of the heart and cardiovascular system, a number of parameters and indices are used [2]. In addition to the common parameters - pulse, heart rate, blood pressure, minute blood volume, cardiac output, various indices are often used - the Ruffier index , the Robinson index, indices characterizing the inotropic and chronotropic reserves of the heart muscle [2].

The study of regional features of adaptation of the circulatory system and heart to dosed functional motor tests in young students is of theoretical and practical interest.

The aim of the work: to assess the functional state of the adaptive mechanisms of the cardiovascular system of students in response to hypoxia caused by dynamic motor load.

II. Methods

Students of the educational institution were involved in the study of the parameters of the cardiovascular system. This work involved male and female students of the Biological and Chemical Faculty and the Agrotechnological Institute of Grozny. The age of the students ranged from 21 to 23 years, which corresponds to mature age, the first period. At the time of the examination, male and female students had no complaints about the state of the cardiovascular system. They gave their verbal consent to participate in the study. Second-year female master's students also took part in the study. Only female master's students were examined, since there were no males among the master's students at the university.

We conducted a functional study of the cardiovascular system in response to physical activity using the Ruffier test, which is often used to assess the functional state of the cardiovascular system. The Ruffier test involves performing 30 squats in one minute.

At rest, blood pressure and heart rate were measured. To measure them, we used an automated device for measuring blood pressure and heart rate – MT-40 (USA). This device automatically measures the pulse and two types of pressure – systolic (BPs , upper) and diastolic (BPd , lower) pressure. Pulse pressure (BPp) was calculated as the difference between the maximum and minimum pressure of the subject. After performing the Ruffier motor test, the subjects ’ blood pressure and heart rate were immediately measured.

We studied the following parameters: heart rate, blood pressure (systolic, diastolic, pulse, average), pulse at rest and after a minute of Ruffier's robe . We also determined several different indices - the Kerdo index, the Robinson index, the Ruffier index and the adaptation potential index according to R. M. Baevsky.

Heart rate and blood pressure measurements were taken at rest (15 seconds), after the Ruffier test (15 seconds immediately after the test) and for 15 seconds at the end of the first minute of recovery.

The value of the adaptation potential was calculated at rest, after performing the Ruffier test and after a minute of recovery.

For statistical processing of the results of the study of blood pressure, heart rate and various indices, including the value of the adaptation potential, the Paired Student's criterion was used. The results of the study were processed by the computer program " Biostatistics ".

IV. Discussion

Cardiovascular system parameters at rest and after the Ruffier test . Systolic pressure in male and female students increased significantly after the Ruffier test (Table 1, Fig. 1). According to literature, systolic pressure increases after physical exertion [2, 5].

Table 1: *Systolic pressure (mmHg) in subjects examined after the Ruffier test*

Subjects	State of rest	Ruffier's test	Recovery, 1 min
Girls	118.6±2.32	133.2±2.88**	119.6±2.64
Young men	121.3±2.91	142.4±3.24**	122.3±3.42

*- $p< 0.05$

Unlike systolic pressure, diastolic pressure does not undergo statistically significant changes in both male and female students after the Ruffier test (Table 2, Fig. 2). According to literature [2], diastolic pressure in response to physical activity either increases slightly or does not change immediately after the load. After a fairly short period of time - less than 3 minutes after the load - this indicator returns to the original value or even decreases. As can be seen from Table 2, we note this pattern in both male and female students.

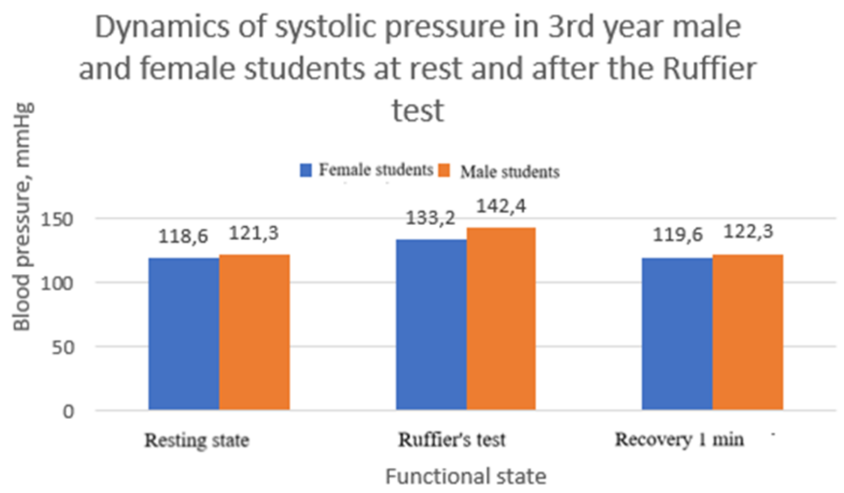

Figure 1: *The nature of changes in systolic blood pressure in 3rd year students after performing a functional motor test*

Table 2: *Diastolic pressure (mmHg) in male and female students after the Ruffier test*

Subject	State of rest	Ruffier's test	Recovery, 1 min
Girls	72.8±2.05	76.4±2.23	68.2±1.72
Young men	74.5±2.11	80.3±2.21	73.7±2.41

p>0.0

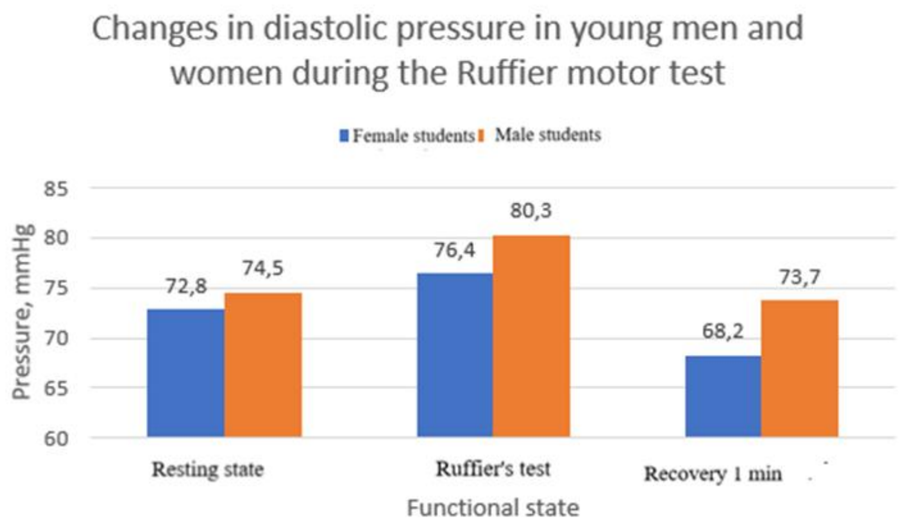

Figure 2: *Lower arterial pressure in 3rd year male and female students after performing the Ruffier test*

It should be noted that the World Health Organization provides the following categories for assessing blood pressure (regardless of gender): systolic pressure of less than 120 mm Hg is considered normal, and less than 130 mm Hg is considered normal systolic pressure. The following categories of assessments are accepted for diastolic pressure: - normal (less than 80) and normal (less than 85). According to these data, the pressure of the surveyed male and female students (general group value) can be considered normal. At the same time, individual fluctuations in blood pressure among male and female students have a wide range.

According to E. A. Ryazanova and L. A. Girenko [9], an increase in heart rate after physical exercise (Martine's test) by more than 31 units indicates an unsatisfactory state of the cardiovascular system. In the present study, the subjects performed physical exercise in the form of the Ruffier test . In those examined by us, the heart rate after the Ruffier test increases quite high, although it does not exceed the limit of 31 units (Table 3, Fig. 3). Moreover, performing the Ruffier test causes a reliable increase in the heart rate (Table 3, Fig. 3).

Table 3: *Heart rate (bpm) in male and female students after the Ruffier test*

Subjects	State of rest	Ruffier's test	Recovery, 1 min
Girls	80.1±2.44	107.5±3.22**	88.7±3.55
Young men	73.4±2.32	98.6±3.65**	79.9±3.67

** p< 0.02

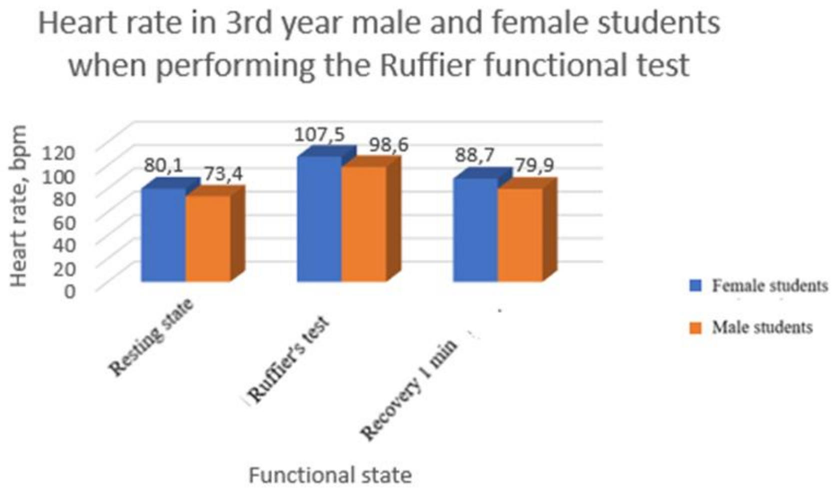

Figure 3: *Heart rate dynamics in 3rd year students after short-term physical activity*

An increase in pulse rate by 27.4 units was noted in girls and by 25.2 units in boys. Consequently, it can be concluded that the organism and cardiovascular system of the students we examined are satisfactorily adapted to physical activity.

Evaluation of the functional state of the cardiovascular system by indices at rest and after performing the Ruffier test . At rest, the Kerdo index in female students indicates the prevalence of sympathetic influences on the work of the heart. As can be seen from Table 4 and Figure 4, girls have a more pronounced sympathetic effect on the activity of the heart and blood circulation: their CI is +9 at rest. Kerdo index values from -10 to +10 are considered normative. Positive CI values indicate the prevalence of sympathetic influences on the work of the heart. In young men, the CI value is negative (-1.5) (Table 4), which indicates a parasympathetic effect on the work of the heart at rest.

After performing the test In Ruffier , both in girls (+29 c.u.) and in boys (+18.5 c.u.), the influence of the sympathetic branch of the autonomic nervous system increases. The values of the Kerdo index after the load and a decrease in its value after 1 minute indicate a satisfactory state of the cardiovascular system of male and female students. At the same time, sympathicotonia is more pronounced in female students and it persists after 1 minute of recovery. In young men, sympathicotonia is noted after the load, and normotonia after a minute of recovery . Female and male individuals responded differently to physical activity.

Table 4: *Kerdo index (cu) in male and female students after the Ruffier test*

Subjects	Peace	Ruffier's test	Recovery, 1 min
Girls	0.091 (+9 USD)	0.29 (+29 USD)	0.231 (+23.1 USD)
Young men	-0.015 (-1.5 USD)	0.185 (+18.5 USD)	0.077 (+7.7 USD)

p>0.05

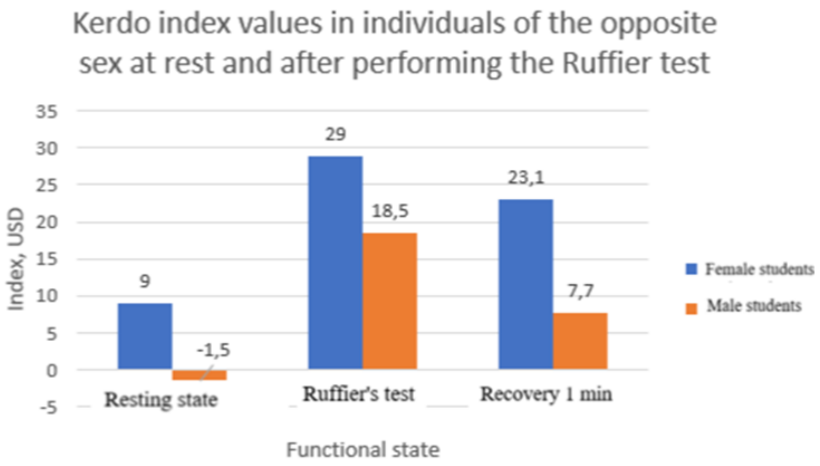

Figure 4: *Changes in the Kerdo vegetative index in students and third-year students*

Analysis of the functional state of the cardiovascular system using the Robinson index revealed the following features (Table 5, Fig. 5). The Robinson index values for girls were - 94.9 c.u., and for boys - 89.0 c.u. For girls, this indicator exceeded the standard limits of the index in a state of rest (85-94 c.u.), corresponding to the average functional state of the cardiovascular system [10].

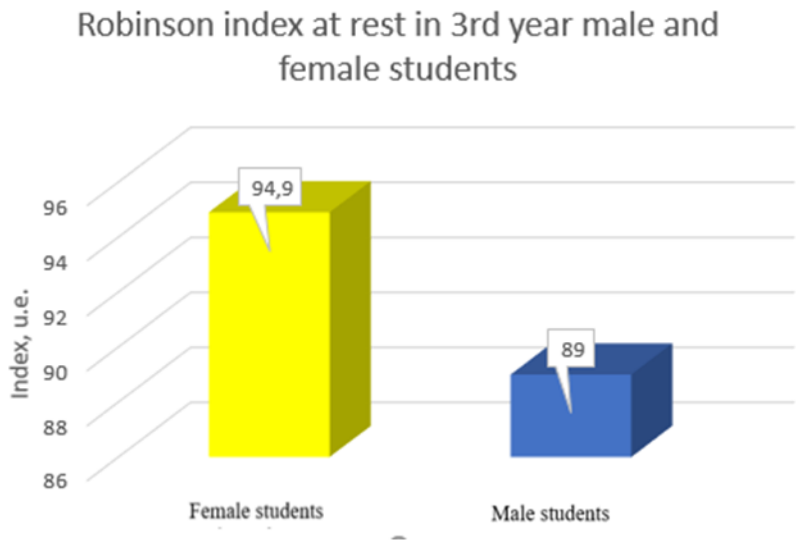

Figure 5: *Comparison of Robinson indices in individuals of the opposite sex. The Robinson index evaluates the functional state of the cardiovascular system at rest.*

As can be seen from Table 5, the IR indicators of female students were at the upper limit of the average functional state. The girls showed a slight decrease in the functional capabilities of the circulatory system.

Table 5: *Robinson index at rest in male and female students*

Floor	IR	Meaning
Girls	94.9 (cu); The upper literary limit of the average functional state of the cardiovascular system is 94 (cu).	Upper limit of the average functional state of the cardiovascular system. Some decrease in the functional capabilities of the cardiovascular system
Young men	89.0 (cu); The upper limit of the average functional state is equal to 94 (cu).	The value falls within the limits of the average functional state of the cardiovascular system. Average functional capabilities of the cardiovascular system

Ruffier index allows us to draw a conclusion about the state of the functional reserves of the cardiovascular system after performing a physical load. According to our data, the students we examined had average Ruffier index values . Thus, for girls its value was 7.63 c.u. , and for boys 5.19 c.u. (Table 6, Fig. 6). The literary norm of more than 15 c.u. indicates low reserves of the cardiovascular system.

Physical activity allows us to identify the features of the functioning of the circulatory system, hemodynamic parameters that are hidden when examining a person at rest. Physical activity is considered a stress factor for the body. It causes hypoxia in the cardiac and skeletal muscles [4]. The Ruffier index allows us to adequately assess the adaptive capabilities of the body, the circulatory system in response to muscle activity.

Table 6: *Ruffier index in male and female students*

Floor	IR values, c.u.
Girls	7.63 (from 7 to 9 – average heart performance [8]
Young men	5.19 (4 to 6 – good cardiac performance in response to physical activity [8]

Ruffier index in persons of the opposite sex, calculated based on changes in the parameters of the cardiovascular system after physical exercise

The magnitude of the adaptation potential at rest and after the Ruffier test .

AP is an integral indicator that takes into account the parameters of physical development and indicators of the cardiovascular system [3].

7 and Figure 7 below show the values of the adaptation potential of male and female students. For female students, the AP was 2.24 c.u., and for male students, it was 2.21 c.u. These values were determined in a state of rest.

According to some authors [1, 3], AP values below 2.6 c.u. are considered satisfactory adaptation of the circulatory system. In the male and female students we examined, AP at rest did not exceed this value. However, after performing the Ruffier test, the AP value rose above 2.6 c.u. (Table 7, Fig. 7). This AP value corresponds to the tension of the adaptation mechanisms. The reason for this is clear: physical activity causes an increase in blood pressure and heart rate. And AP is closely related to the parameters of the cardiovascular system and is calculated based on three of its parameters - systolic and diastolic pressure and pulse. At the same time, the AP values were higher in absolute value in female students, which may indicate a less pronounced adaptation to muscle loads in them compared to male students.

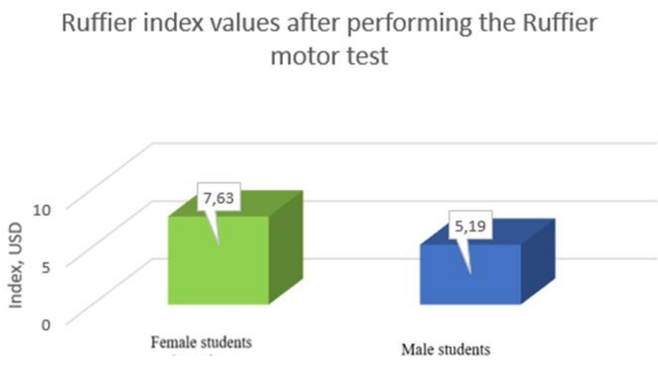

Figure 6: Ruffier index in male and female students

However, according to other authors, there are other limits for the AP values and their interpretation. They are most often found in the literature. In particular, the AP value of up to 2.10 c.u. is accepted as satisfactory adaptation and indicates sufficient functional reserves of the circulatory system. The functional stress of the adaptation mechanisms corresponds to AP values from 2.11 to 3.20 c.u. AP values from 3.21 to 4.30 c.u. are unsatisfactory adaptation, expressed in insufficient adaptability to physical activity, and finally, a breakdown of adaptation, corresponding to AP values of more than 4.30 c.u., a sharp decrease in the functional capabilities of the cardiovascular system [6]. According to this author, the AP values of our male and female students correspond to the stress of the adaptation mechanisms even at rest. After loading, the AP values increase even more, although they correspond to the state of tension of the adaptation mechanisms, that is, they are in the range from 2.11 to 3.20 conventional units.

Table 7: *The magnitude of the adaptive potential of male and female students studying in senior years*

Floor	AP at rest, c.u.	AP after Ruffier's test , c.u.	AP after 1 min recovery, c.u.
Students	2.21±0.176	2.82±0.210	2.34±0.176
Female students	2.24±0.195	2.86±0.193	2.38±0.182
r	>0.05	>0.05	>0.05

p>0.05

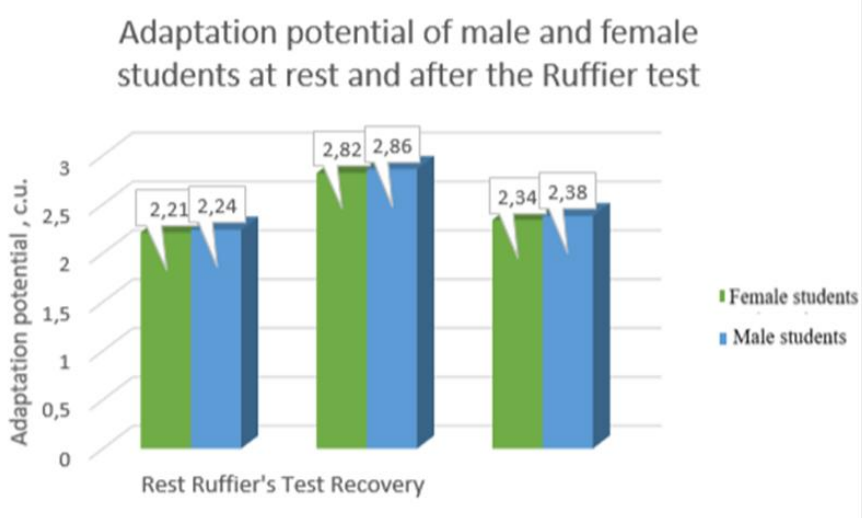

Figure 7: *The magnitude of the adaptation potential in individuals of the opposite sex at rest, after performing the Ruffier test and one minute of recovery*

No statistically significant differences in the magnitude of AP between male and female students were found at rest and after exercise.

Thus, the functional state of the cardiovascular system in 3rd year male and female students can be characterized as satisfactory. Physiological reserves of the body and cardiovascular system in male and female students are characterized by average functional capabilities. At the same time, students demonstrated higher physiological reserves of the cardiovascular system. In general, males are more adapted to muscle loads and to hypoxic conditions that occur in the cardiac and skeletal muscles during dynamic muscle loads.

Assessment of the functional state of the cardiovascular system of graduate students based on the results of the Ruffier test . After performing the Ruffier test, the HR of graduate students increased by 29% compared to rest, and after 1 minute of recovery, the increase in HR was 7%.

The dynamics of changes in heart rate in second-year full-time female master's students is presented in Table 8. As can be seen from the table below, after the functional test, the increase in heart rate is statistically significant (Table 8, Fig. 8). After one minute of recovery, the increase in heart rate was still significantly higher than at rest. Compared with third-year students, the recovery of female master's students after the Ruffier test is delayed, since even after one minute the heart rate does not reach the resting value . Such results can possibly be explained by a longer period of physical inactivity in female master's students, since the duration of their studies at the university is more than five years.

Table 8: *Heart rate indicators at rest and after performing the Ruffier test in 2nd year female master's students*

Functional state	Peace	Ruffier's test	Recovery, 1 minute
Heart rate, bpm	78.8±3.75	101.5±3.81***	83.9±0.40***

Ruffier index obtained by us when performing the Ruffier test on graduate students was 6.42 U (Table 9). Values above 6 to 10 indicate average performance of the cardiovascular system [8]. According to this source, the Ruffier index value from 6 to 7 occupies an intermediate position between good and average performance.

Thus , it can be concluded that the functional state of the cardiovascular system of second-year master's students is satisfactory.

Table 9: *Ruffier index after performing the Ruffier test*

Functional state	Ruffier's test
Index Ruthie	6.42±1.111

Evaluation of functional reserves of the cardiovascular system , health of young people studying is an urgent task. Most methods of evaluating functional reserves calculate some integral indices that are based on measurements of hemodynamic parameters at rest. At the same time, measurements at rest cannot fully reflect the state of human functional reserves and adaptive capabilities. To study the reserves of the cardiovascular system, motor tests are used. Motor muscle load causes hypoxia in the human body. Physical activity acts as a stress factor. In response to such an impact, human functional reserves are mobilized. As a rule, those well adapted to motor activity have good functional reserves of the body. Young people studying, due to the specifics of the educational process, are at risk, so assessing their health and functional reserves using functional motor tests is of practical importance.

1. Based on the nature of the change in blood pressure and heart rate in response to a motor test (Ruffier test), male and female students exhibit a normotonic type of response from the cardiovascular system;

2. The value of the Ruffier index indicates a satisfactory functional state of the cardiovascular system in male and female students;

3. According to the Robinson index, average (in girls) and good (in boys) functional capabilities of the cardiovascular system are noted;

According to the Kerdo index, sympathetic influences on the work of the heart at rest slightly prevailed in third-year female students ; parasympathetic influences prevailed in young men; an increase in the index was noted in both male and female students after the Ruffier test and an increase in the influence of the sympathetic link on the work of the heart;

5. The value of the adaptive potential of male and female students corresponds to the tension of the adaptation mechanisms, while the functional reserves are still preserved, although reduced;

6. The Ruffier index is an important indicator for assessing the physiological reserves of the cardiovascular system, as it characterizes its response to a motor test and adaptation to muscle work;

7. The cardiovascular system of the examined male and female students demonstrates satisfactory adaptation to short-term physical activity.

The interplay between climatic conditions and the adaptation of the cardiovascular system in students to physical activity is a critical area of study, especially in the context of sustainable development in education. Understanding how different climatic factors influence cardiovascular responses can lead to more effective training regimens, promote healthier lifestyles, and ensure the safety and well-being of students during physical activity.

1. Impact of Climate on Cardiovascular Responses: The body's cardiovascular system is designed to respond to the demands placed upon it during physical activity. However, external climatic conditions can significantly alter this response. For example, in hot and humid environments, the body may struggle to regulate its core temperature, leading to increased heart rates and potential heat-related illnesses. Conversely, in cold climates, blood vessels constrict to conserve heat, which may impair circulation and overall cardiovascular efficiency. Understanding these responses allows educators to tailor physical activities and training programs that account for local climate variations, ensuring that students can perform safely and effectively.

2. Adapting Training Regimens: Educators and coaches must adapt training regimens to the specific climatic conditions that students face. This includes modifying the timing of physical activities, choosing appropriate types of exercise, and ensuring adequate hydration and nutrition. For example, conducting outdoor training sessions during cooler parts of the day can mitigate heat stress, while incorporating warm-up routines that prepare the cardiovascular system for exertion in colder climates can enhance performance and reduce injury risks. By developing adaptive training strategies, educational institutions can improve cardiovascular health and performance among students while also instilling lifelong habits of safety and awareness regarding environmental conditions.

3. Importance of Education and Awareness: Promoting awareness of the effects of climate on health is essential for fostering resilience among students. Educational programs should emphasize not only the physical aspects of fitness but also the environmental context in which students operate. This can be achieved through integrated curricula that connect physical education with environmental science, encouraging students to understand how their surroundings impact their health. By educating students about the importance of adapting to climate conditions, we empower them to make informed decisions about their health and well-being.

4. Sustainable Development Goals: This discussion aligns with several Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-Being) and Goal 4 (Quality Education). By focusing on the intersection of climate, health, and education, we can develop holistic approaches that promote student well-being while addressing environmental challenges. Schools can act as models for sustainable practices, promoting outdoor activities that are climate-sensitive and fostering a culture of health and fitness. Furthermore, students equipped with knowledge about the relationship between climate and health are more likely to engage in sustainable behaviors, contributing to community resilience and environmental stewardship.

5. Future Research Directions: Further research is needed to explore the long-term effects of climatic conditions on cardiovascular health in various populations. Longitudinal studies can provide valuable insights into how consistent exposure to specific climatic factors influences cardiovascular adaptation over time. Additionally, investigating the role of technology, such as wearable fitness trackers, in monitoring cardiovascular responses under varying climatic conditions can offer practical solutions for enhancing student health and performance.

In conclusion, the influence of climatic conditions on the adaptation of the cardiovascular system in students is a multifaceted issue that requires careful consideration in educational settings. By understanding these dynamics and implementing adaptive strategies, we can promote not only the physical health of students but also a broader commitment to sustainable development and environmental awareness.

References

[1] Abdumananov A. A. Software package for assessing the index of human adaptive potential / A. A. Abdumananov , M. K. Karabaev , A. A. Abdumuminov // Scientific dialogue: Questions of medicine. - 2018. - P. 4-6.doi:10.18411/spc-15-12-2018-0.

[2] Agafonova M. E. Evaluation of functional reserves of the athletes' body in the conditions of training camps: functional tests / M. E. Agafonova // Scientific and practical seminar. 09.2021. - Minsk. - 2021. - P. 4-10.

[3] Baevsky R. M. Assessment of the adaptive potential of the circulatory system during mass

preventive examinations of the population / R. M. Baevsky, A. P. Berseneva, N. R. Paleev. - M .: Express-information, VNIMI. - 1987. - 65 p.

[4] Belchenko L. A. Adaptation of humans and animals to hypoxia of different origins/L. A. Belchenko// Soros educational journal. – 2001. – Vol. 7. - No. 7. – P. 33-39.

[5] Grechkina L. I. Assessment of hemodynamic parameters as markers of potential risk of cardiovascular diseases in young men with different types of circulatory self-regulation / L. I. Grechkina // Health risk analysis. - 2019. - No. 1. - P. 118-124.

[6] Krayushkin A. I. The relationship between the adaptive potential, the area of the hand and the circumference of the chest depending on the body weight in young men / A. I. Krayushkin, A. I. Perepelkin, A. B. Doronin // International journal of applied and fundamental research – 2016. - No. 6. – P. 260-262.

[7] Methods for assessing the functional state of students . URL : https://apni.ru/article/505-metodi-otsenki-funktsionalnogo-sostiyaniya/Accessed : 01.01.2024 .

[8] Normal Physiology: Workshop/Edited by K. V. Sudakov. – M.: OOO "Medical Information Agency". – 2008. – 232 p.

[9] Ryazanova E. A. Assessment of health indicators and physical fitness of students / E. A. Ryazanova, L. A. Girenko // URL: https ://nsktvs.ru/ node / 151. - 2018. - No. 2 (6). Date of access: 01.01.2024.

[10] Sergeychik N. A. Assessment of the functional state of the cardiovascular system of female students / N. A. Sergeychik, V. M. Stepantsov, S. S. Kvetinsky // http://lib-bteu.by/handle / 22092014 / 5006 . Date of access: 12/13/2023 .

[11] Tyatenkova N. N. Assessment of the functional capabilities of the cardiorespiratory system in young people / N. N. Tyatenkova , O. S. Aminova // Hygiene of children and adolescents. - 2021. - Vol. 29. - No. 7. - P. 50-56.

[12] Seo DY Cardiac adaptation to exercise training in health and disease/ DY Seo , HB Kwak, AH Kim et [al.]// Pflugers Arch. – 2020. – Vol. 472(2). – P. 155-168.

ASSESSING THE VULNERABILITY OF BUILDINGS TO THE THREAT OF KARST SINKHOLES

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Abstract

Karst sinkholes pose a great danger to people and infrastructure in many countries, so effective methods for assessing karst hazard are needed. However, there are currently no modern regulatory documents and methods for assessing the danger of karst sinkholes. The article describes the methods and provides examples of the application of several methods for assessing karst hazard, tested in real conditions in the karst zone of the Bryansk region.

Keywords: sinkhole formation, karst collapse, electrical resistivity tomography, ground-penetrating radar, dynamic-geophysical method, dynamic sounding method

I. Introduction

Sinkholes pose a serious danger to people and infrastructure. They can form suddenly and without apparent cause, making them unpredictable and difficult to predict.

Sinkholes can occur as a result of various factors, such as underground waters washing away soil and rocks, or natural geological processes. They can also be caused by human activity, such as construction or mining, the use of rural baths and toilets that discharge waters that are chemically aggressive to limestone rocks into the ground.

Karst sinkholes can have serious consequences: destruction of buildings and structures, damage to communications, and loss of life. They can also cause environmental problems, such as groundwater pollution or changes to the landscape.

To prevent the danger of karst sinkholes, it is necessary to conduct research and monitor geological conditions in areas where there is a risk of their occurrence. It is also important to take precautions, when constructing and operating facilities in such areas.

When designing buildings and structures in areas prone to karst sinkholes, it is necessary to take into account the geological features of the area and use special construction technologies. This will reduce the likelihood of destruction of buildings and structures when a karst sinkhole occurs. It is also necessary to identify developing karst sinkholes in populated areas in advance. [1]

II. Study area and geological setting

Bryansk region is located in the central part of the East European Plain. The length from west to east is 270 km, from north to south - 190 km. In the southeast of Bryansk region there are settlements, which are characterized by karst sinkholes. Mainly, research on karst sinkholes was conducted in the city of Novozybkov and the village of Vyshkov.

In the walls of the failure, a section of soil and vegetation layer with a thickness of 0.2 meters and clay rocks with a visible thickness of 6-7 meters will be exposed.

Below the observed clay rocks lie waterlogged sands, under which there is a layer of chalk deposits with interlayers of Upper Cretaceous marls. Karst and suffusion phenomena are associated with the area of distribution of Upper Kaman chalk rocks and Paleogene terrigenous deposits in the southwestern regions of the Bryansk region. Karst processes are confined to zones of tectonic disturbances and the associated increased fracturing of the chalk strata.

Increased fracturing of the chalk rock mass, chemical dissolution of chalk rocks by aggressive waters of Quaternary deposits, mechanical leaching of chalk rocks and removal of clayey chalk in the discharge area lead to the formation of karst-suffusion cavities and subsequent failures.

Active use of agrochemicals, runoff from large livestock complexes, failure to comply with sanitary protection standards cause pollution of the aquifer complex with nitrates, nitrites, chlorides, sulfates. Groundwater is especially poorly protected, and therefore its use by household wells is not always environmentally safe.

III. Methods

There are several challenges associated with detecting emerging sinkholes in urban areas. First, settlements are usually located near water bodies; thus, there is an abundant supply of groundwater near the village. Second, with frequent anthropogenic activities affecting geophysical detection. Thirdly, power cables are buried under the subsurface around the village, resulting in an electric surface current that affects some processes [2].

Therefore, accurate detection results cannot be obtained using only a single geophysical method [2], [3]. Therefore, we integrated multiple geophysical approaches, namely, dynamic-geophysical method (DGM), Ground-penetrating radar (GPR), dynamic sounding method (DSM), to improve the accuracy of detecting sinkholes.

Ground-penetrating radar GPR

The objective of the GPR survey was to determine the condition of the soil mass in the failure zone along longitudinal and transverse profiles. And also, to study the school territory for the presence of forming failures. The profiles are located both along and across the failure of the soil relative to the direction of the street. The purpose of the GPR studies was to identify zones of possible manifestation of karst and suffusion processes on radargrams [2].

GPR is based on the study of the field of high-frequency electromagnetic waves (frequencies from the first tens of MHz to the first units of GHz are used). The method is based on the difference in rock permittivity. The emitted pulse, propagating in the examined environment or object, is reflected from the boundaries at which the electrical properties change - electrical conductivity and permittivity. The reflected signal is received by the receiving antenna, amplified, converted into digital form and stored. As a result, from an ordered set of reflected signals, a section of the examined environment is formed, perpendicular to the plane of the georadar antennas, called the GPR profile [4].

The main quantities measured in GPR are the travel time of an electromagnetic wave from the source to the reflecting boundary and back to the receiver, as well as the amplitude of this reflection. Such interfaces in the studied environments are, for example, the contact between dry and water-saturated soils (groundwater level), contacts between rocks of different lithological composition, between rock and the material of an artificial structure, between frozen and thawed soils, between bedrock and loose rocks.

Dynamic sounding method DSM

For DSM, small-sized and powerful geological equipment will be appropriate. This method is used where clayey and sandy soils of any type of occurrence are studied. DSM specializes in obtaining complete and very accurate data on sandy and clayey soils.

DSM stages:

- Geological equipment is installed on a prepared site, appropriate equipment is selected so that its parameters meet the tasks and operating conditions;
- Then, using a hammer, the probe is driven into the ground;
- After a series of blows, the depth of the probe in the ground is measured;

- Sounding is completed when the probe reaches the design depth, or when, after a series of blows, the probe is immersed in the ground no more than 3-4 cm.

Dynamic geophysical method (DGM)

DGM is based on the assessment of the integral rigidity of a structure based on characteristic features and criteria that appear when processing the dynamic parameters of the "soil-structure" system.[5]

One of the features characterizing rigidity is the period or frequency of natural oscillations of the structure. Since the period of natural oscillations of the structural system of the structure is directly proportional to its mass and inversely proportional to its rigidity, then by measuring the frequency or period of natural oscillations, one can evaluate the rigidity of the structure. To evaluate the standard value of the period of natural oscillations of the structure, expressions obtained from the solution of differential equations describing its oscillation are used [6], [7]:

$$T=k\times\sqrt{(m/EJ)} \quad (1)$$

where

m – linear weight of the system, kg/m;

EJ – the rigidity of the system as the product of the modulus of elasticity and the moment of inertia, H×м2;

k – coefficient taking into account the structural design of the building.

IV. Results

As an example of the methods' operation, the data measured in the area of the school in the village of Vyshkov in the Bryansk region were taken. Since this zone was the most socially important, the largest number of measurements were made there by various methods. The main measurement methods were: dynamic probing, GPR and DGM.

GPR

In the surveyed area 12 GPR profiles were made. One of them is shown in Fig. 1.

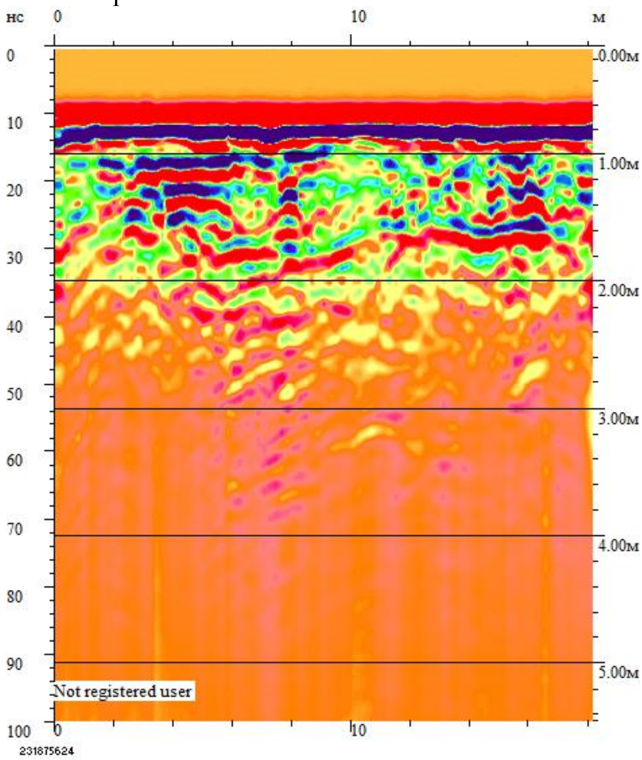

Figure 1: *GPR profile at the site of a possible karst failure*

On all georadar profiles the device does not give data below 3-4 meters, which indicates strong waterlogging of the soil. With the help of GPR, small anomalies were noticed and 2 zones of possible formation of a karst failure were identified.

DSM

DSM confirmed the high-water content of the soils. (Fig. 2) In addition, in places of possible karst failures, the dynamic probe easily entered the soil massif and showed weak soil resistance.

Figure 2: *Waterlogged soils on the extracted probe*

DGM

The dynamic parameters of the soil-building system include the frequencies of natural vibrations and the damping decrements along the X, Y, Z axes.

The frequencies characterize the rigidity of the system, the damping decrements show how the vibrations of the system are damped.

When assessing the soil mass, the researchers were guided by the following points:

- each type of soil of the same thickness is characterized by a certain level of the average weighted period (Taw);
- the values of Taw vary depending on the thickness and type of soil;
- the presence of a loose soil layer (arable land, etc.) causes the presence of high values of Taw in the immediate vicinity of the source of soil vibrations;
- at a distance of about 30-40 m from the source, the values of Taw approach the values of the prevailing period of vibrations (Tpr) for a layer thickness of 8-10 m ($Tpr=4H/v_s$);
- with distance for soils of great thickness (H>10 m) at a distance of more than 40 m, an abrupt increase in Taw is observed, approaching the corresponding Tpr; moreover, for soils (thickness H≈8-10 m) the increase in Taw with a distance of more than 30-40 m is small.

Thus, the study of average-weighted periods allows us to study both the physical and mechanical properties of soils and their resonance properties, determined by the equality of average-weighted and prevailing periods of oscillations.

Another indicator for searching for failures was the characteristic pronounced pulsation of the soil massif. (Fig. 3)

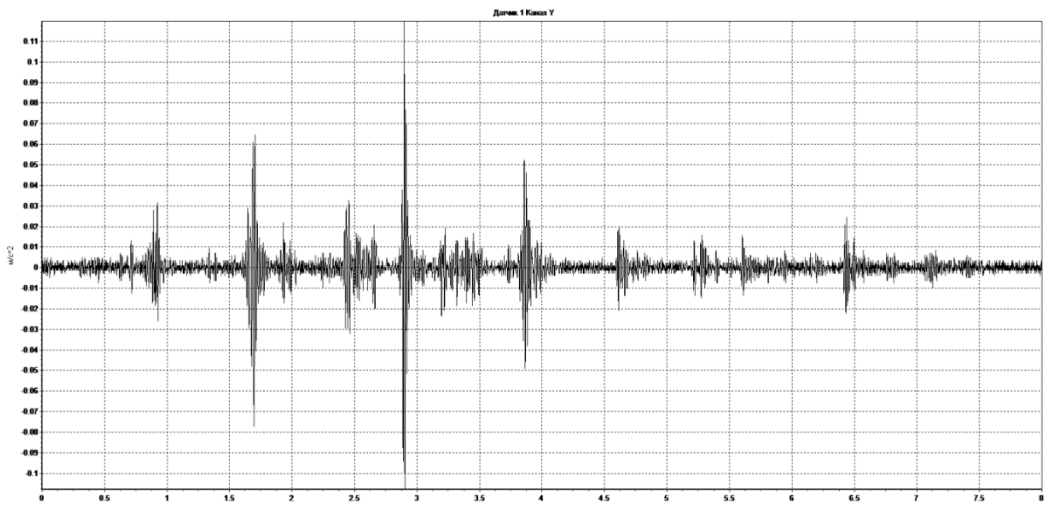

Figure 3: *Soil mass vibrations with pronounced pulsation*

Based on dynamic geophysical measurements (Table 1) and expert analysis, a map was constructed with zones of increased karst hazard. (Fig. 4)

Table 1: *The degree of karst hazard assessed using dynamic geophysical measurements*

Point	Fx, Hz	Fy, Hz	Fz, Hz	Degree of karst danger (in points from up to 10)
	100	105	100	9
2	30-100	3,75;60	41,648	6
3	38	39,2	0,15	8,5
4	5,25	4,35	5,2	9
5	34,6	94,8	0,15	8,6
6	92	92	20	7
7	89	89	60	5
8	65	114	0,15	6
9	100	100	100	8,7
10	6,3	7,25	0,15	5
11	110	105	0,15	6
12	185	180	0,15	5
13	125	110	100	6,5
14	112	100	110	8
15	5,4	2,85	0,15	4
16	100	100	0,15	7
17	100	90	100	6
18	100	12,8	12,8	4
19	65	64	64	3
20	12,8	12,8	12,8	2
21	12,8	12,8	12,8	5,7
22	10-25	10-25	10-25	4
23	9,95	12,8	12,8	3

Figure 4: *High karst hazard zones (red) at the school construction site, obtained from the results of processing DGM*

According to the dynamic geophysical soil tests in 2023, there is a threat of karst hazard at the building construction site (Fig. 4). The vibration spectra in the low-frequency region are equal to (2.3-7.25) Hz and correspond to waterlogged soils.

V. Discussion

During the surveys conducted in the karst hazardous area, a huge amount of data was collected. The data collection included various types of work, such as dynamic probing, ground penetrating radar and dynamic geophysical methods.

The collected data helped to better understand the characteristics of karst phenomena in this area and to develop recommendations for the safe use of the territory. They can also be used to predict possible changes in the karst system and to develop measures to prevent dangerous situations.

The main reason for the occurrence of karst sinkholes in the Bryansk region is the shallow depth of the chalk layer and its high-water saturation. And as a result of human activity such as the use of private rural baths and toilets, as the active use of agrochemicals, runoff from large livestock complexes, non-compliance with sanitary protection standards, pollution of the aquifer complex with nitrates, nitrites, chlorides, sulfates is caused. Groundwater is especially poorly protected.

In the course of the study of karst sinkholes by the three methods described above, DGM was found to be the most suitable. With the help of this method, anomalous areas of possible formation of karst sinkholes were identified.

The results of this method were subsequently confirmed by DSM. This method confirms places where the soil is greatly weakened, but this method is too point-based and labor-intensive. To assess karst hazard zones even in a small area, it is necessary to make a huge number of measurements with driving a titanium rod into the soil at each point. As an independent method, the DSM is not applicable separately from others.

GPR showed the most mediocre results. This method shows itself excellently for assessing soils to a depth of 10 m, but if the soils are not water-saturated. In this situation, the signal was jammed at depths of 3-4 m and the specialists were practically not able to see the anomalous zones.

References

[1] G. Kaufmann *и др.*, «Mapping and modelling of collapse sinkholes in soluble rock: The

Münsterdorf site, northern Germany», *J. Appl. Geophys.*, т. 154, сс. 64–80, июл. 2018, doi: 10.1016/j.jappgeo.2018.04.021.

[2] R. Liu, H. Sun, J. Qin, и Z. Zheng, «A multi-geophysical approach to assess potential sinkholes in an urban area», *Eng. Geol.*, т. 318, с. 107100, июн. 2023, doi: 10.1016/j.enggeo.2023.107100.

[3] Y. Jeng и C.-S. Chen, «Subsurface GPR imaging of a potential collapse area in urban environments», *Eng. Geol.*, т. 147–148, сс. 57–67, окт. 2012, doi: 10.1016/j.enggeo.2012.07.009.

[4] R. Martel, P. Castellazzi, E. Gloaguen, L. Trépanier, и J. Garfias, «ERT, GPR, InSAR, and tracer tests to characterize karst aquifer systems under urban areas: The case of Quebec City», *Geomorphology*, т. 310, сс. 45–56, июн. 2018, doi: 10.1016/j.geomorph.2018.03.003.

[5] G. Nigmetov, A. Savinov, и T. Nigmetov, «Monitoring of individual seismic risk at all stages of development of a possible earthquake source», *Reliab. Theory Appl.*, 2023, doi: 10.24412/1932-2321-2023-575-489-499.

[6] A. Savinov, G. Nigmetov, T. Nigmetov, и R. Galliulun, «The Possibility of Vibrodynamic Data from Phone Accelerometers for the Rapid Assessment of the Technical Condition of Buildings and Structures Use», 2023, сс. 371–379.

[7] G. Nigmetov, A. Savinov, и T. Nigmetov, «Assessment of individual seismic risk for the population, taking into account the actual seismic resistance of buildings and the seismicity of soils», *Reliab. Theory Appl.*, 2022, doi: 10.24412/1932-2321-2022-470-172-179.

SEISMIC HAZARD FOR AN OIL AND GAS FIELD IN THE WATERS OF THE MIDDLE CASPIAN SEA

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Abstract

In order to ensure trouble-free operation of offshore oil production and transportation facilities, it is necessary to consider seismic hazard in their design. As part of this work, seismic hazard calculations were performed for the Zhenis oil and gas field facilities located in the Kazakhstan sector of the Middle Caspian. According to this project, the initial seismicity and seismic microzoning were clarified, i.e., accounting for real soil conditions made by different methods. Calculations showed that the intensity of seismic shocks in the Zhenis field can be 8.31 points on the MSK-64 scale, which corresponds of acceleration of a sea bottom ground of 0.253 g.

Keywords: Caspian Sea, seismic hazard, offshore oil and gas facilities, seismic microzoning

I. Introduction

The assessment of the seismic hazard of the water areas is carried out to ensure the seismic resistance of marine structures. However, research in this area makes it possible to solve other tasks that are not directly related to the problems of seismic safety of field development facilities. In particular, information about the maximum seismic impacts in a particular region makes it possible to solve not only the traditional tasks of engineering seismology and earthquake-resistant construction, but also to find application in the study of global climate change.

There are many hypotheses that differently explain the global climate change on our planet. Among them, as it seems to the authors of this article, a new theory of academician L. I. Lobkovsky about the influence of strong subduction earthquakes on the Earth's climate [24]. The author shows that strong earthquakes (M=8-9) result in tectonic waves in the lithosphere, which contribute to the emergence in the sedimentary cover of additional stresses commensurate with the stresses created by tidal deformation waves, and which are accompanied by the dissociation of metastable gas hydrates and the release of large volumes of methane into the atmosphere, which in turn leads to rapid global warming and global sea level rise. In this regard, it seems relevant to assess the level of seismic hazard in other areas, in particular, in the Caspian Sea, which contains gas hydrates in its sedimentary apron [3] and located at a relatively short distance from the Alpine-Himalayan collision zone.

Modern normative maps of general seismic zoning OSR-2015 A, B, C do not contain information on the intensity of seismic shaking (score) in the water areas of inland and marginal seas of Russia. Such information in integer MSK-64 score values is contained in the OSR-97 maps, which are not up to date.

Seismological monitoring using temporary and permanent networks of autonomous (ground and bottom) seismic stations is carried out to refine seismotectonic models of the studied region and detailed seismic zoning (DSZ) [10-13]. Description of operating systems of bottom seismological monitoring is given in works [14,18,21,26]. The results of using monitoring data for constructing seismotectonic models are given in [15,16,22,23,26]. If instrumental observations are not carried out, it is necessary to carry out work to clarify the initial seismicity (CIS) by computational methods, using both seismotectonic models already developed for the area under study and refined models. In our case (the Middle Caspian region), an example of such a model is given in [27], and a refined model in [19].

The purpose of seismic microzoning (SMR) is to quantify the influence of local conditions (soil composition, relief features, presence of active faults, etc.) on the seismicity of the site, indicating the change in the intensity of shaking in points according to GOST 6249-52 (Russian Standard) or in acceleration values in units of gravity (g).

II. Clarification of initial seismicity

The initial seismic impacts for the offshore oil and gas field Zhenis (Kazakhstan sector of the Middle Caspian Sea) were calculated by the method of probabilistic seismic hazard analysis (PSHA) [9] using the modified program SEISRISK III [6].

The input data for the PSHA are models of possible earthquake source zones (PES zones), earthquake recurrence models for these zones, and suitable attenuation models for the computed ground motion parameters (accelerations or response spectra). These models are prepared based on the analysis of available geological-geophysical and seismological data for the study area.

In this work we used the lineament-domain-focal (LDF) model of seismic hazard zones of the Middle Caspian Sea, which is the basis of seismic hazard calculations under the Global Seismic Hazard Assessment Program project [27], refined in accordance with [19] and shown in Fig. 1.

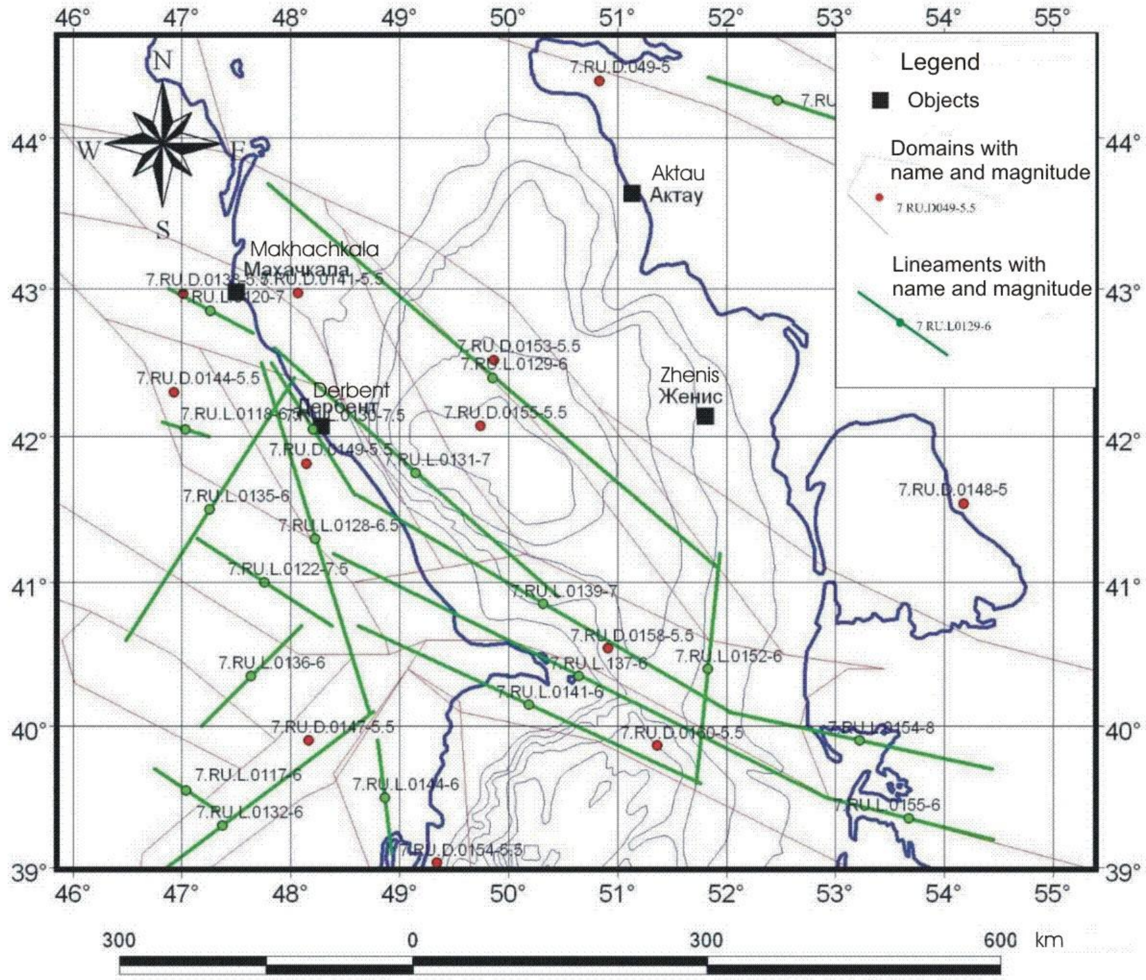

Figure 1: *Lineament-domain-focal model of seismic hazardous zones of the Middle Caspian Sea, which is the basis for seismic hazard calculations under the Global Seismic Hazard Assessment Program Project [27], refined in accordance with [19]*

The recurrence curves for this model are shown in Fig. 2 (lineaments). They are nonlinear relationships between the decimal logarithms of the number of earthquakes occurring over a period of one year within the specified PES zone (lineament or domain) and the magnitude of the earthquake. The plots are constructed using the database of the Global Seismic Hazard Assessment Program Project [27] with refinements in accordance with [11,12].

In this work, we used the models of attenuation of SA (T, 5%) acceleration response spectra for the simplest oscillatory systems modeling the response of individual elements of complex structures to seismic effects - linear oscillators with 5% attenuation. For each spectral period T of ground oscillations, a separate dependence of the response spectrum on the magnitude M and the distance R to the observation point is required. Values of M: from 4.0 to 8.0 in steps of 0.5; values of R: from 1 km to 1024 km to the observation point. These models were developed from databases of strong ground motions recorded from earthquakes with foci in the Earth's crust (H<=35 km) occurring in tectonically and, therefore, seismically active regions of the globe. Among the initial data were records of earthquakes in Turkey, Iran, Caucasus (Spitak), Central Asia. The Caspian Sea region also belongs to tectonically active regions of the globe, and the main hazardous events here are earthquakes with foci in the Earth's crust. Therefore, the applicability of these attenuation models in this case can be considered justified. The used models [1,2,4, 7] are shown in Fig. 3.

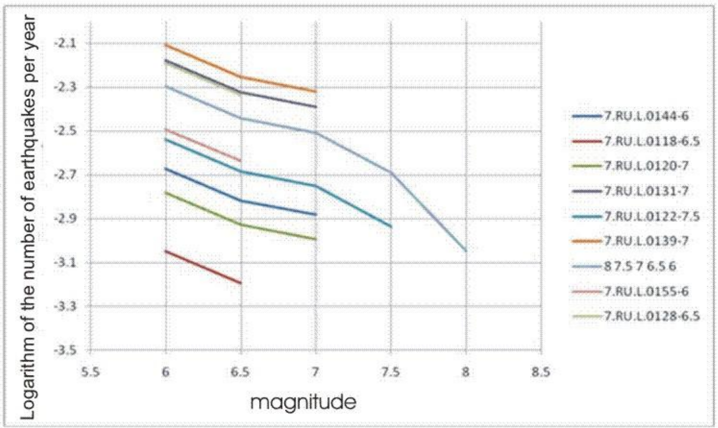

Figure 2: *Earthquake recurrence curves for earthquake dangerouse lineaments of the Middle Caspian Sea and adjacent land areas*

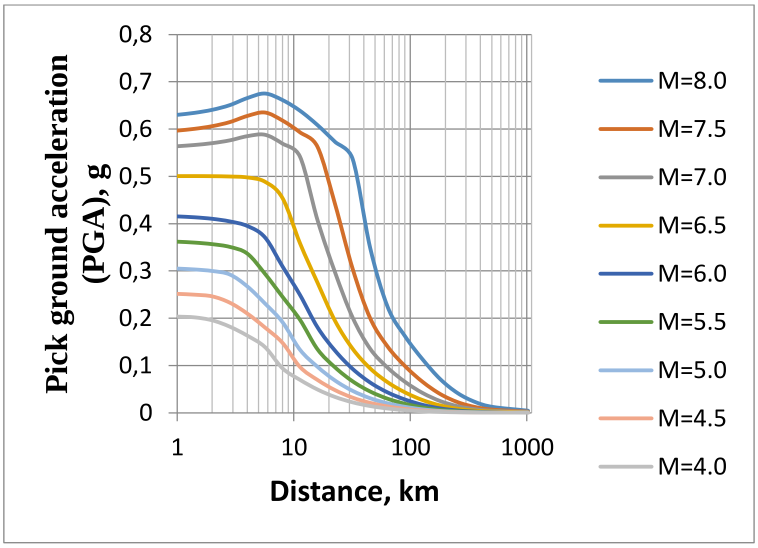

Figure 3: *Models of peak ground acceleration attenuation (PGA, g) as a function of distance*

The performed calculations have shown that for average soils of the Zhenis site for the design-basis earthquake (DBE, recurrence period 5000 years) seismic shaking intensity is 0.2 g in terms of PGA (peak horizontal ground acceleration) or 8 points in terms of seismic shaking intensity in MSK-64 scale points, which practically coincides with the data of OSR-97C map.

For the operating-basis earthquake (OBE, 500-year recurrence period), the seismic shaking intensity is 0.075 g in terms of PGA (peak horizontal ground accelerations) or 6.55 in terms of seismic shaking intensity in MSK-64 scale points, which is 0.45 points below the value shown on the OSR-97A map.

Various methods exist for modeling the nature of expected ground motions at the site under investigation. One of the most useful methods for design purposes is the method of calculating synthetic (artificial) accelerograms, velocigrams and seismograms whose response spectrum coincides with the design one.

In this work, we used the method proposed in [25] to calculate the ensemble of the most probable expected accelerograms for the area of the Zhenis well site. The method is based on the summation of a Fourier series consisting of sinusoidal oscillations with amplitudes varying according to the lognormal law, both in time and frequency, and with random phases uniformly distributed in the interval $[0, 2\pi]$.

Fig. 4 shows the response spectrum with 5% attenuation calculated with the SEISRISK III program for a recurrence period of 5000 years assuming that the Zhenis site is composed of soils of II category according to SNiP II-7-81* (Russian Standard), as well as the average statistical response spectrum constructed from an ensemble of 10 synthetic accelerograms. This ensemble of accelerograms (Fig. 5) corresponds to the design-basis earthquake (DBE) - close seismic events with magnitudes MLH=5.5 occurring at a distance of 5 km from the site. Both spectra are close to each other. The difference does not exceed 10%.

The performed calculations have shown that for average soils of Zhenis site for the design-basis earthquake (DBE, recurrence period 5000 years) seismic shaking intensity is 0.2 g in terms of PGA (peak horizontal ground acceleration) or 8 points in terms of seismic shaking intensity in MSK-64 scale points, which practically coincides with the data of OSR-97C map. For the operating-basis earthquake (OBE, recurrence period 500 years) intensity of seismic shaking makes 0.075 g in terms of PGA (peak horizontal ground acceleration) or 6.55 points in terms of intensity of seismic shaking in MSK-64 scale points, which is 0.45 points lower than the value specified in OSR-97A map. The SEISRISK III-calculated spectra of initial seismic shaking for medium soils with 5% attenuation (red curve in Figure 4) and synthetic accelerograms modeling the initial seismic shaking were further used for SMZ purposes.

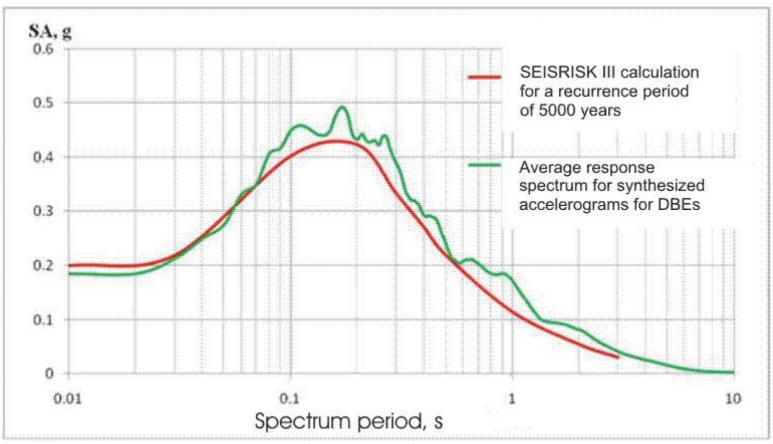

Figure 4: *Reaction spectrum with 5% attenuation calculated using the SEISRISK III program for the recurrence period of 5000 years and the average statistical reaction spectrum constructed from an ensemble of 10 synthetic accelerograms of the corresponding DBEs*

III. Seismic microzonation

For the purposes of seismic microzonation of the Zhenis site seafloor ground models were developed using high-resolution seismic data from the HR MRW CDP seismic survey and drilling data (Fig. 6).

The HR MRW CDP seismic record obtained in the study area is divided into two parts corresponding to the Cenozoic and Mesozoic stages of sedimentation.

The upper part of the section (interval - 50÷1000 ms, the most interesting for SMZ purposes), corresponding to the Cenozoic sediments (Quaternary, Pliocene-Quaternary, Miocene and Maikop), is characterized by parallel-layered, rather high-frequency record with numerous extended reflecting horizons (Fig. 6).

Within the Quaternary seismic complex, there is an intense reflecting horizon A, corresponding to the roof of the Apsheron sediments (the crimson-colored line in the section shown in Fig. 6.1). This seismic horizon can be traced throughout the Caspian megabasin. In the central part of the megabasin it lies conformally with the overlying and underlying boundaries, in the lateral parts it is distinguished as a shear surface with elements of roof adjoining the lower boundaries. The horizon is traced over the whole area in the record interval of 163-172 msec.

The bottom of Quaternary sediments is marked at the level of 186÷197 msec. The B horizon corresponding to this boundary is traced on the temporary sections (light green color line in Fig. 6).

Several types of seismic geologic sections were developed.

● Cross-sections to a depth of 35 m from the seafloor, constructed from longitudinal seismic wave velocity data and recurrence relations linking longitudinal and transverse seismic wave velocities in the upper layer of bottom sediments. These are the Mudrock Line equation [7], and the Boore relations [8], which relate seismic wave velocities in sediments and rock densities.

● Cross-sections to a depth of 35 meters from the seabed, based on seismic and drilling data. The latter were used for reconstruction of the upper (15 m) part of the section.

● Cross-sections constructed to a depth of 140 m for a deep well using drilling data for the upper part (74 m) and seismic data to a depth of 140 m (Fig. 7).

SMZ calculations to take into account the influence of bottom soils on seismic parameters were performed using two different methods: the seismic rigidity method and the calculation method using the NERA program [5].

The NERA calculation for the section developed to a depth of 140 m at the location of the deep borehole gave A_{max}=0.215 g or 8.08 points of MSK-64 scale. This calculation for this section using the NERA program was performed in accordance with the recommendations of STO 95 12022-2017 (Departmental Standards of Rosatom State Corporation). For the section to a depth of 35 m, these values were higher: A_{max} = 0.253 g and 8.31 points in seismic shaking intensity values on the MSK-64 scale.

The calculations of grade increment by the method of seismic rigidity were performed using two relations.

1. S.V. Medvedev's formula:

$$\Delta I = 1.67\log(R_{ref}/R_i), \quad (1)$$

where R_{ref} is the seismic rigidity of the reference soil, R_i is the seismic rigidity of the investigated soil. ($R=V_s \times \varrho$, V_s – shear wave velocity, ϱ – density of the rock or ground). It was used to process the section constructed to a depth of 35 m.

2. Formula from the current SMZ norms SP 283.1325800.2016 (Russian Standard):

$$\Delta I = 2.5\log(bR_{ref}/(R_i+R_{ref})) \quad (2)$$

where R_{ref} is the seismic rigidity of the reference soil (V_s>800 m/s, ϱ>2.5 g/cm^3), R_i is the seismic rigidity of the investigated soil, b is the maximum dynamic coefficient.

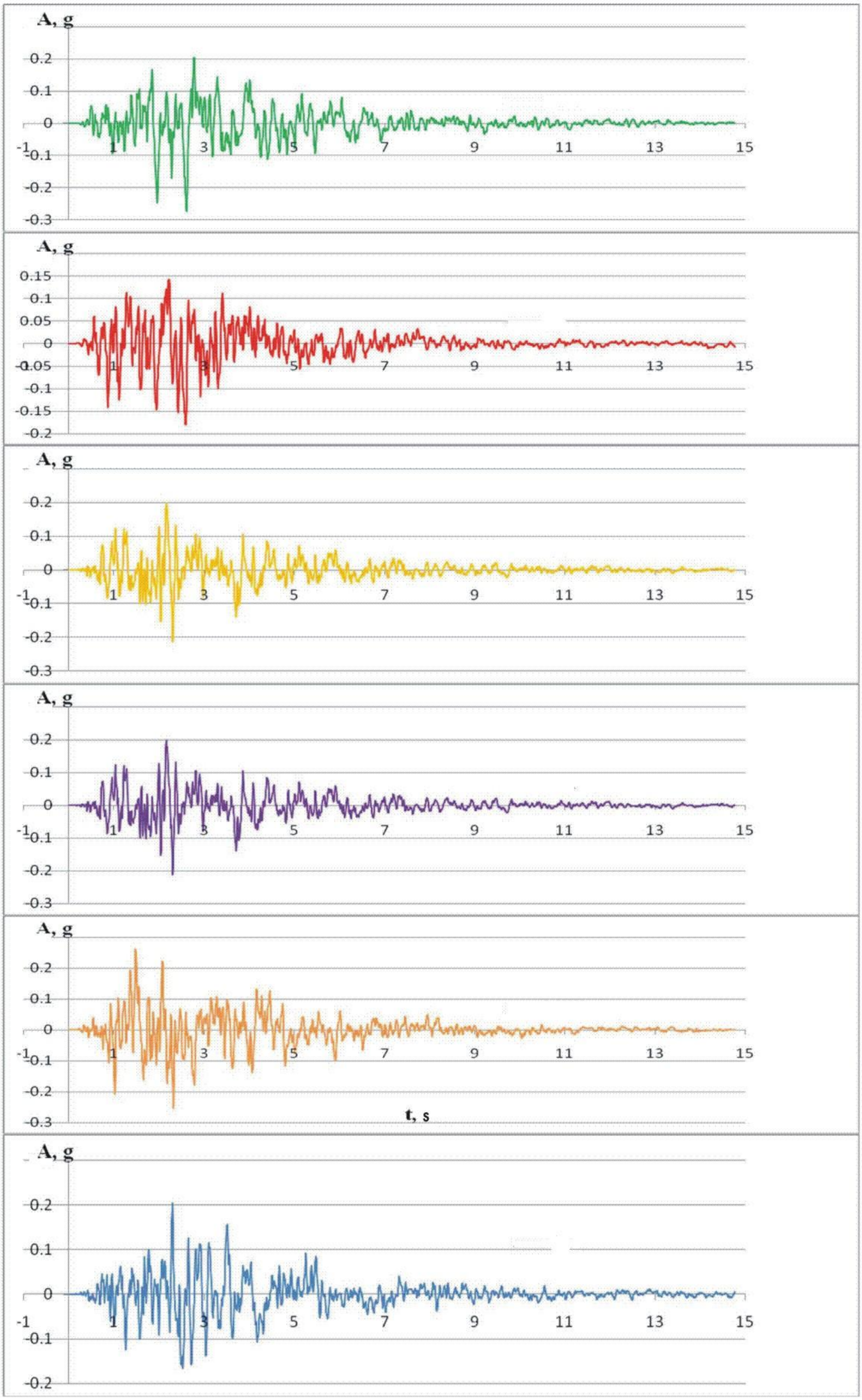
A, g
0.2
0.1
0
-0.1
-0.2
-0.3
-1
1
3
5
7
9
11
13
15
A, g
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
t, s

Figure 5: *Examples of the ensemble of synthesized accelerograms for the design-basis earthquake (DBE) MLH=5.5, R=5 km*

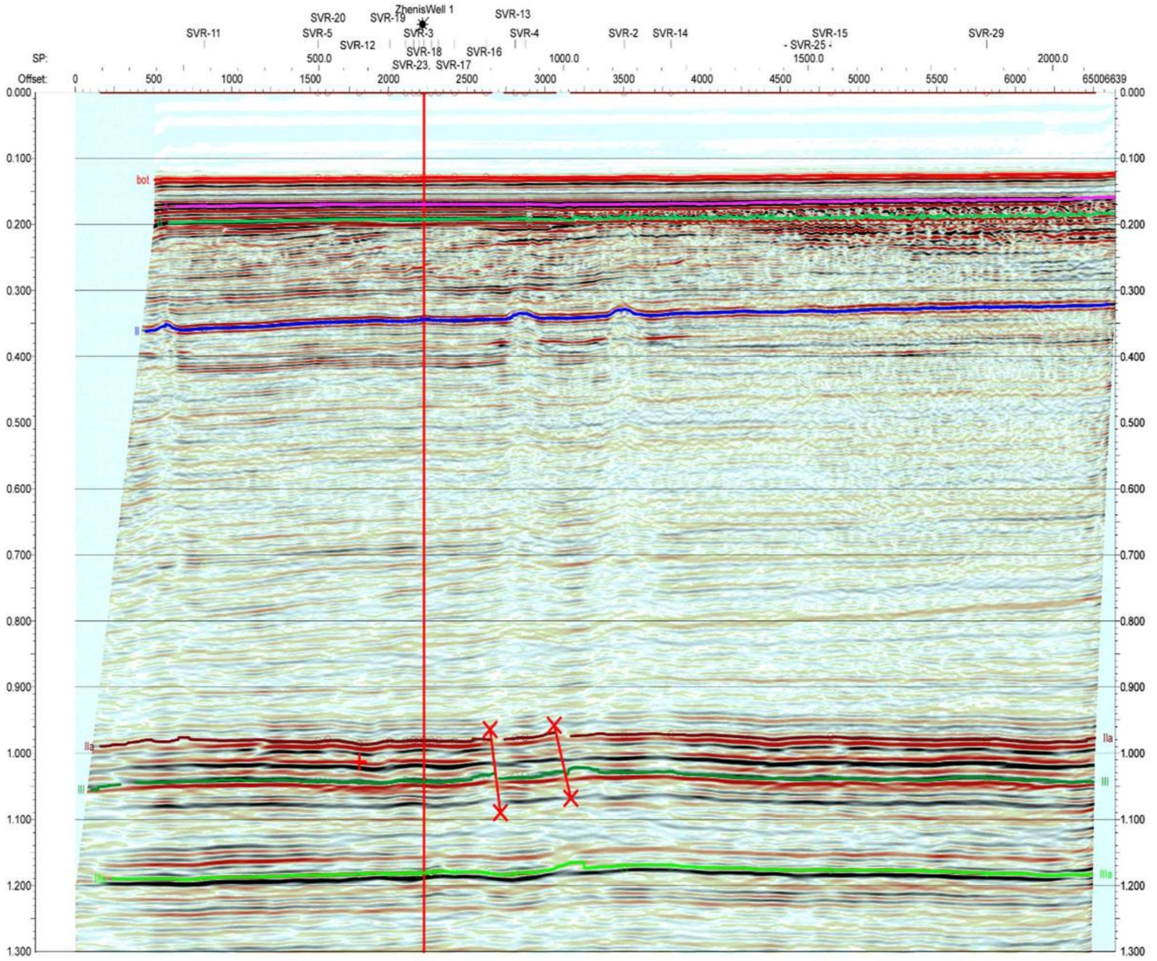

Figure 6: *Time section along the profile passing through the well at the Zhenis site*

Formula (2) was used to calculate the grade increment for the deep cross-section (140 m) in accordance with the guidelines of SP 283.1325800.2016 (Russian Standard). The use of these two formulas yielded the following values of the pointness at the bottom soil surface: for the 35 m cross-section A_{max} = 0.236g, I = 8.208; for the 140 m cross-section and the formula from SP 283.1325800.2016 A_{max} = 0.275 g, I = 8.430. The discrepancies in the results of using different calculation methods can be explained by the fact that all the above approaches to calculating seismic impact parameters to account for ground conditions have been developed for land. They need to be verified by in situ measurements on the seafloor using bottom seismographs and records of remote and local earthquakes. Such studies are very rare, but their necessity is evident for both SMZ and DSZ purposes. Examples of seismological monitoring and DSZ at sea are given in [10-15, 18, 21-23].

A total of 18 such cross-sections were constructed, which were further used for calculations using the NERA program to determine seismic parameters on the seafloor surface in the southwestern part of the Zhenis site.

The distribution of the calculated seismic parameters over the study area is shown in Fig. 8 and 9 for the design-basis earthquake (DBE).

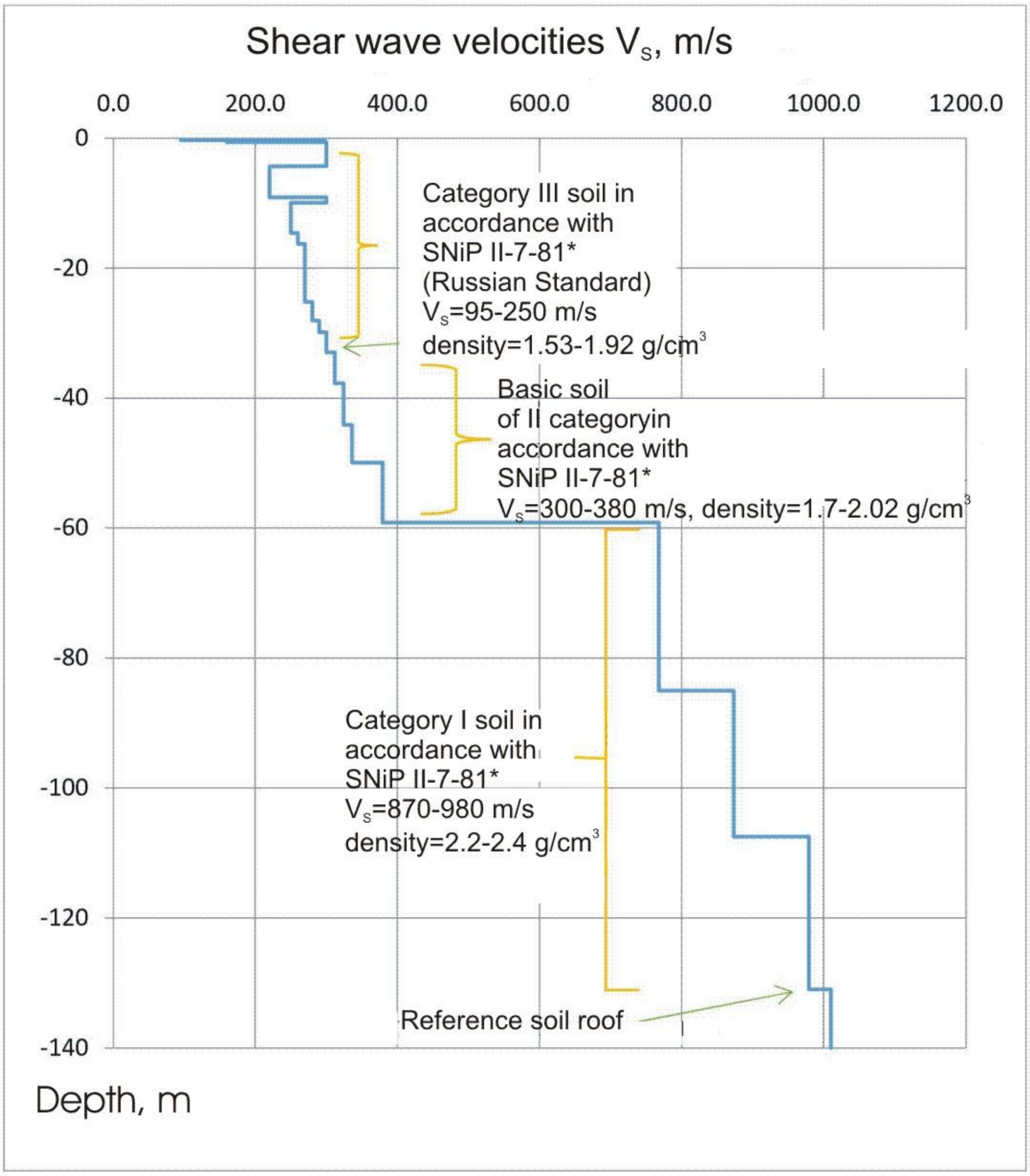

Figure 7: *Seismogeologic cross-section for the well obtained from drilling data to a depth of 74 m and seismic data from CDP reflection waves to a depth of 140 m*

Thus, the results of seismic zoning of the Zhenis site, obtained by two different methods and different input parameters: the method of seismic rigidity and the computational method according to the NERA program with cross-sections constructed solely on the basis of seismic data and cross-sections constructed with the involvement of geotechnical data, showed insignificant differences in the values of seismic effects on the ground surface.

In addition, it is necessary to point out the following circumstance: from Fig. 10 it can be seen that the spectrum on the surface of bottom sediments, calculated without taking into account real soil conditions, significantly differs in shape from the spectrum calculated taking into account geotechnical data. Although the amplitudes of maximum accelerations in both cases practically coincide. Perhaps the spectrum acquires a resonant shape due to the presence in the section of a layer of very soft clays up to 9 m thick, which is detected by drilling and not found by seismic methods. Or it is necessary to take into account the properties of bottom sediments according to the methods described in the works [17, 20].

VI. Conclusion

The performed calculations have shown that for average soils of the Zhenis site for the DBE seismic shaking intensity is 0.2 g in terms of PGA (peak horizontal ground acceleration) or 8 points in terms of seismic shaking intensity in MSK-64 scale points, which practically coincides with the data of OSR-97C map.

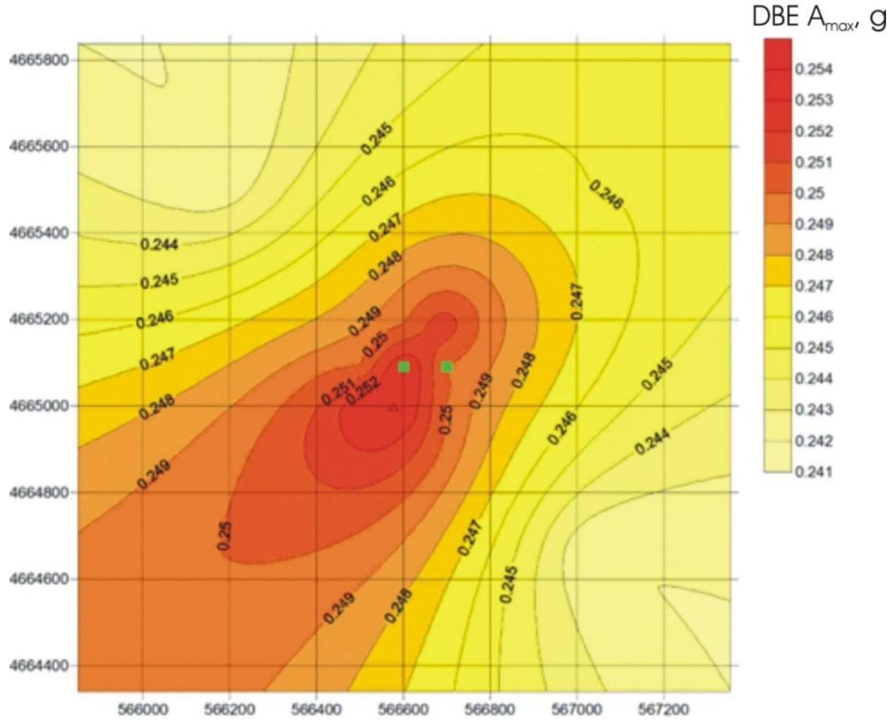

Figure 8: *Distribution of the amplitude of the maximum acceleration of the bottom soil A_{max} in fractions g in the southwestern part of the Zhenis site. Well locations are shown in green boxes*

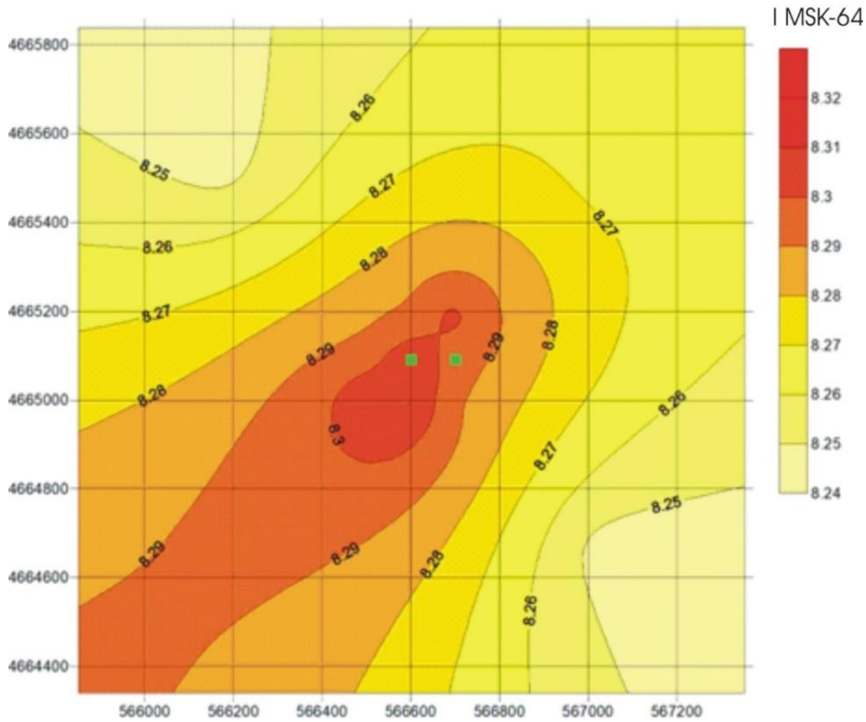

Figure 9: *Distribution of seismic impact intensity on the bottom soil surface in MSK-64 scale points in the southwestern part of Zhenis site for SSE. Well positions are shown in green squares*

The SMZ calculations to take into account the influence of bottom soils on seismic parameters were performed using two different methods: the method of seismic rigidity and the calculation method using the NERA program [4]. For the first method, seismogeological sections constructed to a depth of 35 m using seismic data were used.

For the calculation method, geotechnical cross-sections were also used. All calculated seismic parameters, taking into account the influence of bottom soil, were plotted on the SMZ maps.

A NERA calculation was also performed for a cross-section developed to a depth of 140 m at the BHV well location. This calculation showed that the amplitudes of the maximum accelerations A_{max} are smaller than A_{max} calculated from the section to a depth of 35 m: 0.215 g and 0.253 g for the maximum design earthquake. These values are 8.08 and 8.31 points in the values of seismic shaking intensity on the MSK-64 scale. All this is true for the DBE.

This is not the case with the of operating-basis earthquake OBE. The A_{max} for the OBE plotted on a cross-section to a depth of 140 m is 0.1 g or 7 MSK-64. For another cross-section plotted to a depth of 35 m, the A_{max} is 0.073 g or 6.69 MSK-64.

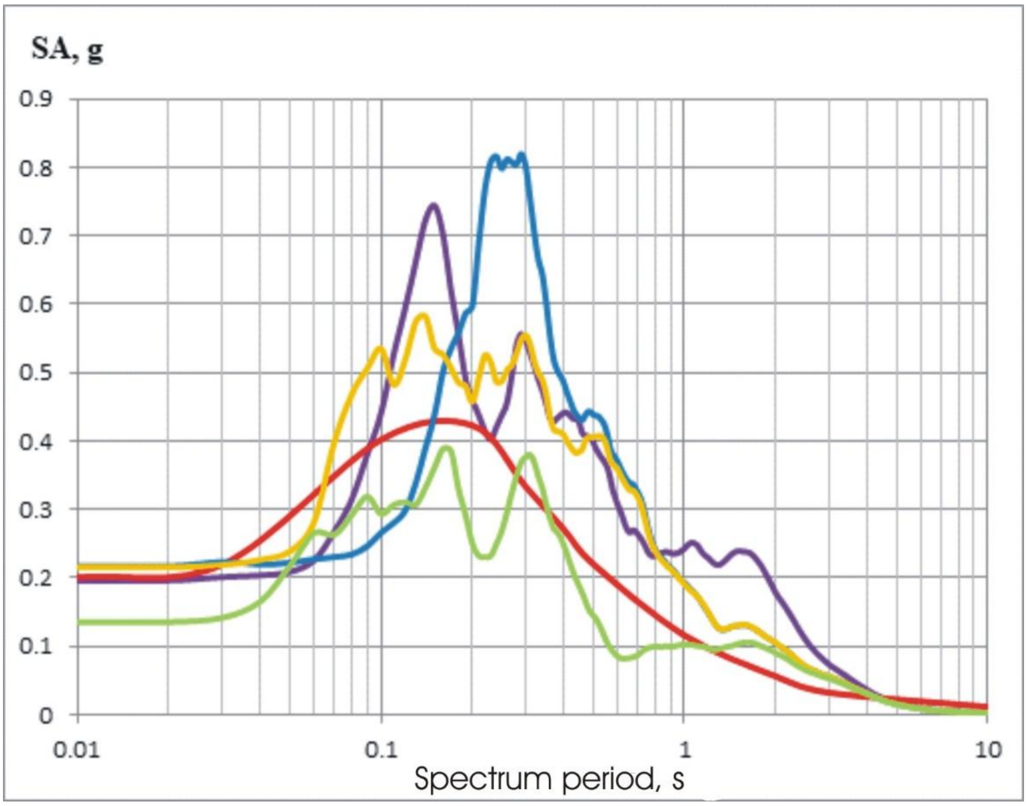

Figure 10*: Seismic response spectra with 5% attenuation for the Zhenis site for DBE. Red curve - initial seismic impacts, green curve - seismic response spectrum on the roof of Apsheron sediments (roof of basic soils); yellow curve - spectrum on the surface of the bottom soil of the well (74 m), calculated on the basis of the cross-section constructed without taking into account geotechnical data at the depth of 35 meters; blue curve - the same one for the section built with geotechnical data, purple curve - the same one for the section with geotechnical data built at a depth of 140 m to the reference soil roof*

This effect can be explained by the fact that for a OBE, seismic impacts are less intense than in the case of DBE. Therefore, the seismic signal is less affected by the non-linear properties of the ground, which weaken its amplitude.

For the OBE for the BHV borehole on the bottom soil surface of the Zhenis site, the maximum acceleration value A_{max}= 0.1 g or IMSK=7 MSK, as more conservative values, should be assumed for the OBE.

The results of using the seismic rigidity method were very close to the results obtained by the computational method.

Methods for assessing the potential for bottom liquefaction show a non-zero probability of this occurring. However, the burial of the anchors in the case of a semi-submersible drilling rig, or of the platform supports

in the case of a jack-up drilling rig, reduces this probability to zero. To the southeast of the Apsheron sill, a lineament structure can be traced, where earthquakes with M = 8 can occur, which, according to L. I. Lobkovsky's ideas, generates decomposition of gas hydrates.

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References

[1] Ambraseys, N.N., J. Douglas, S.K. Sarma, and P.M. Smit (2005). Equations for the estimation of strong ground motions from shallow crustal earthquakes using data from Europe and Middle East: Horizontal peak ground acceleration and spectral acceleration. Bull. Earthquake Eng. 3, 1–53.

[2] Atkinson, G.M. and D.M. Boore (2006). Earthquake ground-motion prediction equations for eastern North America. Bull. Seism. Soc. Am. 96 (6), 2181–2205, doi: 10.1785/0120050245.

[3] Bagirov E., Lerche I. Impact of natural hazards on oil and gas extraction: the South Caspian Basin. Kluwer Academic/Plenum Publishers. 1999.353 p.

[4] Balassanian S., Ashirov A., Chelidze T. et al. Seismic hazard assessement for the Caucasus test area // Annali di geofisica. 1999. V. 42, N 6. P.1139-1151.

[5] Bardet J.P., Tobita T. NERA. A Computer Program for Nonlinear Earthquake Site Response Analyses of Layered Soil Deposits. University of Southern California. April 2001. 44 p.

[6] Bender B, Perkins D.M. SEISRISK III: A computer program for seismic hazard estimation // U.S. Geological Survey Bulletin 1772. Washington. 1987. 48 p.

[7] Boore D. M. Determining Generic Velocity and Density Models for Crustal Amplification Calculations, with an Update of the Boore and Joyner (1997) Generic Site Amplification for Vs (Z)=760 m/s // Bull. Seismol. Soc. Am. 2016. V. 106, №1. P. 316-320.

[8] Castagna J.P., Batzle M.L., Eastwood R.L. Relationships between compressional wave and shear wave velocities in clastic silicate rocks // Geophysics. 1985. V.50. P. 571-581.

[9] Cornell C. A. Engineering seismic risk analysis // Bull. Seism. Soc. Amer. 1968. V. 8, N 5. P. 1583-1606.

[10] Kovachev S.A. , Kuzin I.P. , Soloviev S.L. Microseismicity of the frontal Hellenic arc according to OBS observations // Tectonophysics. 1992. V. 201, Issues 3-4, P. 317-327.

[11] Kovachev S.A., Kaz'min V.G., Kuzin I.P., Lobkovsky L.I. New data on mantle seismicity of the Caspian region and their geological interpretation // Geotectonics. 2009. V. 43. № 3. P. 208-220.

[12] Kovachev S.A., Kaz'min V.G., Kuzin I.P., Lobkovsky L.I. New data on seismicity of the Middle Caspian basin and their possible tectonic interpretation // Geotectonics. 2006. V. 40. № 5. P. 367-376.

[13] Kovachev S.A., Krylov A.A. Microseismicity of the Persian Gulf and the Zagros Mountain Massif According to Bottom Seismological Observations // Vulkanologiâ i sejsmologiâ. 2023. V. 17. N. 6. P. 41-59.

[14] Kovachev S.A., Krylov A.A. Results of seismological monitoring in the Baltic Sea and western part of the Kaliningrad oblast using bottom seismographs // Izvestiya Physics of the Solid Earth. 2023. V. 59, N2. P. 94-114.

[15] Kovachev S.A., Kuzin I.P., Lobkovskii L.I. Detailed seismological observations on the central shelf and continental slope of the Northeastern Black Sea using sea-bottom stations // Izvestiya, Physics of the Solid Earth. 2003. V. 39. № 1. P. 19-24.

[16] Kovachev S.A., Libina N.V. Assessment of initial seismicity for offshore platforms: a case study of the Pechora Sea // Oceanology. 2024. V. 64. № 1. P. 139-148.

[17] Krylov A.A., Alekseev D.A., Kovachev S.A. et al. Numerical modeling of nonlinear response of seafloor porous saturated soil deposits to SH-wave propagation // Applied Sciences (Switzerland). 2021. T. 11. № 4. C. 1-17.

[18] Krylov A.A., Ananiev R.A., Chernykh D.V., Alekseev D.A., Balikhin E.I., Dmitrevsky N.N., Novikov M.A., Radiuk E.A., Domanyuk A.V., Kovachev S.A. et al. A complex of marine geophysical methods for studying gas emission process on the Arctic shelf // Sensors. 2023. T. 23. № 8. C. 3872.

[19] Krylov A.A., Ivashchenko A.I., Kovachev S.A. Seismic hazard assessment for oil-and-gas-bearing shelf zones: a case study of the North Caspian region // Oceanology. 2015. V. 55. № 6. P. 910-915.

[20] Krylov A.A., Kovachev S.A. et al. Matnerapor - a matlab package for numerical modeling of nonlinear response of porous saturated soil deposits to P- and SH- waves propagation // Applied Sciences (Switzerland). 2022. T. 12. № 9.

[21] Krylov A.A., Kovachev S.A. et al. Ocean-bottom seismographs based on broadband met sensors: architecture and deployment case study in the Arctic // Sensors. 2021. T. 21. № 12.

[22] Krylov A.A., Lobkovskii L.I., Kovachev S.A., Baranov B.V., Rukavishnikova D.D., Tsukanov N.V., Dozorova K.A., Semiletov I.P. Geodynamic regimes in the Laptev Sea region according to the latest seismological data // Doklady Earth Sciences. 2023. V. 513. № 2. P. 1338-1343.

[23] Lobkovskii L.I., Kuzin I.P., Kovachev S.A., Krylov A.A. Seismicity of the Central Kuril Islands before and after the catastrophic M = 8.3 (November 15, 2006) and M = 8.1 (January 13, 2007) earthquakes // Doklady Earth Sciences. 2015. V. 464. № 2. P. 1101-1105.

[24] Lobkovsky, L.I.; Baranov, A.A.; Ramazanov, M.M.; Vladimirova, I.S.; Gabsatarov, Y.V.; Semiletov, I.P.; Alekseev, D.A. Trigger Mechanisms of Gas Hydrate Decomposition, Methane Emissions, and Glacier Breakups in Polar Regions as a Result of Tectonic Wave Deformation. Geosciences 2022, 12, 372. DOI: 10.3390/geosciences12100372

[25] Sabetta F, Pugliese A. Estimation of response spectra and simulation of nonstationary earthquake ground motions // Bull. Seism. Soc. Amer. 1996. V. 86, N 2. P. 337-352.

[26] Soloviev S.L., Kovachev S.A. On the determination of local magnitude of near earthquakes from OBS observations // Acta Geophysica Polonica. 1994. V. XLII. N. 4. P. 274-280.

[27] Ulomov V.I., Shumilina L.S., Trifonov V.G. et al. Seismic hazard of northern Eurasia // Annali di geofisica. 1999. V. 42, N 6. P. 1023-1038.

THE INFLUENCE OF NATURAL AND CLIMATIC CONDITIONS ON THE INTEGRATION PROCESS OF DEPORTED PEOPLES IN SPECIAL SETTLEMENTS

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Abstract

This paper delves into the complex role that natural and climatic conditions played in the integration process of deported peoples who were forcibly relocated to special settlements, particularly during the Soviet era. The research investigates how the extreme environments—ranging from harsh winters and scorching summers to remote and isolated regions—impacted not only the physical survival of the deportees but also their social, economic, and cultural adaptation in these new and often hostile locations. The analysis draws on historical data to examine how different environmental factors influenced the daily lives, labor conditions, and community structures of the deported populations. In many cases, these peoples were relocated to areas with severe weather conditions, poor infrastructure, and limited access to basic resources, which created significant barriers to their integration into the local economy and society. The climatic extremes often forced the deportees to adapt quickly to new agricultural practices, unfamiliar landscapes, and arduous working conditions, while also challenging their physical endurance and mental resilience. Furthermore, the paper explores how these environmental hardships affected the relationships between deportees and the local populations, as well as their interactions with Soviet authorities. The study also looks into the long-term effects of these forced migrations on the cultural and social identity of the deported peoples, highlighting the enduring legacy of such relocations in shaping the historical memory of these communities.

Keywords: green economy, sustainable development, traditional business models, ecological sustainability, innovation, resource efficiency, biodiversity, climate change, eco-friendly technologies, strategic planning

I. Introduction

The forced relocation of entire populations to special settlements during the Soviet era represents one of the most significant social and demographic transformations of the 20th century. From the 1930s through the 1950s, millions of people, often from ethnic minority groups, were deported to remote and underdeveloped regions of the Soviet Union. These resettlements were a result of political and security considerations, with the Soviet government aiming to control potentially “disloyal” populations by moving them far from their native lands. However, beyond the political motives, these deported peoples faced immense challenges due to the natural and climatic conditions of the areas they were forced to inhabit.

This study focuses on the impact of those environmental conditions—particularly the harsh climates, geographic isolation, and scarcity of natural resources—on the integration process of these deported peoples. Integration, in this context, refers not only to the economic incorporation of the deportees into local labor systems but also their social and cultural adaptation to their new surroundings. For many, the abrupt shift from familiar environments to regions with extreme cold, desert heat, or dense forests created profound obstacles to survival and social cohesion.

The conditions in which these people found themselves often determined the pace and extent of their adaptation. In Siberia, for example, where winters could be long and harsh, deportees had to endure subzero temperatures while attempting to cultivate new lands or work in labor camps with limited resources. In contrast, those relocated to Central Asia faced a different set of environmental challenges, including extreme heat and droughts that affected agricultural productivity and basic living conditions. The diversity of these climatic challenges created varied experiences of integration, with some communities managing to establish new livelihoods while others struggled under the weight of environmental and economic pressures.

In this context, the objective of the research is to analyze how these natural and climatic conditions influenced the integration of deported peoples into special settlements. By exploring the intersection of environmental hardship, labor demands, and social adaptation, this paper seeks to shed light on how geography and climate affected not only the immediate survival of these populations but also their long-term socio-economic and cultural integration into Soviet society.

This investigation into the role of climate and geography will help to enrich our understanding of the broader historical experience of forced migration and resettlement. While much of the existing scholarship on deportations has focused on the political and economic aspects, the environmental factors remain underexplored. By focusing on the natural conditions that deported peoples faced, this study aims to fill this gap, offering a nuanced perspective on the integration processes within special settlements.

II. Methods

This study employs a multidisciplinary approach to analyze the influence of natural and climatic conditions on the integration process of deported peoples in special settlements. The methods used include a combination of historical analysis, geographical assessment, and qualitative case studies, drawing on both primary and secondary sources. The research is designed to provide a comprehensive understanding of how environmental factors shaped the experiences of these deported populations during their resettlement and adaptation.

1. **Historical Document Analysis**:

The primary method involves the analysis of archival records, government reports, and personal testimonies from deported individuals. Soviet-era documents, including official resettlement plans, labor assignments, and population censuses, provide crucial insights into the logistical and administrative aspects of the deportations. These records are cross-referenced with memoirs, letters, and oral histories of deportees to capture the lived experiences of those affected. By comparing official Soviet reports with personal narratives, the research aims to uncover the discrepancies between state policies and the realities faced by the deported peoples.

2. **Geographical and Climatic Data Assessment**:

A significant aspect of the research focuses on the geographical and climatic conditions of the regions where deportees were sent. This involves the use of historical climate data and geographic mapping to analyze the specific environmental challenges faced in different regions, such as Siberia, Kazakhstan, and the Russian Far East. Factors such as average temperatures, precipitation levels, and soil quality are examined to assess how they impacted agricultural productivity, labor requirements, and living conditions in the special settlements.

By mapping deportation locations and overlaying climatic data, the study seeks to correlate environmental conditions with integration outcomes. For example, settlements in extremely cold regions are compared with those in arid or semi-arid areas to identify patterns in survival rates, labor output, and community development.

3. **Case Study Analysis**:

The research also employs a case study approach to provide detailed accounts of specific deported communities and their adaptation processes. These case studies focus on deported groups such as Chechens, Crimean Tatars, and ethnic Germans, who were relocated to different regions under varying climatic conditions. Each case study looks at factors such as employment in local industries, agricultural success, mortality rates, and social cohesion to understand how natural environments influenced integration.

By using a comparative case study method, the research highlights how some groups managed to adapt more successfully than others, depending on the environmental conditions they encountered. These case studies are drawn from a variety of sources, including regional archives, local histories, and ethnographic studies.

4. **Qualitative Interviews and Oral Histories**:

In addition to archival research, the study incorporates qualitative interviews and oral histories where available. Interviews with descendants of deportees, as well as existing oral history projects, provide personal insights into the challenges faced by these populations and how they perceived the impact of climate on their daily lives. This qualitative data helps to capture the emotional and psychological aspects of integration that are not always reflected in official documents.

5. **Thematic Analysis**:

The data collected from archival research, climate analysis, case studies, and interviews are subjected to thematic analysis. Key themes such as "adaptation to harsh climates," "resource scarcity," "labor struggles," and "social cohesion under environmental stress" are identified and analyzed to explore the broader patterns of integration. This thematic approach helps to link the specific experiences of different deported groups with the overarching influence of environmental conditions.

6. **Comparative Analysis**:

Finally, a comparative analysis is conducted between different groups of deported peoples and the various regions to which they were relocated. This allows for the identification of factors that either facilitated or hindered the integration process across different natural and climatic contexts. Variables such as the type of labor, proximity to local populations, government support, and climatic severity are considered in comparing the experiences of deported communities.

Through this combination of methods, the study aims to offer a comprehensive and nuanced understanding of the role that natural and climatic conditions played in shaping the integration of deported peoples in special settlements.

III. Results

Soviet and Russian historian N. F. Bugai explains the deportations of individual ethnic groups by the fact that the Soviet authorities feared their possible betrayal. This assumption became the basis for preventive accusations and forced expulsion of entire peoples. The reasons for deportations also included: collaboration with the fascists (treason), belonging to a nation or religion with which the war was waged, which could lead to support for the enemy due to ethnocultural proximity. The strategic goals of these deportations included: 1) establishing fear in order to control the country; 2) undermining the internal unity of peoples and promoting ethnic assimilation; 3) shifting the blame for the political and economic mistakes of the regime onto the repressed peoples; 4) increasing the population in sparsely populated regions of Siberia, Kazakhstan and Central Asia; 5) providing labor resources for the backward regions of the USSR. Thus, according to the decree of the Presidium of the Supreme Soviet of the USSR of October 12, 1943 and the resolution of the Council of People's Commissars of October 14, 1943, the Karachays were subject to deportation to the Kazakh and Kirghiz SSRs. On November 2, 1943, 69,207 people were deported from the Karachay Autonomous Region, as well as 424 Karachays found in neighboring regions. The bulk of the deportees were placed in the South Kazakhstan Region (25,212 people), the Dzhambul Region (20,285 people) and Kirghizia (22,900 people), and small groups were sent to Tajikistan, the Irkutsk Region and the Far East. They were later joined by 2,500 demobilized Red Army soldiers. In the early years, the local population, under the influence of propaganda, was suspicious of the settlers from the North Caucasus. However, the similarity of the languages of the Karachays and Balkars with the languages of the Kyrgyz, Kazakhs and Uzbeks contributed to the establishment of trusting relationships between the special settlers and the local population.

IV. Discussion

Despite being deported under extremely difficult conditions, Chechens and other ethnic groups played a significant role in the development of Kazakhstan's economy. They were employed across various industries, including mining, agriculture, and construction, often under grueling circumstances. For example, in 1945, Chechen workers on the Balqash mine exceeded production quotas by 200-300%. This indicates that, although initially inexperienced in certain industries, they adapted quickly and contributed to crucial sectors like coal mining and industrial construction. Their labor not only helped meet the economic demands of the war and post-war periods but also facilitated the modernization of Kazakhstan's infrastructure.

Discussion Point: How did the contribution of Chechen laborers affect the broader narrative of forced resettlement in the Soviet Union? Did their participation in nation-building challenge the negative stereotypes associated with them?

2. Adaptation and Professional Development

The process of adapting to new professions was not without challenges. Many settlers initially struggled due to their lack of experience in industrial work and poor Russian language skills. However, through bunched work teams and training programs, they eventually gained the skills necessary to meet and exceed production standards. For instance, the introduction of brigade methods of teaching proved to be an effective approach for accelerating skill acquisition, as evidenced by the remarkable productivity of individual workers like the drill operator Mezhidov and others.

Discussion Point: What does this tell us about the adaptability and resilience of deported populations under extreme pressure? How important were education and skills development in their successful integration?

3. Harsh Living and Working Conditions

The text underscores the inhumane living conditions experienced by the special settlers upon their arrival. The forced relocations were conducted under severe circumstances, leading to overcrowding, lack of food and clothing, and high mortality rates. Despite these obstacles, the settlers managed to not only survive but also thrive in the industrial workforce. This raises the question of the role that labor played in their survival and integration into new environments. Labor became a means of both survival and resistance to their marginalized status.

Discussion Point: How did the harsh living conditions affect the settlers' psychological and physical well-being? In what ways did work serve as a mechanism for survival and eventual social inclusion?

4. Political and Social Context of Deportation

The deportation of Chechens, along with other ethnic groups, was part of a larger Soviet policy that sought to control perceived threats to state security during World War II. The settlers were initially stigmatized as "traitor peoples," which justified their harsh treatment and relocation. However, as the text highlights, by the 1950s, there was a shift in attitudes, with authorities beginning to publicly acknowledge and reward the contributions of these workers.

Discussion Point: How did the shift in political attitudes towards special settlers reflect broader changes in Soviet society during the post-war period? How did their labor contributions challenge or reinforce Soviet narratives about loyalty and productivity?

5. Historical Memory and Legacy

The narrative around Chechen special settlers, and deported peoples more broadly, has a complex legacy. On one hand, their forced relocation was a significant human rights violation, but on the other hand, their labor contributed to the economic development of Kazakhstan and other regions. This duality poses difficult questions about how such historical experiences are remembered and interpreted.

Discussion Point: How should the legacy of forced resettlement and labor be remembered? Should the focus be on the hardship endured, the contributions made, or both? What are the implications for contemporary discussions about historical memory and reconciliation?

In sum, the experience of Chechen special settlers in Kazakhstan highlights themes of resilience, forced adaptation, economic contribution, and shifting political perceptions in Soviet history. These themes invite a broader conversation about the complex dynamics between state policy, labor, and the lived experiences of marginalized populations.

On December 28, 1943, the deportation of Kalmyks to the Krasnoyarsk and Altai Territories, Omsk and Novosibirsk Regions began. One of the largest groups deported from the North Caucasus were the Chechens. On February 23, 1944, about 400,000 Chechens and more than 90,000 Ingush were forcibly resettled. According to the report of the Deputy Chief of the 3rd Directorate of the NKGB of the USSR D. V. Arkadyev from March 11, 1944, out of 180 trains with deportees, 171 arrived at their destination, and 9 trains remained en route. By March 11, 1944, 468,583 people had arrived at the resettlement sites: 24,281 in Jalal-Abad Region, 16,565 in Dzhambul Region, 29,089 in Alma-Ata Region, 34,167 in East Kazakhstan Region, 20,808 in South Kazakhstan Region, 39,542 in North Kazakhstan Region, 20,309 in Aktobe Region, 31,236 in Semipalatinsk Region, 41,230 in Pavlodar Region, and 37,938 in Karaganda Region. They were later joined by thousands of Chechens and Ingush who had been discharged from the Red Army after February 1944. More than 60,000 people were resettled in Kazakhstan.

On March 8, 1944, about 38,000 Balkars were deported, and on May 18, 1944, more than 180,000 Crimean Tatars were expelled from Crimea. Professor V. B. Ubushaev from the Kalmyk State University rightly emphasizes that "the deportations of peoples were carried out spontaneously and had no legal basis. For each people subject to punishment, L. Beria opened a special case with incriminating documents, which he then presented to I. Stalin. These materials were selected tendentiously and did not stand up to serious verification." In the areas where special settlers were resettled, the NKVD organized special commandant's offices, and the status of the deportees was determined by the instructions of the NKVD and the NKGB of the USSR, decrees of the State Defense Committee, as well as the regulation of January 8, 1945 "On the special commandant's office." The deportees could participate in elections to the Supreme Soviet of the USSR and were gradually drawn into public life, but their rights were limited in wartime conditions. Once a month, they were required to report to the commandant's office, signing a special journal. The special settlers retained the status of citizens of the USSR, but did not have the right to leave their designated places of residence, which had a negative impact on social life based on family support. Many families were separated, and the Ministry of Internal Affairs carried out work to find and reunite them. The authorities of the Union republics and local executive committees were engaged in the economic arrangement of the settlers, based on the decisions of the Council of People's Commissars of the USSR. Usually, preparations for the placement of deportees began a month or a month and a half before their eviction, providing for a set of measures to arrange for the resettled families. However, in practice, the implementation of these measures encountered difficulties due to a lack of material and economic resources, harsh climatic conditions and sometimes the negligence of local authorities. This led to an increase in morbidity and mortality among the settlers. For example, in Kazakhstan in 1944, 32,502 people died, and in 1945, 32,111 people. The highest mortality was recorded in the second half of 1944 and the first half of 1945, which coincided with the period of acclimatization, as well as food difficulties and a shortage of clothing and footwear.

Special settlers worked actively in all sectors of the national economy of Kazakhstan. Documents from regional archives testify to the significant contribution of Chechens to this activity. By the fall of 1944, 2,158 Chechen special settlers worked in enterprises and collective farms in Leninogorsk. At first, their productivity was low due to lack of experience, weak discipline and difficult living conditions. Additional difficulties were created by the language barrier, but over time, the special settlers mastered professions and increased their labor efficiency. The use of team training methods helped speed up this process, and by August 1944, 415 people fulfilled and 382 exceeded labor standards. In 1946, 1,044 people worked in the mines of Leninogorsk, including 332 Chechens, many of whom significantly exceeded plans. From the first days of their stay in the Karaganda region, able-bodied men were involved in production. In 1945, 628 Chechens worked at the Balkhash mine, of which 426 regularly exceeded the plan by 200-300%. New professions for special settlers were actively mastered: in 1947, 75 tractor drivers and 7 drivers were trained, 472 people were trained at FZO enterprises, and 355 people mastered new specialties. By January 1, 1948, 10,393 people worked at 75 industrial enterprises in the Karaganda region, 2,414 in Temirtau, and 3,122 in Balkhash.

By 1952, 15,114 special settlers from the North Caucasus worked at enterprises and construction sites in the region, including Chechens employed in the coal industry and construction. They participated in coal mining, construction of industrial and residential facilities, and railway repair. The reports noted that most of the special settlers were conscientious about their work, and from the mid-1950s their successes were openly encouraged.

Thus, the deported peoples, including the Chechens, despite the difficult conditions of resettlement and life, made a significant contribution to the development of the country's economy, refuting the myth of "traitor peoples."

References

[1] Isakieva Z. S. Labor contribution of deported Chechens and Ingush to the mining industry of Central Kazakhstan in the 40-50s of the XX century / Z. S. Isakieva: abstract of dis. ... candidate of historical sciences: 07.00.02. - Vladikavkaz, 2016.- 31 p.

[2] Tsutsulaeva S.S., Mamsurova M.Sh., Daudov A.Z., Shamsadov S.S. Rehabilitation and restoration of national autonomy of the chechen people: historiographic problems, 2020. C. 3457-3463.

[3] Bugaev A.M. National-state construction in Chechnya: historical experience and modernity, 2001. P.21-22.

[4] Tsutsulaeva S.S. Issues of deportation of the Chechen people in historical literature, 2019. P. 30-35.

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective.

Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

INNOVATIVE COMPOSITES MADE FROM RUBBER WASTE

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Abstract

In recent years, there has been significant focus on utilizing production and household waste to create polymer composites. These composites can be employed either independently or in a modified form, and can also serve as additives. The aim of our study was to develop composite materials using epoxy resin and household rubber waste and to evaluate their properties. We tested various aspects, including water absorption, flexural strength, and adhesion.

Keywords: adhesive, rubber, composite, ecology, epoxy resin

I. Introduction

Today, no country is free from issues related to waste management. This is especially true in large nations with high populations, where both domestic and industrial waste can reach enormous volumes. Landfills consume vast areas of land and contribute to soil, air, and water pollution, which often leads to various diseases and epidemics. Thus, a comprehensive approach to waste management is essential to address these challenges. The primary objective is to minimize both domestic and industrial waste. People often dispose of garbage in landfills, rivers, or valleys, making waste a significant source of environmental pollution. Typically, waste is "disposed of" by being dumped in landfills, where it is then crushed and covered with layers of soil. It may seem as though the waste has "disappeared" once buried, but this is not the case. Waste is just hidden underground and remains a significant environmental concern. Decomposing waste generates harmful gases that are released into the atmosphere, and rainwater infiltrates the waste, becoming contaminated with its harmful substances. If a landfill lacks a system to collect and treat this contaminated runoff, the polluted water can eventually mix with groundwater or rivers, leading to severe pollution. Additionally, some waste decomposes very slowly, taking decades to break down while continuously polluting air and water. On a positive note, silicon-containing compounds can enhance the properties of composite materials. Epoxy resins, known for their excellent physical, mechanical, and technological characteristics, are widely utilized in creating various materials, including heat-sensitive adhesives and composites designed for extreme conditions [1-10].

Our objective is to develop new construction materials using recycled rubber waste, epoxy resin, and ethyl silicate. By incorporating rubber waste, we not only recycle household waste but also contribute to environmental improvement. These materials stand out from other options due to their cost-effectiveness, user-friendly technology, and resistance to microorganisms. Additionally, they meet all contemporary standards for building materials.

II. Experimental part

Processing. In a specialized mixer, we combine epoxy resin, ethyl silicate, and rubber waste in varying proportions. After adding a stabilizer, we thoroughly mix the components. The mixture is then poured into specific molds and left to set overnight. The following day, we remove the material from the molds, conduct a thermostatic treatment, and proceed with testing.

Fourier transform infrared spectra were determined with a Varian 660-IR FT-IR Spectrometer. The KBr pellets of samples were prepared by mixing (1.5–2.0) mg of samples, finely grounded, with 200 mg KBr (FTIR grade) in a vibratory ball mixer for 20 s.

Microstructure of the samples was studied by NMM-800RF/TRF type of optical microscope SEM and EDS observations were conducted. Measurements were performed under a microscope - Tescan Vega 3, LMU, LaB 6 cathode. Maximum accelerating voltage was 30 kV, resolution 2.0 nm. The microscope was also equipped with an energy dispersive spectrometer of X-ray-induced electron beam specimens (EDS, Oxford Systems). EDS was used to analyze the sample compositions.

Impact viscosity determination, also called *shock viscosity* determination, is a technique applied to soft solids and is essentially a drop impact test. The drop height h is the vertical distance between the upper surface of the tested material (h_1) and the bottom surface of the drop hammer at the end of the impact event (h_2). With the sample mass m and the acceleration g, the work performed by the falling hammer is mg ($h_1 – h_2$), anormalized with respect to the horizontal cross-section of the specimen.

Vicat softening depth consists in the determination of the depth of the indentation with respect to the top surface caused by a flat ended indenter with the cross-section of 1 mm^2. The load applied is 10 or 50 N and the cross-section of the indenter end is circular. The term *Vicat hardness* is also in use – really confusing since larger values correspond to lower hardness.

Water absorption is determined simply as the percentage weight change of the sample after submersion in water. We have performed such measurements after 3 hours and 24 hours exposition to water

III. Results and discussions

Composites were produced using epoxy resin, rubber waste, and ethyl silicate, and were subjected to testing. We determined the strength limit of the composites and examined how it depended on both the content of rubber waste and its modification with ethyl silicate. Based on the curves shown in Fig. 1, we observed an increase in the strength limit of the epoxy resin-based composites with varying concentrations of rubber waste. The three curves presented in the figure exhibit both qualitative and quantitative differences. The first curve represents the strength limit as it relates to the amount of unmodified rubber waste. This curve displays a broad peak, illustrating the well-known relationship between composite strength and filler concentration. The mechanical strength of composites containing unmodified rubber waste peaks at relatively low concentrations (10-20%). In contrast, rubber waste modified with ethyl silicate (3-5%) significantly enhances the mechanical strength of the composite, shifting the maximum strength to higher concentrations of rubber waste (as shown in curves 2 and 3). This finding is practically important: the more mineral fillers a polymer composite includes, the lower its intrinsic cost. Curve 3 shows an interesting trend: a single peak is observed at relatively low filler concentrations, while at higher concentrations, the curve becomes disrupted. This disruption occurs because achieving high filler content in composites is technically challenging, primarily due to difficulties in uniformly distributing the filler within the polymer matrix.

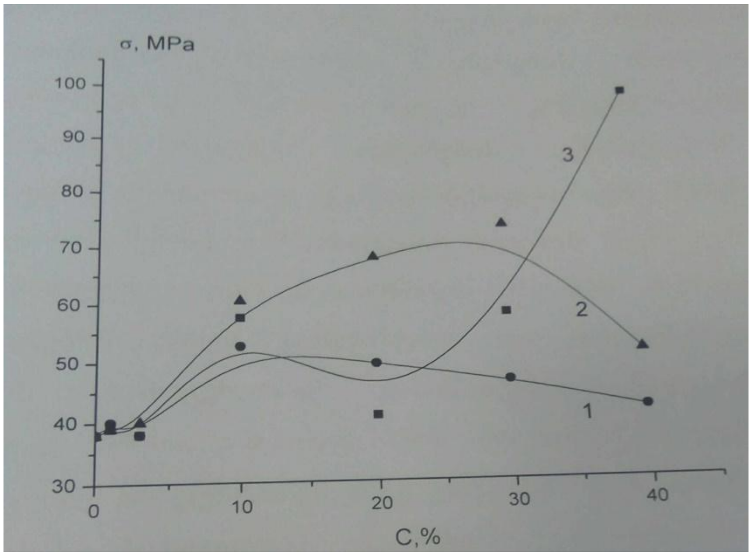

Figure 1: *Dependence of the strength limit of ED-20 + rubber residue composites on the content of rubber residue for*

The curves indicate that finely dispersed rubber tire powder significantly enhances both the mass density and strength of the composites compared to those with the same concentrations of unmodified rubber. The addition of ethyl silicate, a modifier, greatly impacts the mechanical properties of the composites. The siloxane compound on the rubber grain surfaces activates them, and during heat treatment, ethyl silicate likely forms bonds with the macromolecules of the epoxy resin. It fills the gaps between polymer blocks and creates a "buffer" zone between the rubber and the polymer. This interaction between the epoxy resin and ethyl silicate results in the formation of additional physical, Van der Waals, sorption, and chemical bonds, which collectively enhance the mechanical strength of the composites compared to their unmodified counterparts. Epoxy resin composites filled with modified rubber powder demonstrate better compatibility compared to those with unmodified rubber, as evidenced by superior mechanical strength indicators. The mechanical stresses in the composite, whether from compressive or tensile forces, are effectively absorbed by the relatively soft siloxane phase. This phase helps to limit and contain the development of microdefects within the carbon chain matrix, thus reducing the overall thickness of the composite. These structural improvements are also reflected in the thermo-mechanical properties of the materials. Composites with rubber residues modified with ethyl silicate exhibit a higher and more consistent softening temperature compared to those with unmodified rubber residues. This behavior correlates well with the mechanical strength values, suggesting that the modified filler has a stronger interaction with the polymer molecules through the modifier than the unmodified filler.

The enhanced compatibility of rubber residues in the carbon chain matrix of the composite, facilitated by ethyl silicate, is evident from the water absorption properties. Table 1 reveals that increasing the filler concentration generally leads to larger microstructures and the formation of interconnected or isolated microvoids, resulting in higher water absorption rates. However, composites with rubber residues modified by ethyl silicate exhibit significantly lower water absorption rates compared to those with unmodified rubber residues. This reduction can be attributed to the well-known hydrophobic nature of siloxane compounds, which greatly decreases water absorption in composites with modified fillers.

Table 1: *Dependence of Composite Water Absorption on Ethyl Silicate Content*

Rubber Residue Content	Ethyl Silicate Content	% of water absorption after 3 hours	% of water absorption after 24 hours	Density
10	0	0	0	1.1252
20	0	0.08	0.12	1.2332
40	0	0.14	0.36	1.2546
10	3	0.053	0.108	1.2198
10	5	0.032	0.100	1.2341
20	3	0.062	0.116	1.2455
30	5	0.072	0.266	1.2678

It has been established that ethyl silicate enhances the hydrophobicity of the composite by a factor of four at a 10% concentration, while also increasing both the softening temperature and mechanical strength. The modification of rubber residues with 3% and 5% ethyl silicate leads to a significant increase in the composite's mechanical strength up to a certain concentration of rubber residues. The strength dependence curve for these modified composites shows a peak much higher than that of composites filled with unmodified rubber waste. Specifically, composites with 5% ethyl silicate-modified rubber waste exhibit substantially greater maximum strength compared to those with 3% ethyl silicate-modified rubber waste. All composites incorporating ethyl silicate-treated rubber waste demonstrate notable hydrophobic properties.

References

[1] Hernandez R. J., Selke S. E. M., and Culter J. D. Plastics Packaging, Hanser, Munich, 2000.

[2] Hunger H. K. Industrial Organic Pigments , VCH, Weinheim, 1993.

[3] Sorokin M.F., Lyalyushko K.A.. Practical training in the chemistry and technology of film-forming substances. Moscow: Chemistry, 1971, 246 p. (in Russian).

[4] Gorlovsky I.F., Bocharova A.M., Suvorova V.D.. Laboratory practical training in chemistry and technology of pigments. L. Chemistry, 1978, 223 p. (in Russian).

[5] Bagazhkov S. G., Sukhanova N. A. Workshop on paint coating technology. M. Chemistry, 1982. 240 p. (in Russian).

[6] Yakovlev A.D. Powder paints. L. Chemistry, 1987, 216 p. (in Russian).

[7] Karyakina M.I., Poptsov V.E. Polymer coating technology. M. Chemistry, 1983, 335 p. (in Russian).

[8] Blagonravova A. A., Nepomnyashchy A. I.. Varnish epoxy resins. M.: Chemistry, 1970, 248 p. (in Russian).

[9] Verkholantsev V.V. Water-based paints based on synthetic polymers. Leningrad: Khimiya, 1968. 200 p. (in Russian).

[10] Goldberg M.M. Materials for paint and varnish coatings. M. Chemistry, 1972, 342 p. (in Russian).

ANTHROPOGENIC ACTIVITIES AND ITS ROLE IN THE FORMATION OF LANDSLIDE PROCESSES IN THE MOUNTAIN TERRITORIES OF THE CHECHEN REPUBLIC

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Abstract

Landslides are considered as a complex process in which anthropogenic activity plays an important role. The purpose of this work is to describe the cause-and-effect relationships in the system "anthropogenic activity - landslides" using the example of mountainous regions of the Chechen Republic. The article is based on field studies and materials from the interpretation of high-resolution space images, which made it possible to identify about 1800 landslides in the territory of the Chechen Republic. They were characterized in terms of landscape position (coordinates, height, exposure, slope, vegetation composing rocks) and involvement in economic activity (forestry, pastures, agriculture, settlements, etc.). The results of the work made it possible to assess the mutual influence of landslides on settlement, on the one hand, and land use (in particular, road construction, irrigation, etc.) on the nature of landslides. A detailed analysis of the obtained database made it possible to identify 356 landslides that somehow fall within the analysis field of the "landslide - person" system. The analysis of the relationships was carried out based on the superposition of various layers of the created geoinformation system. Anthropogenic activity was assessed in three aspects: 1) spatial proximity of landslides and economic objects; 2) intensity and type of economic activity influencing landslide manifestations; 3) dynamics of land use over time, in particular, a sharp change from one type of use to another.

Keywords: landscapes, slope exposure, human impact, landslides

I. Introduction

Mountains and mountain ranges are complex and multifaceted geosocio-ecological systems and play a crucial role in biodiversity, hydrological cycles and human society. Mountainous areas face numerous challenges, including climate change, land use change, which lead to slope instability, erosion, mudflows, landslides. Landslides are caused by geological, meteorological and human factors, which vary not only depending on the natural environment, but also depending on the socio-territorial context. In recent years, the impact of landslides on the economy and settlement has become more serious due to the overlap of various interacting factors. Therefore, mountainous regions around the world are faced with an increase in poorly predictable catastrophic events, cascading effects and an increase in natural disasters. Landslide phenomena often form areas that can be considered as specific disaster zones - risk landscapes. Risk landscapes are complex, heterogeneous and uncertain territories, which confirms the need to consider the relationship between nature and society at different levels of time and space. The mountainous territories of the Chechen Republic have long been well developed [1]. There is a well-developed settlement system here, which underwent significant changes in the 20th century, many settlements were abandoned, the population migrated to the foothills and to the plain. On the other hand, the developed territories in the mountains were affected by slope processes, primarily landslides. Traditional forms of life activity allowed for the formation of relatively long-term symbioses of the environment and settlement with a high degree of adaptation. However, the development of new technologies for the construction of residential buildings, roads, communications and, in general, land use, led to the disruption of traditional adaptation mechanisms and the intensification of landslides.

II. Methods

The article is based on field studies and high-resolution satellite imagery interpretation materials, which allowed us to identify about 1,800 landslides in the Chechen Republic. Profiles were built for key areas, which included not only the landslide body itself, but also the surrounding landscape, including land use and settlement. This allowed us to assess the mutual influence of landslides on settlement, on the one hand, and land use (in particular, road construction, irrigation, etc.) on the nature of landslides. A detailed analysis of the resulting database allowed us to identify 356 landslides that, in one way or another, fall within the scope of the analysis of the "landslide - person" system [2]. The remaining landslides were classified as conditionally natural, since the main factors influencing their dynamics were natural processes: river erosion, natural instability of slopes, earthquakes, etc. All 356 landslides were characterized in terms of geographic location (coordinates, height, exposure, slope, vegetation, landscapes that make up the rocks), as well as in terms of inclusion in economic activity (forest management, pastures, agriculture, settlements, etc.). The analysis of the relationships was facilitated by the presence of various layers of the created geographic information system. The use of layer overlay operations and loading of images from different years made it possible to assess the dynamics of the relationship between economic activity and landslides in different periods of development: in Soviet times (intensive land use), in the 1990s (weakening of economic activity, migrations caused by military actions), in the 2000s and to the present (construction of roads, communications, creation of new settlements in safe places, migrations to the city, etc.). The study of changes in land use was also supported by field surveys of key areas, landscape mapping and profiling [3].

Landscape management within the high-altitude zonal landscape-landslide complexes has undergone significant changes over the past 80 years. The highland landscapes, densely populated before the deportation of the Chechens in 1944, were used as a basis for life – for arable land, hayfields and grazing. The destruction of the settlement system and the deportation of mountain dwellers to the plain led to the expansion of use in the form of distant-pasture livestock farming, mainly as pastures for sheep driven in the summer from collective farms in the foothills and plains. The settlement of abandoned villages was prohibited in Soviet times. In the late 1980s, individual families began to gradually reclaim their ancestral lands. The process stopped during the military actions, but then resumed in the 2000s. However, individual entrepreneurs gradually began to drive small herds (mainly bulls) to summer pastures. With the construction of roads, the development process accelerated. In recent years, high-mountain areas, in particular the basin with Lake Galanchozh in the center, have become a weekend tourism destination. However, the laid dirt roads significantly reduced the stability of the slopes and began to serve as sources for the development of landslide processes. In the foothill-low-mountain zone, where the densely populated areas of the Chechen Plain and the Black Forest meet, mountain forests have long been used for firewood, and individual farms developed sections of clearings in the mountain forests. However, this process was slowed down due to the lack of areas suitable for farming. In Soviet times, forest management began to be regulated. The return of the Chechens in the late 1950s and the restoration of villages led to a change in the settlement structure, an increase in the number of livestock and an increase in the need for firewood [4]. During the military actions of the 1990s, the surrounding landscapes suffered greatly. The restoration in the post-war period was accompanied by the installation of gas supply, which had a positive effect on the forest cover. In addition, the basis of the population's life has changed, which is now largely associated with work in cities. This has led to a decrease in the livestock population, stall keeping and driving to high-mountain areas are used. All this gave the mountain forests a chance to recover.

The development of the oil industry played a major role in the use of the landscapes of the front ranges. The network of wells and infrastructure of the oil industry led to fundamental changes in the landscapes [5]. Population growth due to the oil industry, and later due to internal migration led to an increase in the number of privately owned livestock and, as a result, an increase in the pasture load. Local residents have long used the adjacent slopes for year-round grazing of privately owned livestock, which prevented the restoration of shrubs and trees.

The main load on the landscapes came from the oil industry facilities. Almost everywhere there are roads, slag ponds, oil pipelines. Currently, the number of oil industry facilities has decreased, regulated grazing is underway, which allows us to hope for a reduction in the load due to the regulation of use. Mountain-forest landscapes of the front ranges are experiencing a stage of restoration: forest areas are being compacted, in some places land is being developed for the construction of private houses, mainly for recreational use.

III. Results

Analysis of statistical data for different years on settlement, economic activity and landslide distribution allowed to detail the main factors that directly or indirectly affected the intensity of landslide manifestation. These include: 1) intensive development of oil fields, which affects the change in the seismogenic situation and the state of rocks, 2) changes in the historically established settlement system, the layout of settlements, technologies for building houses of other designs, intra-settlement arrangement of communications and infrastructure with asphalt and concrete pavements, while increasing the number of continuous development centers, 3) changes in the use of land in the host landscape [6]. Development of oil fields. Overlaying oil fields on a landslide map shows that the correlation between them is manifested only in the foothills (Fig. 4). Geological exploration and exploitation of fields leads to a change in the dynamic state of geological structures, the formation of weakened zones and voids, which leads to a violation of the seismic regime in the area. Most of the observed landslide processes on the slopes of the Tersky Range are closely related to oil production processes (mainly the road network to the wells and along the oil pipelines). In the areas of oil production and exploration, slopes are being cut and flooded (Fig. 1). There are several hundred abandoned wells, the injected water overflows from the layers and contributes to the instability of the slopes. The dominant natural complexes here are slopes composed mainly of Neogene deposits of sandstones and clays, partially covered by Quaternary deposits, northern exposure, gentle and medium steep, stepped and hollow, complicated by artificially leveled terraces and roads of the oil industry complex, under mountain forest vegetation of oak, small forests and shrubs of thorn tree on mountain forest chernozem-like and chestnut soils. Subdominant natural complexes are slopes with shrub steppes on chernozem-like and chestnut soils.

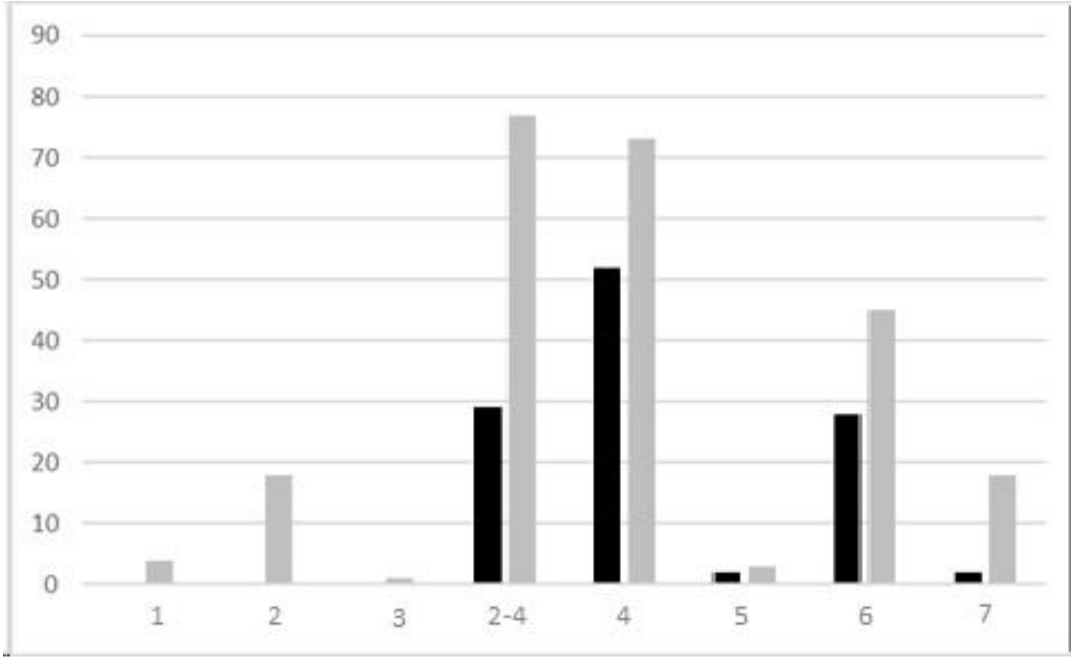

Figure 1: *Distribution of landslides in villages (black) and near villages (gray) in different landscapes: Mountain-forest: 1 - mixed broad-leaved and small-leaved, 2 - broad-leaved, 3. Mountain-forest-meadow. Mountain-forest-meadow-steppe: 4 - typical, 5 - forest-meadow-steppe and forest-steppe. Mountain-steppe: 6 - meadow: 7 - mountain-dry-steppe shrub*

IV. Discussion

Analysis of statistical data for different years on settlement, economic activity and landslide distribution allowed to detail the main factors that directly or indirectly affected the intensity of landslide manifestation. These include: 1) intensive development of oil fields, which affects the change of seismogenic conditions and the state of rocks, 2) change of the historically established settlement system, planning of settlements, technologies of construction of houses of other designs, intra-settlement arrangement of communications and infrastructure with asphalt and concrete pavements, while increasing the number of continuous centers of development, 3) change in land use in the host landscape. Development of oil fields [7]. Overlaying the landslide map of oil fields shows that the correlation between them is manifested only in the foothill areas (Fig. 2). Geological exploration and exploitation of fields leads to a change in the dynamic state of geological structures, the formation of weakened zones and voids, which leads to a violation of the seismic regime in the area. Most of the observed landslide processes on the slopes of the Tersky Range are closely related to oil production processes (mainly the road network to the wells and along the oil pipelines). In the areas of oil production and exploration, slopes are being cut and flooded. There are several hundred abandoned wells, the injected water overflows from the layers and contributes to the instability of the slopes [8]. The dominant natural complexes here are slopes composed mainly of Neogene deposits of sandstones and clays, partially covered by Quaternary deposits, northern exposure, gentle and medium steep, stepped and hollow, complicated by artificially leveled terraces and roads of the oil industry complex, under mountain forest vegetation of oak, small forests and shrubs of thorn tree on mountain forest chernozem-like and chestnut soils. Subdominant natural complexes are slopes with shrub steppes on chernozem-like and chestnut soils.

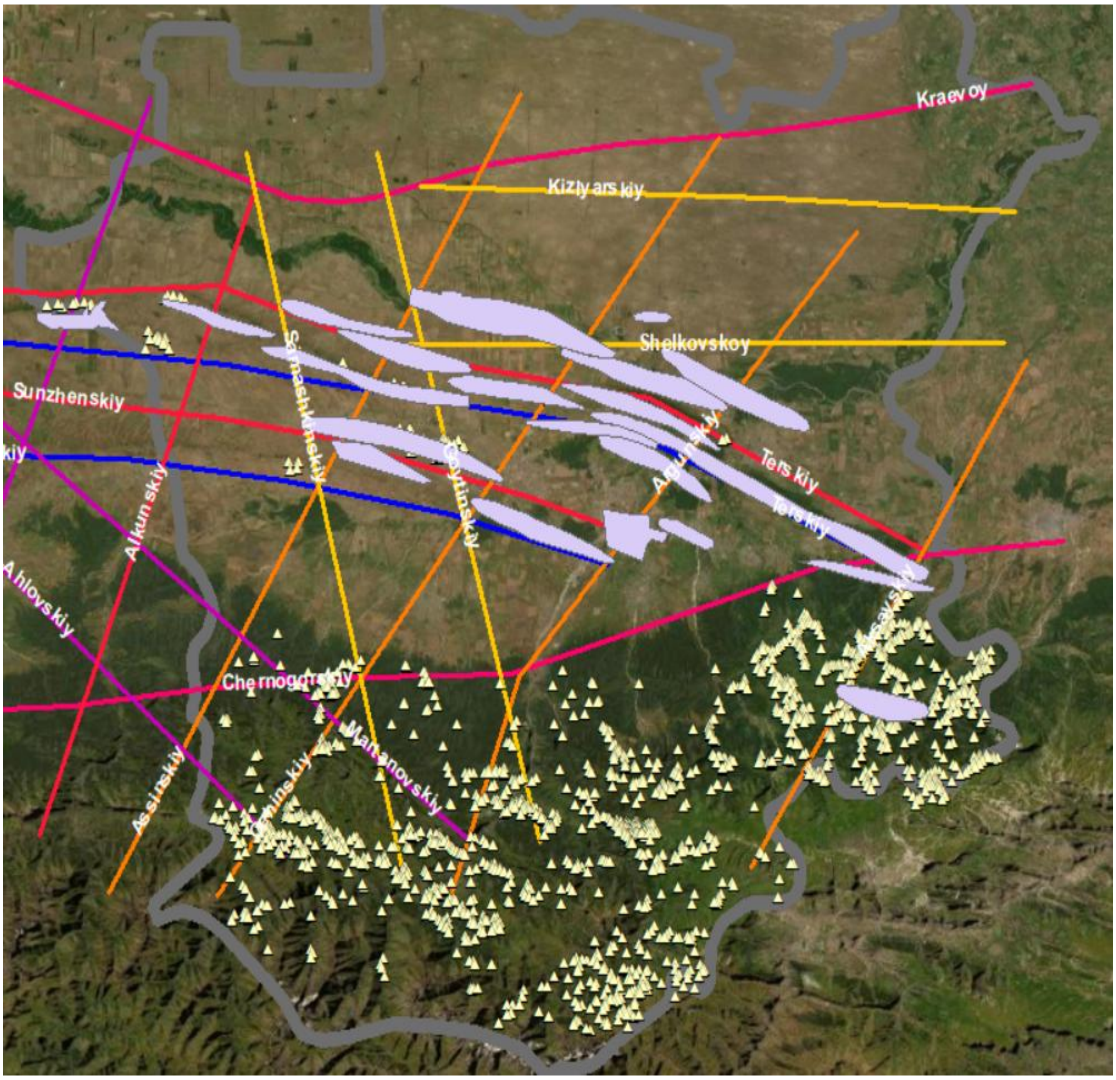

Figure 2: *Landslides (indicated by light triangles), faults (straight lines of different colors) and oil fields (light-colored lenses) in the Chechen Republic.*

A striking example of the impact of land use on landslides is observed in the area of the village of Varanda. After the eviction of the Chechens, Old Believers arrived in these territories, who carried out intensive agricultural activities - arable land with mechanical soil cultivation. As a result, instead of small parcels of arable land and vegetable gardens, which had a terraced nature of distribution, large fields were formed on which the water supply regime of the soils was disrupted [9]. The torrential nature of summer rains contributed to the formation of erosion furrows, subsidence, which disrupted the stability of the slopes. A decrease in the infiltration properties of soils with an increase in water supply led to the occurrence of landslides in watershed areas.

Landslide areas coincide in terms of moisture conditions, fertile substrate with favorable conditions for life. In natural terms, the mountainous territories of the Chechen Republic have a relatively limited number of areas for agriculture and settlement, mainly areas unfavorable for settlement predominate: dissected relief, steep slopes and mountain gorges with turbulent watercourses that wash away these slopes [10]. In the lowlands and midlands, where climatic conditions are relatively favorable for permanent residence, the slopes are composed of loose, rapidly eroding and unstable deposits of clays, argillites and siltstones. Vegetation contributes to the consolidation of landslide-prone areas. However, the very uneven precipitation regime, especially in early spring, when the vegetation cover has not yet formed, serves as a factor in increasing landslide manifestations [11].

Fertile fine-grained substrate has always been attractive for development under arable land. Near such areas, which also had outlets of groundwater used for economic needs and irrigation, people settled, founded new villages (Fig. 3). Traditional Chechen houses in the low-mountain and partly mid-mountain zone, where rocky rocks were rare, were built of light material (usually a wooden frame, and the filler consisted of straw and clay). The roads were unpaved and narrow, they were winding and fit into the relief. Houses and outbuildings also fit into the relief, buildings were scattered along the slopes, and roads were rare. In the second half of the 20th century, with the use of heavy machines, roads began to expand, heavy construction and agricultural machinery passed along them [12]. Houses, starting with foundations and walls, began to be built using brick and concrete structures, which significantly increased the load on the soil. The increased need for water and energy (gas, electricity) led to the emergence of linear water and energy supply facilities. All this together significantly increased the load on the host landscape in landslide areas.

Figure 2: *Landslide processes near the Gendargen-Shunoy road*

The distribution of landslides and the features of settlement and land use differ in different high-altitude landscape zones; the most extensive landslide areas are confined to low-mountain densely populated landscapes of the eastern part of the Chechen Republic. Several types of cause-and-effect relationships are distinguished in the "landslide occurrence - economic activity" system: on the one hand, landslide areas are characterized by good water supply and the presence of fertile substrate for agriculture [13]. On the other hand, landslide processes cause destruction and force the population to migrate to cities and plains. The main factors that influenced the connections in the "landslide occurrence and anthropogenic activity" system should be considered changes in settlement and land use caused by socio-political events of the last century.

Acknowledgments.

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References

[1] Bachaeva T.Kh., Daukaev A.A., Kerimov I.A., Shaipov A.A. Upper jurassicsubsalt complex of the Terek-Caspian troughdue to oil and gas content. IOP Conference Series: Earth and Environmental Science. 2019th International Symposium on Earth Sciences: History, Contemporary Issues and Prospects. 2019. C. 012026.

[2] Gunya A.N., Gakaev R. A. Landscape approach to the study of landslides (on the example of the mountainous territory of the Chechen Republic). Problems of regional ecology. 2024. No. 1. P. 64-73.

[3] Gunya A.N., Gakaev R. A., Badaev S. V. The role of climatic conditions in the activation of landslides in the Mountainous part of the Chechen Republic, 2012, 4(13), pp. 9-12.

[4] Kerimov I.A., Gagaeva Z.S., Gayrabekov U.T., Badaev S.V. The beginning of comprehensive studies of the nature and population of Ciscaucasia in the XVIII century. IOP Conference Series: Earth and Environmental Science. 2019th International Symposium on Earth Sciences: History, Contemporary Issues and Prospects. 2019. C. 012002.

[5] Daukaev A.A., Gatsaeva L.S., Abubakarova E.A., Elzhaev A.S. Analysis of local structure in mesozoic deposits and their oil and gas content to justify geologic exploration. IOP Conference Series: Earth and Environmental Science. Issue 8. 2018. C. 082009.

[6] Kerimov I.A., Abubakarova E.A., Badaev S.V. Tridimensional analysis of gravitational and magnetic fields of Terek-Caspian trough. IOP Conference Series: Earth and Environmental Science. Innovations and Prospects of Development of Mining Machinery and Electrical Engineering - Mining and Exploration of Mineral Resources. 2017. C. 052011.

[7] Bachaeva T.Kh., Daukaev A.A., Kerimov I.A., Shaipov A.A. Upper jurassicsubsalt complex of the terek-caspian troughdue to oil and gas content. IOP Conference Series: Earth and Environmental Science. 2019th International Symposium on Earth Sciences: History, Contemporary Issues and Prospects. 2019. C. 012026.

[8] Gairabekov U.T., Kerimov I.A., Gagaeva Z.Sh. Geoenvironmental assessment of the effect of oil extraction on the landscapes of the Chechen Republic. IOP Conference Series: Earth and Environmental Science. International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering, IPDME 2018 - Mining Ecology. 2018. C. 092008.

[9] Gunya A.N., Gairabekov U.T., Sh Gagaeva Z., Kerimov I.A. Landscape-structural factors of the development of a mountainous region (on the example of the Chechen Republic). IOP Conference Series: Earth and Environmental Science. 2021 International Symposium "Earth Sciences: History, Contemporary Issues and Prospects, ESHCIP 2021". IOP Publishing Ltd, 2021. C. 012141.

[10] Tucker C.M., Hribar M.Š., Urbanc M., Bogataj N., Gunya A., Rodela R., Sigura M., Piani L. Governance of interdependent ecosystem services and common-pool resources. Land Use Policy. 2023. T. 127. C. 106575.

[11] Daukaev A. A., Gatsayeva L. S., Gakaev R. A., Golik V.I. Synergetic manifestations of natural and man-made geodynamic processes on the territory of the Chechen Republic. Bulletin of Tula State University. Earth Sciences. 2023.No. 4. P. 188-197.

[12] Gagaeva Z.Sh., Kerimov I.A. Landscape small-scale mapping and sustainable development. WIT Transactions on the Built Environment. 3rd International Conference on Evaluation, Monitoring, Simulation, Management and Remediation of the Geological Environment and Landscape, Geo-Environment 2008. Сер. "Geo-Environment and Landscape Evolution III: Evolution, Monitoring, Simulation, Management and Remediation of the Geological Environment and Landscape" sponsors: WIT Transactions on the Built Environment. New Forest, 2008. C. 203-209.

[13] Shogenov M., Chechenov A., Gunya A. Exploring civil society in the North-Western Caucasus: the state, local government, and communities on a convoluted path toward social stability. Demokratizatsiya. 2020. T. 28. № 2. C. 269-303.

NEW APPROACHES TO OILY WASTE TREATMENT TO MINIMISE TECHNOLOGY-RELATED THREATS AND RISKS

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Abstract

The relevance of the scientific issue concerns with the search for scientific methods of technology-related emergencies prevention. Those caused by dumping and disposal of wastes in the natural environment. The purpose of the study is to find new approaches for preventing the discharge of oily waste into water bodies and soil caused by stationary and mobile sources of pollution. At the annual international scientific and practical event "Integrated Safety-2024" we reported on new approaches to preventing excessive pollution of natural objects with oil waste. However, it creates risks of man-made emergencies with unfavourable environmental consequences for water bodies. Our report was highly appreciated by the participants. The authors plan to test and adapt the proposed technologies and methods for preventing the formation and disposal of oily wastes as sources of increased environmental danger.

Keywords: environmental safety, oily waste, pollution, magnetic fluid, recycled raw materials, utilisation

I. Introduction

Industrial, energy, and transport facilities are factors of increased environmental hazard. Environmental hazard is a source of technological emergencies risk concerning with unfavourable socio-economic, environmental, and other consequences. The factors of such hazard are emissions of harmful substances into the air, discharges of polluted wastewater, and the formation of toxic waste [1-5].

One of the most widespread and dangerous environmental pollutants is oily waste. Indeed, oil sludge, oily wastewater, waste oil, and a wide range of other similar wastes generated practically by all industries and sectors of the economy [6-9]. In addition, the recycling of iron-containing waste as a result of metallurgical, machine-building, and chemical industries is currently a serious problem. However, these wastes contain valuable components that can be used as raw materials for the production of sought-after products.

In this paper authors consider the high relevance of the posed scientific problem and present the results of their research.

II. Methods

Research methods are based on collected information system analysis. It allows us to substantiate the choice of the algorithms and tools for solving the scientific issue. Additionally, to find strategic ways for solving the stated issue in accordance with the logical chain: object - subject - research context, we use the conceptual analysis and numerical methods of data processing.

The research is also based on the experimental data obtained during establishing and validation of water purification technology. This technology allows ones to remove oil products using magnetic liquids recycled on industrial waste.

III. Results

This particular research is two-staged one. The first its objective is related to the prevention of negative impact of oil-containing wastes and effluents from water transport on drinking water sources. Therefore, we solved this by development new approach and technologies for treatment of oily waste and effluents (by separation of oil sludge and treated wastewater) using magnetic liquids made of industrial waste.

The second its objective is related with the application of magnetic liquids obtained using industrial wastes [10-13]. This objective refers to the development of oil-containing wastewater treatment technology (by separation of oil waste and treated wastewater).

Nowadays, the following method of water purification from oil products by magnetic liquids is known: spraying of magnetic liquid through special spraying devices onto the oil film and subsequent collection of "magnetised" oil products by an electromagnetic device.

However, this water purification technology requires large volumes of magnetic fluid. The high cost of industrial magnetic fluids produced from "pure" raw materials is one of the factors hindering the widespread adoption of this technology in terms of economic feasibility. Researchers of Yaroslavl State Technical University have developed and patented environmentally safe technologies for obtaining cheap magnetic liquids using iron-containing industrial waste.

This project was successfully laboratory tested. Nowadays, it is in the industrial testing phase.

The proposed water purification technology is based on magnetisation of oil products with paraffin based magnetic liquids. Magnetised petroleum products are separated by a magnetic field in the process of treating contaminated water with magnetic fluid. The innovative method of water purification has many advantages. Firstly, it effectively removes oil products from water. Secondly, it allows ones to avoid the use of hazardous chemicals. This significantly reduces the unfavourable impact on the environment and humans. Moreover, volumetric water purification by using magnetic fluid is a relatively fast and cost-effective process. It significantly accelerates the water purification process by reducing the time of filtration and sedimentation of contaminants [14-18].

Magnetic fluid is a suspension of magnetic material nanodispersed particles stabilised by a surfactant in a carrier fluid. Three components are required to produce a magnetic liquid: a liquid base, magnetic particles of colloidal size (magnetite), and a stabiliser to prevent the colloidal particles from sticking together. Therefore, taking into account these conditions and limitations, YSTU researchers used iron-containing wastes of metallurgical, machine-building, and chemical industries as raw materials for obtaining magnetic particles.

The proposed technology of obtaining magnetic liquid utilises iron-containing production wastes and provides wider application of the obtained product (for example, for water purification from oil and oil products) due to its significant cost effectiveness.

The magnetic liquids obtained using waste products were characterised by physical and chemical methods of analysis. The saturation magnetisation of ML was 14-17 kA/m, volume fraction 4-6 %, density 800-950 g/dm^3. To confirm the structure and composition of the ML, spectra of the samples (Figure 1) were obtained on a FT-IR spectrometer RX (Perkin Elmer) with an NPVO Spectrum Two attachment in the frequency range of 400-4000 cm^{-1}.

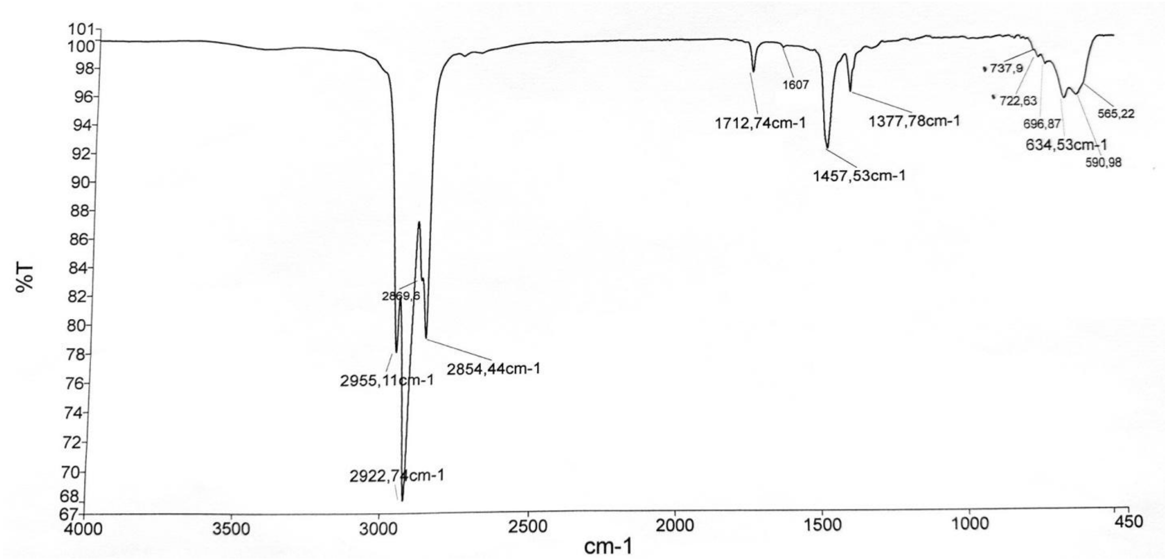


Figure 1: *Infrared spectrum of the magnetic fluid*

In the IR spectrum of the ML sample (Figure 1), there are absorption bands 696.87-565.22 cm^{-1}, which correspond to the Fe-O bond vibrations. This confirms the presence of the mineral form of magnetite in the synthesized sample.

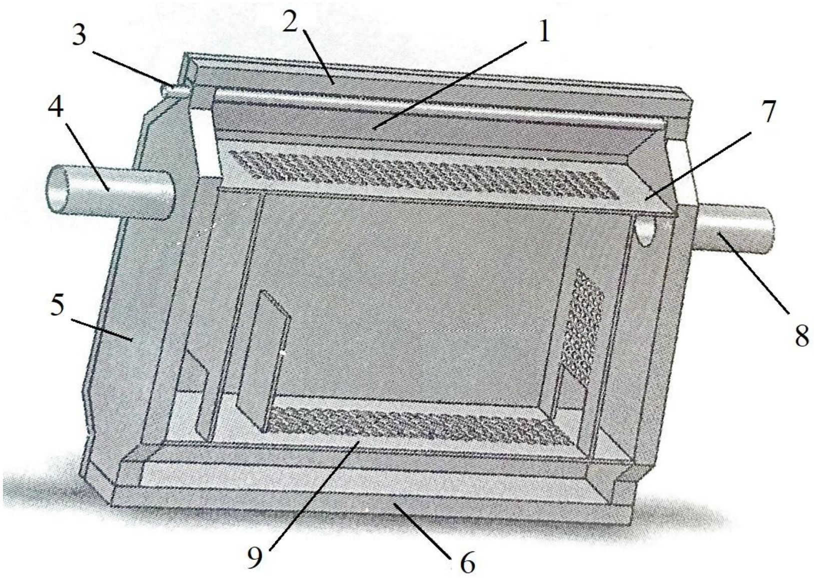
To remove oil products, we used magnetic liquids from production wastes for surface and volumetric water purification. Experiments show the high efficiency of application (90-96%) of the obtained magnetic liquids for "magnetic" water purification from oil products. The residual content of oil products in the water is less than 8 mg/dm^3 compared to industrial oil traps, where the residual content of oil products is more than 50 mg/dm^3.

Implementation of the proposed technology will cause a reduction in the impact of heavy metal ions and petroleum products on water bodies. This will improve water quality, reduce population morbidity and mortality, decrease costs on drinking water treatment, contribute to aquatic ecosystems conservation, increase the yield of fish economic water bodies, and reduce pollution of coastal areas by heavy metals and petroleum products. Hence, heavy metals and petroleum products extraction, treatment, and disposal reduce the environmental impact. Technical specifications and technological regulations for obtaining magnetic liquid and its application were developed and approved during the conducted research on the process of oil products collection on water surface by magnetic liquid.

In addition to surface water purification, experiments on volumetric purification of water from oil products were conducted. We use the apparatus described in the patent [19] (Figure 2).

The magnetofluid cleaner is a cell in which the side steel walls are set parallel to each other and taper at the top at an angle of 45°. Magnets are attached to them, arranged in two tiers along the entire length of the wall, according to the north-south pole arrangement in order to close the magnetic flow. The magnetic field at the top of the cell is larger than in the gap between the permanent magnets. It allows the magnetised petroleum product to be trapped. There are also separating plates with holes in the cell located above and below the magnets. They divide the cell into three layers: upper (magnetised petroleum products), middle (metal chips), and lower (heavy petroleum products) one.

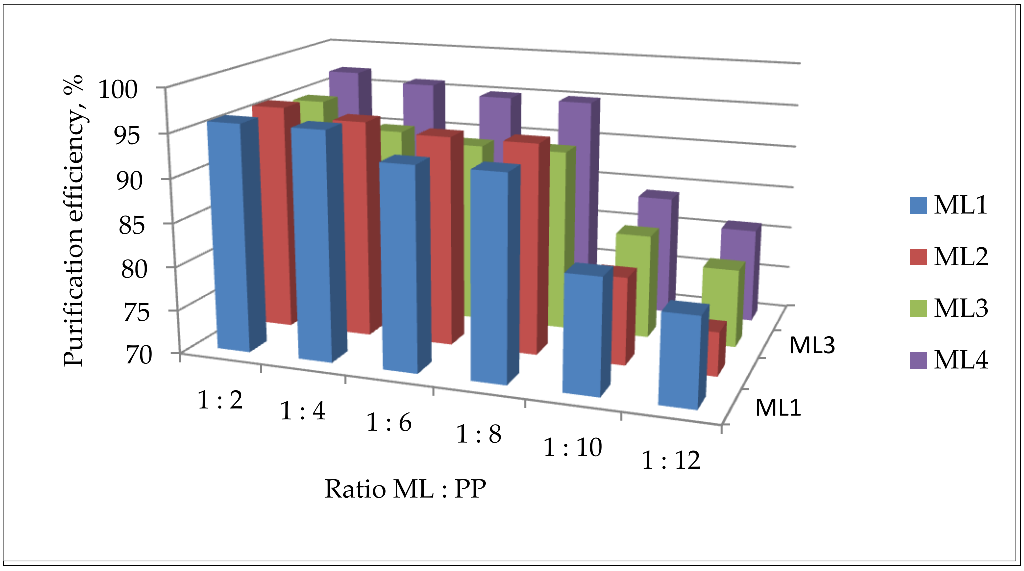
The principle of magnetic-liquid separator-cleaner operation is quite simple and highly efficient. Wastewater contaminated with oil products mixed with magnetic liquid, enters the unit body through the inlet pipe *8*, where ferromagnetic material is located. Oil droplets in contact with the chips are adsorbed on their surface, forming a thin layer due to the hydrophobic (water repellent) property of ferromagnetic chips and the oleophilic (attractive) property of oil products. The drops of petroleum product held on the surface of the ferromagnetic material chips float to the upper layers of the chamber under the action of Archimedes' forces arising in the gravitational field. As the polluted effluent moves through the apparatus, the content of oil products in the water gradually decreases due to coalescence and adsorption processes. The purified water is discharged from the chamber through branch pipe *4*.



1 – lateral steel wall; 2 – top cover; 3 – tube for magnetised oil product pumping out; 4 – tube for treated water pumping out; 5 – lateral wall; 6 – bottom; 7 – top plate with holes and two partitions; 8 – tube for water supply with magnetised oil product; 9 –bottom partition with holes and limiting partition

Figure 2: *Wastewater treatment plant for treatment of oil products using magnetic fluid*

The ratio: magnetic liquid / oil products changed during the experiments. The results of the experiments are presented on the diagram (Figure 3).



ML-1 is a magnetic liquid obtained from cupola dust, PAO Avtodiesel, Yaroslavl, Russia; ML-2 is a magnetic liquid obtained using waste from Olcona – Olenegorsk Mining and Processing Plant, Murmansk region, Russia; ML-3 is a magnetic liquid obtained using gas cleaning waste from OAO Severstal, Cherepovets, Russia; ML-4 is a magnetic liquid obtained using pure components.

Figure 3: *Experimental results of volumetric water purification using liquid magnets*

According to the diagram analysis, the optimum ratio of magnetic fluid to oil products during cleaning is 1 : 8; it provides cleaning efficiency in the range 91 %-95 %.

Collected magnetised petroleum products can be used as an additive to the rubber compound. It will result in improved rubber deformation and strength properties [20].

Moreover, the current methods of oily waste utilisation are their burning and landfilling. It causes the loss of valuable components and secondary pollution of the environment. More than 400 thousand tonnes of such waste have been accumulated only in the Yaroslavl region, Russia. Hence, this issue is very urgent both for the region and the country.

In this regard, the pond sour tar of Yaroslavl experimental industrial oil and oil plant named after D.I. Mendeleev, Yarioslavl region, Russia and oil sludge of OAO Slavneft-YaNOS (Slavneft-YANOS PJSC), Yaroslavl, Russia Flottweg plant have been the objects of long-term studies of oil waste reuse in the production of oil-containing products.

YSTU Department of Labour and Nature Protection researchers have developed a technology of producing binding materials for road construction with the use of oil-containing waste - bitumen pastes. Moreover, they determined the quality indicators for their assessment; the obtained bitumen pastes fully completely correspond to the standard requirements.

Indeed, we introduce binding materials obtained using oil-containing industrial wastes.

Development stage - the project has been successfully laboratory tested. Nowadays, it is at the stage of industrial testing at construction sites.

Unlike road bitumen, the use of bitumen pastes based on the following proposed technology:

- full adhesion to the base;
- it is allowed to spill bitumen pastes on the moistened surface;
- the possibility of varying its composition by qualitative indicators required for each individual type of work;
- lower energy consumption due to absence of necessity to maintain high temperatures;
- use of bitumen emulsions at temperatures 30-70 °C makes its application safe.

The economic effect of the research is achieved in decreasing of enterprises payments for storage of oil-containing wastes in sludge collectors, expansion of raw material base for production in Yaroslavl region, Russia, and decreasing of finished products (bitumen paste and asphalt-concrete compositions) production costs.

The approximate prime cost of prepared bitumen paste on the basis of oil-containing waste is about 3, 000 RUB. For instance, the analogue produced by the enterprise OOO Doros, Yaroslavl, Russia is 16, 000 RUB.

Hence, the collected and treated oil products after their separation out of the sub-slope (bilge) waters can be subjected to utilisation, namely - regeneration. Regeneration is the restoration of product useful properties to the level of secondary raw materials, or commercial product suitable for reuse in production and economic processes and operations.

IV. Discussion

The authors proposed ways of solving one of the modern urgent issues - prevention of pollution of drinking water sources surface with oil wastes and oily effluents. It causes threats and risks of man-made emergencies. Our solutions imply prevention of hazardous impact on water bodies by utilisation of oily waste and effluents through innovative technology for oil products separation coming out of the sub-slope water and their reuse as secondary raw materials for wide range of products production.

According to YSTU practical results, modified magnetic liquids effectively remove oil products on water providing high quality of its purification through the separation.

The authors conducted morphological and physic-chemical analyses of the composition and structure of oil waste separated out of waste water (after appropriate treatment (cleaning, separation, drying, resizing). According to their technical and operational characteristics, the following separated oil products can be reused as secondary raw materials to produce a wide range of products: oil-containing lubricants, pastes, additives in rubber mixtures and construction materials (asphalt concrete plants), etc.

The study also considers: environmental acceptability, technical feasibility, and economic efficiency of the proposed approach to the separation and purification of oily mixtures generated during repair and operation of water transport. It also proposed the practical application in water treatment facilities on ships. The final decision on the application of the proposed method and technology of oil waste separation using magnetic liquids will be made after additional researches, their comprehensive discussion, and approbation in the water transport system.

References

[1] Kasperovich E.V. Ship oil-containing (bilge) waters, their physical and chemical parameters and purification // Bulletin of Kamchatka State Technical University. 2005. Iss. 4. Pp. 63-66 (in Russian).

[2] Lozhkin V., Lozhkina O., Rogozinsky G., Malygin I. On information technology development for monitoring of air pollution by road and water transport in large port cities (St. Petersburg, Vladivostok and Sevastopol). Communicationsin Computer and Information Science. 2020. Vol. 1201. Pp. 384-396.

[3] Oltyan I.Y., Arefyeva E.V., Kotosonov A.S. Remote assessment of an integrated emergency risk index. IOP Conference Series: Materials Science and Engineering. International Conference on Construction, Architecture and Technosphere Safety. ICCATS 2020. Sochi, 2020. P. 042053

[4] Vorobyev Y.L., Akimov V.A., Sokolov Y.I. Prevention and liquidation of emergency spills of oil and oil products. Moscow: In-octavo, 2005. 368 p. (in Russian).

[5] Tesker I.M., Anikeyev V.V. Mathematical model of oil patch spreading during oil spill // Izvestiya Vuzov. Geology and Exploration [Izvestiya vuzov. Geologiya i razvedka]. 2005. Iss. 2. Pp. 64-69 (in Russian).

[6] Tshovrebov, E.S.; Kalaeva, S.Z.; Petropavlovskaya, V.B.; Niyazgulov, F.H. Conceptual modeling of a forecasting system for hazardous waste emergencies // Proceedings of Universities. Investment. Construction. Real estate [Izvestiya vuzov. Investicii. Stroitel'stvo. Nedvizhimost']. 2023. Vol. 13. Issue 4 (47). Pp. 702-715 (in Russian).

[7] Tskhovrebov E., Velichko E., Niyazgulov U. Planning measures for environmentally safe handling with extremely and highly hazardous wastes in industrial, building and transport complex // Materials Science Forum. 2019. Vol. 945. Pp. 988-994.

[8] Panarin V.M., Maslova A.A. Information support for the forecast of environmental situations // In Proceedings collection: Priority directions of science and technology development. Reports of XXXII International Scientific and Practical Conference. Edited by V.M. Panarin [V sbornike: Prioritetnye napravleniya razvitiya nauki i tekhnologij. Doklady XXXII mezhdunarodnoj nauchno-prakticheskoj konferencii. Pod obshch. red. V.M. Panarina]. 2023. Pp. 160-164 (in

[9] Panarin V.M., Ryleyeva E.M., Sergeeva E.V., Magradze M.D. Automated system of monitoring of water bodies pollution by industrial enterprises effluents. Patent for invention RU 2818532 C1, 02.05.2024. Application dated 29.08.2023.

[10] Sergeev E.S., Filippova O.P., Kalaeva S.Z. Toxicological assessment of different types of waste oils. From Chemistry Towards Technology Step-By-Step. 2022. Vol. 3. No. 4. Pp. 61-67.

[11] Kalaeva, S.Z. The analysis of magnetic liquids meant for water purification from oil products / S.Z. Kalaeva, V.M. Makarov, N.A. Morozov, Yu. Stradomsky. Bulletin of the ISPU [Vestnik IGEU]. 2007. Issue. 3. Pp. 41-44 (in Russian).

[12] Kalaeva, S.Z. Electrochemical method for producing a magnetic fluid for water purification from oil products / S.Z. Kalaeva, V.M. Makarov, A.G. Erekhinskaya // Problems of regional ecology [Problemy regional'noj ekologii]. 2010. № 4. C. 92-94.

[13] Makarov, V.M. Synthesis and application of magnetic liquids using iron-containing waste on the basis of paraffin / V.M. Makarov, S.Z. Kalaeva, A.M. Shipilin, I.N. Zakharova, A.G.

Erekhinskaya, Y.I. Stradomsky, N.A. Morozov // Izvestia TulSU. Ser. "Earth Sciences" [Izvestiya TulGU. Ser. «Nauki o Zemle»]. 2007. Issue 1. Pp. 76-79 (in Russian).

[14] Kamenshchikov F.A. Removal of oil products on water surface and soil. Izhevsk: Institute of Computer Research, 2006. 528 p. (in Russian).

[15] Makarov, V.M. Obtaining magnetic liquids using industrial waste: a monograph / V.M. Makarov, S.Z. Kalaeva. Yaroslavl: YSTU Publishing House, 2016. 175 p. (in Russian).

[16] Kalaeva, S.Z. Synthesis of magnetic fluids from mining industry wastes / S.Z. Kalaeva N.M. Kachurin // Proceedings of Tula State University. Natural Sciences. Series: "Earth Sciences" [Izvestiya Tul'skogo gosudarstvennogo universiteta. Estestvennye nauki. Seriya: «Nauki o Zemle»]. 2015. Issue 1. Pp. 3-13 (in Russian).

[17] Gennadyeva, A. M. Magnetic liquid method for purifying water from petroleum products / A. M. Gennadyeva, S. Z. Kalaeva // Youth in search for a solution to modern environmental challenges : Proceedings of the All-Russian Scientific and Practical Conference [Molodezh' v poiskah razresheniya sovremennyh ekologicheskih vyzovov : Sbornik materialov Vserossijskoj nauchno-prakticheskoj konferencii], Kurgan, 10-14 April 2023 / Editor-in-Chief N. P. Nesgovorova. - Kurgan: Kurgan State University, 2023. - Pp. 38-43 (in Russian).

[18] Pat. 117461 RF. Device for collection of magnetised oil and oil products on water surface / N.A. Morozov, Y.I. Stradomsky, S.Z. Kalaeva, V.M. Makarov; application and patent pending: Yaroslavl State Technical University. - No. 2012103777/13, avt. 03.02.2012; published 27.06.2012. Bul. No. 13.

[19] Patent 2602566 Russian Federation, MPK C02F 1/48, C02F 1/40. Method of water purification to remove oil products by means of magnetic liquid and device for its implementation / Y.I. Stradomsky, N.A. Morozov; applicant and patentee "Ivanovo State Energy University named after V.I. Lenin" (ISPU) - No. 2015112535/05; filed. 06.04.2015 publ.: 20.11.2016.

[20] Utilisation of magnetized petroleum products in rubber mixtures and rubbers / O. Yu. Solovieva, S. Z. Kalaeva, V. M. Makarov [et al.] // Ecology and Industry of Russia [Ekologiya i promyshlennost' Rossii]. - 2010. - Vol. 12. - Pp. 22-23 (in Russian).

THE INVESTIGATION OF THE EFFICIENT OPERATING MODES OF VARIOUS SOURCE HEAT PUMPS IN THE HEATING SYSTEMS OF INDIVIDUAL RESIDENTIAL HOUSES IN KHANKENDI

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Abstract

*The article investigates the efficiency of various-source heat pumps in the heating system of an individual residential house located in the Nagorno-Karabakh economic zone, specifically in Khankendi. The parameters characterizing the heating supply scheme, along with all the equipment and components related to the scheme, have been calculated utilizing the GeoT*SOL simulation software. This program is one of the modern simulation tools used for the planning and design of heating pump systems. As an example, a private residence in Khankendi has been studied, and schematic diagrams for four different-source heat pump systems for the house's hot water supply and heating have been proposed. Seasonal performance indicators, energy efficiency, losses, solar contributions, efficiency, and more have been computed through computer simulations. The most efficient system has been identified.*

Keywords: alternative energy, heating equipment, GeoTSOL, ground-source, air-source, soil-source heat pump, modeling, simulation

I. Introduction

The 29th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP29) will be held in Azerbaijan this year. In 2024, hosting COP29 in Azerbaijan, one of the largest and most significant international events in the world, marks yet another notable triumph for President Ilham Aliyev. This stands as the most significant success of the Republic of Azerbaijan's foreign policy following our leadership in the Non-Aligned Movement and membership in the Security Council. The Republic of Azerbaijan aims to reduce greenhouse gas emissions by 35% by 2030 compared to the 1990 levels, with even more ambitious targets set for the period after 2030, aiming for a 40% reduction by 2050.

President of the Republic of Azerbaijan has declared the liberated territories as the "Green Energy" zone, with the goal of transforming these areas into a "Net Zero Emission" zone by 2050. This initiative reflects Azerbaijan's commitment to sustainable and environmentally friendly practices [1,2,3].

Within the framework of creating Green Energy Zones in the liberated territories, various measures are planned, including the production of electricity from restored energy sources, energy efficiency initiatives, installation of energy devices (especially solar panels) on building roofs, utilization of solar energy-based LED lamps for street and road lighting, use of recovered energy technologies in heating, cooling, and hot water supply, implementation of smart energy management technologies, and measures for the energy-efficient management of traffic lights.

Despite Azerbaijan's wealth in oil and gas reserves, special attention is being given to the development of the renewable energy sector. In the near future, Azerbaijan aims to transform into an exporter of green and hydrogen energy. Based on agreements and memorandum of understanding signed with leading international green energy companies and external investors, the restored energy production in Azerbaijan is projected to reach 10 gigawatts in the coming years.

Global issues and tasks are addressed and analyzed by extensively studying world experience. In the realm of science, modern advancements, particularly in technology, are applied to the utilization of alternative energy. Research findings are applied to relevant areas, results are analyzed, and effective methods and approaches are selected.

II. Results

The aim of this research is also to address the heating demand of individual residential houses in the city of Khankendi through the use of heat pumps. There are several methods for researching the effective operating modes of heat pumps. Among them, the most modern and effective method providing rapid results is computer simulation.

There are several simulation programs available for the calculations of heat pump systems. Programs used for the calculation of heat pump systems include GeoT*SOL, EnergyPlus, TRNSYS, DesignBuilder, HAP, HEAT2, RETScreen, etc. Each simulation program has its own specific features. In this research, the process of heating the individual residential house in the city of Khankendi through the use of a heat pump system has been investigated using the GeoT*SOL simulation program [4]. This program is a professional tool widely applied in developed European countries for the planning and design of heat pump systems. GeoT*SOL allows selecting various system types and components to achieve the best possible seasonal performance. It enables the calculation of energy consumption and costs to achieve optimal seasonal performance. GeoT*SOL simulates heat pump systems alongside solar thermal collectors and conventional boilers as required.

The analysis of simulation results revealed the significance of pre-calculating parameters characterizing the heating system during the modeling and exploration of "smart village" and "smart city" projects in developed countries [5-9]. As a result of the simulation, it has been clarified through the comparison of the obtained results which scheme will operate more effectively.

The heating pump environment has been selected to include geothermal probes, geothermal collectors, air, and groundwater. Over the course of one-year, dynamic minute-by-minute simulations have been conducted to calculate seasonal performance factors, energy consumption, losses, solar fractions, efficiency, and other relevant parameters for the entire heating pump system. The simulation process was conducted for one system type and four different heat sources. The operating mode of the heat pumps was accepted in monovalent mode. The simulation results yielded the following insights.

The city of Khankendi is located at approximately -46.77° E longitude and 39.83° N latitude. The annual sum of global irradiation has been calculated through simulation and is determined to be 1,498,465 Wh/m². Four different heating equipment schemes relying on various heat sources have been selected for an individual residential house with the same parameters. The aim of the research is to investigate which heat source is more effective for space. For this purpose, all parameters of each scheme were calculated, and all values were compared. According to the schemes provided in Figure 1, the following heating equipment configurations have been selected:

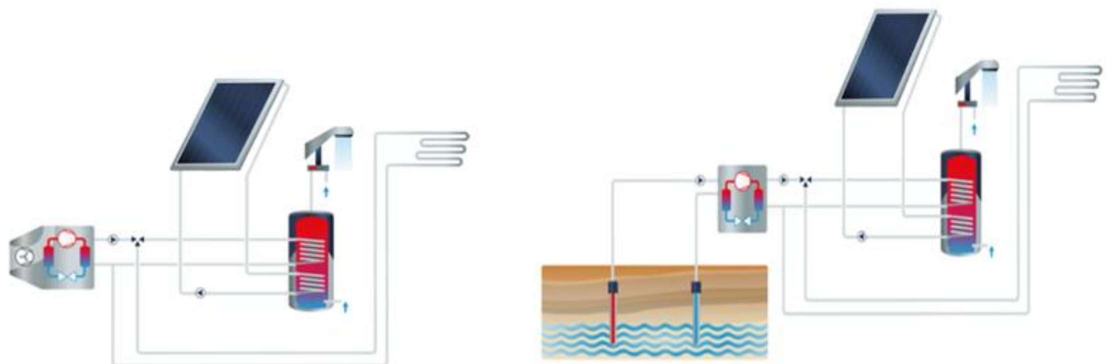
a) Air-source heat pump for hot water supply and heating system,

b) Ground-source heat pump for hot water supply and heating system,

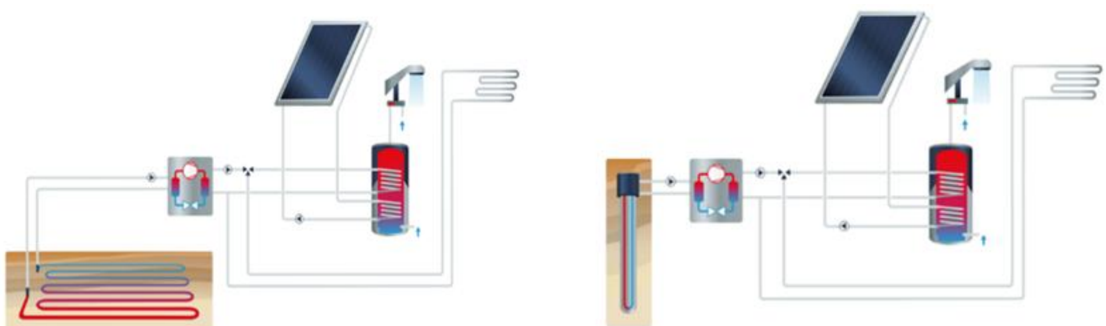
c) Soil-source, collector-type heat pump for hot water supply and heating system,

d) Soil-source, probe-type heat pump for hot water supply and heating system.

There are several operating modes for a heat pump: monovalent mode, monoenergetic mode, bivalent mode, bivalent parallel mode. In the investigated heating equipment system, the heat pumps operate in monovalent mode. In this mode, the heat pump serves as the sole heat source for both space heating and domestic hot water. The heat source should be designed to operate throughout the heating season; in monovalent mode, the heat pump heats the entire space to the lowest external temperature. In this mode, a solar collector is used as the secondary heat source.



a) Air-source heat pump b) ground-source heat pump



c) Soil-source, collector-type heat pump d) soil-source, probe-type heat pump

Figure 1: *Schemes of heating equipment with various heat sources*

The use of solar collectors in heat supply is related to the abundance of solar energy, its inexhaustibility, accessibility, and environmental cleanliness. For the heating equipment of residential buildings, primarily small solar systems are employed. Such systems include solar collectors, storage tanks, circulation pumps, and other auxiliary devices. Computer simulation has been utilized to calculate all specific characteristics of the solar collector for Khankendi.

The energy used for space heating and domestic hot water supply, measured in kilowatt-hours per hour (kWh/h), based on various sources, is shown in Fig. 2. Since the same space is selected for each scheme, all parameters are identical for this position.

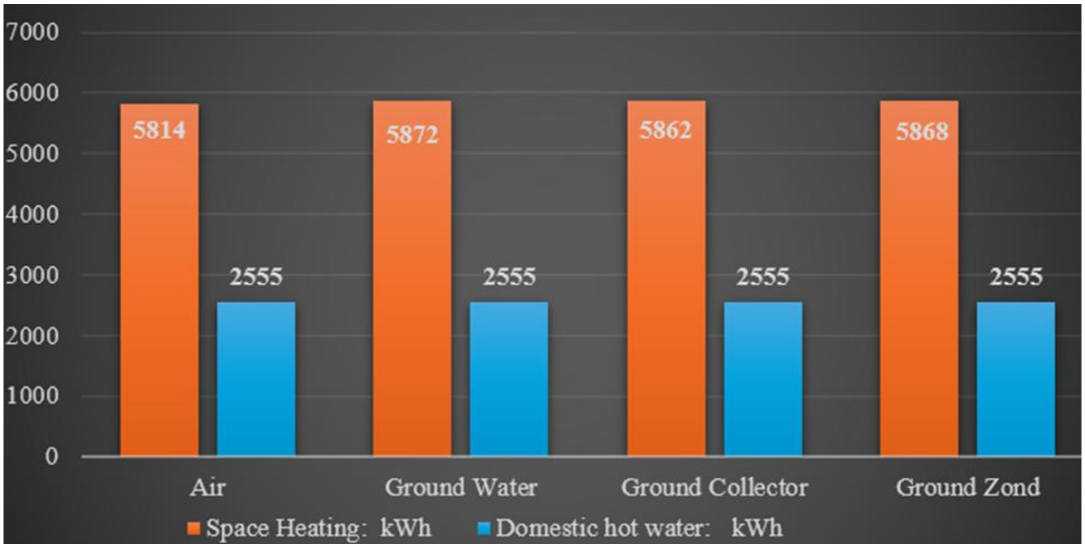


Figure 2: *Energy Used for Space Heating and Domestic Hot Water Supply (kWh/h)*

For each heat source, annual produced energy values have been calculated. The analysis of the results indicates that, although with slight differences, ground-source heat pumps are theoretically preferable.

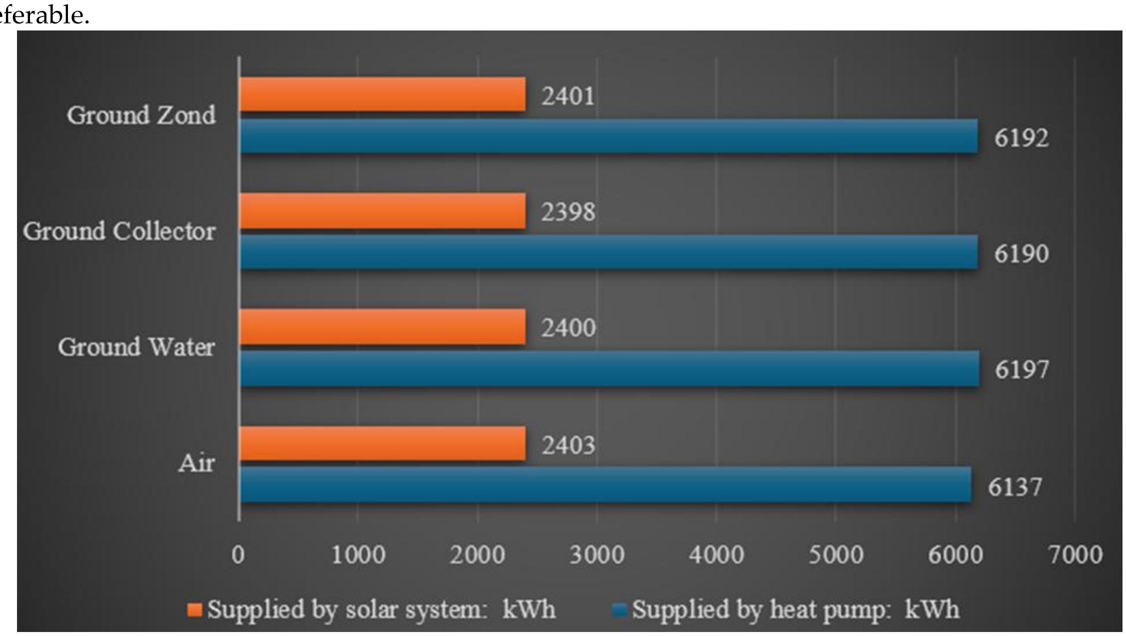


Figure 3: *Energy values produced by various heat sources (kWh/h)*

The efficiency of the heat pump operation is characterized by its performance factor. Fig. 4 illustrates the results obtained from computer simulation for the performance factor of the heat pump, the heat pump system, and generator system with the heat pump.

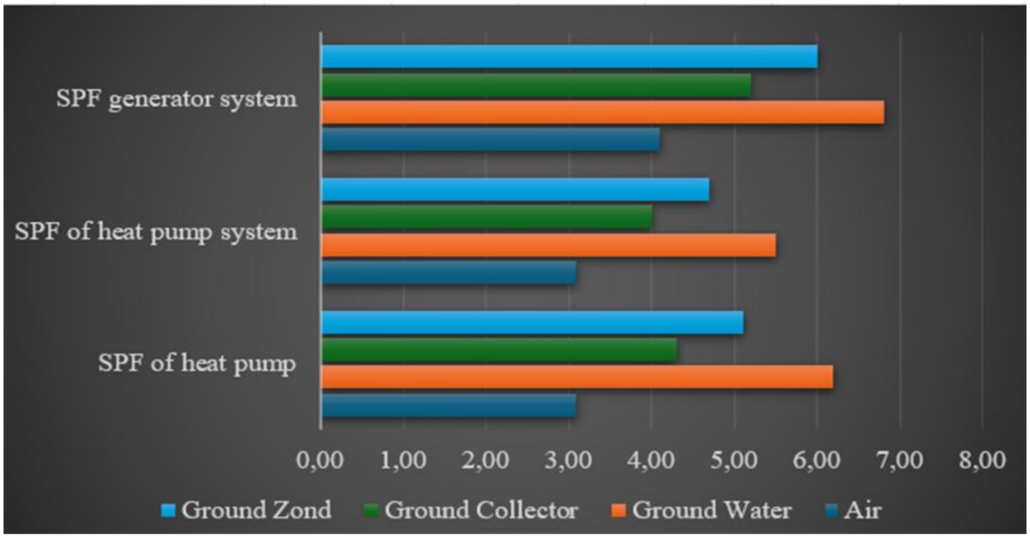


Figure 4: *Performance factor values*

In the comparison of performance values based on schemes, the position related to the ground-source holds an advantage. Namely, the calculated values for the ground-source heat pump, the heat pump system, and the generator system are lower than the others.

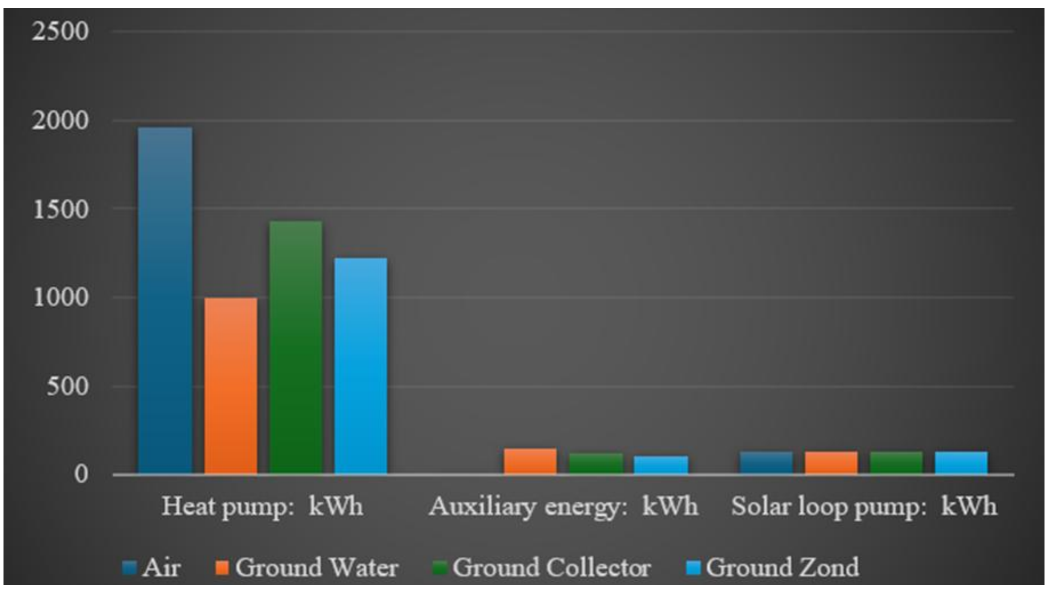


Figure 5: *Annual energy consumption of heat sources*

In each scheme, the heat source consumes electrical energy. According to the simulation, the energy consumed by each energy source in each scheme was calculated and compared. In terms of these parameters, the ground-source heat pump scheme stands out. The annual energy consumption of the energy sources in the corresponding schemes is minimal here (Fig. 5).

Table 1 presents the values of system losses. One of the parameters characterizing the efficiency of the system is the annual tank losses. In this regard, there is not much variation in tank losses among various source heat pump systems.

Table 1: *System losses*

	Air	Ground Water	Ground Collector	Ground Zond
Tank losses: kWh	379	379	380	379
...fraction of solar tank losses: kWh	157	158	158	157
Solar loop piping indoors: kWh	400	400	400	400
Solar loop piping outdoors: kWh	70	70	70	70

Using various source heat pumps in the heating supply scheme, all parameters related to the solar component have been calculated, as presented in Table 2.

Table 2: *Solar fraction of the heating equipment system*

	Air	Ground Water	Ground Collector	Ground Zond
Solar fraction: %	28,10	27,9	27,9	27,9
Solar fraction DHW: %	87,40	87,3	87,3	87,4
Efficiency of solar system: %	23,30	23,3	23,3	23,3

The energy gain of each system is one of the main factors influencing its efficiency. In Fig. 6, the primary energy gain values of the system, including the energy transferred by the collector and through the collector loop, are compared. Here, the most favorable values belong to the ground-source heat pump scheme.

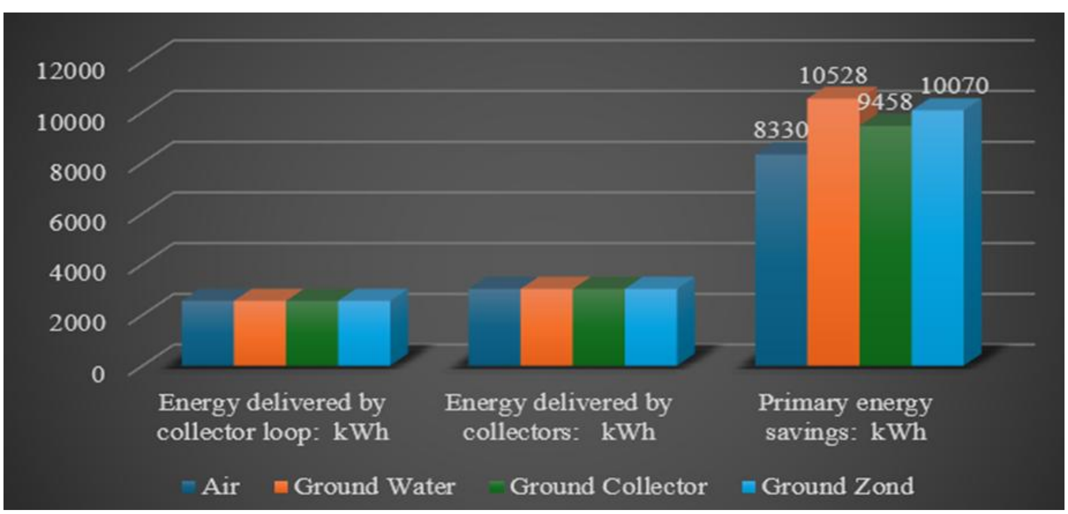


Figure 6: *Primary energy gains in systems*

The world reached a new anti-record in CO_2 emissions into the environment from energy production in 2022. The implementation of these schemes significantly reduces the amount of CO_2 emitted into the environment. In this context, the ground-source heat pump scheme holds an advantage (Fig. 7).

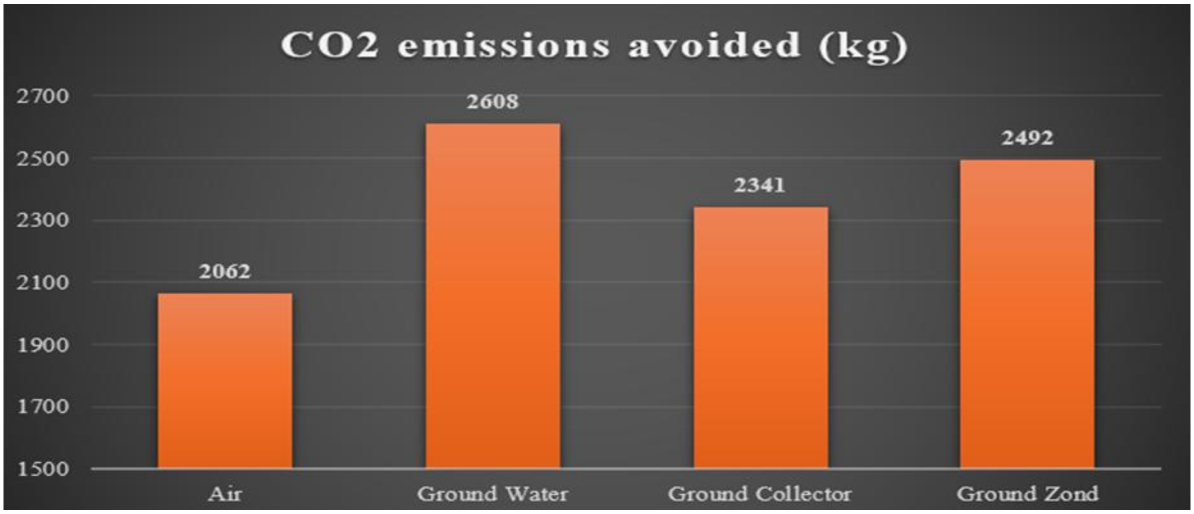


Figure 7: *Amount of captured CO_2 emissions*

Global warming has currently turned into a human catastrophe, primarily due to the disruption of the atmospheric heat balance. The problem arises from the increasing pollution of the environment. One of the main factors contributing to environmental pollution is the emission of flue gases from the combustion of fossil fuels used to obtain electricity and heat energy [7]. In addition to being energy-efficient in utilizing alternative energy, including heat pumps in heating systems, the simulation method prevents a significant amount of carbon emissions from being released into the atmosphere. The advantage of research conducted through the simulation method lies in the rapid and accurate acquisition of results. Heat pump systems do not have a negative impact on the environment during their operation. Combustion of fossil fuels is eliminated during their use, and no noise is emitted during their operation. There is no need for additional expenses during their utilization, and their operational lifespan is long. The application of heat pumps in the heating systems of buildings and for space cooling will lead to a reduction in heating and cooling expenses. There will be a high demand for heat pumps in the economic zone of Karabakh, especially considering the forecasts for the increase in electricity and fuel prices and the abundance of individually constructed houses in this region.

Conclusion

1. The heat pump system is an environmentally friendly heating and cooling system from an ecological perspective. The applied heat pump does not pose an ecological threat to the people living in the environment.
2. The heat pump operates continuously and does not require special attention.
3. In the Karabakh region, specifically in Khankendi city, the possibilities of using heat pumps from various sources for the heating equipment of individual residential houses have been explored, identifying the type with high energy potential.
4. In the Karabakh region, in Khankendi city, the research has shown that the use of ground-source heat pumps is more effective in heating supply, considering the climatic conditions.

5. The fundamental scheme of the heat pump system is provided through computer simulation. Each characteristic parameter of the devices constituting this system has been calculated, and devices produced by the factory have been selected.

6. As a result, energy produced and used, required power, losses, etc., have been calculated for both the system and each component.

References

[1] Presidential Decree of the Republic of Azerbaijan: On declaring the year 2024 as the "Year of Solidarity for a Green World" in the Republic of Azerbaijan. December 25, 2023.

[2] Ilham Aliyev. (February 2, 2021) "Azerbaijan 2030: National Priorities for Socio-Economic Development."

[3] Ilham Aliyev. (January 5, 2022) "Presidential Decree on declaring 2022 as the 'Year of Shusha' in the Republic of Azerbaijan."

[4] GeoT*SOL Basic Version 1.0. "Design and Simulation of Heat Pump Systems User Manual."

[5] Anarbayev A.I., Koroli M.A. "Development and Implementation of a Combined Solar Heat Pump System." "Energeticheskaya Bezopasnost : Sb. Nauch. St. III Mezhdunar. Kongressa," Kursk, October 16-17, 2020. Vol.2. - Kursk, 2020. - P.374-378. - Bibliography: 1 title.

[6] Sadiyev U.A., Normominov M.T. "Use of Pumps in Heat Supply Systems." // International Journal of Academic Engineering Research (IJAER) ISSN: 2643-9085 Vol. 5 Issue 4, April - 2021, Pages: 49-51.

[7] Babayeva S.Sh. "Prospects of using heat pumps in the heating system of an individual residential building in Kalbajar city." / International Conference on Reconstruction and Recovery in Post-Conflict Situations RRPCS 2022. February 24-25, 2022. Baku, Azerbaijan.

[8] International Energy Agency. "Net Zero by 2050: A Roadmap for the Global Energy Sector."

[9] Babayeva S.Sh. (2022) "Research on the operation of heat pumps working in monovalent mode in the heating system." // "Problems of Energy" scientific and technical journal No. 1, Baku, pp. 25-31.

MINING ACTIVITY IN GEORGIA AND NON-STATIONARY MODEL OF INTENSIVE CHANGE OF SOIL POLLUTION

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Abstract

In the era of developed industry, the contamination of the environment with radioactive elements and heavy metals turned out to be particularly dangerous, which became the cause of significant social problems in densely urbanized areas. This is evidenced, for example, by the special scale of oncological diseases and frequent genetic mutations.

Keywords: soil contamination, diffusion model, soli pollution, mining activity

I. Introduction

In the recent past, radiation pollution often occurred in particularly densely urbanized areas of industrial zones in Georgia. At present, the level of radiation contamination of the inspected part of Rustavi territory with Cs-137, Sr-90 and K-40 radioactive elements is not alarming. However, a reliable representation of the retrospective picture of the radiation situation requires an assessment of the change in the level of soil contamination in time and space. For this, we need to know the power of the pollution source and its duration. It is natural that environmental pollution develops both in space and time. Creating an adequate mathematical analogue of the process of spreading pollution in the soil is a task of particular difficulty. Its exact analytical solution is impossible, although there are approximate solutions, on the basis of which it is possible to correctly model the dynamic picture of pollution. In contrast to atmospheric pollution, the process of diffusion in the soil is significantly influenced by the orography of the earth's surface, the agrochemical nature of the soil and its magnetic properties. When modeling the spread of soil surface pollution in time and space, it is permissible to ignore the effect of the convection flow of surface waters.

II. Methods

In general, it is fair that the migration process of chemical pollution in the soil is significantly determined by the slow movement of groundwater, the so-called. Filtration, which is affected by atmospheric precipitation. In addition, in contrast to atmospheric pollution, the process of diffusion in the soil is significantly influenced by the orography of the earth's surface, the agrochemical nature of the soil and its magnetic properties. Despite such diversity, in some cases it is acceptable that some of these factors are not equally effective. When modeling the spread of soil surface pollution in time and space, it is permissible to ignore the effect of the convection flow of surface waters. Depending on the terrain, it is also possible to use the non-stationary diffusion equation.

III. Results

This general feature of the solution of the diffusion equation represented by Fourier components can be useful for the approximate retrospective reconstruction of the dynamic picture of pollution in the central park of Rustavi. It is obvious that for an approximate reconstruction it is enough to interpolate the measurement results separated by a certain time interval by means of the given graphic representations as palettes. In such a case, it becomes possible to specify the approximate date of the initial moment of pollution, as well as the prediction of the moment of leveling to the characteristic background value of surface soil pollution in the future.[1] For example, in the case of an orographically simple surface, the approximation of azimuthal symmetry is physically permissible

$$\frac{\partial K}{\partial t}=D\left(\frac{\partial^2 K}{\partial r^2}+\frac{2}{r}\frac{\partial K}{\partial r}\right),\ t>0 \quad [1]$$

Where, k is the concentration, D is the diffusion coefficient, t is the time, r is the radial coordinate. We can consider two models.

$$T=\left(\frac{n\pi}{R}\right)^2 Dt \geq 0.4 \ [2].$$

In the first case, the circle of initial concentration of chemical pollution. The distribution will be constant. In the second case, at the initial moment we will have point pollution. If we assume that there is no chemical pollution at the boundary, for both models of initial pollution we will have a suitable boundary condition of normalized background value: K(R,t)=0. In general, both variants of are suitable for modeling the dynamic change of chemical pollution on the Earth's surface and in the soil. represent the qualitative-quantitative visualization of the solution for both variants of the condition [2]. It is obvious that for an approximate reconstruction it is enough to interpolate the measurement results separated by a certain time interval by means of the given graphic representations as palettes [3]. In such a case, it becomes possible to specify the approximate date of the initial moment of pollution, As well as the prediction of the leveling moment of soil surface pollution to the characteristic background value in the future.

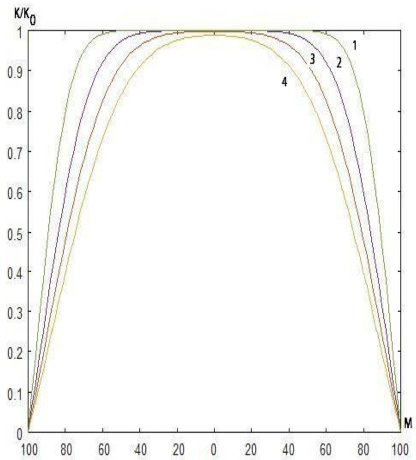

Figure 1: *Figure caption*

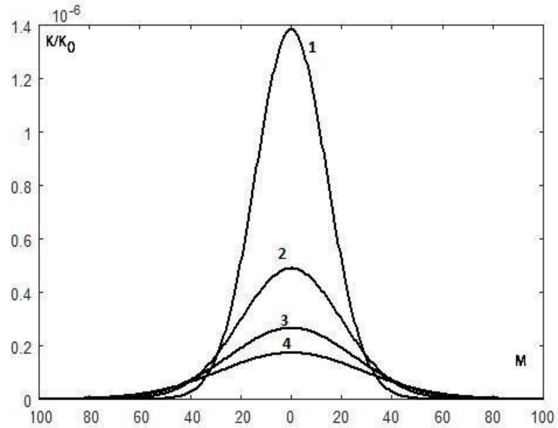

Figure 2: *Figure caption*

IV. Discussion

For the completeness of the analysis, Fig. 3 shows the history of the first graph of Fig. 2. togram (n=20), and in Fig. 4 - the corresponding percentage spread. It should be noted that qualitative information regarding the physical purpose of the immeasurable parameter T is revealed, as the effect of the diffusion coefficient in combination with time becomes evident.[4] Approximation of the ratio of pollution levels by means of the given graphic visualization roughly, However, quite correctly, it allows to determine the quantitative characteristic of the decrease of pollution intensity in time and space.

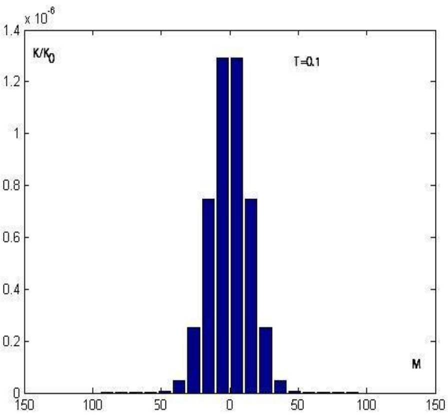

Figure 3.

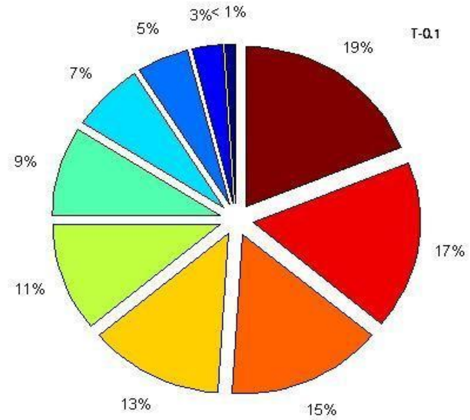

Figure 4.

References

[1] Tikhonov A.N., Samarsky A.A. Equations of Mathematical Physics. 1999 799s

[2] Carslow G., Eger D. Thermal conductivity of solids, M. Science. 1964.- 488 p.

[3] Nadareishvili , Gugushvili . "Radiation ecology" - bibliography. Ecological Scientific Society of Georgia, Bio-medical equipment. Society - Tbilisi, 1991, Vol. I, p. 608

[4] Mirianashvili K., "Atmospheric pollution factors and Mathematical modeling of changes in meteorological elements and Study of their influence on human health Publishing House of the State University, Tbilisi, 2005, 195p.

CLIMATE CHANGE IN MOUNTAINOUS REGIONS AND ITS IMPACT ON THE PHYSICAL DEVELOPMENT OF YOUNG PEOPLE: PROBLEMS AND PROSPECTS

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Abstract

This study examines the implications of climate change in mountainous regions on the physical development of young people. As climate patterns continue to shift, mountainous areas are experiencing alterations in temperature, precipitation, and seasonal cycles, which can significantly affect the growth and health of youth populations. The research highlights various problems arising from these changes, such as increased susceptibility to respiratory and cardiovascular diseases, altered nutrition due to changes in local agriculture, and the psychological impacts of environmental stressors. Moreover, the study identifies potential prospects for addressing these challenges through community engagement, health education, and policy interventions. It emphasizes the importance of fostering adaptive strategies to enhance resilience among young people in mountainous regions, ensuring their physical development is supported in the face of climate change. By implementing sustainable practices and promoting environmental awareness, communities can mitigate adverse effects and promote healthier futures for the youth. The levels of the mass-height index, Broca's index, Quetelet's index and maximum permissible mass in the mid-mountain region among girls decreased to 36.5 kg/cm, 56.0 kg, 362.5 g/cm and 51.7 kg, and on the plain they were 38.5; 62.7; 384.5 and 65.1, respectively. Among young men, at an altitude of 1600 m above sea level, there was a decrease in the values of the mass-height index, Broca's index, Quetelet's index and maximum permissible mass to 43.0 kg/cm, 62.7 kg, 429.9 g/cm and 63.1 kg, and the initial values were 44.2; 66.7; 441.5 and 78.5, respectively. The value of the vital index in low-mountain and mid-mountain conditions increased to 50.0 and 58.7 ml/kg for girls, to 60.6 and 66.3 for boys, and was 46.3 and 54.8 for control students.

Keywords: climate change, mountainous regions, body weight, vital capacity, mass-height index, Broca's index, vital index.

I. Introduction

Climate change poses one of the most significant challenges of the 21st century, impacting ecosystems, weather patterns, and human health across the globe. Mountainous regions, known for their unique biodiversity and distinct climatic conditions, are particularly vulnerable to the effects of climate change. As temperatures rise and weather patterns become increasingly unpredictable, the physical development of young people living in these areas is at risk.

Young people in mountainous regions face a myriad of environmental challenges that can adversely affect their growth and health. Factors such as increased air pollution, altered precipitation patterns leading to water scarcity, and the shifting availability of local food sources directly influence their nutrition, physical activity levels, and overall well-being. These changes can lead to an array of health issues, including respiratory illnesses, nutritional deficiencies, and reduced physical fitness. Moreover, the psychological impact of climate change, characterized by anxiety about the future and stress related to environmental instability, can further hinder the healthy development of youth.

Understanding the intricate relationship between climate change and the physical development of young people in mountainous regions is essential for developing effective interventions. This study aims to explore the multifaceted problems arising from climate change in these areas, while also identifying potential prospects for promoting resilience and adaptive strategies. By fostering community engagement and enhancing health education, stakeholders can play a vital role in addressing the challenges posed by climate change, ensuring the physical well-being and development of young people in mountainous regions.

This research not only highlights the pressing need for action but also emphasizes the importance of sustainable practices that can mitigate the effects of climate change. Ultimately, it seeks to provide insights that will contribute to healthier futures for young populations in vulnerable mountainous areas, enabling them to thrive despite the environmental challenges they face.

The physiological development of students living and studying in mountainous regions is shaped by unique environmental factors that distinguish these areas from lowland or urban settings. Mountain terrains are characterized by higher altitudes, lower atmospheric pressure, reduced oxygen levels, colder temperatures, and rugged landscapes, all of which contribute to a distinctive physical and physiological adaptation process in individuals.

This setting imposes various challenges on the human body, particularly during developmental stages such as adolescence, when the body is highly responsive to environmental conditions. Factors such as altitude-induced hypoxia (reduced oxygen supply), increased physical activity due to steep terrains, and the need for thermal regulation all play significant roles in shaping the growth, cardiovascular fitness, respiratory capacity, and overall stamina of students in these regions.

The unique demands of mountain environments stimulate specific adaptive responses, which can lead to variations in lung capacity, red blood cell production, muscular development, and metabolic efficiency compared to students living at lower altitudes. Understanding these physiological adaptations is critical for ensuring that educational and health programs are tailored to meet the needs of students in mountain regions.

This introduction sets the stage for exploring how the interplay of environmental stressors, physical activity, and altitude influences the physiological growth and health outcomes of students, highlighting both the benefits and challenges posed by mountainous terrains.

In various environmental conditions, the human body is capable of maintaining the constancy of the internal environment through adaptive responses, as well as regulating the functional activity of its systems due to the fact that it is a self-regulating and self-sustaining system.

In response to the effects of mountain hypoxia, the human body begins a process of adaptive reactions, primarily from the cardiorespiratory and nervous systems. People who are not prepared for the effects of mountain hypoxia begin to feel the negative effects of altitude at an altitude of 2500-3000 m above sea level. When healthy people climb mountains at an altitude of 4000 meters, every fifth person experiences symptoms of altitude sickness, the severity of which depends on the individual characteristics of the body. Residents living at an altitude of 4500 m experience adaptation disorders that lead to decreased performance.

Mountainous terrain above 4500 meters is uninhabited, and the conditions of this terrain have a negative impact on human health. The body's adaptive reactions disappear at an altitude of 6500-7000 meters [10].

Researchers have long established that prolonged exposure to high-altitude hypoxia is accompanied by an increase in the body's reserves and stimulation of the activity of vital body systems. At the same time, the negative impact of negative environmental factors is reduced. The process of adaptation to mountain conditions is to some extent controllable, but its effectiveness decreases at high altitudes. The number of people doing their jobs and enjoying active recreation in the mountains increases year after year. Therefore, research aimed at studying the state of human body systems and developing methods for preventing possible disruptions in their functioning in mountainous areas is relevant.

On the other hand, as the number of people living in mountainous conditions increases, the number of people exposed to the negative factors of this area increases. Therefore, determining the state of the body and its resistance to the effects of mountain conditions is of particular importance. This makes the study of the physiological development of students in mountainous areas important.

II. Methods

Laboratory equipment of the Department of Physiology and Anatomy of Humans and Animals was used to conduct the research.

The object of the study were 180 (90 girls and boys) clinically healthy full-time students. Of these, depending on the altitude of residence above sea level (Grozny - 170 m, Shatoi district - 600 m, Sharoi district - 1600 m), 3 groups were formed. Each group included thirty girls and boys. Residents of the plain were considered the control or first group, lowlanders - the second, and mid-mountains - the third.

To determine the physiological development of students, we used body weight, body length, maximum permissible weight according to B.I. Tkachenko 1994 and calculated indicators: mass-height indicator MHI = weight, kg x 100 / height, cm; body mass index BMI = weight, kg / height, m **2** ; vital index VI = VC, ml / weight, kg; Quetelet index CI = weight, g / height, cm; expected body weight according to Broca's index: for height up to 155 cm, weight = height, cm – 95; 156-165 cm, weight = height, cm – 100; 166-175 cm (height – 105); 175 and above (height – 110). The state of the respiratory system was studied using the Diamant-S spirograph.

Biometric control of experimental data was carried out using the Biostatistics program, comparison of average indicators of groups using the Student's criterion.

IV. Discussion

The weight, height and VC of students in the mountains are given in Tables 1-2 and Figures 1-2. From these tables and figures it is evident that in mountain conditions there is a statistically significant change in the weight, body length and VC of students.

Thus, the body length of girls and boys in the third group is 12.7 (P < 0.01) and 13.3 cm (P < 0.02) lower than the initial values.

Table 1: *Physical development indicators and vital capacity of lungs of girls*

Terrain	Height in cm	Body weight in kg	YELLOW in L
Plain	164.7±3.49	63.3±1.38	2.93±0.061
Lowlands	158.6±3.12	61.7±1.53	3.08±0.062
Middle Mountains	152.0±1.86***	55.1±0.83****	3.23±0.041***

*** – P < 0.01; **** – P < 0.001

The body weight of girls and boys living in mid-mountain conditions decreased by 8.2 (P < 0.001) and 7.8 kg (P < 0.01) compared to the values of lowland residents.

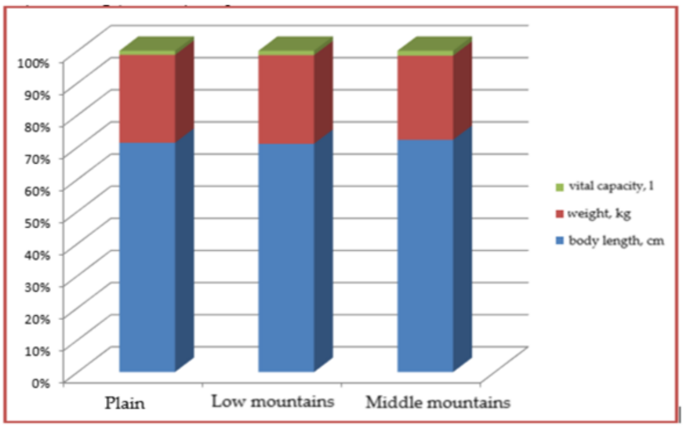

Figure 1: Height, weight and vital capacity of female students under hypoxic conditions

Our results are confirmed by other researchers. Thus, the distinctive features of mountain dwellers are short stature and reduced body weight [12]. Long-term residence in conditions of mountain hypoxia is accompanied by a decrease in body length and weight by an average of 13.5 cm and 9 kg [12]. Living in the highlands reduces a person's height and weight by 17.7 cm and 15.3 kg compared to lowland residents [11, 13, 8].

Most populations of people of different racial and ethnic origins living in mountainous areas are characterized by slow growth processes and large body sizes [2]. Due to the low body volume, highlanders consume less oxygen [5].

Exposure to mid-mountain conditions increased the level of vital capacity in girls by 0.30 l ($P < 0.01$) and in boys by 0.37 l ($P < 0.02$) relative to the values of the control groups.

People living in conditions of high-altitude hypoxia have a high number of respiratory movements per minute, high lung ventilation and lung capacity, as well as large respiratory volumes of the lungs [15].

Table 2: *Height, weight and vital capacity of young men*

Terrain	Height in cm	Body weight in kg	YELLOW in L
Plain	173.7±2.90	76.7±1.26	4.20±0.072
Lowlands	167.6±3.68	72.5±1.69	4.39±4.39±0.095
Middle Mountains	160.4±3.63**	68.9±1.39***	4.57±0.103**

** – $P < 0.02$; *** – $P < 0.01$

Aidaraliev A.A. [3] concluded from the results of his research that an increase in respiratory volume is the cause of increased lung ventilation in humans when exposed to hypoxia.

According to B. Messerli and J.D. Ives [7], as well as O.G. Gazenko [16], mountain dwellers have a large chest, high vital capacity and a high level of oxygen in the blood. At the beginning of the process of human adaptation to conditions of oxygen deficiency in the inhaled air, an increase in the amount of alveolar ventilation occurs [6]. An increase in the depth of breathing and ventilation of the lungs is the human body's response to the effects of insufficient oxygen content in the environment [14]. Apparently, exposure to high-altitude hypoxia causes an increase in the vital capacity of the lungs in students due to an increase in the tone of the inspiratory muscles.

Thus, due to the high tone of the inspiratory muscles, the vital capacity in conditions of high-altitude hypoxia is 10% greater [1]. Probably, due to the stimulation of the respiratory center by the oxygen deficiency, the strengthening of the respiratory system function is caused. When a person adapts to conditions of mountain hypoxia, the functional activity of the systems that supply the body with oxygen increases [9].

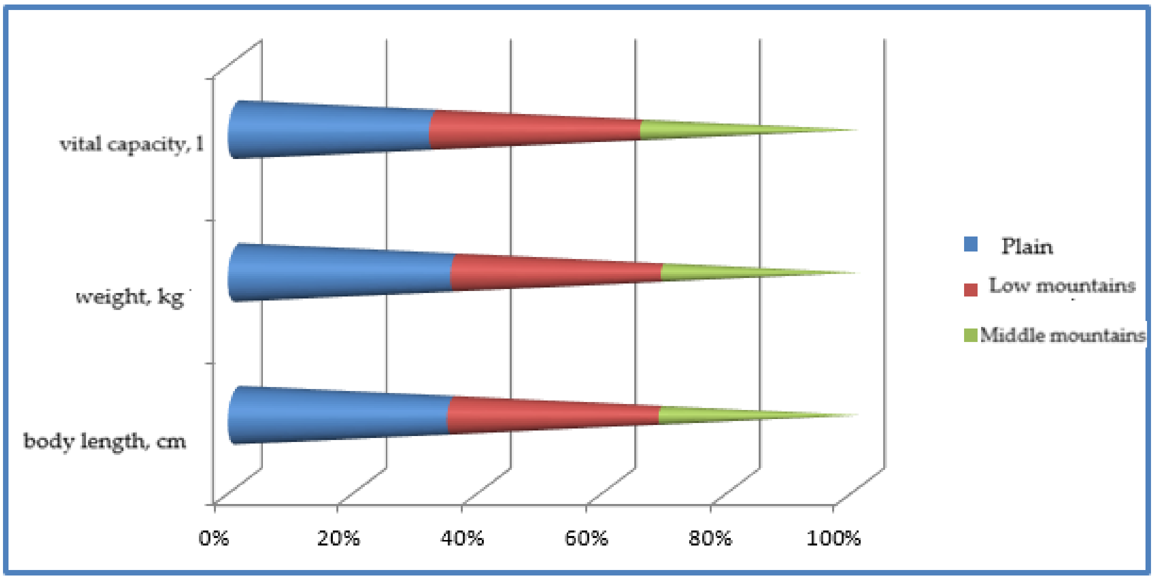

Figure 2: *Weight, height and vital capacity of young men under hypoxia*

Increased pulmonary ventilation and a reduction in the time of hemoglobin oxygen saturation are caused by low oxygen content in the external environment [4]. When exposed to hypoxia, statistically significant changes occur in the physiological development indicators of students, with the exception of body mass index (Table 3-4 and Fig. 3-4).

Thus, the value of the mass-height indicator in girls and boys in mid-mountain conditions is lower by 2.0 (P < 0.001) and 1.2 kg/cm (P < 0.05) relative to the initial level.

Table 3: *Indicators of physiological development of girls in conditions of mountain hypoxia*

Indicators	Altitude above sea level in meters		
	170	600	1600
Weight-height index, kg/cm	38.5±0.23	38.9±0.49	36.5±0.37****
Body mass index, kg/ m2	23.4±0.54	24.6±0.51	23.9±0.39
Broca's index, kg	62.7±1.72	59.1±1.84	56.0±1.05***
Vital index, ml/kg	46.3±0.28	50.0±0.66****	58.7±0.62****
Quetelet index, g/cm	384.5±2.30	388.8±4.86	362.5±3.67****
Maximum permissible weight, kg	65.1±3.72	58.5±3.18	51.7±1.91***

*** – P < 0.01; **** – P < 0.001

The MCI value of girls in the conditions of the plain and low mountains (38.5 and 38.9 kg/cm) indicates a normal ratio of body length and weight, and in the mid-mountain (36.5) - low nutrition. The level of MCI in the groups of boys shows their increased fatness.

The level of the Quetelet index in groups of men indicates the presence of excess weight. The decrease in the maximum permissible weight in girls and boys in the midlands was 13.4 (P < 0.01) and 15.4 kg (P < 0.02) relative to the values of the control students.

The maximum permissible weight for the group of girls in plain conditions is 1.8 kg higher than the actual weight, and for the second and third groups it is 3.2 and 3.4 kg lower, respectively. The actual weight of the boys in the first group is 1.8 kg lower than the maximum permissible weight, and in low-mountain and mid-mountain conditions it is 2.2 and 5.8 kg higher.

Thus, mountain hypoxia causes a reliable decrease in the level of mass-height index, Broca's index, Quetelet index, maximum permissible mass and a statistically significant increase in the vital index in students.

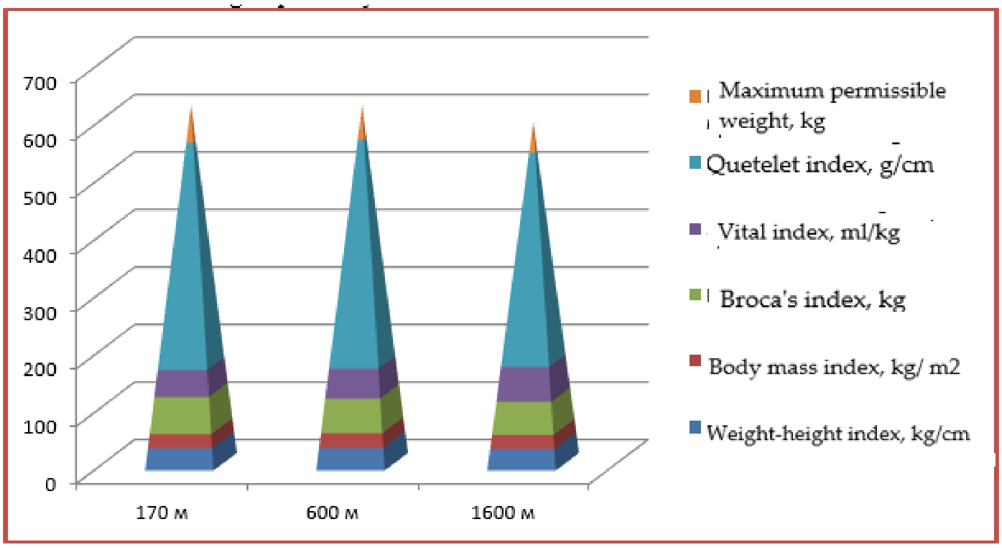

Figure 3: *The impact of hypoxia on physiological development indicators of female students*

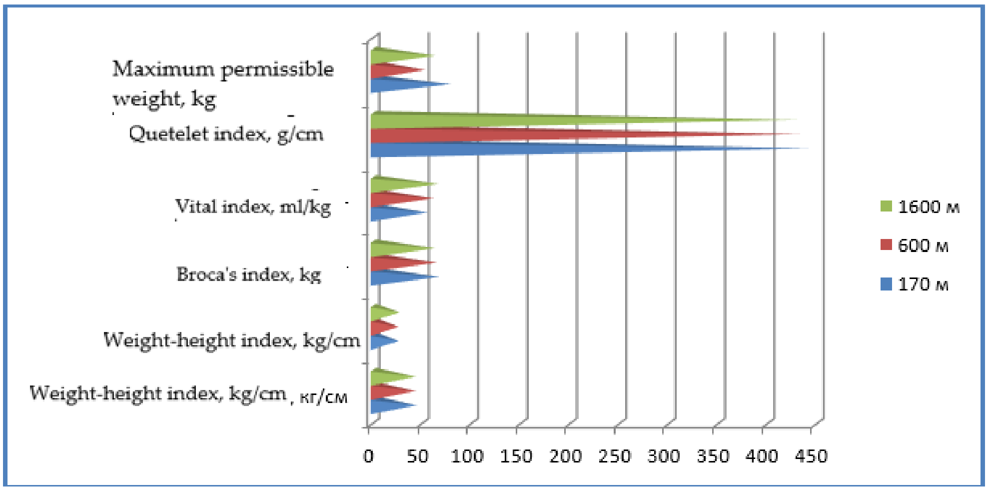

Figure 4: *The influence of mountain hypoxia on the physiological development of young men*

In girls and boys living in mid-mountain conditions, body height is 7.8 ($P < 0.01$) and 7.7% ($P < 0.02$) lower, and weight is 13.0 ($P < 0.001$) and 10.2% ($P < 0.01$) lower than in lowland residents.

At an altitude of 1600 m, the level of vital capacity in girls is 10.2% higher, and in boys it is 8.8% higher compared to the values of students in the control groups. Under conditions of high-altitude hypoxia, statistically significant changes occur in the values of the MRP, Broca's index, GI, IC, and the maximum permissible weight of students. The mass-height index of girls and their peers living in the mid-mountain regions is lower by 5.2 ($P < 0.001$) and 2.7% ($P < 0.05$) compared to the values of the first groups. In the mid-mountain region, the Broca index is 10.7% lower ($P < 0.01$) among girls, and 6.0 lower among boys relative to the baseline values. The level of vital index in girls and boys in the low mountains increased by 8.0 ($P < 0.001$) and 10.6% ($P < 0.001$), and in the mid-mountain regions by 26.8 ($P < 0.001$) and 21.0 ($P < 0.001$) compared to the values of students in the control groups. The Quetelet index value in mid-mountain conditions decreased by 5.7% ($P < 0.001$) among girls and by 2.6% ($P < 0.05$) among boys relative to the level of those living on the plain. The maximum allowable weight of girls and boys living in the mid-mountain areas decreased by 20.6 ($P < 0.01$) and 19.6% ($P < 0.02$) compared to the initial values.

The impact of climate change on the physical development of young people in mountainous regions is a complex interplay of environmental, social, and health factors. As this study outlines, the physiological effects of changing climate patterns can manifest in various ways, influencing the overall well-being and growth trajectories of youth. Understanding these interconnections is crucial for developing targeted interventions and policies.

One of the most immediate consequences of climate change in mountainous areas is the deterioration of air quality due to increased pollution and wildfires, leading to respiratory diseases. Young people, whose lungs and immune systems are still developing, are particularly vulnerable. Research has shown that children and adolescents living in areas with poor air quality experience higher rates of asthma and other respiratory illnesses. Additionally, changes in temperature and precipitation can exacerbate these conditions, leading to a cycle of health issues that further hinders physical development.

Nutritional status is another critical area impacted by climate change. As agricultural patterns shift due to changing climatic conditions, the availability of local food sources may decline, leading to food insecurity and poor nutritional outcomes. In mountainous regions, where access to diverse food options is already limited, these changes can result in higher rates of malnutrition among young people. Poor nutrition during critical growth periods can have long-lasting effects on physical development, including stunted growth, weakened immune systems, and cognitive impairments.

The psychological impacts of climate change should not be overlooked. Young people in mountainous regions may experience heightened anxiety and stress due to environmental changes, including natural disasters, loss of familiar landscapes, and uncertainty about the future. These psychological factors can contribute to mental health issues, which may further impede physical development. Creating supportive environments where young people can express their concerns and seek help is essential for addressing these challenges.

Addressing the impact of climate change on the physical development of young people requires comprehensive community engagement and policy interventions. Schools and local governments can play a crucial role by integrating climate education into curricula, raising awareness about the health implications of climate change, and promoting sustainable practices.

Programs that encourage physical activity in nature can help mitigate some of the health risks associated with climate change while promoting mental well-being. Initiatives that support local agriculture and food security can also improve nutrition, ensuring that young people have access to healthy foods that are essential for their growth and development.

Additionally, mental health support systems should be established to assist young people in coping with the stressors associated with climate change. This can include counseling services, community workshops, and youth-led initiatives aimed at fostering resilience and promoting mental health.

Further research is essential to deepen our understanding of the long-term effects of climate change on the physical development of young people in mountainous regions. Longitudinal studies can provide valuable insights into how changing climate patterns influence growth and health over time. Investigating the effectiveness of specific interventions aimed at mitigating these impacts will also be crucial for informing future policies and practices.

In conclusion, the physical development of young people in mountainous regions is intricately linked to the challenges posed by climate change. By recognizing the multifaceted nature of this issue, stakeholders can develop targeted strategies that address health implications, promote resilience, and support sustainable practices. Ensuring the well-being of young populations in vulnerable areas is not only vital for their individual health but also for the broader goal of fostering sustainable and healthy communities in the face of climate change.

References

[1] Agadzhanyan N.A. Mountains and body resistance / N.A. Agadzhanyan and M.M. Mirrakhimov. – M.: Nauka, 1970. – 184 p.

[2] Adaptation processes to highland conditions. https://vk.com/wall-767095_223443 .

[3] Aidaraliev A.A. Comprehensive assessment of the body's functional reserves / A.A. Aidaraliev [and others]. – Frunze: Publishing house "Ilim", 1991. – 195 p.

[4] The impact of hypoxia on humans in the mountains https://student-servis.ru/spravochnik/vliyanie-gipoksii-na-cheloveka-v-gorah .

[5] Mountains of the World / edited by B. Messerli and J.D. Ives // Global Priority. – Moscow, 1999. – 430 p.

[6] Mountain dwellers turned out to be slimmer and healthier than plains dwellers. https://www.rosbalt.ru/style/2013/02/14/1093848.html .

[7] Mateeva E.V. Response of the human cardiovascular and respiratory systems to normobaric hypoxia before and after a course of interval hypoxic effects / E.V. Mateva // Fundamental research. - 2014. - No. 6-7. - P. 1406-1411

[8] Novikov V.S., Soroko S.I., Shustov E.B. Maladaptation states of a person under extreme influences and their correction. St. Petersburg: Politekhnika-print. 2018. 548 p.

[9] Human physiology in high altitude conditions: Handbook of physiology / edited by O.G. Gazenko. – Moscow: Nauka, 1987. – 520 p.

PROBLEMS OF CONSERVATION OF BIODIVERSITY IN THE CHECHEN REPUBLIC: CONDITIONS AND ANALYSIS

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Abstract

The Chechen Republic has one of the highest levels of biological diversity, due to the unique natural conditions and the presence of various high-altitude zones, ranging from semi-deserts to glaciers. This diversity includes animals from Europe, Asia, Siberia, and even Africa, making it a fascinating place to explore. However, the biological diversity in the region is still poorly understood. The vertebrate fauna in the Chechen Republic includes 44 fish species and subspecies, nine amphibian species, at least 31 reptile species, more than 320 bird species that nest, and up to 88 mammal species. Unfortunately, this rich ecosystem is threatened by the devastating effects of war, which have led to uncontrolled and intensive exploitation of natural resources. As a result, preserving the biodiversity of the area is a significant challenge. Many areas have changed, losing their original appearance. The environmental conditions for many animal species have deteriorated, leading to fewer of them. Some species, such as bison, moose, tarpans, kulans, and beavers have completely disappeared, while others, like the common grouse and geese, are becoming rare. Bezoar goats, chamois, martens, otters, minks, bustards, strepets, cranes, grey partridges and ulars have become few. Taking into account the current ecological situation in the republic and to preserve the unique fauna and flora, it is essential to take measures to conserve and increase the biodiversity of the landscapes.

Keywords: biological diversity, protected areas, natural framework

I. Introduction

The development of STR (Scientific and Technical Revolution) is accompanied by an increase in the level of economic development, which inevitably leads to a decrease in biodiversity and a reduction in species. If these processes exclude each other, then saving biodiversity both of living organisms and ecosystems becomes the most difficult task. In that case, it is necessary to think about conservation of biodiversity as an integral part of sustainable development rather than just as a part of nature conservation. In this context, a special role belongs to the creation and development of special educational systems for protected natural areas. This is one of the main directions in the work of state environmental organizations. Specially protected territories are part of our national heritage, and their conservation and protection is essential [1]. The protection regime of specially protected natural territories and the status of environmental institutions located within them differ in several categories. All of these territories form a state-owned nature reserve fund, which is under the jurisdiction and management of a specially authorized state body in the field of environmental protection.

II. Methods

We live in a time of many global challenges that can only be addressed through the combined efforts of all nations. Not even the most developed countries can solve these challenges on their own, as they affect everyone and require a collaborative approach to overcome.

The issue of preserving biodiversity has reached a point where it is a concern not only for those who study biological systems, but also for scientists, economists, politicians, and the general public [2].

For countries seeking to conserve and enhance the variety of biological resources, policies should be guided by addressing environmental challenges, which in turn will facilitate sustainable economic growth.

Turning to the term "diversity", it refers to differences between groups of entities and phenomena, and the extent of these variations can be quite varied. Biological diversity, in particular, pertains to the variety of living organisms, making "biological diversity" and "biodiversity" synonymous terms [3].

As it is known, the advancement of STR (Scientific and Technical Revolution) is accompanied by an upsurge in economic development levels, which in turn inevitably leads to a decline in biodiversity and reduction in species numbers. If these trends are mutually exclusive, the preservation of biodiversity for both living organisms and ecosystems becomes a challenging and difficult endeavor. In such a scenario, it becomes necessary to conceive of biodiversity conservation not as a component of environmental protection but rather as an integral aspect of the sustainable development paradigm.

The 1992 Convention on Biological Diversity, held in Rio de Janeiro, was a significant event in this regard. The Convention was intended to serve as a foundation for environmental research and the practical application of the findings of these studies. Two key concepts were emphasized in the Convention: preservation and utilization. This meant conserving and sustainably utilizing biodiversity. The term "sustainable utilization" used in the Convention referred to the idea that the rate and extent of utilization should not lead to the depletion of biodiversity. Thus, the Convention upheld the principle of protecting biodiversity through responsible use. It was acknowledged that the solution to biodiversity loss lies in collaborative efforts to conserve and restore biodiversity[4].

The global environmental issue is no longer solely related to the threat of biodiversity, but also to the impact on human health. Catastrophic oil spills and forest fires affecting tens of thousands of hectares, as well as imperceptible, but threatening forms of pollution, often occur in nature. Their effects may not be immediately apparent, but they can manifest themselves after some time and be unexpected [5].

An integrated approach to protecting and preserving what humanity has involves a resolute system of rules and penalties as well as an environmental monitoring service. The concept of "environmental ethics" is now in use and is a rapidly developing new area of philosophy that vividly illustrates the high ethical value of nature.

Following the principles of environmental ethics can help to preserve natural and biological diversity, which should become a fundamental and priority direction for the development of both the state and society. As a result of complying with these principles, there will be a steady decrease in production and consumption levels, leading to a more sustainable approach to resource extraction and consumption [6]. Additionally, there will be an expansion of protected natural areas, helping to ensure the long-term survival of biodiversity.

III. Results

There are several arguments in favor of the ethics of biodiversity conservation, regardless of the economic value of each species. In this context, all species contribute to the overall goal of survival. It is important to consider the diversity of species, rather than focusing on their numerical value, geographical location, age, or economic importance. Each species has a unique role in the natural and human world, and their extinction can have a significant impact on other species and ecosystems. This connection between all living things is essential for maintaining balance and harmony in nature [7,8].

In Russia, biodiversity conservation efforts began with the signing of Decree No. 236 by the President of the Russian Federation on February 4, 1994, titled "On the State Strategy of Environmental Protection and Sustainable Development in the Russian Federation".

In 2001, the National Strategy for the Conservation of Biodiversity in Russia was developed. This strategy highlighted the main directions and principles and set priorities for the long-term conservation of biological diversity in Russia.

The leading principles of this strategy included the following:

1) preservation of genotypes and reproductive capacity;
2) maintenance of population numbers and habitats;
3) protection of species and their natural habitats;
4) restoration and preservation of biocenoses;
5) preservation of natural ecosystems;
6) protection of natural complex territories;
7) conservation of the species composition of the biosphere as a whole.

But the preservation of biodiversity on the planet is a challenge that can only be addressed through the efforts of all nations. This issue is comparable to other global challenges that humanity has faced. We must recognize that this is not simply a matter of protecting nature, but rather a fundamental shift towards a more sustainable development model [9].

In its importance, this issue is of international concern and the solution to biodiversity problems lies in each country fulfilling its obligations. To this end, national legislation must be aligned with international standards.

Addressing biodiversity issues is crucial not only for the environment but also for human wellbeing. Surprisingly, conservation of biodiversity has been shown to be a leading factor in reducing poverty. As most people in underdeveloped countries live in rural areas, addressing biodiversity conservation issues would allow them to secure food and income.

The population of the Earth, depending on their place of residence, are oriented towards certain sources of livelihood. More than 3 billion people feed and live at the expense of marine and coastal areas. For 1.6 billion, forests and forest products are the source of livelihood, and the loss of biodiversity threatens the well-being of over 1 billion humans living in arid and semi–arid areas.

IV. Discussion

Summing up, biodiversity, its conservation, and protection are essential for the normal function of ecosystems and human well–being. This applies not only to economic development but also to health, food security, water supplies, and disaster prevention.

The steady growth of the world's population and, as a result, the proportional increase in its needs, which can be met by expanding industrial and agricultural production and developing transport, creates increased anthropogenic pressure on the environment.

The Law of the Chechen Republic No.10-RL (Russian Law) on Environmental Protection of July 4, 2006 with amendments regulates relations in the “nature-society” system in order to maintain dynamic balance.

Based on this, it follows that efforts must be made in order to create a natural ecological framework in the territory of the Republic to create conditions for sustainable development and conservation of landscapes and biological diversity.

To fully understand the role of natural and ecological systems, it is important to consider not only specially protected areas, but also other features such as forest belts, parks, green zones, and water protection areas. These additions to the protected framework will help reduce human impact on natural landscapes and ecosystems [10].

Additionally, it is essential to create areas where nature management can be approached with reference to cultural and historical traditions. This approach can help ensure a more gentle approach to environmental management, using traditional methods that have been proven effective over time. Finally, including disturbed lands within the natural and ecological system is crucial for maintaining balance and sustainability [11].

However, all these measures and proposals need to be supported by financial resources in order to ensure that they are implemented. Therefore, it is essential that all measures related to specially protected areas are included in the socio-economic development plans of the republic, as well as in the territorial schemes and district planning schemes, and in all forest management plans.

Another important condition for the use of SPNT (specially protected natural territories) is that it is possible only with the permission of relevant authorities in the field of environmental protection.

In this regard, we cannot ignore the "Red Book of the Chechen Republic", which was first published in 2007. Although the purposeful study of flora and fauna in the Chechen Republic has been going on for much longer, the Red Book summarizes a list of rare and endangered plant and animal species that require special protection.

It is a great responsibility for the Directorate of Specially Protected Natural Territories in the Chechen Republic to preserve and protect endangered plant and animal species listed in the "Red Book". The Directorate is responsible for implementing special protection measures for protected areas in order to ensure their survival. The Directorate should strengthen the special protection regime and monitor the functioning and management of protected areas to ensure that they are properly protected [12].

It is also important to pay attention to the lack of warning and signage along the perimeter and boundaries of protected areas, as well as to organize proper records of owners, landowners, and users in order to establish clear responsibility for compliance with special protection regulations.

The task of ensuring proper control over specially protected natural areas is a challenging one, but it is essential for the conservation and restoration of biodiversity. This task begins at the local level and extends to the level of administrative and municipal authorities.

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References

[1] Ahmieva R.B. Vetrosaschitnye Forest Plantations and Their Role in the Reduction of Adverse Climatic Phenomena. Fundamental and Applied Scientific Research: Current Issues, Achievements and Innovations: Collection of Academic Papers of the VIII International Scientific Conference: In 4 Parts. P. 1. Penza, Nauka i Prosveshcheniye Publ., 2017, pp. 200-202.

[2] Gunya A.N., Gakaev R. A. Landscape approach to the study of landslides (on the example of the mountainous territory of the Chechen Republic). Problems of regional ecology. 2024. No. 1. P. 64-73.

[3] Gunya A.N., Gakaev R. A., Badaev S. V. The role of climatic conditions in the activation of landslides in the Mountainous part of the Chechen Republic, 2012, 4(13), pp. 9-12.

[4] Kalov, R. O., Gakaev R. A. The place of natural grass ecosystems in the global carbon balance. Problems of regional ecology. 2022. No. 6. P. 50-54

[5] Gakaev, R., Bakhaev, M.-S., Edisultanov, S. Global climate policy trends and challenges for Russia. Reliability: Theory and Applications, 2022, 17, pp. 450–457

[6] Kasimov N. S., Klige R. K. Modern global changes in the natural environment: Monograph: In 2 Volumes.Vol. 1. M.: Scientific World, 2006. 696 p.

[7] Gakaev R.A., Akhmieva R.B., Dzhandarova L.Kh., Trends in Global Low-Carbon Development, 172, 05002 (2023). DOI: 10.1051/shsconf/202317205002

[8] Eskiev M., Akhmieva R., Jandarova L. Carbon farming as a new climate change management tool in Russia. BIO Web of Conferences. I International Conference "Biotechnologies in the Context of Human Development" (BCHD - 2023). Les Ulis, 2023. C. 02003.

[9] Gakaev R., Sequestration of carbon in soil on the example of forest cenoses in the Chechen Republic, 2022, 2650, 030002

[10] Gakaev R.A., Functional classification of forests: Study of carbon sequestration, 76, 06004 (2023). DOI: 10.1051/bioconf/20237606004

[11] Gakaev R.A., Akhmieva R.B., Dzhandarova L.Kh., Trends in Global Low-Carbon Development, 172, 05002 (2023). DOI: 10.1051/shsconf/202317205002

[12] Daukaev A. A., Gatsayeva L. S., Gakaev R. A., Golik V.I. Synergetic manifestations of natural and man-made geodynamic processes on the territory of the Chechen Republic. // Bulletin of Tula State University. Earth Sciences. 2023.No. 4. P. 188-197.

SEASONAL CLIMATE CHANGES AND THEIR IMPACT ON FEMALE STUDENTS' IMMUNITY: RELATIONSHIP WITH THE CONCEPT OF SUSTAINABLE DEVELOPMENT

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Abstract

This study explores the impact of seasonal climate changes on the immunity of female students, highlighting the intricate relationship between environmental factors and health. Seasonal fluctuations, including temperature variations, humidity levels, and air quality changes, can significantly influence immune system responses. The research examines how these climatic factors affect the health and academic performance of female students, particularly in terms of increased susceptibility to illnesses during certain seasons. Moreover, the study emphasizes the importance of sustainable development in addressing these challenges. By promoting environmentally friendly practices and raising awareness about the impact of climate change on health, educational institutions can create supportive environments that enhance student resilience and well-being. The findings underscore the necessity of implementing health education programs focused on nutrition, physical activity, and stress management tailored to seasonal variations. Ultimately, this research advocates for a holistic approach that integrates health promotion with sustainable development strategies, aiming to improve the quality of life for female students in the context of a changing climate. The work is devoted to the study of the state of the health coefficient of female students in different seasons of the year. The conducted studies show that statistically significant changes in the blood pressure and health coefficient of girls are subject to seasonal changes. Thus, the level of SBP in girls increased to 127.5 mm Hg in winter, and was 113.4 in summer. The value of diastolic pressure in winter increased to 81.2 mm Hg, and the initial value was 74.5. The value of the health coefficient is maximum in winter - 1.83 and minimum in summer - 1.59. The heart rate in winter increased to 81.4 beats per minute, and in the control girls it was 77.2.

Keywords: Seasonal climate changes, season of the year, body weight, heart rate, blood pressure, health coefficient

I. Introduction

Seasonal climate changes have profound effects on various aspects of human health, including the immune system's functionality. For female students, who often juggle academic responsibilities, social engagements, and personal challenges, these seasonal fluctuations can pose significant health risks. Research indicates that variations in temperature, humidity, and air quality can lead to increased susceptibility to infections, allergies, and stress-related illnesses, all of which may adversely impact academic performance and overall well-being.

In recent years, the connection between environmental factors and health has gained increased attention, particularly in the context of sustainable development. The concept of sustainable development emphasizes the need for environmentally conscious practices that not only protect natural ecosystems but also promote the health and well-being of communities. As the climate continues to change, it becomes imperative to understand how these alterations affect specific populations, particularly vulnerable groups such as students.

This study aims to explore the intricate relationship between seasonal climate changes and the immunity of female students. It seeks to identify the specific ways in which environmental factors influence their health and to emphasize the importance of integrating health education and sustainable practices into academic settings. By understanding these dynamics, educational institutions can develop effective strategies to enhance the resilience and well-being of female students, ensuring they thrive academically and personally despite the challenges posed by a changing climate.

Considering that the health of an organism is determined by its adaptive capabilities, health is the process of adaptation of an organism to the environment [1]. A prerequisite for the successful functioning of the body is the assimilation of the rhythm set by nature. Due to the high level of coherence of cells, tissues, organs and body systems, the human body is often compared to a symphony orchestra. Biological rhythms caused by the rotation of the Earth around the Sun play an important role in the lives of humans and animals. Seasonal rhythms are considered to be seasons of the year that have different climatic conditions.

Rhythms with an annual period are the vegetation cover of the Earth, the migration of birds, the winter hibernation of animals and the activity of the reproductive system. The change of seasons is caused by the cycle of the year. The length of daylight causes the seasonal cycles of the plant and animal world.

The rhythmicity of biological processes is an inseparable property of living matter. The vital activity of plant and animal organisms occurs in rhythmically changing environmental conditions.

The process of adaptation to seasonal conditions of flora and fauna is aimed at creating optimal conditions for their vital activity. Various natural factors that affect a person and to which he adapts determine his health, well-being, activity, etc. Affecting all organs and systems of the human body, seasonal biorhythms change its performance and health. Accordingly, due to the adaptation of organisms to changing living conditions, biorhythms determine their survival. Different climate zones are characterized by different weather conditions. The reflection of various physiological processes in the human body occurs due to the presence of more than 100 biological rhythms.

Thanks to the biological clock, various rhythms of physiological processes are established. The complex of periodic changes called biorhythm is an amazing feature of the human body. Thus, biorhythm is a periodic change in the activity of the body's functional processes. The individual characteristics of the human body and the effectiveness of its mechanisms of adaptation to seasonal conditions determine its ability to withstand the impact of environmental factors.

The seasonal rhythms of each region are based on its climate. Thus, the features of the winter season of the year are an increase in the basal metabolism and fat metabolism, an increase in lung ventilation and irritability of the sympathetic branch of the autonomic nervous system.

In the summer season, the direction of changes occurring in the body is opposite.

Ukhtomsky A.A. believes that the time it takes for biological rhythms to be assimilated is individual for each person. Alternating increases and decreases in functional activity is more effective and economical than maintaining an average intensity for each organism. Achieving the highest possible human efficiency is only possible during the period of maximum activity.

The functional activity of the human body systems is high in the summer and low in the winter. The fact that a person works all year round requires him to maintain high activity of the body systems in the winter season.

Changes in biorhythms are a strong stress even for healthy people. In this connection, stimulation of the process of adaptation to living conditions must be carried out taking into account the peculiarities of human biorhythms. If a person stops following the call of nature, then disturbances from the biorhythm system occur in a short time.

Currently, the interest of doctors and physiologists in seasonal changes has grown significantly [21, 15, 22]. The study of biological rhythms allows us to determine the state of physiological functions, adaptive reserves and the body's immune system.

In recent years, much attention has been paid to the practical use of biorhythms.

The importance of studies devoted to seasonal changes is that in order to assess the normal indicators of body systems, it is necessary to take into account their seasonal characteristics.

Thus, the basis of treatment for many diseases is the restoration of the normal rhythm of the heart, lungs, stomach, intestines and central nervous system.

Taking into account the characteristics of circadian rhythms, the accuracy of diagnosis and the effectiveness of therapeutic interventions will be higher.

The body's mastery of the laws of biological rhythms allows it to maintain high performance and health.

Therefore, research aimed at determining the state of health coefficient of female students is relevant.

II. Methods

The research was conducted in the laboratories of the Department of Physiology and Anatomy of Humans and Animals. The respondents of the research were 35 clinically healthy female students of the biology and chemistry faculty of the full-time form of study. The summer season indicators were considered as control. The readings were made in a state of rest in the middle month of each season. The calculation of the health coefficient was made according to the formula:

KZ = 0.01 × HR + 0.01 SBP + 0.008 DBP + 0.014 V + 0.009 MT + 0.004 Sex (m-1, f-2) - 0.009 P - 0.273

where:

HR – heart rate in beats per minute;

SBP and DBP – systolic and diastolic blood pressure in mmHg;

A – age in years;

BM – body weight in kg;

H – height in centimeters

To determine the heart rate, systolic blood pressure and diastolic blood pressure, an automatic tonometer OMRON was used M 3 Expert.

For statistical processing of the research results, the Biostatistics program was used, and for comparison of the average indicators of the groups, the Student's criterion was used.

Seasonal features of anthropometric indicators are given in Table 1 and Figure 1.

Table 1: The influence of the season on the physical development of girls

Season of the year	Indicators		
	Height in cm	Weight in kg	Age in years
Summer	162.6 ± 2.95	61.1 ± 1.20	18.9 ± 0.13
Autumn	165.0 ± 2.49	62.5 ± 0.97	19.2 ± 0.15
Winter	166.1 ± 2.81	64.1 ± 1.08	19.5 ± 0.16
Spring	162.8 ± 2.91	61.3 ± 1.28	19.8 ± 0.22

There are no reliable changes in the height and weight of girls by seasons, however, their level is higher in winter and lower in summer. Thus, the body length higher in winter by 3.5 cm compared to the summer level.

The increase in body weight in the group in winter was 3.0 kg compared to the initial value. The difference in age between the mean values of the groups was 0.9 years.

Other researchers have also come to similar results in their studies. Thus, body weight increases by up to 5% in autumn and winter [5]. Throughout the year, body weight is at its maximum in winter and minimum in summer, which is explained by high physical activity in summer and low in winter [8]. The increase in body weight of each person in autumn and winter conditions ranges from 2 to 5 kg, which occurs due to the reduction in daylight hours, leading to overeating, as well as a slowdown in the metabolic process [9]. In studies conducted by Japanese scientists on elementary school children, it was found that their weight increases in autumn and winter and decreases in summer [3].

According to the results of research by American scientists, it has been established that the growth rate of children is higher in the autumn-winter season of the year, compared to the level of spring-summer [7]. Factors such as the accumulation of fatty tissue, changes in diet, reduction in the duration of daylight hours, a decrease in ambient temperature and increased stress cause an increase in body weight in the autumn and winter [5].

IV. Discussion

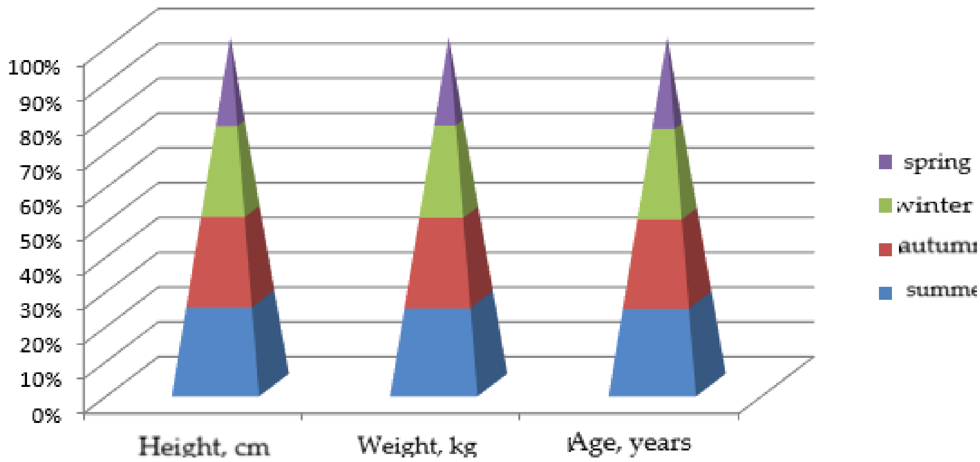

Figure 1: *Seasonal features of anthropometric indicators of girls*

The reasons for changes in body weight by season are activity and nutrition [4] . For example, an increase in physical activity and energy use in the summer reduces body weight, while a decrease in the winter, on the contrary, increases it [4]. In autumn and winter, the production of the hormone melatonin by the pineal gland increases, which increases drowsiness and appetite [4].

Scientists claim that the greatest growth rate of schoolchildren occurs in the first half of the year [3]. Scientists believe that cold climates contribute to increased height and weight, and that large bodies are better able to tolerate low ambient temperatures [10].

Table 2: *Seasonal features of some indicators of the cardiovascular system and health coefficient of girls*

	Indicators			
Season of the year	Heart rate in beats per minute	SBP in mmHg	DBP in mmHg	Health coefficient
Summer	77.2±1.61	113.4±2.28	74.5±1.56	1.59±0.053
Autumn	80.0±1.69	119.2±2.77	77.9±1.62	1.70±0.062
Winter	81.4±1.88	127.5±2.84***	81.2±1.78**	1.83±0.066**
Spring	80.3±1.58	120.5±1.96*	80.1±1.57*	1.75±0.042*

* – P < 0.05; ** – P < 0.02; *** – P < 0.01

Some indicators of the cardiovascular system and the health coefficient of girls in different seasons of the year are given in Table 2 and Figure 2. It follows from them that the season of the year has a statistically significant effect on SBP, DBP and the health coefficient.

Thus, the level of systolic blood pressure in girls in the winter and spring seasons of the year is higher by 14.1 ($P < 0.01$) and 7.1 mm Hg ($P < 0.05$) relative to the value in the summer period of the year.

The diastolic blood pressure value of girls in winter and spring increased by 6.7 ($P < 0.02$) and 5.6 mmHg ($P < 0.05$) compared to the level of control girls. The heart rate of girls in winter is 4.2 beats per minute faster compared to the value of girls in the control group. Our results are confirmed by other scientists. Thus, blood pressure is subject to seasonal changes [26, 17]. According to a number of authors, its value is higher in winter than in summer [90, 13, 69, 16, 18].

According to K.J. Radke and J.L. Jr. Izzo [24], the heart rate increases by 5% in winter.

Apparently, high levels of adrenaline and noradrenaline in the blood in winter increase heart rate, systolic blood pressure and diastolic blood pressure, while low levels in summer decrease them.

Our findings are confirmed by other authors. Thus, from the analysis of the results of studies by various authors, it can be concluded that the causes of seasonal fluctuations in HR, SBP and DBP are seasonal changes in the production of catecholamine hormones, temperature and day length [14, 23, 25, 27].

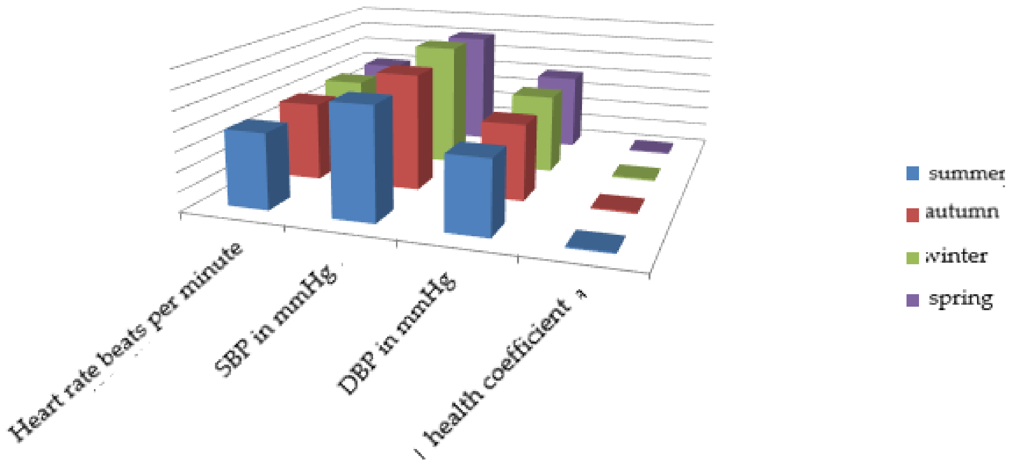

Figure 2: *The influence of the season on the level of heart rate, systolic blood pressure, diastolic blood pressure and the health coefficient of girls*

In winter, the concentration of catecholamines in the blood increases, and in summer it decreases [27].

Also, factors that increase blood pressure include low temperatures in the external environment, short daylight hours, narrowing of blood vessels and high sweating [23, 14, 25, 20, 12].

The level of the health coefficient of girls in winter and spring is higher by 0.24 ($P < 0.02$) and 0.16 ($P < 0.05$) relative to the initial value. The state of the health coefficient of girls in all seasons of the year indicates a satisfactory level of their health. With the increase of the value of the health coefficient of students, there is a decrease in their health level. A high level of health among girls is revealed in the summer period of the year, and a low one - in the winter season of the year.

Apparently, the improvement of girls' health in summer occurs due to a decrease in the intensity of metabolism, the prevalence of anabolism processes, an increase in the motor regime, an increase in the duration of daylight hours and the ambient temperature. Similar conclusions were reached in their studies [8, 9, 5, 4, 10] .

Analysis of the results of the studies by A.A. Artemenko [2] and E.A. Shtrikh [11] indicate that modern students are characterized by physical inactivity, poor physical fitness, and poor health. According to V.D. Sonkin and others [22], students have low physical fitness and poor health. Thus, in the spring and winter seasons of the year, there is a reliable increase in the level of SBP, DBP and the health coefficient of female students.

The length and weight of girls' bodies do not undergo statistically significant changes across seasons. In winter, there is a 2.2% increase in body length and a 4.9% increase in weight compared to summer levels. The value is 10.3% higher in spring ($P < 0.05$) and 12.4% higher in winter ($P < 0.01$) relative to the control group value. The increase in the DBP value in spring was 7.5% ($P < 0.05$), and in winter – 9.0% ($P < 0.02$) compared to the value for the summer season. The increase in the health coefficient of girls in the spring season was 10.1% ($P < 0.05$), and in winter – 15.1% ($P < 0.02$) relative to the level of control girls. The heart rate level in winter is 5.4% higher than the baseline value.

The interplay between seasonal climate changes and the immune system of female students is a multifaceted issue that warrants thorough exploration. As this study indicates, fluctuations in weather conditions can significantly affect the health of this demographic, making them more susceptible to infections and illnesses. For instance, during colder months, lower temperatures and increased indoor crowding can facilitate the spread of respiratory viruses, while warmer months may bring about allergens like pollen, contributing to respiratory issues and allergies.

The heightened vulnerability of female students to seasonal illnesses not only affects their physical health but also their mental well-being. Stress and anxiety related to health concerns can detract from their academic focus and overall quality of life. Therefore, understanding the specific health implications of seasonal climate changes is crucial. Educational institutions should consider implementing preventive health measures, such as vaccination programs and awareness campaigns about seasonal illnesses, to safeguard students' health.

The link between these health challenges and sustainable development is particularly pertinent. Sustainable development emphasizes the importance of a healthy population in fostering economic growth and social equity. By addressing the environmental factors that contribute to seasonal health issues, universities can play a pivotal role in promoting sustainable practices. For example, initiatives aimed at improving campus air quality, enhancing green spaces, and encouraging sustainable transportation can mitigate some of the adverse health impacts associated with climate change.

A holistic approach is necessary to effectively address these issues. This involves not only raising awareness about the effects of seasonal climate changes but also integrating health education into academic curricula. Programs focusing on nutrition, physical activity, and stress management can empower female students to take charge of their health, equipping them with the tools to build resilience against seasonal health challenges.

Further research is essential to understand the long-term effects of seasonal climate changes on the immune health of female students. Longitudinal studies could provide insights into how these changes influence health over time and inform targeted interventions. Additionally, research exploring the effectiveness of specific health education programs in mitigating seasonal health risks can help develop best practices that educational institutions can adopt.

In conclusion, the impact of seasonal climate changes on the immunity of female students presents significant challenges that intersect with the goals of sustainable development. By recognizing the health implications of these environmental factors and implementing strategic interventions, educational institutions can foster healthier and more resilient student populations. A proactive approach will not only enhance the well-being of female students but also contribute to broader efforts toward sustainable development and community health.

References

[1] Agadzhanyan N.A. Mountains and body resistance / N.A. Agadzhanyan and M.M. Mirrakhimov. – M.: Nauka, 1970. – 184 p.

[2] Artemenko A.A. Concept of optimization of functional state and increase of adaptive

capabilities of a person: diss...: doc. biol. sciences / A.A. Artemenko; Cherepov. state univ. – Cherepovets, 2015. – 368 p.

[3] Aidaraliev A.A. Comprehensive assessment of the body's functional reserves / A.A. Aidaraliev [and others]. – Frunze: Publishing house "Ilim", 1991. – 195 p.

[4] Shtikh E.A. Features of the formation of the assessment of physical health of female students // Theory and practice of physical education. - 2008. - No. 8. - P. 63-64. [5] Mountains of the World / edited by B. Messerli and J.D. Ives // Global Priority. – Moscow, 1999. – 430 p.

[6] Fedecostante M. Summer does not always mean lower: seasonality of 24 h, daytime, and night-time blood pressure / M. Fedecostante [et al] // J Hypertens. – 2012. – P. 30.

[7] Forman JP Vitamin D and Risk of Hypertension. Plasma 25-Hydroxyvitamin D Levels and Risk of Incident Hypertension / JP Forman [et al] // Hypertension. – 2007. – P. 49.

[8] Hansen AM Seasonal and biological variation of urinary epinephrine, norepinephrine, and cortisol in healthy women / AM Hansen [et al] // Clin Chim Acta. – 2001. – P. 309.

[9] Hopman R. Jaherszeitliche krankheitsbereitschaft, Blutdruckhohe und Jahreszeiten / R. Hopman, L. Remen // Z Klin Med. – 1921. – P. 122.

[10] Hozawa A. Seasonal variation in home blood pressure measurements and relation to outside temperature in Japan / A. Hozawa [et al] // Clin Exp Hypertens. – 2011. – P. 33-36.

[11] Kauffmann F. Uber die Haufigkeit Einzelner wichtiger Klagen und unamnestischer Angaben bei Kranken mit arterieller hypertension / F. Kauffmann // Munch Med Wochenschr. – 1924. – P. 36.

[12] Kimura T. Seasonal blood pressure variation and its relationship to environmental temperature in healthy elderly Japanese studied by home measurements / T. Kimura [et al] // Clin Exp Hypertens. – 2010. – P. 32.

[13] Kingma BR Increased systolic blood pressure after mild cold and rewarming: relation to cold-induced thermogenesis and age / BR Kingma [et al] // Acta Physiol (Oxford), 2011. – P. 203-206.

[14] Kruse HJ Seasonal variation of endothelin-1, angiotensin II, and plasma catecholamines and their relation to outside temperature / HJ Kruse [et al] // J Lab Clin Med. – 2002. – P. 140.

[15] Lam RW Seasonal depression: the dual vulnerability hypothesis revisited / RW Lam [et al] // J Affect Dis. – 2001. – P. 63.

[16] Modesti PA Seasonal blood pressure changes: an independent relationship with temperature and daylight hours / PA Modesti [et al] // Hypertension. – 2013. – P. 61-64.

[17] Radke KJ Seasonal variation in haemodynamics and blood pressure-regulating hormones / KJ Radke, JLJr. Izzo // J Hum Hypertens. – 2010. – P. 24-29.

[18] Rostand SG Ultraviolet Light May Contribute to Geographic and Racial Blood Pressure Differences / SG Rostand // Hypertension. – 1997. – P. 30.

[19] Sega R. Seasonal variation in home ambulatory blood pressure in the PAMELA population. Pressione Arteriose Monitorate E Loro Associazioni / R. Sega [et al] // J Hypertens. – 1998. – P. 16.

[20] Sharma BK Seasonal variations of arterial blood pressure in normotensive and essential hypertensives / BK Sharma [et al] // Indian Heart J. – 1990. – P. 42.

[21] Woodhouse PR Seasonal variation of blood pressure and its relationship to ambient temperature in an elderly population / PR Woodhouse, KT Khaw, M. Plummer // J Hypertens. – 1993. – P. 11.

MANIFESTATIONS OF NATURAL AND MAN-MADE GEODYNAMIC PROCESSES AND RISKS ON THE TERRITORY OF THE CHECHEN REPUBLIC

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Abstract

The paper attempts to consider geological processes occurring in the upper layers of the Earth, which either simplify or complicate the native relief. In this case, the territory subject to exogenous processes is likened to a nonequilibrium, open thermodynamic system. For successful application of the synergetic approach to natural phenomena, a comprehensive study of the degree of influence of each of the factors acting on the system under consideration on the processes occurring in it is required. Therefore, this paper focuses on the dynamics of the development of exogenous processes in the south-eastern part of the Chechen Republic, subject to exogenous processes. It is shown that these processes are cyclical in nature and cause great harm to the economy and population of the region. Geodynamic processes arising during long-term development of oil and gas fields are also considered. This work can be considered as a preparatory stage for the study of these phenomena based on the synergetic approach. It is expected that these studies can become the basis for systematization, theoretical generalization of the results obtained and the development of methods for predicting natural processes.

Keywords: landslide processes, geological risks, slope erosion

I. Introduction

In recent years, many scientific fields have often used a synergetic approach, which takes into account the collective action of a number of factors on a nonequilibrium system. The essence of the synergetic paradigm is the presence of such properties of the system as nonlinearity, openness, dissipativity. To successfully use this direction, objective data on the nature and degree of influence of each of the acting factors on the system are needed. A synergetic effect in relation to exogenous processes can consist, firstly, in the simultaneous action of several forces or factors on the process under study. It can manifest itself the more, the greater the relationship between the elements of the system. For example, the presence of a slope with a soft soil covering, under which a relatively smooth, impermeable rock is concentrated; heavy precipitation penetrating the boundary between soft soil and impermeable rocks, etc. Secondly, the system must have various options for possible development that cannot be predicted in advance. Such expected processes include landslides, mudflows, avalanches, floods. Depending on specific conditions, these processes can have varying degrees of intensity.

II. Methods

The work is based on methods of system analysis and generalization of available materials using a synergetic approach. The basis for the work were stock, archival materials and published literary sources on the subject of the study, both domestic and foreign. The territory of the Chechen Republic is located within the Eastern Caucasus, which is characterized by specific features that create favorable conditions for the development of dangerous natural and man-made geodynamic processes - a thick layer of clay rocks, strong development of erosional dissection and folded forms, the activity of modern movements of the earth's crust, anthropogenic impact, etc.

Various types of exogenous processes are developed in the territory under consideration. Landslides and mudflows are especially active in the mountainous part, the intensity of which depends, first of all, on the lithological composition and properties of the rocks that make up the earth's crust of a particular territory. In some areas, one of the key factors is also anthropogenic activity: laying of communication lines, deforestation of slopes, laying and widening of roads, etc. A number of scientific articles are devoted to landslide processes in the territory of the Chechen Republic [1, 6]. This work focuses on the synergism of their manifestation.

Synergism of exogenous processes, as noted above, can consist of the synchronous manifestation of landslides, mudflows and floods in appropriate conditions. The material for the mudflow is the lithomass from the landslide area.

Synergy consists in the fact that heavy rains lead to a rise in the water level in rivers and, accordingly, to the erosion of banks composed of easily eroded rocks.

An example of landslides most typical for low-mountain forest-steppe landscapes is the landslide near the village of Belgatoy. It begins at approximately an altitude of 766 meters (below the old mosque) and ends on an alluvial fan superimposed on a river terrace that steeply drops off to the river bed.

The Belgatoy landslide develops on Neogene deposits represented by interbedded sandy argillites with multiple aquifers. They are exposed as the landslide deepens, forming a temporary watercourse in the thalweg part of the erosion-landslide cirque, which, passing the alluvial cone in the lower part, cuts into the depth of up to 5 meters.

III. Results

The dynamics of landslide processes over the past 10 years (2011-2021) shows that landslide and erosion-landslide processes remain active. This is noticeable, first of all, in the remaining unsodded areas in the erosion-landslide cirque.

In general, the integration of the Belgatoy landscape-landslide complex into the landscape structure strongly depends on the geomorphological features and moisture conditions of this territory. Currently, due to anthropogenic activity, the relief, soil and ground moisture conditions have been significantly transformed. The construction of multi-storey buildings, bridges and roads in the 60s of the 20th century, the intensification of agriculture contributed to the activation of landslides, the apogee of which was the catastrophic landslides of 1989 [3, 5]. Another area of active landslide processes is the Benoy-Sayasan-Zandak area of the eastern Black Mountains, where Sarmatian deposits composed of clay rocks come to the surface. That is, the dependence of the occurrence of landslides on the material composition of the rocks that make up the area is clearly visible.

Since the early 1960s, landslide processes have repeatedly intensified in the mountainous part of the Chechen Republic, causing enormous damage to many settlements located there. In this regard, the problems of predicting landslide processes and developing effective methods to combat them, taking into account the specific features caused by many factors that are tied to the studied area, are relevant. An example of effective measures taken to combat landslides in the village of Khochi-Ara, Nozhai-Yurtovsky District, are the events, the essence of which was as follows: a trench 1-1.5 m deep was dug across the mountain slope at an angle of 20-250, the bottom and lower wall of which were lined with polyethylene film. It promotes the flow of water along the drainage ditch. A special drainage pipe was placed on the film, which was covered with crushed stone from above. In turn, this entire system was wrapped in a special material and covered with earth. Landslide processes are also prevented by a concrete barrier along the road, poured as a foundation for the fence. Over the past 8 years since the completion of these works, no manifestations of landslides have been detected.

Another example confirming the effectiveness of the proposed anti-landslide system: in the village of Benoy-Vedeno, Nozhai-Yurtovsky district, landslides began, which were approaching a recently built house every year. According to our recommendation, a protective system was built, which consists of drainage and a concrete wall. It has been working normally for two years, but further monitoring is required. An important factor is the fall of heavy precipitation, which could provoke landslides.

In general, the territory of the Chechen Republic is divided into mudflow-hazardous areas of 4 categories according to the activity of mudflows [4] (Figure 1).

Figure 1: *Complex natural landslide in low mountain forest landscapes (Goy-chu river gorge)*

The formation of an oil-producing complex together with the section of the geological environment covered by it can be considered as a complex open natural-technogenic system caused by the synergy of a number of factors. There are many examples of the manifestation of dangerous geodynamic processes during long-term exploitation of oil and gas fields (technogenic seismicity, subsidence of the daylight surface, etc.). The problem of technogenic seismicity during the development of mineral deposits is relevant for many countries with developed oil production. Technogenic processes (such as various types of flooding, induced seismicity) cause significant damage to structures and complicate the process of developing new territories [10].

Technogenic seismicity is characteristic of some developed hydrocarbon fields of the Tersko-Sunzhenskaya oil and gas region , in particular, for the Starogroznenskoye and Gudermesskoye oil fields. Within the Starogroznenskoye field, earthquakes of low intensity associated with its development were noted in 1938, 1963, 1971, and at Gudermesskoye – in 1950, 1955, 2008. The relationship between seismic activity and the dynamics of oil production from these fields indicates the active development of geodynamic processes.

IV. Discussion

Thus, the paper attempts to consider geological processes in the Chechen Republic from the point of view of a synergetic approach. The main factors influencing the intensity of geological processes are identified. It is shown that the synergism of landslide and mudflow processes in the territory under consideration consists of the simultaneous and joint action of various factors, which at the same time increase the intensity of their occurrence [3,9]. Manifestations of mudflow and landslide processes in the territory of the Chechen Republic are quite active. When they occur, great damage is caused to landscapes and infrastructure of mountainous areas. Communications of settlements, inter-settlement and inter-district highways are exposed to such danger (Figure 2). The synergism of dangerous geodynamic processes (landslides, voids, subsidence of the earth's surface, man-made seismicity) in the development of hydrocarbon deposits consists in the fact that the formation of these processes occurs through the collective action of many factors and conditions, which are based on geomechanical processes [7,11]. When developing oil and gas fields, the moment of occurrence of dangerous geodynamic processes corresponds to the so-called "bifurcation" point.

In our opinion, further studies of the considered and similar exogenous processes in the aspect of synergism can lead to practically important results. On this basis, various theoretical generalizations are possible, which, in turn, can contribute to the development of methods for predicting these processes.

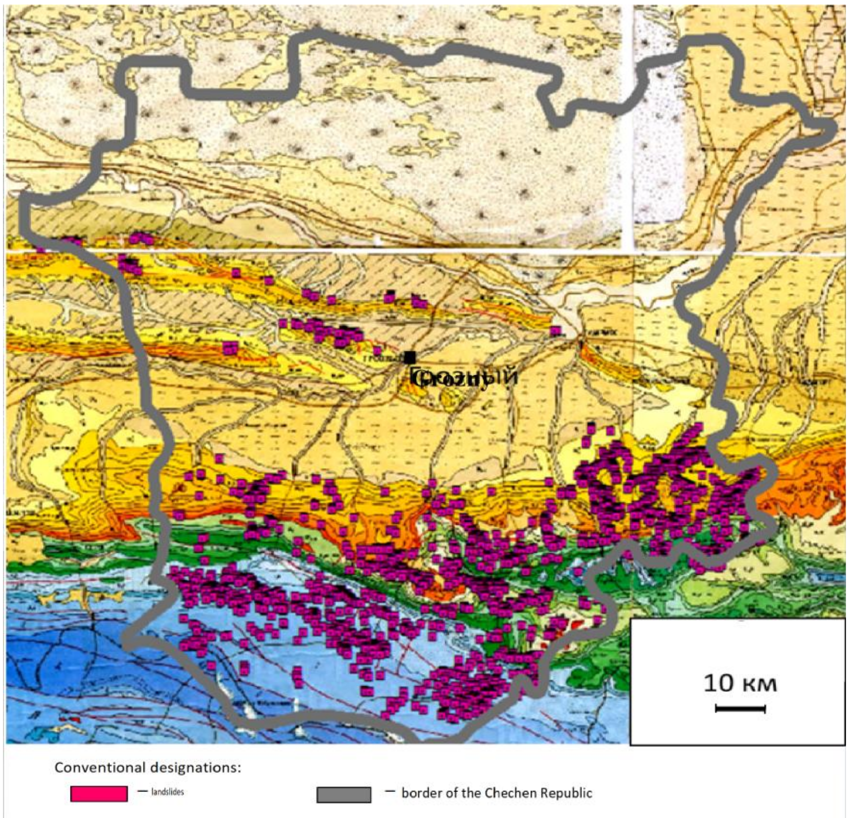

Figure 2: *Spatial distribution of landslides based on the geological map of the Chechen Republic*

The geological structure of the mountainous part of the Chechen Republic is characterized by the participation of a wide range of sedimentary rocks from the Lower Jurassic to the Quaternary period. Moreover, the older rocks are in the south, and are replaced by younger ones as one moves north. The highlands are represented by Lower and Middle Jurassic deposits of flysch rocks, consisting of interbedded siltstones, sandstones and argillites. To the north, in the midlands, the flysch deposits are replaced by a complex of carbonate deposits from the Upper Jurassic to the Lower Cretaceous, consisting of limestones, partially dolomitized, as well as clays and marls. Upper Cretaceous rocks are represented, as a rule, by limestones and marls. To the north of the Upper Cretaceous rocks, there is a belt of Paleogene-Neogene clayey deposits, representing a low-mountain belt. In the lowest part, there are Maikop clays, and higher up, there are Karagan-Chokrak deposits, which, in addition to clays, contain sandstones. Even higher up are the Sarmatian and Akchagyl-Apsheron clayey deposits [2, 8]. The same rocks – from the Maikop to the Akchagyl-Apsheron stages – also make up the Forward Ranges. Between the Forward Ranges and the Black Mountains, Quaternary deposits are widespread, represented by pebbles and sands with clay interlayers (Figure 3).

According to their susceptibility to landslide formation, four main types of rocks are distinguished within the study area: Paleogene-Neogene clays, Cretaceous-Jurassic calcareous rocks, Jurassic siltstones and sandstones, and Jurassic argillites and sandstones.

Figure 3: *Landslide processes near the Nozhai-Yurt - Sayasan highway*

In the southern highland part of the territory, Lower Jurassic argillites predominate, which are close in composition to clays. Therefore, they often serve as an aquiclude, facilitating the development of landslide processes and corresponding relief forms. To the north, a narrow strip of Middle Jurassic siltstones stretches, more dusty, sandy. They are a fertile substrate for soils, in particular, in the Galanchozh intermountain basin, which is considered the historical core of the Chechen settlement, as well as in the Itum-Kalinskaya and Sharoy-Argunskaya intermountain basins. In the northernmost part of the studied territory, Upper Jurassic and Lower Cretaceous rocks are widespread, represented by chalk. They form the Pastbishchny Ridge. Carbonate soils, karst, and partly also gypsum karst are developed in these areas. Significant areas in the northernmost part of the territory are occupied by Paleogene-Neogene clay deposits.

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References

[1] Gakaev R.A. Economic activity and landscape-landslide complexes of the mountainous part of the Chechen Republic. Natural resource potential and ecological rehabilitation of degraded landscapes: Proceedings of the International scientific and practical conference, Grozny, March 17-18, 2023. Grozny: Chechen State University named after A. A. Kadyrov, 2023. P. 95-98. DOI 10.36684/86-1-2023-95-98.

[2] Gakaev R., Dzhandarova L., Ahmieva R. Landscape and Landslide Manifestation in the Residential Areas of the Mountainous Parts of the Chechen Republic. BIO Web of Conferences. 2023. Vol. 63. P. 03005. DOI 10.1051/bioconf/20236303005

[3] Gakaev R., Ahmieva R., Dzhandarova L. Features of Landslide Manifestations in the Mountainous Parts of the Chechen Republic. BIO Web of Conferences. 2023. Vol. 63. P. 03004. DOI 10.1051/bioconf/20236303004

[4] Golubchikov Yu. N., Gunya A. N., Schmidt M. Natural differences in the legal dimension: institutionalisation of the northern and mountain regions of Russia. Geography, Environment, Sustainability. 2022. Vol. 15, No. 1. P. 53-60. DOI 10.24057/2071-9388-2021-084.

[5] Gunya A., Lysenko A., Lysenko I., Mitrofanenko L. Transformation of nature protection institutions in the North Caucasus: From a state monopoly of governance to multi-actor management. Sustainability. 2021. Vol. 13, No. 21. P. 12145. DOI 10.3390/su132112145

[6] Gunya A., Gakaev R. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic. Reliability: Theory & Applications. 2022. Vol. 17, No. S3(66). P. 124-128. DOI 10.24412/1932-2321-2022-366-124-128.

[7] Gunya A. N., Gakaev R. A. Landscape approach to the study of landslides (using the example of the mountainous territory of the Chechen Republic). Problems of regional ecology. 2024. № 1. P. 64-73. DOI 10.24412/1728-323X-2024-1-64-73.

[8] Daukaev A. A., Dadashev R. K., Gatsaeva L. S., Gakaev R. A. Landslides and mudflows in the Chechen Republic: Synergetic aspects. IOP Conference Series: Earth and Environmental Science : International Conference on Innovations and Prospects of Development of Mining Machinery and Electrical Engineering 2019. Vol. 378. – Saint-Petersburg: Institute of Physics Publishing, 2019. P. 012084. DOI 10.1088/1755-1315/378/1/012084

[9] Daukaev A. A., Abubakarova E. A. Exogenous processes in the mountainous regions of the Chechen Republic: synergetic and geological aspects. Bulletin of the KNI RAS. Series: Natural and technical sciences. 2022. No. 1 (9). P. 93-99. DOI 10.34824/VKNIIRAN.2022.9.1.011

[10] Daukaev A. A., Dadashev R. Kh. Landslide processes in the mountainous regions of the Chechen Republic. Tallam. 2021. No. 2(23). P. 18-21. DOI 10.25744/vestnik.2021.23.2.003.

[11] Koehler, J., Gunya A., Alkhazurov M. Insurgency-informed governance in the North Caucasus: observations from Chechnya, Dagestan, and Kabardino-Balkaria. Small Wars & Insurgencies. 2016. Vol. 27, No. 3. P. 367-391. DOI 10.1080/09592318.2016.1151657

TECHNICAL AND ECONOMIC ASPECTS OF REDUCING CARBON DIOXIDE EMISSIONS INTO THE ATMOSPHERE

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Abstract

The article outlines the technical and economic aspects and relevance of reducing carbon dioxide emissions into the atmosphere in the Republic of Azerbaijan (AR). It is noted that transforming Azerbaijan into a clean environment is one of the priorities of the national program "Azerbaijan 2030". The main sources of carbon dioxide emissions into the atmosphere in the AR have also been studied. Several consequences of carbon dioxide emissions into the atmosphere and possible (necessary) actions to reduce them are given. The basics of carbon dioxide retention in the geological structures of the earth and the main criteria for assessing geological objects for their disposal are analyzed. It is indicated that in order to reduce the long-term consequences of global warming, the technology of capturing, transporting and recycling and (or) burying carbon dioxide is considered as one of the key technologies. It is noted that in order to create an underground storage facility for injection of carbon dioxide gas, the geological structure in the subsurface must meet certain criteria. It was revealed that the most suitable objects for creating projects for the disposal of carbon dioxide gas in the subsurface are the depleted oil and gas fields of the Apsheron Peninsula.

Keywords: carbon dioxide, atmosphere, burial, injection, geological structure, renewable energy sources

I. Introduction

The climate agenda, the rise of global energy consumption and the electricity costs reduction have led to a sharp increase in the production volume of renewable energy sources, and their market share has been growing steadily over the past few decades.

Transforming a country into a one with a clean environment is one of the priorities of the national program "Azerbaijan 2030". All issues listed in the Priorities are extremely important for the sustainable development of the country (Fig. 1). In recent years, the Republic of Azerbaijan has been making every effort to participate in the global processes of the "great energy transition of 2030" [1-4].

The Conference of the Parties to the United Nations Framework Convention on Climate Change, or the COP, is a large government-level meeting dedicated to developing a common climate strategy. The 29th COP is planned to be held in Azerbaijan in 2025. Holding the COP 29 in Baku is an endorsement of the country's contribution to environmental protection and the prevention of climate change at the national, regional and global levels. The UNO expressed confidence that the AR will hold the COP 29 at a high level, and this will be another great success for the country, as well as a contribution to slowing down climate change [4].

Figure 1: *Main priorities of social and economic development of the AR*

According to the International Energy Agency (IEA), global carbon dioxide (CDG) emissions will reach record levels in 2023. These emissions are energy-related, largely due to the increased use of fossil fuels. Greenhouse gases (carbon dioxide, CO2) are the most important source of climate change. They are estimated to be responsible for approximately 64% of global warming. The IEA notes that to achieve the global climate goals set in the Paris Agreement, sharp reductions in carbon dioxide emissions, in particular the combustion of fossil fuels, are necessary [5, 6].

The Paris Agreement on Climate Change adopted in 2015 (the COP 21) set participating countries goals to reduce greenhouse gas emissions and limit global warming to 1.5-2 degrees Celsius compared to pre-industrial levels (the period of 1850-1900) [7].

Azerbaijan is also a party to the Paris Agreement, and has made a voluntary commitment to reduce greenhouse gas emissions by 35% by 2030 compared to 1990, and by 40% by 2050. This agreement and all subsequent COPs are dedicated to the implementation of the key goal of this document – keeping the global average temperature rise to 2°C (global peaking) and continue efforts to limit the increase to 1.5°C (climate neutrality). Today, one of the main reasons for climate warming is "greenhouse" emissions into the atmosphere, among other gases, primarily carbon dioxide, the release of which is natural and anthropogenic, is leading (Fig. 2).

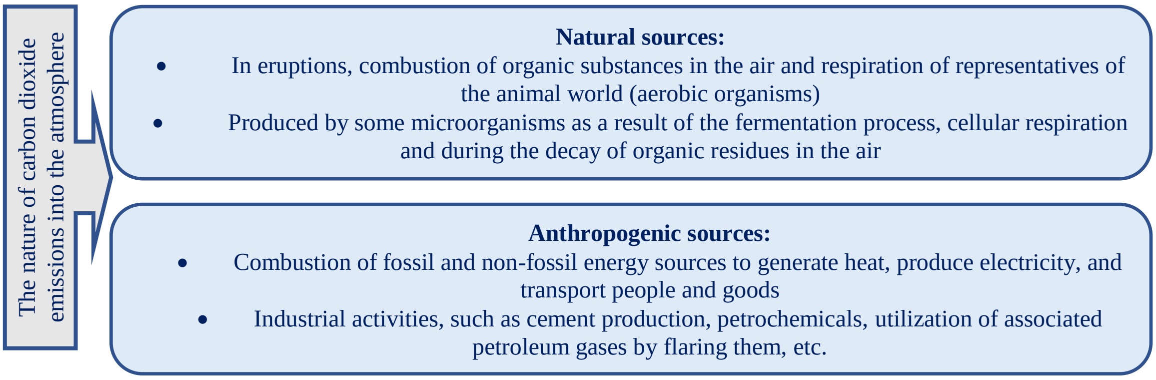

Figure 2: *Nature of carbon dioxide emissions into the atmosphere*

As is known, the main anthropogenic sources of carbon dioxide emissions into the atmosphere are of an industrial (energy) nature (Fig. 3).

II. Methods

The study used the analytical method, the method of comparison. Methods for collecting, processing and analyzing information were determined by the specific objectives of the study based on a systematic approach. Based on the analysis of extensive material, a review of existing options for the utilization and storage of carbon dioxide in the subsurface has been prepared.

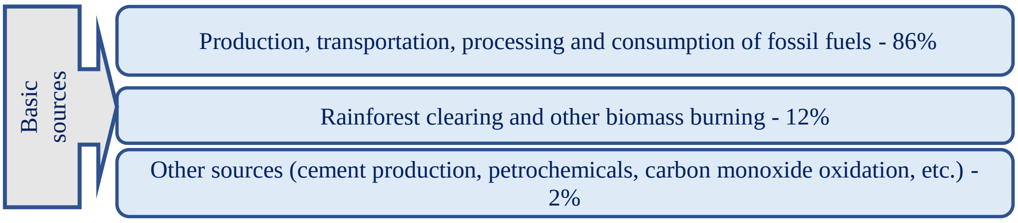

Figure 3: *Main sources of carbon dioxide emissions into the atmosphere*

III. Research results and discussion

According to the IEA, in 2022 alone the volume of emissions amounted to 36.8 billion tons and in 2023 from the energy sector they increased by 410 million tons, or 1.1%, reaching 37.4 billion tons. The increase in carbon dioxide emissions into the atmosphere has serious consequences (Fig. 4). The main volume of about 70% of global CDG emissions comes from electricity and heat generation and transport [5, 8, 9].

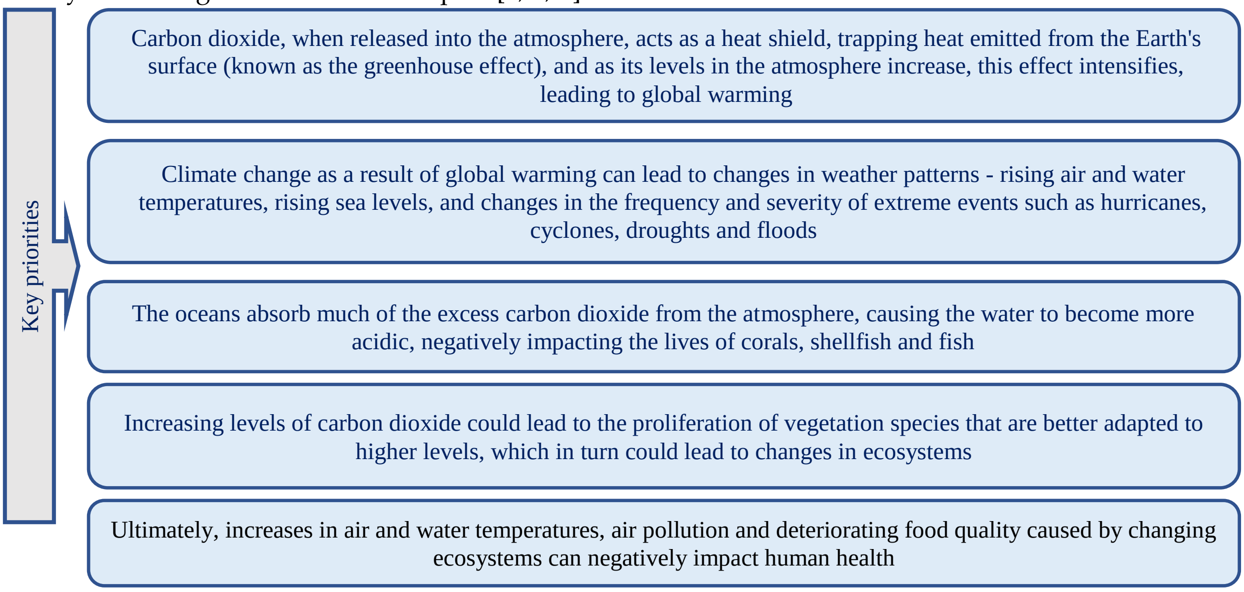

Figure 4: *Some consequences of carbon dioxide gas emissions into the atmosphere*

To reduce greenhouse gas emissions into the atmosphere, the Republic of Azerbaijan is implementing a number of projects, including paying special attention to the production of renewable energy sources (RES). However, additional measures must be taken to reduce atmospheric carbon dioxide emissions (Fig. 5).

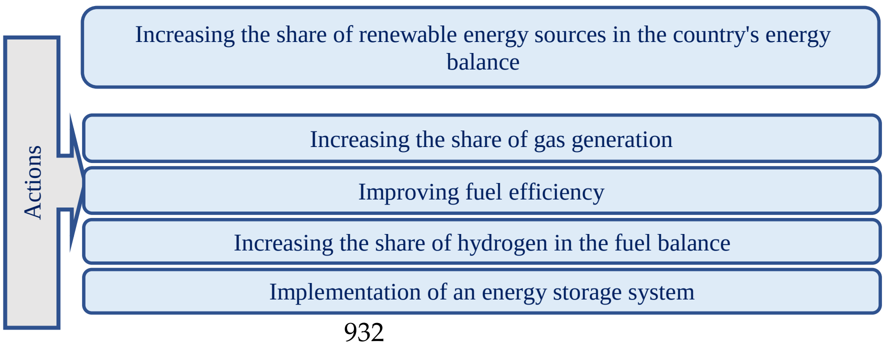

Figure 5: *Action is needed to reduce carbon emissions into the atmosphere*

The development of the petrochemical industry in the AR is accompanied by an increase in greenhouse gases that require disposal. One of the by-products of petrochemical production is carbon dioxide. According to the requirements of state supervisory authorities, production and industrial enterprises must limit the release of carbon dioxide.

The technology for CDG capturing, transporting and disposal (and/or recycling) is currently considered one of the key technologies for mitigating the effects of global warming [9-11]. A VOC removal technology can have two main goals: preventing new VOCs from entering the atmosphere or eliminating previous emissions. The technological chain of CCS elimination projects includes a number of processes [12-14]. (Fig. 6).

Burying CDG means pumping it underground to a depth of 800 meters or more. The geological properties of underground reservoirs determine the reliability of this storage. Porous rocks from depleted hydrocarbon deposits that have contained fossil fuels for millions of years are among the most suitable. Based on foreign experience, depleted hydrocarbon (HC) deposits and geological aquifer structures can be used as objects for disposal of hydrocarbons [15, 16].

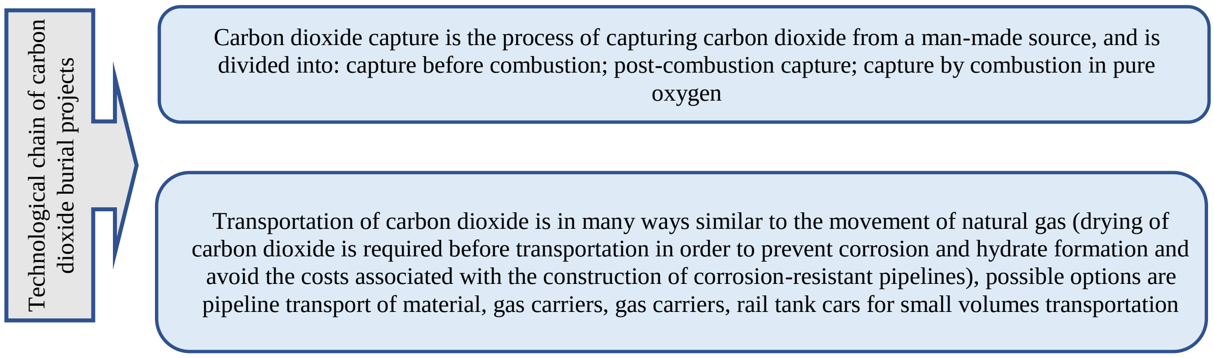

Figure 6: *Some consequences of carbon dioxide emissions into the atmosphere*

Norway was one of the first countries to implement projects to capture carbon dioxide from factories and pump it into subsurface storage facilities. The number of CDG phase-out projects around the world has grown rapidly in recent years, and there are currently 29 such projects (Table 1). The current capacity of CDG phased disposal projects around the world, amounting to about 40 million tons per year, can capture only slightly more than 0.12% of global carbon dioxide emissions [9, 17, 18].

Table 1: *Distribution of carbon capture, utilization and storage by regions (2022)*

Region	Active	In developing	Suspended	Total by region
North America	16	80	2	98
China	4	3		7
Europe	4	46		50
Persian Gulf	3	1		4
The rest of the world	2	11		13
Total	***29***	***141***	**2**	***172***

Four main mechanisms remain at the basis of the retention of CDG in the geological structures of the Earth (Fig. 7).

The principles of carbon dioxide retention in the geological structures of the Earth consist of four main provisions (Fig. 7), where the degree of carbon dioxide retention is determined by the potential of the underground storage (geological structure) [11, 17].

Special requirements must be placed on the geological conditions and characteristics of CDG storage tanks to ensure the safety of long-term storage of injected products. Leaks of CDG, even those to ensure the safety of underground sources of drinking water supply, as well as leaks to the surface must be excluded [11, 19, 20].

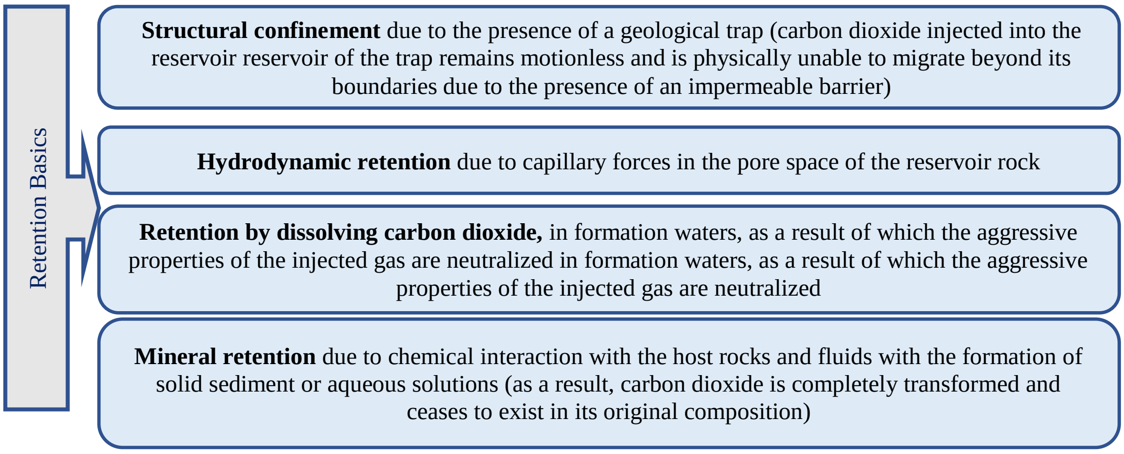

Figure 7: *Basics of carbon dioxide retention in the geological structures of the earth*

To create an subsurface facility for carbon dioxide injection, the geological structure in the earth interior must meet certain criteria (Fig. 8).

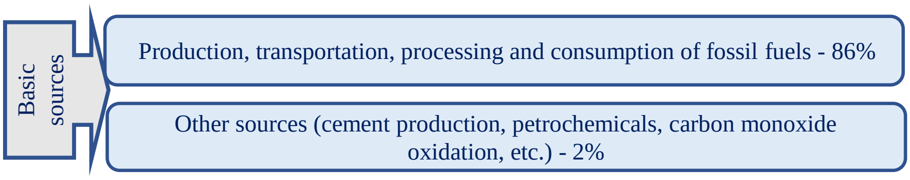

Figure 8: *Basic criteria for assessing geological sites for carbon dioxide disposal*

Natural geological structural traps (reservoirs) with certain thermobaric conditions ensure the safety of the injected CDG at reservoir pressure at the end of injection of a given volume to the initial reservoir pressure. One of the problems regarding the process under consideration is the distribution and distribution speed of the CDG throughout the volume of the natural trap.

Disposal of CDGs in depleted deposits must be carried out not only while maintaining the tightness of the underground reservoir, but also while ensuring the absence of lateral flows of CDGs along the roof of the trap. Therefore, when injecting carbon dioxide into a reservoir, monitoring the distribution of carbon dioxide throughout the reservoir becomes an urgent problem.

Monitoring techniques, first of all, must meet the requirements of accuracy and reliability of determining the gas-water contact. However, an important factor is the simplicity and cost-effectiveness of the technique. Accordingly, the choice of a suitable monitoring technique can specified through choosing the simplest and most economical one, in order to then consider the degree of its reliability and draw a conclusion about the validity of its application One of the simplest and most economical techniques is gravimetric monitoring, based on recording changes in the Earth's gravitational field. When carrying out gravity surveys, data are obtained that describe the gravitational field created by the underlying strata of the earth. In order that the obtained data from gravimetric studies be the most representative, they must be carried out with confidence in the established regime in the formation. This approach will eliminate the anomalous pressure increase in the reservoir associated with the inhibited propagation of the hydrocarbon gas in the reservoir, since without identifying the increase in pressure there is a high risk of reducing the tightness of old wells [21-23].

When making a qualitative interpretation of gravimetric monitoring data, it is necessary to mention the possibility of registering the threat CDG may cross the trap's closing isohypsum using the proposed technique. By controlling the distribution of carbon dioxide throughout the reservoir using gravimetric monitoring, it is possible to stop its injection in time to prevent the flow of carbon dioxide through the structural trap.

To justify the selection of promising geological objects for placement (creation of an underground reservoir) on the basis of depleted deposits for the placement of CDG, it is necessary:

- to identify promising facilities for carbon dioxide storage;
- to assess the potential for carbon dioxide storage in selected facilities;
- to perform a technical and economic analysis of the transportation of CDGs in various ways to selected storage facilities.

Based on a technical and economic analysis of different methods of transporting the projected volume of CDG emissions, it is possible to recommend appropriate geological structures as the subsurface part of operational disposal facilities. The results obtained will be used to substantiate the initial data for the technological design of the construction of an operation facility for the disposal of carbon dioxide gas.

IV. Conclusion

Achieving global goals for economic decarbonization is impossible without implementing projects to capture, transport and use (or) bury carbon dioxide. One of the most important factors for these projects to be successful is the availability of geological facilities for safe long-term storage of carbon dioxide. At the same time, the accumulated experience in the gas business (transportation, underground storage, etc.), including sour gases, as well as access to extensive geological information gives the oil and gas industry a global advantage, allowing it to exploit the AR potential in the field of CDG disposal in the earth interior. According to preliminary estimates, the most suitable sites for creating projects for the use and storage of greenhouse gases in the Azerbaijan interior are located in traditional oil and gas production areas, mainly on the Absheron Peninsula.

The current tasks of developing a new technology for the AR are a targeted geological study of various conditions for storing carbon dioxide in the subsurface and the development of uniform regulatory requirements for the geological parameters of underground carbon dioxide storage structures. In addition, it is important to examine the long-term liability issues associated with establishing ongoing geological monitoring of possible leaks from underground carbon dioxide storage in the subsurface. The gravity monitoring technique allows monitoring the condition of the field into which carbon dioxide is injected.

Azerbaijan's potential in terms of the use and burial of carbon dioxide underground is quite high, but it has not been fully assessed yet, and today there are no industrial projects for the burial of carbon dioxide in the bowels of the country. Additional actions are necessary to implement the above-described project to reduce greenhouse gas (carbon dioxide) emissions into the atmosphere.

References

[1] Gasumov, E.R. (2023). Prospects for the development of "green" energy in Azerbaijan. Bulatov readings, 2, 17-22.

[2] Order of the President of the Republic of Azerbaijan (2023). On declaring 2024 in the Republic of Azerbaijan "The Year of Solidarity for the Green World." Official website of the President of the Republic of Azerbaijan. Url: https://president.az/ru/articles/view/62737

[3] Osipov, A.V., Mustaev, R.N., Monakova, A.S. (2022). Mechanisms and options of the utilization and burial of carbon dioxide in the earth interior. Proceedings of higher educational establishments. // Geology and Exploration, 4:40-53. https://doi.org/10.32454/0016-7762-2022-64-4-40-53.

[4] Gunter, W.D., Benson, S., Bachu, S. (2004). The role of hydrogeological and geochemical trapping in sedimentary basins for secure geological storage for carbon dioxide. Geological Society, London, Special Publications, 233, 129-145. https://doi.org/10.1144/GSL.SP.2004.233.01.09.

[5] Solomon, S. (2007). Carbon dioxide storage: geological and environmental safety - a case study of the Sleipner gas field in Norway. Oslo: Bellona Foundation, 128.

[6] Mustafazadeh, Sh.A. (2023). Problems of climate change in aspects of sustainable development of the Republic of Azerbaijan. In the collection: Sustainable development, geopolitical transformation and national priorities. / Materials of the XIX International Congress with elements of a scientific school for young scientists. In 2 volumes. Moscow, 209-220.

[7] Gasumov, E.R. (2021). Prospects for the production and transportation (export) of hydrogen in Azerbaijan. // Natural and technical sciences, 12, 228-232.

[8] Gasumov, E., Gasumov, R., Suleymanov, G., Kurbanov, K. (2023). Prospects for Azerbaijan's participation in the diversification of energy sources and reducing the risks of energy supple to Europe. The Fifth Eurasian Conference: "Innovations in minimizing natural and technological risks". // "Reliability: Theory Applications", 18, 5(75), 195-205.

[9] Gunter W.D., Benson S., Bachu S. (2004). The role of hydrogeological and geochemical trapping in sedimentary basins for secure geological storage for carbon dioxide Geological Society, London, Special Publications, 233, 129-145. https://doi.org/10.1144/GSL.SP.2004.233.01.09.

[10] Intergovernmental Panel on Climate Change. Special Report on Carbon Dioxide Capture and Storage (2005). New York: Cambridge University Press, 442.

[11] Korolkov, V.K., Los, A.S. (2023). Geophysical monitoring of carbon dioxide distribution in depleted hydrocarbon deposits. In the collection: Innovative technologies in the oil and gas industry. Problems of sustainable development of territories. Stavropol, 48-50.

[12] Dymochkina, M.G., Samodurov, M.S., Pavlov, V.A. et al. (2021) Geological potential for carbon dioxide capture and storage in the Russian Federation. // Oil industry, 12, 20-23.

[13] Dantsova, K.I., Miloserdova, L.V., Osipov, A.V. et al (2022). Monitoring of subsoil degassing using remote sensing materials. // Oil industry, 5, 48-51. https://doi.org/10.24887/0028-2448-2022-5-48-51

[14] Gasumov, E.R. (2022). On the issue of hydrogen energy development. //Innovative technologies in the oil and gas industry. Problems of sustainable development of territories: collection of works III International Scientific and Practical Conference. North Caucasus Federal University. Stavropol, 218-224.

[15] Gasumov, E.R. (2022). Prospects for the development of renewable energy sources in Azerbaijan. In the collection: Technical and technological systems. Proceedings of the Thirteenth International Scientific Conference. Krasnodar, 189-193.

[16] Dmitrievsky, A.N., Khan, S.A., Dorokhin, V.G. (2023). Geological burial of carbon dioxide. Theory, history and methodology. Publishing house "FLINTA". Moscow, 274.

[17] Vysotsky, V.I. (2021). Oil, Gas, Renewable Energy and Carbon Dioxide Emissions (Information Brief). Moscow, 44.

[18] Molodtsov, K.V. (2022). Parade of hydrocarbons. // Oil and gas vertical, 1, 4-9.

[19] Greenhouse gases: causes, consequences and solutions (2023). https://new-science.ru/parnikovye-gazy-prichiny-posledstviya-i-resheniya/?ysclid=lth7t77uvm96686890

[20] Los, A.S., Korolkov, V.K. (2023). Conditions for the burial of carbon dioxide in the aquifer with further geophysical control. In the collection: Innovative technologies in the oil and gas industry. Problems of sustainable development of territories. Stavropol, 60-62.

[21] Labazanova, I.M. (2023). Geological burial of carbon discode in oil and gas wells. //In the collection: Millionshchikov-2023. Materials of the VI All-Russian scientific and practical conference of students, graduate students and young scientists with international participation., 301-304.

[22] Shpurov, I.V. (2021). Tasks of the State Reserves Committee in the context of the energy transition and low-carbon economy // Materials of the All-Russian meeting "Problems of Oil and Gas Geology". Moscow, VNIGNI, 11.

[23] Chadwick, A., Arts, R., Bernstone, C. et al. (2008). Best practice for the storage of CO2 in saline aquifers. UK: British Geological Survey, 267.

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PART-3

ENSURING RESILIENCE OF SPATIAL DEVELOPMENT IN THE CURRENT CLIMATE REALITY

SPATIAL DESIGN ACTIVITY IN THE CURRENT CONTEXT OF HIGH CLIMATE UNCERTAINTIES AND RISKS

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Abstract

The article explores the characteristics of the ongoing transformation of spatial design activities in the current context of high climate uncertainties and risks. A comprehensive methodology of Sustainable Ecosystem Design (SED) is proposed as a special type of thinking activity, based on a systemic approach to decision-making and emphasizing the adaptation of individuals and communities to high climate risks and uncertainties. This planning and design thinking is capable of better reflecting the diversity of broadly understood geographical conditions, expanding the range of socially and culturally acceptable solutions for sustainable development in an unstable and risk-prone environment.

Keywords*:* spatial planning and design, sustainable ecosystem design, climate uncertainties and risks, sustainable development, anthropo-natural systems

I. Introduction

Climate change is a critical risk multiplier that triggers or exacerbates spatial development crises. The impacts of climate change pose threats to food security, health, biodiversity, infrastructure, economy, and finance [1]. The multiplicative effect of climate risks is evident in the crisis faced by governance, planning, and spatial development institutions, which were established under previous environmental and climatic conditions. In other words, within the new environmental and climatic reality, these institutions can no longer be managed according to the conventional metrics developed under classical planning paradigms. This is evidenced by the increasing damage to the well-being of the majority of the planet's population.

In the current context of high climate uncertainties and risks, the existing spatial model of decision-making regarding economic activities is rapidly losing its effectiveness. This decline is a result of the ever-increasing budgetary expenditures required to mitigate damages from natural disasters, with significant compensation costs being deferred to future generations. It is unreasonable to continue designing agricultural policies, constructing roads and erecting buildings in the same manner as before, continually spending resources on reconstruction or rehabilitation due to the adverse effects of climate change that jeopardize public finances and social well-being.

Climate risks are not new; humanity has always responded to epidemics, floods and droughts. History shows that significant climate change has driven some countries to the brink of disaster, while others have successfully adapted to new, challenging realities [2]. The modern risk-reflection of society on the current situation is expressed in growing concern not always accompanied by reasonable actions. The reality is illustrated by the sharp increase in negative news globally, especially after 2020[1] . In such moments, people are overwhelmed by doubts that can either paralyze their ability to act or drive them to unreasonable radical decisions[2] .

People's risk-reflection on climate change lags behind the escalating climate threats, resulting in preventive measures often being delayed. Effective protective actions are typically taken during natural disasters usually perceived by the population as unexpected "black swans"[3] . The situation is exacerbated by the short planning horizon and paternalistic traditions prevalent among a large part of the population, where people, despite being aware of climate threats, are generally reluctant to engage in broadly understood risk insurance through proactive protective measures. The danger of climate vulnerability is frequently underestimated despite N. Stern demonstrating more than ten years ago that the cost of inaction on climate change far exceeds the cost of taking measures [3]. Scientists have calculated that scientifically adapting infrastructure to climate change is highly cost-effective, with a global net present value exceeding 2.5 trillion USD[4] [4]. Considering this phenomenon, G. White [6] noted that people make decisions based on practical choice established by culture and institutions, rather than theoretical choice established by the physical environment (in this case - climate scientists (auth.). In such context, the risks of "gray swans" and particularly dangerous "pink flamingos" increase[5] .

In the context of increasing climate risks and uncertainties, the search, development and implementation of new mechanisms of decision-making regarding spatial development, integrating climate adaptation measures and reducing climate impacts characterized by synergy and long-term sustainable effects, has become more relevant. In the most climate-vulnerable regions and locations, there is an urgent need to rethink urban planning regulations, technological standards and long-established zoning practices. This article examines one such systemic and comprehensive mechanism.

II. Methodology

Spatial design activities under conditions of high climate uncertainties and risks of the "full" world of the Anthropocene are still developing methodologically, as well as the understanding of this new reality of the 21st century [7]. In any case, the real world remains far from the noosphere - the sphere of spirit according to Teilhard de Chardin [8] or the sphere of reason according to V. I. Vernadsky [9]. The most dangerous aspect of the "full" world is its high-risk nature, characterized by the production, distribution and "consumption" of risks [10-14].

It is the risk-reflection regarding the vulnerability of the new world that creates the need for a shift in the fundamental approaches to spatial design activity [15], with an increased emphasis on maintaining the viability of anthropo-natural systems (ANS)[6] , in which humans are not considered beings "accidentally separated" from and opposed to nature. On the contrary, humans play a dominant role, unfortunately simplifying and sometimes destroying ecosystems, as well as creating new, previously impossible ones, including dangerous interactions with living nature.

As institutional systems of the "full" world emerge, it is methodologically important to prevent the appearance of negative strange attractors - future scenarios without humans. This concern underlies the commitments of many countries to gradually transition to carbon neutrality in an effort to slow down climate change. However, the high degree of uncertainty inherent in

[1] The analysis of over 14 million sources, providing publications over the past 125 years in three major languages, showed a sharp increase in anxiety and concern in many parts of the world [2].

[2] The situation is further complicated by the increased danger of climate-related misinformation in the age of global internet access, hindering effective measures for climate adaptation and mitigation.

[3] As N. Taleb wrote in his bestseller, a "black swan" is a catastrophic event that cannot be predicted.

[4] This was later confirmed by numerous studies, although the estimates of the scenarios considered vary: out of approximately 3000 different scenarios, 2904 have cost-benefit ratios less than one [5].

[5] Unlike "black swans", "gray swans" are, although unlikely, still predictable catastrophic events. The most dangerous variant of "gray swans" is "pink flamingos." This term refers to a class of predictable disasters whose risks are ignored due to the cognitive biases of decision-makers, influenced by institutional interest groups.

[6] The anthropo-natural system is a constantly evolving living organism, whose laws of survival and development have formed over billions of years of evolution and periodically undergoes a phase transition before entering a new stage of dynamic stability.

climate knowledge complicates this process. M. Weitzman is particularly categorical in his "dismal theorem," asserting that the uncertainties associated with future climate change are so significant that there is a non-negligible probability of catastrophe. According to M. Weizmann, the danger lies in the tails of the probability distribution of climate risks, where there may be an unexpectedly thick end or "fat-tailed distribution," meaning the tails never entirely diminish [16].

Spatial planning activities under conditions of high climate uncertainties and risks within the "full" world of the Anthropocene are still developing methodologically, as is the understanding of this new 21st-century reality [7]. The real world remains far from the noosphere—the sphere of the spirit, as described by Teilhard de Chardin [8], or the sphere of reason, as conceptualized by V. I. Vernadsky [9]. The most perilous aspect of the "full" world is its high-risk nature, characterized by the production, dissemination, and "consumption" of risks [10-14].

It is the risk-reflexivity regarding the vulnerability of the new world that necessitates a shift in fundamental approaches to spatial planning activities [15], with an increased emphasis on maintaining the viability of anthropogenic-natural systems (ANS), wherein humans are not considered beings "accidentally" separated from and opposed to nature. On the contrary, humans play a dominant role, unfortunately simplifying and sometimes destroying ecosystems, as well as creating new, previously impossible ones, including dangerous interactions with living nature.

As institutional systems of the "full" world emerge, it is methodologically important to prevent the appearance of negative strange attractors—future scenarios without humans. This concern underlies the commitments made by many countries to gradually transition to carbon neutrality in an effort to slow down climate change. However, the high degree of uncertainty inherent in climate knowledge complicates this process. M. Weitzman is particularly categorical in his "dismal theorem," asserting that the uncertainties associated with future climate change are so significant that there is a non-negligible probability of catastrophe. According to Weitzman, the danger lies in the tails of the probability distribution of climate risks, where there may be an unexpectedly thick end or "fat-tailed distribution," meaning the tails never entirely diminish [16].

Given a scenario where the probability of a global climate catastrophe is minimal yet existent, and its consequences tend toward infinity (self-destruction of a significant portion of the planet's population), it is essential to align with UNESCO's position[7]: For humanity to prioritize climate change risks, we need to change mindset [17]. It is most important to increase the value of the responsibility in the behavioral model of economic activity as a foundation for changing the priorities and structure of economic activity (Tab. 1).

Table 1: *Traditional vs resilience approaches to spatial planning and design*

Approaches to spatial planning and design	
Traditional approach	*A resilience approach*
Considers the object or process individually	Considers the entire anthropogenic-natural system (ANS) in which the object or process will be used
Focused on technical issues	Synergistically addresses both technical and non-technical issues
Solves immediate problems	Aims to solve problems permanently or for the longest possible term
Takes into account the local context	Considers local, national and global contexts
Assumes others will address political, ethical, and social issues	Recognizes the necessity of engaging with a wide range of experts in sociology, ecology, etc.
Ignores the importance of achieving carbon neutrality	Focuses on ensuring carbon neutrality

[7] https://ru.unesco.org/themes/obrazovanie-v-interesah-ustoychivogo-razvitiya-0.

The task of reducing climate development risks and enhancing the resilience of anthropo-natural systems (ANS) is addressed by the author's development of the Sustainable Ecosystem Design (SED) tool [18-20]. The subject of SED is practical activity systems that can be identified, described and turned into objects of goal-oriented spatial development transformations in an unstable external environment to improve the resilience of ANS. In other words, it represents a particular approach to reality, focusing on exploring the possibilities, methods, and means of "restructuring" a fragment of reality to align it with "some idea", an ideal with carbon neutrality, preserved biodiversity and high-quality human life. In the current conditions of high climatic uncertainties and risks, spatial planning and design activities are justifiably based on the principles, structures and processes of Risk Management standards (such as GOST R ISO 31000-2019 in the Russian Federation [21] and others), which are oriented to adapting to the increased probabilities and severities of climate change impacts.

SED is implemented through the design of climate-resilient systems and spatial infrastructures that integrate human society with its natural environment for the benefit of both. The essence of SED lies in an ethically oriented, goal-appropriate, systems approach to designing the development of ANS. The primary focus is on coordinated actions in adaptation[8] and mitigation[9] within public administration, economic sectors and infrastructure in response to changing climatic conditions. Driven by their goals, humans consume, conserve, and create ecosystem services.

In SED, priority is given to climate-related, natural-biological, and socio-cultural constraints and regulations, which create a regulatory framework, or "bubble" into which it is necessary to fit increasingly complex economic activities. As a result, the importance of ecosystem regeneration[10] increases as well as of nature-oriented solutions, the potential for cyclical economic development based on balanced and other approaches. The system of constraints and regulations inherent in SED (in some ways extending urban planning norms) reduces the likelihood of hypothetical negative development trajectories for ANS.

III. Results

The research conducted by the author in the Russian Federation, the Kyrgyz Republic and the Republic of Uzbekistan on climate-related issues, with a focus on achieving a synergistic effect of climate adaptation and mitigation measures, has confirmed the effectiveness of institutional approaches to to Sustainable Ecosystem Design (SED) as a special type of spatial planning and design. Under conditions of high climate uncertainties and risks, SED is considered as a goal-oriented activity aimed at implementing sustainable development approaches for territories and settlements. In terms of form, represents forward-looking long-term planning, while in terms of the content of planning decisions, it pertains (with rare exceptions) to strategic planning and is seen as a goal-oriented activity to implement sustainable development approaches for territories and settlements under high risks and uncertainties.

Theoretical model. SED involves a systemic vision, pragmatic solutions, and methods that help coordinate disparate efforts in green architecture, sustainable agriculture, eco-engineering, and more. It is characterized by an indisputable ethic of Life, recognizing the inherent value of all living things. SED can be described using a four-pillar dynamic sustainability model (Figure 1),

[8] Climate change adaptation means planning and taking measures in response to expected climate change impacts. This includes making changes to how we live and what we do before the impacts occur (proactive action), and being prepared to respond to increasingly likely and frequent extreme events (reactive actions).

[9] Mitigation is a set of measures taken to reduce and mitigate the negative impacts of climate change. Its main goal is to reduce greenhouse gas emissions and the causes of global warming.

[10] Regeneration - restoration, renewal, or compensation of something during the course of activity.

where the three dimensions - social, economic, environmental - are joined by an institutional[11] one with six interconnections.

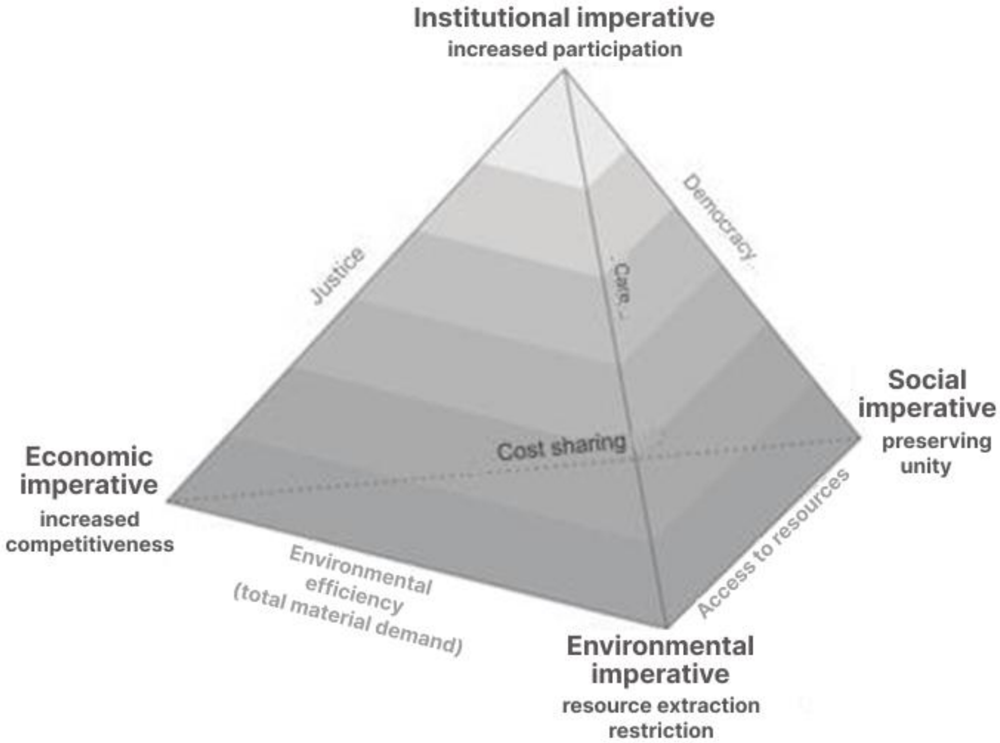

Figure 1: *Four-pillar model of SED under conditions of high uncertainties and risks*
Source: developed by the author based on [22].

The institutional component of sustainability introduces the concept of understanding of value-driven motives and moral incentives for activities aimed at achieving climate neutrality, from local communities to humanity as a whole. The four-pillar dynamic model of sustainability places value on three aspects of development - care, justice, and democracy - derived from the primacy of responsibility for future generations. This value-driven socio-cultural impact, in turn, influences the social, economic, and environmental imperatives (Figure 2). Under high climate uncertainties and risks, this makes spatial development more humane, inclusive, and sensitive to environmental variability[12] .

SED should be viewed as a value-driven, action-oriented, institutional response to ecosystem degradation, increasing climate threats and biodiversity loss. It is a goal-oriented spatial design interdisciplinary approach that seeks to take into account the environmental, social, and cultural features of specific areas when addressing spatial development tasks. It is characterized by the implementation of sustainable development goals; systematic application of regulatory institutions (tools) for ecosystem services; geographical specification of basic methodologies for spatial planning, consideration of the cyclical nature of resource flows; and pursuit of carbon neutrality. In organizational terms, SED relies on the creation of multidisciplinary teams of local specialists and external experts.

SED requires reliable measurements of the contribution of planning and design decisions to people's well-being on a particular territories and the impact of human activities on the environment. There is a growing demand [25] for interdisciplinary synthesis of knowledge based

[11] D. North most successfully defined institutions as "rules of the game" in society, or human-created restrictive frameworks that organize relationships between people. Such institutions (formal and informal) emerged as a behavioral response of people with only partial rationality to threats (real or imaginary) to their security [23].
[12] Of course, the institutional imperative in its Kantian perspective is unattainable, as people are only partially rational and do not possess all information.

on qualitative monitoring observations as the foundation for creating an effective information system for to support spatial design activities in the current context of high climate uncertainties and risks - from primary ecosystem state measurements and analysis of ecosystem service flows (including spatial) to future scenario modeling through knowledge analysis and systematization, aimed at increasing sustainability capital.

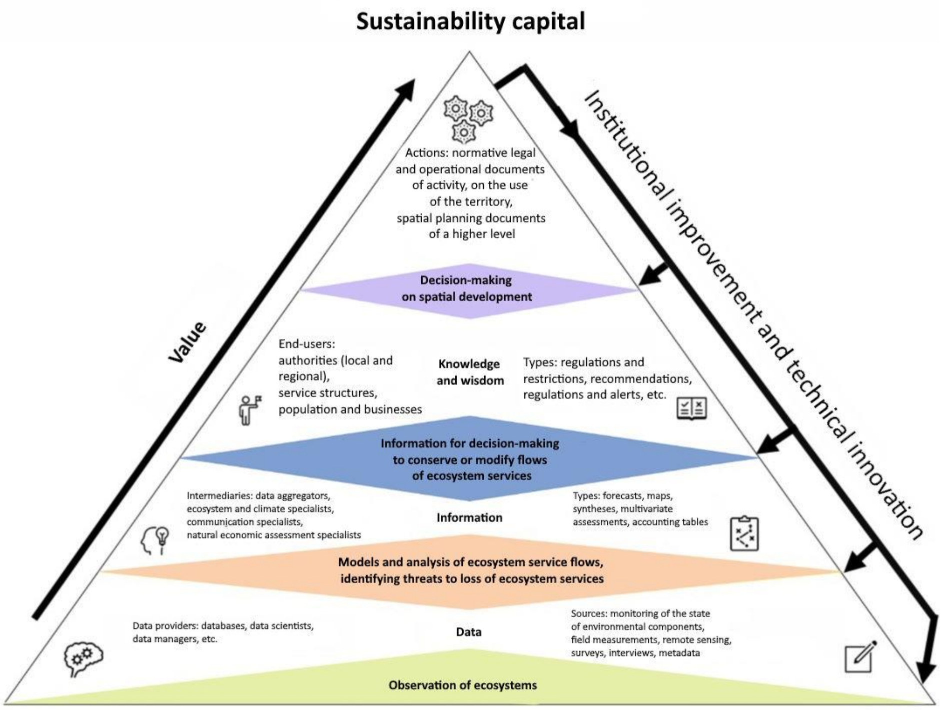

Figure 2: *From ecosystem state observations and ecosystem service flows to sustainability capital*
Source: compiled by the author based on [24].

This chain of creating an effective information system to support spatial design activities in the current context of high climate uncertainties and risks is depicted as a large triangle in Fig. 2. It shows that, starting from its lower part and moving upwards, primary monitoring data are given a higher state status, for example, through statistical and departmental indicators. Subsequently, through generalization within the framework of the System of Environmental-Economic Accounting (SEEA EA) [26, 27], models, and analytics, these systems of indicators are aggregated into complex indicators for assessing the territory development, primarily by the size and structure of the territory's sustainability capital and its dynamics.

The systemic basis for obtaining and transforming knowledge-intensive formalized and dispersed information into knowledge envisaged by the UED allows to ensure the necessary quality of development and analysis of development plans and projects, as well as their assessment for compliance with the goals and approaches of sustainable development, to ensure the search for reasonable trade-offs between different land use options.

Our practical experience in the regions of Russia and Central Asia has shown that natural-scientific and legal knowledge alone is not sufficient for strategic spatial development decisions concerning the future. It is fundamentally important that sustainable development requires wisdom, which expands people's ability to make decisions under high uncertainties and with care for the future.

IV. Discussion

The search for new approaches to the reform of spatial and design for the development of countries, regions, and places is the subject of extensive and rapidly growing literature. An analysis of this literature reveals a broad recognition of the close synergistic relationship between climate change and ecosystem health. regarding the methodological complexity of assessing the impact of extreme risks on socio-economic development. Successful climate adaptation and achieving climate neutrality are not ends in themselves but are crucial criteria for spatial and design activities in an unstable external environment, necessary to ensure the long-term survival of both people and nature.

SED implies goal-oriented integration of practical actions for climate adaptation and reducing negative impacts on the climate from the perspective of minimizing the risks of losing development sustainability. SED is focused on the preservation, restoration, and creation of new viable ecosystems that are important for both humans and biota. It is always territorially specific and unique, combining climate-neutral and sustainable functioning of human and natural spatial systems with engineering and social infrastructures.

The information developed within the framework of SED should enable the application of broadly understood insurance mechanisms, ranging from engineering protective measures to social and economic ones. Insurance for economic risks in the climate sphere is in its infancy due to significant "fat tails" associated with uncertainties. For example, the construction of temperature-independent energy systems or population migration may encounter difficulties in conditions of multi-level and interconnected uncertainties [2]. Addressing this gap has become the focus of the global Network for Greening the Financial System[13].

The principles we set out for a unified system of indicators for evaluating decision-making within the SED and for assessing the efficiency of such decisions allow us to determine the effectiveness of projects and development plans by combining RBM (results-based management) and CBA (cost-benefit analysis) approaches, as well as RIAM (rapid impact assessment matrix). This makes it possible to assess measures within existing informational constraints in terms of their effectiveness, economic efficiency for the innovation beneficiaries, socio-economic efficiency for local communities, and sustainable development of territories in the long term. In this context, while developing SED, we unexpectedly encountered a lack of scientific knowledge about anthropo-natural systems (ANS). The reason for this situation is deeper than it seems at first sight, as it is fundamentally related to the orientation of scientists and experts in biology and ecology towards studying predominantly intact ecosystems. Meanwhile, such knowledge, albeit useful, proved insufficient for the designing solutions of the problems of ensuring the sustainability of ANS, which include industrial, civil and infrastructure facilities.

Despite its obvious demand, SED is still spreading slowly. This is because it imposes increased requirements on the quality of territory study, which requires specialists trained to work in conditions of high climate uncertainties and risks. When using SED tools, the abilities of managers, planners, and designers to think systemically and engage in interdisciplinary interaction come to the forefront; as well as focus on reducing risks of losing viability and ranking these risks; ability to identify and prioritize critical "red points" of effort, ability to work with large data sets and artificial intelligence systems. Widespread use of SED is also hindered by the currently short planning horizon of many resource managers, who perceive the importance of only immediate social and economic tasks and the political conjuncture. They perceive the real tasks of strategic planning as declarative, and scientific activity as disconnected from real life.

Our experience has shown that SED approaches are currently most positively received by people in areas significantly affected by climate change, such as the Aral Sea region or southern Kyrgyzstan, which have suffered from natural disasters or anthropogenic and natural catastrophes.

[13] NGFS - Central banks and supervisors - Network for Greening the Financial System. Scenario Portal. https://www.ngfs.net/ngfs-scenarios-portal/

V. Conclusions

Spatial design activities in the current context of high climate uncertainties and risks require a system-forming SED methodology, which sets the vector for goal-oriented systemic transformations of spatial development in an unstable external environment to enhance the viability of disturbed ANS through a system of planned and project measures for spatial development within interconnected, geographically specific constraints and regulations of economic activity.

SED allows reducing losses and damages through comprehensive development of territory and synthesis of climate adaptation and mitigation measures. It increases the efficiency of public and private investments from the perspective of sustainable development of territories, facilitates sustainable use of natural capital, and enables the education of the population on the sustainable use of development assets and their capabilities in the face of climate challenges.

In the context of the climate agenda, SED is expressed in giving climate-neutral development a human face, perceiving climate threats from a general security perspective, strengthening positive synergies between climate adaptation and mitigation measures, and creating institutional conditions to increase the interest of key economic sectors and a wide range of stakeholders in achieving climate neutrality. And the leading position is taken by the ability of managers, planners and designers to think systemically and engage in interdisciplinary interaction.

References

[1] EEA European climate risk assessment - Executive summary / European Environment Agency. 2024. URL: https://www.eea.europa.eu/publications/european-climate-risk-assessment

[2] Human Development Report 2021/2022 / UNDP. 2022. URL: http:// hdr.undp.org.

[3] Stern N. The Economics of Climate Change: The Stern Review. Cambridge and New York: Cambridge University Press, 2007.

[4] Hallegatte S., Rentschler J., Rosenberg J., Nicolas C., and Fox C. Strengthening New Infrastructure Assets. A Cost-Benefit Analysis. Policy Research Working Paper 8896, World Bank. Washington, DC, 2019.

[5] Rimjhim A., Carapella P., Mogues T., and Pico-Mejía J. Accounting for Climate Risks in Costing the SDGs. IMF Working Paper WP/24/49, International Monetary Fund. Washington DC, 2024.

[6] White G. F. (1961). Choice of use in resource management. Natural Resources Journal, 1: 23-40.

[7] Daly H. (2005). Economics in a full world. Scientific American, 9: 100-107.

[8] Teilhard de Chardin P. Divine Environment. Moscow: Ast, 2021.192 p.

[9] Vernadsky V. И. (1944). A few words about the noosphere. Uspekhi sovremennoi biologii, 18: 113-120.

[10] Beck U., Lash S., Wynne B. Risk Society. Towards a New Modernity. New York: SAGE Publications, 1992.

[11] Beck U. Ecological Politics in the Age of Risk. Cambridge: Polity, 1994.

[12] Giddens A. The Consequences of Modernity. Stanford: Stanford. University Press, 1992.

[13] Luhmann N. Risk: A Sociological Theory. London: Routledge, 2017.

[14] Yanitsky, O.N. (1997). Modernization in Russia in the light of the concept of "risk society". Where is Russia going? General and special in modern development. Vol. 4 / Under the general editorship of T. I. Zaslavskaya. Moscow: Ostozhye. C. 37-48.

[15] Fomenko G.A., Fomenko M.A. (2020). Professional consulting, planning and design of spatial development under increasing uncertainties and risks. Strategic decisions and risk management, 4: 366-377.

[16] Weitzman M.L. (2009). On modeling and interpreting the economics of catastrophic climate change. Review of Economics and Statistics, 91: 1-19.

[17] Fomenko G.A. Management of environmental activities: bases of sociocultural methodology. Moscow: Nauka, 2004. 390 c.

[18] Fomenko G.A. Sustainable ecosystem design: prerequisites and approaches: educational and methodological manual. Yaroslavl: ANO NIPI "Cadaster", 2021. 216 c. (Series "Planning and design of spatial development").

[19] Fomenko G.A. Sustainable ecosystem design: main features and peculiarities: educational and methodological manual. Yaroslavl: ANO NIPI " Cadaster", 2021. 136 c. (Series "Planning and design of spatial development").

[20] Fomenko G.A., Fomenko M.A. Sustainable ecosystem design: focus on ecosystem services: teaching manual. Yaroslavl: ANO NIPI " Cadaster", 2022. 260 c. (Series "Planning and design of spatial development").

[21] Risk Management. Principles and guidelines: national standard of the Russian Federation. (GOST R ISO 31000-2019).

[22] Valentin A., Spangenberg J.H. (2000). Guide to community sustainability indicators. Environmental Impact Assessment Review, 20: 381-392.

[23] North D. Institutes, institutional changes and functioning of the economy. Moscow: Nachala, 1997.

[24] Heymans J.J., Le Traon P.-Y., Petihakis G., Visbeck M. (2021). Sustaining in situ Ocean Observations in the Age of the Digital Ocean. EMB Policy Brief., 9.

[25] Setting the Course for Sustainable Blue Planet: Recommendations for Enhancing. EU Action. URL: https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1469.

[26] System of Environmental-Economic Accounting 2012 - Central Framework. URL: https://unstats.un.org/unsd/envaccounting/seearev/seea_cf_final_en.pdf.

[27] System of Environmental-Economic Accounting - Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. N. Y., 2021. URL: https://seea.un.org/ecosystem-accounting.

DEVELOPMENT OF STANDARDS FOR THE TRANSPORTATION AND STORAGE OF HYDROGEN AS THE BASIS FOR THE SAFETY HYDROGEN'S USAGE

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Abstract

Today, the standardization of hydrogen is an important topic for increasing its production, while raising many questions. Hydrogen and its derivatives are central components of a decarbonized energy system. On the one hand, many countries are now establishing regulatory frameworks for renewable and low-carbon hydrogen, often accompanied by specific requirements for hydrogen. Similar processes are underway in Germany, Japan and the United States. The article discusses trends in the development of standards for the transportation of hydrogen through pipelines as the cheapest mode of transport and the prospects for creating a unified regulatory framework in this area, allowing the formation of a single world network for the transportation of hydrogen. Based on the results of the study, we came to the conclusion that at the present stage, the standardization of hydrogen is extremely underdeveloped, both on a global scale and at the national level. There are a number of regional initiatives that have not been widely adopted. Therefore, today it is extremely important to develop cooperation in this area at the international level. The Working Party on Regulatory Cooperation and Standardization Policies (WP.6) seems to be a good platform.

Keywords: standards, regulatory policy, hydrogen, certification, requirements

I. Introduction

Global standardization for the transportation of hydrogen fuels is becoming a cornerstone for the implementation of sustainable development goals, since hydrogen is the most promising and environmentally friendly of all possible energy sources today. The most promising in terms of cost is the transportation of hydrogen through existing pipelines, where the development of regulatory requirements for the transportation of hydrogen will make it possible to determine the possibility of using both existing networks and the principles of creating new hydrogen pipelines.

Today, the scientific community pays great attention to the standardization of hydrogen itself (Yang [1], Wurster [2]). However, there is no unified approach to the standardization of hydrogen at the international level. Although it should be noted that there are a large number of regulatory documents developed at the national level of different countries, as well as attempts to develop international standards in this area by the international organization for standardization - ISO. The lack of uniform approaches to the standardization of hydrogen makes it difficult to use, and more importantly, in our view, the development of both hydrogen infrastructure and hydrogen trade exchange.

The prospects for global standardization in the field of hydrogen technologies are very encouraging. States and companies recognize the importance of developing common standards to facilitate the use of hydrogen in various industries, including automotive, energy and industrial. The development of hydrogen transportation, distribution and storage is becoming a key element of hydrogen standardization. Therefore, today the standardization of hydrogen infrastructure is being actively discussed at various venues. An important player in this field is the UNECE Working Party 6, where a project to harmonize different aspects of hydrogen pipelines has been implemented since 2023.

II. Methods

In this study, we relied on the scientific research of such experts in the field of hydrogen standardization as A. Ramensky [3], A. Shvarovsky [4], F. Gale, D. Goodwin, H. Lovell, H. Murphy-Gregory, K. Beasy, M. Schoen.

The methodological basis of our study was the national legislation of the EAEU countries, China, the USA, the European Union, international and regional strategies for the implementation of hydrogen energy, for example, the Roadmap on hydrogen standardization developed by the European Organization for Standardization (CEN/CENELEK) in 2023 [6].

Historically, the first attempts to standardize hydrogen date back to the beginning of the 20th century, when the scientific community first began to talk about standardization in hydrogen energy and, accordingly, about the need to create uniform requirements for hydrogen. Later, the Paris Climate Agreement 2015, aimed at decarbonizing the global economy, became an incentive for the development of hydrogen standardization. The development of alternative types of energy, including hydrogen, plays a key role in this process.

Today, the efforts of the international community are focused on the development of standards for hydrogen and its use, on the one hand, and attempts are being made to standardize hydrogen infrastructure on the other. An example is the flagship TransHyDE project, implemented since 2021 in Germany with the support of the German Federal Ministry of Education and Research, which aims to support the transportation, distribution and storage of hydrogen and other chemical energy carriers in practice.

III. Results

Within the framework of this study, it seems useful to look at who is involved in the development of standards for hydrogen and hydrogen infrastructure at the international and regional level. On a global scale, two major standardization organizations should be singled out here – the International Organization for Standardization (ISO) and the European Organization for Standardization (CENCENELEK). Statistics on the development of standards for hydrogen and hydrogen infrastructure at the international and regional level are presented in Table 1.

Table 1: *Development of hydrogen standards*

Organization	All Standard	Standards for Hydrogen pipeline
ISO	177 standards	1 standard
CEN	150 standards	1 standard

As can be seen from the analysis, a fairly broad regulatory framework for hydrogen energy has been developed on a global scale, but very little attention is paid to the standardization of hydrogen. Especially in terms of pipelines for hydrogen. The results in this direction have been achieved in Russia, where, in the course of the implementation of the national standardization program, new standards for steel pipes and cylinders for the transportation and storage of hydrogen were developed. The developer of a series of standards, consisting of three documents and establishing requirements for the transportation of hydrogen through steel and seamless pipes and for the storage of hydrogen in cylinders, is the technical committee TC 357 "Steel and cast iron pipes and cylinders". The standards are based on the results of research on overcoming hydrogen embrittlement, the destruction of metals, in particular, high-strength steel, when interacting with hydrogen. Moreover, Russia has created a series of products for the creation of pipelines for hydrogen - Sputnik H, which includes pipes for the production and distribution, transportation and storage of hydrogen.

The current situation suggests the need to intensify efforts in this direction in order to really reduce the cost of transporting hydrogen and thereby increase trade in hydrogen.

The largest number of standards has been developed in the International Organization for Standardization, but this fact does not mean that the harmonization of standardization in this area at the global level has been achieved. The fact is that the regulations for the adoption of ISO standards at the national level provide for three options: standards identical to ISO, standards modified, standards not equivalent to ISO. An analysis of the distribution of ISO adoption of hydrogen standards in different countries is presented in table 2.

Table 2: *Types of adaptation of standards for hydrogen*

Country	Type of adopted standards		
	Identical (IDT)	Modified (MOD)	Nonequivalent (NEQ)
Europe	+		
China and Kazakhstan	+	+	+
Gulf countries	+	+	
USA	+	+	
Russia	+		

If the standard is accepted as identical, it means that no changes have been made to the text of the document. In the case of adopting a standard as a modified one, the structure of the international standard is retained in the national standard, but the text of the document contains technical deviations that must be explained and justified. A non-equivalent standard differs from a modified standard in that the technical changes to the text are not explained.

Thus, when adopting ISO International Standards, countries are left with the opportunity to make significant changes to the requirements contained in the document without justification. This practice is actively used by China, where 6 standards for hydrogen pipelines have been developed, based on ISO international standards [1].

IV. Discussion

I. Key standards at the global level have not been developed

A key obstacle faced by standards developers is the difficulty of developing global international standards that take into account the diverse technical and legal requirements that are present in national legislations of different countries. From the analysis of standards for transporting hydrogen through pipelines it is clear that foreign technology for transporting hydrogen through pipelines is actively developing. At the global level a number of standards or guidelines have been formed covering the design, construction, operation, and maintenance of hydrogen pipelines. However, the existing standards for hydrogen pipelines mainly apply to gas pipelines and industrial pipelines, but since the transportation through pipelines has different characteristics, it is not fully applicable to hydrogen pipelines. Therefore, the existing documents require a significant revision.

The positive effect of the development of standards for hydrogen pipelines at the global level is that the efforts of international organizations allow many countries to form their regulatory legal system taking into account the safety requirements established in the international arena, the criteria for assessing efficiency, and the features of the conceptual apparatus. The solution to the problem of the difference in requirements contained in regulatory documents is to organize a dialogue among all stakeholders in global standardization in the field of hydrogen pipelines. The platform for such dialogue is Working Party on Regulatory Cooperation and Standardization Policies (WP.6) of UNECE.

II. Standards as the basis for the safety of hydrogen pipelines

The creation of a safe hydrogen infrastructure consists of three essential elements: standards themselves, certification schemes and labeling. The interaction of these elements is shown in Figure 1.

Figure 1: *Steps to ensure the safety of hydrogen pipelines*

Standards are therefore only the first step towards safety. The second important element is the certification of hydrogen pipelines - certification. Today, the difficulty lies in the fact that mainly developments in the field of certification relate to the reconstruction of existing networks for the transportation of hydrogen. An example of certification of existing pipelines for the transport of hydrogen is the program developed by the German certification body TUV-Sud entitled "Assessment of the suitability of new high-pressure gas pipelines for hydrogen operation (H2-ready certificate)", which aims to verify the suitability of existing pipelines. However, a comprehensive approach to the certification of hydrogen pipelines requires an analysis not only of existing networks, but also of the possibility of constructing new pipelines specifically for hydrogen. At the current stage, it is necessary to coordinate the efforts of the world community in this direction. The development of really working certification systems for hydrogen pipelines will make it possible to move on to the last step towards the creation of a safe hydrogen pipeline - the development of requirements for labeling hydrogen pipelines. The prospects for the implementation of this task in view of the great interest of both state bodies and the scientific community in the problem seem to be quite realizable.

References

[1]Yang, Y. Development of Standards for Hydrogen Safety. E3S Web of Conferences, 2020. DO - 10.1051/e3sconf/202019402013

[2] Wurster, R. Compendium of Hydrogen Energy 4, 195 (2016)

[3] Ramenskiy, A. Hydrogen as a fuel: the object and the purpose of standardization. *Alternative Energy and Ecology (ISJAEE),* 2015:33-44, Doi = {10.15518/isjaee.2015.01.03}

[4] Shkarovskiy, A. Interchangeability and standardization of the parameters of combustible gases when using hydrogen. *AEJ.* 2022:33-45.

[5] Gale, F. Renewable hydrogen standards, certifications, and labels: A state-of-the-art review from a sustainability systems governance perspective, *International Journal of Hydrogen Energy. 2024:654-667, DOI* https://doi.org/10.1016/j.ijhydene.2024.02.038

[6] Roadmap on hydrogen standardization

20230301_ech2a_roadmaphydrogenstandardisation.pdf (cencenelec.eu)

[7] Hitchcock, D. Additions and Corrections - The Standardization of Hydrogen Ion Determinations. I. Hydrogen Electrode Measurements with a Liquid Junction. *Journal of the American Chemical Society* 1937:2755 https://doi.org/10.1021/ja01291a609

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ECONOMIC BENEFITS AND RISKS OF TRANSITION TO SUSTAINABLE DEVELOPMENT IN KEY INDUSTRIAL SECTORS

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Abstract

The transition to sustainable development in key industrial sectors presents both opportunities and challenges. On the one hand, adopting sustainable practices can lead to significant economic benefits, such as increased resource efficiency, cost savings in energy consumption, and access to new markets driven by growing demand for environmentally responsible products. Industries that prioritize sustainability also become more resilient to climate-related risks, including supply chain disruptions and regulatory changes aimed at reducing carbon emissions. Moreover, sustainable development fosters innovation, creating new business models and driving technological advancements. On the other hand, this transition carries inherent economic risks. High upfront investments in green technologies, infrastructure, and process transformations can be prohibitive for companies, especially in sectors with low profit margins. Additionally, the uncertainty surrounding evolving environmental regulations and market demands may cause disruptions to established business operations. Industries like energy, agriculture, and transportation face significant challenges in balancing short-term financial pressures with the long-term advantages of sustainability. This paper analyzes the economic benefits and risks associated with transitioning to sustainable development in these key sectors, focusing on how innovation, supportive policy frameworks, and financial incentives can help mitigate risks and promote long-term economic gains. It aims to provide insights into the strategies that industries and policymakers can adopt to ensure a smoother, more economically viable shift towards sustainability.

Keywords: sustainable development, industrial sectors, economic benefits, economic risks, climate resilience

I. Introduction

The global shift towards sustainable development has become a crucial priority for governments, businesses, and industries alike, as the impacts of climate change, resource depletion, and environmental degradation intensify. Key industrial sectors, including energy, agriculture, and transportation, are under growing pressure to adopt sustainable practices that minimize their environmental footprint while remaining economically viable. This transition is driven by a combination of regulatory mandates, market forces, and societal expectations for environmentally responsible production and consumption.

The benefits of moving towards sustainability are clear: enhanced resource efficiency, reduced operational costs, and new opportunities for innovation and growth. Companies that integrate sustainable practices can access emerging green markets, improve their brand reputation, and strengthen resilience against climate-related risks such as supply chain disruptions and stricter environmental regulations. Moreover, the increasing global focus on reducing carbon emissions has created incentives for industries to invest in renewable energy, waste reduction, and circular economy models.

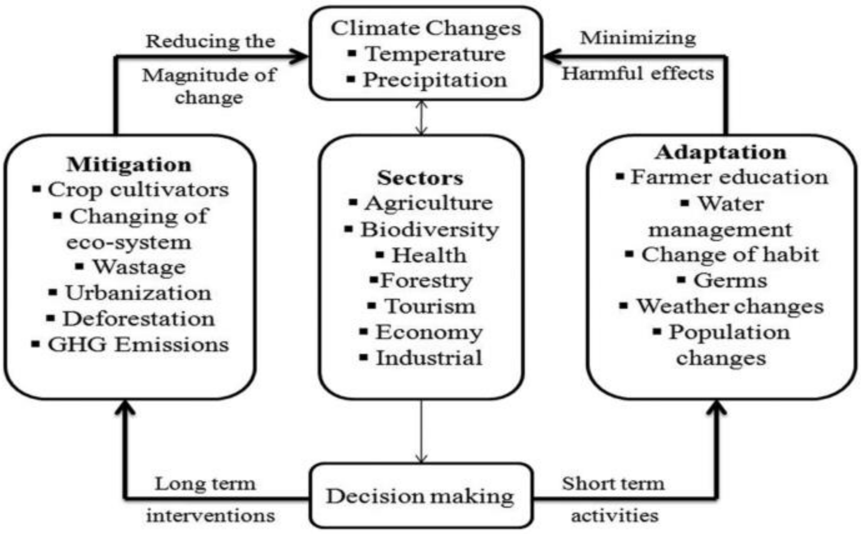

Figure 1: *Sectoral impacts of climate change with adaptation and mitigation measures*

Researchers express significant concern regarding the methodologies for adaptation and mitigation within various sectoral and geographical contexts. Key sectors that require focused adaptation and mitigation policies include agriculture, industry, forestry, transport, and land use. It is essential to address adaptation and mitigation efforts at both national and international levels. In recent decades, the world has grappled with the pressing issue of climate change, making it imperative to adapt to its effects for sustainable economic and social development. To effectively address climate change (CC), there is a need to formulate comprehensive policies and strategies on an international scale. Figure 1 illustrates current studies related to the sectoral impacts of climate change, along with corresponding adaptation and mitigation measures implemented globally.

However, the path to sustainable development is not without risks. High initial investment costs, uncertainty surrounding future regulations, and the potential for market disruptions pose significant challenges, particularly for industries that rely heavily on traditional, carbon-intensive processes. For many businesses, the question of how to balance short-term economic pressures with the long-term advantages of sustainability remains a critical concern.

This paper explores the economic benefits and risks of transitioning to sustainable development across key industrial sectors, focusing on how innovation, regulatory frameworks, and financial incentives can mitigate risks and promote long-term economic sustainability. By examining the complex dynamics at play, this research aims to provide a comprehensive understanding of the economic implications of this transition and offer insights into strategies for navigating these challenges.

II. Methods

To explore the economic benefits and risks of transitioning to sustainable development in key industrial sectors, this study employs a mixed-methods approach, combining quantitative data analysis with qualitative insights from case studies and expert interviews. The following methods were used to structure the research:

- Literature Review:

A comprehensive review of existing academic literature, industry reports, and policy papers was conducted to identify the current state of research on sustainable development in industrial sectors such as energy, agriculture, and transportation. This review helped define key concepts, challenges, and opportunities, providing a theoretical foundation for the study.

- Quantitative Analysis:

Data on investment trends, operational costs, and economic performance in industries transitioning to sustainable practices were collected from global databases, industry reports, and financial records. Key metrics analyzed included resource efficiency gains, cost reductions, and return on investment (ROI) in sustainable technologies, compared to traditional methods. Additionally, climate-related risks and financial impacts (e.g., insurance costs, supply chain disruptions) were quantified to assess the economic risks of inaction.

- Case Studies:

Detailed case studies of companies and sectors that have undergone successful transitions to sustainability were conducted to provide real-world examples of how economic benefits and risks manifest in practice. These case studies focused on leading firms in energy (e.g., renewable energy investments), agriculture (e.g., sustainable farming practices), and transportation (e.g., electric vehicle adoption), examining the strategies and outcomes of their sustainable initiatives.

- Expert Interviews:

Semi-structured interviews were conducted with industry experts, policymakers, and sustainability consultants to gather qualitative insights into the challenges and opportunities of transitioning to sustainable development. These interviews provided contextual understanding of the economic factors influencing decision-making, the role of policy, and the financial incentives that can mitigate risks in different sectors.

- Comparative Sector Analysis:

A comparative analysis across sectors (energy, agriculture, transportation) was performed to identify common patterns, sector-specific challenges, and the unique risks each sector faces. This method allowed for a holistic understanding of the economic impacts of sustainability transitions, while also identifying key differences in strategies required for various industries.

By combining these methods, this study aims to present a robust analysis of the economic implications of transitioning to sustainable development, highlighting both the benefits and the risks across key industrial sectors. The findings offer actionable insights for policymakers, businesses, and investors seeking to navigate the complex landscape of sustainability.

III. Results

The transition to a green economy involves redefining economic models and policies to promote environmental sustainability while ensuring economic growth and social well-being. This shift requires adopting practices that reduce carbon emissions, conserve resources, and encourage the use of renewable energy. The goal of this transition is to strike a balance between economic development and ecological preservation.

The benefits of moving to a green economy are substantial and wide-ranging (Fig.1). Environmentally, it helps mitigate climate change, protect ecosystems, and preserve biodiversity. By decreasing reliance on fossil fuels and embracing renewable energy, carbon emissions are reduced, and the overall ecological footprint is minimized, creating a healthier planet for future generations.

Economically, the green transition offers significant advantages. It promotes innovation, leading to the development of sustainable technologies and practices, which, in turn, generate new employment opportunities. Green sectors such as renewable energy, eco-friendly construction, and waste management contribute to job creation, economic growth, and long-term prosperity.

Additionally, businesses benefit from enhanced resource efficiency and cost savings. Implementing energy-efficient technologies, adopting sustainable supply chain practices, and optimizing resource use can lower operational costs. By minimizing waste, improving energy use, and embracing circular economy principles, companies can significantly cut expenses while enhancing their competitive edge.

However, the transition to a green economy also carries risks that must be managed. Businesses may face high upfront costs related to adopting sustainable technologies, retraining employees, or retrofitting existing infrastructure. Careful planning, strategic decisions, and financial investment are required to overcome these initial hurdles. It's important to recognize that this transition is a long-term strategy, and sustainable policies and investments may take time to deliver profitable returns. For example, the construction of renewable energy infrastructure, such as wind farms and solar plants, demands significant upfront investment and planning. Yet, as these projects begin generating clean energy, they gradually become financially viable and deliver substantial returns over time.

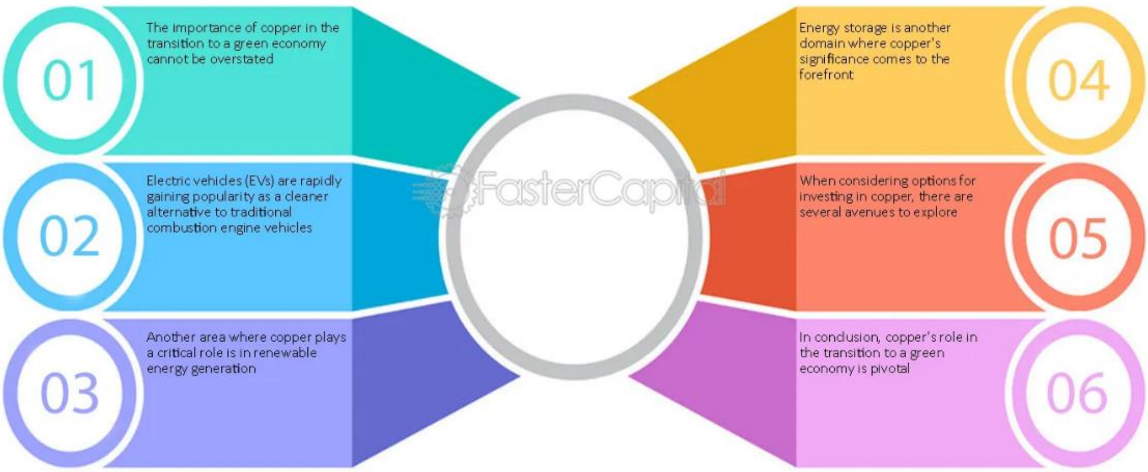

Figure 2: *Copper's Role in the Transition to a Green Economy*

The Crucial Role of Copper in the Green Economy Transition

The significance of copper in the shift toward a green economy cannot be overstated. As global attention increasingly turns to renewable energy sources and sustainable technologies, the demand for copper is anticipated to surge dramatically. This versatile metal is essential in a variety of green technologies, including electric vehicles (EVs), solar panels, wind turbines, and energy storage systems. From a sustainability perspective, copper is an optimal material due to its high conductivity, durability, and recyclability. Additionally, its antimicrobial properties make it particularly valuable for applications in healthcare and sanitation, especially in light of the ongoing COVID-19 pandemic.

The Growing Demand for Copper in Electric Vehicles

Electric vehicles are quickly becoming a cleaner alternative to traditional combustion engine vehicles. However, the transition to EVs necessitates a substantial increase in copper production. EVs require four times more copper than conventional vehicles, largely due to their electric motors, wiring, and charging infrastructure. With governments worldwide committing to phasing out the sale of new internal combustion engine vehicles in the coming decades, the demand for copper in the automotive sector is expected to rise significantly. Investing in copper now can yield long-term benefits as the EV market continues to expand.

Copper's Essential Role in Renewable Energy Generation

Copper is also vital in renewable energy generation, particularly in solar panels and wind turbines, which depend heavily on copper for electrical wiring and connections. The International Copper Association estimates that a single onshore wind turbine can contain up to four tons of copper, while large-scale solar farms can require hundreds of kilotons of copper for their infrastructure. As countries work to decrease their carbon footprints and increase their reliance on renewable energy sources, the demand for copper will inevitably grow. Investing in copper mining companies or copper exchange-traded funds (ETFs) can provide investors with valuable exposure to this expanding sector.

Copper's Importance in Energy Storage Solutions

Energy storage further highlights copper's significance. Batteries, essential for storing energy from renewable sources and ensuring a stable power supply, rely on copper for wiring and electrical connections. Lithium-ion batteries, commonly used in electric vehicles and renewable energy storage, contain a substantial amount of copper. Additionally, redox flow batteries, which offer scalable and efficient solutions for grid-scale energy storage, also incorporate copper in their design. As the demand for energy storage solutions rises, so will the need for copper. Investing in companies involved in battery manufacturing or copper mining can be a wise choice for long-term gains.

Investment Opportunities in Copper

When considering investment options in copper, several avenues are available. One approach is to invest directly in copper mining companies, providing exposure to the entire copper supply chain, from extraction to production. However, investing in individual mining firms carries risks related to geopolitical factors, labor disputes, and environmental concerns. An alternative is to invest in copper ETFs, which offer a diversified portfolio of copper mining companies, spreading risk across multiple entities and providing greater liquidity. Additionally, investing in renewable energy companies that significantly rely on copper can also be a practical strategy, as their success is closely linked to the demand for copper.

In summary, copper plays a pivotal role in the transition to a green economy. As the demand for renewable energy, electric vehicles, and energy storage solutions continues to grow, so too does the necessity for copper. Investing in this versatile metal presents a smart opportunity for long-term gains, as it is positioned to be a critical component of sustainable technologies. Whether through direct investments in copper mining companies, copper ETFs, or renewable energy firms, investors can strategically position themselves to benefit from the escalating demand for copper in the journey toward a greener future.

Additionally, companies must navigate regulatory risks as governments introduce policies to drive the green transition. Staying updated on evolving compliance requirements is critical, as non-compliance can result in fines, penalties, and reputational harm. By proactively aligning with environmental regulations and engaging in sustainability initiatives, businesses can reduce regulatory risks and show their commitment to responsible practices.

As we move toward a more sustainable future, the concept of a "green economy" has gained significant traction. A green economy is characterized by its low carbon emissions, resource efficiency, and social inclusivity. Its primary goals are to mitigate environmental risks, address ecological scarcities, and foster sustainable economic growth and social well-being. The advantages of a green economy are extensive and impactful, affecting our environment, economy, and society as a whole (Fig.3).

Job Creation

One of the most prominent benefits of a green economy is job creation. As we transition to more sustainable practices, the demand for labor in green industries—such as renewable energy, sustainable transportation, and eco-tourism—is set to rise significantly. The International Labour

Organization estimates that this transition could lead to the creation of up to **24 million new jobs globally by 2030**.

Economic Growth

A green economy has the potential to stimulate substantial economic growth. Research indicates that investments in green sectors can yield higher returns than traditional investments, and these sectors are expanding more rapidly than the overall economy. For instance, the renewable energy industry has experienced a **43% increase in employment since 2010**, while the broader economy has only grown by **3%** during the same period.

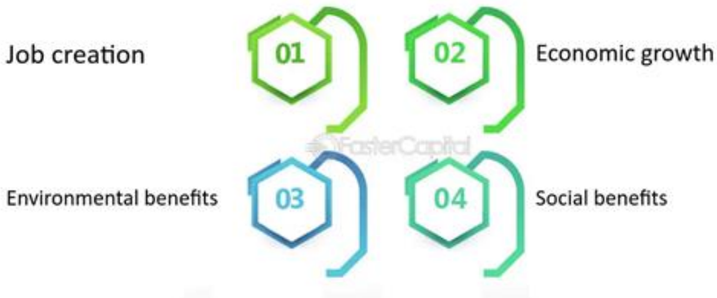

Figure 3: *Benefits of a Green Economy - Green Economy: Driving Economic Growth through the Green Economy*

Environmental Benefits

Transitioning to a green economy can significantly lessen our environmental impact. By prioritizing renewable energy sources and sustainable practices, we can reduce greenhouse gas emissions, enhance air and water quality, and protect biodiversity. For example, wind power generates **zero emissions** and requires minimal water, making it a much cleaner energy source compared to traditional fossil fuels.

Social Benefits

A green economy also offers considerable social benefits. Investments in sustainable infrastructure and public transportation can improve access to essential services and help mitigate social inequalities. For example, a green economy could enhance access to healthcare and education for low-income communities and provide greater availability of green spaces and recreational areas.

The benefits of a green economy are extensive and impactful, influencing our environment, economy, and society as a whole. By investing in green industries and sustainable practices, we can create new jobs, foster economic growth, reduce our environmental footprint, and enhance social well-being. Embracing a green economy is not just an environmental imperative; it is a pathway to a more prosperous and equitable future for all.

IV. Discussion

Understanding what a company's transition to a green economy truly entails is crucial, as it represents not only a global necessity but also a strategic opportunity for businesses. This transition involves embedding sustainability into a company's core strategies, supply chains, and operations. By adopting green practices, businesses can improve their brand image, appeal to environmentally conscious consumers, and gain a competitive edge in the marketplace.

In addition, transitioning to a green economy enhances operational efficiency by optimizing resource use, reducing waste, and incorporating renewable energy. These initiatives lead to significant cost savings, increased profitability, and greater resilience to fluctuations in resource prices.

The European Union (EU) serves as a model of progress in the green economy transition, with its strong commitment to sustainable development. The EU has made substantial strides in adopting renewable energy, implementing energy efficiency measures, and embracing circular economy principles. These efforts have not only minimized environmental impacts but also enhanced energy security by reducing reliance on fossil fuel imports. As a result, the transition has improved air quality, public health, and the overall well-being of the population.

Moreover, the EU has positioned itself as a global leader in sustainable innovation and technology. European companies have pioneered cutting-edge solutions in areas such as renewable energy, energy storage, sustainable mobility, and circular economy practices. The supportive ecosystem for green businesses within the EU has fostered collaboration, research, and development, driving economic growth and boosting competitiveness on a global scale.

For the full benefits of the green economy transition to be realized, cooperation between businesses and policymakers is essential. Governments can support this process through policies, incentives, and funding, helping to reduce risks for companies. Measures such as tax incentives, grants, and subsidies for green investments, along with regulatory frameworks that promote sustainable practices, are critical to facilitating this transition.

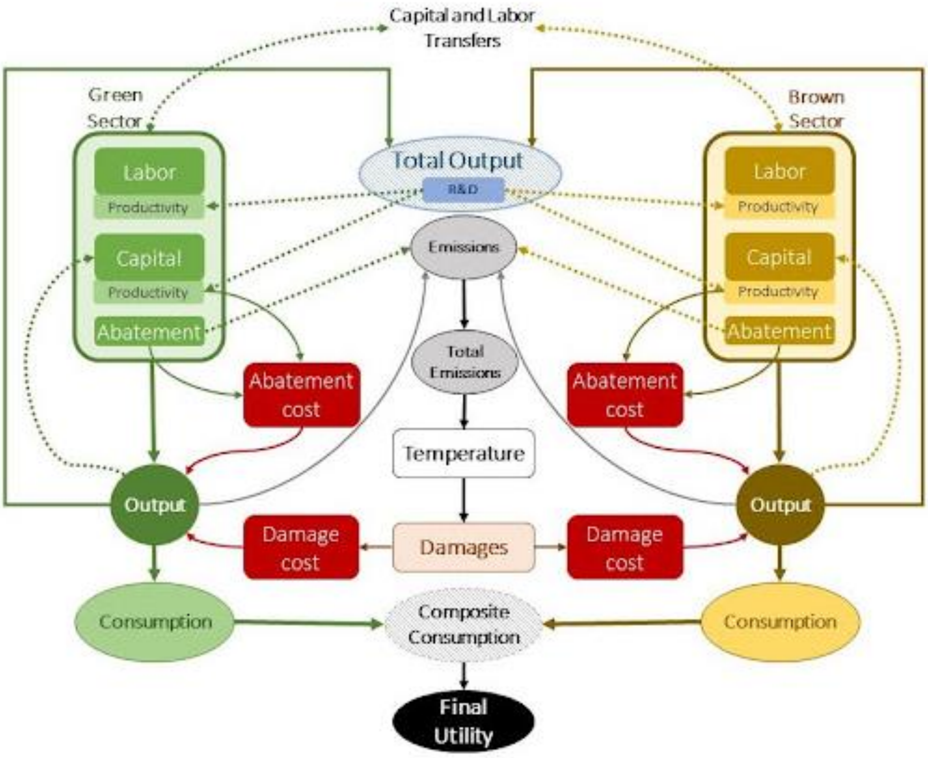

Figure 4: *Transitioning to a green economy*

A widely accepted viewpoint, supported by scientists, policymakers, and the general public, emphasizes the need for an integrated approach to addressing the climate crisis and advancing sustainable development. Achieving a transition to a green global economy while sustaining economic growth will require significant alterations in the frameworks of global production and consumption (fig.4). However, the precise mechanisms of resource reallocation—specifically, how and where these changes should take place—depend heavily on the underlying assumptions regarding the speed of the green transition.

Businesses, on the other hand, must develop a comprehensive strategy that includes sustainable practices, stakeholder engagement, and continuous innovation. This involves assessing current operations, setting ambitious sustainability targets, and investing in research and development of green technologies. Collaboration with suppliers, customers, and industry peers is vital to driving collective action and building a sustainable value chain.

Furthermore, companies should integrate sustainable principles throughout their entire operation. This includes sourcing materials responsibly, adopting energy-efficient manufacturing processes, reducing waste and promoting recycling, and managing supply chains with sustainability in mind. By taking a holistic approach to sustainability, businesses can ensure their long-term viability and resilience in a rapidly evolving green economy.

In addition to the strategies mentioned earlier, sustainability reporting plays a crucial role in helping companies transition successfully to a green economy. It provides a structured framework for businesses to measure, monitor, and communicate their environmental, social, and governance (ESG) performance to stakeholders. This process is essential for ensuring transparency, accountability, and continuous improvement in sustainability practices.

By adopting robust sustainability reporting practices, companies can gain a clear understanding of their environmental impacts, resource usage, and social responsibilities. This enables them to identify areas where they can improve, set meaningful targets, and monitor their progress over time. Transparent reporting also allows stakeholders—including investors, customers, employees, and communities—to assess a company's commitment to sustainability and make more informed decisions based on this information.

Moreover, sustainability reporting promotes accountability by encouraging companies to disclose their ESG performance and showcase their efforts in reducing environmental footprints, promoting social equity, and upholding good governance practices. This can enhance a company’s reputation, build trust with stakeholders, and attract both socially responsible investors and environmentally conscious customers.

Sustainability reporting also serves as a platform for sharing best practices, lessons learned, and innovative solutions within industries. This promotes collaboration among peers and encourages the exchange of knowledge, accelerating the collective transition to a green economy. By openly sharing successes and challenges, companies can inspire others, contribute to sector-wide improvements, and help drive broader sustainability goals.

In the context of the green economy transition, sustainability reporting becomes an essential tool for businesses to communicate their progress in aligning with sustainability objectives, reducing their environmental impacts, and embracing greener practices. It allows companies to demonstrate their contribution to the green economy and their commitment to long-term environmental stewardship. Furthermore, as investors, regulators, and consumers increasingly demand transparency and accountability in business practices, sustainability reporting enables companies to meet these expectations effectively.

Thus, sustainability reporting is a vital component of any company's journey towards a green economy. It provides a clear framework for measuring and communicating ESG performance, fostering accountability, transparency, and ongoing improvement. By integrating sustainability reporting into their operations, businesses can navigate the complexities of the green economy transition, gain stakeholder trust, and contribute meaningfully to a more sustainable future.

In conclusion, the transition to a green economy offers numerous benefits for businesses, society, and the environment. Shifting to sustainable practices not only helps mitigate environmental impacts but also drives economic growth, innovation, and job creation. While there are risks and challenges involved in this transition, proactive businesses can address these risks through careful planning, compliance with regulations, and engagement with stakeholders. At the same time, it is critical for policymakers to create supportive frameworks that encourage businesses to pursue sustainability and contribute to a more sustainable future.

References

[1] Taranova I.V., Kasaeva T.V., Shavrina J.O., Tekeeva H.E., Boeva K.Y. Methods of fraud management in the financial services market of the region// Business 4.0 as a Subject of the Digital Economy. Cham, 2022. С. 291-295.

[2] Podkolzina, I.M., Gladilin, A.V., Reshetov, K.Y., Taranova, I.V., Gladilin, V.A. Building a Financial Security System to Ensure Russia's Food Security // Lecture Notes in Networks and Systems, 2021, 205, страницы 539–548

[3] Gakaev , R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. С. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[12] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 2137-2144

THERMAL-PHYSICAL CHARACTERISTICS OF GALA-ALTI GEOTHERMAL WATER OF SHABRAN DISTRICT OF AZERBAIJAN AT HIGH PRESSURE AND TEMPERATURES

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Abstract

The article presents the experimental data obtained using high-precision experimental devices on the density of the Gala-alti geothermal water of the Shabran region of Azerbaijan at high pressure and temperature.

Geothermal energy is a part of alternative energy and is widely used for various purposes all over the world. In recent years, due to the increase in the cost of traditional energy sources and their possible shortage in the future, technologies using thermal waters are being actively developed. In order to use geothermal waters in various power plants, it is necessary to know their thermophysical properties. Geothermal waters in Azerbaijan were studied in the 20th century [1-5]. Most of these studies are related to geological analysis and chemical structure analysis of geothermal waters. In order to study the methods of using geothermal waters and obtaining energy from them, it is necessary to study their thermal-physical properties. This article presents experimental data about the "Gala-alti" geothermal water in the Shabran region of Azerbaijan.

In order to measure the density of the "Gala-alti" geothermal water of Shabran region at high pressure and temperature, a high-precision experimental device using the vibration-tube densimeter method was used [6]. This method for modern experimental thermal physics is characterized by high measurement accuracy, simplicity, insignificant time and economic costs, as well as the possibility of automation of the measurement process. The working principle of the experimental device is given in [7-9]. The main element of the Anton-Paar DMA HPM vibrating tube densimeter unit is a measuring cell consisting of a Hastelloy C-276 vibrating tube made of nickel-based stainless steel alloys with high corrosion resistance. The measuring element is designed to measure temperature in the range T=263.15-473.15 K and pressure p=0.1-140 MPa. The temperature in the measuring chamber containing the U-shaped tube is maintained using an external thermostat F32-ME (Julabo, Germany) with an error of 0.01 K. Temperature is measured using a platinum resistance thermometer (ITS-90).) Pt100 (Type 2141) with an error of ±15 mK. The pressure is generated using a HIP pump (No. 37-6-30, USA) and pressure sensors (WIKA Alexander Wiegand GmbH & Co., Germany) using P-10 accuracy class 0.1% and HP-1 accuracy class 0.5% is measured by The signals from the pressure gauges are also transmitted to the computer control system. In these conditions, the error in density measurement was $\Delta\rho/\rho = \pm(0.01 - 0.03)\%$*. (p, ρ,T) dependences were measured using isotherms from the minimum possible pressure for a given temperature and then increasing it in increments of about 10 MPa. Researches were carried out in the range T=(274.15 - 413.15) K and pressures up to p=100 MPa. Densities obtained at atmospheric pressure were compared with those measured on the DSA 5000M. The data obtained by different methods are in good agreement with each other within* $\Delta p/\rho = \pm 0.02\%$*. The obtained results of density of "Gala-alti" geothermal water of Shabran region are shown in Table 1.*

For the measurement of the thermal physical properties of the Gala-alti geothermal water of the Shabran region of Azerbaijan, the methodologies that allow for very accurate measurements in

the liquid phase at high state parameters have been selected and substantiated. An experimental device was assembled and adjusted for measuring density at different temperatures and pressures using the vibrating tube densimeter method. In order to check the working capacity of the experimental unit, the densities of aqueous solutions of water, toluene, methanol, and NaCl as reference substances were studied in a wide range of state parameters.
Since the thermal-physical properties of the Gala-alti geothermal water of the Shabran region of Azerbaijan were studied for the first time, it is impossible to compare them with the literature data. The obtained data were compared with the thermal-physical properties of pure water and it was determined that similar anomalies of water in the behavior of the studied properties are known.

Keywords: geothermal water, density, experimental studies, thermal-physical properties, energy

I. Introduction

Geothermal energy is a part of alternative energy and is widely used for various purposes all over the world. In recent years, due to the increase in the cost of traditional energy sources and their possible shortage in the future, technologies using thermal waters are being actively developed. In order to use geothermal waters in various power plants, it is necessary to know their thermophysical properties. Geothermal waters in Azerbaijan were studied in the 20th century [1-5]. Most of these studies are related to geological analysis and chemical structure analysis of geothermal waters. In order to study the methods of using geothermal waters and obtaining energy from them, it is necessary to study their thermal-physical properties. This article presents experimental data about the "Gala-alti" geothermal water in the Shabran region of Azerbaijan.

II. Methods

In order to measure the density of the "Gala-alti" geothermal water of Shabran region at high pressure and temperature, a high-precision experimental device using the vibration-tube densimeter method was used [6]. This method for modern experimental thermal physics is characterized by high measurement accuracy, simplicity, insignificant time and economic costs, as well as the possibility of automation of the measurement process. The working principle of the experimental device is given in. The main element of the Anton-Paar DMA HPM vibrating tube densimeter unit is a measuring cell consisting of a Hastelloy C-276 vibrating tube made of nickel-based stainless steel alloys with high corrosion resistance. The measuring element is designed to measure temperature in the range T=263.15-473.15 K and pressure p=0.1-140 MPa. The temperature in the measuring chamber containing the U-shaped tube is maintained using an external thermostat F32-ME (Julabo, Germany) with an error of 0.01 K. Temperature is measured using a platinum resistance thermometer (ITS-90).) Pt100 (Type 2141) with an error of ±15 mK. The pressure is generated using a HIP pump (No. 37-6-30, USA) and pressure sensors (WIKA Alexander Wiegand GmbH & Co., Germany) using P-10 accuracy class 0.1% and HP-1 accuracy class 0.5% is measured by The signals from the pressure gauges are also transmitted to the computer control system. In these conditions, the error in density measurement was $\Delta\varrho/\varrho = \pm(0.01 - 0.03)\%$. (p, ρ,T) dependences were measured using isotherms from the minimum possible pressure for a given temperature and then increasing it in increments of about 10 MPa. Researches were carried out in the range T=(274.15 - 413.15) K and pressures up to p=100 MPa. Densities obtained at atmospheric pressure were compared with those measured on the DSA 5000M. The data obtained by different methods are in good agreement with each other within $\Delta p/\rho = \pm 0.02\%$. The obtained results of density of "Gala-alti" geothermal water of Shabran region are shown in Table 1.

Table 1: *Experimental values of pressure p, density ρ, temperature T of "Gala-alti" geothermal water of Shabran region*

p/MPa	ρ/kg·m³	T/K	p/ MPa	ρ/ kg·m³	T/K
0.101	1000.75	274.15	20.169	1007.69	293.18
1.023	1001.21	274.15	30.215	1011.95	293.18
5.023	1003.18	274.15	40.220	1016.13	293.18
10.005	1005.62	274.15	50.160	1020.23	293.18
19.968	1010.41	274.15	59.912	1024.18	293.18
29.934	1015.10	274.15	69.940	1028.18	293.19
40.005	1019.73	274.15	79.925	1032.10	293.18
49.936	1024.19	274.15	90.002	1035.98	293.15
59.998	1028.60	274.15	99.985	1039.77	293.14
70.005	1032.88	274.15	0.101	997.92	298.15
80.065	1037.07	274.15	0.784	998.22	298.15
89.935	1041.08	274.15	5.021	1000.07	298.16
99.964	1045.05	274.15	10.002	1002.23	298.15
0.101	1000.82	278.12	20.003	1006.52	298.14
0.613	1001.09	278.10	30.014	1010.74	298.15
5.134	1003.19	278.11	39.985	1014.88	298.13
10.124	1005.54	278.11	49.952	1018.95	298.15
20.102	1010.17	278.11	59.924	1022.95	298.16
30.043	1014.68	278.12	70.024	1026.94	298.15
40.042	1019.18	278.12	79.934	1030.79	298.14
50.115	1023.62	278.12	89.968	1034.62	298.15
60.112	1027.95	278.12	99.235	1038.10	298.14
69.967	1032.21	278.10	0.101	993.06	313.15
80.007	1036.26	278.13	0.954	993.43	313.15
90.021	1040.41	278.15	5.143	995.21	313.15
99.845	1044.36	278.14	10.014	997.28	313.15
0.101	1000.71	283.21	19.986	1001.45	313.15
1.377	1001.21	283.23	29.935	1005.54	313.15
5.259	1003.04	283.22	39.947	1009.59	313.15
10.092	1005.28	283.21	50.004	1013.59	313.15
20.173	1009.81	283.21	59.924	1017.46	313.15
29.794	1014.08	283.21	70.024	1021.34	313.15
40.468	1018.73	283.21	80.045	1025.11	313.15
50.065	1022.68	283.25	89.924	1028.76	313.15
59.969	1026.78	283.27	99.935	1032.39	313.15
70.048	1031.24	283.21	0.101	983.66	333.15
79.948	1035.33	283.20	0.750	983.94	333.14
0.101	998.97	293.18	20.093	992.20	333.13
0.774	999.27	293.18	30.074	996.33	333.15
5.023	1001.14	293.18	40.067	1000.39	333.14
10.019	1003.31	293.18	50.067	1004.37	333.15
0.101	1000.75	274.15	59.999	1008.24	333.17
1.023	1001.21	274.15	70.137	1012.10	333.15
5.023	1003.18	274.15	79.997	1015.78	333.16
10.005	1005.62	274.15	89.985	1019.42	333.15
19.968	1010.41	274.15	99.947	1022.96	333.14
29.934	1015.10	274.15	0.101	971.50	353.15
40.005	1019.73	274.15	20.169	1007.69	293.18
49.936	1024.19	274.15	30.215	1011.95	293.18

The experimental data were generalized using the equation of state:

$$p = A \cdot \rho^2 + B \cdot \rho^8 + C \cdot \rho^{12} \tag{1}$$

Here the coefficients A(T), B(T) and C(T) in equation (1) are functions of temperature.

$$A(T) = \sum_{i=1}^{4} a_i T^i$$

$$B(T) = \sum_{i=0}^{3} b_i T^i \tag{2}$$

$$C(T) = \sum_{i=0}^{3} c_i T^i$$

The obtained coefficients ai, bi and ci in equation (2) are given in Table 2. Equations (1) - (2) describe well the experimental data on density of "Gala-alti" geothermal water in Shabran region.

Table 2: *Values of the coefficients a_i, b_i and c_i in equation (2)*

a_i	b_i	c_i
a_1 = -3.77278411	b_0 = 8820.374609	c_0 = -6716.43133642012
a_2 = 0.0103724374	b_1 = -72.493837104	c_1 = 57.00035877163
a_3 = $-0.1779354\cdot10^{-4}$	b_2 = 0.2129181614	c_2 = -0.16486118
a_4 = $0.2274616251\cdot10^{-7}$	b_3 = $-0.20544052\cdot10^{-3}$	c_3 = $0.15801767\cdot10^{-3}$

The errors are calculated using the following equations and are presented in Table 3.

Standard error:

$$STD = \sqrt{\frac{\sum(\rho_{exp} - \rho_{calc})^2}{n(n-1)}} \tag{3}$$

Absolute error:

$$ABD = \frac{1}{n}\sum\left|\rho_{exp} - \rho_{calc}\right| \tag{4}$$

Average percentage error:

$$APD = \frac{100}{n}\sum\left|\frac{\rho_{exp} - \rho_{calc}}{\rho_{exp}}\right| \tag{5}$$

where ρ_{exp} – experimental density values; ρ_{calc} –– density values calculated using the equation of state; n – number of experimental data.

Table 3: *Error values of equation (1)*

Average percentage error	Standard error	Absolute error
0.0097	0.142	0.12

The density of the geothermal water "Gala-Alti" of the Shabran district at atmospheric pressure was also measured using the DSA 5000M installation, which allows measurements to be taken at atmospheric pressure and temperatures up to 363.15 K with an accuracy of 0.01% (more accurate measurements than at high pressures).

Based on the equation of state, the following thermophysical properties were calculated:

- isothermal compressibility coefficient

$$\kappa_T = 1/[2A(T)\rho^2 + 8B(T)\rho^8 + 12C(T)\rho^{12}] \tag{6}$$

- isobaric coefficient of thermal expansion

$$\alpha_p = (1/\rho)(\partial p/\partial T)_\rho (\partial p/\partial \rho)_T^{-1} \tag{7}$$

$$\alpha_p = \frac{A'(T) + B'(T)\rho^6 + C'(T)\rho^{10}}{2A(T) + 8B(T)\rho^6 + 12C(T)\rho^{10}} \tag{8}$$

where A', B' and C' derivatives of coefficients A, B and C of the equation of state defined by the following formula:

$$A(T)=\sum_{i=1}^{3}a_iT^i,\ B(T)=\sum_{i=0}^{2}b_iT^i,\ C(T)=\sum_{i=0}^{2}c_iT^i. \quad (9)$$

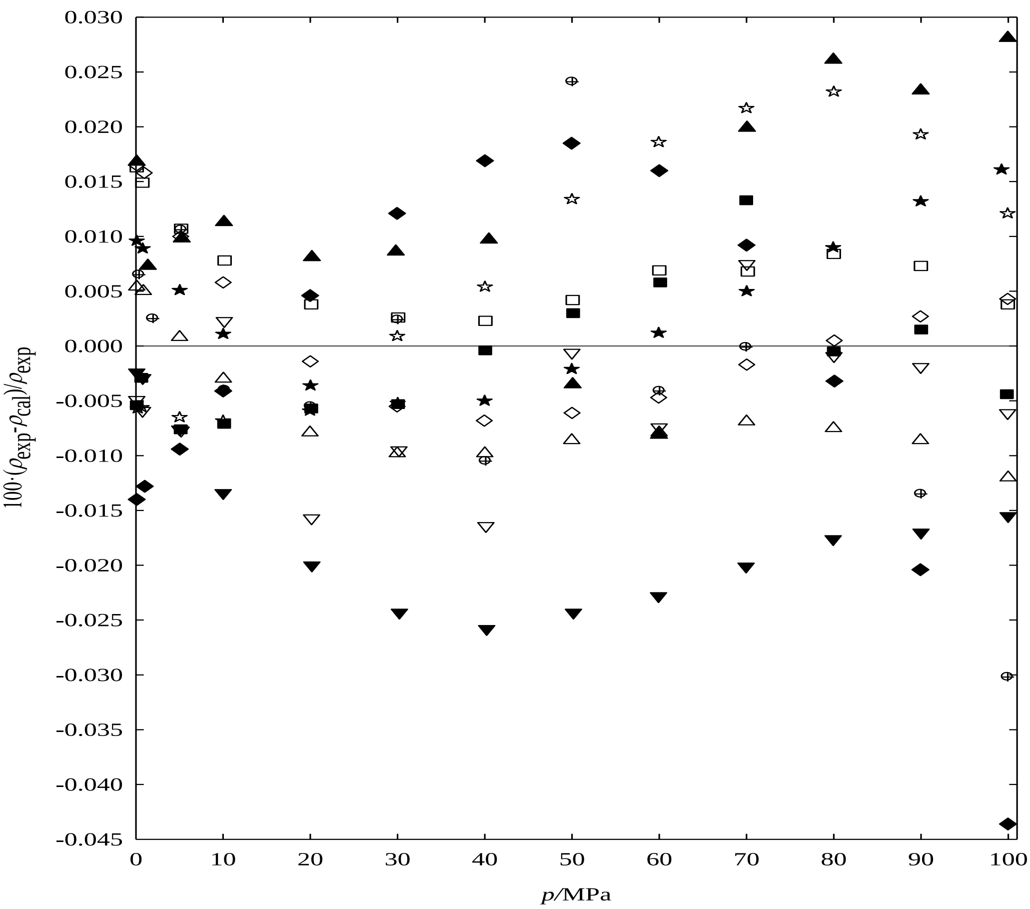

Figure 1: *Dependence of the pressure p on the pressure p of the density of the experimentally measured density of the Gala-alti thermal water of the Shabran region of Azerbaijan and the density ρ_{cal} calculated with the help of the equation of state $\rho_{exp.}$ ◆, 274.15 K; ■, 278.12 K; ▲, 283.21 K; ▼, 293.18 K; ★, 298.15 K; ◇, 313.15 K; □, 333.15 K; △, 353.15 K; ▽, 373.16 K; ☆, 393.15 K; ⊕, 413.15 K.*

III. Results

For the measurement of the thermal physical properties of the Gala-alti geothermal water of the Shabran region of Azerbaijan, the methodologies that allow for very accurate measurements in the liquid phase at high state parameters have been selected and substantiated. An experimental device was assembled and adjusted for measuring density at different temperatures and pressures using the vibrating tube densimeter method. In order to check the working capacity of the experimental unit, the densities of aqueous solutions of water, toluene, methanol, and NaCl as reference substances were studied in a wide range of state parameters.

IV. Discussion

Since the thermal-physical properties of the Gala-alti geothermal water of the Shabran region of Azerbaijan were studied for the first time, it is impossible to compare them with the literature data. The obtained data were compared with the thermal-physical properties of pure water and it was determined that similar anomalies of water in the behavior of the studied properties are known.

References

[1] Tagiev I.I., I.Sh. Ibragimova, A.M. Babaev. Resources of mineral and thermal waters of Azerbaijan, 2001, Baku, Chashyogly, 168 p.

[2] Gashkay M.A.. Mineral springs of Azerbaijan, Baku, 1952, 503 pp.

[3] Ismailova M.M.. NATO Science Series, 74, 279-288 (2006).

[4] Akhmedov A., J. Safarov, M. Bashirov, E. Hassel. Scientific notes of Azerbaijan Technical University, 1, 110 117 (2014).

[5] Akhmedov A., J. Safarov, A. Klinov, M. Bashirov, E. Hassel. Bulletin of Kazansky.

[6] Mammadova E., J. Safarov, A. Klinov, A.Shahverdiyev, E. Hassel. Bulletin of Kazansky. 2015.

RISKS IN ENTREPRENEURIAL ACTIVITY OF ENTERPRISES

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Abstract

Undoubtedly, almost every entrepreneur in the process of doing business faces various risks, the severity of which depends on many factors. In particular, the entrepreneur's ability to predict and evaluate certain events on time, competently select business partners, calculate the financial return from the project, and, of course, respond to the current situation as quickly as possible and give a rational solution in the interests of business. At the same time, in our opinion, entrepreneurial activity, in any case, is still accompanied by a number of unexpected events that are almost impossible to predict accurately. In connection with it, there always exist risks of failure and partial or complete loss of profit. This and many other factors increase the relevance of the chosen topic of our research, in which we reveal the essence of risks, their main types, and also suggest ways to reduce them through the use of generally accepted methods to deal with them.

Keywords: entrepreneurship, entrepreneurial risks, economics, risk, hedging, diversification, insurance, limitation

I. Introduction

Undoubtedly, in the course of its entrepreneurial activity practically each organization faces a large number of different risks that require urgent solutions.

It is important to understand that risks have different origin, ranging from the factors of their occurrence to the scale of negative consequences. That is, risk situations can occur in absolutely any field of activity. As an example, we can consider a situation where a supplier violates the terms of delivery of goods, turning out to be a scammer, and leaves the customer both without money and an order. Another example is the incompetence of a new employee in solving standard issues related to his position. These and many other examples clearly illustrate and confirm the fact that entrepreneurs face risks at absolutely any stage of running business. Also, an important place in our lives is occupied by risks from the external environment, such as natural hazards, economic crises, natural disasters and many more. All of the above can play a decisive role in the activities of enterprises and lead the organization to bankruptcy. In this connection, the importance of such a phenomenon as risk management, is increasing as it is a certain system for managing risks and relationships that arise in the process of managing them.

That is why the task of all enterprises is to seriously focus on the quality of risk management and the search for effective anti-crisis ways to manage them.

So, what is a risk? Economists interpret this term from the point of view of probable damage, failure due to the fact that the result is very ambiguous.

As the world practice of many countries shows, underestimating economic risks when developing business tactics and strategies has a very negative impact on the development of society, leading the country's economy to stagnation.

Unfortunately, many enterprises, even now, in the era of the 21st century, underestimate the importance of holding events that reduce the management risks of running business.

In our opinion, it is almost impossible to completely avoid risks, but it is always possible and necessary to try to find ways to reduce them.

Thus, it is very important to understand the margin between justified and unjustified risk in each situation.

II. Methods

Undoubtedly, the topic of our research is very relevant.

First of all, this is due to the fact that entrepreneurial activity is interpreted from the point of view of an independent direction, carried out at your own risk, and aimed at systematically making a profit from the activities performed.

In this connection, the relevance of the issue of entrepreneurial risk management is increasing every day.

The main aim of our research is to study the essence and role of entrepreneurial risks for the economic activity of enterprises.

The object of our research is entrepreneurial risks. And the subject is to find ways to reduce the risks under consideration.

In the course of writing this scientific paper, we studied the works of both domestic and foreign economists, periodical articles, textbooks, teaching aids, and Internet resources devoted to the topic of our research.

III. Results

As practice shows, even in leading industrial powers, risk management as a separate science has appeared quite recently. The term risk management was first mentioned in the American economic publication Harvard Business Review in 1956. It was then that the idea of hiring an employee as a risk manager to reduce production losses appeared. In addition, discussions about risks began since 1950, using mathematical research methods. A clear confirmation is the use of probability theory techniques to predict certain steps of organizations when faced with various situations. Thus, due to the increasing instability of the economic situation because of the oil crisis of 1973, the need for risk assessment measures has increased. After this, risk assessment became widespread in business, especially in the United States. That is, since the 1970s, the first consulting companies appeared, which, first of all, were engaged in assessing the risks of various foreign markets with studying the economic instability of certain countries in order to identify their influence on large Western corporations. It should be noted that the first qualification certificates in risk management were also issued in the USA back in 1973.

Let`s also note, that in 1975 the name of the organization, previously known as the American Society of Insurance Management, was changed to the Risk and Insurance Management Society, which has the abbreviation RIMS. Many industrial corporations began actively buying futures contracts in foreign currencies, using them as a kind of risk management tool. Many economists believe that the desire of companies to protect themselves from financial market instability has been an auxiliary tool that has served the development of investment capital since the 1970s.

At the same time, it should be noted that in those days industrial corporations did not open special risk management departments. A clear proof of the above idea is a survey of relevant corporations conducted in 1973, in which only 25% of respondents announced the presence of their own risk assessment units, and only 10% of respondents reported the use of consulting agencies. A similar survey was also conducted in 1975, which again confirmed the unpreparedness of transnational corporations to develop full-fledged approaches to assess the political stability of their foreign markets.

At the same time, banks pursued a more active policy. In particular, in 1975 in the USA, Chase Manhattan Bank created a special country risk committee. Furthermore, we`d like to note that by 1970 the term risk management hadn't been commonly used yet. That is, to solve certain problems and assess risks, top managers turned to various organizations, government officials, scientists, etc. It is important to note that all this had a chaotic origin, since there was no clearly formed scheme for fighting risks. As world practice shows, risk management methods in industrial companies began to develop rapidly in the last decades of the twentieth century.

Risk management methods were used more actively in certain complex industries, in particular in transport, energy, oil production, etc. It was connected with the fact that these areas required more detailed analysis due to technological difficulties and safety requirements.

This is how the rapid development of risk management begins.

Thus, the process of risk management in a simplified form includes 4 main stages:

1. The process of risk identification, the essence of which is to identify and predict certain risks in a particular sphere of activity;
2. Carrying-out risk analysis, the essence of which is to determine the probability of a particular event occurrence, as well as to assess the possible amount of potential damage;
3. Risk mitigation through the development of certain measures aimed at preventing possible risk events, and in case they occur then the measures to eliminate the consequences are developed;
4. Carrying-out control measures aimed at managing and resolving issues related to existing risks, with the development of preventive maintenance work, the main purpose of which is to eliminate certain risks in the future, or to minimize their impact in the future.

IV. Discussion

Now we would like to consider the main types of entrepreneurial risks, which are classified into three types according to their consequences:

- ✓ Acceptable risks;
- ✓ Critical risks;
- ✓ Catastrophe risks.

Let's consider each type in detail.

Let's start with the acceptable risks. The essence of such risks lies in the fact that in this case, the losses of enterprises are much less than the projected profit.

For example, let`s consider the following situation: the owner of a car repair shop ordered a certain lot of spare parts, which did not reach the customer intact, and therefore the owner suffered losses because he had to reorder it.

But despite this fact, the situation is revealed in the context of acceptable risks, since the losses of the enterprise turned out to be less than its monthly profit.

As for critical risks, they occur in the case of significant expenses that exceed the expected profit.

This may be accompanied by the fact that the money invested in the business may not be repayable.

An example is a faulty lot of all goods, which was supposed to bring a monthly profit.

And finally, the last type of risk, known as catastrophe risk, is characterized by the fact that it can lead the enterprise to a complete loss of property or capital –closure or bankruptcy.

For example, an entrepreneur decided to open a takeaway business and invested about two million rubles in this area, expecting cover its cost within the first six months.

But, unfortunately, the circumstances were not the best, as there was a fire in the organization, which led to the loss of all property.

Accordingly, for the full restoring of all losses, considerable financial investments are needed again, but the entrepreneur no longer has them.

Therefore, the enterprise is heading towards bankruptcy. This is interpreted as a catastrophe.

Thus, having considered the classification of risks according to the scale of their consequences, we would also like to highlight two generally accepted reasons for their occurrence:

- ✓ External;
- ✓ Internal.

External risks, as a rule, cover all factors of the external environment, in particular, economic instability in the country, various natural disasters, emergencies, changes in the legislative framework, etc.

Internal risks are associated with changes in the internal environment of the enterprise. In particular, faulty calculations, selection of personnel, violation of delivery time, problems with product quality, shortage of raw materials, etc.

Considering the topic of risks, the following questions arise: “How to minimize risks”? “What methods are practiced at the present stage of economic development”? Let's try to answer these questions.

In our opinion, it is quite possible to avoid the negative consequences of risks through timely making the most effective and rational decisions on identification and assessment of risks.

This requires a continuous analysis of the companies’ activities, examining all transactions and their conditions, external factors, and, in general, the entire financial condition of the company.

In the economic environment, it is common to distinguish four main methods aimed at minimizing risks, including:

- ✓ Insurance;
- ✓ Hedging;
- ✓ Diversification;
- ✓ Limitation.

Let's consider the essence of each tool in detail.

As for the insurance method, it is necessary to understand the possibility and desire of an entrepreneur to insure his property, equipment, loss of income, expenses due to failures of obligations of suppliers of goods, bankruptcy, liability to third parties etc.

This is done in order to obtain compensation or full coverage of all expenses of the organization from the insurance company.

As for hedging, its essence is to protect enterprises from price risks.

As an example, we can consider the situation of an individual entrepreneur signing a contract for the supply of certain spare parts at a fixed price throughout the year.

An important place is also given to diversification, the main task of which is to increase the efficiency of entrepreneurial activity by redistributing risks.

At the same time, diversification pursues the following most important goals:

- ✓ Finding a competitive advantage;
- ✓ Increasing the profitability of production;
- ✓ Reducing the probability of enterprise bankruptcy.

An example of diversification is the opening of a new business by an entrepreneur with minimal investment, since the current business does not yet have a wide possibility, which does not exempt the entrepreneur from paying salaries to employees and rent.

Therefore, the entrepreneur decides to open another source of income in the same premises.

And finally, limiting, which is responsible for setting limits and restrictions on the amount of expenses, loans or investments.

In addition, we would like to focus on the state of risk management in foreign infrastructure companies.

Let's look at the Table below.

Table 1: *The state of risk management in foreign infrastructure companies*

Criterion	BC Hydro, Canada	Chubu Electric Power, Japan	Nothern powergrid, United Kingdom	Pacific Gas and Electric Company, USA	National grid, United Kingdom and USA
Having a risk manager position or a corresponding organization department	The responsibilities of the company's CEO include identifying risks, informing the board of directors and managing risks.	The functions of the corporate planning and strategy department include identifying the most important risks and formulating a risk management plan for functional units	-	Vice President responsible for risk and audit	A special risk management team has been created. In addition, the responsibility of the board of directors includes the risk management and internal control system
Availability and completeness of information on risks in reporting to shareholders	+	+	+	+	+
Availability of a corporate risk management system	+	+	+	+	+
Operational risk management within the risk management system	+	-	+	+	+
Comment	The functions of all committees created by the board of directors (audit and finance, capital projects, safety, human resources and environment, etc.) include identifying and managing relevant risks in the area of activity	The functions of all committees created by the board of directors (audit and finance, capital projects, safety, human resources and environment, etc.) include identifying and managing relevant risks in the area of activity	Every year, the effectiveness of the risk management system is reviewed at the level of the company's president and CEO and is confirmed by a corporate certificate	The functions of committees created by the board of directors include: – control over risk management (finance committee); – control over the practices used on risk management (committee on nuclear energy,	The functions of all committees created under the auspices of the board of directors (audit, finance, safety, environment and health, executive committee) include risk management. The effectiveness of the risk management system is reviewed annually by the board of

				operations and safety)	directors

V. Conclusions

Thus, as world practice shows, risk management is gradually becoming an independent type of professional activity, the importance of which is increasing daily. As it was mentioned above, risk acts as an integral part of the entrepreneurial activity of any economic entity. In this regard, the knowledge of risks, factors that influence its significance, ways to fight them, most of which are foreign in origin, serve as the very tool that increases the efficiency of entrepreneurial activity. A very important place is given to the ability to respond quickly and promptly to force majeure circumstances, and search for the most effective method for a particular case to protect against risk situations. Thus, we can conclude that risk management issues play a very important role for all entrepreneurs.

References

[1] Abbasova O.M. Improving the development of small business enterprises / O.M. Abbasova // Bulletin of the Academy of Knowledge. – 2020. – No. 3 (38). – pp. 10–14.

[2] Belov P. G. Risk management, system analysis and modeling in 3 parts. Part 3: textbook and practical course for Bachelor's and Master's programmes / P. G. Belov. - M.: Publishing URAIT, 2019. - 272 P.

[3] Gusakov N. A., Development of management decisions in entrepreneurial activity // Economics and management: Russian scientific magazine — 2019. — No. 4. — pp. 77-81.

[4] Kasyanenko T. G. Analysis and assessment of risks in business: textbook and practical course for academic Bachelor's program / T. G. Kasyanenko, G. A. Makhovikova. — 2nd, revised and enlarged edition - M.: Publishing URAIT, 2019. - 381 P.

[5] Kiseleva I.A., Simonovich N.E., Knyazeva I.Yu. Entrepreneurial risks: psychological features of risk assessment in business // Vestnik VGUIT. 2019. No (79). pp. 492-499.

[6] Musaeva L.I., Altynbaeva L.E. Risks of business activity // Issues of sustainable development of society. 2020. No. 7. pp. 141-145.

[7] Pimenov N. A. Financial risk management in the economic security system: textbook and practical course for academic Bachelor's program / N. A. Pimenov. — 2nd, revised and enlarged edition - M.: Publishing URAIT, 2019. - 326 P.

[8] Sinyavsky N. G. Entrepreneurial risks: monograph / N.G. Sinyavsky, V.A. Dadalko. — Moscow: INFRA-M, 2020. — 177 P.

[9] Shapkin A. S. Economic and financial risks. Assessment, management, investment portfolio / A. S. Shapkin, V. A. Shapkin. - 9th edition - M.: Publishing and trading corporation "Dashkov and Co", 2018. - 544 P.

[10] Kuptsov, M.I., Yablochnikova, I.O., Yablochnikov, S.L., Dzobelova, V.B. & Mineev, V.I. (2020). Modeling Internet Business Optimization Processes, 2020 International Conference on Engineering Management of Communication and Technology (EMCTECH), Vienna, Austria, 2020, pp. 1-5, doi: 10.1109/EMCTECH49634.2020.9261507.

TAXES AS A TOOL TO ENSURE ENVIRONMENTAL SAFETY

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Abstract

In this paper, taxes and fees are considered as a means of regulating the environment, ecological state. The experience of ensuring environmental safety through taxation is described. The authors consider the shortcomings and disadvantages existing in the Russian tax system and environmental problems within the country. The results of taxation system analyses are given and systemized. In the paper the authors outline proposals and ideas for environmental protection using tax instruments.

Keywords: taxes, environmental safety, tax regulation, environmental protection

I. Introduction

At the present stage of development of all human activity spheres, inexorable processes are taking place to change the environment. The human impact on the environment condition is getting more intense every day. As a result of human activity, environmental pollution occurs, the depletion of natural resources and the gradual destruction of flora and fauna (for example, transport greatly pollutes the environment with exhaust gases when moving). That is why the state policy in the field of economic development and the ecological state of the environment should be interconnected.

Within the implementation of measures for the economic regulation of the environment, taxes act as a key tool to minimize the damage that is caused to the environment in the course of economic activity.

The use of exhaustible natural resources is conditioned by the need of mankind to be provided comfortable living. Today, the desire for high standards of living is associated with the depletion of natural resources, environmental pollution (for example, during the extraction of depleted hydrocarbon raw materials).

Industrial and entrepreneurship development, carried out without taking into account the impact on nature, can lead to serious problems both in the environmental condition, and, in the long term, on the economic development of society.

Not only individual citizens are responsible for making decisions to prevent environmental disasters and problems, but also the State. Public authorities need to develop and implement effective environmental management tools for economic purposes. Taxes occupy a special place here as a special form of control and regulation of the activities of business entities.

II. Methods

The main methods we used by throughout this work are

- methods of analysis and synthesis;

- a statistical method that made it possible to identify certain trends in the tax policy of the Russian state (based on the analysis of tax revenues and benefits);
- a comparative law method through which the main global trends in the development of taxes as an instrument for ensuring environmental safety were determined.

To conduct the study, we analyzed the data from the Federal Tax Service on the application of preferential taxation coefficients in connection with the use of highly effective environmental technologies.

As well regulatory documents of the Russian Federation and other countries aimed at regulating the environment through tax instruments were analyzed. Moreover, the research of theoretical economists and actual statistical data on environmental taxation in selected countries of Europe, Asia and America are considered.

III. Results

Today, environmental well-being is one of the main questions affecting the development of society in general and individual economies in particular. Special attention is paid to the issues of greening the use of natural resources in the process of their exploration for the development of industry and entrepreneurship.

The existing legal system of the Russian Federation, which provides for economic mechanisms to stimulate environmental protection activity through the introduction of tax and other liabilities for the use of natural resources, does not have the necessary tools for effective regulation and control over the implementation of environmental safety standards. This circumstance leads to a decrease in the level of pollution of the natural environment.

The experience of European countries in the field of the economy ecologization demonstrates the successful application of market instruments aimed at improving the state of the environment. There are environmental taxes and payments among them. Such financial responsibility is aimed at correcting the economic behavioral model of both producers and consumers, in the direction of reducing the negative impact on nature.

In addition, subsidies, tax incentives and preferences play an important role (for example, tax holidays for enterprises engaged in the protection and protection of fixed territories). Incentive measures are of great importance to stimulate innovative technologies and the introduction of new environmentally friendly technologies. Moreover, liability and compensation mechanisms occupy an important place in the environmental management system, providing compensation for environmental violations.

The existing in Russia payment system for negative environmental impacts does not fully contribute to solving the tasks of improving the environmental situation and preserving natural resources. This is related to the fact that the targeted use of funds for environmental needs is not guaranteed by either the tax administration or other government agencies. The problem of creating an effective system for monitoring compliance with environmental standards and norms remains relevant for many countries applying the environmental payment system. The reason for this is technical limitations in the sphere of monitoring and measuring the actual quantity of harmful emissions and discharges [3, pp. 453-457].

Unfortunately, Russian environmental taxation practice remains underdeveloped compared to foreign countries, where this system has become widespread and is actively used as a tool to encourage enterprises to choose environmentally friendly production technologies [7]. (Environmental taxation in this article refers to taxes in the field of environmental management).

The absence in Russia of a clearly defined legislative concept of "environmental tax" and an appropriate regulatory framework highlights gaps in the theory of taxation and limits opportunities for the formation of an effective environmental policy of the state.

The experience of the European Union countries since the 1970s has demonstrated significant achievements in the field of greening taxation. A centralized approach to the adoption of regulatory acts at the EU level, combined with the adaptation of the tax systems of individual states, contributed to the formation of an effective environmental taxation scheme.

The example of the United Kingdom is one of the most significant in terms of encouraging enterprises to carry out environmentally responsible production. In the UK, a tax on landfill with differentiated rates has been successfully operating since 1999. These rates depend on the type of waste. Moreover, in the UK there is a system of benefits for organizations investing in environmental projects.

Table 1: *Approaches to environmental taxation in different countries.*

Country	Types of environmental taxes and payments	Features	Application examples
In general	Electricity, coal, hydrocarbon derivatives, natural gas and gas condensate	Taxes do not promote emission reduction	
United Kingdom	Targeted environmental taxes	Tax revenues are used for environmental protection	
Germany	Noise tax, emissions taxes, waste and pollution payments, energy and transport taxes	Strict environmental policy policy; taxes based on environmental indicators of vehicles	Transport tax is calculated based on environmental indicators
Russia	Tax on engine power, fees for the use of natural resources	Non-ecological approach to transport tax; does not encourage emission reduction	Proposal to use the experience of Germany to encourage the transition to environmentally friendly cars
Finland	Carbon tax	Encourages the introduction of energy-saving technologies	Introduction of a carbon tax in 1990
China	Environmental Tax, solid waste	tax Tax benefits for companies that reduce emissions	Replacement of the pollution fee with an environmental tax in 2018
Brazil, India, South Africa	(There is no clear concept of "environmental taxes")	Start of development of environmental tax reform in Brazil	

[5, p. 304], [8], [9], [10], [11], [12].

This table provides examples of key aspects of environmental taxation of global economies, collected on the web pages of the legislative bases of various states. The purpose of the imposed taxes, their impact on the environmental safety of the country and the world are examined here, as well the preservation of the environment [5, pp. 302-306].

Special importance is attached to the development and implementation of a set of economic and market instruments aimed at minimizing the negative environmental consequences of economic activity.

The main directions in this area are:

- formation of a system of compulsory payments for the use of natural resources and emissions of pollutants, the amount of which should correspond to the costs of implementing environmental measures;
- transformation of approaches to the regulation of excess impacts on ecosystems through mechanisms of compensation for damage caused to the environment;

- introduction of tax benefits and preferences for "green" enterprises and organizations that carry out their activities without harm to the environment (for example, tax holidays or a reduced tax rate).

It should be emphasized that the subject of tax incentives are to be:

- technologies, including artificial intelligence, which more accurately determines the consequences of a decision related to the introduction of a particular tax; [2, p. 325]
- processes that meet the criteria of minimum waste, resource conservation and environmental cleanliness, which includes the use of the best available technologies approved at the legislative level;
- green energy and its use in production processes;
- human resources that develop non-toxic ways and methods of work (in production, logistics, sales of goods and services), etc.

It is important to support investments in the development of production facilities for the prevention, reduction and disposal of waste through recycling, along with the production of environmentally-friendly goods. Accordingly, the main recipients of tax benefits should be entities initiating scientific research and development in the field of ecology, as well as investing in the modernization and creation of new environmentally friendly manufactures [4, pp. 82-84].

The principles of resource recycling and waste-free production act as a fundamental base for the neo-industrial development of a modern economy. The implementation of an effective utilization and recycling system, in particular of motor vehicle waste, stimulates the intensification of research and innovation activity by both manufacturers and recyclers.

It is important to point out that the income from recycling fees should be used to finance infrastructure and environmental projects, including subsidizing the costs of enterprises for the implementation of waste management measures [5, pp. 302-306].

IV. Discussion

Effective ecological adaptation of business structures contributes to improving the quality of society life and stimulates economic progress. Therefore, improving the system of monitoring compliance with environmental laws is one of the most important aspects of public policy. Considering the tools of tax impact, it is important to mention that it enables indirect regulation of the multivariable activities of economic agents. That is why this study is aimed at analyzing and developing tax incentive mechanisms for enterprises to minimize their negative impact on the environment.

Research in the field of tax regulation of environmental policy reflects the relevance of the issues of development and implementation of tax instruments aimed at environmental optimization of economic activity. Many authors emphasize the advantages of environmental taxation in light of its ability to provide economic entities with flexibility in choosing strategies to reduce harmful effects on the environment [5, pp. 302-306].

The issues of tax support for technologies that are simultaneously characterized by a high degree of environmental friendliness, innovation and energy efficiency, as well as the problems of tax regulation in the context of waste management and decarbonization of the economy become the subject of detailed analysis in the works of many modern authors.

Since the current environmental situation has an increasing impact on human activities and, in particular, on economic activities, including production, logistics, and the sale of goods. It is important, in the context of the trend towards economic globalization (which has been shaken recently), to analyze world experience and bring effective tools to the international level. This means the introduction of mandatory environmental taxes and payments for all countries of the world, or at least for such communities as the CIS.

Focusing on the need to adapt the tax system to the current challenges of socio-economic transformations, it is important to consider various approaches to tax incentives for environmentally oriented changes in business practices and public relations, offering specific mechanisms for improving this system [6, pp. 59-61].

Initiatives aimed at introducing and developing the best available technologies, obtaining and using equipment capable of significantly reducing pollution levels. In addition, investments in the creation and modernization of facilities to reduce the volume and danger of waste should become the basis for tax incentives. These measures provide not only for improving the environmental situation, but also for stimulating research activities and the development of innovative technologies in the field of waste disposal and recycling.

The problem of the disbalance between income from environmentally oriented fees and environmental protection expenses requires comprehensive consideration and adjustment. At the moment, the established amounts of payments for pollution do not perform their main function - effective compensation the costs associated with eliminating environmental damage.

This highlights the imperfection of both environmental law and its administration system. In this regard, the need for a radical revision of approaches to tax incentives for environmentally responsible business behavior becomes obvious. This implies not only a reassessment of pollution payment standards, but also the introduction of measures aimed at strengthening responsibility for non-compliance with environmental standards, including a system of fines.

The existing payment system in the Russian Federation for negative environmental impacts shows clear signs of inefficiency and incomplete compliance with modern environmental and economic requirements. The immutability of the current strategy in the foreseeable future will inevitably lead to further degradation of the environmental situation.

And this, in turn, will provoke serious socio-economic consequences, including a decrease in production capacity and crisis in the economy. It is obvious that in order to prevent such negative scenarios, a comprehensive rethinking and qualitative updating of the environmental taxation system is required. It is also necessary to identify new areas for tax benefits and preferences that will facilitate the transition to more environmentally friendly and resource-saving production processes.

It seems advisable to introduce a set of tax exemptions for bonds belonging to the "green" categories and bonds focused on "national and adaptation projects" in the field of ecology. The key measures that can increase the attractiveness of such instruments for investors and at the same time help attract additional funds for environmental initiatives are:

- reduction of the corporate income tax rate to 10% in respect of income received in the form of interest on these bonds;
- reset the corporate income tax rate based on financial results arising from the sale or other disposal of these bonds, provided that the taxpayer has owned them for at least one year.

Such tax incentives not only contribute to expanding financial opportunities for the implementation of environmentally significant projects, but also activate the development of sustainable financing instruments. That fully corresponds to the strategic guidelines for the development of the financial market of the Russian Federation, outlined in the document "Main directions of budget, tax and customs tariff policy for 2024 and for the planning period 2025 and 2026 years" [13].

During the assessment of the fiscal consequences of the implementation of these measures, carried out on the basis of an analysis of data provided by the Moscow Exchange, it was revealed that potential shortfalls in the federal budget as a result of reducing the tax rate to 10% on interest income from "green" and "adaptation" bonds may amount to an insignificant percentage of the total tax income received from corporate income tax.

This highlights that the introduction of the proposed benefits will have a limited impact on the fiscal indicators of the budget, while the expected positive effect on the environmental sector of the economy and the promotion of sustainable investment may be significant.

The current law gives taxpayers the right to accelerate depreciation of the main technological equipment operated in the case of the use of the best available technologies with high energy efficiency or a high energy efficiency class (with a coefficient not higher than 2).Statistical data on the application of these benefits by taxpayers in 2020-2022 are presented in the Figure 1.

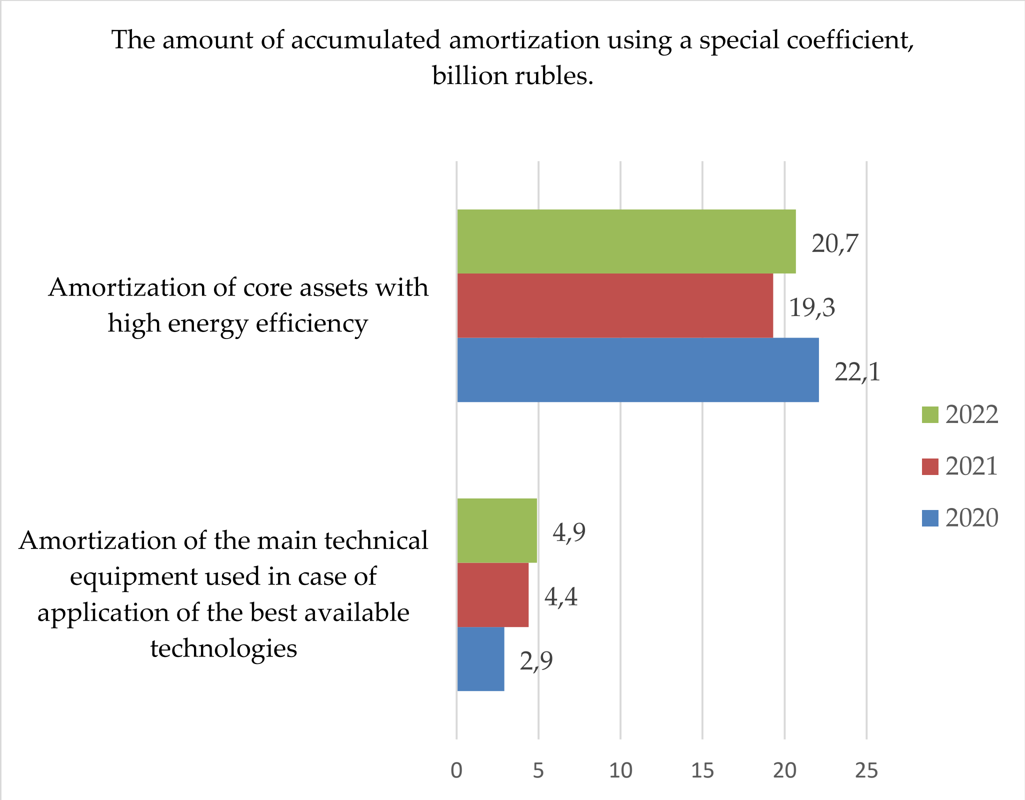

Figure 1: *The amount of accumulated amortization using a special coefficient, billion rubles.*

According to the presented data, it can be seen that the amortization of the main technical equipment used in the application of the best available technologies increased from 2.9 billion rubles in 2020 to 4.9 billion rubles in 2022. On the other hand, the amortization of core assets with high energy efficiency decreased from 22.1 billion rubles in 2020 to 20.7 billion rubles in 2022.

IV. Conclusion

Thus, analyzing the existing environmental situation and the tax system, it can be concluded that there is an imbalance between the amount of income from environmental taxes and the costs of protecting and restoring the natural environment. The established amounts of payments for environmental impact do not meet their original purpose — to compensate for the costs of eliminating negative consequences for the environment.

In this regard, it is necessary to realize that not all economic entities fully fulfill their obligations to pay environmental fees, which indicates shortcomings both in environmental legislation and in the system of its administration. The lack of targeted payments for environmental damage and the inadequate link between revenues and government expenditures on environmental protection measures indicate the inefficiency of the environmental payment system in force in the Russian Federation.

In order to overcome the revealed problems and to improve the efficiency of the existing tax system, it is necessary to carry out a comprehensive revamp:

- standards of tax payment for environmental impact on the environment;
- mechanisms for regulating and controlling taxation, including stricter responsibility (including criminal responsibility) for misdemeanors of environmental law.

Also, in our opinion, there is an inadequate tax burden on non-ecological enterprises. It is obvious that the Russian tax system is excessively lenient. We assume that in order to achieve the best results in the protection and protection of the environment, it makes sense:

- increase in tax rates for enterprises polluting the environment (industrial factories that neglect cleaning products, etc.);
- tax preferences for the introduction of innovative technologies, artificial intelligence into industry to reduce harm to the health of employees of enterprises;
- reduction of the tax rate for enterprises that take on responsibilities not only to minimize damage to nature, but also to restore the ecology of additionally appointed territories.

Thus, the ecologization of human activity should be systematic and considered by representatives of various scientific fields, including economists and lawyers. Only in close connection and with the introduction of a great number of economic and legislative restrictions and preferences – the safety of the environment is possible.

References

[1] Federal Law No. 7-FZ of 10.01.2002 (as amended on 12/25/2023) "On Environmental Protection" (with amendments and additions, intro. effective from 01.01.2024) // SPS Consultant-Plus

[2] Aguzarova L., Aguzarova F., Tsallaeva K. The impact and prospects of using artificial intelligence in the economy / // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 323-329. – DOI 10.24412/1932-2321-2023-575-323-329. – EDN PPGKLI.

[3] Artemenko D.A., Aguzarova L.A., Aguzarova F.S., Porollo E.V. Causes of Tax Risks and Ways to Reduce Them. European Research Studies Journal, 2017, Volume XX, Issue 3B, pp. 453-459 (in Greece). EDN: YCAWZN

[4] Aguzarova, L. A. F. S. Aguzarova, K. E. Tsallaeva Tax regulation of investment activity // Audit and financial analysis. – 2022. – No. 1. – pp. 82-86.

[5] Kopaygorodskaya A.P. Recognition in Russia and abroad // SKIf. 2020. №4 (44). – pp. 302-308

[6] Kruchinina N. V. Ecologization of taxation as an economic tool for environmental protection management // Digest-finance. 2011. №9. – C. 58-63

[7] The official website of the President of Russia www.kremlin.ru

[8] The official website of the Federal Tax Service of Russia https://www.nalog.gov.ru/rn77/related_activities/statistics_and_analytics/forms/

[9] Climate change taxation reforms and incentives in Germany https://cms.law/en/int/expert-guides/cms-expert-guide-to-climate-change-tax-reforms-and-incentives/germany

[10] Carbon Taxes in Europe https://taxfoundation.org/data/all/eu/carbon-taxes-in-europe-2023/

[11] China's Environmental Protection Tax https://www.china-briefing.com/news/china-environmental-protection-tax/

[12] UK environmental taxes: 2022 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/ukenvironmentaltaxes/2022

[13] The main directions of budget, tax and customs tariff policy for 2024 and for the planning period of 2025 and 2026 https://www.consultant.ru/document/cons_doc_LAW_458280/

THE ROLE OF THE GEODYNAMİC REGİME İN THE FORMATİON OF STRUCTURES AND THE FORECASTİNG OF OİL AND GAS PROSPECTS İN THE AJİNOHUR DEPRESSİON

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Abstract

Taking into account the main role of compressive stresses in the formation of local folds developed in the Ajinohur depression, the distribution characteristics along the depression, influence intensity and direction over the an idividual zones of the depression were determined.
For the analysis, the local folds of the Ajinohur depression were studied and they were scaled according to size on the plan. The isomorphic maping method was applied for the first time for qualitatively assess the intensity of compressive stresses in the study area. The influence direction of compressive stresses were determined.
The Ajinohur depression is located in the southwestern limb of the Greater Caucasus folding system close to the arch, terefore, the intensity of compressive stresses is higher. In the isomorphic map constructed for this depression, the isolines generally extend in the west-northwest-east-southeast direction, while isolines are relatively close in the longitudinal direction, at the same time, these are with high values (2.4-7.5 unit). So, it is indicate the high intensity of compressive stresses in the area. This situation is also confirmed by the morphological and isomorphic maps constructed on the same scale based on the dimensions of the local folds found here in the Neogene sedimentary complex. As can be seen from the maps, long brachyfolds are mainly more developed than the short brachyfolds in the area. The linear alignment of the folds in the all Caucasus direction and the complexation with upthrust faults indicate that compressive stresses play a major role in their formation.
The Ajinohur depression surrounded by the Kura-Gabirri, Yevlakh-Aghjabedi, Lower Kura, Shamakhi-Gobustan oil and gas regions. This regions are characterized by the presence of industrially significant oil and gas accumulations. İndustrially significance of these regions are identifide by the digging wells, and are characterized by the presence of numerous deposits that are in operation. It should be noted that there is a great risk of having industrially important hydrocarbon resources in the Acinohur possible oil and gas region, which is surrounded by promising oil and gas regions on four sides.

Keywords: Ajinohur depression, compressive stresses, upthrust, mud volcanoes, folds, oil, gas

I. İntroduction

Ajinohur depression, as is the object of the study, covers the northwestern part of the Kura intermountain depression and the southern slope of the Greater Caucasus folding system. İt is contains 28 local folds. Jurassic-Cretaceous and Pliocene-Quaternary sediments are spread in different parts of the area. Tectonically, the Acinohur area is divided into 3 zones. The folds that made up these zones are complicated by upthrust faults.

Ajinohur depression has a complex tectonic structure, geodynamically it is located adjacency of collision zones of Greater and Lesser Caucasus. İt is surrounded by the Ghabirri-Ajinohur basin from the west and stretches along the south of the Greater Caucasus megaanticlinorium. The folds located in the northern part of the depression complicated by cleavages and upthrusts with an enormous amplitude, are mainly Jurassic and Cretaceous age. The structures located in the area, which have a shingle- shaped, were formed by the influence of upthrusts. The sediments forming the section are terrigenous-carbonate. The uncovered thickness of Cretaceous system section is 3000 m [3,4].

The Pliocene-Quaternary age rock complexes are wide spread over the southern and central part of the depression.

A complete cross-section of the Productive series belonging to Lower Pliocene is exposed on the right bank of the Girdman River and is represented by two facies. The upper part of the section consists of grayish-brown clays and coarse-grained sands, and the lower part consists of alternating layers of different-grained sandstone and sand-clay interlayers. The thickness of the Productive series is up to 2000 m [5].

Aghjagil sediments are widely distributed within the Ajinohur. Lithological composition consists of hard limestone clays, sandstones and conglomerates. The thickness of these sediments is up to 1500 m.

Absheron sediments are spread over a wider area and lithologically consists alternation of coarse-grained sandstones and clays.

The Quaternary sediments are also widespread in the depression and it is section lithologically consists alternation of clays, sands and sandstones. Its thickness varies from 30 m to 1700 m [6].

5 anticlinal zones running parallel to the Greater Caucasus megaanticlinorium are singled out in the Ajinohur depression: 1. Dashyuz-Heyvanli; 2. Gudbarakdag-Gamigaya-Acibulag; 3. Acinohur-Savalan-Kurdmashi; 4. Khojashen-Goychay; 5. Bozdag-Garaja-Garamaryam [7,8].

In the mentioned anticlinal zones, local folds are mainly brachy and linear, and in rare cases, short brachy and isometric folds have developed. A characteristic feature of the folds is that they are complicated by upthrusts faults.

The amplitudes of the upthrust type of faults that complicate the folds located in the northwest of the area are greater than those of the same type of structures in the central and southern zones. The amplitude of the upthrust that complicates the Gudbarakdag structure located in the northwest of the depression is 1700 m, the amplitude of the longitudinal upthrust that complicates the Gamigaya fold located next to in the southeast is 700 m, while the amplitude of the upthrust that complicates the Western Khojashen fold is 1500 m [9,10]. This is due to the high intensity of compressive stresses in the northwestern part of the depression.

The southwestern limb of the Ajinohur depression dip steep. The reason for this the anticlines are asymmetric, echelon folding of the structures, and the complication of arch parts of the folds by upthrust type faults. The central and southern zone of the depression is characterized by this view.

Gradual weakening of intensity of disjunctive and plicative dislocations of different sizes distributed throughout the area from north to south is observed [11].

II. Method

The local folds developed in the Ajinohur depression are mapped to scale in the plan. In addition, the new method of isomorphic maps was applied for the first time in the research work, which allows qualitative assessment of the intensity of compressive stresses on the territory, as well as determining the direction of influence. As can be seen from the morphological scheme, the anticlinal zones formed by the local folds in the Ajinohur depression extend perpendicularly to the directions of compressive stresses, that is from the northwest to the southeast (Fig. 1).

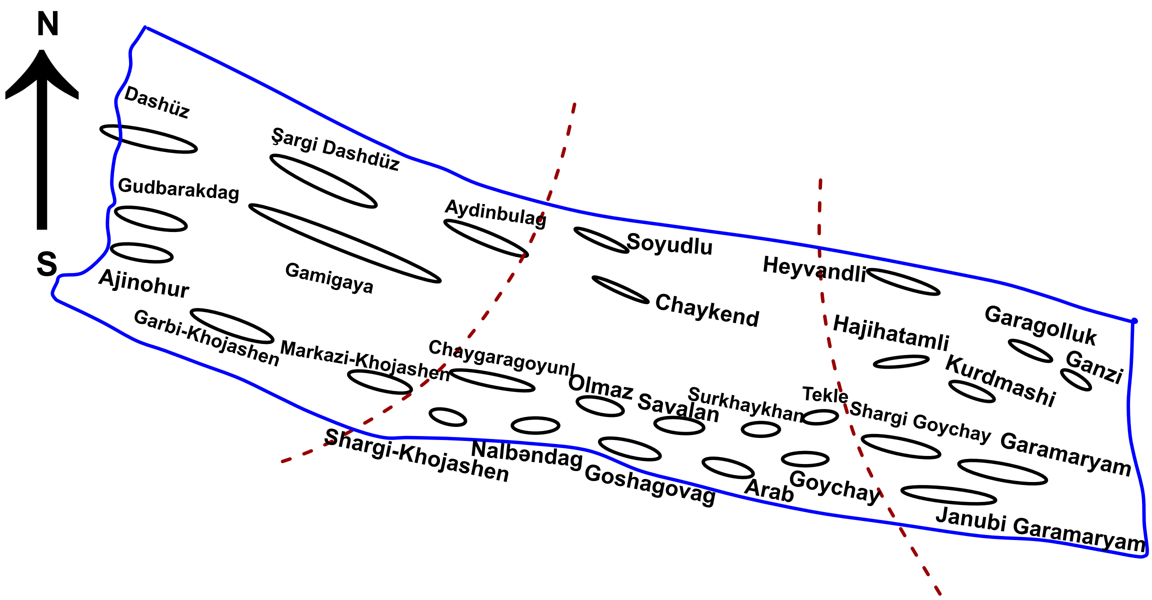

Figure 1: *Ajinohur possible oil and gas-bearing region. Morphological scheme of local folds*

-local folds, *-boundaries between of zones*

Ajinohur depression is characterised by the high intensity of compressive stresses. İt is confiemed by the course of the isolines from the west-northwest to the east-southeast on the isomorphic map drawn up for the area, the variation of the width-to-length ratio of the structures between 7.5-2.4 unit, as well as the contour intervals (Fig. 2). Based on the size of the folds, it is possible to distinguish 3 zones in the area: north-west, center, south-east. Short brachy and isometric folds are developed in the central part, while linear and long brachy folds are developed in the northwest and southeast part of the depression. According to the mentioned characteristics, local uplifts in all three zones have different morphology and are complicated by faults of different amplitudes. Folds were formed in zones of compressive stresses of different intensity. The difference in the structure of the folds is due to compressive stresses of different intensity.

Local folds in the Ajinohur depression, which rests on the West Caspian deep fault from the southeast, and is relatively close to the Greater Caucasus collision zone from the northeast, are long brachy and linear elongated forms, because they are more affected by compressive stresses. The folds located in the north-northwest part of the depression are more complex. Also, this structures are complicated by cover and upthrust type faults, with an amplitude of 1200-1300 m, while horizontal displacement is 2 km [1,12].

Despite the fact that the study area is located in a geodynamically active zone, the formation of long brachy and linear elongated folds, as well as comlpication of this folds by the cover and upthrust type faults due to the influence of high-intensity compressive stresses, mud volcanism did not develop in the area [13,14].

The relationship between mud volcanoes and compressive stresses can be determined by correlating some features of the geological structure. The sedimentary layer in the Ajinohur depression is relatively thin (7-9 km) and consists of 46% clayey, 48% sandy, and 6% carbonate sediments (Fig. 3).

Although the length-to-width ratio of local uplifts is 7.5 - 2.4 unit, several structures, for example, Garbi Khojashen, Shakgi Khojashen, Chaykend, Gamigaya were complicated by mud volcanism consisting of mud gryphons and salses related to the longitudinal upthrust type faults [15]. Mud gryphons and salses are accompanied by water flow with gas and oil films. Despite the high intensity of compressive stresses in the Ajinohur depression, the rheologically active clay mass that will create mud volcanoes in the cross section of the sedimentary layer has a low energy potential capable of forming mud gryphons and salses. There are a small number of salses and mud gryphons on the upthrust that complicates the folds along the axial line in the depression. İt is shows the transverse bending mechanism is involved for development of these folds. Despite of this, the linear arrangement of the salses and mud gryphons toward the all Caucasus direction, especially their genetic connections with upthrust type faults, shows that there is a main role of compressive stresses in the formation of there structures.

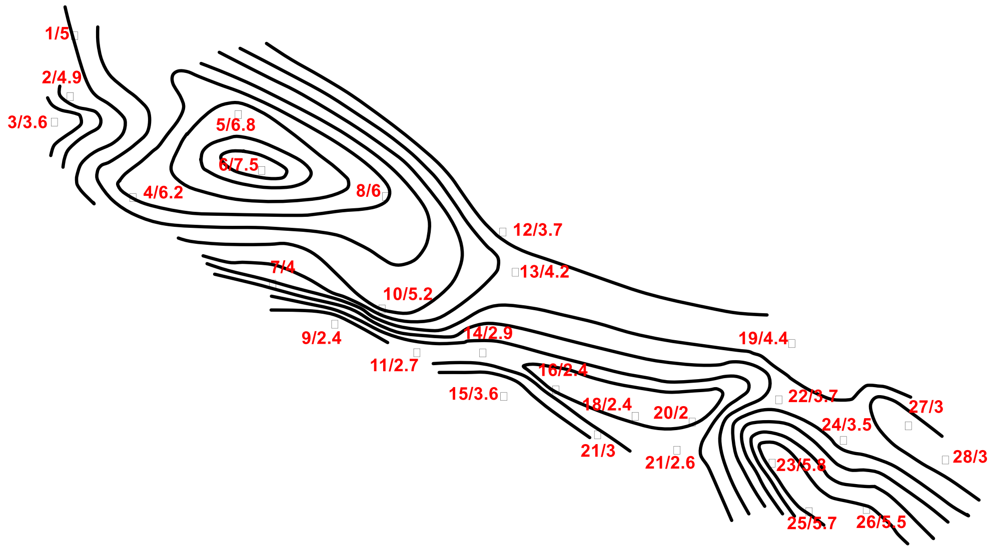

Figure 2: *Ajinohur possible oil and gas-bearing region. Isomorphic map*
1/5-well number (in the numerator) and the ratio of length to width (in the denominator);
-isohypses; - structures

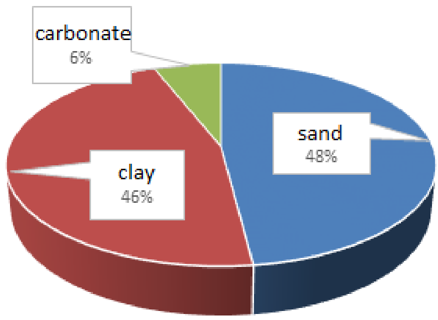

Figure 3: *Composition of the sedimentary layer in the Ajinohur depression*

It should be noted that the lithofacies composition of the sedimentary layer is one of the factors influencing the formation and types of both mud volcanism and faults.

If the rock complexes that make up the fold are relatively hard, that is, more competent, or if relatively plastic layers are in the minority in the section, then due to the tensile stresses created in the arch part of the fold, a relatively dense network of cracks is first formed, and then due to the continuation of the external influence in that zone, the integrity of the layers is destroyed, breaks, while as a result, the hanging wall of the fault under the effect of compressive stresses moves along the fault surface onto the foot wall and causes the formation of an upthrust type of fault [16].

As it can be seen from what has been said, upthrust (as well as shariage) type fault is actually the development of a plicative dislocation, that is a fold in the direction of a disjunctive, that is, a fault dislocation. In such cases, the reservoirs existing in the footwall, that is in the autochthonous (since they are screened by the allochthonous) can be promising in terms of oil and gas.

Thus, as can be seen from what has been said, the occurrence of residual (plastic or brittle) deformation in rocks as a result of external influence depends significantly on their physical properties, that is, whether they are competent or incompetent [8].

Due to the fact that the layers composed of competent rocks are more prone to brittle deformation, they undergo brittle deformation under the influence of compressive stresses and cause the formation of disjunctive dislocations in the development of folds.

As mentioned above, the northern tectonic zone of the Ajinohur depression is characterized by a wide spread of Jurassic-Cretaceous structures, where mainly competent terrigenous-carbonate sediments were formed. For this reason, the local folds developed here under the influence of compressive stresses are mainly complicated by upthrust, cover and sliding type faults. The fact that faults with huge amplitudes indicates the high intensity of the effected compressive stresses.

In the central and southern Ajinohur, the amplitudes of the faults that complicate the latitudinal directed anticlinal folds of the Pliocene-Quaternary sediments are smaller than in the northern zone. It is due to the lack of the intensity of the compressive stresses is relatively weak here, and at the same time, there are more incompetent rocks.

It is known that oil and gas are produced from almost all of the oil and gas-bearing regions surrounding the Ajinohur depression. Oil is exploited from wells dug into the Shirak formation and Sarmatian sediments in the Mirzaani-Aresh depression located in the north-west of Georgia [9,12]. Industrially important oil is extracted from Eocene sediments in the Tarsdallar area in the Kura-Gabirri interfluve oil and gas-bearing region, located in the western part, and the field is being exploited. Intensive oil flows were obtained from wells drilled in Mammadtepe, Demirtepe-Udobna areas. Oil and gas-bearing of Maykop sediments has also been proven here. Oil and gas manifestations from Sarmatian sediments in Sajdag, Armudlu, Chobandag, Palantoken, Akhtakhtatepe, Keyruk-Keylan areas were obtained. The oil-gas content of terrigenous-carbonate sediments of Eocene, Maykop and Chokrak in the Yevlakh-Aghjabedi, Ganja oil-and-gas-bearing region in the southwest has been proven. In the southeast, the Umbaki and East Hajiveli oil fields in South-West Gobustan are assossiated with the Chokrak horizon and sandy-siltstone reservoirs of the Maykop (Oligocene-lower Miocene) series.

Evidence of oil-gas content of Paleogene-Miocene, Pliocene sediments in the regions surrounding Ajinohur depression, analysis of geological-geophysical researches, structure-mapping drilling and exploration wells gives grounds for high assessment of the prospectivity risk of the mentioned sediments in this area.

III. Conclusıon

1. The intensity of compressive stresses in the Ajinohur depression is unevenly distributed along the area and section.

2. The north-western and south-eastern parts of the Ajinohur depression were more suffer to the influence of compressive stresses, while the central zone was relatively less.

3. The local folds of the Pliocene-Quaternary sedimentary complex in the Ajinohur depression were mainly formed as a result of the action of the longitudinal bending mechanism caused by compressive stresses.

4. Mud volcanism does not develop in the study area. The reason is assossiated with the sedimentary layer that is characterized by a relatively small thickness and the low clay content.

5. Oil-gas content of Paleogene-Miocene, Pliocene sediments in the regions surrounding the Ajinohur depression is identified, therefore, it is an indicator of the risk of formation of oil and gas accumulations in the reservoirs of the autochthonous limbs of cover-type structures in this area, taking into account other factors.

Reference

[1] Mammadova S.A. Modeling of hydrocarbon formation conditions in the sedimentary layer of Ajinohur region. Azerbaijan Oil Economy, Baku, 2008, 5, 1-5 p.

[2] Mukhtarova Kh.Z., Nasibova G.J. About the types of traps formed in the Kura and South Caspian depressions and the role of tectonic disturbances in them. News of the Tomsk Polytechnic University, Engineering of georesources, 2020, 331(1), pp.77-86.

[3] Karimov V.M., Ganbarova Sh. A. Assessment of the relationship of reservoir properties of hydrocarbon fields in the Lower Kura depression (Kursengi and Southern Kursengi areas). Journal of Geology, Geography and Geoecology, Dnepr, 2022, 31(2), 223-232. DOI: https://doi.org/10.15421/112221

4. Kerimov V. Yu., Mustayev R. N., Senin B. V., Aliyeva S.A. Modern structural and tectonic model of the Caspian region. Information Journal of the Federal Educational and Methodical Association on Applied Geology, Mining, Oil and Gas Activities and Geodesy Eurasian Mining, 2022, 37(1), 27-33 p. https://www.rudmet.ru/catalog/journals/details/8/.

[5] Gurbanov V. Sh., Sultanov L. A., Aliyeva S. A.. Studying the regularities of changes in physical properties of rocks and forecasting deep-seated oil and gas collectors of Mesocainozoic sediments in Azerbaijan. // Mountain Journal, Moscow, 2020, 8(2277), 45-50 p. https://www.rudmet.ru/catalog/journals/8/2020/

[6] Maharramov B.I., Aghazade B.G.. Paleostructural analysis and oil-gas content of Kaynazoic complex sediments in the interriver region of Kura and Gabirri. Scientific works, Baku, 2009, 12, 30-38p.

[7] Suvarov C.G., Sultanov L.A. About some results of petrophysical studies on Kura depression. Azerbaijan Oil Economy, Bakı, 2008, 3, 1-6 p.

[8] Yusifov Kh.M., Mammadov S.B., Efendiyev A.A., Sadigov A.J., Rzayev A.A. Distribution zones of non-anticlinal type traps in Eocene sediments of Western Azerbaijan and their oil and gas prospects. Scientific works, Baku, 2004, 2, 14-22 p.

[9] Suleymanov A.M., Zaynalov R.L., Maharramov B.I.. Paleogeographical and paleotectonic bases of oil and gas prospects of the Cretaceous sediments of the Kura intermountain depression. Scientific works, Baku, 2006, 6, 36-45 p.

[10] Suleymanov A.M., Zaynalov R.L., Maharramov B.I. Paleostructural analysis and oil-gas content of the Mesozoic complex sediments of the Kura intermountain depression. Scientific

[11] Alekbarova S.A. Some features of the tectonic structure of the Ajinohur oil and gas region. Azerbaijan Oil Economy, Baku, 2017, 3, 3-7 p.

[12] Akhundov Sh. Kh. Prospects of searches for complex (tectonically-screened) hydrocarbon deposits (HC) in the Kura depression. Sientific works, Baku, 2011, 3, 20-23 p.

[13] Rustamov R.I., Akhundov Sh.Kh., Khalilov N.N. Geothermal conditions of the Gabirri-Ajinohur depression. Sientific works, Baku, 2010,3, 6-9 p.

[14] Salmanov A.M., Maharramov B.I., Abbasov G.A., Huseynov R.M., Abdullayeva G.T. Thickness variability of different Eocene lithofacies in non-anticline traps. SOCAR Proceedings, Baku, 2019, 2, 4-15 p.

[15] Badikova A. D., Mukhamadeev R. U., Shiryaeva R. N., Mustafin A. G., Ibragimov I. G., Rullo A. V. Spectral methods of analysis for studying oil sludge residues. SOCAR Proceedings, Baku, 2019, 4, 32-38 p.

[16] Akhundov Sh. Kh., Ganiyev A. A. About the connection of oil and gas bearing sedimentation basin with rates of tectonic movements and rates of deposition (the case of the Gabirri-Ajinohur depression). Azerbaijan Oil Economy, Baku, 2006, 10, 20-24 p.

[17] Yusifov KH.M, Raxmanov R.R. Search strategi oft the Mezosoik oil in Azerbaijan. Azerbaijan Oil Economy, Baku, 2012, 2, 3-10 p.

[18] Aliyev A.K, Yusifov Kh.M, Sapunov A.G. On tectonic features and further perspectives of oil and gas bearing between Kura and Iori rivers. Works of AOIO, 1988, 8-24 p.

DEVELOPMENT OF SMALL AND MEDIUM BUSINESS IN CONDITIONS OF SUSTAINABLE DEVELOPMENT

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Abstract

The article discusses the features of the development of small and medium-sized businesses in conditions of sustainable development. Attention is focused on the concept of corporate social responsibility from the point of view of strengthening the socio-economic security of small and medium-sized businesses. The relationship between the imperatives of the concept of sustainable development and ensuring the security of the state of a small and medium-sized business, in particular in the socio-economic aspect, has been identified. It is substantiated that in the conditions of economic transformation and the transition to a model of a socially oriented market economy, it is necessary to harmonize the principles of managing the socio-economic security of small and medium-sized businesses with the targets of sustainable development, first of all, taking into account ensuring economic growth and achieving social progress.

Keywords: sustainable development, small and medium-sized businesses, social responsibility, enterprise personnel, government regulation, concept

I. Introduction

Achieving a high level of national competitiveness is impossible without ensuring the effective operation of small and medium-sized enterprises, stimulating the creation of a significant number of jobs [7].

In the conditions of the formation and development of a socially oriented market economy, the model of which is based on the requirement for an effective combination of market economic methods with state regulation of the national economy and its social orientation, the problem of sustainable development has become one of the main issues of today. The task of carrying out economic activities that do not deplete natural resources and are aimed at supporting the social sphere is becoming increasingly important for business.

Considerable attention from the world community is aimed at finding a balance between the economic and social needs of society while complying with environmental standards. Understanding the long-term problems of our planet and ensuring security are considered as a prerequisite for further sustainable and safe development for the functioning of both current and future generations.

The key need to solve problems of an economic, social and environmental nature, which are recognized as the triad of the concept of sustainable development, actualizes the problem of strengthening the socio-economic security of business entities in the context of transformation of the national economy.

The following scientists have studied the problems of sustainable development: A.B. Ankudinov [1], D.M. Borisov [1], V.I. Danilova-Danilyana [9], I.N. Gollai [2], M.E. Kadomtseva [4], N.A. Piskulova [9] and others. Recent scientific research in the field of socio-economic security indicates that in the modern theory of security in this area, a significant contribution is made by the works of leading scientists: N.L. Gryaznova [3], V.N. Druzhkova [3], E.V. Karanina [5], V.I. Lobanov [5] and others.

Despite the fact that socio-economic security is a fundamental category and the basis of the economy of the future, one of the effective factors in strengthening it in the context of transformation of the national economy and strengthening the social orientation of market reforms is taking into account the principles of the concept of sustainable and safe development in the further development. At the same time, further research requires questions of clarification of the essence of socio-economic security at the level of a business entity and its provision, taking into account the principles of the concept of sustainable development, which determined the choice of direction for this research.

II. Methods

The purpose of the article is to study the essence of the socio-economic security of an enterprise as a new category of economic security.

The importance of the SME sector is widely recognized throughout the world due to its significant contribution to various socio-economic goals such as higher employment growth, manufacturing, export promotion and entrepreneurship development [10].

In Russia in recent years, despite the not very favorable situation, the number of representatives of small and medium-sized businesses has been increasing. For sustainable existence and development, many of them need to integrate into the supply chains of large businesses and corporations and comply with the principles of sustainable development (ESG).

According to official data [6], at the end of 2023, 6.3 million small businesses were registered in Russia: 2.27 million – legal entities; 4.04 million are individual entrepreneurs. The number of small and medium-sized businesses is growing from year to year: by 7% in 2022, despite the "perfect storm" (negative effect of a combination of many unfavorable factors) of the external environment, and by 6% in 2023 [8].

Sustainable development of an enterprise is one of the basic values of its activities. Other important values - market position, profitability, scope of activity - without sustainable development in a turbulent business environment, as I. Ansoff wrote about in the 80s of the twentieth century, do not ensure the long-term activity of the enterprise. The history of entrepreneurship shows that long-term favorable conditions for the development of an enterprise are the exception rather than the rule. In practice, there is an alternation of favorable conditions and economic crises, including systemic global ones. The idea of alternating favorable and unfavorable conditions for the activities of an enterprise is not fundamentally new: the cyclical nature of business activity is covered in the scientific works of famous researchers.

III. Results

The development of an enterprise is important under any conditions of its activity, but it acquires particular value in times of crisis - as an effective way to overcome it, ensure the viability of the enterprise and the possibility of its further activity even in difficult unfavorable environmental conditions. During the periodic occurrence of crises in the external environment of the enterprise, a clear task arises - ensuring not only sustainable activity, but also the development of the enterprise in the decreasing part of the business cycle and at its lowest point - in the crisis. Moreover, we are not talking about an attempt to "wait out" the crisis, but about the active actions of the enterprise in unfavorable conditions, which should lay the foundations for its sustainable development in the ascending parts of the business cycle.

In accordance with the concept of sustainable development, which is recognized by the world community as the basis for the further sustainable existence of mankind, the most promising in the development of modern socio-economic systems is the idea of sustainable development based on the formation of the economy of the future to ensure the functioning of both present and future generations. The concept of sustainable development presupposes the unity of key components, which include economic growth, social progress and the environmental imperative [1; 2; 4]. Economic growth for the national economy presupposes the creation of a more competitive and highly efficient economy, which has a positive effect on increasing the standard of living of the population and improving its well-being. Only in conditions of ensuring the full use of all benefits provided in the social sphere, economic growth contributes to sustainable development, that is, the economic priorities of sustainable development include compliance with the principles of equality and social justice.

The problem of sustainability of socio-economic systems in the context of sustainable development is manifested in all its dimensions: economic, social and environmental. Strengthening the social orientation of market reforms makes it necessary for the state's socio-economic policy to be aimed at achieving high standards of quality of life and universal human values. Economic security depends on the state of the labor market, the level and dynamics of wages, the effectiveness of social and other components of state policy. In the socio-economic aspect, sustainability involves solving issues of poverty, employment, leveling the stratification of society by property status, ensuring access to education, protecting the health of citizens, preventing a decline in the birth rate, increasing life expectancy, eliminating deformation of the demographic and social structure of society and social conflicts and etc. It should be noted that among the goals of sustainable and safe development, according to the concept of sustainable development, along with the priority of economic growth, there is the need to comply with the principle of social justice, stabilize the population and increase its level of well-being, access to education.

Dynamic changes in the development of society at the present stage are accompanied by a certain aggravation of socio-economic and resource-ecological problems, the basis for solving which is the transition to a model of sustainable development, as M.E. quite rightly emphasized. Kadomtsev [4]. The concept of "sustainable development" in the modern sense and the basic idea of safe development have become widespread since the late 80s of the twentieth century. From the point of view of interpreting the concept of sustainable development as a dominant idea for the further development of human civilization, the unity of the economic, social and environmental components, which reveals the essence of the concept itself, also reflects a certain level of economic security. Therefore, a scientific approach to studying the state of ensuring economic security and its most important components, taking into account indicators of sustainable development, is common.

The concept of sustainable development in the context of the concept of the further balanced existence of society is comprehensive and multifaceted, since it concerns the implementation of this principle at all levels of the economic system - both at the global, national and regional, and at the microeconomic level. This means that the global task of ensuring the sustainability of socio-economic systems at the current stage of development and in the long term must be implemented through specific tasks at each of the hierarchical levels of the economic system. In a market economy, the problems of sustainable development of enterprises as the basic level of the economic system become of particular importance. Taking this into account, it is appropriate to focus on the results of a study of the sustainable development of an enterprise as a necessary condition for the successful functioning of a business and its relationship with the sustainable development of socio-economic systems of the highest level, given by the author in [2]. In another work, the authors [1] point out the need to intensify the social responsibility of all subjects of ensuring social security, subject to the failure of the state to respond individually and in a timely manner to the aggravation of existing threats associated with accumulated social problems and the increasing level of social tension. At the same time, corporate social responsibility of a business is considered as a factor that has an impact on ensuring social security. The social responsibility of an enterprise in a market environment is implemented through such areas as: social responsibility to employees (working conditions, decent wages, motivation and reward system); social responsibility of the enterprise to the state (timely payment of taxes and other payments); social responsibility to the society of the territories in which the enterprise operates (expenses to improve the living conditions of the population, programs for participation in public life). According to the authors [1], social responsibility is an integral part of socio-economic security, and at the same time it is a factor influencing its level. Social security of business is a guarantor of social security of the population.

As part of the study of the content of the category of socio-economic security and its objects, the work [5] states the fact that the constant development of economic security has led to the identification of new types of economic security, therefore, along with the already established categories of economic security and social security, the category "socio-economic security", which should not be considered as the result of a merger of social and economic security. Socio-economic security is formed in the process of interaction between economic and social security, while the social component acts rather as a superstructure of the category of socio-economic security, since the growth of activity and productivity of economic entities is not the final goal, such growth should affect the well-being of the population, in particular thanks to increasing wages, the volume of social assistance, improving the quality of social services.

The strengthening of mutual coherence between the social and economic components of development is due to a number of trends, since economic security as a complex characteristic of the development of an economic system synthesizes all forms of manifestations of social relationships that can cause a real or potential conflict of interests.

Naturally, the concept of security requires a new dimension in the status of socio-economic. When analyzing the definitions of socio-economic security of an enterprise in their work, the authors [9] point in this context to the ability of an enterprise to withstand adverse external and internal influences by harmonizing socio-economic interests in order to ensure sustainable activities, that is, the concepts of "sustainable development" and "social -economic security of the enterprise" are closely interconnected. The implementation of the economic interests of a business entity (primarily making a profit) and conducting a socially responsible business (social responsibility to employees, the state and society) influence to a certain extent the level of socio-economic security of the enterprise and create the basis for ensuring the security of the state of such a business entity. Proponents of the harmonization approach to the interpretation of the essence of the socio-economic security of an enterprise consider the conditions for ensuring the socio-economic security of an enterprise through the prism of multi-vector harmonization of the interests of the enterprise with the subjects of the external environment. At the same time, the social significance of the activities of large industrial enterprises can be traced during the provision of jobs and income to residents of the territories, replenishment of local budgets, construction and maintenance of social infrastructure.

Among other factors in increasing the level of economic security of an enterprise, a significant role is given to managing the motivation of the enterprise's personnel as one of the conditions for the safe development of a business entity. The level of satisfaction of the socio-economic needs of workers in relation to the development goal affects the feeling of security and safety. If a sufficient level of material remuneration for the corresponding work forms the basis for satisfying the economic needs of the employee, then the main factors for realizing the social interests of the staff should be noted the needs for self-expression, recognition of individual successes, social relations of the employee, creation of prerequisites for his self-development, etc. In terms of increasing social - economic security of a business entity, it should be noted the formation of an effective system of personnel motivation, which makes it possible to fully satisfy both economic and social needs in the process of work.

IV. Discussion

In the process of clarifying the essence of the concept of socio-economic security of an enterprise, V.N. Druzhkova, N.L. Gryaznova [3] come to the fair conclusion that social and economic security are decisive in the activities of an enterprise, based on the fact that the main value of an enterprise is its personnel, and the level of labor productivity, opportunities reproduction and efficient use of labor resources. At the same time, studies of the social aspects of sustainable development suggest that the sustainable development of an enterprise is due to a certain mutual consistency of socio-economic interests, since in order for an enterprise to pursue an effective social policy, it is necessary to achieve a sufficient level of economic security.

Differences in approaches to defining the essence of social responsibility of business are explained by the predetermination of the content of this concept by local economic traditions, the scope and specifics of doing business, the size of the enterprise, the geographic region in which it operates, and, of course, the time horizon. Among the features of the considered definitions of social responsibility of business, it is necessary to highlight the voluntary nature of such activities and the orientation towards achieving business success, which does not contradict socially responsible goals.

Summarizing the views of researchers, it should be noted that the system of social responsibility of business is a complex set of relationships between business and stakeholders, which is focused on obtaining social, economic and environmental benefits in the process of economic activity, which will not harm society and the environment. It is the balancing of the economic, social and environmental interests of humanity that must be ensured through a responsible attitude and mutual understanding between individuals, the state, society and business structures. This will ensure the formation of a favorable environment for the beginning of new thinking and the correct perception of one's significance and purpose in society.

Consequently, it becomes important to ensure that businesses have a responsible attitude towards the environment, the process of producing safe products, providing their employees with the necessary benefits, meeting the needs of consumers, as well as interaction with various groups of stakeholders. This approach is due to the combination of environmental, economic and social components of sustainable development, thanks to which it is possible to achieve the introduction and implementation of modern strategic guidelines for social responsibility of business.

For most modern enterprises, the basis is compliance with ethical standards in operations and regular and fair remuneration of employees. But more and more companies are becoming convinced of the need to improve management systems in order to develop mutually beneficial relationships with all stakeholders in order to realize all the benefits of a corporate responsibility strategy: creating increased investor interest in the company; increasing customer and stakeholder loyalty; increased social awareness of consumers; improving relations with society and local authorities; increasing competitiveness; increasing the level of organizational culture; formation of a positive image of the enterprise among employees; attracting and retaining the best employees, etc.

An enterprise is not only an economic unit and an instrument for generating profit, it is also a system that influences and is itself influenced by its environment: suppliers, consumers, local communities, public organizations, as well as employees, shareholders and investors. The CSR strategy should become a standard element of the company's development strategy, and activities within its framework, the desire to gain competitive advantages with a simultaneous sense of civic duty, will become the main motive of business entities implementing this idea.

It should be especially emphasized that the socio-economic security of an enterprise guarantees sustainability and stability, that is, it is closely related to the conditions for ensuring the sustainable development of the enterprise. This allows us to point out the dialectical relationship between the sustainable and safe development of a business entity and the socio-economic security of an enterprise, which are inextricably linked. Indeed, speaking in the terminology of the concept of sustainable development, it is economic growth that forms the potential, which, in turn, creates the basis for meeting the socio-economic needs of workers, protecting their interests and rights and improving the quality of life, that is, in general, contributes to the achievement of social progress , which ultimately affects the ability to ensure an appropriate level of socio-economic security of a business entity.

At the present stage of transformation of the national economy and its transition to a model of a socially oriented market economy, problems of sustainable development must be solved in combination with issues of ensuring an acceptable level of socio-economic security of domestic enterprises, which is fully consistent with the postulates of the concept of sustainable and safe development of society.

Consequently, in conditions of increasing social orientation of market transformations, the balanced development of an individual enterprise in the light of the concept of sustainable development provides for the unity of its components and reflects the level of socio-economic security of a business entity, which creates grounds for subordinating the principles of managing the socio-economic security of an enterprise to the fundamental goals of its sustainable development.

References

[1] Ankudinov A.B., Borisov D.M. Corporate social responsibility as a factor of long-term growth // News of USUE. – 2013. – No. 1. – P. 109-114.

[2] Gollai I.N. Sustainable development of the enterprise and interests of stakeholders / I.N. Gollai // SUSU Bulletin. – 2021. – No. 2. – P. 152-163.

[3] Druzhkova V.N. Analysis and assessment of the state of labor resources that determine personnel security as a component of the economic security of an organization / V.N. Druzhkova, N.L. Gryaznova // Equipment and technology of food production. – 2017. – No. 2. – P. 133-141.

[4] Kadomtseva M.E. Concept of sustainable development // AlterEconomics, – 2023. – No. 1. – P. 166-188.

[5] Karanina E.V., Lobanov V.I. Transformation of the category of socio-economic security in modern conditions // Russian Journal of Management. – 2022. – No. 1. – pp. 66-70.

[6] Number of SMEs in the Russian Federation. Of. website of the Ministry of Economic Development of Russia. – URL: https://www.economy.gov.ru/material

[7] Krakovetskaya I.V., Vorobyova E.S. and others. Trends in the development of small and medium-sized businesses in the Russian Federation in crisis conditions // Economics, entrepreneurship and law. – 2023. – No. 1. – P. 113-124.

[8] Large businesses and SMEs: how to enter into a contract and what does ESG have to do with it? EcoStandard.journal. – URL:https://journal.ecostandard.ru/esg/ustoychivoe-razvitie

[9] Sustainable development: New challenges / V.I. Danilova-Danilyana, N.A. Piskulova. – M.: Aspect Press, 2015. – 336 p.

[10] Chepalo A.S. ESG strategies as a factor in the development of small and medium-sized businesses // Leadership and management. – 2023. – No. 3. – P. 987-1000.

INTERNATIONAL PRACTICE OF TAX RISK MANAGEMENT

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Abstract

The article examines the essence of tax risks, based on the international experience of various countries. Undoubtedly, the topic of our research is quite relevant at the present stage of the development of economic relations. After all, as we see it, the role of taxes is very significant for any state, since taxes act as the main source of state budget replenishment of practically any country. But at the same time, there are many dishonest taxpayers who try to avoid tax payments as much as possible, using various tools to optimize the burden of taxation, including illegal ones. In addition, during the research we identified the main zones of tax risk for identifying dishonest taxpayers in various foreign countries.

Keywords: taxes, tax risks, economics, burden of taxation, tax optimization, tax legislation, tax control

I. Introduction

Under the conditions of modern developing economic relations, such a phenomenon as “tax risks” is acquiring universal significance in the field of taxation. This phenomenon is influenced by many processes and factors that occur all over the world. Unfortunately, the analysis of the financial and economic situation for most countries shows a process of reduction in tax revenues to the country's budget, which, in turn, is accompanied by a decrease in the revenues of the state budget of a particular country. In this connection, the relevance of the topic of our research, devoted to the study of the essence and nature of tax risks, the reasons for their occurrence, as well as the search for methods to fight them, increases.

Note that the term “risk” takes its impetuous origin from the very development of market relations. As for tax risks, they should be classified as a group of economic risks, which, in turn, include other risks, such as financial, banking, insurance, etc. In addition, many economists classified tax risks as financial risks before. But, subsequently, economists came to a common opinion about classifying them as an independently existing type of economic risks. As practice shows, currently there is no clearly formed concept of tax risks, both from the practical and theoretical sides.

But despite this fact, many researchers classify tax risks into two main groups:
- ✓ Risks on the taxpayer`s part;
- ✓ Risks on the state`s part.

That is, simply put, the risks on the state`s part consist in the shortfalls of tax revenues from citizens to the state budget due to various tax minimization schemes.

But for citizens, tax risks are associated with the imperfection of the country's tax legislation, increase of burden of taxation, etc.

Thus, summarizing all the above, we can come to the following definition of the essence of tax risks, which is interpreted as the probable occurrence of negative material, primarily financial, consequences either for the state or for the taxpayer in connection with the actions or inactions of certain participants of tax legal relations. In other words, for both the taxpayer and the state, the concerned category serves as a source of financial losses. As it is known, there are internal and external factors that influence tax risks for both taxpayers and the state. As for the internal factors of tax risks for the state, we would like to note, first of all, the tax policy pursued in the country. As for taxpayers, it is the procedure for submitting tax reporting and paying taxes, as well as tax planning. External factors of tax risks for taxpayers cover such phenomena as changes in terms of taxation. As for the state it is the creation and existence of offshore zones. Let's also add a common external factor for both the state and taxpayers, which is the world price situation for exported products and the general state of the world market.

Thus, summarizing all the above, we can conclude that tax risks in any case are accompanied by negative consequences that have a financial nature and consist in losses, damages, as well as shortfalls in profits and income.

In addition, tax risks are associated with the probability of negative consequences of a legal, social and psychological nature.

That is why the importance and relevance of studying tax risks, the reasons for their occurrence and ways to minimize them is increasing every day.

II. Methods

The fundamental goal of our research is to identify the essence of tax risks and the main methods to fight them, based on international experience.

The subject of our research is to find ways to reduce tax risks. And the object is tax risks.

In the course of writing this scientific work, various textbooks, teaching aids, works of both domestic and foreign scientists and economists, as well as periodical articles, magazines and Internet resources devoted to the topic of our research were used.

III. Results

Thus, having studied the phenomenon of our research, we`d like to consider the main reasons for the emergence of tax risks.

First of all, we would like to note the imperfection of tax legislation as the first reason for the tax risks formation. In our opinion, this factor can have a negative impact on both taxpayers and the activities of the state. Drawing on the modern experience of many countries around the world, one can observe the manifestation of imperfections in tax legislation in matters of taxpayers reducing their tax obligations, which, in turn, automatically reduces state revenues through reduced tax revenues.

On the other hand, the actions of taxpayers can have very legal grounds with due to additional assessments by the tax authorities, which, in turn, is accompanied by financial losses and various legal proceedings. As the next reason for tax risks, we`d also like to note the ambiguity and inaccuracy of judicial practice regarding tax administration. After all, a situation where courts make very ambiguous decisions on the same issue it often observed.

In the emergence of tax risks, a key role is also occupied by the incompetence of personnel, as well as various technical errors, or intentional ones, which are often accompanied by deliberate noncompliance with the law.

Moreover, as we see it, such a phenomenon can occur both on the part of the state and taxpayers. To minimize tax risks, countries are actively pursuing tax policy, which is aimed at improving the quality of audits, applying the basic principles of taxation that are applied everywhere in many foreign countries, as well as bringing closer together in matters of information interaction between various authorities, in particular customs, law enforcement, tax authorities, etc. That is, the state’s main aim is to fight against dishonest taxpayers who use one or another method to hide the taxation base. As for tax risks, we`d also like to focus on those large taxpayers who register in offshore zones.

This, in turn, negatively affects the financial component of any country, since it can result in a decrease in the amount of revenues to the country’s budget.

Thus, we`d like to summarize all of the above and note the main well-known causes of tax risks:

✓ Introducing various amendments and changes to the country’s legislation, in particular, the abolition of tax benefits, or an increase in the tax rate, which is risky for taxpayers with not updating their tax accounting;

✓ The emergence of contradictions in regulatory documents in connection with various amendments;

✓ Lack of qualified personnel who can correctly calculate the taxation base, amounts of taxes and contributions;

✓ Unscrupulous analysis on the part of companies when concluding transactions with unreliable counterparties;

✓ Use of illegal schemes by taxpayers to optimize the burden of taxation.

IV. Discussions

Besides, during the research, we identified and classified the main groups of tax risks, based on the international experience of foreign countries.

For clarity, we would like to refer to Table 1 below.

Thus, based on the data presented, we clearly see that most countries note the use of taxpayers of various schemes involving offshore companies as the main source of tax risk.

Also, an important place is given to the factors of abuse of double tax agreements, the formation of artificial losses and the application of imperfections in tax legislation.

Table 1: *The main area of tax risks according to the international practice of foreign countries*

Country	Main areas of tax risks
Australia	✓ Tax schemes aimed at tax evasion using prepaid options for services; ✓ Use of new financial instruments; ✓ Schemes aimed at removing company assets (variation of the wage fund, use of offshore companies, “thin capitalization” tools).
United Kingdom	✓ Artificial creation of losses: using offshore bank accounts to hide assets and income.
Germany	✓ Transfer of income to low-tax jurisdictions; ✓ Abuse of double tax agreements; ✓ Tax evasion by permanent representative offices of foreign organizations.
Ireland	✓ Schemes using offshore companies; ✓ Concealment of income and capital gains; ✓ Artificial creation or “inflation” of losses; ✓ Abuse of double tax agreements.
Spain	✓ Real estate schemes;

	✓ Use of offshore companies; ✓ Tax planning.
Italy	✓ Schemes using offshore companies and trusts; ✓ Comprehensive contractual schemes both at the national and international levels; ✓ Abuse of double tax agreements.
Canada	✓ Transactions aimed at artificially understating income and asset value growth, inflating expenses, overstating losses; ✓ Abuse of double tax agreements; ✓ Illegal use of tax benefits; ✓ Use of offshore companies, transfer pricing; ✓ Intentional bankruptcy.
South Korea	✓ Schemes using "trading agreements"; ✓ Tax evasion using offshore companies; ✓ Use of derivative securities in schemes to create artificial losses and tax deferral.
Netherlands	✓ Schemes aimed at distorting the taxation base; ✓ Offshore companies; ✓ Individuals with a high level of income and a significant value of their property.
New Zealand	✓ Income split and creation of artificial losses (for individuals); ✓ Exploitation of "gaps" in tax legislation, often using financial instruments (for companies).
Norway	✓ Schemes using offshore companies
USA	✓ Schemes using imperfections in tax legislation; ✓ Tax evasion using offshore structures to hide income, creating artificial expenses and losses.
France	✓ Tax offenses on a particularly large scale, especially at the international level; ✓ Non-declaration of economic activity.
Sweden	✓ Schemes using offshore companies, bank cards and foreign holding companies (for individuals, small and medium-sized businesses); ✓ Schemes with commercial real estate, loans (of a company).
Japan	✓ International tax planning schemes based on preferential provisions of foreign tax systems and abuse of double tax agreements; ✓ Use of foreign shell companies; ✓ Use of new financial instruments in schemes.

Thus, we can conclude that the tax risk assessment system acts as a many-sided element and can be considered in various aspects depending on the organizational and operational structure of tax authorities.

In other words, some countries focus on referring risks to certain groups of taxpayers, in particular such groups as:

- ✓ Individuals;
- ✓ Small and medium-sized business;
- ✓ Large corporations;
- ✓ Individuals with large incomes and property.

Other countries are studying the risks from the point of view of the legality of using basic tax planning tools.

It concerns, for example, the use of double tax agreements, which serves as a formal method of tax optimization, but at the same time has high tax risks for the budget.

But the situation of non-declaration of income and property undoubtedly serves as an illegal way to optimize taxes.

In our opinion, the proposed and discussed above methodology of systematization and segmentation of tax risks, which acts as the basis of tax monitoring, serves as the most important factor in building an effective system of tax administration.

V. Conclusion

Thus, based on the foreign experience of various countries in identifying tax risks, we can draw a conclusion about the important role of introducing penalties at the legislative level for promoters (lawyers, auditors, etc.) of aggressive tax planning schemes (promoter penalty regime).

Such obligations exist in the laws of other countries, in particular in Canada, New Zealand, Australia, the USA, and the UK.

Thus, based on the experience of developed countries, we can conclude that their tax services carry out their work using a comprehensive analysis of tax risks.

In our opinion, the development of a tax monitoring system, which is based on risk management techniques, will become an auxiliary tool in identifying certain problems of tax administration and legislation at the early stages of their manifestation.

In addition, we support the idea, the essence of which is that if there are certain measures to identify information, as well as appropriate structural units for tax monitoring, the success of the state tax policy implementation will be manifested through the timely detection of certain tax risks and their effective management.

Thus, we revealed the topic of our research.

References

[1] Grishchenko A.V. Tax regulation of the non-profit organizations' activities / Grishchenko Alexey Valerievich. – M.: Finpress, 2022 – 191 P.

[2] Morozov A.A. Tax system and legislative regulation of taxation / A.A. Morozov. – M.: Znaniye, 2020 – 104 P.

[3] Kilinkarova E.V. Tax law of foreign countries. M.: Publishing URAIT, 2023 – 334 P.

[4] Krokhina Yu.A. Tax law. M.: Publishing URAIT, 2023 – 504 P.

[5] Lykova L. N. Taxes and taxation. M.: Publishing URAIT, 2023 – 358 P.

[6] Lyutova O.I. The institute of tax obligation in the system of tax law: current issues // Russian Law Journal. 2023 – №3. pp. 133 – 143.

[7] Nikiforov A., Chervonnaya S. The fight against tax evasion: what the Federal Tax Service is focusing on. EJ-Accountant. 2023 – (8): pp.8 - 10.

[8] Panskov V.G. Taxes and taxation: theory and practice. M.: Publishing URAIT, 2023 – 826p.

[9] Kuptsov, M.I., Yablochnikova, I.O., Yablochnikov, S.L., Dzobelova, V.B. & Mineev, V.I. (2020). Modeling Internet Business Optimization Processes, 2020 International Conference on Engineering Management of Communication and Technology (EMCTECH), Vienna, Austria, 2020, pp. 1-5, doi: 10.1109/EMCTECH49634.2020.9261507.

[10] Solovyova A.A. Construction is an industry with a high risk of shadow employment. Construction Accounting and Taxation. 2022 – (10): pp. 43 - 47.

[11] Shadurskaya M.M., Smorodina E.A., Toropova I.V. Corporate tax management. M.: Publishing URAIT, 2023 – 241 P.

[12] Fakhrutdinov R.D. Tax law. M.: Publishing URAIT, 2024 – 134 p.

ESG APPROACHES IN BUSINESS AS THE FORMATION OF NEW THINKING

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Abstract

ESG approaches are based on the philosophy of sustainable development of economic activity, which follows the principles of a responsible attitude to the environment, high social responsibility, and high quality corporate governance. In Russia, the principles of ESG are less common than abroad, but they are already gradually being introduced into business. At the same time, the three categories of ESG are increasingly being integrated into investment analysis, processes and decision making. Many Russian companies are firmly integrated into the agenda by implementing numerous projects, as developed countries are pushing domestic companies to implement such standards to improve the image and investment attractiveness of companies. And here we should not forget about the importance of both climate change issues and corporate governance practices, as well as the efforts and achievements of companies in the field of ecology and social responsibility, which, on the one hand, is the matter of being responsible for the well-being of employees, and, on the other hand, is contribution into the development of the territories where such companies are located.

Keywords: environmental, social, corporate governance, competitiveness of the economy, sustainable development

I. Introduction

An increasing number of investors, especially in the West, when making decisions about investing in a particular company, take into account its impact on the environment and society. The United States is expected to introduce mandatory requirements for issuers to disclose financial information on climate risks and greenhouse gas emissions, and is also expected to introduce, following the example of some European countries, mandatory standardized disclosure of ESG information.

Russian business is also increasingly interested in the principles of responsible investment. ESG stands for Environmental, Social, and Corporate Governance. In 2022, President of the Russian Federation Vladimir Putin instructed the Government of the Russian Federation to consider determining the criteria for classifying investment projects as projects that meet the requirements of the concept of environmental, social and corporate responsibility (ESG).

A significant increase in interest in this agenda is directly related to such factors as environmental problems, a sharp aggravation of social and economic inequality. The global competitiveness of the country's economy and the ability to achieve sustainable development goals will largely depend on professionals in the development, evaluation and management of ESG projects.

II. Methods

The theoretical and methodological basis of the study was the theory of sustainable development, supply and demand in the manufacturing sectors of the economy, quality management, institutional design, research on the competitiveness of firms and goods; environmental friendliness; economic laws of modern market economy; concepts, strategies, various developments and scientific hypotheses of Russian and foreign scientists and experts in the field of economics and industry management. In the process of research, the author used general scientific methods of systemic and comparative analysis, expert assessments, modeling of multifactorial dependencies of complex systems, sociological research, analysis of hierarchies, economic synergy, rating assessment; methods of statistical and mathematical analysis; the principles of logic, purpose, functionality.

III. Results

The abbreviation ESG can be deciphered as "environment, social policy and corporate governance" (Fig. 1). In a broad sense, this is the sustainable development of commercial activities, which is based on the following principles:

1. environmental responsibility (E — environment);
2. high social responsibility (S — social);
3. high quality corporate governance (G — governance).

In Russia, the principles of ESG are less common than abroad, but they are already gradually being introduced into business. One of the topical issues is the reduction of carbon dioxide emissions from the extraction and processing of fuel, as well as the development of new energy sources. As part of the national project called 'Ecology', the task was set to send 100% of waste for sorting by 2030 and to halve the volume of waste disposal. In addition, a third of the country's largest banks have already introduced ESG-assessment of companies into the lending process, and another 20% are planning to. This means that banks will test each borrower for compliance with the principles of sustainable development.

Climate dominates discussions on the ESG agenda, but there is no single list of goals, and concepts often overlap. At the same time, the three categories of ESG are increasingly integrated into investment analysis, processes and decision making (Fig. 1).

The demand for ESG standards in Russia, despite the difficult relations with the West, will continue, and these standards will be adjusted depending on their compliance with real tasks and priorities. Many companies are firmly integrated into the agenda, having implemented numerous projects, as developed countries are pushing domestic companies to implement such standards to improve the image and investment attractiveness of companies. And here it is important not to forget about the responsibility for the well-being of employees and the contribution to the development of the territories in which they work.

Many companies in Russia understand the need for sustainable development in the long term and provide competitive advantages, such as lower lending rates, protection from competition, and gradually become a formalized communication channel: government-business, community-business, society-business, etc.

At present, Russia has formed its own rating of sustainable development of Russian companies. The rating consists of four components:

1. ***Social policy and personnel:***

- staff turnover
- involvement of personnel in the learning process (improving the professional level of employees)
- formation of a personnel reserve of university graduates and trainees
- voluntary medical insurance programs
- health-improving treatment of employees
- indexation of wages to a level not lower than inflation
- investment in work safety

- no injuries at work

2. *Ecology:*

- environmental costs
- implementation of the processing of all waste
- implementation of secondary processing of raw materials
- voluntary programs in the field of ecology that are not related to direct production activities

3. Development of the region of presence:

- programs for the formation of a comfortable urban environment
- the number of regions of the Russian Federation where social programs are being implemented
- donations to charity
- availability of programs and investments that are in line with the SDGs (sustainable development goals) - 2030.

ENVIRONMENT	***SOCIAL***	***GOVERNANCE***
carbon footprint, greenhouse gas emissions, biodiversity, energy efficiency, climate change and pollution reduction, waste management, water use and deforestation.	labor standards, wages and benefits, racial justice, pay equity, human rights, talent management, public relations, privacy and data protection, health and safety, supply chain management and other issues of human capital and social justice.	includes "E" and "S" category governance – corporate board composition and structure, oversight of strategic sustainability and compliance, executive compensation, political input and lobbying, bribery andcorruption.

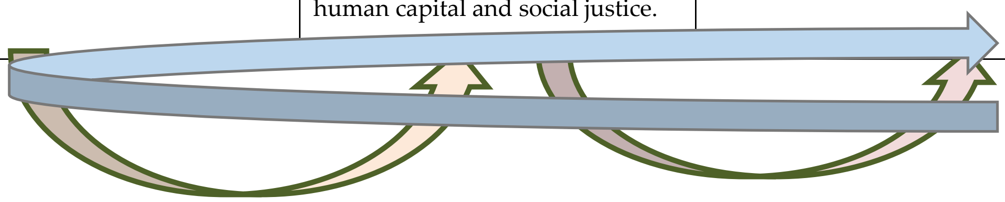

Figure 1: *Philosophy of ESG approaches*

4. Working with small and medium-sized businesses - the share of purchases from small and medium-sized businesses in the total cost.

The most important indicator of the development of an innovative economy is human capital, the country index (human capital index) of which depends mainly on the level of education and health of the economically active population. The level of this indicator directly affects the productivity of people involved in the development of an innovative economy.

According to the latest data from the World Bank, Russia is among the countries with an average level of the index at 0.68 (a high value starts at 0.7). And although the level of education of specialists in the Russian Federation is higher than in some countries with high HAI values, Russia is still inferior to them in terms of the health of specialists. That is why corporate healthcare initiatives now play a special role.

The most important area for investment in human capital is the development of professional educational programs and support for educational institutions in the preparation of future highly qualified specialists.

ESG standards are not only the quality of education and healthcare, but also the development of the urban environment with which local residents interact every day. Therefore, favorable conditions must be created everywhere in order for highly qualified specialists not to seek to change their place of residence for the sake of a more comfortable urban infrastructure. In Russia, the national project "Housing and Urban Environment" is devoted to achieving this goal. The key goals of the national project are to provide affordable housing for middle-income families, including creating opportunities for them to purchase (construct) housing using a mortgage loan, increase the volume of housing construction, improve the comfort of the urban environment, create a mechanism for direct participation of citizens in the formation of a comfortable urban environment, ensuring a sustainable reduction of the uninhabitable housing stock.

Successful cases of the largest Russian companies implementing ESG principles and projects in their practice are presented below (Fig. 2,3,4).

LUKOIL GAZPROM NOVATEK ROSNEFT	SUPPORT REGIONS	1. Landscaping 2. Creation of a comfortable urban environment in small towns and historical towns (play areas for children, organization of winter games), an environment suitable for comfortable life (this solves the staff turnover problem) 3. Support for healthcare, purchase of equipment, opening of medical laboratories 4. Development of tourism 5. Support for the culture of indigenous peoples 6. Repair and construction of sports facilities 7. Support for children's sports 8. The volume of funds for charity is growing 9. Construction and restoration of churches
ELSIE (Coal Company) SUEK SIBUR EUROCHEM	ECONOMIC DEVELOPMENT OF REGIONS	1. Attracting investments to the region by creating its attractive image 2. Increasing economic and tourism potential 3. Implementation of tourism projects (Murmansk region), due to this, stimulation of the development of small and medium-sized businesses, transport, hotels, trade, catering 4. Volgograd region - projects to increase the cultural and tourist attractiveness of the region (the birthplace of Stepan Razin, the site of the Battle of Stalingrad) 5. Support for city initiatives and participation in various federal targeted programs 6. Support for initiatives coming from people (urban development projects, cultural projects, volunteer and environmental initiatives)

Figure 2: *ESG projects in terms of support and development of the regional economy*

EUROCHEM Phosagro MMK (Magnitogorsk Iron and Steel Works) SUEK OMK (United Metallurgical Company) →	SOCIAL POLITICS →	1. Human resources management with good care (management with a human face) 2. Comfort and quality of workplaces 3. Wage increase 4. Development of methods of long-term motivation 5. Funding for charitable projects 6. Corporate housing programs 7. Rehabilitation of employees' children 8. Support for local educational institutions in preparing for future industry specialists, organization of career guidance tours 9. Creation of educational and industrial clusters (integration of education with production) 10. Creating conditions for the development of schoolchildren's talents and support for talented students 11. Rehabilitation programs for veterans (coal industry) 12. Implementation of active longevity practices

Figure 3: *ESG projects in terms of social policy development*

NLMK (Novolipetsk Iron and Steel Works) PHOSAGRO OMK TMK →	ECOLOGY →	1. Production of ecological fertilizers (from ore of volcanic origin, unique in its purity) 2. Creation of carbon polygons and farms designed for monitoring greenhouse gases (planting trees near industries) 3. Protection of water resources (installation of the most modern industrial wastewater treatment systems, an innovative system for storm and wastewater treatment) 4. Emission reduction programs and recycling 5. Introduction of water-saving technologies, regulation of water demand 6. Closed cycle of use of water resources within the framework of production processes 7. Conservation of biodiversity (TMK released 28.5 thousand sturgeon fry into the Sea of Azov basin) 8. Involvement of employees and volunteers in the cleanup of territories and settlements 9. Reforestation. landscaping 10. Environmental education projects 11. Solving problems of soil pollution 12. Selection of partners with an ecological approach to production and high social responsibility

Figure 4: *ESG projects in terms of supporting regions*

To calculate the synergistic socio-ecological and economic effect from the implementation of ESG projects, it is proposed to understand the ratio of the effectiveness of these projects and the costs associated with them.

Due to the significant amount of information and the complexity of calculations, it is proposed to use an indicative method to determine the synergistic socio-ecological and economic efficiency of the implementation of ESG projects.

1. The complex economic index of social, environmental and economic efficiency of the implementation of ESG projects is proposed to be calculated according to formula 1:

$I_{\text{эк}} = k_1 i_{in} + k_2 i_{comp} + k_3 i_{br} + k_4 i_H + k_5 i_{in},$

k_1, k_2, k_3, k_4, k_5 – specific weights of the contribution of each chain index to the economic complex index of socio-environmental and economic efficiency of the implementation of ESG projects; $k_1 + k_2 + k_3 + k_4 + k_5 = 1$;

i_{in} – index of increase in investments in the economy of the region per year;

i_{comp} – index of competitiveness of enterprises in the region;

i_{br} – index of complex competitiveness of industries in the region;

i_H – index of the proportion of families that have the opportunity to purchase housing using their own and borrowed funds;

i_{in} – growth index of potential income received by employees from the increase in their labor productivity due to the improvement of their working conditions.

2. The complex social index of socio-environmental and economic efficiency of the implementation of ESG projects is calculated according to formula 2:

$I_{\text{соц}} = m_1 i_H + m_2 i_{NF} + m_3 i_{\text{р}} + m_4 i_{\Delta C}$,

m_1, m_2, m_3, m_4 – specific weights of the contribution of each chain index to the social complex index of socio-environmental and economic efficiency of the implementation of ESG projects; $m_1 + m_2 + m_3 + m_4 = 1$;

i_H – index of the level of provision of the population with housing (at the end of the year);

i_{NF} – index of the number of employees who have improved their level of education or improve their qualifications on a permanent basis;

$i_{\text{р}}$ – index of labor productivity increase when using long-term motivation methods;

$i_{\Delta C}$ – index of reduction in the cost of treatment and maintenance of health.

3. The complex environmental index of socio-environmental and economic efficiency of the implementation of ESG projects is calculated according to formula 3:

$I_{\text{экол}} = \varphi_1 i_d + \varphi_2 i_{\text{эсп}} + \varphi_3 i_{\text{эсж}}$,

$\varphi_1, \varphi_2, \varphi_3$ – specific weights of the contribution of each chain index to the environmental complex index of socio-environmental and economic efficiency of the implementation of ESG projects;; $\varphi_1 + \varphi_2 + \varphi_3 = 1$;

$i_{d_{\text{э}}}$ – index of the share of environmentally friendly products output from the total volume of commissioning per year;

$i_{\text{эсп}}$ – index of ecologization of production processes;

$i_{\text{эсж}}$ – index of the share of ecologization of the living environment.

Next, the final comprehensive index of social, environmental and economic efficiency of the implementation of ESG projects is calculated.

$I_{\text{итог}} = \tau_1 I_{\text{эк}} + \tau_2 I_{\text{соц}} + \tau_3 I_{\text{экол}}$,

τ_1, τ_2, τ_3 – specific weights of the contribution of each complex index to the final complex index of social, environmental and economic efficiency of the implementation of ESG projects;

$\tau_1 + \tau_2 + \tau_3 = 1$.

Table 1: *Evaluation scale of complex indices for evaluation of social, environmental and economic efficiency of the implementation of ESG projects*

Index name	Meaning	Grade
Comprehensive economic index of socio-environmental and economic efficiency, $I_{эк}$	$I_{эк} \geq 1$	**great**
	$0,8 \leq I_{эк} < 1$	**good**
	$0,5 \leq I_{эк} < 0,8$	**satisfactorily**
	$I_{эк} < 0,5$	**unsatisfactory**
Comprehensive social index of socio-environmental and economic efficiency, $I_{соц}$	$I_{соц} \geq 1$	**great**
	$0,8 \leq I_{соц} < 1$	**good**
	$0,5 \leq I_{соц} < 0,8$	**satisfactorily**
	$I_{соц} < 0,5$	**unsatisfactory**
Comprehensive environmental index of socio-environmental and economic efficiency , $I_{экол}$	$I_{экол} \geq 1$	**great**
	$0,8 \leq I_{экол} < 1$	**good**
	$0,5 \leq I_{экол} < 0,8$	**satisfactorily**
	$I_{экол} < 0,5$	**unsatisfactory**
Final comprehensive index of socio-environmental and economic efficiency , $I_{итог}$	$I_{итог} \geq 1$	**great**
	$0,8 \leq I_{итог} < 1$	**good**
	$0,5 \leq I_{итог} < 0,8$	**satisfactorily**
	$I_{итог} < 0,5$	**unsatisfactory**

Conclusions

ESG standards should become part of the corporate culture, an element in shaping the mindset of employees. Understanding this will give companies new opportunities for development. The ESG agenda has the deepest roots that reflect the contradictions that humanity has accumulated to date and that need to be addressed.

As a result of the irregularity of the capitalist form of economic relations and the dominance of profit as the goal of activity, mankind has faced an extraordinary problem - the loss of nature. The problem of biodiversity loss is much larger than climate change. Scientists say the planet has entered its sixth mass extinction and nature is disappearing before our eyes. Only this process occurs through the fault of man. The solution to this problem reflects the environmental aspect of ESG standards.

Despite the most powerful geopolitical crisis in 2022, the ESG agenda in Russia continues to evolve, as evidenced by some facts:

1. Issues of green, social bonds took place, for example, they were issued by the largest issuers, VEB.RF, DOM.RF, Rostelecom, Atomenergoprom.
2. The volume of bank ESG loans, according to expert estimates, has grown.
3. The largest companies continue to disclose non-financial statements. Almost all companies that received the ESG rating came to its confirmation in 2022.
4. All issuers raising money through green, social, transitional bonds have fulfilled their obligations to place a report on the intended use of funds on the Moscow Exchange.

5. In 2022, the first deal with carbon units was made and the first verified climate project appeared. Despite the fact that only 20 carbon units were sold, this event demonstrated the readiness of the Russian carbon units market in terms of technical feasibility and availability of conditions for its further development.

6. The labor market is recovering from a turbulent downturn, and the demand for experienced graduates in sustainable development and ESG is gradually returning.

The main tasks for 2023 are: to gradually return the environmental decisions and requirements postponed due to the economic situation; adopt a federal law on non-public reporting with revised positions taking into account the new time; revision of corporate strategies for sustainable development in the direction of increasing attention to the problem of biodiversity reduction and loss of nature; ensuring transparency of the green portfolio of the banking market, the largest banks can agree on a voluntary reporting format to disclose the general parameters of the green or ESG portfolio by volume, dynamics, industry profiles.

So, the following year ESG will evolve further in various ways, penetrating deeper and deeper into all areas of human activity.

References

[1] Does ESG Disclosure Influence Firm Performance? / Department of Business Administration, John Cabot University, 00165 Rome, Italy. / Silvia Carnini Pulino [и др.]. // Sustainability. 2022. №14.7595. ISSN 2071-1050 DOI: 10.3390/su14137595

[2] ESG Scores and the Credit Market / Department of finance, Hanyang University Business School, Seoul 04763, Korea. / Ga-Young Jang [и др.]. // Sustainability. 2020. №12.3456. ISSN 2071-1050 DOI: 10.3390/su12083456

[3] ESG based assessment of the enterprises efficiency / Peter the Great St. Petersburg Polytechnic University. / Demidenko Daniil [и др.]. // π-Economy. 2022. №15.4. ISSN 2782-6015 DOI: 10.18721/JE.15406

[4] ESG metrics and social equity: Investigating commensurability / Department of Civil Engineering, Kyushu University, Fukuoka, Japan. / Alexander R. Keeley [и др.]. // Frontiers in Sustainability. 2022. №3. ISSN 2673-4524 DOI: 10.3389/frsus.2022.920955

[5] Laurențiu-Paul Barangă, Elena-Ioana Țanea. Introducing the ESG reporting - benefits and challenges / The Bucharest University of Economic Studies, Bucharest. // Revista de Studii Financiare. 2022. №7.13. С. 174-181. ISSN 2537-3714 DOI: 10.55654/JFS.2022.7.13.14

[6] Maya Finger, Mosi Rosenboim. Going ESG: The Economic Value of Adopting an ESG Policy / Business Faculty, The College of Management Academic Studies, Rishon Lezion 75190, Israel. // Sustainability. 2022. №14.13917. ISSN 2071-1050 DOI: 10.3390/su142113917

[7] Ryohei Hisano, Didier Sornette, Takayuki Mizuno. Prediction of ESG compliance using a heterogeneous information network / Social ICT Research Center, Graduate School of Information Science and Technology, The University of Tokyo. // Journal of Big Data. 2020. №7.1. С. 1-19. ISSN 2196-1115 DOI: 10.1186/s40537-020-00295-9

[8] So Ra Park, Jae Young Jang. The Impact of ESG Management on Investment Decision: Institutional Investors' Perceptions of Country-Specific ESG Criteria / Department of Tourism Management, Cheju Halla University, Jeju-si 63092, Korea. // International Journal of Financial Studies. 2021. №9.48. ISSN 2227-7072 DOI: 10.3390/ijfs9030048

THE INFLUENCE OF HUMAN FACTORS ON PERCEPTION OF SUSTAINABILITY IN EDUCATIONAL TECHNOLOGIES

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Abstract

In the context of global environmental challenges and the need for sustainable development, understanding the perception of sustainability becomes critical for the effective implementation of educational technologies. This paper explores how human factors such as cultural values, personal beliefs, motivation, and social environment influence students' perception of sustainability and their interaction with innovative educational technologies. The study analyzes various aspects, including psychological and sociocultural components, that shape students' attitudes toward sustainable practices and technologies. It examines factors that facilitate or hinder the adoption of sustainable concepts in educational platforms such as adaptive systems, online courses, and gamification. The results of the study show that positive perceptions of sustainability are associated with a high degree of engagement and awareness of individual responsibility for the environment. In addition, the cultural and social contexts in which students learn significantly influence their perception of sustainable practices and technologies. The paper highlights the need to integrate human factors into the development of educational programs and technologies aimed at sustainable development. Understanding these factors can help create more effective and inclusive educational systems that foster resilient behaviors and awareness in students.

Keywords: sustainable practices, adaptive learning systems, online courses, ecological awareness, behavioral change

I. Introduction

As the world grapples with pressing environmental challenges, the need for effective education on sustainability has never been more critical. Educational technologies, particularly innovative and adaptive systems, offer powerful tools for fostering understanding and engagement in sustainability among learners. However, the success of these technologies is significantly influenced by human factors—such as cultural values, personal beliefs, motivations, and social contexts—that shape individuals' perceptions of sustainability.

Understanding how human factors affect the perception of sustainability in educational settings is essential for designing effective curricula and technologies that resonate with diverse student populations. For instance, students' cultural backgrounds can greatly influence their attitudes toward environmental issues, impacting their receptiveness to sustainability concepts taught through technology. Personal beliefs about environmental responsibility and sustainability practices further complicate this dynamic, as they can either enhance or hinder engagement with educational content.

Moreover, motivation plays a pivotal role in shaping how students interact with educational technologies. Factors such as intrinsic motivation, relevance of the material to their lives, and social influences can affect students' willingness to engage with sustainability topics. Additionally, the social environment in which students learn, including peer interactions and community values, can significantly shape their perceptions and attitudes toward sustainability.

This paper seeks to explore the intricate relationship between human factors and the perception of sustainability in educational technologies. By examining how these factors influence learning experiences and outcomes, the research aims to provide insights that can enhance the development and implementation of educational technologies aimed at promoting sustainable practices. Ultimately, understanding this interplay is crucial for cultivating a generation of environmentally aware individuals capable of addressing the complex challenges posed by a rapidly changing world.

In addition to expanding access to education, educational technologies also improve the quality and relevance of learning. Tools such as AI-driven personalized learning platforms can adapt educational content to the specific needs and learning pace of individual students, enhancing engagement and retention of knowledge. By using data analytics and machine learning algorithms, these platforms can identify knowledge gaps and provide targeted interventions to improve learning outcomes. Moreover, virtual reality (VR) and augmented reality (AR) technologies are being used to create immersive learning environments that can simulate real-world scenarios, providing hands-on experience and fostering critical thinking, problem-solving, and creativity—skills that are increasingly important in the modern workforce.

The impact of innovative educational technologies is also visible in the corporate and industrial sectors, where continuous training and upskilling are necessary to keep pace with technological advancements. In many industries, workers are required to adapt to new tools, systems, and methodologies to remain competitive. Educational technologies, such as corporate e-learning programs and virtual training simulators, offer flexible, cost-effective solutions for upskilling employees without disrupting business operations. These tools enable workers to develop new competencies, increase their productivity, and contribute to the growth of their organizations, ultimately enhancing the overall competitiveness of a nation's workforce.

Despite the many advantages, integrating these technologies into education systems presents significant challenges. Infrastructure limitations, particularly in less developed regions, pose major obstacles to the widespread adoption of digital learning tools. Additionally, the digital divide, characterized by unequal access to technology and internet connectivity, can exacerbate inequalities in human capital development. Moreover, teachers and educators must be equipped with the necessary skills to effectively utilize these technologies in the classroom, which requires ongoing professional development and training. Furthermore, there are concerns about data privacy, the cost of implementing advanced technologies, and the need for policy frameworks that can support the integration of these tools into formal and informal education systems.

This study aims to explore the impact of innovative educational technologies on human capital development and, in turn, their role in promoting economic growth. It will analyze the ways in which these technologies are reshaping education and training systems globally, particularly in developing countries, where the need for human capital development is most urgent. By examining case studies, empirical data, and theoretical frameworks, this research seeks to highlight the potential of these technologies to bridge skill gaps, improve employability, and foster long-term economic growth. Additionally, it will address the challenges and opportunities associated with implementing these tools, emphasizing the importance of supportive infrastructure, policy frameworks, and investments in teacher training to maximize their effectiveness.

In conclusion, the rapid advancement of educational technologies presents a unique opportunity to revolutionize the development of human capital. As countries strive to remain competitive in the global economy, investing in these tools will be essential to building a highly skilled and adaptable workforce capable of driving innovation and economic growth. The integration of educational technologies into both formal education and lifelong learning systems will be a key determinant of future economic success, particularly in regions where traditional educational resources have been limited. By addressing the challenges of implementation and leveraging the full potential of these technologies, countries can unlock new pathways to economic development and global competitiveness.

II. Methods

This study employs a multi-method approach to analyze the impact of innovative educational technologies on human capital development and their contribution to economic growth. The research methodology is divided into three main components: literature review, quantitative analysis, and case study analysis. Each of these methods provides distinct insights and complements the overall understanding of how educational technologies influence human capital development.

1. Literature Review:

The first phase of the study involves conducting a comprehensive literature review to explore existing research on the relationship between educational technologies, human capital development, and economic growth. This review focuses on academic publications, reports from international organizations, and policy documents that discuss the role of technology in education. By synthesizing previous studies, this method identifies key theoretical frameworks and empirical findings that serve as a foundation for the current analysis.

The literature review also examines various types of educational technologies—such as e-learning platforms, artificial intelligence-driven systems, virtual reality, and gamification—and their effectiveness in different contexts. Special attention is paid to research exploring the use of these technologies in developing countries, where challenges such as limited infrastructure and unequal access to technology may affect their impact. This review highlights gaps in existing knowledge and suggests areas where further research is needed, laying the groundwork for subsequent quantitative and case study analyses.

2. Quantitative Analysis:

The second method involves quantitative analysis using secondary data from reputable sources such as the World Bank, UNESCO, and the Global Competitiveness Index (GCI). This analysis investigates the relationship between human capital development indicators—such as education levels, workforce skills, and technological adoption—and economic growth across different countries.

Key variables considered include:

- Educational attainment levels (e.g., literacy rates, enrollment in primary, secondary, and tertiary education).
- Human capital investment (e.g., government expenditure on education and training).
- Technological integration in education (e.g., percentage of schools with internet access, use of e-learning platforms).
- Economic indicators (e.g., GDP growth, productivity rates, employment levels).

Using statistical tools such as regression analysis and correlation coefficients, the study examines the extent to which the adoption of educational technologies correlates with improvements in human capital and economic performance. Additionally, longitudinal data are used to assess trends over time, allowing for a deeper understanding of how technological advancements in education contribute to sustained economic growth. The quantitative analysis also accounts for regional disparities, providing insights into how developing and developed countries experience different outcomes from technological integration in education.

3. Case Study Analysis:

The third method is qualitative case study analysis, which focuses on specific countries or regions that have successfully implemented innovative educational technologies to improve human capital development. These case studies provide detailed insights into the practical challenges, successes, and lessons learned from the adoption of technology-driven education systems.

The selected case studies include countries with varying levels of economic development and technological infrastructure, such as:

- Singapore, known for its high level of human capital investment and advanced use of e-learning and AI-driven educational tools.
- Estonia, a leader in digital education and online learning, which has transformed its education system using technological innovation.
- Kenya, where mobile learning initiatives and online platforms are bridging education gaps, particularly in rural and underserved areas.

Each case study examines key factors such as government policies, infrastructure investments, teacher training programs, and public-private partnerships that have facilitated the successful integration of educational technologies. The case studies also highlight the socioeconomic impact of these initiatives, particularly in improving access to education, enhancing employability, and fostering long-term economic growth. Through a comparative analysis of these cases, the study identifies best practices and policy recommendations that can inform future efforts to leverage educational technologies for human capital development in other regions.

III. Results

The exploration of the influence of human factors on the perception of sustainability in educational technologies yielded several significant findings. These results highlight the complexities of integrating sustainability education into technology-mediated learning environments and underscore the importance of considering human factors in the design and implementation of these technologies.

1. Impact of Cultural Values on Sustainability Perception

Students from diverse cultural backgrounds demonstrated varying levels of awareness and concern regarding sustainability issues. The study revealed that cultural values significantly shape students' perceptions of environmental responsibility. For instance, students from cultures with strong traditions of conservation and communal living exhibited a heightened sense of stewardship toward the environment. In contrast, those from cultures with less emphasis on sustainability reported lower levels of engagement with related educational technologies.

2. Role of Personal Beliefs and Attitudes

Personal beliefs about environmental issues were found to be a strong predictor of students' willingness to engage with sustainability content. Survey data indicated that students who identified as environmentally conscious were more likely to participate actively in courses focused on sustainability. Conversely, those who expressed skepticism about environmental problems tended to disengage from educational technologies designed to promote sustainability, highlighting the need for approaches that address these beliefs.

3. Motivation and Engagement Levels

Motivational factors were crucial in determining students' engagement with educational technologies focused on sustainability. The findings showed that intrinsic motivation—driven by personal interest and relevance of the material—correlated positively with higher levels of engagement and knowledge retention. For example, students who perceived sustainability topics as personally relevant were more likely to interact with adaptive learning systems and complete online courses. Additionally, extrinsic motivators, such as grades and social recognition, also played a role, but to a lesser extent.

4. Influence of Social Environment

The social environment, including peer influence and community values, emerged as a significant factor affecting students' perceptions of sustainability. Students reported feeling more motivated to engage with sustainability education when they were part of supportive peer groups that emphasized environmental consciousness. Furthermore, community initiatives promoting sustainability positively impacted students' perceptions, leading to increased participation in educational technologies designed to enhance their understanding of sustainable practices.

5. Technological Interaction Patterns

Analysis of interaction data from adaptive learning systems revealed patterns in how different student groups engaged with sustainability content. Students with a strong interest in environmental issues utilized interactive features—such as simulations and gamified elements—more frequently, which facilitated deeper learning and application of sustainable practices. In contrast, students with lower interest levels tended to utilize only basic features, indicating a missed opportunity for more profound engagement with the material.

These results underscore the critical role of human factors in shaping perceptions of sustainability within educational technologies. By acknowledging and addressing cultural values, personal beliefs, motivations, and social environments, educators and developers can create more effective and inclusive learning experiences that resonate with diverse student populations. This understanding is vital for fostering a generation of environmentally aware individuals equipped to address the pressing challenges of sustainability in the modern world.

The motivation behind global educational reforms is largely driven by the development of innovative educational technologies, which aim to enhance higher education, foster economic growth, and transform education into an innovation-oriented space. These reforms align with market-driven economic principles, democratic values, and global advancements in science and technology by reshaping the educational process and updating content, leading to the accelerated growth of education. The integration of these technologies ensures the competitiveness of higher education institutions in the educational services market and contributes to improving the quality of education.

Innovative educational technologies, which encompass both formal and informal learning methods, focus on enhancing educational outcomes and achieving core educational objectives. The progression of a specialist's training through these technologies can be categorized into four levels: existing education, direct training in an innovative environment, testing of educational outcomes using modern methods, and implementing educational results through innovative technologies.

Various groups of innovative educational technologies have been identified:

- **Digital technologies**: These play a central role in the digital transformation of education, fostering a specialist's digital culture and improving motivation and productivity through the inclusion of digital tools and professional software in curricula.
- **Quality management and information support**: These innovations provide tools for monitoring and controlling the educational process, aiding in the development of both individuals and institutions.
- **Person-centered technologies**: Focus on creating a safe, conflict-free educational environment that prioritizes individual development and the realization of human potential.
- **Educational and didactic technologies**: These methods include group work, independent

learning, project-based learning, and interactive techniques such as games and audiovisual tools, all aimed at enhancing the educational process.

Innovative pedagogical methods have also become widespread, emphasizing real-world professional activity, interactivity, and advanced technologies like simulation, group training, and video learning. Additional modern tools include e-learning, anticipatory learning, and the use of various digital platforms for communication, such as forums, video conferences, and multimedia. Furthermore, the technological infrastructure of higher education institutions—such as internet access and computer labs—plays a crucial role in fostering innovation and supporting the creative endeavors of both students and teachers.

IV. Discussion

The features of innovative education play a crucial role in enhancing higher education and producing competitive specialists. These features should be considered in the learning process, and include:

- Openness to the future in innovative higher education;
- Focus on predicting and programming personal development;
- Emphasis on a person-centered approach and human development;
- Building partnerships using innovative educational technologies, fostering mutual assistance, collaboration, and co-creation;
- Integration of creativity into higher education;
- Acknowledgment of the instability and constant contradictions in the educational system and individuals.

The systematic application of innovative educational technologies by teachers is essential for improving higher education today. The more diverse teaching methods and strategies a teacher utilizes, the better they can motivate learners, making classes more engaging and effective. This approach encourages solving non-standard problems, facilitates practical learning, and ensures the mastery of innovative professional skills. A competitive specialist continuously hones their teaching skills, adopts innovative strategies, and selects new technologies and methods.

The findings of this study highlight the intricate relationship between human factors and the perception of sustainability within educational technologies. Understanding these dynamics is crucial for educators, curriculum developers, and technology designers aiming to promote sustainable practices effectively. This discussion will explore the implications of the results, potential strategies for improving educational outcomes, and areas for future research.

1. Cultural Values and Sustainability Education

The strong influence of cultural values on students' perceptions of sustainability emphasizes the need for culturally responsive educational practices. Educational technologies should be designed to incorporate local contexts and cultural narratives related to sustainability. By acknowledging the cultural backgrounds of students, educators can create more relevant and engaging learning experiences. For instance, integrating examples of local environmental issues or traditional practices of conservation can resonate more deeply with students, fostering a sense of connection and responsibility toward their environment.

2. Addressing Personal Beliefs and Attitudes

The study revealed that personal beliefs significantly impact engagement with sustainability topics. To enhance participation, it is essential to address skepticism and misinformation about environmental issues. Educational technologies can include features that provide evidence-based information, countering misconceptions and fostering critical thinking. For example, interactive modules that simulate environmental impacts can illustrate the consequences of unsustainable practices, helping students to see the relevance of sustainability in their lives. Additionally, incorporating narratives of successful sustainability initiatives may inspire positive attitudes and encourage proactive behavior.

3. Enhancing Motivation through Personalization

Motivational factors play a critical role in determining student engagement levels. The findings suggest that personalized learning experiences can enhance intrinsic motivation and lead to greater engagement with sustainability content. Adaptive educational technologies that tailor content to individual interests and prior knowledge can create a more compelling learning environment. Moreover, incorporating gamification elements, such as rewards for sustainable actions or competitions among peers, can provide extrinsic motivation that complements intrinsic interest, making learning more enjoyable and impactful.

4. Leveraging the Social Environment

The positive influence of the social environment on perceptions of sustainability indicates that collaborative learning strategies can enhance engagement with sustainability topics. Group projects, peer discussions, and community-based initiatives can foster a sense of belonging and shared responsibility. Educational technologies can facilitate these collaborative efforts by enabling students to connect with each other and engage in collective problem-solving activities related to sustainability. Online forums and social media integrations can provide platforms for students to share experiences, exchange ideas, and support one another in adopting sustainable practices.

5. Implications for Technology Design

The study's results underscore the importance of designing educational technologies that take human factors into account. Developers should prioritize user experience and ensure that technological features align with the motivations and needs of diverse learners. This may involve incorporating flexible learning paths, interactive content, and opportunities for self-directed learning. Additionally, ensuring accessibility for all students, including those with varying levels of technological proficiency, is crucial for maximizing engagement and effectiveness.

6. Future Research Directions

While this study provides valuable insights, further research is needed to explore the longitudinal effects of educational technologies on sustainability perceptions and behaviors. Future studies could investigate how different demographic factors, such as age, gender, and socioeconomic status, influence engagement with sustainability education. Additionally, examining the impact of hybrid learning environments, which combine in-person and online instruction, could provide further understanding of how human factors interact with educational technologies.

References

[1] Taranova I.V., Kasaeva T.V., Shavrina J.O., Tekeeva H.E., Boeva K.Y. Methods of fraud management in the financial services market of the region// Business 4.0 as a Subject of the Digital Economy. Cham, 2022. C. 291-295.

[2] Kasaeva T.V., Taranova I.V., Valishina G.L., Atabaev A.R., Novoseltseva A.P. Development of the medical healthcare sector in russia based on the experience of socio-economic transformations of foreign countries and regions// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 252-256

[3] Gakaev , R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms

of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. С. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[12] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 2137-2144

ECONOMIC MODELS OF TRANSITION TO SUSTAINABLE DEVELOPMENT: ANALYSIS OF SUCCESSFUL STRATEGIES IN WORLD PRACTICE

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Abstract

This paper explores various economic models and strategies that have successfully facilitated transitions toward sustainable development in different regions around the world. By analyzing the mechanisms employed in these transitions, the study identifies key economic, policy, and institutional factors that contributed to success. The analysis spans different sectors, including energy, agriculture, and manufacturing, with a focus on green technologies, circular economy practices, and renewable energy integration. The paper also reviews international cooperation efforts, regulatory frameworks, and the role of innovation in driving sustainable growth. The findings suggest that a combination of public policy incentives, private sector engagement, and social inclusivity is crucial for achieving long-term sustainability. Case studies of countries such as Sweden, Germany, Costa Rica, and China illustrate the diversity of approaches and the lessons that can be drawn from them. The research contributes to a better understanding of the pathways and tools necessary for a global transition toward a sustainable economic model.

Keywords: green economy, circular economy, renewable energy, policy incentives, innovation, international cooperation, environmental sustainability, transition strategies

I. Introduction

In recent decades, the global community has increasingly acknowledged the necessity of sustainable development as a fundamental principle for economic growth. Sustainable development involves pursuing economic progress while addressing environmental protection and social equity, ensuring the well-being of both current and future generations. As societies face the impacts of climate change, resource depletion, and social inequality, understanding the economics of sustainable development has become critical. This research paper explores the complex interaction between economic principles and sustainable development goals, highlighting the challenges impeding progress and examining potential solutions. By synthesizing existing literature and empirical evidence, the paper aims to illuminate the intricacies of achieving sustainable development from an economic standpoint. The urgency of addressing sustainability issues is evident in the rising frequency of environmental disasters, increasing income inequality, and ecosystem degradation. In this context, policymakers, businesses, and civil society are being urged to adopt comprehensive approaches that balance economic growth with environmental care and social inclusivity. Through a multidisciplinary perspective, this paper seeks to dissect the economics of sustainable development, shedding light on the trade-offs, synergies, and policy measures required to build a more equitable and resilient future. By critically examining existing frameworks, identifying knowledge gaps, and proposing innovative strategies, this paper aims to contribute to the ongoing dialogue on sustainable development and stimulate action toward a more sustainable and prosperous world. Sustainable development has become a critical concern in today's world, as societies face the pressing challenge of balancing economic growth with environmental protection and social equity. Popularized by the Brundtland Commission in 1987, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Since then, it has served as a guiding framework for governments, businesses, and communities worldwide. The pursuit of sustainable development is complex, involving the interconnectedness of economic, environmental, and social factors. Economists play a key role in addressing these challenges by analyzing trade-offs, creating incentives, and developing policy frameworks to support sustainable practices. The economics of sustainable development covers a broad spectrum of topics, including resource management, the transition to clean energy, poverty reduction, and climate adaptation. Despite widespread acknowledgment of the need for sustainability, significant challenges remain. Economic systems often prioritize immediate profits over long-term sustainability, leading to resource depletion, worsening inequality, and environmental degradation. Furthermore, many sustainability issues are global in scope, requiring international collaboration, which is often hindered by political and economic conflicts. In this context, the demand for innovative solutions is more urgent than ever. This review paper aims to provide an in-depth exploration of the economics of sustainable development, focusing on the obstacles to achieving sustainability and the possible ways forward. By integrating existing research and identifying areas where further study is needed, the paper seeks to enhance understanding of the economic forces at play in sustainable development and to guide the creation of policies that foster a more inclusive, resilient, and environmentally conscious global economy.

II. Methods

This paper employs a qualitative research design to investigate the economics of sustainable development, focusing on identifying challenges and exploring potential solutions. Qualitative methods are particularly well-suited for an in-depth analysis of the complex interactions between economic factors and sustainable development objectives, allowing for a nuanced understanding of the topic.

Data will be collected through an extensive literature review, drawing from academic journals, books, reports, and other scholarly materials that address the economics of sustainable development. The review will utilize online databases such as Google Scholar, JSTOR, and PubMed to access relevant research. Additionally, reports from governmental and non-governmental organizations, as well as industry white papers, will be included to provide a broad perspective on the subject.

The inclusion criteria for the literature review will focus on sources that discuss key aspects of sustainable development economics, such as economic growth, environmental sustainability, social equity, poverty reduction, and technological innovation. Only peer-reviewed articles and reputable sources published within the last ten years will be considered to ensure that the research is both up-to-date and credible. Exclusion criteria will include studies that do not directly address the economics of sustainable development or lack empirical evidence to support their findings. Non-English language publications will be excluded due to language constraints.

Ethical considerations in this research involve proper citation and acknowledgment of all sources to avoid plagiarism. The accuracy and relevance of the information will be critically assessed, with attention given to respecting diverse viewpoints in the literature. Care will be taken to avoid bias in both the selection and interpretation of data, ensuring an objective and balanced analysis of the economics of sustainable development.

III. Results

A series of recent crises and growing instability in the global economy and politics, as well as an increasing number of global risks and challenges, force us to reconsider the concept of sustainable development. Previously perceived as an abstract theoretical construct, the system of global goals and objectives that seemed distant from everyday problems has been seriously tested for viability and relevance in recent years. For everyone who has lived through the COVID-19 pandemic with its profound socio-economic consequences, and who is now observing fundamental changes in the economy and geopolitics, the term "sustainable development" takes on new meaning and significance.

Attempts to question the need to follow the UN Agenda for Sustainable Development until 2030, adopted in 2015, against the backdrop of intensifying crises have quickly given way to an awareness of the importance of joining forces to achieve the 17 Sustainable Development Goals (SDGs). This requires efforts at all levels - from states and regional associations to municipalities, companies and individuals representing society as a whole.

Increased attention to the topic of sustainable development is also due to worsening climate problems. Experts once again emphasize the imbalance in the climate system and the onset of irreversible consequences for the climate. Global environmental and climate risks have been leading the annual World Economic Forum (WEF) global risk reports for several years in a row, which only confirms the need for urgent action.

IV. Discussion

The concept of sustainable development is a process of economic and social transformation, in which the use of natural resources, investment direction, scientific and technological progress, personal development and institutional changes are coordinated in such a way as to strengthen the current and future potential to meet human needs and aspirations. At the corporate level, this concept covers a system of principles, processes and results aimed at maintaining a balance between economic, environmental and social aspects both in companies and in society as a whole. Maintaining this balance contributes to the preservation of vital systems and long-term well-being. The concept is closely related to the ESG approach (environmental, social, governance - the environment, society and corporate governance), which is aimed at managing non-financial risks taking into account the impact on the environment, society and the principles of effective management. This approach includes such processes as ESG rating, ESG investing and ESG transformation, and represents a continuous improvement of business processes. Current economic and political crises have only increased the importance of strengthening the sustainability of companies and made it urgent to develop more relevant ESG criteria for long-term development.

In the post-pandemic era, not only institutional investors, but also politicians in developed countries are declaring their commitment to ESG principles, paying attention to the implementation of "green" technologies, human-oriented corporate practices and improving the quality of life. The concept of the "green" economy, which emerged at the end of the 20th century, remains important, focusing on the need to minimize the negative impact of economic activity on the environment, placing sustainable development and environmental safety above simple economic growth at any cost.

The process of aligning the Decision Support System (DSS) to sectoral modeling varies based on the capabilities and flexibility of the selected modeling methodology. This section, along with the following one, details how this alignment is conducted for the Global Energy Model (GEM).

The integration of thematic results into GEM, as well as the alignment of outcomes, is influenced by the degree to which each sector experiences endogenous feedback loops.

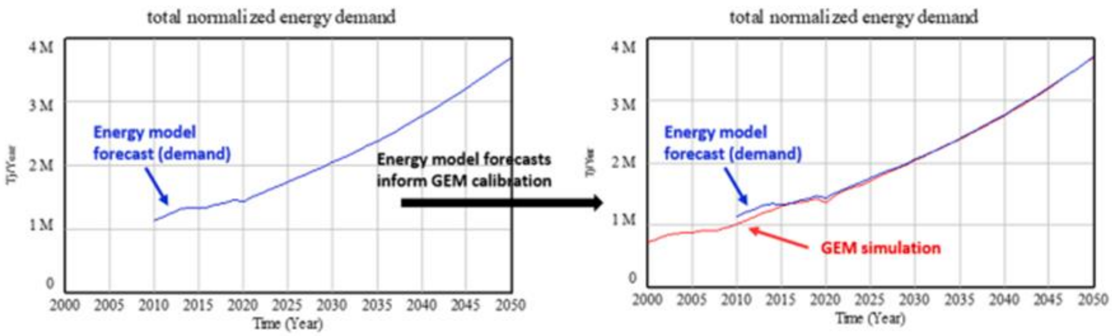

Figure 1: *Illustration of reference mode and the alignment of behavior in GEM*

Soft Coupling of Methods

The soft coupling of methods can be achieved either through direct input or calibration:

- Direct Input: This involves importing the results from thematic modeling as data time series into GEM. When there is limited or no relevant structure in GEM or when the parameters are not influenced by endogenous feedbacks, the outputs from sectoral models are fed into time-based table functions within GEM.
- Calibration: This approach is utilized to align GEM results with sectoral modeling outputs when the relevant indicators are influenced by GEM's endogenous feedback structure. Calibration requires several steps, which will be demonstrated using the example of total energy demand.

Steps for Calibration

1. Creating an Artificial Simulation:
   - The first step involves generating a simulation specifically for calibration purposes. In this case, the energy demand data for alignment is sourced from the Low Emissions Analysis Platform (LEAP) (SEI, 2018).
   - The System Dynamics (SD) modeling software enables the importation of data from sectoral models into GEM and the creation of a simulation file that can be visualized. This imported data is termed "reference modes" and is utilized to conduct behavioral validation tests.
   - The left graphs in Figure 3 illustrate the reference data from the LEAP model, specifically total energy demand and energy-related CO2e emissions, which are essential for calibrating these parameters within GEM.
2. Importing Baseline Real GDP Data:

Since LEAP does not account for feedback mechanisms affecting macroeconomic productivity, baseline real GDP data is imported as time series. This is necessary because GEM incorporates feedback loops that treat real GDP as a driver of energy demand and related costs. These factors subsequently impact sectoral real GDP through total factor productivity.

The interplay between real GDP and energy demand is reciprocal; thus, a change in real GDP influences energy demand and vice versa. To facilitate calibration of GEM in line with LEAP projections, it is crucial that real GDP remains exogenous during the calibration process to replicate the conditions (ceteris paribus) present in the LEAP model.

This calibration process ensures that the energy demand and CO2e emissions in GEM are accurately aligned with the projections and feedback mechanisms represented in the LEAP model, thereby enhancing the reliability of the model's outputs.

The events of 2022–2023 are increasingly raising doubts about the comprehensive achievement of the Sustainable Development Goals (SDGs) within the framework of Eurasian integration. The destruction of supply chains, rising prices for raw materials and commodities, including food, are creating difficult conditions for achieving the SDGs, especially those related to ending hunger (SDG 2) and ensuring health and well-being (SDG 3). Sergey Glazyev, Minister for Integration and Macroeconomics of the EEC, notes the trend towards chaos in food markets, emphasizing that global resources and technologies make it possible to produce food for 20 billion people — twice as many as the current population of the planet. However, the problem lies in the unfair distribution of resources, unequal international economic relations, and rising prices caused by the quantitative easing policy of reserve currency issuers.

For an effective transition to sustainable development, it is necessary to develop an adequate system of goals and indicators. It is necessary to improve the methodology for selecting statistical indicators reflecting the achievement of SDGs in the EAEU countries, as well as to create new indicators for missing areas. It is also important to implement international standards and take into account recommendations, such as the OECD recommendations, to improve the quality and comparability of economic statistics. This is critical for the formation of the EEC's own dossier on sustainable development and the preparation of a new report. Of particular importance is the coordination of statistical activities in the EAEU region, strengthening professional and research potential, as well as the introduction of advanced international standards in methodology and data classification.

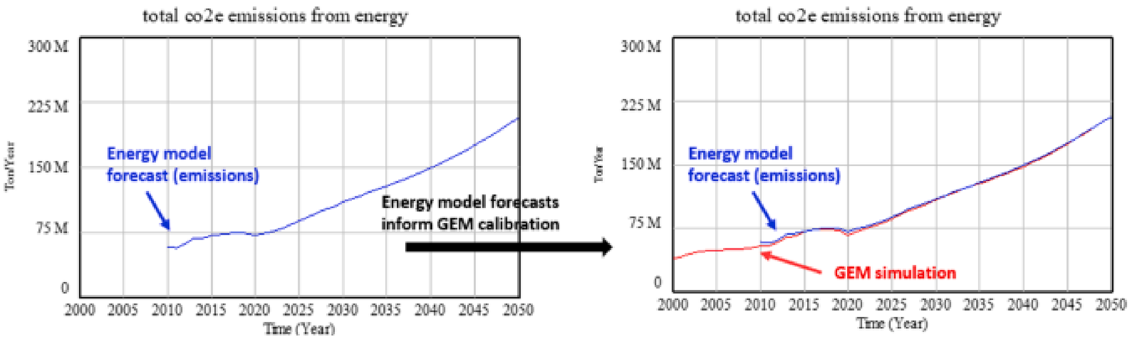

Figure 2: *Illustration of reference mode and the alignment of behavior in GEM*

The demand aligns with the results from LEAP, and closing the endogenous feedback loops enables us to (i) examine how macroeconomic indicators evolve under LEAP projections and (ii) subsequently adjust the energy demand trajectory forecasted by LEAP. Figure 4 illustrates a comparison of simulations with and without the endogenous feedback effects through total real GDP. The findings indicate that the energy mix derived from the sectoral model contributes to increased economic growth (for instance, through lower costs). This additional growth results in greater energy demand and related emissions than what LEAP initially predicted.

This process is conducive to iterations. Specifically, the updated total real GDP forecast from GEM can be integrated back into LEAP. This integration aids in assessing whether the anticipated emission reductions remain achievable or if the increased demand necessitates more robust mitigation efforts. This methodology is applied across all modules except for ecosystem service provisioning. The exception arises because modeling current and future ecosystem service provisioning requires iterative processes among GEM, GIS, and ecosystem services models like InVEST.

References

[1] Daukaev, A. Main trends in climate change in the Holocene epoch of the antropogenic

period in the world and in the Caucasus / A. Daukaev, R. Gakaev, T. Bachaeva // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 387-390. – DOI 10.24412/1932-2321-2023-575-387-390.

[2] Podkolzina, I.M., Gladilin, A.V., Reshetov, K.Y., Taranova, I.V., Gladilin, V.A. Building a Financial Security System to Ensure Russia's Food Security // Lecture Notes in Networks and Systems, 2021, 205, pp. 539–548

[3] Gakaev , R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, pp. 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[12] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144

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THE EFFECTIVENESS OF CARBON TAXES AND TRADING SCHEMES TO REDUCE CO2 EMISSIONS

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Abstract

Carbon taxes and trading schemes are pivotal instruments in the fight against climate change, aimed at reducing CO2 emissions by providing economic incentives for emission reductions. This paper examines the effectiveness of these mechanisms in various contexts, analyzing their design, implementation, and outcomes across different regions and industries. Carbon taxes impose a direct cost on carbon emissions, encouraging businesses and consumers to reduce their carbon footprint, while cap-and-trade systems set a limit on total emissions and allow for the trading of emission permits. The analysis highlights the strengths and weaknesses of each approach, including their economic impacts, environmental effectiveness, and equity considerations. The findings suggest that both carbon taxes and trading schemes can significantly contribute to emission reductions when designed with careful consideration of local economic conditions and social implications. The paper concludes with recommendations for policymakers to enhance the effectiveness of these tools in achieving climate targets.

Keywords: carbon tax, cap-and-trade, CO2 emissions, climate change, emission reduction, environmental policy

I. Introduction

Climate change represents one of the most pressing challenges of our time, driven primarily by anthropogenic greenhouse gas (GHG) emissions. The escalating impacts of climate change—ranging from extreme weather events to rising sea levels—underscore the urgency for effective policy measures to mitigate these effects. Economic theories regarding externalities provide a foundational framework for understanding the role of market failures in exacerbating environmental degradation. In the early 20th century, economist Arthur Pigou introduced the concept of externality, which refers to costs or benefits resulting from an action that are not accounted for by the producer. For instance, the combustion of fossil fuels not only generates energy but also releases harmful emissions, imposing significant social costs on society that far exceed the private costs incurred by producers.

As the global community grapples with the challenges posed by climate change, policymakers have increasingly turned to market-based mechanisms, such as carbon taxes and emissions trading systems (ETSs), as strategies for reducing GHG emissions. These tools are designed to internalize the external costs associated with carbon emissions, thereby creating economic incentives for businesses and consumers to shift towards cleaner alternatives. The Pigovian tax, named after Pigou, is one such approach that aims to align private costs with social costs, thereby promoting more efficient resource allocation and encouraging sustainable practices.

Despite their theoretical appeal, the implementation of carbon taxes and ETSs has sparked considerable debate regarding their effectiveness, equity, and economic impacts. Critics argue that the costs associated with these policies can disproportionately burden vulnerable populations and that the actual reductions in emissions may fall short of established targets. Conversely, proponents assert that when designed and implemented correctly, these policies can drive significant reductions in GHG emissions while fostering innovation in clean technologies.

This study aims to critically examine the effectiveness of carbon taxes and emissions trading schemes in mitigating climate change by reviewing contemporary empirical and theoretical research on these market-based instruments. By investigating their design, implementation, and outcomes, the paper seeks to provide a comprehensive understanding of how these policies can be optimized to achieve climate goals. The following sections will outline the economic theory underpinning these instruments, discuss their design considerations, evaluate their practical implementation, and analyze their effectiveness in reducing emissions and their broader economic implications. Ultimately, this research aspires to identify best practices and inform policy design that enhances global efforts to combat climate change.

The economic and environmental effects of climate change and associated policies have emerged as a significant topic of international policy discussions over recent decades. In 2015, at the United Nations (UN) Climate Change Conference (COP21), 196 parties reached a consensus on a legally binding global treaty, known as the Paris Agreement (The Paris Agreement | UNFCCC). This agreement primarily aims to limit the increase in global average temperature to well below 2°C above pre-industrial levels while striving to keep the rise to 1.5°C. However, a 2023 report by UNFCCC indicates that the world is currently not on track to meet the goals set forth in the Paris Agreement, highlighting the urgent need for additional action to reduce global greenhouse gas (GHG) emissions and achieve net-zero emissions by 2050. This shortfall is evident despite the introduction of over 70 carbon-related policies by 2024, which include 39 carbon taxes and 36 emissions trading systems (ETSs) implemented across various national and subnational jurisdictions worldwide. This situation raises critical questions about the effectiveness of these policies: Are carbon taxes and ETSs effective in curbing GHG emissions? Which of the two policies has yielded the best results? Can the effectiveness of these policies be enhanced? What are the economic implications of such policies? To address these inquiries, this study provides a thorough review of contemporary empirical and theoretical research analyzing the impact of the two primary market-based instruments—carbon taxes and ETSs—on global environmental and economic conditions.

A carbon tax is a price-control mechanism that internalizes the external costs associated with carbon emissions by imposing a direct charge on emissions. In contrast, an ETS is a quantity-control mechanism aimed at reducing carbon emissions by establishing a cap on the total allowable GHG emissions for each period. Both systems are designed to increase the relative cost of producing goods that emit GHGs compared to those that do not, thereby decreasing the incentive to produce GHG-emitting products. Although other ad valorem taxes, such as fuel or value-added taxes, may also influence the relative pricing of GHG emissions, these taxes are primarily implemented to generate government revenue rather than to reduce emissions. Consequently, few studies have attempted to quantify the environmental and economic impacts of such ad valorem taxes across different countries. This review, therefore, focuses on the effects of carbon taxes and ETSs, specifically emphasizing their role in reducing GHG emissions rather than merely increasing government revenue. By conducting a systematic literature review of empirical outcomes and theoretical insights regarding the impact of these instruments on environmental and economic conditions, this study aims to synthesize research findings in both physical and economic sciences. This work also integrates and updates existing information about the environmental impacts of carbon pricing mechanisms and their economic consequences. A key distinction from previous reviews is that this study comprehensively covers both carbon taxation and ETSs, analyzing their relative effects rather than examining a single policy tool in isolation. By doing so, we aim to identify best practices and inform policy design that can ultimately enhance global efforts to combat climate change.

The remainder of this paper is organized as follows: Section 2 outlines the economic theory underlying carbon tax and ETS policies. Section 3 discusses the design considerations for each policy. Section 4 explores the practical implementation of these policies. Section 5 assesses the effectiveness of the policies in reducing emissions and their economic impacts. Sections 6 and 7 compare carbon taxes and ETSs and discuss potential policy integration. Finally, Section 8 summarizes our conclusions and offers suggestions for future research.

II. Methods

This study utilizes three specific methods to evaluate the effectiveness of carbon taxes and emissions trading systems (ETSs) in reducing greenhouse gas (GHG) emissions:

1. **Systematic Literature Review**:
   - A systematic literature review was conducted to collect and analyze empirical studies and theoretical papers focusing on carbon taxes and ETSs. The review involved searching databases such as JSTOR, Google Scholar, and ScienceDirect for relevant articles published from 2000 to 2024.
   - The inclusion criteria prioritized peer-reviewed articles that assess the impact of these policies on GHG emissions and their economic implications. Studies were categorized based on their findings related to effectiveness, economic impact, and social equity.
   - This method allowed for the identification of trends, common themes, and gaps in existing research, enabling a comprehensive understanding of the current state of knowledge regarding carbon pricing mechanisms.
2. **Case Study Analysis**:
   - The study analyzed specific case studies from countries and regions that have implemented carbon taxes and ETSs, such as Sweden, the European Union, and California.
   - Each case study focused on the design and implementation of the policy, the context in which it was applied, and the measurable outcomes in terms of GHG emissions reductions and economic effects.
   - This method provided practical insights into the real-world application of carbon pricing mechanisms, illustrating the challenges and successes experienced in different geographical and political contexts.
3. **Comparative Policy Analysis**:

   A comparative analysis was performed to evaluate the effectiveness of carbon taxes versus ETSs. This involved assessing various dimensions, such as:
   - **Emission Reduction Targets**: Comparing the actual GHG reductions achieved by each policy type.
   - **Economic Impact**: Analyzing how each policy affects economic growth, industry competitiveness, and employment levels.
   - **Social Equity**: Evaluating the distributional impacts of these policies on different socioeconomic groups.

   This method enabled the identification of best practices and lessons learned from each policy approach, facilitating recommendations for enhancing the effectiveness of carbon pricing mechanisms.

By employing these methods, the study aims to provide a detailed analysis of how carbon taxes and emissions trading systems function in practice and their effectiveness in addressing climate change.

III. Results

In the 20th century, economist Arthur Pigou first introduced the concept of externality, which refers to costs or benefits that arise from an action but are not borne by the producer of that action. A clear example of this is climate change, where energy use and industrial processes contribute to anthropogenic climate change through greenhouse gas (GHG) emissions, representing a negative externality. In such scenarios, the marginal social cost incurred by society is significantly greater than the marginal private cost of production experienced by a firm, leading to a market failure where the optimal quantity of production exceeds the socially optimal quantity. Pigou proposed that policymakers could rectify this market failure by imposing a tax on market activities that reflects the social damage caused, known as a Pigovian tax.

Figure 1 illustrates a typical Pigouvian tax, where the private marginal benefit of consuming goods declines as the quantity demanded increases, while the private marginal cost of supplying goods rises with the quantity supplied. An efficient market achieves equilibrium when private marginal benefits equal private marginal costs, occurring at the quantity q_{market} and price p_{market} shown in the figure. However, when a good's consumption generates negative externalities—such as air pollution from fossil fuel consumption—the social marginal cost reflects the marginal external cost in addition to the private marginal cost of supply. A "social marginal cost" line represents this cumulative cost, illustrating how the externality can be internalized by imposing a tax on the purchase of the good (indicated by the line representing private marginal cost plus tax). The tax rate is set to equal the marginal external cost, aligning with the social optimum. This taxation shifts the market equilibrium to the optimal point $q_{optimum}$.

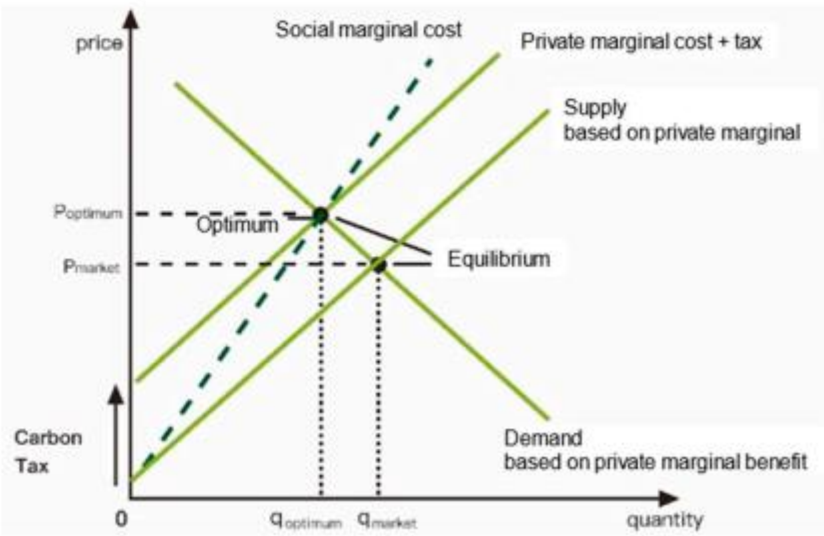

Figure 1: *Pigouvian tax*

Carbon taxes, as a first-best or optimal solution to address the negative externalities associated with anthropogenic carbon dioxide emissions, have become a preferred policy in many countries pursuing ambitious climate goals. However, these taxes face criticism. Early theoretical and practical discussions regarding the identification of social costs, as well as the costs of misallocation linked to market intervention versus maintaining the status quo, were explored by prominent 20th-century economists such as Coase, Hayek, Ostrom, and Baumol. More recently, political economy literature has associated carbon taxes with climate capitalism, while narrow, discipline-specific perspectives have led to the emergence of technocentric and economistic viewpoints.

The theoretical foundations of emissions trading systems (ETS) can be traced back to the research of Nobel Prize laureate Ronald Coase. Coase posited that when trade in externalities, such as greenhouse gas (GHG) emissions, is feasible and transaction costs are low, bargaining among parties will lead to a Pareto efficient outcome, regardless of the initial distribution of property rights. This principle, now known as the Coase Theorem, suggests that government intervention can mitigate market failures arising from negative externalities by clearly defining property rights.

As depicted in Fig. 2, when a cap on emissions is established, it imposes a hard limit on the market supply, rendering the supply curve inelastic and unresponsive to price fluctuations as seen in traditional supply-demand models. The new equilibrium is determined by the cap, resulting in a $q_{constrained}$ and an increase in the price $p_{optimum/}$

Building on these principles, Dales introduced the concept of property rights within the context of pollution control in 1968 by formalizing an Emissions Trading Program, which has since become the foundation of contemporary ETSs. Under this framework, entities granted the right to emit GHGs can do so, provided they comply with specific legal conditions. Legally, emissions rights are treated as limited-use rights associated with environmental resources, conceptualizing the environment as a tradable commodity with the government as the ultimate proprietor.

In this system, the government allocates a fixed quantity of emissions rights to firms, permitting them to emit GHGs during their production processes. Moreover, by facilitating the trading of these rights under regulatory conditions, emissions effectively become a tradable commodity. Firms facing higher marginal costs for pollution can purchase emissions rights from those with lower emission costs. Consequently, this cap-and-trade market structure fosters a Pareto-optimal allocation, minimizing total emissions costs while capping the overall volume of GHG emissions produced in the market.

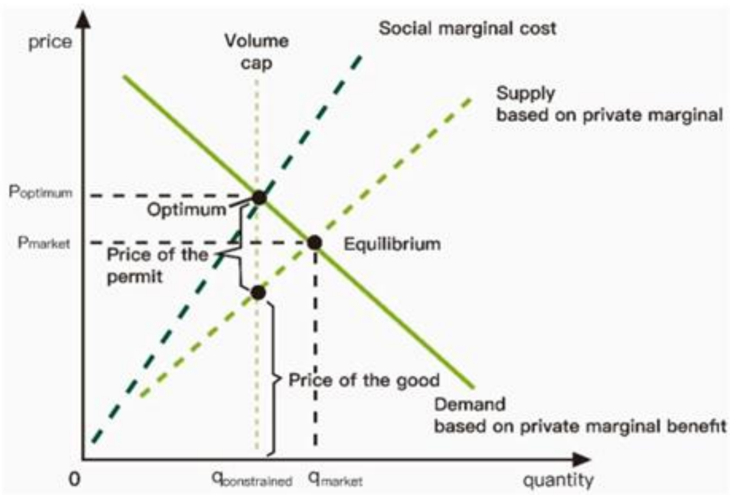

Figure 2: *Coasian model*

IV. Discussion

After determining the emissions cap, policymakers must decide how to allocate pollution permits under the emissions trading system (ETS). There are two primary allowance allocation schemes used to date: free allocation and public auction.
The main advantages of free allocation include zero transaction costs and the potential for equitable distribution of permits, resulting in low resistance to execution and ease of

implementation. This method has often been employed during the initial pilot stages of ETSs. Common approaches for permit distribution include:

- Grandfathering: Allocating permits based on historical emissions.
- Output-Based Allocation: Assigning permits according to current emissions.
- Fixed-Sector Benchmarking: A combination of historical and current emissions for allocation.

However, research indicates that grandfathering may undermine ETS efficiency due to inadequate financial support for system operation. Consequently, some studies have suggested employing formal pricing and auction methods to improve the effectiveness of carbon emissions trading.

Auctions provide several advantages over free allocation:

1. Reduced Disputes: Auctions minimize conflicts between stakeholders that can arise from free distribution, aligning with fairness and justice principles appropriate for ETSs.
2. Increased Government Revenue: By auctioning permits, governments can generate additional revenue, which can be reinvested in environmental initiatives or used to offset costs associated with the transition to a low-carbon economy.
3. Incentives for Innovation: The auction pricing mechanism encourages firms to enhance their technical capabilities and innovate towards low-emission technologies, thereby contributing to overall emissions reductions.

By considering these allocation strategies, policymakers can better design ETSs to achieve their environmental goals while promoting equity and economic efficiency.

This review indicates that many studies have arrived at similar conclusions regarding the absolute advantages and disadvantages of carbon taxes and emissions trading systems (ETSs) in terms of emissions reduction. Consequently, the current debate has shifted towards comparing the implementation of carbon taxes and ETSs, as summarized in Table 1. This shift is driven by the necessity to examine the relative benefits of each approach concerning emissions reduction, cost savings, economic efficiency, technological advancements, political acceptance, and stakeholder engagement.

Theoretical research suggests that the impacts of these two mechanisms should align when information is complete, transaction costs are negligible, and price controls are set at the intersection of the marginal costs and benefits of emissions reduction. However, in practice, information is rarely complete, and transaction costs typically exceed zero. Therefore, while both mechanisms can effectively reduce emissions, their associated costs and incentive effects logically differ.

Given the significant establishment, implementation, and administrative costs associated with ETSs, it is not surprising that carbon taxes tend to incur lower costs in these areas, making them more accessible during the initial stages of implementation. However, carbon taxes increase production costs for businesses, which can constrain profit margins and influence optimal decision-making. Firms may also pass the tax burden onto downstream producers and consumers by raising prices, potentially leading to inflation and negatively affecting overall economic conditions. Additional critiques of carbon taxes include the challenges of determining an optimal tax rate and policymakers' delays in responding to current market conditions.

Despite the benefits of carbon taxes, evidence indicates that ETSs may have a greater impact on emissions reduction and innovation incentives. Furthermore, ETSs can lower information costs and enhance the competitiveness of polluters. According to Murray et al., cap-and-trade systems are more welfare-enhancing than carbon taxes if mechanisms such as storage, banking, or borrowing of emissions rights are permitted. The ETS also clarifies overall emissions abatement goals and facilitates emissions management across international borders, making it better suited for long-term implementation. Additionally, once the total emissions allowance is established, the emissions reduction target can be more readily adjusted to align with current market conditions.

	Advantages	Disadvantages
Carbon Taxes	• Lower establishment, implementation, and administrative costs	•Higher production cost •Cause inflation and worsen the overall economic situation •Optimal tax rate is difficult to determine •Takes time for policymakers to respond to current market conditions
ETSs	•Greater emission reduction effect and incentive to innovate •Lowers information costs •Enhance the competitiveness of polluters •Cap-and-trade system is more welfare-enhancing •Better suited in the long run •More easily adjusted to current market conditions	•Larger establishment, implementation, and administrative costs •Lack price transparency

Table 1: *Comparisons between carbon taxes and ETSs.*

Nevertheless, while ETSs offer key advantages over carbon taxes, it is important to note that their establishment, implementation, and administrative costs are relatively high. Furthermore, the induced price from the carbon cap is not always transparent, which can complicate planning for firms and create uncertainty regarding overall emissions reduction costs. Even the EU ETS, one of the largest globally, has faced price volatility due to excessive quota distribution and periods of economic downturn. Therefore, it is crucial to closely monitor ETSs to ensure their effectiveness, efficiency, and sustained capacity to reduce emissions.

References

[1] Mrochko L.V., Spiridonova G.V., Kuznetsova M.I., Solovieva E.A. Ecological worldview as the basis of modern business in the ESG concept//Economic and social-humanitarian research. 2023. No. 1 (37). P. 83-92.

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] N. Dobbeling-Hildebrandt, ¨ K. Miersch, T.M. Khanna, M. Bachelet, S.B. Bruns, M. Callaghan, O. Edenhofer, C. Flachsland, P.M. Forster, M. Kalkuhl, et al., Systematic review and meta-analysis of ex-post evaluations on the effectiveness of carbon pricing, Nat. Commun. 15 (1) (2024) 4147, https://doi.org/10.1038/ s41467-024-48512-w.

[5] Santikarn M; Churie Kallhauge AN; Bozcaga MO; Sattler L; Mccormick MS; Ferran Torres A; Conway D; Mongendre L; Inclan C; Mikolajczyk S; et al.; Washington, D. C.: World Bank Group, 2021.

[6] Fröhlich M (2023) Gender issues in European economic law. In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[7] European Commission (2022a) Communication from the Commission. Guidelines on the application of the Regulation (EU, EURATOM) 2020/2092 on a general regime of conditionality for the protection of the Union budget. Brussels, 2.3.2022 C (2022) 1382 final.

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V.

Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144.

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

SOCIO-ECONOMIC AND ECOLOGICAL FACTORS IN THE PARADIGM OF SUSTAINABLE DEVELOPMENT

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Abstract

The article examines socio-economic and environmental factors in the paradigm of sustainable development of the domestic economy. Some approaches to the interpretation of the concept of "sustainable development" as a scientific definition are analyzed, a triune model of sustainable development is defined, which includes economic, social and environmental aspects. The fundamental principles of sustainable development have been identified, conceptualizing the principle of reasonable consumption and a harmonious combination of man and nature. Ways and mechanisms for solving problems and achieving sustainable development goals at the national level are proposed, which involve complex and strategic changes. The role of public policy is emphasized in order to ensure coordinated activities of government bodies and local self-government towards achieving the goals of sustainable development of the domestic economy.

Keywords: sustainable development, domestic economy, ecology, social factors, resource potential

I. Introduction

One of the most significant problems facing a modern state is the problem of sustainable development, which arose as a result of the financial, economic, social and environmental crises. Global economic transformations, fluctuations in financial markets, excessive consumption of natural resources, pollution of basic ecological systems of life-supporting importance, significant reduction in the volume of agricultural land, etc., have led to catastrophic consequences and pose a real threat to national security. The need to increase economic capacity, using outdated technologies, impoverishment of production assets; high competition, low economic awareness, etc. have led to an imbalance between economic, social and environmental social systems. As scientists emphasize, it is the quantitative factor of production without an increase in quality and rational use of potential that causes depletion of natural resources, environmental pollution, worsens the quality of life of the population, and predetermines the emergence of environmental problems in most regions of the country.

If economic extensification and inefficient environmental management continue, the country may lose its own natural resource potential and have catastrophic consequences for the lives of future generations. In this regard, the priority is the problem of sustainable development of the national economy, which is aimed at integrating the economy and ecology into an integral integrity, and provides for the preservation of economic, environmental, social and natural resource potentials to meet the needs of future generations.

Currently, the issue of sustainable development is the subject of scientific analysis in the works of both foreign and domestic researchers. Various aspects of this issue are reflected in the works of S. Bobylev [1], A.A. Voloshinskaya [5], I.S. Kokorin [4], V.M. Komarov [5], N.A.

Piskulova [7], E.S. Yankovskaya [4] and many others. Despite the great contribution of scientists, the problem requires a more in-depth and systematic analysis, not only from a theoretical but also a practical point of view.

The issues of defining the conceptual foundations of sustainable development, determining theoretical approaches to the interpretation of the concept of "sustainable development" as a scientific definition, integration and differentiation of models of sustainable development, strategies and mechanisms for ensuring it are becoming relevant. The practical direction of solving the problem focuses on the need to form new strategies for the development of the national economy in accordance with the environmental paradigm; humanistic principles and values that improve the quality of life of people and restore the resource environment; initiation of the formation of an innovative, technology-oriented resource-saving economy.

II. Methods

The purpose of this article is to study socio-economic and environmental factors in the paradigm of sustainable development of the domestic economy.

The concept of sustainable development has gained great popularity in recent decades. This is due to a number of challenges that have faced society and require immediate intervention. The environment and its resources have always been the livelihood of humanity, but anthropogenic impacts are increasingly having a negative impact on nature. As a consequence, there is an imbalance in the ecosystem, an aggravation of the environmental situation, which, in turn, affects the standard of living and well-being of the population.

The concept of sustainable development is based on the search for a balance between three aspects of human life: environmental, social and economic. However, long-term and systematic human intervention predetermines global problems, the solution of which depends not on the desire of individual subjects, but on humanity as a whole.

Therefore, in the third millennium, discussions are actively underway to integrate representatives of all countries into decision-making and the formation of a common strategy to overcome pressing problems. The implementation of the concept of sustainable development is impossible without awareness of the personal role and importance of everyone. An important factor is public support and its influence on political decisions.

The theoretical analysis of the problem showed that the definition of the concept of "sustainable development" has an extensive system of interpretations. The concept of "sustainable development" was first proposed by the World Commission on Environment and Development in 1987. Since then, the category of "sustainable development" has undergone significant progressive changes and has acquired even greater relevance. The need for its comprehensive analysis is determined by the following reasons: the rate of resource consumption exceeds the rate of their restoration; the rate of consumption of updated resources exceeds the rate of their timely restoration; the scale of emissions of pollutants exceeds the ability of the environment to absorb and neutralize them.

Note that the translation of the concept of "sustainable development" is not entirely correct, since the concepts of "development" and "consistency" to a certain extent negate each other. Equilibrium defines the static state of the system, which is achieved by the influence of various oppositely directed forces that cancel each other out. Since any unbalanced state of the system is undesirable, the main task of modern research is to identify destabilizing socio-economic factors and ways to restore balance. Even in dynamic systems, states of disequilibrium alternate with their long-term states of equilibrium.

Domestic researchers of the concept of sustainable development consider it undesirable to transfer its ideology to the national economy, which requires growth, not balance. Indeed, if sustainable development is the balanced development of socio-economic and environmental systems, then economic growth based on highly industrial development will invariably be accompanied by the exploitation of natural resources, which exhaust their potential every year. With this approach, "sustainable development" is based on mutually exclusive provisions that make the problem of economic growth unresolved.

III. Results

Real positive changes are possible when the following strategic priorities of state policy are achieved, with people at the center:

– development of intellectual potential and implementation of an innovative model of economic growth in order to strengthen scientific and technological potential capable of ensuring high-tech production and creating a new strategic product - knowledge and information;

– improving the state's social policy, in particular in the area of increasing labor costs, which will contribute to the high-quality reproduction of human capital and the growth of the country's competitiveness;

– strengthening the decentralization of the economy in order to implement effective socio-economic reforms while minimizing environmental risks.

At the moment, the interpretation of the concept of "sustainable development" is ramified and covers the categories of economic growth, quality of life, environmental protection, solving environmental and humanitarian problems, rational use of resources, etc. Scientists are trying to illuminate the phenomenon of sustainable development in a structurally balanced form, taking into account its social (meeting the material and cultural needs of society), environmental (preservation of the environment) and economic (economic and technological development) components [7].

The generality of approaches gives grounds to understand sustainable development as a positive continuous process of movement that meets the needs of the population at the present time and does not jeopardize the ability of future generations to meet their own needs while preserving the environment. Attribution of the stability of these components presupposes not only the immutability of the main parameters, but also the ability to maintain and grow, reveals the ability to be in a state of dynamic equilibrium, despite the negative influence of various, both external and internal factors. Sustainable economic development in [5] is understood as such development of countries, regions, and societies, during which economic growth occurs with the possibility of restoring ecosystems to support the livelihoods of present and future generations.

Sustainable development primarily involves:

1) Improving the quality of life of people within the limits of economic activity that does not lead to the destruction of the natural mechanism for regulating the human environment and its global changes;

2) Adaptability, flexibility, efficiency of the national economy to meet global challenges; return the economic system to a dynamic and productive state;

3) The ability to quickly recover from shocks.

Sustainable development minimizes the risks of sharp fluctuations in socio-economic processes; ensures the duration of maintaining a certain level of parameters of economic systems; efficiency of production facilities.

IV. Discussion

Sustainable development should be based on two fundamental principles – anthropocentric and biospherocentric [1]. The anthropocentric principle in a broad sense refers to the idea of not only the biological survival of humanity, but, first of all, its harmonious development; search for alternative ways of relationships between man and society. Issues of morality, ethics, preservation of human freedoms, the rule of law and social justice, the priority of spiritual development are significant; scientific integration of worldview; reducing social tension; the inadmissibility of violence and aggression towards others. At the center of the anthropocentric paradigm is man, as a subject of independent, free choice and responsible action, striving for self-development and perfection in the natural environment. In this plane, the priority is the role of "Homo sapiens", as a creature of rational consumption of goods, in contrast to "Homo consumens", who thoughtlessly uses everything that nature has created to satisfy his needs.

The biosphere-centric principle means preserving the biosphere as the natural basis of life on the planet, providing conditions for its sustainability and evolutionary development. It provides for the protection of biodiversity, the absence of ecophobia, the implementation of the ecological foundations of life, etc. Biospherecentrism orients society toward the rational use of natural reserves and the achievement of a harmonious connection between man and the environment.

Summarizing conceptual approaches, it should be noted that the most comprehensive concept is one in which sustainable development is considered as a process aimed at ensuring a high quality of life through achieving balanced socio-economic and environmental development, carried out on the basis of rational use of all resource potential. In this context, the most justified is the ecological-economic concept, in which sustainable development is considered as the integration of two factors: the process of capitalization due to the production of economic goods and the process of preserving living conditions, restoration and conservation of natural resources. We should also mention the scientific works of such scientists as V.I. Danilov-Danilyan [2], M.N. Ignatieva [3], K.S. Losev [2], P.G. Oldak [6], N.F. Reimers [8], where the emphasis is on the ability of natural potential to be restored and preserved by strictly limiting the irrational use of resources and solving environmental problems. IN AND. Danilov-Danilyan, K.S. Losev [2] argue that sustainable development is the ability of a system to achieve its goals, despite the destabilizing influence of the internal and external environment through the use of socio-economic and environmental resources [2]. Moreover, scientists propose a solution to the environmental context of sustainable development through the consistent implementation of technological systems, innovative management solutions that allow increasing the efficiency of the economy and the use of natural resources while simultaneously maintaining or improving the quality of life in general.

Within the framework of the triune approach, the sustainable development of the national economy is considered as a complex integration of the following interacting factors: environmental, social and economic [4].

The economic factor, first of all, presupposes the stable, continuous and efficient functioning of the economy, the presence of a set of markets, goods and services, capital, securities, real estate, labor, etc.; competitive environment and antimonopoly legislation; sustainable GDP growth, increase in assets, capitalization of the economy; favorable investment climate; activation of production, increasing production potential, effective economic structure, etc. [4; 5; 7]. Sustainable economic development is expressed in the following indicators:

– volumes of inflow and outflow of foreign investment;
– volumes of gross fixed capital formation;
– growth of GDP per capita;
– increase in the cost of living;
– cost of fixed assets;
– level of depreciation of fixed production assets;
– increase in the average monthly salary of employees;
– creating a more competitive economy.

Thus, sustainable socio-economic development means realizing a high-efficiency, low-wage economy; its indicators should be used in long-term planning, forecasting and assessing the efficiency of national production.

The social aspect of sustainable development of the national economy shows the need to resolve issues of a humanitarian nature: overcoming unemployment, poverty; housing provision; free access to quality education and medicine; creating conditions to improve the demographic situation; care for health and well-being, increasing life expectancy; addressing issues of gender inequality, exploitation and discrimination, partnerships and peace; infrastructure development, etc. [1]. Its main indicators are: duration and quality of life; state of human health; the level of education; income level; employment level; degree of realization of human rights.

The environmental direction of sustainable development is to minimize the negative consequences of natural resource depletion and environmental pollution for subsequent generations; conservation and reproduction of the environment; climate change mitigation; conservation of marine resources; protection of terrestrial ecosystems; consumption of high-quality drinking water and food; introduction of the "green economy" [4]. This group of controlled parameters includes such indicators as the quality of the atmosphere, water, areas in a natural and modified state, forests, subject to taking into account their degree of preservation, the number of biological species under threat of extinction, etc.

Effective solution to the problems of social, economic and environmental development lies in supporting:

– efficient allocation of resources;

– stable positive economic dynamics, in accordance with the ecological system of life support;

– fair distribution of natural resources not only in current conditions, but also with a forecast for the future;

– rational use of limited natural resources;

– application of environmental resource-saving technologies;

– processing and destruction of waste;

– maintaining the sustainability of existing social and cultural systems;

– reduction of interethnic and intercultural conflicts;

– fair distribution of resources and opportunities among the entire population of the planet;

– solving problems of a humanitarian nature.

Thus, the optimal implementation of tasks and achievement of sustainable development goals at the national level involves complex and strategic changes, namely:

1) Gradual restoration of ecosystems to a level that ensures the sustainability of the natural environment to meet vital needs;

2) Effective self-organization of social, environmental and economic systems;

3) Biosphere compatibility in a situation of reduced level of anthropogenic pressure on nature;

4) Economic efficiency in conditions of acceptable environmental organization of economic activity.

To do this, it is necessary to make changes to the processes of planning, modernization and monitoring of national economic development indicators, to ensure government funding for sustainable development, and to improve the system for implementing regulatory and evaluation mechanisms. The implementation of the concept of sustainable development can only be achieved if the efforts of the entire world community are united, but each state must begin to move towards this goal independently.

The concept of sustainable development can be considered the dominant development strategy for society in the third millennium, since it depicts ways to solve global problems of humanity that relate to economic, social and environmental components.

In its evolution, the concept changed with a change in the main emphasis on its interpretation, the interaction of its main components, and the understanding of the interaction between man and the environment improved. However, the most important goal that society must achieve is that it cannot develop beyond the capabilities of the ecosystem, because such behavior threatens the well-being of existing and future generations. Since achieving this goal is global in nature, it requires the involvement of a wide range of stakeholders.

Sustainable development of the national economy presupposes the formation of a balanced connection in the "man-nature" system, functioning under the condition of achieving a high standard of living of the population, an effective, prosperous economy and conserved resources. Achieving the goal of sustainable development of the national economy is complex and depends on a large number of mechanisms, conditions and factors. The issue of government regulation is of fundamental importance here. Concepts and strategies for sustainable development of the Russian Federation must be supported by relevant regulatory documents, legislative acts and programs for the socio-economic development of the country, in order to ensure coordinated activities of state authorities and local governments towards achieving the goals of sustainable development of the domestic economy.

References

[1] Bobylev S. Sustainable development: a paradigm for the future // World Economy and International Relations, – 2017, – No. 3, p. – 107–113

[2] Danilov-Danilyan V.I., Losev K.S. Economic challenge and sustainable development. – M.: Progress-Tradition, 2000. – 416 p.

[3] Ignatieva M.N. Basic provisions of the geo-eco-socio-economic approach to the development of natural resources // Izv. USGU. – 2014. – No. 3 (35). – P. 74–80.

[4] Kokorin I.S., Yankovskaya E.S. Regulatory and legal framework for managing the sustainable development of Russian companies: statistical analysis, goals, mechanisms // Leningrad Law Journal. – 2023. – No. 2 (72). – pp. 202–221

[5] Komarov V.M., Voloshinskaya A.A. National strategies for sustainable development: comparative analysis // ECO. – 2021. – No. 1. – P. 112-129

[6] Oldak P.G. Equilibrium nature management. An economist's view. – Novosibirsk: Nauka, 1983. – 128 p.

[7] Piskulova N.A. Challenges forecological restructuring of the world economy // Russian Council on International Affairs. –2019.–URL: https://russiancouncil.ru/analytics-and-comments/analytics/vyzovy-dlya-ekologicheskoy-perestroyki-mirovoy-ekonomiki/

[8] Reimers N. F. Columns of the Temple of Nature // Nature and Man. – 1995. – No. 6. – P. 31–33.

EXTREME DESIGN STORMS FOR FLOATING NUCLEAR POWER PLANT PROJECTS

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Abstract

The overflow of waves over the crest of the protective structures of the port of refuge of a floating nuclear power plant creates a threat of accident risks. The design of hydraulic structures of floating nuclear power plants requires the determination of design storms with a frequency of up to 1 time in 10000 years: overflows, force loads, etc. This is an unconventional task for marine hydraulic engineering. The methodology and results are shown in relation to the design of the PEVEK floating nuclear power plant (FNPP) port in the Chaun Bay of the East Siberian Sea. To calculate the probability of waves of rare recurrence up to 1 time in 10000 years, the method of annual maxima applied to storms for the thirty-year period 1991–2021 is used, the distribution of peak values in which is approximated using GEV (in the form of a Weibull distribution). Maps of possible large wind waves of recurrence once every 5, 10, 25, 50, 100, 1000, 10000 years on the approach to the port were obtained. To calculate the characteristics of waves in the East Siberian and Chukchi Seas, up to the deep-water boundary of the FNPP water area, the SWAN model was used, the wind fields for the calculation of which are based on the data of the NCEP/NCAR reanalysis of wind fields in the period from 1991 to 2021. To construct extreme wave fields of various recurrence, the maximum values of wave heights for each year were selected at 993 points of the nodes of the rectangular grid with a cell size of 22 m for the FNPP water area. Thus, a numerical model of wave generation and transformation has been developed based on the adaptation of the SWAN model on an unstructured grid covering the East Siberian Sea design area. The mesh cells thicken towards the FNPP water area, decreasing in this region to a characteristic size, about 2.5 m. To calculate extreme wind-wave fields over a 30-year period, 37 storm scenarios were selected. Those periods of extreme winds from July to September were selected, in which the average wind speed in the area of the Chaunskaya Bay exceeded 10 m/s. Wave fields were obtained for all these storms in the FNPP region, the statistical processing of which made it possible to obtain wave fields of significant (13% in the storm system) waves with a frequency of 5, 10, 25, 50, 100, 1000 and 10000 years. At about 300 m from the shore, the height of significant waves of this frequency will vary in the range from 1.3 m to 3.4 m. Wave heights of 50%, 5%, 1%, 0.1% of the probability in the storm system in the same area were calculated. For waves of 1% probability with recurrence once in a hundred years, the height of the waves reaches 3.1 m, once in 1000 years - 4 m, once in 10000 years - 4.5 m.

Keywords: storm, nuclear power plant, overflow, accident risks

I. Introduction

The site for the construction of onshore and hydraulic structures for the operation of the floating nuclear power plant based on the floating power unit of project 20870, is located one kilometer northeast of Pevek.

In the available materials of hydrometeorological surveys, it is noted that in the water area of the port of Pevek, in the area of the berths, with the winds of the north-eastern quarter, the maximum wave height can be 1.8 m.

The purpose of the research is to ensure the selection of a rational layout and designs of hydraulic structures designed for a floating nuclear power plant in Pevek, Chukotka region.

Figure 1: *Overview map of the East Siberian Sea and the Chukchi Sea with the location of the city of Pevek*

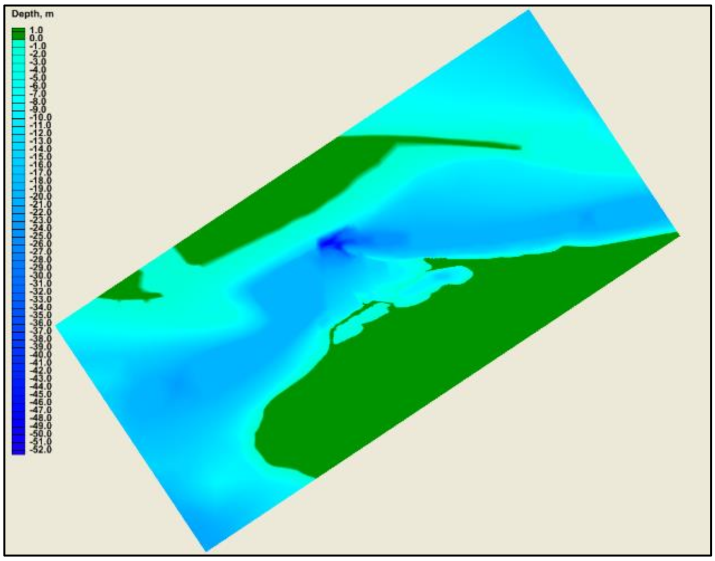

Figure 2: *Distribution of depths in the Pevek Strait, constructed from a digital map supplemented by digitization of the depth map*

In accordance with the work plan, the research includes the following works:

1. Analysis, evaluation and generalization of source materials, including:
   - fund materials and observational data obtained as a result of engineering surveys;
   - factors that cause hydrodynamic and thermohaline processes;
   - typification of ice conditions of the Chaunskaya Bay.
2. Analysis of options for the layout of hydraulic structures with recommendations for choosing the final option for the location of the station.
3. Assessments of lithodynamic processes in the area of the station location to justify dredging operations.
4. Mathematical modelling of lithodynamic processes in the area of the station location to substantiate dredging operations.

5. Modeling of wave, current and ice fields (including under conditions of a combination of unfavorable hydrodynamic factors of rare recurrence - waves, currents, fluctuations in sea level and ice) to determine the layout of hydraulic structures that provide minimum loads from waves, currents and ice, namely:

- mathematical modelling and calculation of wave and wind fields in the water area, including the places of potential location of the hydroelectric station (calculations should be carried out using modern methods for the provision of loads once in 10000 years, taking into account the change in sea level according to global estimates due to climate change, as well as tidal and surge currents);
- mathematical modelling in 2D format and calculation of current fields in the water area, including the locations of the potential location of the station gas station (calculations should be carried out using modern methods for the provision of loads once in 10000 years, taking into account the change in sea level according to global estimates due to climate change, as well as tidal and surge currents);
- Mathematical modelling and calculation of the dynamics of ice fields in the water area under storm conditions, for the areas of potential location of the gas station. The calculation should be carried out taking into account the typification of possible ice impacts on hydraulic structures in the Chaunskaya Bay, including loads from a moving hummocky ice field, in particular an "ice storm", from a continuous ice field when it expands, loads from ice jammers.

Next, we will consider the method adopted in this work for determining extreme design waves with a probability of up to 1 time in 10000 years.

II. Methods

The following methods and models were used for numerical modeling of waves in the studied water area. COASTOX-MORHO is a software system designed to solve two-dimensional equations of wave propagation, current formation, sediment transport, bottom and shore erosion based on high-performance numerical algorithms. COASTOX uses finite volume methods on unstructured grids, parallelization algorithms for calculations on multiprocessor and/or multi-core systems. The system can be used for calculations on personal computers and multiprocessor clusters, additional modules of the system allow you to calculate the transfer of pollutants (toxic elements and radionuclides) in rivers and the coastal zone of the sea.

In the last decades, the spectral model of the Technical University of Delft (Denmark) SWAN [1], distributed in open code, has become a generally accepted tool in the world practice of coastal engineering for calculating the transformation of wind waves from deep water to the coastal zone.

The HWAVE-S model [2] is a semi-spectral version of the HWAVE monochromatic model. Models of this class are based on the assumption that irregular wind waves are represented as a linear superposition of an infinite number of harmonic waves propagating independently of each other. Such models also include the REF/DIF-S [3] and ARTEMIS models [4]. HWAVE-S allows you to simulate the refraction-diffraction transformation of the wind wave spectrum near structures.

In the implementation of projects for scientific and technical support of engineering projects, both the above models and open-source models are used - the WRF meteorological model, the VERY oceanographic model, the Wave Watch spectral model of the formation and transformation of wind wave fields.

According to the existing technology of mathematical modeling, in the tasks of marine hydraulic engineering and hydraulics (design of hydraulic structures of ports and shore protection structures), the following main stages are distinguished:

1. Calculation of climatic characteristics of wind waves at specified points on the approach to the object under study (port, coastal area) on the basis of spectral models of wind waves from wind fields over the sea for a long-term (30 - 50 years) period (using meteorological element fields from the reanalysis of NCEP\NCAR or ERA-40 meteorological fields, with their possible downscaling (dynamic interpolation) using numerical weather forecast models.

2. Calculation of the wave regime of a coastal zone or enclosed sea area based on mild slope equations (in elliptical, parabolic or hyperbolic approximation) or nonlinear dispersion equations of the Boussinesque type.

3. Calculation of coastal currents generated by the combined influence of wind, waves and sea tides, taking into account the possible reverse influence of currents on the transformation of waves.

4. Calculation of sediment transport in the coastal zone and reformation of the bottom and banks.

In modern practice, three methods of statistical analysis of extreme values of oceanographic (hydrometeorological) parameters are used, based on approaches developed in the modern theory of statistics of extreme values [5-9]. These approaches are considered using the example of extreme wind wave statistics, taking into account that the same approaches are applicable to statistics of extreme values of current velocities and other hydrometeorological characteristics.

III. Results

I. Technologies for Mathematical Modeling of Wind Wave Fields in the Water Area of the FNPP Location

To calculate the characteristics of waves in the East Siberian and Chukchi Seas, up to the deep-water boundary of the FNPP water area, the following will be used: the SWAN model, for the calculation of which wind fields are used, the data of the NCEP/NCAR reanalysis of wind fields in the period from 1991 to 2021 are used, with the involvement of data refined from satellite observations and wave measurements in the region for adjustments.

NCEP/NCAR reanalysis is a project of the National Centers for Environmental Prediction (NCEP) of the US Hydrometeorological Service (NOAA) and the US National Center for Atmospheric Research (NCAR) to restore meteorological element fields over the past 40 years around the globe, using instrumental observations and modeling results [10], http://www.cpc.ncep.noaa.gov/products/wesley/reanalysis.html, http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml).

As the main source of meteorological data after 1999, the final analysis (http://dss.ucar.edu/datasets/ds083.2/) meteorological fields were used, which were used to initialize global weather forecast models of the US National Center for Environmental Forecasting (NCEP). These fields are calculated by the Global Data Assimilation System (GDAS, http://www.emc.ncep.noaa.gov/gmb/gdas/).

An important circumstance in favor of the choice of these data was their relatively high resolution (1 degree compared to the resolution of 2.5 degrees of the NCEP and ERA-40 reanalysis data) and the fact that, in addition to standard observations, these data assimilate a variety of satellite measurements, including propulsion wind measurements made using the SSM/I microwave radiometer [11], as well as other measurements. produced from NOAA satellites (using AMSU, HIRS instruments) and GOES geostationary satellites. These data were not used in the calculations of the NCEP R2 and R1 re-analyses, so it is preferable to use the data of the final analysis. Data from the final analysis have been available since 1998. For earlier periods (from 1990), NCEP reanalysis data 2 [12] were used, which cover the entire required period.

In addition, downscaling (dynamic interpolation) of wind data from NCEP reanalysis for several of the strongest storms for the FNPP region was carried out by the WRF meteorological regional model, with a grid resolution of up to 1*1 km to assess the significance of such downscaling for the accuracy of calculating wave characteristics on the approach to the FNPP water area. In the event that downscaling shows a significant effect of grid thickening on the calculation accuracy for wind speed, such calculations will be performed for all selected storms for the calculation period.

The results of the SWAN model calculations will be used as boundary conditions for the HWAVE–S model, a half-spectral model that, based on the equations of gentle slopes, allows you to successfully describe the diffraction effects and the effects of wave reflection from the protective structures, which is especially important for the area adjacent to the FNPP barrier breakwaters.

Taking into account the ROT methodology, at least 30 of the strongest storms will be selected over the specified 20-year period and the distribution of peak values in the resulting sample is approximated using GEV and GPD distributions. At the same time, as an estimated value of wave height for each control point near structures, the highest of the probability values of 1 time in 10000 years, calculated by these two methods, will be recommended. In addition, similar calculations will be made for the 21st century maximum possible storm scenarios, taking into account adjustments for changes in sea level and wind speed, in line with existing studies of climate global change.

Such a methodology is adopted on the basis that the requirements for the design characteristics of extreme wave parameters once every 10000 years do not mean that it is necessary to consider not the period of 10000 years of continuous operation of the floating nuclear power plant, but only the risks of the implementation of such an extreme phenomenon as storm waves of probability once every 10000 years during the 21st century, which justifies the use of climate change scenarios in the 21st century to calculate such availability.

II. Computational Grids of the Wind Wave Model in the Water Area of the FNPP Location

Wind field calculations were carried out on an unstructured grid covering the East Siberian Sea from 150° to 178° E. longitude and to the north to 80° S. latitude (Fig. 3). The number of computational mesh nodes is 94143, the number of elements is 185910. The linear size of the elements in the FNPP water area is about 2.5 m.

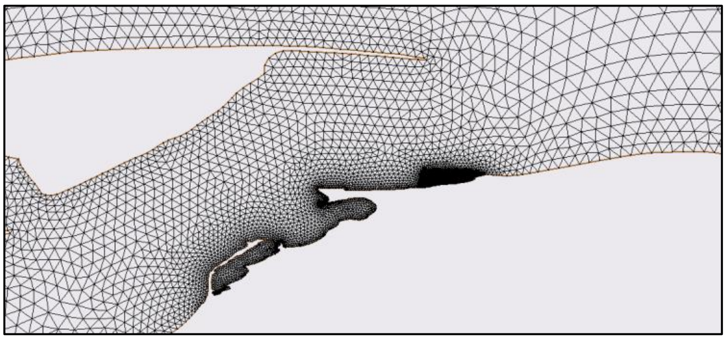

Figure 3: *A fragment of the grid for calculating wind waves in Pevek area.*

To construct extreme wave fields of various recurrence, the maximum values of wave heights for each year were selected at 993 points of the nodes of the rectangular grid with a cell size of 22 m for the FNPP water area. For each point of the grid, Weibull distribution parameters were obtained, from which the values of the heights of waves of rare repeatability were calculated. Maps of possible large wind waves of recurrence once in 10000 years are given in Fig. 4 (the map is built in the metric coordinate system). The dots show the location of the proposed wave protection moles of the floating nuclear power plant.

For greater clarity of the values of the heights of waves of rare recurrence, the values at the cross-section points (Fig. 5) located at a distance of about 300 m from the shoreline on the isobath were interpolated from the above fields.

Graphs of the heights of significant (13% certainty) waves along this section for waves of different recurrence (YRP - years return period) are presented in Fig. 6.

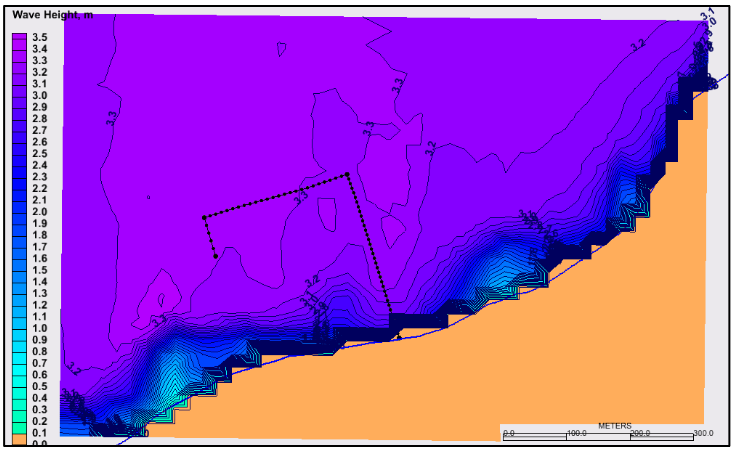

Figure 4: *Heights of significant waves, possible once in 10000 years*

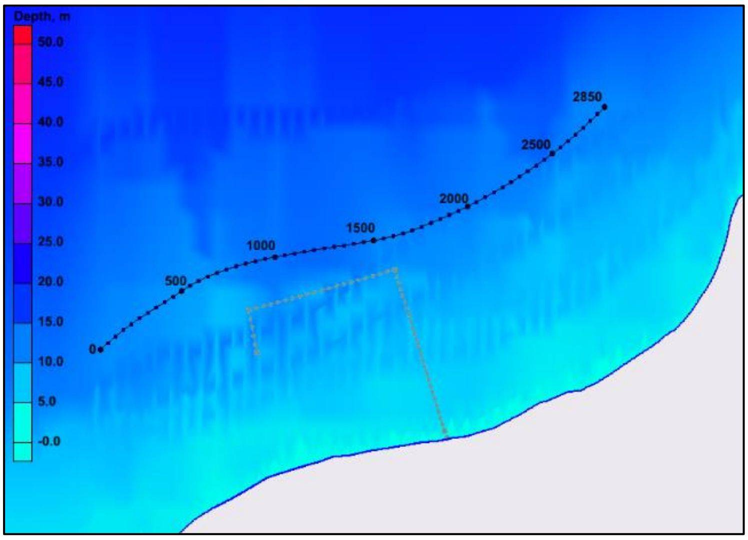

Figure 5: *Line of issuing points, 300 m from the shoreline*

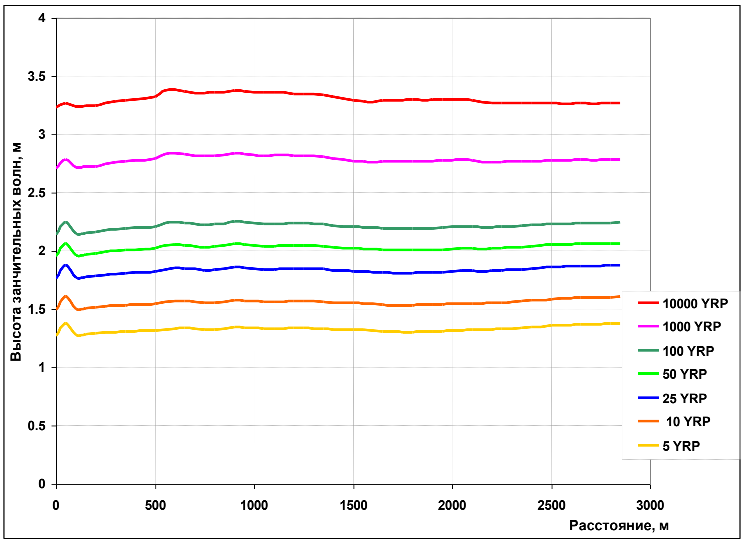

Figure 6: *Heights of significant waves of rare repeatability along a cross-section*

Wave heights of 50%, 5%, 1%, 0.1% of probability (availability in the storm system) were calculated according to Glukhovsky's formula [13] for waves of rare recurrence:

$$\frac{h}{\bar{h}} = \left[-\frac{4}{\pi}(1 + 0{,}4h^*)\ln F_h \right]^{\frac{1-h^*}{2}} \qquad (1)$$

where h is the height of the waves of a given position, $h^* = \bar{h}/D$, F_h is the security of the wave height (fractions of one), D is the actual depth of the place (m).

The average wave height ($\bar{h}$) was calculated iteratively using formula (1) from the height of significant or 13% of the waves.

IV. Discussion

To calculate the availability of waves of rare recurrence up to 1 time in 10000 years, the POT method was used, applied to storms for the twenty-year period 2000 - 2021, the distribution of peak values in which is approximated by GEV and GPD distributions with the selection of the highest values from those calculated by these two methods. The generally accepted methodology for calculating oceanographic parameters in the context of climate change is based on the use of projections - scenarios of global meteorological processes in the 21st century, recommended by the UN International Commission on Climate Change (IPCC), followed by the calculation of global oceanological models of sea level change. The results of such calculations regarding the global change in wind fields and sea level were used to adjust the calculations of wave heights, current velocities and erosion intensity in the FNPP area.

For all types of modeling, initial data files were prepared, including bathymetry of the site with grids thickening to the construction site. This made it possible to simulate the fields of external factors in the design area on grids with dimensions up to 2.50 m in the plan. In addition, the necessary hydrometeorological information was collected as initial information for modeling. Survey materials, information from international hydrometeorological databases available on the Internet, as well as direct requests to Roshydromet organizations were used as sources of information. Thus, the models used are "tuned" for the conditions of the FNPP design site and can be used in the future.

Modeling was carried out for specific conditions, the modeling results were compared with the available observational data and measurements of the relevant parameters: current velocity, ice thickness. Comparisons show that the models can be successfully used to determine the design characteristics of the external load on the plant's hydraulic structures.

Wind field analysis in the region, conducted using the wind field from 2000 to 2021 from NCEP/NCAR Reanalysis-2. It should be noted that the atmospheric pressure obtained from the results of Reanalysis-2 at the installation point of the weather station, at the FNPP onshore site, in July-August 2021, is in good agreement with the measurement data. The dynamics of the change in wind speed at this point corresponds to the measured one, with a slight excess of the speed in the peaks of the storm wind from Reanalysis-2 over the measurement data in the specified period.

A numerical model of wave generation and transformation has been developed based on the adaptation of the SWAN model on an unstructured grid covering the East Siberian Sea from 150° to 178° E. longitude and to the north to 80° S. Latitude. The grid cells condense to the FNPP water area, decreasing in this region to a characteristic size: about 2.5 m. 37 storm scenarios were selected to calculate extreme wind-wave fields for the 30-year period from 1991 to 2021. Those periods of extreme winds from July to September were selected, in which the average wind speed in the area of the Chaun Bay exceeded 10 m/s. Wave fields were obtained for all these storms in the FNPP region, the statistical processing of which made it possible to obtain wave fields of significant (13% in the storm system) waves with a frequency of 5, 10, 25, 50, 100, 1000 and 10000 years. At a distance of about 300 m from the shore, the height of significant waves of this frequency will vary in the range from 1.3 m to 3.4 m. Wave heights of 50%, 5%, 1%, 0.1% of the probability in the storm system in the same area were calculated. For waves of 1% probability with a recurrence of once in a hundred years, the height of the waves reaches 3.1 m, once in 1000 years - 4 m, once in 10000 years - 4.5 m. At the same time, at the 10 m isobath in the FNPP water area, the maximum height of significant (13%) waves did not exceed 2 m over the analyzed 30-year period.

The periods of waves with recurrence from 5 to 100 years, with the probability in the storm system from 50% to 0.1% in the water area of the floating nuclear power plant, vary in the range of 4.4 - 6.5 seconds, and for waves with a recurrence of once every 10000 years, the periods reach 7.8 seconds. It should be noted that the simulation results for waves with a recurrence of once in a hundred years do not contradict the data given in the Terms of Reference for Design Surveys, according to which "on the approach to the port of Pevek" 1% of the wave has a height in the range of 3 m - 5 m and a period of 6.9 seconds.

The wave height fields in the design area are quite heterogeneous, it is advisable to take this fact into account when choosing the location of the berth. The height of waves in a storm with a recurrence of 1 time in 10000 years with a probability of 1% is about 5 m.

To calculate the load from waves on the hydraulic structures of the station, it is recommended to take at the approach to the structure, at a water depth of 10 m, the height of waves in a regime storm with a recurrence of once every 10000 years, a probability in the storm system of 1% - 4.6 m, a probability of 0.1% - 5.4 m, an average wave period of 6.91 s, the direction of the waves - N-SW. If necessary, the period of waves of 1% probability – 7.81 s, and the period of waves of 0.1% – 7.94 s, with a recurrence of 1 time in 10,000 years, can be used for calculations.

Similar wave modes are recommended to be adopted in physical modeling of the stability of hydraulic structures to the wave load.

References

[1] Holthuijsen, L. H. (2007) Waves in oceanic and coastal waters. Cambridge University Press.

[2] Demchenko, R., Kolomiets, P. and Sorokin M. (2010) Modeling wave transformation in the coastal zone of the shelf using the HWAVE-S half-spectral model. Mathematical and imitational modeling of systems. MODS 2010.

[3] Kirby, J.T. and Ozkan, H.T. (1994) Combined Refraction/Diffraction Model for Spectral Wave Conditions REF/DIF S, Version 1.1. Documentation and User's Manual, Research Report No. CACR-94-04, Center for Applied Coastal Research, Department of Civil Engineering, University of Delaware, Newark.

[4] Kuang, C. and Stansby, P. (2006) Sandbanks for coastal protection implications of sea - level rise/ Part 3: wave modeling. Tyndal Centre for Climate Change Research, Working Paper 88

[5] Coles, S. (2001) An introduction to statistical modeling of extreme values. Springer-Verlag.

[6] Ghil, M., Yiou, P., Hallegatte, S., Malamud, B. D., Naveau, P., Soloviev, A., Friederichs, P., Keilis-Borok, V., Kondrashov, D., Kossobokov, V., Mestre, O., Nicolis, C., Rust, H. W., Shebalin, P., Vrac, M., Witt, A., and Zaliapin, I. (2011) // *Extreme events: dynamics, statistics and prediction, Nonlin. Processes Geophys.*, 18, 295–350, doi:10.5194/npg-18-295-2011.

[7] Pisarenko, V.F., Bolgov, M.V., Osipova, N.V., Rukavishnikova, T.A. (2002) Application of the Theory of Extremal Events in Problems of Approximation of Probability Distributions of Maximum Water Discharges. // *Waters resources*. 29, 6, 645-657.

[8] Pisarenko, V.F. and Rodkin, M.V. (2007) Distributions with heavy tails: applications to the analysis of catastrophes. Moscow: GEOS. (// *Computational Seismology*, issue 38).

[9] Pranov, B.M. (2010) On the Application of Extreme Statistics in the Problems of Technosphere Safety. // *Technosphere Safety Technologies* (http://ipb.mos.ru/ttb) 6 (34) – December 2010.

[10] Kalnay, E. and Kanamitsu, M. et al. (1996) The NCEP/NCAR 40-year reanalysis project. // *Bull. Amer. Meteor. Soc.* 77.

[11] Okamoto, K. and Derber, J. (2005) Assimilation of SSM/I radiances in the NCEP global data assimilation system. International TOVS Study Conference ITSC-XIV Beijing, China.

[12] Kanamitsu, M., et.al. (2002). NCEP-DOE AMIP-II Reanalysis (R-2). *Bulletin of the American Meteorological Society*. 11, 1631-1643.

[13] Glukhovsky, B.Kh. (1966) Study of marine wind waves. Leningrad: Gidrometeoizdat.

SMALL BUSINESS AND GREEN ECONOMY: POINTS OF INTERACTION

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Abstract

The article is devoted to the role and importance of small business in the modern world and its contribution to the development of green economy. It is noted that serious attention in economically developed countries is paid to the development of small enterprises as one of the most important sectors of the economy, which plays an important role in the socio-economic development of the country. The economic advantages of small business are considered, which include: lower cost in creating jobs; high internal mobility in changing demand using local resources inefficient for large-scale production; high profitability of activities in "narrow" segments of the market, small capital in organizing business, etc. It is determined that for all countries the financial infrastructure of small business is the most important component of the economic system. The processes of revival and development of entrepreneurship in Russia with the beginning of market reforms of the late XX century have been studied. It is established that the sustainable development of business structures, including those belonging to small business, is impossible without taking into account the trends of "green" economy, since the satisfaction of consumers today should not infringe on the interests and needs of future generations.

Keywords: entrepreneurship, middle class, small business, market transformation, post-industrial era, green economy

I. Introduction

Entrepreneurial activity in the modern economy represents the main source of increasing the material well-being of the population. In all countries, the financial infrastructure of small and medium-sized businesses is accepted to be considered as the most important part of the national economy. [1] In this regard, the authorities of many states in every possible way promote the development of small business enterprises, which, in turn, leads to employment growth. In the process of managing the development of territories, the activity of entrepreneurial structures is currently taken into account. At the same time, an important factor at the local level for municipalities is the activity of entrepreneurial structures classified as small businesses.

II. Methods

Within the framework of the Second International Scientific and Practical Conference on the problems of financing and crediting of the small and medium business sector in Russia, the necessity of accelerating the process of creating a domestic socially oriented financial structure of small and medium-sized entrepreneurship in the country was determined.

Toreev V.B. and Voronovskaya O.E. believe that the domestic banking sector is more focused on servicing large businesses, thus significantly increasing the costs of lending to small companies and leading to an increase in interest rates on loans.

Aleksandrov A.L. and others note that the formation of market relations in Russia has led to significant changes in the standard of living of the Russian population and set new tasks for state institutions in the field of economic welfare.

Ivanovskaya M.A. and Glukhova Z.V. in their work consider the processes of the impact of scientific and technological progress, globalization and internationalization processes on the environment, the state and exploitation of natural resources to ensure the life activity of modern society.

Basareva V.G. reveals the relationship between the level of development of small enterprises and the level of decline in industrial production. According to the author, the confirmation of the hypothesis of mutual influence of these processes in the period of transformational decline helps to adjust selective measures of state support of small business and increase their effectiveness in the crisis.

Vanyukov D.A., studying the history of the USSR of the period of developed socialism, called the era of "stagnation", believes that despite this name, this time was as significant for the country as Stalin's construction and Gorbachev's perestroika.

Muravyev A.I. and others in their work consider the processes of formation, development and prospects of entrepreneurship in Russia and abroad, investigate the most important aspects of economic management, such as financial and personnel management, securities transactions, innovation activity, marketing, etc.

Schumpeter E.A. pays great attention to the development of the technique of economic analysis, also studying the historical context of this development, the evolution of other social sciences and social thought in general, the formation of economists as a scientific community.

One of the important features of small business in developed countries in modern conditions, according to K.V. Pavlov and I.G. Andreeva, is its integration into the production networks of large industrial structures.

As noted by Nikulina O.V., in the conditions of modernization of the national economy, the purposeful formation of an effective mechanism for managing the innovative development of industrial enterprises using the advantages of the implementation of cluster strategies for Russia can ensure the transition to a qualitatively new level of economic development and the status of a world technological leader in the context of globalization.

A.A. Pakina and V.A. Gorbanev believe that the transition of world development to the post-industrial phase is accompanied by the aggravation of global problems, the solution of which is possible within the framework of green economy, the basic principles of which meet the modern concepts of balanced development and largely coincide with the provisions of the domestic concept of rational nature management.

According to Volkova I.A., Galynchik T.A., small and medium-sized businesses are more susceptible to greening, thus can affect the change of the environmental situation in the region, optimize the process of using natural resources.

When conducting this scientific research, such scientific methods as the method of comparative analysis, statistical analysis, comparative analysis, functional analysis, positive and normative analysis were applied. The scientific research was conducted in accordance with the problem-chronological principle, the principles of systematicity and scientific objectivity.

III. Results

Effective socio-economic development of many countries of the world is determined by the development of small and medium-sized enterprises. Small and medium-sized enterprises carry out their activities as follows independently and in integration with backbone companies. This activity is ensured by a well-developed, historically established and formed for solving the tasks of accelerated economic development by the system of financing and crediting of small and medium-sized enterprises. In the Document on the Policy on Small Business in the European

Union, published in 1995, it was noted that targeted assistance for small companies is the most profitable way to create new jobs in the country [2].

Small business reduces the level of social tension in society and strengthens the processes of democratization of market relations, contributing to the formation of the middle class, raising the standard of living of its citizens, preventing the development of the shadow economy, which is its most important social function. The presence and growth of the middle class in the country confirms the effectiveness of reforms and can be considered an indicator of the strength of the entire system of socio-economic and political institutions, while its absence indicates the opposite. Even Aristotle in the ancient centuries noted the importance of the "middle class" as a factor of society stabilization [3].

It is worth noting that the first to use the concept of "entrepreneurship" in the 18th century was the English banker and economist Richard Cantillon, who implied under this concept an economic activity, as a result of which the correspondence of commodity supply and demand in conditions of risk is ensured, and an entrepreneur is a person who turns the means of production acquired in the market into capital. The result of the functioning of capital is the creation of products that are sold on the market at a higher price than its cost, and since its market price is not known in advance, entrepreneurial activity is a risk. In the Middle Ages, as well as throughout the XVII-XIX centuries in the definition of these concepts was dominated by profit through a rational combination of factors of production, and risk was presented as inherent in business, but since the XX century, especially it can be seen in the works of A.I. Schumpeter, the innovative nature of entrepreneurial activity becomes a dominant feature [4].

IV. Discussion

One of the important conditions in the development of entrepreneurship is motivation and if in the XIX century there was a predominance of motives of economic nature, then for the modern period prevail become socio-psychological, consisting in the fact that entrepreneurial income can often be no higher than the salary of a highly skilled worker. In modern economic science there are two main approaches as to who is an entrepreneur. Some economists consider any owner of the means of production to be an entrepreneur, which is acceptable for small and part of medium-sized businesses, while others consider a manager in this capacity, which is true for large businesses. It should be noted that the scientific position of the mid-1970s regarding the continuity of the process of concentration of ownership of capital, increasing the size of enterprises and firms in practice has not been sufficiently confirmed. In fact, in industrialized countries there was a growth in the number of small businesses, and more jobs in the country, attributable to these structures, thus highlighting small business as the most important source of employment and labor income for the population. It was also noted by scientists from different countries that the growth of employment in small companies was determined by the situation in the sector of large enterprises. According to their opinion, the labor force released by large enterprises was injected into small businesses. Large companies in years of economic instability could drastically reduce the number of their employees, while for small structures this period was more favorable. Significant increase in the number of small businesses, in accordance with the Birmingham model of development in England small businesses, was the result of regional and national industrial decline and corporate restructuring [5].

The formation of entrepreneurship in developed countries occurs on the basis of cooperation between large and small companies, when the activities of large firms are oriented not to suppress small companies, but to realize mutually beneficial cooperation with them. Thus, the structures of large and small businesses try to mutually complement each other, especially it can be observed in the sphere of specialization of individual productions and innovative developments [6]. If the activities of large companies are aimed at satisfying mass and rather homogeneous demand, small businesses operate in small market segments, distinguished by a limited range of production. Market niches are markets, for the most part, of high-tech finished products, the existence of which is determined by the peculiarities of the development of modern economy and international trade relations, when the demand in a particular market due to its small capacity can not be satisfied by large businesses or there is no possibility to cover the entire market with production. [6] An ancient Chinese proverb stating that a small boat, unlike a large ship, is easier to maneuver is appropriate here.

In the period of post-industrial development, the needs of small business structures regarding the introduction of innovations, research and marketing are increasing. There is a need to produce small batches of different goods characterized by high added value. Such spheres of economy as sports, recreation, entertainment, health care, fruit production and flower breeding, including traditional sectors of the economic system, have great opportunities in this direction. Almost all countries have actively developed small business, which takes into account modern features of the world economy functioning in full: innovation imperative, autonomization of the employee and his creative interaction with the employer, high rates of implementation of business ideas in the activities carried out.

Thus, according to English economist G. Bennock, it was small business in the XX century that created more than half of such significant inventions as electronic tubes for TV sets, air-conditioning unit, electrostatic copying machine, ballpoint pen, mixer, toaster, vacuum cleaner, transistor and many others. In developed countries, innovation policies focus on small and medium-sized innovative enterprises. In Japan, for example, the share of small innovative companies in the economy reached 99% of the total number of enterprises and they produced up to 52% of the country's GDP. [7] In the U.S., when conducting the program "Innovation activity of small enterprises" a good result was obtained, when the state for 20 years for every dollar spent was able to get eight, at the same time under this program, funding could receive only those companies that implemented the scientific results of universities [7].

The social functions of small business, in addition to those already discussed, are also assistance in attracting additional labor resources, almost unclaimed by other groups of employers, such as pensioners, minors, mothers with many children, and people with limited working capacity. This circumstance is also important due to the fact that the share of these categories of people in the total Russian population is constantly increasing. Small companies employing hired labor are flexibly adapted to use the labor of the elderly, home-based workers, and young students.

Increasing the employment rate and, as a result, reducing the unemployment rate, improving people's living standards and reducing the number of poor people through inclusion in the small business sector contributes to the realization of other social functions of small business such as counteracting negative social phenomena by reducing crime, drug addiction, alcoholism; providing an opportunity for self-realization of people who have a special initiative and entrepreneurial spirit.

Among the economic advantages that contribute to the development of small business structures, one can include lower cost of job creation, high internal mobility in changing demand based on the use of local resources inefficient for large-scale production, high profitability of activities in "narrow" segments of the market, focused on a specific and limited range of consumers, ease of organization, small capital in the organization of production activities, etc.

Entrepreneurship requires not only solid economic knowledge, determination, business acumen, willingness to take risks, but also the presence of extraordinary thinking, the ability to create and these circumstances determine the representation of entrepreneurship as a separate factor of production.

The condition for the formation of market structures in Russia was the revival and development of entrepreneurship, which was a prohibited activity during the Soviet Union. Although the monopoly on entrepreneurial activity during the Soviet era belonged to the state, the unofficial private entrepreneurial sector occupied a significant place in the Soviet economy, especially in the Baltic republics. Thus, according to the American economist V. Trail, by the early 1980s the shadow sector of the Russian economy accounted for up to 30% of the gross national product of the state, and the excess of income of "shadow workers" from the official statistical level reached 8-10 times, up to 15 million people were fully or partially involved in this sphere. [8]

In the late 80s of the XX century in the country there is a revival of entrepreneurial activity, which was indicated by the adoption of the USSR law "On individual labor activity" of November 19, 1986 and the law "On cooperation in the USSR" of May 26, 1988. Later on, other laws were adopted: the law of the RSFSR "On Enterprises and Entrepreneurial Activity" of December 25, 1990; the law of the USSR of April 2, 1991 "On the General Principles of Entrepreneurship of Citizens in the USSR". In 1987 cooperatives began to appear and actively develop, the number of which for 1989 increased 2.6 times, amounting to more than 102 thousand on January 1, 1990 and 132 thousand - by January 1, 1991 [9].

Government support played an important role in the development of small business. Thus, on June 14, 1995 the country adopted the Federal Law "On State Support of Small Business of the Russian Federation", which referred to the subjects of small business and individuals engaged in entrepreneurship without forming a legal entity. However, there were difficulties associated with the fact that these forms of entrepreneurship in state planning were not taken into account, thereby hampering the flow of resources into the area under consideration, which negatively affected its competitiveness, delayed the registration of enterprises, especially joint ventures, due to bureaucratic delays, which could sometimes take more than 1 year to overcome. Imperfect legislation in the field of private entrepreneurship also put obstacles in the way of the development of entrepreneurial structures in the country, resulting in the fact that the share of private companies in the total volume of production in these years amounted to only a few percent.

Thus, as of 1998, 6% of Russians over the age of 15 were successfully engaged in entrepreneurial activity. [10] Also among the Russian regions in terms of the level of development of small business structures there was noted quite high differentiation, the index of which was up to 10 times. According to the data for 1999, the Central Federal District accounted for the largest share of small business entities - 34.2%, including Moscow - 19.8%, and the smallest share - the Far Eastern Federal District - 4.3%. [11]

It is worth noting that the state support provided to small and medium-sized businesses, carried out in Russia in the form of preferential taxation, reduced contributions to extra-budgetary funds, providing easier access to cheap sources, accelerated depreciation contributed to the increase in the number of small and medium-sized companies on the basis of unbundling of large firms and separation of legally more profitable units from them under the guise of small and medium-sized businesses. As a result, the tax base and tax revenues were reduced, as this increase in the number of SMEs was based on a decrease in the number of unbundled parent companies of large businesses. In the late fifties and early sixties of the XX century, similar processes were observed in the U.S. economy in the conditions of substantial state support to small business. [12] Therefore, in order to provide state support not to subdivisions of large companies, but to those who really need it, they began to talk about the need to strengthen the targeting of benefits to small and medium-sized businesses.

In general, it should be noted that market reforms for Russia and Eastern European countries were implemented with huge losses due to the policy of "Washington Consensus", while such countries as post-war Germany and Japan, today's China and Vietnam on the basis of stimulating their comparative competitive advantages or in modern times, gradually liberalizing the economy, focusing on macroeconomic stability and competitiveness of their producers, were able to achieve high results at the expense of insignificant amount of losses.

In the Russian economy, small business as a subject has existed for several decades, playing an increasingly important role in the socio-economic development of the country. Small business in the country continues to develop, acquiring more and more features typical of a civilized form of the market, but, despite tangible state support, in recent years it has lagged behind its Western counterparts in terms of the level of its development, which makes it impossible to present it as the main "generator" of the middle class.

Sustainable business development in modern conditions is impossible without taking into account the trends of "green" economy, since meeting the needs of modern society should not harm the interests and needs of future generations. The changes that are taking place within the world and national economies have led to the need to revise many of the foundations of the theory of economic science, in which there are new types, methods, techniques and models, one of which is the green economy. [13] More and more countries of the world, transnational corporations, entrepreneurs and ordinary citizens choose the path of responsible attitude to resources and determine their actions in accordance with the global environmental agenda.

In Russia, not only large companies have taken the orientation on "greening" business, but also among small businesses there are more and more "green" projects. The reform of waste collection and disposal, the implementation of which began on January 1, 2019, has brought environmental problems to a new level of required solutions on the part of the state, business and technology. The concept of green economy development is presented as a new trajectory of harmonious (clean) development of society as an alternative model to the existing (raw material) economy, interconnecting further economic development depending on the state of the environment. According to the UNEP conclusion, the main areas of green economy are such sectors of economy as agriculture and fisheries, water and forestry, industry (primarily energy), construction, domestic and industrial waste management, transportation, tourism [14].

Green technologies lead to the improvement of the environment due to the reduction of negative impact on it, ensure the improvement of public health, contribute to the achievement of safety, resource efficiency and environmental friendliness of the functional activities of small companies. Small business management in the conditions of ecological transformation occurs with the help of a certain set of interrelated resource and incentive effects. The transition to green technologies leads to a synergetic effect, resolving the contradictions between the main goal of organizations' activities - profit and their interest in caring for the environment, saving and reproduction of natural resources, preserving public health. It is also important to take into account regional specifics in the process of small business development as a necessary aspect, both in environmental projects and in the process of formation of programs to improve the efficiency of small business structures [15].

In all countries of the world it is possible to observe the regulation of entrepreneurial activity by the state. In some countries, for example, Italy, the Netherlands and Russia, the normative base of entrepreneurial activity is included in the civil law, in other countries - France, Germany, Portugal, these norms are considered as an independent branch, there are countries where these norms are codified, i.e. Commercial Codes operate along with the Civil Code. But common for all these states is the allocation of entrepreneurial activity as a sphere of regulation, contributing to a better consideration of the peculiarities of this activity and, consequently, its development.

In the Russian economy there are many obstacles to the development of small business structures. The number of small enterprises in the country is not increasing at a very high rate, and the contribution of small business to the production of Russian GDP is not so significant. To overcome the existing negative trends in this area, it is necessary to develop and apply an effective system of state support of small business structures. The gradual transition of the country to a qualitatively new state, with the predominance of the "new economy", should be accompanied, first of all, by an active state policy, pursuing the goal of using the main and most promising potential for the development of scientific knowledge. What place Russia will occupy in the rapidly changing and contradictory world depends on the extent to which it will be possible to use this potential. The crisis and its consequences provide a unique opportunity to radically improve the fundamental legislative framework.

References

[1] Resolution of the Second International Scientific and Practical Conference on the Problems of Financing and Lending to Small and Medium Business in Russia // Regional Economics: Theory and Practice. - 2005. - № 8(23). - C. 16-20.

[2] Toreev, V.B.; Voronovskaya, O.E. Effectiveness of the programs to support small business // Economic Science of Modern Russia. - 2002. -№ 3. - C. 73-87.

[3] Aristotle. Politics // Aristotle. Works: In 4 t. - Moscow: Mysl, 1983. - VOL. 4. - P. 376-644.

[4] Schumpeter J.A. History of Economic Analysis. Translation from English. ed. by V.S. Avtonomov in three volumes. Volume I. - St. Petersburg: Economic School, 2001. - 496 c.

[5] Basareva V.G. Small business in the regional economy: the consequences of industrial decline // Regional Economics: Theory and Practice. - 2009. - № 17 (110). - C. 65-69.

[6] Pavlov, K.V.; Andreeva, I.G. Small business development in the Belgorod region through the prism of the analysis of the all-Russian tendencies // Regional economy: theory and practice. - 2009. - № 11(104). - C. 2-8.

[7] Aliev E. From Small to Big. Features of small business development in the social sphere // Social policy and social partnership. - 2006. - № 7. - C. 24-31.

[8] Khodov L. About the structure of small business and the peculiarities of its motivation // Voprosy ekonomiki. - № 7. - 2002. - C. 147-152.

[9] Pakina A.A., Gorbanev V.A. Prospects of green economy as a new development paradigm // Bulletin of MGIMO-University. - 2019. - №12(5). - C. 134-155.

[10] Volkova, I.A.; Galynchik, T.A. Small and medium business in the conditions of ecological transformation: regional aspect // Moscow Economic Journal. -2022. - № 1. URL: https://qje.su/ekonomicheskaya-teoriya/moskovskij-ekonomicheskij-zhurnal-1-2022-37/

THE CONCEPT OF SUSTAINABLE DEVELOPMENT AND FINANCIAL MECHANISMS: GREEN HYDROGEN AND BLUE BONDS

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Abstract

The UN concept of "sustainable development" is increasingly penetrating various spheres of life, subordinating not only political interests, but also forcing economics and science to work closely together to preserve a favorable environment, biodiversity and reduce climate emissions. On the one hand, in the current global paradigm, this attitude is mainly positive, as it aims to achieve the goals of the Paris Climate Agreement, prevent negative environmental impacts and other high goals, including the protection of the interests of future generations. However, the "green fever" that is sweeping the world, namely the race of states and various international organizations, carries significant risks. The goals and economic targets set by Governments are sometimes not just overly ambitious, but simply unrealistic and utopian, as in the case of the transition to blue hydrogen in the next five years. In addition, another problem associated with the implementation of the principles of sustainable development is the problem of abuse of rights in the financial market, as well as increasing the competitiveness and attractiveness of investments in this area through the issuance of specialized securities, the so-called "green bonds" or their specialized variety of "blue bonds". However, it should be noted that with all the marketing activities that accompany the issuance of each financial instrument of this type, it is currently impossible to ensure their liquidity solely for supposed good purposes. Thus, without a clearly formulated economic plan confirming the real financial attractiveness of both projects on the introduction of blue water and projects on the issue of blue bonds, both are doomed to very low performance.

Keywords: sustainable development, green hydrogen, low carbon hydrogen, green taxonomy, European green deal, ESG principles, financial instruments, green bonds, blue bonds

I. Introduction

The main trends of the regional policy of sustainable development at the present time can be traced most clearly within the framework of the ongoing activities of the European Union (EU), since it is the institutions of this integrating organization that make it possible to cover all the diversity of social relations that are currently being built within the concept of ESG (economic, social, and corporate governance).

Several key factors can be identified in the trends of recent years. First of all, the strengthening of legal regulation, which is manifested firstly in the preferred form of adopted legislative acts, namely regulations that do not require an additional period for implementation, which in turn should encourage Member States to ensure their compliance as soon as possible.

Second, as exemplified by the so-called Green Taxonomy (Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment), the trend towards the adoption of framework legislation is expected to continue. This will come into force in 2020 and will create the necessary basis for the adoption of technical and other requirements on its basis, under the delegated powers of the European Commission, allowing for faster decision-making. The chosen mechanism will continue to be applied in the future, which is confirmed when more specific reference is made to the legal regulation of non-financial reporting or the establishment of a CBAM (Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism).

In particular, Regulation (EU) 2019/2088 on the disclosure of sustainability-related information in the financial services sector ("SFDR") and the technical standards adopted by the European Commission on April 6, 2022, in addition to the above regulation, are to be used by financial market participants for the disclosure of sustainability-related information (e.g. Commission Delegated Regulation (EU) 2022/1288 of 6 April 2022).

They contain pre-contractual templates detailing the disclosures in prospectuses required under the SFDR, including information on the taxonomy required for products under Articles 8 (environmental and social investments) and 9 (investments with a partially sustainable purpose), as well as templates for the disclosure of periodic reporting for such products in the relevant annexes.

Third, it should be noted that work on EU-wide adoption issues will continue in the future. The Green Taxonomy is a similar proposal in the area of social projects.

The EU Social Taxonomy, together with the previously adopted Green Taxonomy, is a set of measures developed within the European Union and aimed at promoting the implementation of the UN SDGs on "sustainable development".

As stated in the draft, the lack of a clear definition of the essential characteristics of social investments hampers their development and potential contribution to solving social problems. In particular, the lack of agreed standards and the large number of projects with the prefix "social" do not allow for a reasonable choice, including on the part of investors.

A social taxonomy can address these issues and harmonize the way social issues are measured, making it easier for investors to make informed and consistent decisions and helping to direct resources to socially responsible activities and companies. However, the mechanisms used to verify environmental and sustainable activities are not equally applicable to social development.

In its quest for regulatory uniformity in this area, the EU may be deviating from its own motto of "unity in diversity" in order to ensure formal equality where it is sometimes not only not economically advantageous but also not achievable due to the specificities of the socio-cultural environment.

Fourthly, it is important, in our view, to note the growing interest in alternative energy sources. This refers both to general requirements for the revision of the Renewable Energy Directive and more specific legislative proposals that are part of the Fit-for-55 program, such as the Directive on common rules for the internal markets for renewable gas, natural gas and hydrogen. The production of so-called “blue” hydrogen is now taking on an increasingly important role, including being seen as a substitute for other natural fossil fuels: coal and natural gas, and will therefore require a coordinated regulatory mechanism within the EU.

II. Green taxonomy as a legal framework for the realization of the concept

The term “taxonomy” is of Greek origin (“taxos” - structure, order, “nomos” - law) and was originally used exclusively in biology, to define the doctrine of the principles and practice of classification and systematization of plants [1].

Nowadays, the term developed and used in natural sciences has been borrowed and used by researchers as a definition of other classification systems, for example, "economic taxonomy" [2], "taxonomy of the educational system" [3], 'military taxonomy' [4] and 'taxonomy of sustainable (including) green development projects', which will be discussed below.

One cannot but agree that "the existence of various international bodies and organizations at both the universal, interregional, regional and subregional levels complicate the task of creating an effective system of economic development. There is therefore a need to strengthen coordination among them to avoid fragmentation and duplication of their functions and to ensure sustainable coherent development" [5].

Despite the fact that the experience of the European Union in the field of sustainable development and the creation of a complex structured system of verification of green projects is one of the best, it should also be emphasized that when developing its own taxonomy, the European legislator was guided by already existing acts in this field, such as the Taxonomy of Climate Bonds [6], as well as the Taxonomy of Green Projects [7].

The Green Project Taxonomy is a guide to climate-related assets and projects. It is a tool for issuers, investors, governments, and municipalities to help them understand which key investments will deliver a low-carbon economy. The taxonomy uses a traffic light system to identify suitable assets and projects (the ASEAN Taxonomy, among others, is built on the same principle) and includes sectoral criteria that provide details on which assets can be financed with climate-certified bonds and loans.

Regarding the Climate Bonds Taxonomy, this document, like the above-mentioned ones, creates a certain system of criteria for green (sustainable) development areas, with an indication of prioritization.

In any case, all previously developed acts are of a recommendatory nature and, existing since 2013, have not had such a noticeable impact on states or international organizations as the EU draft taxonomy.

The prerequisites for the creation of a special system of systematization and classification of "green" projects or "sustainable development projects" in the EU were the successive adoption of several fundamental acts.

The initial contributions to the taxonomy were the UN General Assembly Resolution establishing a new global framework for sustainable development: "Transforming our World: The 2030 Agenda for Sustainable Development" ("2030 Agenda"), which includes the Sustainable Development Goals (SDGs) and three dimensions of sustainability: economic, social and environmental, and the previously adopted Addis Ababa Action Agenda of the Third International Conference on Financing for Development (Addis Ababa).

The Addis Ababa Action Agenda has identified several global, cross-cutting areas in which there is a need for greater cooperation, both at the international level and State control at the national level. The areas of cooperation referred to in the programme are as broadly defined as possible (e.g., domestic public resources; private business and finance at the national and international levels; international development cooperation; international trade as an engine for development; debt and debt sustainability; addressing systemic issues; science, technology, innovation and capacity-building) and have a wide range of focus, including, at the same time, health issues, support for environmental projects, and support for the development of the environment.

Although the Sendai Framework is narrower in scope and focuses mainly, as the name suggests, on disaster risk reduction, the priority area of the Framework is "understanding disaster risk" through "collecting, analyzing, systematizing and using relevant data and practical information and ensuring its dissemination, taking into account the needs of different categories of users, as appropriate" (para. 24 (a) of the Framework).

As the researchers emphasize, it was "the Sendai Conference, which endorsed the UN

Framework for Disaster Risk Reduction 2015-2030, that gave impetus to international congresses and other activities at the national level" [8].

The second equally important factor was the adoption of the 2015 Paris Climate Agreement, endorsed by the European Union in 2016.

Thus, the provisions of the Paris Agreement stipulate strengthening the response to climate change "by aligning financial flows with greenhouse gas emission reduction and sustainable development" (Article 2 (1) (c)).

The adoption of the above-mentioned acts has, in turn, triggered an EU response. First, the European Commission in the Communication "Next steps for a sustainable European future. European Action for Sustainable Development" reaffirms its commitment to the principles of sustainable development in general and specific SDGs in particular, dividing the EU's future activities until 2030 into two areas: firstly, the full integration of the SDGs into the European policy framework and the current priorities of the European Commission, assessing the situation of the EU and identifying the most pressing sustainable development challenges, and secondly, analyzing the further development of the long-term vision and direction of sectoral policies after 2020, preparing for the long-term progress.

The subsequent Joint Statement of the Council of the EU and the representatives of the governments of the Member States meeting within the Council, the European Parliament and the Commission "A New European Consensus on Development. "Our World, Our Dignity, Our Future" 2017 (better known as the 'New European Consensus on Development') is essentially declaratory in nature and does not contain specific regulatory measures, unlike the subsequent European Commission's Action Plan "Financing for Sustainable Growth".

One of the objectives set out in the above-mentioned Financing for Sustainable Growth Action Plan is to "reorient capital flows towards sustainable investments to achieve sustainable and inclusive growth".

The creation of a single classification system for sustainable activities is the most important and urgent action envisioned by the Plan. Thus, it is explicitly stated that "the shift of capital flows towards more sustainable activities must be underpinned by a common holistic understanding of the environmental sustainability of activities and investments." And the first step in this journey should be the creation of clear guidance on environmental activities that will help inform investors about capital investments that finance environmentally sustainable economic activities. Further guidance on activities that contribute to other sustainable development goals, including social goals, can be developed at a later stage.

The Financing for Sustainable Growth action plan, together with the 2019 European Green Deal, has laid the groundwork for the European Parliament and Council to adopt a taxonomy to categorize environmentally sustainable activities.

Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment (better known as the "Taxonomy Regulation", hereinafter also "Regulation (EU) 2020/852") does not in fact contain such a term as "taxonomy", operating with the phrase "classification system for environmentally sustainable economic activities", which translates the EU climate and environmental objectives into criteria for specific economic activities for investment purposes.

It recognizes as "green" or "environmentally sustainable" economic activities that make a significant contribution to at least one of the EU's climate and environmental objectives, but at the same time do not significantly undermine the remaining five and minimum social safeguards.

The delegated acts on the taxonomy adopted under Regulation (EU) 2020/852 establish and maintain clear criteria for activities in order to define what is meant by 'significant contribution' and 'harm', and introduce mandatory disclosure obligations for certain companies and investors, requiring them to disclose their share of activities aligned with the taxonomy.

However, the EU taxonomy is not a mandatory list of economic activities in which investors must invest. Nor does it set mandatory environmental performance requirements for companies or financial products. Investors are allowed to freely choose their investment targets. However, over time, the EU taxonomy is expected to promote change and drive the transition to sustainable development.

It should be noted that economic activities that are not recognized by the delegated acts of the EU taxonomy as making a significant contribution to one of the EU's climate and environmental objectives are not necessarily environmentally harmful or unsustainable. Moreover, the delegated acts should be "living instruments" that will be supplemented and updated over time as necessary, as it is obviously not possible to define a complete list of possible environmentally beneficial activities overnight.

Considering the Taxonomy Regulation, we will conditionally distinguish two main directions of legal regulation: firstly, defining the criteria of sustainable development, and secondly, ensuring the functioning of the information disclosure system.

Characterizing the first direction of legal regulation, let us turn to the term "environmentally sustainable investments", defined as "investments in one or more types of economic activities that qualify as environmentally sustainable in accordance with the Taxonomy Regulation".

Thus, such activities must make a "significant contribution" to one of the six environmental objectives listed below:

-climate change mitigation;

-adaptation to climate change;

-sustainable use and protection of water and marine resources;

-transition to a circular economy;

-pollution prevention and control;

-protection and restoration of biodiversity and ecosystems.

It also defines four conditions that an economic activity must meet to be recognized as compliant with the EU taxonomy:

-making a significant contribution to at least one environmental objective;

-no significant harm to any other environmental objective;

-compliance with minimum social safeguards;

-compliance with the technical selection criteria.

The previously mentioned technical selection criteria are developed in delegated acts, in particular Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives. For each economic activity under consideration, the technical selection criteria define requirements for environmental performance that ensure that it makes a significant contribution to the environmental objective under consideration and, at the same time, does not cause significant harm to other environmental objectives.

In addition, the delegated legislation distinguishes between "enabling" and "transitional" economic activities.

Enabling economic activities "do not contribute significantly to climate change mitigation through their own activities".

Such activities play a crucial role in decarbonizing the economy by directly enabling other activities with low carbon and environmental performance. Therefore, technical selection criteria should be established for those economic activities that play an important role in ensuring that the targeted activities become low-carbon or reduce greenhouse gas emissions.

Transitional economic activities are “activities that cannot be replaced by technologically and economically feasible low-carbon alternatives but support the transition to a climate-neutral economy”.

These activities can play a crucial role in mitigating climate change by significantly reducing their current high carbon footprint, including by helping to phase out fossil fuels. Consequently, technical selection criteria should be established for those economic activities where near-zero carbon solutions are not yet viable, or where near-zero carbon activities are not yet feasible but not yet feasible at the scale that has the highest potential to significantly reduce greenhouse gas emissions.

It is worth noting that current practice shows that both above economic activities are currently speculative political instruments and subject to substantial lobbying, particularly where the gas and nuclear sectors of the economy are concerned.

The Delegated Regulation on Technical Criteria provides for two main Annexes - the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives (Annex I) and the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives (Annex II).

The Annexes include the following areas for green activities:

-forestry (e.g. afforestation);

-environmental protection and restoration (e.g., wetland restoration);

-manufacturing (e.g., production of energy-efficient building equipment);

-energy (e.g., electricity generation using solar photovoltaic technology);

-water, sewerage, waste management and remediation (e.g., construction, expansion and operation of a wastewater collection and treatment system);

-Transportation (e.g., conversion of inland waterborne passenger and freight transport);

-building and real estate (e.g., installation, maintenance, and repair of electric vehicle charging stations in buildings (and parking lots adjacent to buildings));

-information and communication (e.g., data-driven solutions to reduce greenhouse gas emissions);

-professional scientific and technical activities (e.g., research, development, and innovation in the direct capture of CO2 from the air).

The technical selection criteria for “significant contribution” to the environmental objective favors that the economic activity either has a significant positive environmental impact or significantly reduces a negative environmental impact, such as a significant reduction in greenhouse gas emissions.

The “no significant harm” technical selection criteria contribute to ensuring that the economic activity does not interfere with the achievement of other environmental objectives, i.e. does not have a significant negative impact on them.

The two sets of criteria together ensure consistency between the objectives of the EU taxonomy and ensure that progress towards one objective is not achieved at the expense of another.

The European Parliament and Council have prioritized the economic activities that can make the greatest relevant contribution to the two environmental objectives under consideration.

The first Delegated Act focuses on climate objectives (climate change mitigation and adaptation to climate change) and therefore includes activities that are most relevant for reducing greenhouse gas emissions and building resilience to climate change. This includes the sectors with the highest contribution to CO2 emissions (energy, manufacturing, transportation, construction) and activities that contribute to their transformation, as transforming activities in these sectors is necessary to achieve the EU's climate objectives.

In addition, so far, the Delegated Regulation on technical criteria reflects a fragile compromise on whether nuclear energy and natural gas should be included among the activities covered by the act.

On January 1, 2022, the European Commission launched a consultation with the Member States' Expert Group on Sustainable Finance and the Sustainable Finance Platform on the draft text of a Supplementary Delegated Regulation covering certain gas and nuclear activities.

The European Commission's Delegated Regulation would label investments in nuclear power plants as “green” if the project has a plan, means and site for the safe disposal of radioactive waste. In addition, to be considered green, new nuclear power plants must receive a construction permit by 2045.

Investments in natural gas-fired power plants will also be considered green if they produce emissions of less than 270 grams of CO2 equivalent per kilowatt-hour (kWh), replace more polluting fossil fuel-fired power plants, receive a construction permit by December 31, 2030, and plan to transition to low-carbon by the end of 2035.

Gas and nuclear power generation will be granted green status on the basis that they are “transitional” activities, defined as those that are not fully sustainable but have emissions below the industry average and do not fix polluting assets.

This draft has already generated several highly significant disputes. For example, EU member states such as France and Poland are actively pushing for the inclusion of nuclear energy in the taxonomy list, arguing that it is a critical low-carbon technology needed to ensure energy security while the EU transitions to renewable energy in the coming decades.

Along with Germany, other countries such as Austria or Luxembourg vehemently oppose such a move amid concerns about nuclear accidents and waste. They would like to see nuclear power disappear from the EU instead of encouraging the construction of new power plants through “green labeling” [9].

Supporters of natural gas argue that it is cleaner than coal and should be used as a transition fuel, while opponents believe it undermines the EU's environmental goals.

Regarding the second area - ensuring the functioning of the information disclosure system, we consider it necessary to note the following.

The Taxonomy Regulation, in conjunction with the other two acts, is intended to provide a single harmonized framework.

The Regulation defines certain mandatory disclosure rules. Alongside these, companies can also use the EU taxonomy on a voluntary basis.

Large financial and non-financial companies subject to the Non-Financial Reporting Directive (discussed in more detail below) will be required to disclose their environmental performance. Similarly, financial market participants (e.g. asset managers) will be required to disclose the extent to which the activities that their investment products finance meet the criteria of the EU taxonomy.

Separately, in our view, it is worth noting that there are many possible options for voluntary use of the EU taxonomy by market participants that are not defined in the documents. For example, companies can use the EU taxonomy criteria as a baseline for their environmental and sustainability strategies and transition plans. Companies and project organizers can also choose to meet the EU taxonomy criteria to attract investors interested in making green investments.

III. Blue hydrogen: pros and cons

Let us consider in more detail the problem of legal regulation of processes related to the creation, storage, circulation of such a renewable energy source as "sustainable" ("renewable" hydrogen).

Speaking about the peculiarities of the technological process, simplified, the procedure of its production is based on electrolysis, splitting water into oxygen and hydrogen, by using for this purpose other energy from other renewable sources (solar energy, wind energy, etc.).

Of its competitive advantages in the market of energy resources are:

-decarbonization of industry due to the abandonment of sources such as natural gas, oil and their derivatives, and nuclear power;

-significantly higher energy intensity compared to existing alternatives;

The possibility of long-term, large-scale storage of renewable hydrogen, including utilizing existing storage capacity for natural gas and liquefied natural gas;

-reduction of greenhouse gas emissions by at least 70%, which in turn is coordinated with the requirements of the Paris Climate Agreement and internal acts of the EU itself.

The legal basis for the system operation is laid down by several acts of the European Union. Thus, the definition of "low-carbon hydrogen" is given in the Renewable Energy Directive, and it is understood as "hydrogen the energy content of which is derived from non-renewable sources, which meets the greenhouse gas emission reduction threshold of 70 % compared to the fossil fuel comparator for renewable fuels of non-biological origin set out in the methodology for assessing greenhouse gas emissions savings from renewable fuels of non-biological origin and from recycled carbon fuels, adopted pursuant to Article 29a(3) of Directive (EU) 2018/2001".

At the same time with the above notion there are the following definitions: "renewable fuels of non-biological origin / renewable hydrogen" (Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen (Art. 2, para. 11)) and "low carbon gas". In the former case, the term covers liquid and gaseous fuels whose energy content is derived from renewable sources other than biomass, while in the latter case it covers other fuels, i.e. much broader than just "low-carbon hydrogen", although it does cover it (Gas and Hydrogen Markets Directive (Art. 2 para. 12)).

At the same time, it is worth noting that, based on the literal interpretation of the Directive, none of the above-mentioned energy sources can be fully classified as "sustainable" according to the EU Green Taxonomy, as the latter, in turn, assumes a minimum of 73.4%.

It is difficult to assess what is the reason for such discrepancy and multiplicity of terminology of the European legislator. For example, the concept of creating "low-carbon fuels" represents the need to achieve ESG principles. At the same time, for such a complex in all senses technological process of production, achieving higher indicators may not lead to the development of technological processes, but on the contrary become an additional obstacle, including for investment.

However, despite the existing differences in terminology, the EU continues to pursue a coordinated policy of creating a legal framework and adopts several strategically important documents in addition to the above-mentioned ones: The Delegated Act on a methodology for renewable fuels on non-biological origin and the Delegated Act establishing a minimum threshold for greenhouse gas (GHG) emissions savings of recycled carbon fuels.

The first document establishes criteria under which hydrogen and other fuels based on it can be considered renewable fuels of non-biological origin (RFNBOs), while the other aims to set thresholds and considers such existing greenhouse gas emissions over the entire technological cycle, including the direct extraction process, subsequent refining and eventually transportation to consumers.

It considers greenhouse gas emissions throughout the entire life cycle of the fuel, including emissions during the extraction phase, emissions associated with obtaining electricity from the grid, emissions during refining, and emissions associated with the transportation of that fuel to the final consumer.

These criteria include, firstly, the additionality requirement that increased hydrogen production must be done in conjunction with new renewable electricity generation capacity, and secondly, the temporal and geographical correlation criterion. The latter is aimed at creating production facilities directly in those regions of the EU where renewable energy production is available. The very idea of the European legislator in this case is aimed at creating and encouraging the creation of specialized enterprises in the most suitable regions, including to reduce the use of fossil energy resources.

The main problem associated with the production of this kind of "renewable energy source" is the following factors. In order to achieve the necessary production of "blue hydrogen" on such a scale by currently known methods, a huge amount of energy resources is required, but the currently available alternative energy sources cannot provide such capacities. Therefore, the only possible source of energy in this case is fossil fuels, which is confirmed by the available data of the International Energy Agency [10].

The second negative factor in the production of blue hydrogen is the fact that the total emissions of negative substances into the atmosphere during its production are much higher than in the case of other energy sources, including natural gas [11].

Thus, at the moment we are talking about the fact that it is possible to question the initially existing idea justifying the necessity of its production exactly as an environmentally friendly energy source.

IV. Green and blue bonds

In addition to the delegated legislation on the EU taxonomy discussed earlier, a major achievement of European legislation has been the Regulation on European Green Bonds, the so-called "green bonds".

"Green bonds" are securities issued by the issuing company to finance specific projects aimed at minimizing the negative impact on the environment. If we omit the specific purpose, which is evident from the name itself, in essence, these bonds are still the same debt securities evidencing fixed-income financial obligations.

Despite the fact that this type of bonds is currently quite common all over the world and is widely used, for example, in Japan [12], it was the European Investment Bank in 2007 that first issued green bonds called "Climate Awareness Bonds" for the purpose of financial assistance to projects in the field of alternative energy sources. In turn, these assets received their current name thanks to the bonds of the same name issued by the International Bank for Reconstruction and Development [13].

Until recently, in order to acquire the status of "green", the issue of bonds must comply with special principles formulated by the international capital markets association, or meet the requirements of the organization "Climate Bonds Initiative", followed by a special confirmation.

The new EU Regulation is intended to replace the various existing standards and establish uniform criteria for issuing such bonds, preventing divergence of national requirements that may arise as a result of the adoption of a directive or adherence to other standards, not only for public but also for private entities, including those outside the EU.

Issuers that voluntarily use the designation "European Green Bonds" or "EuGB" should follow the same rules across the EU in order to increase market efficiency by reducing divergence and thus also reducing the cost of valuation of these bonds for investors.

The provisions of the draft Regulation imply, among others, the following:

-compliance with "transparency" requirements (in order to allocate bond proceeds through detailed reporting requirements);

-"external verification" (hiring an external expert to conduct the compliance procedure);

-"supervision by the European Securities Markets Authority (ESMA) of external experts" (the latter must be registered with and supervised by ESMA).

While the EU is "treading water" and considering additional measures to integrate the financial sector into the "sustainable agenda," much more promising projects are emerging in other regions.

In particular, with the support of the Asian Development Bank, countries in the region have revised the classic structure of the European Green Bond and created a new investment product based on it - Blue Bonds [14, 15]. Belize, Barbados, the Seychelles and Gabon are following suit [16].

Developing a sustainable blue economy, including reversing the decline of marine fisheries, expanding low-carbon aquaculture, scaling up marine renewable energy, and decarbonizing maritime transport, is an integral part of addressing the triple planetary crisis of a rapidly changing climate loss and pollution of nature. The ocean is a vital sink for heat and carbon.

V. Conclusion

When we talk about sustainable development, we are not just talking about the need to protect the environment at a particular point in time, but also to make a contribution to the future. Thus, it is not so much about the need to incentivize investment in high-risk projects, but rather about investing for future generations.

Nevertheless, the existing initiatives analyzed in this paper are currently more populist in nature and have little current feasibility.

However, despite all the negative arguments against "blue hydrogen" as a "renewable energy source", as well as with regard to the little promising and practically nowhere used in practice "blue bonds", both of these projects carry significant value in terms of possible development directions, which should be improved, strengthened and supported in many ways, both economic and legal, and therefore cannot be canceled completely.

References

[1] Pavlinov, I. (2021). Taxonomic Nomenclature: What's in a Name. *Theory and History.* 10.1201/9781003182535.

[2] Day, A.C.L. (1955). The taxonomic approach to the study of economic policies. *The American Economic Review* 45.

[3] Bloom, B. S., Engelhart, M. D., Furst, E.J., Hill, W.H., Krathwohl, D.R. (1956). Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. *New York: David McKay Company*.

[4] Taxonomy for Recordkeeping in Field Missions of UN Peacekeeping Operations. United Nations, (2006). Available at: https://web.archive.org/web/20081216211423/http://archives.un.org/unarms/doc/taxonomy/20060609_Taxonomy [Accessed 19 Sep. 2024].

[5] Abashidze, A.H., Solncev, A.M., Kiseleva, E.V., Koneva, A.E., Kruglov ,D.A. (2016). Achieving the Sustainable Development Goals (2016-2030): international legal dimension. *Vestnik RUDN. Series: Legal Sciences.* No. 1, pp.65-78. (in Russian).

[6] Climate Bonds Taxonomy, (2021). Available at: https://www.climatebonds.net/files/files/Taxonomy/CBI_Taxonomy_Tables-08A%20%281%29.pdf [Accessed 19 Sep. 2024].

[7] Green Project Mapping. ICMA, (2021). Available at: https://www.icmagroup.org/assets/documents/Sustainable-finance/2021-updates/Green-Project-Mapping-June-2021-100621.pdf [Accessed 19 Sep. 2024].

[8] Tihomirova, Y. M. (2017). Risk Management Strategy and International Disaster Resilience Agreements for Security: measures of implementation of the UN Sendai Framework for Disaster Risk Reduction, 18. 04. 2015 г. *International cooperation of Eurasian states: politics, economics, law*, (2(11)), 110-120., (2(11)), 110-120. (in Russian).

[9] Noyan, O. Austria threatens to sue Commission over EU taxonomy rules. 3.01.2022. Available at: https://www.euractiv.com/section/politics/short_news/austria-threatens-to-sue-commission-over-eu-taxonomy-rules/ [Accessed 19 Sep. 2024].

[10] International Energy Agency, (2023). Global Hydrogen Review. Available at: https://iea.blob.core.windows.net/assets/cb9d5903-0df2-4c6c-afa1-4012f9ed45d2/GlobalHydrogenReview2023.pdf [Accessed 19 Sep. 2024].

[11] Howarth, R.W., Jacobson, M.Z. (2021). How green is blue hydrogen? *Energy Sci Eng*. No. 9. Pp. 1676–1687. https://doi.org/10.1002/ese3.956.

[12] Nozdreva, R.B. (2018). "Green bonds" as a modern tool of environmental financing in business in Japan. *Financial Business.* No. 2. Pp. 9-23. (in Russian).

[13] Bogacheva, O.V., Smorodinov, O.V. (2016) "Green" bonds as the most important tool for financing "green" projects. Financial Journal. No. 2 (30). pp. 70-81. in Russian).

[14] Asian Development Bank's Ocean Finance Framework, (2022.) Available at: https://www.adb.org/sites/default/files/publication/777461/adb-ocean-finance-framework.pdf [Accessed 19 Sep. 2024].

[15] Green and Blue Bond Framework, (2021). Available at: https://www.adb.org/sites/default/files/publication/731026/adb-green-blue-bond-framework.pdf [Accessed 19 Sep. 2024].

[16] Belize Blue Bonds for Ocean Conservation, (2023). Available at: https://www.nature.org/content/dam/tnc/nature/en/documents/Belize-Blue-Bonds-2023-Impact-Report.pdf [Accessed 19 Sep. 2024].

STUDY OF INNOVATIVE METHODS IN EVALUATION AND EFFICIENT PLACEMENT OF PERSONNEL COMPOSITION IN AN INDUSTRIAL ENTERPRISE

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Abstract

In this article, the development of new research methods and methods for the assessment of personnel composition, the determination of personnel resources in industrial enterprises, as well as the issues of their efficient placement and bringing labor productivity to the maximum level were discussed. Thus, the selection of employees within equal opportunities based on the competition organized on the basis of certain laws, the creation of a social security system for each employee and the consideration of the effective activity and full protection of the rights of that employee during the period of operation, the continuous operation of employees, cases of absence. In order to prevent and continuously maintain development, the possibilities of conducting internal and external trainings, directing employees to appropriate maintenance activities based on effective placement, training additional reserve personnel for management positions and giving instructions based on their duties have been investigated and evaluated. The model of formation of the innovation potential of the personnel in the industrial enterprise was established and the ways of efficient use of the existing potential of the personnel were studied.

Keywords: personnel policy, personnel turnover, labor productivity, wages, personnel resources

I. Introduction

The evaluation and efficient placement of personnel in terms of composition is one of the important factors to be noted in the field of the economy as well as in the industrial enterprise in general. In general, the study of this issue and the work on this topic have been given more space in recent times. Especially if we look at the last century and the times when the industry first appeared, we can see that there was no serious approach to the study of personnel composition. This situation became widespread after the emergence and development of science and technology. The emergence of such an issue created a basis for the correct evaluation and efficient placement of personnel, the investigation of the reasons for their low productivity and improper organization of work in this direction.

Looking at the modern era compared to the previous period, we can see that the personnel policy incorporates certain radical changes as well as further development. For example, it can be noted that before, the regulation of personnel turnover was carried out in an irregular manner and without any laws or restrictions. There are a number of national factors of competitiveness, which we can attribute to highly qualified personnel and motivated workforce from material and moral point of view. In earlier times, these factors were studied in a completely different way. Because at that time, land, capital, and natural resources were dominant. We can even see it clearly during migration. If the early times were mainly based on "muscle power", nowadays "brain power" plays an important role [2].

If we look at the studies of economists, it would be more correct to start with the works of Adam Smith and David Ricardo. Thus, in 1776 Adam Smith's "Inquiry about nations and the causes of their wealth" and in 1817 David Ricardo's book "Principles of Political Economy and Taxation" noted that labor acts as an important element in the economy between the personnel potential and the value category. was done. Regarding economic relations, the opinions of Elton Mayo and F. Rosthlisberger based on their research were correctly reflected. Both economists studied for a long time the impact of the physical factors identified in the factories of the "Western Electric Company" in Chicago on the productivity of workers [7].

As a result, Mayo created the theory of "social system" and his research proved once again that the important system in enterprise organization is "social system" and its important subject is "man". In general, Mayo came to the following conclusions:

- Each employee operating in the enterprise has a unique character and is variable;
- Every economic interest does not have the main role for the spent activity;
- It is impossible to be sure that the group or groups formed in terms of a number of functions are an exemplary group [7].

It is possible to think in two ways, firstly, the low level of personnel turnover reduces the negative effects on labor productivity. The explanation of this idea is mainly explained by the direct and indirect costs, which include employee turnover. Economists justified the mentioned arguments through a number of theories. For example: the English economist Ian Shaw in his book published in 2005 under the title "Circulation, Social Capital Losses and Productivity (Performance)" linked human and capital theories. Kato and Yanadori's 2007 book "Average Employee Tenure, Voluntary Turnover Rate, and Labor Productivity" proved the idea based on organizational disruption framework theory. American economist and sociologist Gerry Becker's 2004 book, Organizational Rules: Industry and Corporate Change, also made a connection with Ian Shaun's theory of man and capital. In general, Berker and Shaw noted that human and capital theory have an important role in increasing the labor productivity of employees and enterprises. A more extensive explanation of this argument is provided by writers in the following format: Park and Kim 2013 "Turnover rates and organizational performance", J.B and Barney "Enterprise resources and sustainable competitive advantage", Lepak and Snell "Human resource architecture" [10].

In the book "Voluntary turnover, social capital and organizational performance", Des and Shau generally classified the damage caused by personnel turnover to the productivity of the enterprise in 2 formats:

- In general, the inability of an enterprise to positively see the result of the capital invested in employees;
- Damages caused to the competitiveness of the enterprise due to the loss of capital in terms of employees [1].

Hausnext noted that the staffing flow has caused a number of operational delays at the enterprise, which he claims have ultimately had strong operational implications. The flow of personnel directly and indirectly affects the functioning of the enterprise. As an example of an indirect way, the time and financial costs spent on hiring new replacement employees, socializing them, familiarizing them with the work environment and learning the work process, and increasing their personal development by being involved in training. Directly, we can mention missed work opportunities due to unfulfilled obligations, unfinished work, lack of personnel in the enterprise for specialties, and lack of sufficient information about the process in the replaced employees. In all of these cases, as a result, it leads to a linear decrease in labor productivity and a delay in the execution process of operations. Looking at this issue from another point of view, Ian Shaw proposed several nonlinear relationships [8].

For the first time in economics science, personnel evaluation appeared in the United States at the beginning of the 20th century. For this reason, as a number of businesses developed, new methods and methodologies, methodological approaches were formed. If we look at the evaluation of personnel in Azerbaijan for the modern era, we can see the use of a number of methods. These methods are widely used: interview, testing, standard, self-report, descriptive, compulsory selection, etc. is attributed. Each of the mentioned methods has its own disadvantages. In an era where science and technology are developing, new methods of staff evaluation are being sought and researched. The main reason for this is to achieve a more active evaluation of self-evaluation elements.

If we look at the process of management or personnel management, a number of evaluation methods are studied in the works written by many economists. As an example of economists, M.B. Kurbatova, V.E. Khrutsky, M.I. Magura et al. I can mention the methods analyzed by them: 360-degree assessment, method of written characteristics, self-assessment, management by goals, method of rating table of behavioral relations, method of evaluating the level of observation based on behavioral observations [12].

Evaluation and comprehensive study of personnel resources in industrial enterprises is based on a certain system, which in itself combines 3 aspects. The first is the study of the ability of each employee individually and the evaluation of the ability from the point of view of objectivity. The second aspect is the determination of the appropriate requirements for the heads of any department. Finally, I would like to note that every manager prepares a personnel plan [3].

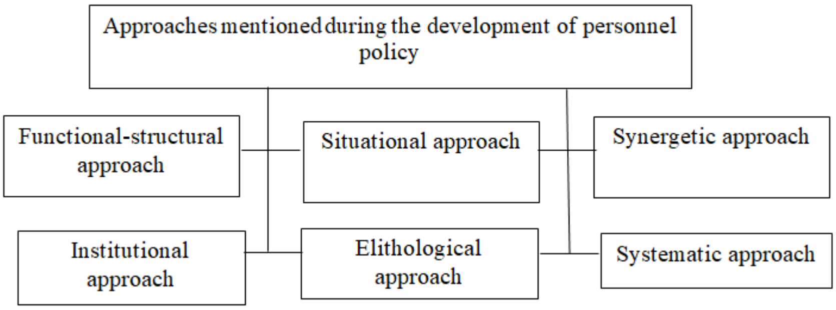

Figure 1: *Directions of personnel policy development*

In each tradition of statecontrol, a number of approaches are especially noted when the state's unique personnel policy is developed:

- Functional-structural approach - the role of labor resources is quite large and is aimed at the classification of functions, differentiation of the management system.

-Situational approach - at this time, the most productive effect is determined, and its determination is carried out on the basis of a specific situation. The form of influence determined at this time is evaluated as the form of influence corresponding to the current situation.

-Synergetic approach - firstly, the principle of self-organization is taken as an important quality characteristic.

- Institutional approach - research is given a wide place and its object is industrial enterprises and their aggregates, which play an important role in the development of personnel policy.

- Elitological approach - the study of the approach is directly related to the study of the concept of "elite". At this time, the study of officials, officials, and government officials is carried out in separate groups.

- Systematic approach - the state studies the elements that form its system and the qualities associated with it in the form of an integrative system [5].

When we study and research human resources in the field of economy, we can note the use of various methods and methods in personnel evaluation. Figure 2 shows the performance evaluation methods.

One of the main goals of every enterprise is to improve labor productivity and take a leading position in a competitive environment. For this, a strategic plan should be prepared properly.

- In any company, there is a need to ensure effectiveness and plan the training process, which is diverse across sectors. The use of the "Efficiency analysis and training planning" methodology in the company or any enterprise together with a number of official and unofficial documents made it possible to achieve certain results:təlim planının formalaşdırılması;

- determination of training priorities;
- collection, analysis and generalization of training needs of the structural unit;
- making changes to the training catalog;
- evaluation and analysis of the effectiveness of the training and development process [9].

When applying the mentioned methods, the Target operating model, Talent Management Concept, etc. the methodology is considered as the main document and the methodology plays an important role during the implementation of a number of processes. Here are some important factors to consider:

- training needs that have arisen in accordance with the requirements of any individual development plan;
- training needs resulting from the analysis of the company's predetermined strategy and development plan;
- Making necessary changes in the analysis of the results during the assessment of training effectiveness and the training needs that may arise as a result of it;
- Training needs that have arisen after the analysis of training on various indicators collected from a number of units based on previous periods.

Monitoring results play a key role when efficiency is analyzed. At this time, feedback requests should be taken seriously [4].

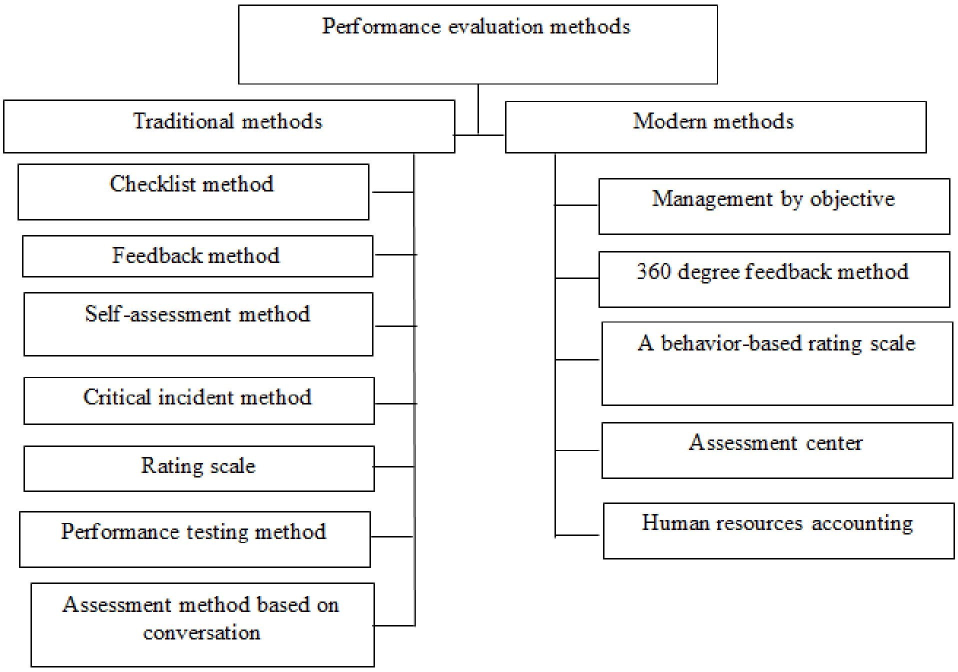

Figure 2: *Performance evaluation methods*

We get the following model based on the number of employees in the industrial enterprise and the costs incurred for the development of personnel, the volume of production for years.

Based on the MS Excel program, the coefficients of the linear regression equation between the number of employees, the volume of production, wages and other similar social payments and labor productivity in SOCAR are obtained as follows:

$$a_0 = 874{,}2;\ a_1 = -0{,}0186;\ a_2 = 1{,}85\ ;\ a_3 = 0{,}255$$

So the regression equation we are looking for will be:

$$y=-0{,}0186X1+1{,}85X2+0{,}255X3+874{,}2 \quad (1)$$

According to the Excel program, between the number of employees in SOCAR, the volume of production, wages and other social payments equivalent to it, and labor productivity, expressed by the linear regression equation y=-0.0186X1+1.85X2+0.255X3+874.2, functional there is a high correlation relationship very close to dependence (R^2= 0.99867). The degree of dependence between indicators According to the Chaddock scale, the quantitative indicator of relationship density in the range of 0.9-0.99 means that the qualitative characteristic of the strength of relationship dependence is quite high [6].

Table 1: *Dynamics of factors affecting labor productivity at SOCAR "Azneft" PU over the years*

Years	The number of employees (person)	Volume of production (tonns)	Wages and other payments (mln. Man.)	Labor productivity
2013	70901	54403408,5	662,67	767,3151084
2014	65568	65518306,26	660,39	999,2421038
2015	56460	60324885,39	597,62	1068,453514
2016	52576	66055570,2	563,68	1256,382574
2017	50933	68087692,82	595,68	1336,809
2018	50122	85545156,24	628,14	1706,738682
2019	50332	91434932,16	682,15	1816,636179
2020	51092	106135780	763,18	2077,346355
2021	50968	99329125,2	821,49	1948,852715
2022	48254	88692674,88	787,35	1838,037777

According to the established relationship equation, it can be concluded that with one unit increase in the number of employees in SOCAR, labor productivity decreases by 0.02 units, with one unit increase in production volume, labor productivity increases by 1.85 units, wages and equivalent One unit increase in other social payments results in an increase in labor productivity by 0.255 units.

As can be seen, according to the obtained table, model (1) is statistically significant. This significance is primarily explained by the fact that the coefficients of the free variables X and the free threshold C are significantly higher than their standard errors. It should be noted that the elasticity coefficient is calculated based on the following formula, expressing the percent increase or decrease of the dependent variable due to the 1% increase of the independent variable X included in the model [6].

$$E = \frac{\propto_i \times \bar{x}_i}{\bar{y}} \tag{2}$$

Here, α_i are the coefficients of the above relationship equation. x ̅- is the average of the number of employees, the volume of production, wages and other similar social payments and labor productivity in SOCAR for the studied periods. The elasticity coefficients calculated based on those indicators will be as follows according to the established model.

$$E_{n.e.} = \frac{\propto_1 \times \overline{x_1}}{\bar{y}} = \frac{-0{,}0186 \times 54720{,}6}{1481{,}581401} = -0{,}68716 \tag{3}$$

$$E_{v.p.} = \frac{\propto_1 \times \overline{x_1}}{\bar{y}} = \frac{1{,}85 \times 78552753{,}1}{1481{,}581401} = 0{,}980819215 \tag{4}$$

$$E_s = \frac{\propto_1 \times \overline{x_1}}{\bar{y}} = \frac{0{,}25 \times 676{,}235}{1481{,}581401} = 0{,}116314049 \tag{5}$$

The calculations show that with a 1% increase in the number of employees in SOCAR, a 0.69% decrease in labor productivity, a 1% increase in the volume of production, a 0.98% increase in labor productivity, and a 1% decrease in wages and other similar social payments. increase results in a 0.12% increase in labor productivity.

Figure 3 shows the production volume forecast model for the next 10 years in SOCAR "Azneft" PU, taking into account the number of employees.

Regardless of the sphere of activity, every enterprise wants the development of its personnel potential to be more extensive and modern, but for this, of course, the unique potential of its personnel should be evaluated. In addition to these, it is possible to mention the use of a number of models that are widely used in modern times. As examples of these models, it would be more correct to mention ADDIE and Bloom Taxcomony.

The essence of the ADDIE model is the planning of learning experiences and their implementation by developers and instructors. In terms of content, the model itself combines 5 parts: analysis, design, development, implementation, evaluation. This model includes stages in itself and assumes their consistent, orderly implementation [10].

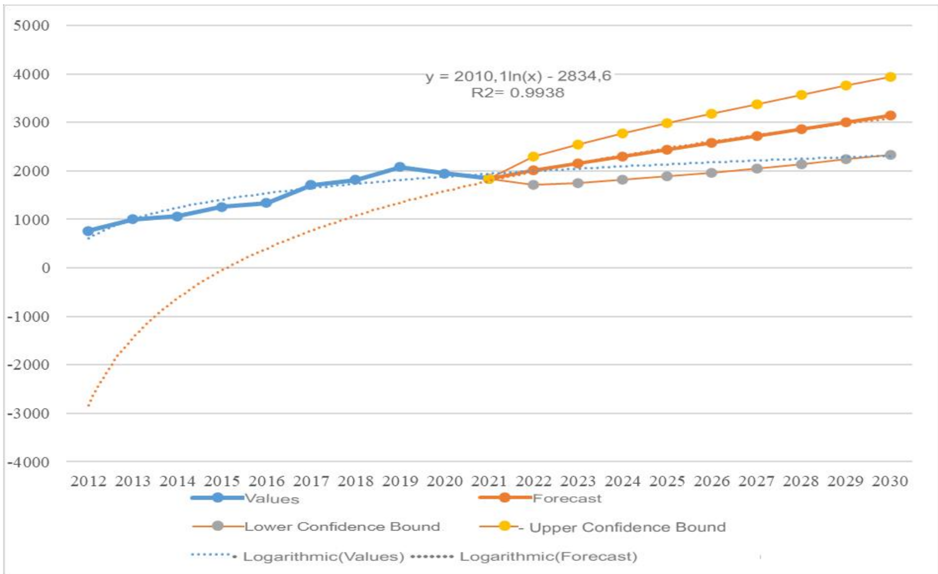

Figure 3: *Analysis of the production volume in SOCAR "Azneft" BU for the next 10 years in terms of the number of employees*

1. Analysis – initially the current situation should be analyzed and the gaps should be filled. For this, it is important to know where everything is prepared. According to the analysis, the qualitative analysis is specifically distinguished in that it enables the identification of goals and objectives for learning.

2. Design – decisions related to the creation of learning programs are made after all the information in the analysis is considered. It requires acceleration in terms of time and attention plays an important role.

3. After the content ideas are decided in the development-design stage, the implementation of those content ideas can be started. At this time, videos are written, graphics are created, fonts and colors are taken care of, visual design is done, etc.

4. Implementation - it is time for employees to complete the course after all the work is completed during the training. At this time, attention is paid to whether they face any problem or whether everything goes well.

5. Evaluation - finally, the evaluation process is carried out and the extent to which employees are satisfied and dissatisfied with the training is comprehensively studied.

Advantages of the ADDIE model: simple measurement of time and costs; to be more effective for learning; plays an important role for a number of models; widely accepted and used globally.

Disadvantages of the ADDIE model: it does not allow repetitive design; it takes a lot of time and is expensive; it is a rigorous process in terms of consistency; it is slower to adapt to sudden project changes.

Bloom's Taxonomy is basically a system that categorizes a set of dominant skills into specific domains of requirements. At this time, it is learned from the simplest skill to the most complex skill. If we look at the history of Bloom's Taxonomy, it was created in 1954 by Benjamin Bloom and his allies Walter Hill, Edward Furst, Max Englehart, etc. mentioned in the book "Taxonomy of Educational Objectives" published by others. So, the main factors that are important to note are based on the order of cognitive skills: understanding, knowledge, application, analysis, synthesis, evaluation. Bloom's taxonomy emphasizes 3 levels to study:

- Cognitive learning is the process of acquiring knowledge based on certain cognition and their mental skills.
- Affective learning - includes the development of certain feelings and a number of emotional areas, learning to analyze and explore them.
- Psychomotor learning - in this case, physical and experiential skills are considered as an important factor, which requires some time to be studied as a broad process.

As a result, it can be noted that this process or theory is intended to be applied in the enterprises of many countries. It is more desirable to apply Bloom's Taxonomy for future periods. However, work is being done in the direction of the development of the theory, in which the existing techniques and technologies of the time are taken into account[11].

One important factor to emphasize is the staffing process. As a definition of the process, it can be noted that it means placing the employee in departments or positions, taking into account his personal qualities. A number of aspects should be considered during deployment. It is very important to correctly determine the demand of organizations, enterprises, and firms for certain tasks for the future period. Even if the requirements for specialists with diplomas are determined, the use of a number of methods during forecasting is especially valued:

1. Normative method - volume of production, volume of work, labor standards intended for specialists
2. Staff nomenclature method - increase and decrease in the number of positions, qualifications based on positions, staff tables
3. Staff nomenclature method - increase and decrease in the number of positions, qualifications based on positions, staff tables

One of the nuances that is important to note is the identification of high- and very-high-important tasks during the placement of personnel. For this, the enterprise develops a certain methodology. The methodology defines appropriate solutions and methods of their application in order to implement the process of identifying high and very high importance tasks. This document is an integral part of the "Training of Attendees" methodology. During the implementation of the process of training participants, the use of the methodology "Determination of high and very high importance tasks" together with other related documents will serve to achieve the following results:

- Determination of high and very high importance tasks;
- Approval of the catalog of high and very high importance positions for the Company;

The following documents were used in the development of the methodology: concept of talent management; target operating model; charts for identifying high priority tasks for training followers; project solution on the main provisions; project solution for training followers.Metodika üzrə hədəf qrupları aşağıda göstərilmişdir:

- Specialist in the training of trainees;
- A specialist performing the functions of an IR partner
- Heads of structural units;
- Business experts;
- Employees working in high and very high importance positions.

During the development of the methodology, the concept of Talent Management, Target Operating Model, process diagrams and project solutions were based. In case of inconsistency between the methodology and the above-mentioned documents, the methodology is taken as the main document and is referred to during the implementation of the processes.

II. Conclusion and recommendations

1. The conducted regression calculations show that a 1% increase in the number of employees in SOCAR, a 0.69% decrease in labor productivity, a 1% increase in the volume of production, a 0.98% increase in labor productivity, and a 1% increase in wages and other similar social payments % increase and results in 0.12% increase in labor productivity.

2. Based on the dynamics of changes in the number of employees for 10 years, a model for forecasting the production volume was proposed for SOCAR "Azneft" PU, which is the research object.

3. Regardless of the sphere of activity, the unique potential of each enterprise's personnel should be evaluated so that the development of personnel potential is broader and more modern. For this purpose, it is more correct to use ADDIE and Bloom Taxconomy models.

4. Taking into account the employee's personal qualities, a methodology is proposed for determining high and very important tasks during his placement in departments or positions and personnel placement.

Reference

[1] The concept of personnel policy of the State Statistical Committee of the Republic of Azerbaijan

[2] Andrunik A.P., Gordeev A.E., Cherdantsev V.P., "Human resource management", "Album of graphic schemes", Perm 2015

[3] Akberdin R.Z. "Improving the structure, functions and economic relationships of the company's management units in different forms of management", R.Z. Akberdin, A.Ya. Kibanov. — M.: GAU, 2015. — 321 p

[4] Borisova N.N. "Innovation-oriented human resource management: Monograph", , 2014, 200c.

[5] Bushueva A. A. "Improvement of the personnel development management subsystem: organization of personnel training". // Innovative development of modern science: collection of articles of the International Scientific and Practical Conference — Ufa: RIO MITSII OMEGA SCIENCES, 2015. — p. 97

[6] Yadigarov T.A. Operations research andthe solution of econometric problems in the MS Excel and Eviews software package: theory and practice. Baku. European publishing house, 2019

[7] https://www.indeed.com/career-advice/career-development/deployment-plans

[8] https://www.indeed.com/career-advice/career-development/deployment-plans

[9] Personnel of the organization and its management / internet resources: - http://dps.smrtlc.ru/Od_PM/Od_0.htm

[10] Human resources, personnel and labor potential of the organization / Internet resources: - http://www.persona-nova.ru/article11.html

[11] https://edumap.az/bloom-taksonomiyasi-nedir-ve-tenqidi-dusunme-bacariqlarini-nece-inkisaf-etdirir

[12] https://markzone.az/muessiselerde-telim-neticelerinin-qiymetlendirilmesi-metodlari/

HUMAN POTENTIAL OF SUSTAINABLE DEVELOPMENT OF SOCIO-ECONOMIC SYSTEMS

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Abstract

The article studies the role of human potential in the development of modern socio-economic systems and its impact on their sustainability. A retrospective look at sustainable development and the influence of human potential on modern social and economic processes allows to generate a forecast of possible risks and threats in the conditions of digital transformation.
The authors highlight the threats that have become a reality in the modern development of society and that have a negative impact on the strengthening of human potential and the sustainability of socio-economic systems.
It is noted that the decline in demand for human capital in economic activity against the background of the introduction of digital systems that ensure productivity can lead to global negative social, economic, political consequences.

Keywords: sustainable development, digitalization, human capital, human potential, economic growth

I. Introduction

In the context of digital transformation, the development of socio-economic systems of the countries of the world is faced with a number of emerging problems; one of the most acute and uncertain is the problem of preserving and revealing human potential.

The sustainability of social and economic systems supposes such a state and development, in which the basics of the life activity of the entire society will not be disturbed: preserving the environment, providing conditions for saving the population, creating opportunities for self-realization and personal growth of citizens.

Man has always been the center of all ongoing processes in society and played a decisive role in the system of sustainable development. At the same time, "Sustainable development" itself (the term was first used in the Report of the United Nations Conference on Environment and Development in Rio De Janeiro, 1992) was presented in the context of increasing environmental risks, which made it possible to take a new look at the problems of environmental pollution as a result of destructive human activities.

The proclamation of the principle of sustainable development has changed the perception of the conceptual approach to the issues of movement and improvement of socio-economic systems, whose important and determining factor in the sustainability is the balance of human activity in the environment, economy, and social sphere.

II. Methods

The main goal of sustainable development is to ensure the growth of human well-being without disrupting the quality of the environment. There is some contradiction in this.

On the one hand, a person, in his strive to improve the quality and standard of living, uses all the resources at his disposal, often ignoring an economical and rational approach to natural resources and the environment. On the other hand, growth in the well-being of people and their next generations is possible only in case of maintaining the quality of the environment.

In this regard, there is a need for a systematic and comprehensive approach to solving this problem, requiring political will, understanding of economic feasibility and social responsibility of all members of society.

Acting as the central link of the entire eco-socio-ecological system, man is not a passive user, but an active participant, a subject of all processes, taking an active part in their formation and movement, realization of goals and control over their achievement. Therefore, the disclosure and use of his potential in modern society is a determining factor of economic growth.

The purpose of the study is to determine the place and importance of the human factor in the conditions of digital transformation, associated with a number of threats to the reduction of human potential disclosure.

Two groups of applied research methods contributed to the achievement of the goal: theoretical and empirical.

III. Results

Human potential, being a set of spiritual and physical forces such as knowledge, skills, talents, capabilities, abilities, contributes to decision-making to achieve personal and social goals. This potential is the driving force of socio-economic progress, but in case of disclosing of its two qualities: instrumental, allowing to shape the environment and living conditions and existential, revealing and enhancing a human's personal qualities, abilities and capabilities.

Initially, the concept of human potential in economics was described by Nobel Prize winner Amartya Sen, who defined human potential as the possibility to freely choose value-oriented activities. Sen became the founder of the theory of human capabilities, which became the goal and means of economic development and growth. The perception of human potential in the context of opportunities has become classic over time, but in the mid-2000s a new approach to revealing human potential through a person's whole internal abilities, personal qualities, creativity, cognitive and communication abilities, and non-cognitive skills began to gain popularity.

In recent years, particular importance has been attached to the revealing non-cognitive human skills, since it is openness to new experience, sociability, compromise, conscientiousness and extraversion that contribute to decision-making in conditions of uncertainty and change.

In the modern world, the development of human potential, as the main resource for increasing national wealth, is seen in the development of a set of fundamental factors of an effective individual:

- the factor of education that allows to improve professional skills, adapt to and navigate changing environment. The importance of self-development determines the prospects for future changes and allows improving knowledge and skills of the future, such as digital literacy, critical thinking, communication skills, etc.;
- the factor of development of entrepreneurial and innovative initiatives. Entrepreneurship and innovation are now in the focus of attention of organizational and management structures of the world countries, since they are the trend of sustainable development of socio-economic systems. All conditions are created for their maintenance and development: tax incentives, financial support, information and administrative support;

➢ the factor of social protection and inclusivity. A modern vision of sustainable development based on revealing human potential cannot be achieved without reducing inequalities. Within the framework of the implemented state policies of various countries, the problem of inequality is among the most important and requires immediate action to provide the population with equal opportunities for access to healthcare, education, and cultural growth. The social orientation and inclusivity of national government systems is a determining condition for sustainable development and growth;

➢ the factor of interaction of all social groups, government structures, business, scientific community on terms of partnership and synergy. The synergetic approach, in contrast to the compromise one, supposes achieving such coordination between all subjects of socio-economic relations in which all interests will be considered.

The modern world is undergoing global changes associated with rapidly occurring digitalization processes, which radically changes the paradigm of the use of human potential and human capital. As before, human capital is the main factor of production, surpassing financial and natural resources in terms of influence on sustainable growth. However, the development of artificial intelligence and the introduction of its functionality into the life of society creates new threats not only to the stability of socio-economic systems, but also to human identification in general.

The development of mankind has always been accompanied by new achievements, the level and qualitative components of which corresponded to each historical stage. Scientific and technological progress acts as a trigger for processes of rapid development and qualitative changes that bring additional convenience, benefits and opportunities to the entire society.

Modern technologies have completely changed the traditional mechanisms of functioning and management of socio-economic systems. Society receives many additional benefits from the development of convergent nano-, bio-, and information technologies, which create and allow functioning effectively complicated self-organizing complexes (ecosystems). Digitalization of significant social, political, business and economic functions of people is taking place, replacing their activity.

This creates real conveniences for mankind: the quality of life is changing, opportunities for self-development and growth in an extensive information environment are expanding, and there appears time for spiritual and cultural growth.

Serious threats arise despite the obviousness and inevitability of digitalization processes, which are still being introduced into the life of society pointwise, but will become widespread in the near future.

First of all, this is the threat to the fragility of the technogenic world, its dependence on minor technical failures, when all information resources can be lost, or access to them will be stopped (the phrase "plug-dependent civilization" is well-known).

An important problem in the context of dynamic digitalization is its infrastructure support. The underdevelopment of digital infrastructure, insufficient and heterogeneous material and technical support for innovation, differentiated and limited access to digital resources for all final consumers create concerns about such accelerated digitalization.

Cybersecurity is becoming a key problem in preserving not only personal data, but statehood as a whole. The functioning of the global virtual space has no limits and, therefore, is not subjected to regulation by national legal norms in the exchange of information.

Negative consequences of digital transformation do not end with the above-mentioned risks and threats, despite the fact that their damage to human potential development is obvious. One of the serious problems of digitalization for man is the gradual displacement of labor force, substitution of many functional elements of a modern economy with automated systems.

The introduction of modern technologies based on artificial intelligence (AI) into production processes leads to a productivity growth, but the result is a separation of business productivity from labor productivity, which leads to negative social consequences.

The productivity growth of economic entities, in isolation from the growth of labor productivity, will lead to an uneven distribution of the resulting benefits. The beneficiaries will be only a few (owners, shareholders), which will provoke an even greater increase in inequality and widen the gaps between segments of the population.

The threats and risks of digitalization in the political sphere are primarily threats to social stability and sustainable development.

Experts believe that one of the main risks of the new technological society is that full-scale robotization of production can cause colossal imbalances between supply and demand in the labor market.

Many researchers consider this threat to be extremely important, due to its obvious reality, and call on governments to define at the legislative level a list of professions that should be assigned to people. Otherwise, a significant part of the population, which becomes free of work, may suffer negative consequences of drug addiction, alcoholism, gambling addiction, etc.

The growth of social inequality in the context of the above-mentioned problem is inconsistent with the concept of human development, entails not only threats of inequality, but also an increase in the fiscal burden on budgetary systems, at the expense of which the states will smooth the gaps in the level of well-being of the population.

Developing the threat of inequality, it can be assumed that a certain category of citizens, being unemployed and without savings, risks losing access to other social services: health care, education, culture and sports. Professional skills and motivation for self-development and retraining will gradually be lost.

The loss of human potential due to the emerging challenges of digital transformation is becoming one of the most pressing problems that concern not only the social sphere, but also penetrate and will impact all components of socio-economic systems.

However, the most serious threat is not the material and spiritual components of the problem (their importance cannot be excluded), but the global problem of the loss of human identification as a biological species. This will cause a global collapse, which may result in a transition from self-development to self-destruction.

IV. Discussions and conclusions

So, the negative consequences of digitalization in the socio-economic environment, leading to the loss of human potential, include:

- loss of workplaces and growth of unemployment;
- increasing the efforts (administrative, financial) of states to ensure retraining and reeducation of citizens, increasing their financial literacy in the face of growing fraud risks;
- increased digital fraud, piracy and the spread of malicious information;
- unauthorized use of personal data resulting in financial, property and other losses;
- illegal use of personal data for the purpose of abuse, data diddling, etc.

The emerging new world generates and scales up tasks to preserve human potential, since its modern configuration creates significantly more threats than benefits for preserving the role and importance of human beings in sustainable and progressive development.

Currently, against the background of geopolitical contradictions, there is no agreement between the leading countries of the world on systematic work towards preserving human potential and its transformation and effective use as human capital in the economic interests of the world community.

There is also no agreement on the issues of maintaining work motivation and guaranteeing the professional demand of the population in the context of digital transformation.

According to the 2030 Agenda, the EAEU has outlined a range of problems for human potential development, recognizing that the time has come for decisive action for its development and implementation within the framework of obligations to achieve Sustainable Development Goals, expanding the horizons of interaction within the framework of this economic integration project.

References

[1] Verenikin A.O. Development and relationship between "human capital" and "human potential". Human capital and education. Multi-authored monograph. V.N. Cherkovets, E.N. Zhiltsov, R.T. Zyablyuk, eds. M.: TEIS; 2009. 324 P.

[2] Babintsev V.P., Kurkina M.P. Human potential as a scientific category [Text] // NOMOTHETIKA: Philosophy. Sociology. Right. Issue 20, No. 8 (127). 2012

[3] Grishina E.S. Factors influencing the human potential of the region [Text] // Creative Economy. No. 1. 2013.

[4] Grishina E.S. Monitoring study of the human potential of the region [Text] // Creative Economy. No. 2. 2013.

[5] Eremina E.V. The importance of human potential in the development of the region [Text] // Russian Journal of Education and Psychology. No. 5(13). 2012.

[6] Eremina E.V. Regional identity in the context of sociological analysis [Text] // Russian Journal of Regional Studies. No. 3. 2011.

[7] Kadomtseva S.V., Palochkina V.V. Models for financing human development in the transition to the information society. Social policy and social partnership. 2016;(3): pp. 10–23.

[8] Wings of Icarus: about the risks and threats of digital transformation of society. Advances in Law Studies. Vol. 9, No. 4, 2021.

[9] Report of the World Commission on Environment and Development (WCED): Our Common Future Translation from English. Edited by S.A. Evteev and R.A. Perelet, 1987. http://устойчивоеразвитие.рф/files/monographs/OurCommonFutureintroduction.pdf

[10] Nikulina Yu.N. Formation of a regional policy of social partnership in the field of training competitive specialists [Text] // Creative Economy. No. 9.

[11] Yurova N.V. EAEU's Human Potential: New Risks and Opportunities for Development. EURASIAN INTEGRATION: economics, law, politics. 2023; 17(3):79-91. https://doi.org/10.22394/2073-2929-2023-03-79-91

[12] Radoushinsky D. A. , Radushinskaya A. I., Khaykin M. M. Improving the quality of implementation of the container transportation project along the NSR based on the environmental and energy transition agenda Polar Science. 2023. №35. pp. 100923-100923. https://doi.org/10.1016/j.polar.2022.100923

[13] Radoushinsky, D.; Gogolinskiy, K.; Dellal, Y.; Sytko, I.; Joshi, A. Actual Quality Changes in Natural Resource and Gas Grid Use in Prospective Hydrogen Technology Roll-Out in the World and Russia. Sustainability 2023, 15, 15059. https://doi.org/10.3390/su152015059

[14] Digitalization of the Social Sphere in Russia During the COVID-19 Pandemic: Analysis, Risks, Prospects / V. Dzobelova, N. Davletbayeva, O. Tegetaeva [et al.] // Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East (AFE-2022) : Agricultural Cyber-Physical Systems, Tashkent, 25–28 января 2023 года. Vol. 733-1. – Zug: Springer Cham, 2024. – P. 323-332. – DOI 10.1007/978-3-031-37978-9_31. – EDN CIFHRE.

[15] Digitalization and Industry 4.0-Changes Caused by COVID-19 / M. S. Rysalieva, V. B. Dzobelova, A. V. Olisaeva [et al.] // Strategies and Trends in Organizational and Project Management, Rostov-on-Don, 19–20 мая 2021 года / Editors: Pavel V. Trifonov, Marina V. Charaeva. – Rostov-on-Don: Springer Nature, 2022. – P. 12-20. – DOI 10.1007/978-3-030-94245-8_2. – EDN ZVSEKQ.

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MAIN TRENDS IN INVESTMENT RISK MANAGEMENT

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Abstract

Assessment and management of investment risks are key aspects of successful investing, requiring special knowledge and strategies. Risk analysis and forecasting methods help investors make reasonable decisions and minimize potential losses. Effective risk management allows to minimize losses and maximize investment returns. To achieve these goals, various methods and strategies must be used. However, successful investing requires not only the ability to assess risks, but also to develop effective strategies for their management. Constant monitoring of the situation in financial markets, analysis of economic and political events, as well as the ability to quickly respond to changes will help to reduce risks and increase investment returns. This article considers the features of investment activity; the factors playing the most significant role in assessing the risk of investment projects; it also provides a classification of investment risks, determines their essence and causes of occurrence, as well as methods for their determination.

Keywords: investment risks, assessment methods, risk management, investment strategies, investment returns, risk analysis, financial instruments

I. Introduction

Investment activity is one of the most popular topics in the modern economic sphere of human activity. Popularity of investment activity has increased significantly with the increase in the level of financial literacy of the population. There is an understanding of how much investments help stabilize an individual's financial situation in a modern market economy.

The investment industry is a complex structure that includes various types of assets (shares, real estate, precious metals, derivatives, etc.). To get involved in investment activities as comfortably and easily as possible, it is necessary to study the basic concepts, structural elements, investment tools and strategies, types of assets, etc. It is understanding and knowing the answers to these questions that will allow you to minimize losses and maximize profits in the course of various investment activities.

Investment risks represent the probability of shortfall or complete loss of profit and/or invested assets in the course of implementation of investment projects where the object is the property interests of the investor.

The article examines methods of investment risk assessment and management, investigates quantitative and qualitative methods of assessment, diversification and hedging strategies, and defines the role of risk management in the overall investment process.

II. Methods

In the course of this synthetic research, the materials included publications in scientific journals referring to this issue, educational materials and textbooks related to the topic of the work, statistical data posted on the websites of the State Statistics Service, as well as the results of studies conducted in this area earlier. The main tools are observations, surveys and focus group discussions. Methods of logical and statistical analysis were also used in the research.

III. Results

Any activity related to the field of investment, as a type of commercial activity, is based on a number of features that significantly influence the process of determining the amount of investment risk. Multiple diversity of investment measures, that differ significantly both in their profitability and the level of inherent risk, significantly complicates the optimization of the investment portfolio. In addition, this area is the most susceptible to external economic, political and social effects.

Duration of the life cycle of the investment project; Due to the large scatter, it is quite difficult to take into account the 2 previous points and qualitatively and effectively predict the influence of factors on the profitability of an investment project and the amount of investment risk. Insufficient and sometimes complete absence of statistical data from the previous period on which one could rely when choosing tactics.

One of the main factors that directly influences the process of investment risk assessment is the degree of market volatility. The higher the volatility, the greater the opportunity for high profits, but the risk of loss also increases. As it is known, high volatility in economic theory indicates frequent and significant fluctuations in the value of an asset, wherein value fluctuations often exceeding 10% of the base value. With low volatility, prices are less susceptible to sudden fluctuations and price fluctuations do not exceed 2% of the base price.

Another important factor, in our opinion, is the degree of liquidity of investments. Illiquid assets may be difficult to sell in case of quick conversion into cash, that significantly increases investment risks. Liquidity is calculated using the following formula:

$$k = \frac{\mathrm{A1} + \mathrm{A2} + \mathrm{A3}}{\mathrm{P1} + \mathrm{P2}} \tag{1}$$

Where A1, A2, A3 are assets, and P1 and P2 are current and short-term liabilities, respectively. Another way to calculate the liquidity ratio is the ratio of current assets to short-term liabilities. The ideal result of the calculation is a result in the range from 1 to 2. Going beyond this range to a greater extent will indicate an imbalance in asset management, in the opposite direction – absence of profit or the presence of losses.

Also, an important factor is portfolio diversification, which is often recommended for novice investors. A variety of assets allows reducing the overall risk of investments, since losses on one type of asset can be compensated by profits on others. There are several types of diversification: according to the type of assets (investment in different investment instruments), by country, by economic sectors.

Finally, fundamental and technical analyses also have a significant impact on investment risk assessment. Analysis of market trends, financial condition of companies and macroeconomic indicators allows investors making reasonable decisions and managing risks more effectively.

As already mentioned above, geopolitical situation is another factor that most strongly influences the amount of investment risk. Global instability, political conflicts, military actions or changes in legislation have a great impact on the market and investment opportunities, due to the significant dependence of the investment sector on them. Investors should consider these risks to adapt strategy depending on the current environment.

Perhaps the most volatile aspect in the investment risk assessment is the human factor and market psychology. Emotions can significantly influence the decisions and behavior of market participants.

Finally, an important factor in investment risk assessment is the level of financial literacy. Having sufficient knowledge about financial markets, investment instruments and strategies allows making more reasonable decisions and effectively managing risks. Education, self-education and consultation with experts can significantly improve financial literacy and help investors achieve successful results in the market.

As for considering the risk management plan in general, it comes to defining the following actions:

1) Analysis of risks of the previous period, where the frequency and probability of occurrence of investment risks, as well as their mathematical expectation, are important elements.
2) Analysis of macro- and microeconomic trends, extrapolation of their development
3) Assessment of the impact of possible investment risks during project implementation.
4) Analysis of project flexibility under the influence of external effects

Investment risks, by their nature, represent potential threats and possible losses that may arise when investing capital in order to make a profit. The classification of investment risks includes financial, market, operational, political and other types of risks, each of which requires special attention and analysis when making investment decisions. It is important to remember that risk management plays a key role in achieving successful investment results, so it is necessary to carefully study and analyze all aspects of risk before making investment decisions.

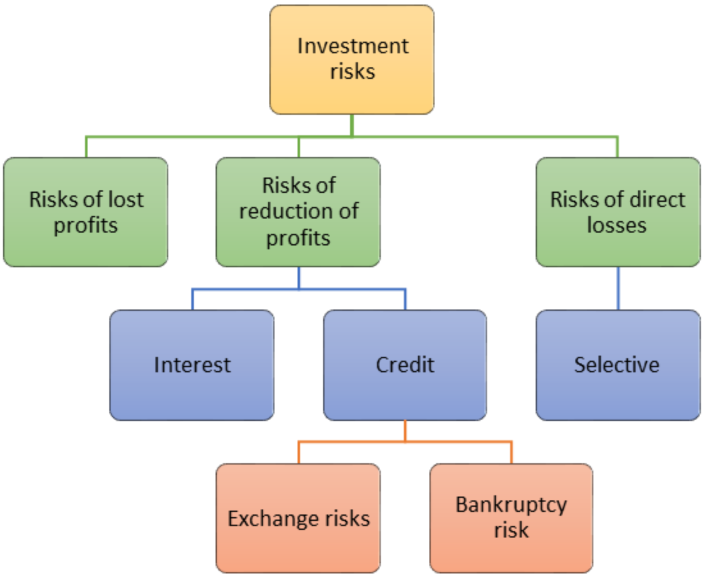

Figure 1: *Classification of investment risks*

The first level of classification is represented by three main risks: the risk of lost profits (the risk of indirect (incidental) financial damage as a result of activities), reduction of profits and direct losses (Fig. 1). The second level arises as a result of a decrease in interest and dividends and is divided into interest and credit risks. Selective risks are the risks of the wrong choice of type of investment.

Since we have examined the basic classification of investment risks, let`s consider in more detail the methods by which we can determine, in fact, the very amount of risk associated with investment activities (Fig. 2).

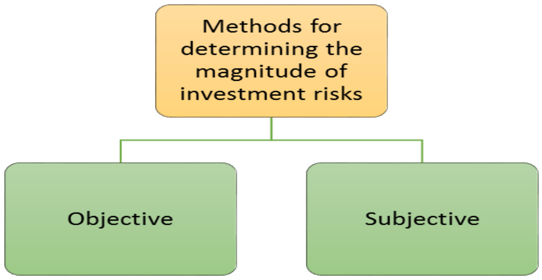

Figure 2: *Methods for determining the magnitude of investment risks*

Objective methods for determining the magnitude of investment risks are based on the collection, processing and analysis of statistical indicators, while subjective methods are based precisely on personal experience and the assessment of experts, the opinion of other specialists. The first ones are applied in case of a representative statistical sample of risks in a certain structure of investment activities. Almost always, in objective methods of determination, probability theory and game theory are used, based on which the mathematical expectation of the occurrence of a necessary event is represented by the product of the absolute value of this event and the probability of its occurrence.

Investment risk assessment is based on two main criteria: the average mathematical expectation M(X) and the fluctuation of the possible result (σ), where

$$\mathrm{M(X)} = \sum_{i=1}^{n} x_i p_i \tag{2}$$

Average mathematical expectation is the expected average profitability or loss from an investment, which is calculated as the product of the probability of an event occurring (p) and the magnitude of that event (x). This criterion allows investors to assess how profitable or risky an investment is in the long term.

Fluctuation or volatility shows the degree of the deviation results around the average expected value. It is calculated as the product of the quotient 1 and the number of observations reduced by 1 and the sum of the squared difference between the arithmetic mean and the price change.

$$\sigma = \frac{1}{n-1}\sum_{i-1}^{n}(m - x_i)^2 \tag{3}$$

The higher the volatility of an investment, the greater the chance of both high profits and significant losses. Therefore, to fully assess the risk of an investment, fluctuations of the possible result must also be taken into account.

One of the most important tasks here is to find a balance between a high mathematical expectation of profitability and an acceptable level of volatility, which will not only maximize potential profits, but also minimize possible losses.

In addition to these two factors, for a more accurate assessment, it is also necessary to consider the correlation between different assets, which shows how strongly they move together, thus allowing to apply a diversification method and reduce the overall risk. For example, if assets are positively correlated, then losses on one asset may be partially compensated by gains on another asset.

Another important aspect of investment risk management is understanding the concept of statistical probability. Besides average expected value and fluctuations, investors should consider the possibility of occurrence of different investment results. This will help them determine not only expected profits, but also potential losses under various scenarios.

Finally, successful portfolio management requires a deep understanding of all aspects of risk, including average mathematical expectation, volatility, correlation and probability. Careful analysis of these factors will help investors make reasonable decisions, optimize their investments and achieve their financial goals in the long term.

So, for example, an investor is considering purchasing shares of Company Z. The average mathematical expectation of this investment is 10% per annum, based on the analysis of historical data and the current situation in the industry. However, the volatility of Company Z shares is assessed as high, with possible fluctuations in profitability from -20% to +30% throughout the year.

Thus, the investment risk for this investment is average, since the average mathematical expectation is 10%, but the volatility is quite high, which increases the chances of both high profits and significant losses. An investor should carefully consider the pros and cons before deciding to purchase shares of Company Z.

Let's consider another example. We have two investment portfolios A and B. A: M(A)=10%, σ=20%, M(B)=5%, σ=10%.

Basing on the data, we can draw the following conclusions: the amount of investment risk for portfolio A is higher than for portfolio B. This is due to the higher volatility of portfolio A, that increases the chances of receiving both high profits and significant losses.

Thus, when assessing investment risk, it is important to consider not only the average mathematical expectation, but also fluctuations of the possible result to make a reasonable decision on choosing an investment portfolio.

In the economic literature there are three main investment strategies to which an investor can resort. All of them are distributed mainly according to the risk level and the type of assets used.

1) Conservative investment strategy (use of the most reliable instruments, such as deposits, government bonds, Eurobonds, stable currencies and precious metals, i.e. those ones, that will not lead to an absolute loss of profit in case of negative external effects). David Rubenstein said, "Persist – don't take no for an answer. If you're happy to sit at your desk and not take any risk, you'll be sitting at your desk for the next 20 years."

2) Balanced strategy (use of reliable assets and speculative instruments; the principle of diversification, which we discussed earlier, is quite often applied here). Ray Dalio said: "More than anything else, what differentiates people who live up to their potential from those who don't is a willingness to look at themselves and others objectively". In our opinion, it is this quote that defines the main task when applied.

3) Speculative or investment strategy (it includes a larger part of risky instruments). The investor is exposed to maximum risk using it. The most appropriate statement here is John C. Bogle's quote: "If you have trouble imagining a 20% loss in the stock market, you shouldn't be in stocks".

Let's consider an example: Olga saved up 100 000 rubles from her first job. She understands that money lying idle is most susceptible to inflation. She decides to invest her funds, creates a personal account in a bank for investing, and now she faces question of where to start from, where to invest them. She has two options to consider:

1) Investment in shares of Company A: the cost of 1 share is 100 rubles (i.e. Olga can purchase 1000 units of shares), the probability of success calculated by experts, is 50% (which is quite risky), the estimated possible profit is 150% (cost for 1 share will increase from 100 rubles to 150). Thus, in case of success, Olga's profit will be 50 000 rubles.

2) Investment in bonds of Company B. In this case, Olga's guaranteed profit will be 10 000.

The risk analysis shows that Company A shares are a riskier option since the probability of success is only 50% and the possible profit could be much higher or lower. While bonds of company B are a more reliable option, as they guarantee a fixed income.

And if we consider the option specifically for a beginner, then it is better for Olga to choose the second option, as the least exposed to risk.

IV. Conclusion

Thus, investment risk assessment is a complex and many-sided process that requires considering many factors, ranging from the degree of market volatility to the financial literacy and emotional stability of the investor. The ability to analyze emerging trends and manage these factors helps to minimize risks and increase one`s chances of achieving the desired results.

The famous economist John Keynes, in his work "The General Theory of Employment, Interest and Money," wrote "The game of professional investment is intolerably boring and over-exacting to anyone who is entirely exempt from the gambling instinct; whilst he who has it must pay to this propensity the appropriate toll". His quote quite clearly describes human activity in the field of investment.

References

[1] Malkiel B. Efficient capital market: the case of the stock market. – M.: Olimp-Business, 2016. – 416 P.

[2] Davidson P. Investments. – St. Petersburg: Peter, 2015. – 608 P.

[3] Bernstein W. Opposing analysts solve financial mysteries: in search of success in the stock market. – M.: Williams, 2019. – 400 P.

[4] Loftstrom M., Luks F. Risk management in investment projects. – M.: HSE Publishing House, 2018. – 234 P.

[5] Lieva I.A., Maslieva L.V. Investment analysis and securities portfolio management. – M.: KNORUS, 2017. – 368 P.

[6] Damodaran A. Theory and practice of assessing the value of financial assets. – M.: Williams, 2015. – 1222 P.

[7] Graham B., Dodd J. Safe investing in the period of instability. – M.: Alpina Publisher, 2016. – 320 P.

[8] Bekoeva A. A. Investment literacy as a higher level of formation of financial culture and an integral part of the social goals of sustainable development / A. A. Bekoeva // International scientific and practical conference of young scientists and specialists on sustainable development, investments and financial risks "Finatlon Forum": Conference proceedings, Moscow, April 25, 2023. – Moscow: Federal State Autonomous Educational Institution of Higher Education "Moscow Polytechnic University", 2023. – pp. 502-512.

[9] Mirkin B. I., Dimitrova S. D., Mirkin L. B. Market statistics and analysis: textbook. – M.: Finance and Statistics, 2019. – 406 P.

[10] Kuptsov, M.I., Yablochnikova, I.O., Yablochnikov, S.L., Dzobelova, V.B. & Mineev, V.I. (2020). Modeling Internet Business Optimization Processes, 2020 International Conference on Engineering Management of Communication and Technology (EMCTECH), Vienna, Austria, 2020, pp. 1-5, doi: 10.1109/EMCTECH49634.2020.9261507.

[11] Zhukov V. A. Investment analysis in the securities market. – M.: Publishing URAIT, 2017. – 512 P.

[12] Zhang S., Markowski P. Portfolio management. – M.: INFRA-M, 2018. – 384 P.

[13] Shelopaev F. M. Investment risks and methods for their determination // News of the Tula state university. Economic and legal sciences. 2011. No. 2-1.

GREENHOUSE GAS ANALYSIS AT THE CARBON TEST SITE OF THE CHECHEN REPUBLIC: MONITORING METHODS AND RESULTS

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Abstract

The article presents the analysis of greenhouse gases at the carbon test site of the Chechen Republic, which serves as an important platform for research in the field of climate change and ecosystem management. The main focus is on the methods for monitoring carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) levels used to assess the carbon balance in various ecosystems of the test site, such as mountain, forest and steppe. The work considers both traditional methods, such as gas analyzers and meteorological stations, and modern technologies, including drones and remote sensors. The evaluation of the obtained data allowed us to identify the key sources of greenhouse gas emissions and determine their impact on the local and global climate. The results showed significant variations in greenhouse gas levels depending on the season, ecosystem type and land management practices. The article also discusses practical recommendations for optimizing monitoring methods for more accurate and effective accounting of carbon flows, as well as the significance of the obtained data for the development of climate change mitigation strategies in the Chechen Republic. The results of the study can serve as a basis for further research in the field of carbon cycle and sustainable management of ecosystems in the context of climate change.

Keywords: carbon polygons, local ecosystems, carbon flows, biodiversity, carbon management, monitoring, research, greenhouse gases

I. Introduction

There are two types of greenhouse effect: natural and enhanced. The natural greenhouse effect is caused by naturally occurring greenhouse gases and is critical to life on Earth. Without this effect, the average surface temperature of the planet would be about 33°C cooler. The enhanced greenhouse effect is due to the additional radiative forcing caused by increased greenhouse gas (GHG) concentrations caused by human activity.

The main greenhouse gases whose concentrations are increasing in the atmosphere are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs). Due to the long lifetime of these main greenhouse gases, they accumulate in the atmosphere.

Emissions from human activities are causing an enhanced greenhouse effect and climate change. The planet is currently warming faster than at any time in recorded history.

Changes in the chemical composition of the atmosphere lead to changes in weather conditions and disruption of the natural balance, which creates enormous risks for humans and all living beings on Earth.

Atmospheric levels of three major greenhouse gases – carbon dioxide, methane and nitrous oxide – have reached new records, according to the World Meteorological Organization (WMO) Greenhouse Gas Report 2021.

In 2021, atmospheric carbon dioxide levels were 149% of pre-industrial levels, mostly due to emissions from burning fossil fuels and cement production. About half of the CO2 emitted by human activity remains in the atmosphere, while the other half is absorbed by land and oceans, which act as "sinks" — systems that can absorb greenhouse gases. The balance between sources and sinks changes annually due to natural variability.

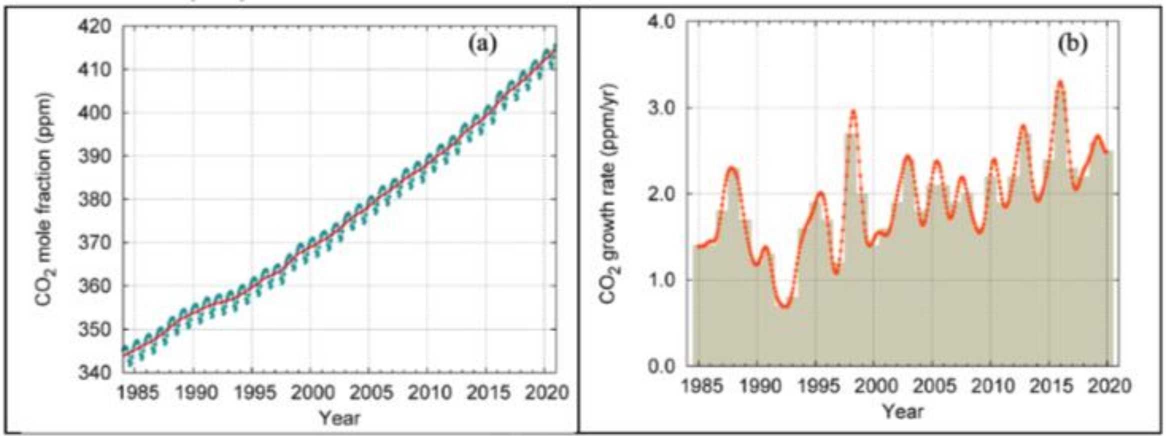

Figure 1: *Globally averaged atmospheric CO2 mole fraction (left) and growth rate (right), 1984-2020.*

As future greenhouse gas emissions increase, land ecosystems and oceans become less effective at absorbing CO2 and acting as a buffer against rising temperatures, which could lead to additional warming of the Earth's atmosphere.

Methane (CH4) accounts for about 16% of the warming effect of long-lived greenhouse gases and remains in the atmosphere for about a decade. 40% of methane in the atmosphere comes from natural sources such as wetlands, while human activities such as rice farming and biomass burning account for the remaining 60%.

Nitrous oxide (N2O) is a potent greenhouse gas and ozone-depleting substance. It is responsible for about 7% of warming caused by long-lived greenhouse gases. Human-related sources, such as fertilizer use and biomass burning, account for about 40% of its presence in the atmosphere.

II. Methods

Concentrations of carbon dioxide (CO2), the most important greenhouse gas, reached 413.2 parts per million in 2020, 149% of pre-industrial levels. Methane (CH4) is 262% and nitrous oxide (N2O) is 123% of the levels that existed in 1750, when human activity began to upset the Earth's natural balance. The economic downturn caused by COVID-19 has not had a noticeable impact on atmospheric greenhouse gas levels and growth rates, although there has been a temporary decline in new emissions.

With continued emissions, global temperatures will continue to rise. Given the long lifetime of CO2, the temperature levels already recorded will persist for several decades even if emissions are rapidly reduced to zero. This, along with rising temperatures, will lead to more frequent extreme weather events, including intense heat and rain, melting ice, rising sea levels, and ocean acidification, with far-reaching socioeconomic consequences.

About half of the CO2 emitted by human activity remains in the atmosphere, while the other half is absorbed by oceans and land ecosystems. The report raises the possibility that the ability of land and ocean ecosystems to act as "sinks" may decline in the future, reducing their ability to absorb carbon dioxide and offset more severe temperature increases.

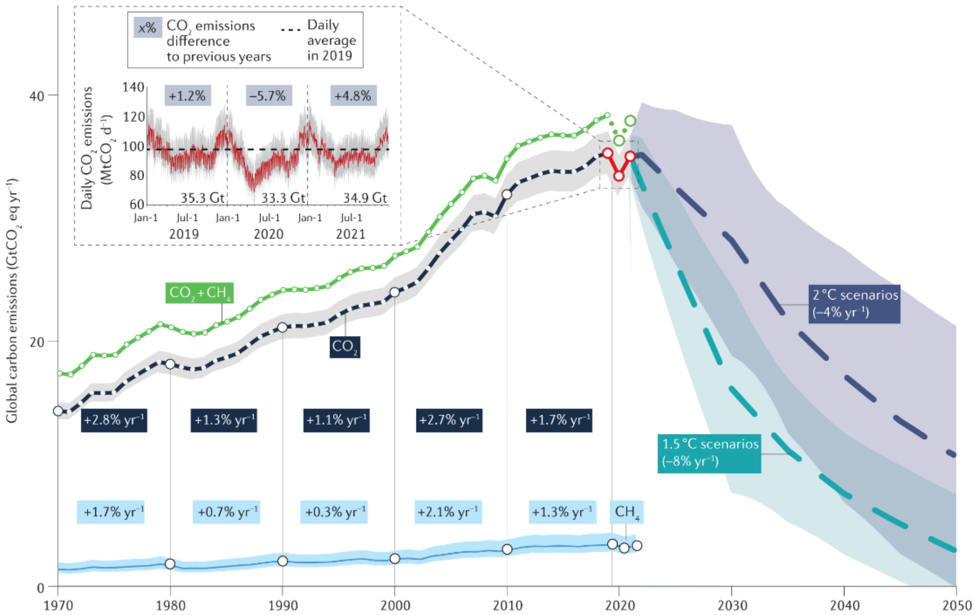

Figure 2: *Global CO_2 and CH_4 emission trends*

Global CO $_2$ emissions have exhibited a rapid increase (Fig. 2). However, embedded within this long-term trend are interannual fluctuations arising from global energy, finance and health crises. For example, during 2020, global lockdowns owing to the COVID-19 pandemic temporarily reduced CO_2 emissions [1 , 2] . The Carbon Monitor program [1,3] — which provides near-real-time daily global CO $_2$ emissions from power generation (29 countries), industry (73 countries), road transportation (406 cities), aviation and maritime transportation, and commercial and residential sectors (206 countries) - offers an opportunity to track the evolution of these CO $_2$ emissions, and in doing so, assess remaining carbon budgets and progress in reaching the Paris Agreement. Here, we document the status of CO $_2$ and fossil CH $_4$ emissions for 2021, revealing a rebound from COVID-related 2020 reductions and a corresponding decrease in the remaining CO $_2$ budget.

According to the report, from 1990 to 2020, radiation exposure— warming effect on our climate — long-lived greenhouse gases increased by 47%, with CO2 accounting for about 80% of that increase. The data is based on monitoring by the WMO's Global Atmosphere Monitoring network. The Greenhouse Gas Bulletin provides a clear scientific message for climate negotiators at COP26. "At the current rate of increase in greenhouse gas concentrations, we will see temperature increases by the end of this century that significantly exceed the Paris Agreement goals of limiting the temperature increase to 1.5 to 2 degrees Celsius above pre-industrial levels," said WMO Secretary-General Professor Petteri . Taalas : "We are on the wrong path."

"The amount of CO2 in the atmosphere passed the 400 parts per million mark in 2015. And just five years later it exceeded 413 ppm. This is not just a chemical formula and numbers on a graph. It has serious negative consequences for our daily lives and well-being, for the state of our planet and the future of our children and grandchildren," added Professor Taalas .

"Carbon dioxide stays in the atmosphere for centuries, and in the oceans even longer. The last time the Earth experienced similar concentrations of CO2 was 3-5 million years ago, when the temperature was 2-3°C higher and sea levels were 10-20 meters higher than now. However, there were not 7.8 billion people on the planet then ," said Professor Taalas .

"Many countries are now setting carbon neutrality targets, and we hope that COP26 will see a sharp increase in commitments. We need to translate our commitments into actions that impact the gases that cause climate change. We need to rethink our industrial, energy and transport systems, as well as our way of life."

III. Results

Carbon landfills play an important role in combating climate change and sustainable management of natural resources. significance Can highlight in several key aspects :

1. **Carbon Balance Monitoring**: Carbon polygons serve as sites for scientific research into the carbon cycle. They monitor greenhouse gas concentrations to assess the level of carbon uptake by ecosystems and the impact of human activity on climate.
2. **Technology development and testing**: Carbon polygons develop and test new technologies and methods to reduce greenhouse gas emissions and increase carbon sequestration. This includes agroforestry practices, rotational grazing, and other sustainable agricultural approaches.
3. **Biodiversity conservation**: Carbon landfills help preserve natural ecosystems and biodiversity. They create conditions for the restoration of degraded lands and support the sustainability of ecosystems, which is important for combating climate change.
4. **Education and Outreach**: These sites also serve an educational function, providing opportunities to study ecology, climate and sustainable development. They serve as a place for learning and sharing experiences among scientists, students and local communities.
5. **Stimulating sustainable development**: Carbon landfills contribute to the development of local sustainable development strategies that can be adapted to specific regional conditions. This includes the creation of jobs in environmental protection and sustainable farming.
6. **Global collaboration**: Carbon polygons facilitate international collaboration on climate change research. They can serve as platforms for sharing knowledge and best practices between countries and research institutions.

Carbon landfills are thus an important tool in the fight against climate change, providing both scientific data and practical solutions to improve the carbon balance and conserve natural resources.

Carbon polygons play a key role in understanding and managing greenhouse gases and combating climate change. They are unique research sites where the carbon balance and concentrations of greenhouse gases such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are monitored. This data helps to assess the impact of human activity on climate and identify sources and sinks of carbon.

Carbon landfills also develop and test new technologies and methods to reduce greenhouse gas emissions and increase carbon sequestration. This can include sustainable agricultural practices such as rotational grazing and agroforestry , which help conserve biodiversity and restore degraded land.

Simplified scheme showing greenhouse gases (GHG) and their effects on plants. GHG (H_2O vapor, clouds, CO_2, CH_4, N_2O, and NO) have both natural and anthropogenic origin, contributing to greenhouse effect. Short-term effects of GHG increase is mainly CO_2 rise, that activates photosynthesis (PS) and inhibits stomatal opening (SO). Long-term effects of GHG increase are extreme climate changes such as floods, droughts, heat. All of them induce the generation of reactive oxygen species (ROS) and oxidative stress in plants. Nitric oxide (NO) could alleviate oxidative stress by scavenging ROS and/or regulating the antioxidant system (AS). GHG and volatile organic compounds (VOC) react in the presence of sunlight (E#) to give tropospheric O_3. Although tropospheric O_3 is prejudicial for life, stratospheric O_3 is beneficial, because filters harmful UV-B radiation. The size of arrows are representative of the GHG concentration.

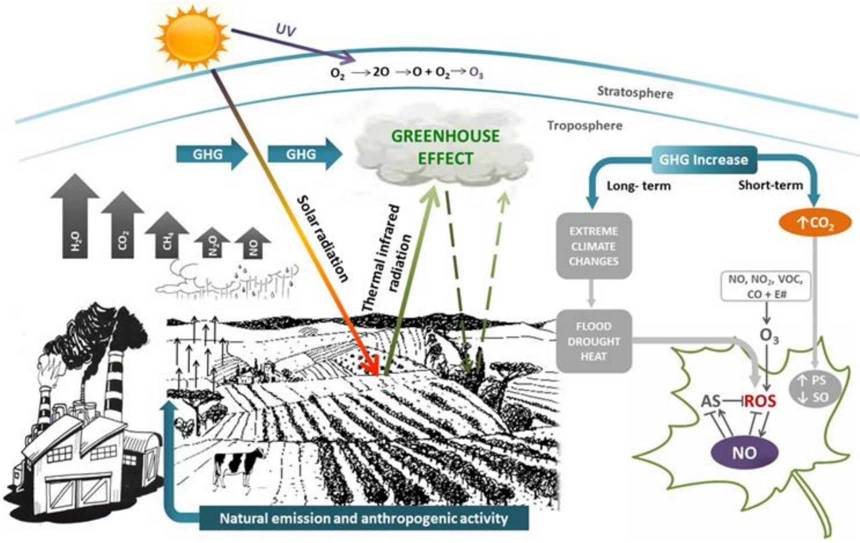

Figure 3: *Greenhouse gases*

The educational function of carbon polygons is also important: they provide an opportunity for learning and exchange of experience among scientists, students and local communities. This contributes to the development of local sustainable development strategies that are adapted to the specific conditions of the region and creates jobs in the field of environmental protection.

In addition, carbon polygons stimulate global cooperation in climate change research by serving as platforms for the exchange of knowledge and best practices between countries and scientific institutions. Carbon polygons are therefore an important tool not only for greenhouse gas research and monitoring, but also for developing practical solutions aimed at improving the carbon balance and preserving natural resources.

IV. Discussion

WayCarbon carbon testing ground in the Chechen Republic is a unique scientific platform designed for research in the field of climate change and ecosystem management. It was created to monitor and analyze greenhouse gas levels, as well as to develop and implement technologies aimed at reducing carbon emissions and increasing carbon absorption.

Main characteristics of the WayCarbon carbon polygon :

1. Scientific Research: WayCarbon conducts detailed studies of the carbon cycle, including monitoring atmospheric concentrations of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Scientists use a variety of monitoring methods, including weather stations, drones, and sensors, to collect data on carbon emissions and uptake.
2. Ecosystem diversity: The site is located in a variety of landscape types, including steppes and subalpine meadows, allowing for research in a variety of ecosystems and the assessment of their carbon sequestration capacity. Each of these zones has its own characteristics and the research conducted in them.
3. Sustainable Agriculture: The carbon site is home to a regenerative livestock project that includes rotational grazing. This helps maintain biodiversity, restore ecosystems, and increase carbon sequestration, as healthy pastures are better able to absorb CO2.

4. Educational function: WayCarbon also serves as a platform for education and awareness-raising among local communities and students. Participation in research and educational programs helps to shape the next generation of specialists in the field of ecology and sustainable development.

5. Global collaboration: The site actively collaborates with international scientific organizations and universities, facilitating the exchange of knowledge and best practices in the field of climate change research.

6. Socio-economic aspects: The WayCarbon carbon landfill creates new jobs and contributes to the development of the local economy through sustainable management of natural resources and the implementation of environmentally friendly technologies.

WayCarbon carbon polygon in the Chechen Republic is an important tool for combating climate change, providing essential data for monitoring greenhouse gases and developing practical solutions. Its unique scientific base and focus on sustainable development help preserve ecosystems and shape a future focused on environmental protection and social well-being.

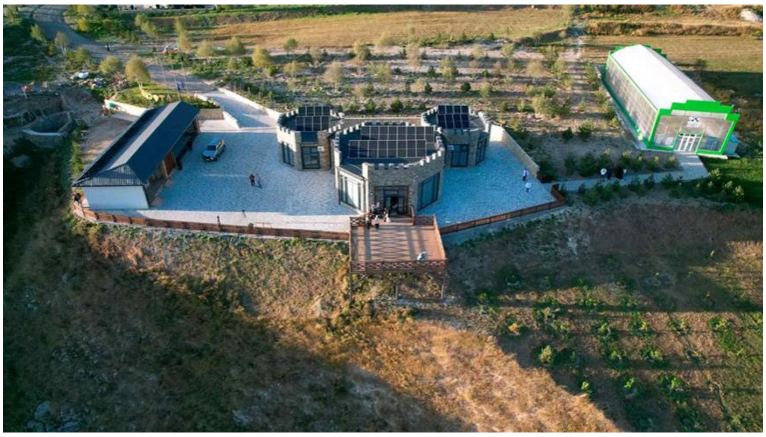

Figure 3: *Carbon Polygon of Kadyrov Chechen State University*

Another way to achieve carbon neutrality is to create conditions for the absorption of carbon dioxide (CO2), which helps offset carbon emissions. This can be done, for example, by planting grasses and trees with high carbon sequestration potential.

What is carbon sequestration? It is the process of absorbing carbon, in this case CO2. The site actively monitors emissions, i.e. the amount of carbon dioxide released from the soil, and the rate at which it is absorbed by plants. The goal is to achieve carbon neutrality, which means zero emissions versus carbon sequestration.

Paulownia, a tree known for its high carbon sequestration potential, was chosen as one of the recommended plant species. In addition, poplar trees provided by the Voronezh Forestry University are also planted at the landfill. Both of these trees are characterized by fast growth, which makes them suitable for carbon absorption projects.

There are plans to introduce other native crops that will also contribute to carbon sequestration. According to forecasts, the carbon farm area will reach 30 hectares by the end of the year. This will significantly increase the volume of carbon dioxide absorption and will contribute to achieving carbon neutrality at the landfill.

At the carbon polygon in the mountains, you will be shown greenhouses where paulownia and poplar trees are grown. These plants have a high potential for absorbing carbon dioxide, which makes them important for projects to improve the carbon balance in the region.

In the laboratory of the engineering center, you will be able to see young seedlings in test tubes. Paulownia, known as one of the most effective trees in terms of carbon sequestration, undergoes a special adaptation process to successfully take root in mountain conditions. First, the seedlings are placed in laboratory test tubes, where they develop in a controlled environment. Then they are transplanted into pots, where they continue to grow and prepare for more difficult conditions. Only then do the young trees go to the greenhouses of the carbon polygon, where they receive the necessary care and attention.

Figure 4: *Planting Paulownia*

The experts at the site will provide detailed information on all stages of growing trees with high sequestration potential. In addition, scientists conduct research and study the sequestration potential of other plants, such as mulberry, willow, linden and ash. This research helps to understand which plant species are most effective in absorbing carbon dioxide in different climates and which of them can successfully grow in mountainous areas. Thus, the carbon polygon not only contributes to the fight against climate change, but also develops scientific knowledge about the vegetation that can help in this process.

The WayCarbon carbon polygon and the A.A. Kadyrov Chechen State University play an important role in achieving carbon neutrality in the Chechen Republic. Thanks to the work carried out, the university territory has already achieved carbon neutrality, which is a significant achievement for the region. At present, it is planned to formalize the status of the first climate-neutral Russian university in the Institute of Global Climate and Ecology. The absence of large-scale production in the republic is an important factor contributing to the implementation of environmental initiatives, since it helps to avoid significant greenhouse gas emissions.

The university's expert council of professors believes that the region is likely to be carbon neutral, but evidence needs to be provided to confirm this. The initiative is actively building evidence bases to assess the university's impact on the environment. Factors such as emissions from transport, energy consumption, and the implementation of climate projects aimed at absorbing CO2 are taken into account.

WayCarbon carbon landfill is planted with plants with high carbon sequestration potential, such as paulownia and poplar. These trees grow quickly and significantly contribute to the absorption of CO2. By the end of the year, the carbon farm is planned to be expanded to 30 hectares, which will help increase the volume of carbon absorption and bring the university closer to carbon neutrality. If the results of the projects confirm a zero or negative carbon impact, CSU will be able to officially secure its status as a carbon neutral university. This will be a significant contribution to efforts to combat climate change both at the regional and national level.

Acknowledgments

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References

[1] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev, L. Gatsaeva, M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009.

[2] Filipchuk A., Moiseev B., Malysheva N., Strakhov V., Environmental Development 26, 68–75 (2018)

[3] Kornienko TV Questions of linguistic kinship, 2013. No. 9. P. 155-162.

[4] Munchaev RM, Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House, 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L. : Gidrometeoizdat , 1979. 408 p.

[8] Gakaev , R. Carbon sequestration in landscapes of the Chechen Republic / R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 193-196. – DOI 10.24412/1932-2321-2022-366-193-196. – EDN KHSSVY.

[9] Khotinsky NA, Savina SS Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin VI, Deniz DS Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11.No. 4. P. 1893-1904.

[11] Gakaev, R. Features of Landslide Manifestations in the Mountainous Parts of the Chechen Republic / R. Gakaev, R. Ahmieva, L. Dzhandarova // BIO Web of Conferences. – 2023. – Vol. 63. – P. 03004. – DOI 10.1051/bioconf/20236303004.

DIGITAL TECHNOLOGIES AND THE INTEGRATION OF A GREEN ECONOMY: LEGAL PECULIARITIES AND ELECTRONIC TRANSACTIONS

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Abstract

Digital and electronic transactions enable to facilitate e–commerce and, based on the use of a green economy, eliminate obstacles to environmental pollution.
The study shows that there are the leaders of the countries which use the institutional and legal norms of the "green economy" in the process of electronic agreements, such as Germany, Great Britain, Hong Kong, Singapore, while at the legislative level these countries determine the norms that regulate digital signature, the use of asymmetric cryptosystem technology, two–factor authentication, storing information in the form of electronic records, while the potential for digitalization is more typical for the finance and insurance industry.
Is important to use legal instruments of using the electronic transactions in the terms of the greening process and the development of state policy at the national and territorial levels. Digital technology and ecology are proved to be two cross–cutting issues that relate to public actions. The participation of all stakeholders in public policy development, transparency and accountability are of great importance.

Keywords*:* digitalization, digital transactions, electronic transactions, ecosystem, digital signature, digital transformation

I. Introduction

Ensuring the use of this system is predetermined by a long–term impact on the development and creation of a competitive digital economic environment, a positive impact on the efficiency and transparency of agreements (Abramova et al., 2023), (Zverkova et al., 2023).

So, the following foreign scientists considered in the works (Davitadze et al., 2023). The Growth and Development of E–Commerce. (Gorbacheva et al., 2021), Harmonisation of the rules on electronic commerce and Serbian law. The Digital Currency Challenge for the Regulatory Regime.

II. Literature Review

The economic literature analyzes various scientific issues of using digital transactions, identifies theoretical and methodological approaches related to green technologies. Among the scientists who have made a significant contribution to these studies are: who focuses on innovations and knowledge which have an impact on the development of economy digitalization.

Cartwright study agreements, conclusion of contracts, release of liability and unfair conditions, deals with the characteristics of an offer or acceptance, the identification of the moment of concluding an agreement and risks.

Elliot focus on the conclusion of an agreement after the proposal is accepted without further negotiations, to the interconnection of the digital economy, the modernization of relations between a human and the environment, the transformation of the business model, focuses on the state regulation of e–commerce and tools for the formation of a single Eurasian economic space, etc.

III. Methods

The general scientific and special methods, such as deduction and induction, statistical analysis were used to solve the set goals. A two–part methodology was used in the study on digital transactions and the impact on a green economy. Firstly, a systematic approach was applied in a general form, when digital transactions were considered taking into account feedback, the impact on the ecosystem, etc.

IV. Results

In addition to a wide range of problems, from collecting detailed digital information online to processing data, it is important to focus on the improvement of ecosystems condition.

Table 1*: Leaders of countries using institutional and legal norms of the "green economy": electronic transactions and digital signatures*

Countries	Name of law	Key features and peculiarities
Leader in cryptography		
1. Great Britain (leader in cryptography)	Electronic Transactions Law	1.1. Supports the use of asymmetric cryptosystem technology 1.2. Regulates the provision of cryptographic services 1.3. Defines and provides confirmation, legal status of an electronic signature
leader in digital transactions, processes and the creation of a paperless economy		
2. Germany (leader in digital transactions, processes and the creation of a paperless economy)	Law on Digital Signature	2.1. Use of electronic signiture: SES–*standard electronic signiture*; QES – *qualified electronic signature*; AES – *authentic electronic signature*. 2.2. Most agreements only require a simple electronic signature 2.3. *Electronic signatures including seals, time stamps, delivery service registrations and certificates to authenticate websites* are used
Leader in two–factor authentication		
3. Singapore (leader in two–factor authentication)	Electronic Transactions Law	3.1. Electronic records can be used to express an offer or acceptance in conclusion of a contract 3.2. A method to identify the person who signs two–factor authentication is used

		3.3. The availability of an electronic signature panel for capturing signatures 3.4. Use of distributed ledger technology, smart contracts and biometrics
Leader in the preservation and recognition of electronic records		
4. Hong Kong (China) (leader in the preservation and recognition of electronic records)	Electronic Transactions Law	4.1. Provides a legal basis for the recognition of electronic records and signatures, giving them the same legal status as on paper 4.2. Signature requirement, according to the law, can be done by any form of electronic signature and submission or storage of information in the form of electronic records
5. Saudi Arabia	Electronic Transactions Law	5.1 Electronic transactions: transactions which are carried out by electronic means. 5.2 Transactions: a procedure or group of procedures that is performed between two or more parties to create obligations for one party or mutual obligations. 5.3 The clauses of the law are applied to transactions in which the parties agree to carry out their transactions by electronic means 5.4 Authentication procedures are considered commercially acceptable if they take into account the commercial terms of the parties to the transaction.
6. Australia	Electronic Transactions Law	6. Duration of electronic transactions For the purposes of Commonwealth law, a transaction is not invalid because it was carried out fully or partially through one or more electronic messages.
7. Canada	Electronic Transactions Law	7. Errors that may occur when working with electronic agents An electronic record created by an individual using an electronic agent of another person's is not valid and unenforceable if the individual has made a material error in the record
8. Singapore	Electronic Transactions Law	8.1 Electronic Transactions Act (ETA) (Cap 88) was first adopted in July 1998 to provide a legal basis for electronic signatures and to give predictability and certainty to contracts concluded electronically. 8.2. In July 2010, the ETA was canceled and re–enacted to ensure the permanent security and use of electronic transactions. 8.3. Commercial Code for Electronic Commerce Transactions: ETA was adopted to create a predictable legal environment for electronic commerce. It clearly defines the rights and obligations of the parties to the transaction.

Source: it was developed by the authors based on materials
https://www.legislation.gov.au/Details/C2011C00445
https://www.iclc–law.com/ar/
https://www.bclaws.ca/civix/document/id/complete/statreg/01010_01
https://www.imda.gov.sg/regulations–and–licensing–listing/electronic–transactions–act–and–regulations
https://www.scielo.br/scielo.php?pid=S0103–40142012000100024&script=sci_arttext

The analysis of the leading countries which use the institutional and legal norms of «green economy» increasingly shows a significant gap between countries with weak market economy and leading countries (Table 1). Germany is the leader in digital transactions, creating paperless economy. Along with this country, the active participants in this process of electronic agreements are: Great Britain, Singapore, Hong Kong, which are developing a rather effective model of electronic transactions in the terms of using green technologies.

Despite the inequality in the digital economy, the enterprises in the countries have opportunities to get benefit from the digitalization of electronic transactions. Such opportunities can arise from the productive use of global digital platforms.

The present and future shifts and changes, that lead to the need for faster use of digital transactions, can be caused by several reasons, often simultaneously, at the level of customer behavior and expectations, new economic realities, social shifts, ecosystem/industry disruption and (accelerating implementation and innovation) emerging or existing digital technologies.

Wassily Leontief proposed a theory of general equilibrium that can be implemented empirically, and proved that the so–called partial analysis cannot provide a sufficiently broad basis for a fundamental understanding of the structure and functioning of economic systems. He began using the large–scale mechanical computing machine in 1935 and the electronic computing machine in 1943 while compiling the first input–output tables for the American economy. In recent years, he has focused on the analysis of environmental disruption and economic growth, while maintaining an active interest in the broader issues of scientific methodology for social and economic policy, as well as evolutionary and revolutionary changes.

Jean Tirol, French Nobel laureate, noted that "as innovation is deeply rooted, the age of knowledge will open up many opportunities ... universities or highly educated people on their own cannot define the era of innovation, as some of the startups started from humble beginning to succeed). This potential starts to be implemented in the age of information, digital and telecommunication technologies.

Emmanuelle Benicourt, quoting such an authoritative scientist, stated: «information is the basis for the allocation of resources based on the action of the market mechanism».

The electronic transactions in the legislation of some countries of the world are determined primarily by key parameters using any type of modern technical tools, i.e. they represent any act or contract concluded or subject to the partial or full execution by electronic communications using electrical, digital, magnetic, wireless, optical, electromagnetic, or any other equivalent tools.

It must be noted that such types of agreements began to appear to a greater extent due to the development of the Internet and computer technologies. The academician S.Glazyev notes that «ubiquitous computerization and a large–scale expansion of the scope of computer systems have initiated the emergence of the current topic of the digital revolution» (Glazyev, 2020). Due to the strengthening of these trends and the automation process for many industries, this will lead to the creation of new jobs (more than 2 million all over the world) for such professions as analysts, software developers, engineers and other highly qualified experts. However, this will lead to the reduction of 7 million jobs requiring the involvement of mid–level personnel, whose work will be performed by robots in future.

The electronic contracts, that today enterprises exchange and propose the possibility to dynamically, automatically create and apply behaviorally related services, are designed to achieve business goals. In cases when there are many contracts within a particular application, it can be difficult to determine whether the system can reliably perform all of them, but electronic contracts with computer analysis can automate the verification process.

And nowadays, we are becoming the participants of the fourth revolution – the digital one, which led to a large–scale transformation of all sectors of the economy.

The smartphone has become a point for receiving and providing services, a key link for making transactions. At the same time, «the gross value of goods in the cross–border e–commerce market ... will grow by about 25% annually till 2020 ... New 'micro–jobs' platforms, such as Upwork and Freelancer also provide entrepreneurs and enterprises with the ability to sell services online».

The fact that people will become entrepreneurs can significantly reduce the expected unemployment rate due to workplace automation.

Changing to another profession in the framework of paid employment will create preconditions for additional costs, for example, connected with acquiring a new qualification (Fossen & Sorgner, 2018). That is, the part of the employees will gradually be released from their jobs and may become interpreters who will be able to use environmental standards in a new way.

It should be taken into consideration that at the same time many Western and Northern European companies developed their main IT systems in the 1970s and 80s. These systems functioned properly until the last decade. However, in recent years, the IT environment has changed dramatically with the emergence of web communications, network computing and plug–

and–play systems. Having joined the digitization race quite late, the digital competitors are often less attached to such legacy systems because they do not have to discount the large investments of the previous generation. Consequently, it is easier for them to master new technologies, which allows them to jump over intermediate technologies. An example is the banking sector. In Central and Eastern Europe, financial transactions based on the payment cards were made without using checks. Today, the countries of the region can be proud of one of the highest rates of adopting contactless payment in the world. Thus, while digital competitors may find it difficult to compete in the traditional economy, they use them easily in the digital economy.

Potential for automation and digitalization in industry (Figure 1)& Digitalization index (Figure 2).

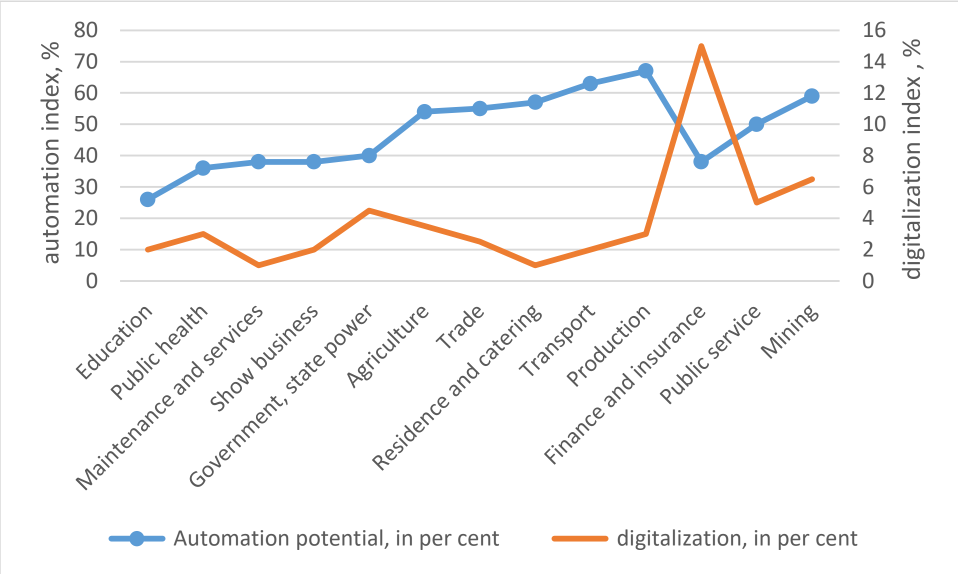

Figure 1: *Potential for automation and digitalization in industry*

Source: it was compiled by the authors based on data, Eurostat; McKinsey Global Institute; McKinsey analysis

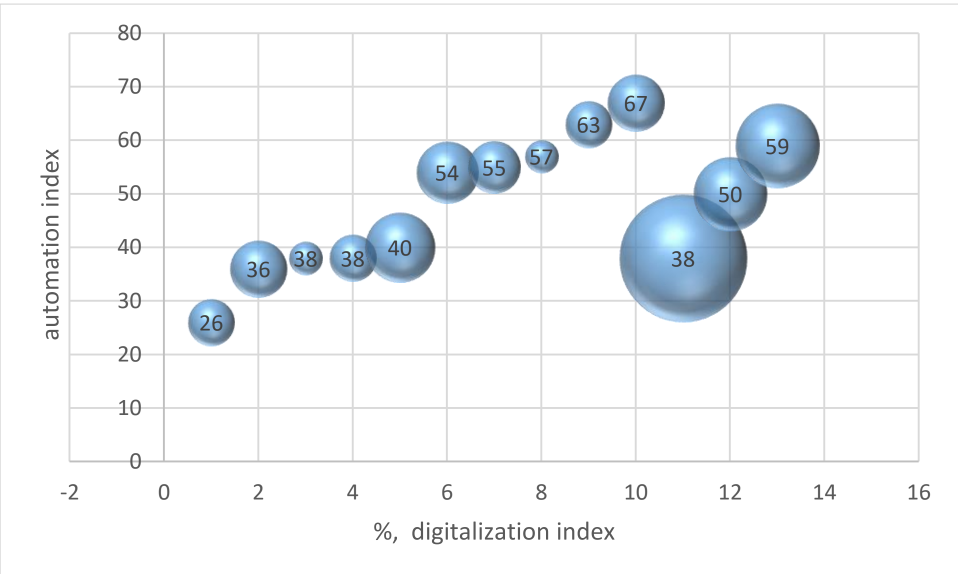

Figure 2: *Digitalization index*

Source: it was compiled by the authors based on data, Eurostat; McKinsey Global Institute; McKinsey analysis

As Figure 2 and Figure 3 shows, the potential for digitalization is more common in the finance and insurance industry than in the education and health sector.

Therefore, e–commerce can be classified according to the criterion of participants in virtual transactions (Table 2).

Table 2: *E–commerce and classification according to the criterion of participants in virtual transactions*

No.	Classification	Meaning
1.	B2G (Business–to–Government)	implies the implementation of transactions between economic entities (legal entities)
2.	B2B (Business–to–Business)	implies the implementation of transactions between economic entities of the market. Technically, such interaction is usually based on specialized open Internet platforms with a standard set of tools and rules. Interactive databases enable not only to provide a large volume of proposals, but also to track the process of order execution. B2B transactions often include organizing wholesale supplies of goods and placing orders at manufacturing enterprises
3.	B2C (Business–to–Consumer)	a type of e-commerce, which implies the transactions between legal entities and individuals. Most often it is retail via Internet. These can be specialized seller portals, electronic trading sites or direct mailings.
4.	C2C (Consumer–to–Consumer)	a type of e-commerce, which implies the transactions between individuals. This is usually trading through electronic bulletin boards (Slando, Avito, etc.) or on electronic trading sites (Molotok, Meshok, eBay, Delcampe, etc.)

Such virtual transactions can be considered as «green technologies, creating hybrid physical–digital solutions, increasing the efficiency of business processes through which eco–innovation is developed, and providing new functional opportunities».

The indicators of green growth in the Republic of Kazakhstan are given in Table 3.

Table 3: *Green Growth Indicators*

		1990	2010	2013	2016
All technologies (total patents)		1039	2384,15	2639,43	2695,71
Selected environment–related technologies		93,08	322,64	278,48	246,92
Environmental management		63,42	145,83	114,25	121,33
Environmental management	Air pollution abatement	15	40,42	36,58	19,5
	Water pollution abatement	34,33	71,17	44,67	50,17
	Waste management	14,08	32,75	33	47,67
	Soil remediation	0	0	0	3
	Environmental monitoring	0	1,5	0	1
Water–related adaptation technologies		8	25,5	30,83	17,5
Water–related adaptation technologies	Demand–side technologies (water conservation)	7	15,5	20	11,5
	Supply–side technologies (water availability)	1	10	10,83	6
Climate change mitigation		52,58	227,31	208,15	169,08
Climate change mitigation	Climate change mitigation in information and communication technologies (ICT)	0	4,17	14,03	6,5
	Climate change mitigation	11,5	128,95	100,95	65,83

	technologies related to energy generation, transmission or distribution				
	Climate change mitigation technologies related to wastewater treatment or waste management	16,83	27,42	27,33	30,67
	Capture, storage, sequestration or disposal of greenhouse gases	1	16,5	10,5	6,5
	Climate change mitigation technologies related to buildings	4	23,83	45,25	25
	Climate change mitigation technologies in the production or processing of goods	19,58	71,98	62,33	69,67

Source: https://stats.oecd.org/Index.aspx?DataSetCode=GREEN_GROWTH

The developed regulatory legal acts in the field of electronic transactions in Kazakhstan are presented in Table 4.

Table 4: *Regulatory legal acts in the field of electronic transactions*

№	Name
1	Civil Code of the Republic of Kazakhstan (general part) № 268–XII dated December 27, 1994 (as *amended* on 10.01.2020)
2	Letter of the territorial Tax code No.1839 "Regarding the accounting and taxation of electronic accounting units of the Webmoney payment system, intended for making payments on the Internet"
3	The order of the acting Minister for Investment and Development of the Republic of Kazakhstan No.74 On approval of requirements for the content, maintenance and information filling with electronic information resources of the e–government web–site dated January 26, 2016

Source: developed by the authors

From Table 1 it can be seen that electronic transactions are very relevant in Kazakhstan, in connection with this, various legal documents are being developed related to the regulation of electronic transactions.

Therefore, the interaction between the parties should be focused in electronic transactions. In fact, a satisfactory emulation of the concepts associated with the definition of who are the specific parties involved in the offer and acceptance on the basis of which the transaction is carried out, must be ensured in order to achieve the necessary functional equivalence of the electronic transaction system. Therefore, today it is important to take into consideration the fact that individuals can create automated electronic agents with which the other party interacts when concluding a contract.

Although the potential of Internet for saving material and energy resouces cannot be denied, it is still too early to say about positive impact of the emerging digital economy on the environment. We do not believe that our society has fully reached the stage when our science and engineering are ready to reconcile our economy and our environment in order to bring about a Copernican pivot which is characterized by saving hydrogen fuel, landless agriculture and an industrial ecosystem in which waste virtually disappears. The growth of e–commerce further stimulated business expansion.

However, in the Republic of Kazakhstan it is important to use sufficiently powerful legal tools of using electronic transactions in the terms of the greening process and the development of state policy. Since at the national and territorial levels, the digital technologies and the environment are two cross–cutting issues that relate to public actions.

Digital technologies provide new tools to support these efforts. In addition to participation of citizen, digital technologies also facilitate the increase and interaction of persons who can contribute through their initiatives to the achievement of common environmental goals: citizens and groups, start–ups, large global operators, etc. Digital technologies should also have a profound impact on the content of state environmental policy. They create new tools for actions of government bodies: behavioral incentives, collaborative mobility systems, common work and production spaces, and «zero carbon society» projects.

V. Discussions

A sharp increase in digital technologies is predicted in the world and the Republic of Kazakhstan, and in this case, many enterprises will accept significant changes in the structure of the business model in the terms of digital transactions, taking into account the state of the ecosystem. The enterprises will need new collaborative technologies. At the same time, e–commerce and sales practice will have to adapt to a new digital format of interaction, which is likely to entail a significant change in legislation and programs for the digitalization of the economy (Antonenko, (2021), Archimandritova & Suptelo, (2022), Bunevich & Gorbacheva, (2022), Burykin, (2020), Gavrilova, (2020), Gavrilova & Demjanjuk,(2023), Davydovsky, (2019), Davitadze & Marakov,(2023), Dzyuba, (2021), Kamyshnikov, (2023), Kozunova, (2021), Koryakov, (2016), Koryakov et al., (2016), Kubova et al. ,(2018), Kuksin, (2020), Makovetsky & Rudakov, (2021). Panshin & Serebryakov, (2020), Suptelo & Dolgikh, (2021),Salikhov & Semenov, (2019), Slabospitsky & Slabospitskaya, (2022), Zhiltsov S. et.al.,(2018), Zonn & Orlovsky, (2019), Tebekin, (2023), Tyunyakova, (2017), Zagorov,(2022), Zubets, (2019), Zueva, 2017, Zhuravleva & Shlyakhin, (2018), Gorda, (2022) [1-18].

VI. Conclusion

In the process of development of the digital economy, the electronic transactions must contain electronic records, or data messages, electronic signatures, which are subsequently created, transmitted and stored in electronic form. Taking into account data analysis and forecast, certain types of economic activities will be expanded and have great forecasting potential. There are the leaders of the countries which use the institutional and legal norms of the "green economy" in the process of electronic agreements, while at the legislative level these countries determine the norms that regulate digital signature, the use of asymmetric cryptosystem technology, two–factor authentication, storing information in the form of electronic records, while the potential for digitalization is more typical for the finance and insurance industry. The leaders of the countries that use the institutional and legal norms of the "green economy" in the process of electronic agreements are highlighted, while at the legislative level in these countries the norms are defined that regulate the digital signature, the use of asymmetric cryptosystem technology, two–factor authentication, storing information in the form of electronic records, while the potential for digitalization is more characteristic of the finance and insurance industry.

References

[1] Fossen F., Sorgner A. The Effects of Digitalization on Employment and Entrepreneurship // – 2018. – (URL: http://conference.iza.org/conference_files/MacroEcon_2018/sorgner_a21493.pdf)

[2] Glazyev S. Great digital economy: challenges and prospects for the economy of XXI century [Electronic resource] /S. Glazyev's author blog. URL: http://zavtra.ru/blogs/velikaya_tcifrovaya_ekonomik.

[3] Kariyawasam, Kanchana. (2008). The Growth and Development of E–Commerce: An Analysis of the Electronic Signature Law of Sri Lanka'. Information & Communications Technology Law. 17. 10.1080/13600830801889301.

[4] Kaluzhsky M.L. E–commerce: marketing networks and market infrastructure /Kaluzhsky M.L.; Omsk State Technical University. – Moscow: Economics, 2014. – P.328

[5] Alhassan, T. F., Ansah, E. O., Niyazbekova, S. U., & Blokhina, T. K. (2024). The impact of foreign investment in financing sustainable development in Sub-Saharan African countries. Russian Journal of Economics, *10*(1), 60-83

[6] Pradesh A. Opportunities galore in digital economy: Nobel laureate // – 2017. – (URL: https://www.thehindu.com/news/national/andhra–pradesh/Opportunities–galore–in–digital–economy–Nobel–laureate/article16989993.ece)

[7] Romel Yu.V. The form of the contract concluded using electronic communications /Romel Yu.V.//Law Magazine – 2009 – No. 4 – P.93–96

[8] Rykov A.Yu. Civil regulation of transactions in the global computer network (Internet) Abstract for the degree of candidate of legal sciences; Specialty 12.00.03 – Civil law; Business law; Family law; Private International Law – M.: 2009. P.26

[9] Alhassan, T. F., Ansah, E. O., Niyazbekova, S. U., & Blokhina, T. K. (2024). The impact of foreign investment in financing sustainable development in Sub-Saharan African countries. Russian Journal of Economics, *10*(1), 60-83.

[10] Urekeshova, A., et al. The Impact of Digital Finance on Clean Energy and Green Bonds through the Dynamics of Spillover. International Journal of Energy Economics and Policy, 2023, 13(2), pp 441–452 DOI:10.32479/ijeep.13987

[11] Zakiryanov, B.K., et al. Development of Rural Green Tourism of Regions of Kazakhstan. Environmental Footprints and Eco-Design of Products and Processes, 2022, pp. 33–38 DOI:10.1007/978-981-19-1125-5_2

[12] Moldashbayeva, L., et al. Green bonds - A tool for financing green projects in countries. E3S Web of Conferences, 2021, 244, 10060 DOI:10.1051/e3sconf/202124410060

[13] Troyanskaya, M., et al. Instruments for financing and investing the green economy in the country's environmental projects. E3S Web of Conferences, 2021, 244, 10054 DOI:10.1051/e3sconf/202124410054

[14] Jazykbayeva, B., et al. The Growth of green finance at the global level in the context of sustainable economic development. E3S Web of Conferences, 2021, 244, 10058 DOI:10.1051/e3sconf/202124410058

[15] Abramova M., Varzin V. et al. Features of the mechanism for implementing sustainable development through the green economy. E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

[16] Zverkova A., et al. Features of the "Green" strategies for the development of banks. E3S Web of Conf., 402 (2023) 08029 DOI: 10.1051/e3sconf/202340208029

[17] Antonenko A.P. Ideological foundations of a new stage in the development of civilization // Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences. – 2021. – № 3 (29). – Pp. 5–8. doi: 10.21777/2587–9472–2021–3–5–8

[18] Archimandritova A.V., Suptelo N.P. Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – 1 (40). 85–94. doi: 10.21777/2587– 554X–2022–1–85–94

[19] Baburin S.N. Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences.– 2019. – 4 (22). – 6–12. doi: 10.21777/2587–9472–2019–4–6–12

[20] Bunevich K.G., Gorbacheva T.A. «Green» trends in the development of the world financial system // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – № 1 (40). – Pp. 52–60. doi: 10.21777/2587–554X–2022–1–52–60

THE ROLE OF ECO-TOURISM IN MITIGATING CLIMATE RISKS AND ENHANCING COMPETITIVENESS

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Abstract

Ecotourism is an important and rapidly growing sector in the tourism industry, offering unique opportunities to mitigate climate risks and enhance the competitiveness of tourism destinations. In the context of global climate change, ecotourism can play a key role in developing sustainable practices that contribute to environmental protection and the socio-economic development of local communities. This paper explores how ecotourism can be a tool for climate change adaptation, reducing negative environmental impacts while improving economic conditions in tourism regions. It focuses on successful examples of ecotourism initiatives that demonstrate how an integrated approach to ecotourism can lead to the creation of resilient ecosystems and economic prosperity. One of the key aspects of ecotourism is its ability to develop sustainable practices, such as the use of renewable energy, resource management, and biodiversity conservation programs. These practices not only reduce the carbon footprint of tourism activities, but also provide long-term economic benefits to local communities through job creation and support for the local economy. The study also examines the involvement of local communities in tourism activities as a way to improve their economic resilience and social well-being. By actively participating in ecotourism projects, local communities can gain access to new sources of income and educational opportunities, which contributes to improving their quality of life. The results show that ecotourism not only mitigates climate risks, but also increases the resilience of local economies to climate change, while providing educational and cultural benefits for tourists. Ecotourism helps to create awareness of the importance of sustainable development among both travelers and local residents, which ultimately contributes to a more harmonious coexistence between humans and nature. Ecotourism is therefore an important aspect in adaptation strategies and development of the tourism industry in the context of a changing climate. Given its potential for creating sustainable development models, this work highlights the need to integrate ecotourism into global and local strategies to combat climate change and improve the competitiveness of tourist destinations.

Keywords: Ecotourism, climate risks, competitiveness, sustainable development, environmental protection, local communities, biodiversity, renewable energy, economic growth

I. Introduction

In recent years, the global tourism industry has gained significant recognition as a vital contributor to economic development, job creation, and cultural exchange. However, this growth is accompanied by pressing challenges, particularly those posed by climate change. The tourism sector is highly sensitive to climate risks, including rising sea levels, extreme weather events, and changes in ecosystems, which threaten the sustainability of popular destinations. As these challenges intensify, there is an urgent need for the tourism industry to adopt innovative strategies that promote resilience and sustainability.

Eco-tourism has emerged as a promising approach to address these challenges, offering a pathway to mitigate climate risks while enhancing the competitiveness of tourism destinations. Defined as responsible travel to natural areas that conserves the environment and improves the well-being of local communities, eco-tourism emphasizes sustainability, education, and community involvement. By focusing on sustainable practices, eco-tourism not only reduces the negative impacts of tourism on the environment but also promotes awareness of ecological issues among tourists and local populations.

The role of eco-tourism in the context of climate change is multifaceted. Firstly, it fosters sustainable development by encouraging practices that protect natural resources and biodiversity. This includes the adoption of renewable energy sources, waste reduction strategies, and conservation efforts that can help mitigate the impacts of climate change. Secondly, eco-tourism contributes to the economic resilience of local communities by creating job opportunities and generating income through sustainable tourism activities. When local communities are actively engaged in eco-tourism initiatives, they are more likely to invest in the conservation of their natural resources, thereby fostering a cycle of sustainability and economic growth.

Moreover, eco-tourism promotes educational opportunities for both tourists and locals. Through immersive experiences in nature, travelers gain a deeper understanding of environmental issues and the importance of conservation. This increased awareness can lead to more responsible travel behaviors and greater advocacy for sustainable practices, both at home and in the destinations they visit.

Despite its potential, eco-tourism also faces challenges, including the need for effective management, the risk of over-tourism in fragile ecosystems, and the necessity for appropriate policies and regulations. Understanding the role of eco-tourism in mitigating climate risks and enhancing competitiveness requires a comprehensive analysis of its economic, environmental, and social dimensions.

This paper aims to explore the role of eco-tourism as a viable solution for addressing climate risks while enhancing the competitiveness of tourism destinations. By examining successful eco-tourism initiatives and their impacts on local communities and ecosystems, this research seeks to provide insights into best practices and strategies that can be implemented across the industry. Ultimately, this analysis will contribute to the broader discourse on sustainable tourism development in the face of climate change, highlighting the importance of eco-tourism in creating a resilient and thriving global tourism economy.

Approaches to strategy development are closely related to the analysis of complex data, which requires the use of a variety of methodological tools. These include logical modeling, inductive and deductive analysis methods, as well as statistical and economic techniques (Fig .1). These tools support the process of systematizing information and forming strong strategic foundations.

It is also important to develop coordination mechanisms and coordinated actions of all participants in the tourism industry. This will ensure a synergistic effect for the effective achievement of common goals. These measures are the foundation for an effective strategy capable of ensuring growth and sustainability both at the national and international levels, strengthening the economic basis of tourism enterprises and the entire sector as a whole.

An analysis of the current trends in the development of the tourism industry reveals a number of important issues that need to be considered when developing strategies for this sector. This involves the need to create a comprehensive regulatory framework that promotes optimal conditions for the operation of tourism and hotel enterprises, taking into account their economic, managerial and administrative contexts. Further, the emphasis is placed on strengthening the role of government regulation with the protection of the interests of all entities in this sphere. In addition, the importance of active participation of public organizations in preserving the basic principles of tourism development and establishing cooperation between government agencies, business representatives, educational and scientific institutions is emphasized.

These findings provide the basis for a strategy of profound change that involves joint efforts by governments and the private sector to carefully examine and respond to the challenges posed by the loss of tourists, stimulate investment and develop programmes that support the growth and strengthening of the sector.

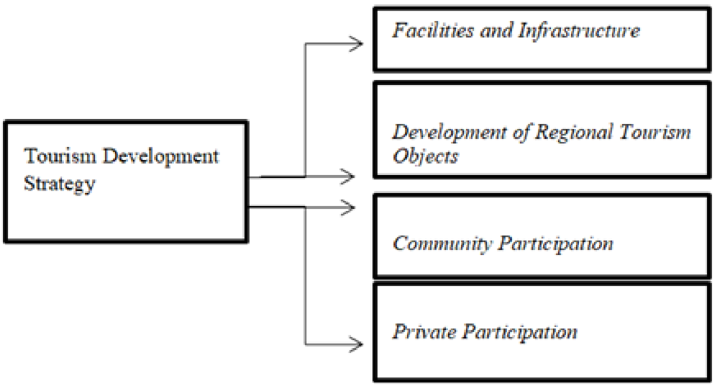

Figure 1: *Tourism Development Strategy*

Particular attention should be paid to the strategy aimed at maintaining stability in an unfavorable economic environment, which uses customer retention measures, including offering additional services, innovation and improving the overall quality of service, which helps to strengthen customer loyalty even in more difficult economic conditions.

On the other hand, the achieved growth strategy is used in situations where the company has limited capacity for innovative development or when the market is close to saturation. Here, we are talking about focusing efforts on optimizing current operations and maintaining the existing sales level by improving and modifying the tours or services offered.

The development of these strategies is based on an arsenal of tools that can solve the tasks set in the context of the current conditions. Such tools include: flexible pricing, service modernization, expansion of partnerships, brand strengthening, marketing and PR campaigns, as well as improving the quality of management and introducing innovations.

The expected results from the implementation of these strategies include, but are not limited to: successful achievement of objectives, increased revenues, enhanced market position, sustainable satisfaction of tourist needs, maximization of return on capital investment and enhanced competitive advantages. This leads to long-term sustainability and prosperity of tourism and hotel enterprises.

II. Methods

Creating a strategy for the eco-tourism industry is a multi-step process, with each step having a significant impact on the final outcome. Research confirms that the approach to strategic planning should be systematic and goal-oriented, with clear priorities and a well-thought-out schedule of specific actions.

At the initial stage – the intellectual stage – the fundamental principles on which the strategy will be built are formed, including a clear mission that unites the common goal, vision of the future and the main functions of the industry. This mission is aimed at increasing the efficiency of the industry and creating conditions for modern competition.

The next step is diagnostics, which involves analyzing external and internal conditions, opportunities and threats in order to consciously approach the formation of long-term and short-term goals. These goals must be detailed into strategic objectives that will serve as beacons in the process of implementing the strategy.

Next comes the analysis of strategic alternatives, which is focused on evaluating and comparing various approaches and development paths in order to select the most appropriate and promising one. The choice of strategy involves weighing all the pros and cons and taking into account the unique aspects of the enterprise, whether these are ultimate goals, management priorities, strategic resources, scale of operations or competitive advantages.

The final stages – implementation of the strategy and its subsequent assessment of its effectiveness – are focused on the practical application of the chosen plan and monitoring of the achieved results. This allows for fairly prompt adjustments to actions in the event of unforeseen changes in the industry or external environment and ensures business flexibility, which is one of the key aspects of a successful strategy in the dynamic tourism industry.

III. Results

The exploration of the role of eco-tourism in mitigating climate risks and enhancing competitiveness yielded several significant findings. These results illuminate the potential of eco-tourism to contribute positively to environmental sustainability, local economic resilience, and social well-being.

1. Economic Benefits of Eco-Tourism

The analysis revealed that eco-tourism initiatives have a notable positive impact on local economies. In regions where eco-tourism has been implemented, there has been a marked increase in job creation and income generation. For instance, case studies from several eco-tourism hotspots, such as Costa Rica and the Galápagos Islands, indicated that eco-tourism contributes significantly to GDP and creates employment opportunities in areas like guiding, hospitality, and conservation management.

Moreover, eco-tourism promotes the diversification of income sources for local communities, reducing their dependency on traditional sectors that may be more vulnerable to climate change, such as agriculture and fisheries. This economic diversification is crucial for enhancing the resilience of communities to climate-related shocks.

2. Environmental Impact and Conservation Efforts

Eco-tourism's focus on sustainability and conservation has led to measurable improvements in environmental management practices. Destinations that adopted eco-tourism practices reported better preservation of natural habitats and biodiversity. For example, protected areas that incorporate eco-tourism have seen increased funding for conservation efforts, resulting in enhanced ecosystem protection and restoration initiatives.

Additionally, eco-tourism promotes the use of renewable energy sources and sustainable practices among local businesses. Surveys conducted among eco-lodges and tour operators indicated a high level of commitment to environmentally friendly practices, including waste reduction, energy efficiency, and responsible sourcing of local materials.

3. Community Engagement and Social Development

The study highlighted the critical role of community engagement in the success of eco-tourism initiatives. Active involvement of local communities in eco-tourism projects fosters a sense of ownership and responsibility toward environmental conservation. Communities that participated in eco-tourism development reported improved social cohesion and enhanced pride in their cultural and natural heritage.

Furthermore, eco-tourism provides educational opportunities for both tourists and local residents. Programs that involve local guides in educating tourists about conservation practices and local ecosystems not only empower communities but also promote sustainable behaviors among visitors. Data indicated that tourists who engaged in educational eco-tourism activities expressed a higher level of environmental awareness and commitment to sustainable practices.

4. Challenges and Barriers to Success

Despite the positive outcomes associated with eco-tourism, several challenges were identified. Issues such as over-tourism in sensitive areas, lack of regulatory frameworks, and inadequate infrastructure can undermine the potential benefits of eco-tourism. In some instances, eco-tourism development has led to environmental degradation when not properly managed.

The findings also indicated that while eco-tourism can enhance competitiveness, its success is highly dependent on effective marketing and branding strategies. Destinations that successfully position themselves as eco-tourism hubs are more likely to attract visitors interested in sustainable travel.

5. Policy Implications and Recommendations

The results underscore the need for supportive policies and frameworks to maximize the benefits of eco-tourism. Governments and stakeholders must work together to establish guidelines that promote sustainable practices, protect sensitive ecosystems, and ensure equitable distribution of economic benefits to local communities.

Investment in infrastructure and capacity-building initiatives is essential for enhancing the effectiveness of eco-tourism programs. Training for local entrepreneurs and stakeholders in sustainable practices, marketing, and visitor management can contribute to the long-term success of eco-tourism initiatives.

The results of this study highlight the vital role that eco-tourism can play in mitigating climate risks while enhancing the competitiveness of tourism destinations. By providing economic opportunities, fostering environmental stewardship, and engaging local communities, eco-tourism emerges as a promising model for sustainable development in the face of climate change. To realize its full potential, however, it is imperative to address the challenges associated with eco-tourism and to implement robust policies that support its growth and sustainability.

When developing a strategy for the tourism industry, the main focus should be on its integration with the socio-economic goals of the state. This includes stimulating the development of technological innovation, attracting investment, ensuring economic stability, and helping to improve the overall level of well-being of citizens.

It is necessary to take into account the geographical location of border areas, because by doing so you create favorable conditions for the tourism industry to flourish thanks to natural advantages and international cooperation.

Improving the quality and diversity of tourism and hotel services is necessary to strengthen the market position and ensure its dynamic development. When planning economic strategies for regions, special attention should be paid to ensuring that the offers created correspond to the demands and expectations of tourists, and that their implementation is aimed at satisfying the real needs of visitors. This will contribute to the creation of conditions not only for successful competition, but also for sustainable socio-economic progress.

IV. Discussion

The findings from this study illustrate the multifaceted role of eco-tourism in mitigating climate risks and enhancing the competitiveness of tourism destinations. As the tourism sector grapples with the challenges posed by climate change, eco-tourism emerges as a viable solution that not only addresses environmental concerns but also supports local economies and communities. This discussion delves into the implications of these findings, highlighting key considerations for stakeholders and suggesting pathways for future development.

1. Integration of Economic and Environmental Goals

The positive economic impacts associated with eco-tourism demonstrate its potential to reconcile economic growth with environmental conservation. By investing in eco-tourism initiatives, stakeholders can create sustainable business models that leverage natural resources while preserving them for future generations. This dual benefit can be particularly crucial in regions where traditional economic activities may be increasingly jeopardized by climate change.

To harness this potential fully, it is essential for policymakers and industry leaders to integrate economic and environmental goals into strategic planning. This might involve creating incentives for businesses that adopt sustainable practices or providing financial support for community-led eco-tourism initiatives. Moreover, fostering partnerships between the public and private sectors can enhance resource mobilization for eco-tourism projects and ensure that they are designed to benefit both the economy and the environment.

2. The Importance of Community Involvement

Community engagement emerged as a pivotal factor for the success of eco-tourism initiatives. The findings suggest that when local communities are actively involved in the planning and implementation of eco-tourism projects, they are more likely to feel a sense of ownership and responsibility for their natural environment. This increased stewardship can lead to more effective conservation efforts and a stronger commitment to sustainable practices.

To strengthen community involvement, stakeholders should prioritize capacity-building initiatives that empower local residents with the skills and knowledge needed to participate in eco-tourism. This includes training in hospitality management, environmental education, and marketing strategies. Such investments can enhance local livelihoods while fostering a culture of sustainability that permeates the community.

3. Addressing Challenges and Risks

Despite the promising outcomes associated with eco-tourism, the study highlighted several challenges that could hinder its effectiveness. Over-tourism remains a significant concern, particularly in ecologically sensitive areas. If not carefully managed, an influx of visitors can lead to habitat degradation, resource depletion, and negative social impacts.

To mitigate these risks, it is essential for eco-tourism destinations to implement robust visitor management strategies. This could involve setting visitor caps, implementing zoning regulations, and promoting off-peak travel. Additionally, developing clear guidelines for eco-tourism practices can help ensure that all stakeholders adhere to sustainable principles. Collaboration between governments, non-governmental organizations, and the private sector is crucial for creating these guidelines and monitoring compliance.

4. Leveraging Technology and Innovation

The integration of technology in eco-tourism presents an opportunity to enhance both visitor experiences and environmental management. Digital platforms can facilitate better communication between tourists and local communities, enabling more informed travel decisions that prioritize sustainability. Additionally, technology can be used to monitor environmental impacts in real-time, allowing for swift responses to any emerging issues.

Innovative practices, such as virtual reality experiences that promote environmental education or apps that track carbon footprints during travel, can also enhance the eco-tourism experience. By leveraging technology, eco-tourism can appeal to a growing demographic of environmentally conscious travelers seeking meaningful and sustainable travel experiences.

5. Future Research Directions

While this study provides valuable insights into the role of eco-tourism in addressing climate risks, further research is warranted to deepen understanding of its long-term impacts. Future studies could investigate the effectiveness of specific eco-tourism initiatives across different geographic regions and cultural contexts. Additionally, exploring the interplay between eco-tourism and other sustainable development goals could yield insights into how this sector can contribute to broader global efforts.

Another area for future research could focus on the social dynamics within communities engaged in eco-tourism. Understanding how eco-tourism affects social structures, gender roles, and cultural practices can inform more inclusive and equitable approaches to sustainable tourism development.

In summary, the discussion highlights the significant potential of eco-tourism to address climate risks while enhancing the competitiveness of tourism destinations. By aligning economic, environmental, and social objectives, stakeholders can create sustainable tourism models that benefit local communities and preserve natural resources. However, realizing this potential requires proactive management, community engagement, and a commitment to continuous improvement. As the tourism sector navigates the challenges of climate change, eco-tourism stands out as a promising pathway toward a more sustainable and resilient future.

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In the last twenty years, tourism has emerged as a leading sector stimulating growth in competitiveness in the context of expanded reproduction within the capitalist economy. With advances in tourism infrastructure and standardization of services, the industry has become an important component of the global economy. Tourism’s contribution to employment is particularly noticeable: every tenth job is related to this sector, with women occupying 54% of such positions, which distinguishes tourism compared to 39% in other sectors.

According to the World Tourism Organization, in 2022, the industry’s revenues contributed 10.2% to the global gross domestic product, while accounting for 30% of global services exports. For 38% of countries, tourism has become the main source of foreign exchange. Before the pandemic, annual growth in international tourism was maintained at 5.1%, reaching 1.5 billion international travelers in 2019.

Europe continues to traditionally hold a leading position in world tourism. In 2023, EU countries accounted for more than half of international tourist arrivals, generating around €407 billion. In terms of regions, Europe controls 51% of the world tourism market, surpassing regions such as Asia (25%), North and South America (30%), Africa (16%) and the Middle East (5%). In Europe, there is a predominantly domestic tourism trend, as only 9% of Europeans prefer to travel outside their own region. The preference for local destinations is confirmed by the fact that every second European travels within the continent at least once a year. The GDP from tourism in the EU as a whole amounted to 10.4%, with particularly high figures in the economies of such countries as Croatia, Iceland, Greece, Portugal, Spain, Italy and Malta, while in Scandinavia and Eastern Europe the tourism sector is of lesser importance.

Since 2007, a comprehensive metric tool, the Travel and Tourism Competitiveness Index (TTCI), has been used to assess the competitiveness and sustainable development of the tourism sector. This comprehensive tool was developed by the World Economic Forum (WEF) in collaboration with global industry and business organizations and covers 140 countries.

The TTCI index combines four sub-indices based on 14 variables and 90 precise indicators that assess both direct and indirect factors that influence the success and progress of tourism.

Among these factors, the key ones are the quality of the business climate, the effectiveness of legislation for business, the infrastructure of safety and health, the advancement of education and transport, the flexibility of the labor market, innovation indicators, such as the level of R&D, the prevalence of mobile phones and the Internet among the population. Also significant are the priorities of state policy in the field of tourism, price competitiveness, environmental sustainability and cultural and natural resources.

An analysis of World Economic Forum data demonstrates the superiority of the European Union (EU) in the field of tourism competitiveness: the average TTCI index for EU countries is 4.3, which is higher than the average values for the Americas (3.9) and Asia (4.2). Notably, of the 30 countries with the highest index, 16 are in the EU, led by the triumvirate of Spain, France and Germany, each with an index of 5.4, adjusted for the latest assessments. This significantly exceeds the average indicators not only for Europe, but also for the world as a whole (3.8). For example, Italy, Greece, Austria and Portugal are also significantly ahead in the ranking. At the opposite end of the spectrum, Cyprus closes the list of European countries in the integral index, occupying 44th place, however, there is a positive trend - an increase of 8 positions since 2018, thanks to active government actions to support the tourism industry.

The European Union dominates in many key areas of competitiveness assessment, with excellent results in security (score 5.8 out of 7), health (score 6.2), education (score 5.0) and information technology (score 5.4). Although slightly lower in tourism infrastructure (4.9), land transport networks (4.1) and environmental sustainability (4.7), these are still above average and indicate a high quality of service on offer.

However, there are some areas of concern, such as the state of the business environment, the development of the aviation industry and innovation progress, where Europe has room for improvement. According to the Global Innovation Index 2020, only four European countries - the Netherlands, Denmark, Finland and Germany - are in the top 10 innovation leaders. High costs of tourism services due to hotel pricing policies, tourist taxes and high fuel excise duties, as well as strict visa policies, may also limit the EU's competitiveness.

However, the key indicators for determining the potential of the sustainable tourism sector in the EU countries in the near and long term are factors that assess the natural and cultural potential, the environmental sustainability of the region and the priority of this sector in state policy.

In the 20th century, the concept of sustainable development gained significant momentum as a decisive principle for socio-economic systems. Over time, anthropogenic influence led to the disruption of the natural self-regulating processes of the biosphere, which, in turn, provoked global environmental shifts and affected the deterioration of the quality of life on the planet.

In response to growing concerns about the ecological state of the planet and the future of human civilization, in 1983 the UN initiated the creation of the Commission on Environment and Development, headed by Norwegian Prime Minister Gro Harlem Brundtland. The Commission's task was to analyze the complex interrelations between environmental and socio-economic problems and to develop sustainable development strategies for different regions of the Earth. This time was characterized by an understanding of the need to update approaches to global development.

"Sustainable development" was formally defined in 1987 by Brundtland in a report entitled "Our Common Future". The essence of this concept is to achieve the needs of modern society without compromising the opportunities of future generations. Key aspects of sustainable development include meeting the basic needs of the least protected sections of the population and taking into account the environmental limitations determined by the state of existing technologies and social organization.

Today, tourism plays a fundamental role in the global economy, attracting millions of people who travel for leisure, business or cultural enrichment. Despite its significant contribution to economic development, this sector also poses a number of serious environmental and socio-economic challenges. Therefore, the industry needs to transition to a sustainable tourism model that could combine economic efficiency with environmental protection and social justice.

The economic efficiency of tourism reflects the degree of optimal use of resources over a certain period of time. It depends on the level of tourism services in the region, the organization of tourism activities in the country and the efficiency of tourism companies.

The magnitude of the economic return of tourism is related to a number of criteria:

1. Equal distribution of economic benefits. Tourism can promote economic equality by attracting investment and generating income that is dispersed across all levels of society within the local economy.

2. Increasing the prosperity of key economic sectors. The revitalization of the tourism industry stimulates the development of subordinate sectors such as the hotel and transport business, as well as information and tourism services, increasing their profitability.

3. Additional financial flows. Tourism accelerates the economic enrichment of the region by attracting external resources, thereby ensuring the diversification of the local economy and stimulating the development of additional business areas.

4. Infrastructure upgrades. The tourism industry is a powerful catalyst for upgrading local infrastructure, including media, utilities and transport networks, which generally improves the quality of life of the population and makes the region more attractive to visitors.

The social effectiveness of tourism is manifested through the improvement of living conditions of society and successful activities in the field of tourism and recreation, influencing the social well-being of the local population.

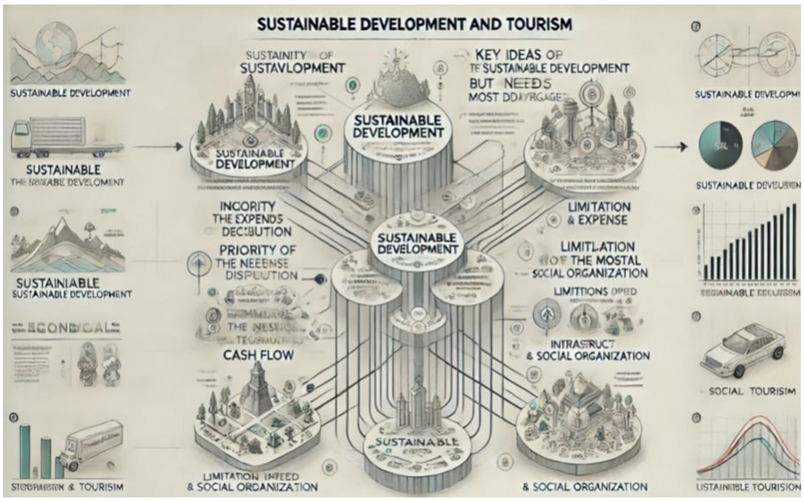

Figure 2: *The relationship between sustainable development and tourism*
(*Source: author's development*)

Community involvement is a critical element in the success and sustainability of eco-tourism initiatives. Engaging local communities not only enhances the effectiveness of eco-tourism but also ensures that the economic benefits are equitably distributed, fostering social cohesion and environmental stewardship. This subsection explores the significance of community involvement in eco-tourism, outlining key benefits and strategies for effective engagement.

1. Empowerment and Capacity Building

One of the most significant advantages of involving local communities in eco-tourism is the empowerment it provides. When communities actively participate in eco-tourism planning and decision-making, they gain a sense of ownership over the resources and projects that affect their lives. This empowerment is essential for fostering a culture of sustainability, as community members become advocates for environmental protection and responsible tourism practices.

Capacity-building initiatives are crucial for equipping local residents with the skills and knowledge necessary to engage effectively in eco-tourism. Training programs focused on hospitality management, customer service, environmental education, and marketing can enhance the ability of community members to contribute meaningfully to eco-tourism efforts. These initiatives not only improve individual livelihoods but also strengthen the overall community's resilience to economic and environmental changes.

2. Cultural Preservation and Heritage Promotion

Community involvement in eco-tourism provides an opportunity for local residents to share their cultural heritage and traditional practices with visitors. This cultural exchange enriches the travel experience for tourists while promoting the preservation of local traditions and customs. By showcasing their unique cultural identities, communities can attract visitors interested in authentic experiences, which can differentiate them from more conventional tourist destinations.

For example, eco-tourism projects that involve local artisans, musicians, and storytellers can create immersive experiences for tourists that celebrate the community's cultural heritage. This not only enhances the tourist experience but also provides a sustainable source of income for local artists and cultural practitioners, helping to maintain the community's cultural identity amidst globalization.

3. Sustainable Resource Management

Involving local communities in eco-tourism also leads to better resource management and conservation outcomes. Community members often possess valuable knowledge about local ecosystems and sustainable practices, which can be leveraged to enhance conservation efforts. When communities are invested in eco-tourism, they are more likely to engage in practices that protect their natural environment.

Participatory resource management approaches, such as community-led conservation projects, can be effective in ensuring the sustainable use of natural resources. For instance, in many eco-tourism areas, local communities have taken the lead in establishing conservation areas, implementing sustainable fishing practices, and protecting endangered species. By giving communities a stake in resource management, eco-tourism can foster a sense of responsibility and stewardship that benefits both the environment and the local economy.

4. Economic Benefits and Job Creation

Community involvement in eco-tourism initiatives directly translates into economic benefits for local populations. By engaging local residents as guides, operators of eco-lodges, and participants in cultural programs, eco-tourism can create job opportunities and generate income within the community. These economic benefits are particularly crucial in rural and marginalized areas where traditional livelihoods may be threatened by climate change and other factors.

Furthermore, eco-tourism can stimulate local economies by encouraging the development of related industries, such as handicrafts, food production, and transportation services. The infusion of income from eco-tourism can lead to broader economic development, improving infrastructure and access to services for the entire community.

5. Strengthening Social Cohesion

Community involvement in eco-tourism can also strengthen social cohesion and foster a sense of community pride. As local residents work together toward common goals, such as preserving their environment and promoting their culture, social bonds are strengthened, and community identity is reinforced. This social capital is vital for resilience, enabling communities to adapt to changes and challenges more effectively.

Additionally, when communities collectively participate in eco-tourism, they are better equipped to voice their needs and concerns to external stakeholders, including government entities and tourism organizations. This enhanced advocacy can lead to more inclusive decision-making processes that reflect the interests and aspirations of local residents.

In summary, community involvement is a cornerstone of successful eco-tourism initiatives. By empowering local residents, promoting cultural preservation, improving resource management, generating economic benefits, and fostering social cohesion, community engagement enhances the sustainability and effectiveness of eco-tourism projects. Stakeholders in the tourism industry must prioritize the involvement of local communities in eco-tourism planning and implementation, ensuring that the benefits of eco-tourism are shared equitably and that communities are active participants in shaping their futures.

Based on the information presented in the table, France, Spain and Italy stand out among the world leaders in terms of the volume of natural and cultural resources with an index approaching six, and are second only to China. Significant biological and landscape diversity is characteristic of the territory of the European Union. Despite the high population density and active economic processes, the EU has preserved exceptional ecosystems to a sufficient extent - from mountain peaks to coastlines and marshy areas. Europe's natural wealth is unique due to its geographical diversity with many islands, as well as variability in geological, orographic, soil, climatic and cultural contexts.

The European Union stands out in particular for its number of protected natural areas. As of 2023, Spain has 49 biosphere reserves out of 686 recognised globally, in addition to hundreds of national parks, game reserves and other protected natural areas. Such sites account for more than a quarter of the EU's land and inland waters, as well as almost a third of its territorial waters. Europe is responsible for 65.6% of all protected natural area locations registered by the UN, although they represent only 12.9% of the world's land area, highlighting the comparatively small size of these areas in Europe.

Europe's cultural and historical contribution is comparable to its natural wealth and is expressed in the diversity of cultures that have left their mark on human history. In 2020, 22% of UNESCO's World Heritage Sites are located in Europe, with Italy leading the list (54 sites), followed by Spain (47) and France and Germany (44 each). This heritage reflects not only architectural structures, but also regional traditions - such as festivals, music, dance, customs and gastronomy - that define the unique cultural essence of European countries.

Cultural and environmental interests of tourists have become key factors influencing the tourism economy. Modern travelers are increasingly abandoning ordinary beach holidays in favor of unique cultural and natural places. They are ready to invest in excursions to historical places, visits to national parks and reserves, as well as in the experience of immersion in the cultural environment and life of local residents.

Growing demand for personalised and eco-conscious tourism is supporting a variety of forms, from green tourism to agritourism and food tours. These destinations are becoming increasingly popular and are showing significant growth. Sustainable tourism is moving from niche to mainstream, with 87% of users of leading booking platform Booking.com stating their willingness to follow its principles.

A significant statistic is the growth rate of ecotourism revenues, which are at 20% annually – six times higher than the overall growth in the tourism industry. This data indicates a change in priorities in tourist behavior, a switch to a more conscious and responsible approach to travel, and highlights the importance of sustainable development in the global tourism industry.

In the field of tourism, the main social performance indicators include the following aspects:

- improving the quality of life of the population in regions with developed tourism, which contributes to raising their well-being;

- modernization of recreational infrastructure, creating conditions convenient for both visitors and local residents;

- protection of natural and cultural values in order to preserve historical and natural monuments; putting unused territories into circulation, which allows for the rational use of land resources; providing education and qualifications to local residents to create new jobs and develop skills;

- strengthening cultural ties through the promotion of mutual cultural enrichment and cooperation with neighboring territories.

Sustainable tourism requires an active environmental approach that includes minimizing environmental impacts, such as pollution control, conservation of natural resources, creation of protected areas, and efficient waste management. This approach is responsible for reducing adverse effects on ecosystems, such as loss of biodiversity or pollution, and preventing an increase in the carbon footprint of transport and construction.

Sustainable tourism must also support social development in host regions by involving local communities in tourism projects and ensuring that benefits are fairly distributed. It is important to protect and promote local traditions to avoid loss of identity and cultural traditions. Tourism can be a source of social transformation, cultural exchange and understanding, but it can also cause negative consequences such as cultural commodification and the destruction of traditional ways of life.

Community participation and empowerment are essential to sustainable tourism. Important components include protecting cultural identities, supporting community enterprises, and ensuring fair sharing of economic benefits. While tourism provides economic benefits through employment and infrastructure, over-reliance on the industry can lead to economic vulnerability. Sustainable tourism strategies focus on economic diversity, supporting local entrepreneurship, and implementing responsible tourism practices to ensure long-term economic stability.

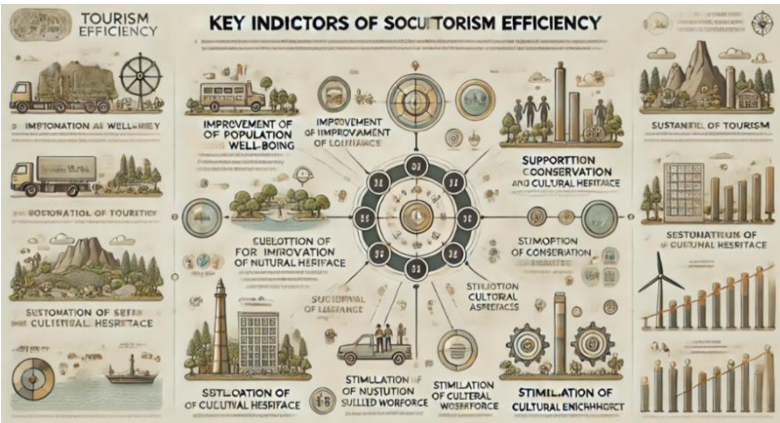

Figure 3: *Key indicators of social performance of tourism, as well as its impact on the environment, social and economic aspects (Source: author's development)*

Unfortunately, as tourism grows, its negative effects become more visible and cause ever greater concern. Experts emphasize that approximately half of the natural and cultural heritage sites are currently under severe pressure due to the intensive tourist flow. Standardized mass tourism can lead to environmental degradation, pollution and, in extreme cases, destruction, threatening the ecological balance of such places.

Climate change is one of the major challenges facing the modern world, and tourism plays its part. According to data, the tourism industry produces between 5 and 12.5 percent of global carbon dioxide emissions, taking into account the contribution of all greenhouse gases that add to the problem of global warming. The bulk of these emissions come from transport, with air travel responsible for 40 percent, as it provides more than half of international tourist movement, and road transport for 32 percent. Hotel services and their impact on the climate account for 21 percent of emissions, including the energy consumed by air conditioning, heating and maintaining swimming pools.

If current tourism trends continue, CO_2 emissions could increase by 135% by 2035, which would have a catastrophic impact on the environment, the ozone layer and natural resources, not only in popular tourist regions of Europe but also worldwide. This prospect highlights the need for urgent action to reduce the carbon footprint of the global tourism industry.

References

[1] Sustainable Development of Tourism. World Tourism Organization – Definition // URL:http://sdt.unwto.org/content/about-us-5

[2] Gakaev R.A., Bayrakov I.A., Bagasheva M.I. Ecological foundations of the optimal structure of forest landscapes in the Chechen Republic. 2006.pp. 50-52.

[3] Global Innovation Index 2020.p.33

[4] World Tourism Barometer.Volume 18.Issue1.January 2020. WEB UNWTO.s3, eu-west-1.am

[5] J La mitad de los sitios de Patrimonio mundial natural estan amenazados.InformeWWF. 66 // URL: http://ecodiario.eleconomista.es/medio-ambiente/noticias/7472644/04/16.

[6] Salamova A.S. Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[7] Salamova A.S. Global networked economy as a factor for sustainable development, 2020, p. 03053.

[8] Weston, R., Guia, J., Mihalic, T., Pratt. L., Ferrer-Roca, N., Lawler, M., and Garatt, D., European tourism: recent developments and future challenges. European Parliament. Policy Department for Structural and Cohesion Policies. Directorate General for Internal Policies

[9] Novara A., T. La Mantia, J. Rühl, L. Badalucco, Dynamics of soil organic carbon pools after agricultural abandonment. Geoderma, 235-236: 191-198 (2019).

[10] Lopes V., S. M. Pires, and R. Costa, 'A strategy for a sustainable tourism development of the Greek Island of Chios', Tourism, 2020, doi: 10.37741/T.68.3.1

[11] Pranee S., T. Kortana, N. Wongjunya, and P. Suchookorn, 'The potential and strategy on tourism promotion and development in the eastern economic corridor: A case study of the eastern province cluster 2, Thailand', African J. Hosp. Tour. Leis., 2020.

INNOVATIVE EDUCATION AS A FACTOR OF HUMAN CAPITAL GROWTH

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Abstract

The development of modern society poses a number of new problems to the domestic education system due to political, socio-economic, socio-cultural, technical, technological, environmental and other factors, among which the issue of improving the quality and accessibility of education due to the growth of human capital should be highlighted.

The fundamental processes taking place in the education system lead to the formation of a new ideology and methodology of education as an innovative direction in this key area today. Innovative learning technologies should be investigated as a mechanism for implementing a fundamentally new educational paradigm.

The main goal of innovative technologies in the field of education is:

- *the developing the ability to motivate actions;*
- *the ability to use the latest achievements of science and practice;*
- *the formation of creative unconventional thinking;*
- *the preparing an individual for life in an ever-changing world;*
- *the qualitative change in the students' personality compared to the traditional system*
- *the ability of using digital technologies and distance learning to implement opportunities for providing on-the-job training;*

The essence of such training is to focus the educational process on the potential of a person and their implementation. Education should develop mechanisms for innovation, find creative ways to solve vital problems, and contribute to the transformation of creativity into the norm and form of human existence.

All this becomes possible thanks to the introduction of didactic and educational programs that are not known in practice into professional activities, as well as new approaches to student training. Innovative activity in education as a socially significant practice aimed at moral self-improvement of a person is important because it is able to ensure the transformation of all existing types of practices in society.

Keywords: education, innovation, human capital, potential, quality of life, standard of living of the population, innovative teaching method

I. Introduction

In the conditions of the modern world, characterized by a change in the educational paradigm, as well as the strengthening of the role of human capital in innovative economic development, the educational sphere acquires a new vector – growth and prosperity.

The processes associated with the modernization (innovation) of education, the development of newfangled technologies and techniques for acquiring relevant skills have ceased to be somewhat unique. The lack of individuality of the process is interdependent not only with the transition of a social society to post-industrialism, but also with a collision with spontaneous, unexplored and non-economic laws that do not depend on the desire and ability of mankind by phenomena such as the new corona virus infection (2020), which provoked forced social isolation, on the one hand, and rebuilt the ongoing economic processes caused by the need for communication in an alternative format with another.

It was an impetus to rethink the directions of economic development as the introduction of active interaction and long-term partnership in the scientific and educational sphere, both for leading technology giants and for small enterprises, regional scientific and educational organizations.

The Era of innovation requires attention and support for human capital, since this is one of the key factors in which a person and his abilities, knowledge can play an important role, declared not only at the national level, but also on the world stage. In this regard, science and education act as the main guide towards achieving the main goals of a global scale, such as the export of personnel and technology, finding innovative talents, increasing labor productivity, and promoting scientific and educational infrastructure.

The indicator of innovation activity is:

• The amount of invested financial resources;
• Transfer of decades of accumulated knowledge in various fields;
• Relevance and search for incentives due to in-depth research in the future.

The use and dissemination of knowledge contributes to the enrichment of a person as a person, and the educational environment as the results of scientific research and the process of formation of educational markets. According to analysts, the innovative educational market will reach $404 billion next year (2025), and $10 trillion in five years [8]. The dynamics of market growth is multidirectional and its high growth rates are most often observed in developed countries.

With regard to the structure of the Russian education system, the growth trend is observed in the share of online education due to some factors, such as:

• increased demand for online education;
• increased demand for IT professionals;
• strengthening digitalization processes;
• expanding the market for competitive platforms;
• Changing consumer tastes, preferences, and learning approaches.

By developing these processes, it will be possible to solve the tasks of ensuring the competitiveness of highly qualified specialists, which are based on innovative progress.

II. Methods

- the modern theoretical and practical development of innovation;
- the statistical dates and analyses;
- the innovative approach to the reproduction of human capital;
- the determination of the impact interaction of science and education on human capital development in an innovative economy through an intersectoral transformation cycle, which demonstrates the role mechanism of reproduction of human capital.

III. Results

The application of the proposed recommendations by the state in practice and improvement of socio-cultural and economic policies in the future. The reliability of the statistical and factual data used has also been determined. The results are justified by the confirmation of their publications in leading peer-reviewed scientific journals.

IV. Discussion

The level of education is a significant indicator of a person's quality of life. It acts as an integral part of human existence, determining its success. It acts as an integral part of human existence, determining its success. Specifically the education - is a key factor in the development of the economic situation in the country, since it contributes to the formation of public culture and the definition of progress in Technique and Technology, strengthening individual moral satisfaction with the standard of living.

Therefore, the head of state has frequently mentioned the importance of providing high-quality education and the diverse development of social society in the contemporary world.

Today, the growth of human potential and its future success depend on the level and quality of fundamental education through innovation. The innovative method of teaching in schools and helps the preschool institution growing generation, the future personnel of our country to take the first, but very important step towards the well-being of their own lives. Certainly, for these purposes, it is necessary to create all possible conditions for expanding the networks of secondary education institutions so that children are brought up in the spirit of patriotism and professionalism.

Only educated and literate youth with modern skills and professions can contribute to the state development. Particularly for this reason that is important to pay attention to the education system's development, since the growth of literacy among the population is a factor determining the strength and prosperity of any state society.

Young people with innovative ideas and skills become active supporters of processes that directly lead to a better life. This is the only way to build a society based on innovative knowledge and high culture.

There are quite a lot of studies in science on the importance of increasing investment in education. In particular, Russian cultural critic Andrei Flier also noted that "The less money the ruling elite invests in culture and education today, the more it will have to invest in the police, justice and penitentiary system tomorrow [4]."

Therefore, the purpose of the Law on Education and Parental Responsibility for the Education and Upbringing of Children was to strengthen their obligation to lay the foundations for the physical, moral and intellectual development of the child's personality.

But, unfortunately, the problems that were inherited from the education system of the 90s have greatly worsened, even other newer ones have appeared, which did not take place at all earlier or were successfully solved by the authorities. The process of degradation in the education and cultural system of those years was accompanied by a lack of financial and logistical resources [1].

The volume of state funding for Russian education has significantly decreased. At the same time, therefore, there was a tendency for the indicator of spending on the educational sector to decrease as a % of GDP.

In those years, the decline in real spending on education and the average salary in this industry were precipitous. There was a significant deterioration in the state of the material and technical base of educational institutions.

According to the data, in government spending on education (in %) to GDP, there was a downward jump from 1991 to 2000 - from 3.6 to 3%. Also, the average salary in the field of education (in %) relative to the subsistence level has significantly decreased by several times - up to 85 [3].

Russia was not only different from developed countries, but also from European countries with economies in transition. The increase in the share of public spending on education in GDP allowed most of these countries to almost no to reduce spending on education at comparable prices during the economic downturn that accompanied economic reform. In most of these countries, the average wage of education workers has not fallen below the average wage of those employed in the economy. Some education indicators financing during the economic downturn in European countries with economies in transition showed the opposite figures, in short, a tendency to increase significantly, especially when observing education expenditures (in%) to GDP [6].

Consequently, this situation has had a negative impact on the socio-cultural standard of living among the population, in particular:

- reduction in the number of students;
- increase in types of training on a commercial basis;
- decrease in publishing activities;
- closure of many libraries,
- houses of culture;
- reduction of visitors to theaters, cinemas, and museums.

Relatively the mental work has moved into the background.

IV. Subsection Four

But, thanks to the measures taken, the skillful policy of the state has managed to achieve some positive results. Gradually, step by step, the situation began to change for the better. Starting in 2000, the country embarked on the path of creation and turned into a great power, in which the standard of living is quite consistent with many European states. Maybe not the most advanced, but we are only at the beginning of the journey.

The implementation of national projects has contributed to a serious change in the infrastructure of the population's life in such areas as:

- health;
- education;
- sport;
- agriculture.

It is clear that education could be done as in England or Switzerland. Nevertheless, there was a noticeable difference between what was and what has become: new schools, computer classes, the Internet and more. First of all, attention was focused on improving the population standards of living by increasing the level of education.

The educational space is built on the basis of basic academic values and demonstration of quality. Quality assessment covers teaching and research, leadership and management, the ability to meet student needs and the provision of non-educational services.

Quality in education is a fundamental condition for trust, relevance, mobility, compatibility and attractiveness in a given space.

As you know, in the Russian Federation, primary and secondary forms of education are mainly public, and in recent years a private form of education has been developing strongly. There is an opinion that the quality of the private form of education is much better than the public one, since it is dominated by an innovative modern teaching method.

However, in practice, even in government structures, education is gradually becoming more and more a paid service, but the quality of education is not improving. At the same time, according to parents, even a 20% drop in income does not lead to a massive rejection of paid education.

Recall that according to the Constitution, the State guarantees the accessibility and free of charge of preschool, basic general and secondary vocational education.

More than 60% of students after grade 9 go to colleges, technical schools and vocational lyceums for secondary special education, while a minority remains in schools.

Teachers have to work because of the remaining participants, although there is less and less demand for them. And schools receive funds from those who want to stay after grade ninth to study in high school and prepare for the Unified State Exam [7].

The desire for students to receive secondary special education is supported, because the country needs workers, not bloggers, as say.

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Nevertheless, the experience of the top five countries in the world (Table No.1), where the level of education is the highest among the rest, shows that the transition to full-time paid education contributes to the development and achievement of a higher quality of education. However, in this matter, in the economic conditions of our country, there is a problem ... since a significant part of the population (middle-income population) has low purchasing power, there is a high level of idle production facilities, relatively high levels of poverty and unemployment remain, and this approach is not entirely acceptable.

The following table shows the ranking of countries in the world by level of education according to the UN data published by 2024 (the index is updated once within two to three years). The index is measured by the country's achievements based on the achieved level of education of the population by two main and necessary indicators: the adult literacy index; the index of the total proportion of students receiving primary, secondary and higher education.

Table 1: *Ranking of countries in the world according to the education level index United Nations Development Programme: Education Index 2024 [5].*

№	Country	Expected duration of study (in years)	Average duration of study (in years)	Education Index
1	Australia	21.1	12.7	1.01
2	New Zealand	20.3	12.9	0.99
3	Iceland	19.2	13.8	0.99
4	Sweden	19.4	12.6	0.96
5	Belgium	19.6	12.4	0.96
11	Germany	17.0	14.1	0.94
17	United States of America	16.3	13.7	0.91
29	Russia	15.8	12.8	0.85
33	Georgia	15.6	12.8	0.89
36	Kazakhstan	15.8	12.3	0.82
47	Belarus	15.2	12.1	0.8
58	Ukraine	15.0	11.1	0.74
76	Kyrgyzstan	13.2	11.4	0.76
77	Turkmenistan	13.2	11.3	0.74
80	Uzbekistan	12.5	11.9	0.73
101	Tajikistan	11.7	11.3	0.68
188	Burkina Faso	9.1	2.1	0.3
191	Niger	7.0	2.1	0.24

The table's figures show that Australia is ahead of New Zealand in this ranking, taking 1st place. In this top five, New Zealand shares the same education index with Iceland - 0.99. Norway is in the second five in this list, although it was in the first in the previous calculation. Germany also lost its leading position (2020), falling to the eleventh position with an index of 0.94, and the United States of America shared this group with it with an index of 0.91.

Among the CIS countries, Russia, ahead of Kazakhstan by 3 positions, is among the third ten countries in the world, ranking 33rd with an index of 0.85, therefore, Kazakhstan is awarded a relatively decreasing index of 0.82.

Belarus ranks in the fourth ten in this ranking, although it was in the thirtieth place (rating for 2020).

Uzbekistan and Tajikistan are gaining a downward trend, as they complete the first half of the list with an education level index of 0.73 and 0.68. Countries such as Mozambique, Ethiopia, Chad, Burkina Faso and Niger occupy the last places from 165 to 191 with indices 0.3 - 0.24 in the list of countries in the world by level of education [9].

In the world of innovative, during the process of changing the structure on employment and increasing the share of intellectual labor, the share of low-skilled labor is simultaneously decreasing. It is the level and quality of education that is one of these sources of human capital.

Innovative education is the intellectual values of a person, the acquisition of skills and abilities aimed at creating socially significant values, and its purpose is to inherit intelligence and the ability for implementation in creative work.

Hence, it follows that the key factors determining the intellectual potential of an individual in any state of the world include the following:

- Political development;
- Economic development;
- Social development;
- The content and quality of education.

If we take into account the conditions of the information age, then the main activity in the field of education will take place under the following mottos as its role and functional structure.

The functional structure is based on levels that meet the requirements of the current society, quality and internationalization - local, national and international.

In human (person), the experience of one individual does not disappear after its death, but accumulates in society due to the developed mind of people and their ability to communicate.

In modern conditions, market institutional transformations have a very significant impact on the standard of living of the population and the development of human capital.

As noted above, the innovative education occupies an important place among the new society and it belongs to strategically important areas of activity that could determine the human capital quality. Based on this, the following measures should be taken in this direction:

- to increase the professional competence of teachers, both in higher and secondary educational institutions through professional development systems every three years at the expense of centralized state budget funds;

- to ensure the flexibility of the vocational education’s structure to changes in the labor market;

- to organize close relations between the branches of the national economy and the higher education system for the effective use of labor resources;

- to strengthen the target orientation towards the system of training specialists for the needs of the national economy of the country;

- to provide targeted social support to the population’s low-income segments in terms of obtaining professional higher education;

- to transfer priority to the public sector for social support of the population, it is necessary, in the issue of the secondary education development;

- to ensure the adaptation of the education system to market conditions.

In general, the recommended directions for improving the branches of the social sphere in the scientific and methodological aspects, although is not a complete system of measures, will make a significant contribution to improving the country's population standard of living for the near future.

The education system, like the rest of the systems that make up the social sphere, depends entirely on the support from the state.

Education reform should take into account the interests of every economic agent. However, the responsibility in this area is too high, because it determines the future of a person.

In order to increase the accessibility of higher education and respect the principle of fairness and transparency in university admissions, the Government has created a Unified State Exam for the younger generation from low-income families, which has become the main link in the national knowledge assessment system.

However, as practice shows, despite efforts aimed at creating conditions on the part of the Government for the education of a growing number of school-age children, the quality of education of the young population has decreased according to the test results. Creating conditions for the education system is becoming a difficult task that affects the economy as a whole. The acute shortage of qualified pedagogues is associated with the outflow of personnel from the education system for economic reasons, due to unworthy wages, having a serious impact on all levels of the education system - from preschool to higher education.

Today, it is necessary to support the low-paying population with budgetary higher education by financing.

Consequently, in 2024, the state provided more funds for the development of the education sector, as budget expenditures increased to 575.2 billion rubles in accordance with the state program "Development of Education".

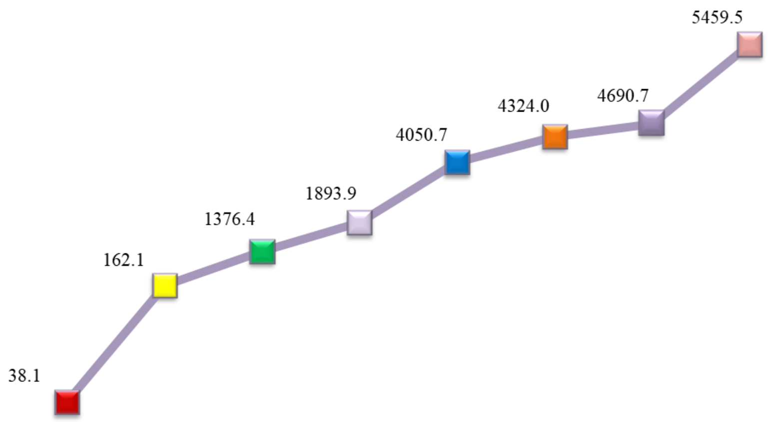

Figure 1: *State budget expenditures on Education in Russian Federation, in bln. ₽ from 2000 to 2023*

At the same time, the indicators of the draft federal budget for this state program compared with the current Federal Law for 2023-2025 in 2024 [2] which increased by 19.9 billion rubles, in 2025 – by 21.7 billion rubles, therefore in 2026 – by 14.6 billion rubles. It should be emphasized that the amount of funds for the implementation of the national project "Education" in 2024 has not decreased and corresponds to previously accepted parameters. In 2025 and 2026, it increased by 2.7 and 2.3 billion rubles, respectively.

One point one billion rubles are additionally provided for the implementation of secondary vocational education (SVE) programs in 2024, 4.2 billion rubles in 2025, and 4.1 billion rubles in 2026 (Figure 1).

We believe that in this context, the State should ensure general access to education through the implementation of the following programs:

- public support for students from low-income families, orphans and gifted children;
- development of a long - term lending system;
- ensuring the flexibility of the structure of vocational education to changes in the labor market;
- organization of close relations between the branches of the national economy and the higher education system.

The analysis of these trends in the changing role of knowledge and education in socio-economic development allows us to conclude that the fundamental change in the function of the social institution of education in the material and spiritual reproduction of the living conditions of society and man. In the context of the growth of scientific, intellectual, educational capacity and high rates of change in the world, innovative education becomes the basis for the successful functioning of the economy and all processes of reproduction of society.

In summary, in our view, the recommended directions can make a certain contribution for improving the country's population standard of living in nearest future.

References

[1] Atokhodzhaeva M.A. Assessment and mechanisms for regulating the standard of living in the economy of Tajikistan: Monograph, Moscow: CENTER for TRANSPORT, 2019, pp.54-58 ISBN 978-5-9903808-7-5.

[2] Education in numbers: 2023: a short statistical collection / T.A. Varlamov, L.M. Gokhberg, O.K. Ozerov; Nat. research. Higher School of Economics University – Moscow: ISIEZ HSE, 2023. – 132 p. – 350 copies. – ISBN 978-5-7598-3004-7 (in the region)

[3] Federal program "Development of a unified educational information environment for 2001-05" (project) - Public education, 2001, No. 1.

[4] Flier A.Ya. Cultural studies for cultural scientists: a textbook for undergraduates and postgraduates, doctoral students and applicants, as well as teachers of cultural studies. — M.: Academic project, 2000. — p. 496

[5] Ranking of world countries by level of education - information about the study [Electronic resource]: Center for Humanitarian Technologies (last edition: 2024 25.08). – Access mode: http://gtmarket.ru/ratings/education-index/education-index-info - [Date of access: 09/10/2024]

[6] Trends in Education Access and Financing during the Transition in Central and Eastern Europe - World Bank Technical Paper N 371. Washington, 1997

[7] United Nations Development Programme. Human Development Index (HDI): Education Index [URL: hdr.undp.org]./ United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics. Data Centre [URL: data.uis.unesco.org]. /United Nations Statistics Division. UNdata [URL: data.un.org]. [Date of access: 18/09/2024]

[8] Global Market Intelligence. URL: https://www.holoniq.com/notes/global-education-technology-market-to-reach-404b-by-2025/ (дата обращения: 27.09.2024).

[9] http://gtmarket.ru/ratings/education-index/education-index-info

TAX REFORMS TO STIMULATE GREEN ENTREPRENEURSHIP GLOBAL TRENDS AND REGIONAL FEATURES

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Abstract

In the context of a worsening environmental crisis and the urgent need for a transition to sustainable development, tax reforms have emerged as a vital mechanism for stimulating green entrepreneurship.

This paper provides an in-depth analysis of global trends in tax reforms aimed at supporting environmentally responsible businesses and examines the regional variations in their implementation. Tax incentives have proven to be effective tools for encouraging companies to adopt eco-friendly practices, invest in renewable energy, and develop innovative solutions that address pressing environmental challenges.

This study categorizes various forms of tax incentives, such as tax credits, exemptions, and reductions for businesses engaged in sustainable practices, including renewable energy production, waste management, and sustainable agriculture. The paper highlights successful case studies from diverse countries, showcasing how tax reforms have effectively driven the growth of green entrepreneurship. For instance, nations such as Germany and Sweden have implemented robust tax policies that incentivize renewable energy investments, resulting in significant advancements in green technology and job creation. Similarly, developing countries, like Kenya and India, are leveraging tax incentives to foster eco-entrepreneurship, balancing economic growth with environmental protection. Furthermore, this study delves into the challenges and opportunities associated with these tax reforms. While many countries are adopting fiscal measures to stimulate green entrepreneurship, the effectiveness of these reforms can vary significantly due to factors such as economic capacity, political will, and regional environmental priorities. Developing nations often face constraints in their ability to implement comprehensive tax incentives, while developed countries may benefit from more substantial financial resources to support such initiatives.

Keywords: green entrepreneurship, tax reforms, eco-innovation, renewable energy, global trends

I. Introduction

As the world grapples with an escalating environmental crisis characterized by climate change, biodiversity loss, and resource depletion, there is an urgent need for innovative solutions that promote sustainability. Green entrepreneurship has emerged as a vital component in this effort, encompassing businesses that prioritize environmental stewardship, social responsibility, and sustainable practices. These ventures not only aim to create economic value but also seek to address pressing environmental challenges, making them essential players in the transition to a sustainable economy.

Tax reforms represent a powerful policy tool that governments can leverage to stimulate green entrepreneurship. By providing financial incentives and support through tax credits, exemptions, and reductions, policymakers can encourage businesses to adopt environmentally friendly practices, invest in renewable energy sources, and develop sustainable technologies. Such fiscal measures are increasingly recognized as essential strategies to align economic development with environmental sustainability, fostering an ecosystem where green businesses can thrive.

Globally, there has been a noticeable shift in how countries approach taxation in relation to environmental goals. Governments are increasingly integrating sustainability into their fiscal policies, with a growing recognition that effective tax reforms can lead to significant advancements in green innovation. For instance, countries like Germany and Denmark have implemented substantial tax incentives for renewable energy investments, resulting in marked improvements in their energy mix and reductions in greenhouse gas emissions. Conversely, developing nations are beginning to explore tax reforms as a means to cultivate green entrepreneurship, aiming to balance economic growth with environmental protection.

However, the implementation and effectiveness of tax reforms can vary widely based on regional contexts, economic capacities, and political landscapes. While developed nations may have more resources to allocate toward substantial tax incentives, developing countries often face challenges related to limited budgets, infrastructure deficits, and competing economic priorities. This disparity leads to diverse approaches in the application of tax reforms, with each region exhibiting unique characteristics in its efforts to stimulate green entrepreneurship.

Moreover, the role of international frameworks, such as the United Nations' Sustainable Development Goals (SDGs), cannot be overlooked. These goals provide a comprehensive blueprint for countries to align their national policies with global sustainability objectives, creating a cohesive framework for implementing tax reforms that support green entrepreneurship. By integrating tax policies with broader environmental strategies, governments can create a conducive environment for innovation and sustainable business practices.

This paper aims to explore the global trends and regional features of tax reforms designed to stimulate green entrepreneurship. By analyzing successful case studies, identifying challenges, and assessing the impact of these fiscal policies on environmental and economic outcomes, the study seeks to provide a comprehensive understanding of how tax reforms can be utilized to foster sustainable business practices worldwide. The following sections will investigate the types of tax incentives commonly used, the regional differences in their application, and the broader implications of these reforms for the global transition to a green economy.

In summary, tax reforms are essential for driving the growth of green entrepreneurship and encouraging businesses to adopt sustainable practices. As countries strive to balance economic development with environmental stewardship, understanding the role of fiscal policies in promoting eco-innovation and reducing ecological impacts is crucial for shaping a sustainable future.

II. Methods

This study employs a multi-faceted approach to analyze the impact of tax reforms on stimulating green entrepreneurship. The methodology includes three primary methods: a **literature review**, **case study analysis**, and **quantitative data analysis**. Each method is designed to provide a comprehensive understanding of the relationship between tax reforms and green entrepreneurship, emphasizing global trends and regional features.

1. Literature Review

The first method involves conducting an extensive literature review to establish a theoretical framework and identify existing knowledge on tax reforms and green entrepreneurship. This review will focus on:

- **Defining Key Concepts:** Understanding the definitions and characteristics of green entrepreneurship and how tax reforms can influence its growth.

- **Identifying Global Trends:** Examining various tax policies implemented worldwide that aim to promote environmentally friendly business practices.
- **Highlighting Best Practices:** Exploring successful examples of tax reforms that have effectively stimulated green entrepreneurship, drawing insights from academic articles, policy reports, and industry publications.

The literature review serves to contextualize the research and identify gaps in current knowledge that the subsequent methods will address.

2. Case Study Analysis

The second method consists of qualitative case study analysis, focusing on specific countries or regions that have implemented tax reforms to foster green entrepreneurship. This analysis will include:

- **Selection of Case Studies:** Identifying diverse examples from both developed and developing countries that illustrate various approaches to tax reforms. Potential case studies may include:
- **Data Collection:** Gathering qualitative data through interviews with stakeholders, such as policymakers, entrepreneurs, and environmental experts, to understand their perspectives on the effectiveness of tax reforms.
- **Impact Assessment:** Evaluating the outcomes of these case studies in terms of job creation, investments in green technologies, and reductions in environmental impact.

The case study analysis provides practical insights and examples that can illustrate the theoretical concepts identified in the literature review.

3. Quantitative Data Analysis

The third method involves quantitative data analysis to evaluate the statistical relationship between tax reforms and green entrepreneurship. This analysis will include:

- **Data Collection:** Gathering quantitative data from various sources, including national statistics, international databases (such as the World Bank and OECD), and reports from environmental agencies. Key indicators may include:
- **Statistical Analysis:** Using statistical techniques, such as regression analysis, to explore correlations between the implementation of tax reforms and the growth of green entrepreneurship. This analysis aims to quantify the impact of specific tax incentives on key economic and environmental outcomes.
- **Comparative Analysis:** Assessing differences in the effectiveness of tax reforms across regions and countries, identifying which strategies yield the best results in promoting green entrepreneurship.

By employing these three methods—literature review, case study analysis, and quantitative data analysis—this study aims to provide a comprehensive examination of the role of tax reforms in stimulating green entrepreneurship. The combination of qualitative and quantitative approaches will allow for a deeper understanding of how fiscal policies can effectively promote sustainable business practices and contribute to a more environmentally responsible economy. The findings will offer valuable insights for policymakers, entrepreneurs, and researchers seeking to enhance the impact of tax reforms on green entrepreneurship.

III. Results

Industrialization has resulted in significant pollution emissions alongside economic growth. Although Russia has experienced rapid economic development and improvements in living standards, environmental pollution remains a serious issue. According to Yale University's 2022 Global Environmental Performance Report, Russia ranks 160th out of 180 countries in terms of environmental performance. As a major contributor to pollution, the environmental management practices of enterprises have garnered increasing attention. Green innovation has emerged as a crucial technological solution for achieving corporate transformation, promoting clean production, and ensuring sustainable development. Various measures have been proposed to foster the advancement of green innovation within businesses.

As of 2019, Russia's Ministry of Science and Technology reported that the country invested approximately 2.2 trillion rubles in research and development (R&D), representing a 12.5% increase from the previous year and accounting for 2.23% of GDP. Of this amount, enterprises contributed 1.69 trillion rubles to R&D, an increase of 11.1% over 2018. To alleviate the R&D burden on companies and encourage them to engage in their own research, the government implements various industrial policies, using tax incentives and subsidies as primary regulatory tools. However, the effectiveness of these two intervention methods is a topic of debate, leading scholars to investigate their impact on firms' R&D performance and the extent of that influence.

With the advent of Keynesian neoclassical economics and theories of government failure, researchers began examining the effects of policies on green innovation. Studies have found a positive relationship between subsidies and firms' green innovation. However, some scholars argue that excessive subsidies might displace companies' original R&D investments, thus hindering green innovation. In light of ongoing debates regarding direct cash subsidies, the focus has shifted toward tax incentives as an indirect fiscal measure. The impact of tax incentives on green innovation has shown mixed results, with some studies indicating a positive effect while others suggest a negative impact. While there is substantial literature addressing the effects of individual policies on innovation, often measured through a single variable related to green innovation, the combined effects of both subsidies and tax incentives remain underexplored. Additionally, external financing factors are vital in a firm's R&D investment, warranting consideration of corporate financing constraints as a mediating variable. Therefore, this paper examines the influence of tax incentives on green innovation across varying subsidy levels and explores the mechanisms by which tax incentives operate.

This research utilizes data from publicly listed manufacturing companies spanning 2010 to 2019, measures the intensity of tax incentive policies using the B-index, and establishes an evaluation framework for corporate green innovation through the entropy weighting method (EWM). It investigates the effects of tax incentives on green innovation in different types of firms, as well as the mediating role of financing constraints and the moderating role of subsidies. This study is innovative in several ways: 1) Instead of employing the Difference-in-Differences (DID) approach to assess policy impacts, this paper quantifies policy effects using the B-index, thus expanding the understanding of corporate green innovation within the framework of endogenous growth theory. 2) Unlike existing research that primarily relies on singular metrics such as R&D investment or patents to evaluate corporate innovation, this paper introduces a comprehensive evaluation system for corporate green innovation, assessing performance from multiple perspectives.

The remainder of the paper is structured into four sections: theoretical analysis and hypotheses, variable description and methodology, empirical analysis with conclusions and discussion, and finally, a section outlining conclusions, insights, and limitations (refer to Figure 1)

The conversation around tax reforms to stimulate green entrepreneurship is multifaceted, encompassing economic, environmental, and social dimensions. In Russia, the potential for developing a robust green economy is significant, yet there are various challenges and opportunities to consider. This discussion examines the implications of tax reforms, the regional context, and the broader societal impact of promoting green entrepreneurship.

1. Economic Implications

Incentivizing Investment: Effective tax reforms can create a favorable environment for investors interested in green technologies. By offering tax credits, exemptions, or reduced rates for renewable energy projects, the government can encourage both domestic and foreign investments.

In a resource-rich country like Russia, tapping into renewable energy sources could reduce dependency on fossil fuels, thereby diversifying the economy.

Job Creation and Economic Diversification: Green entrepreneurship has the potential to generate new jobs, especially in regions transitioning from traditional industries. By promoting sectors such as renewable energy, energy efficiency, and waste management, tax reforms can support economic diversification, creating employment opportunities for a skilled workforce.

2. Environmental Impact

Meeting Climate Goals: Russia has committed to international climate agreements, and stimulating green entrepreneurship is essential for achieving these targets. Tax reforms can support the development of clean technologies, reducing greenhouse gas emissions and fostering sustainable practices across various sectors.

Encouraging Sustainable Practices: By implementing tax incentives for environmentally friendly business practices, the government can encourage companies to adopt sustainable methods. This could include support for energy-efficient manufacturing processes, waste reduction initiatives, and sustainable supply chain practices, contributing to overall environmental preservation.

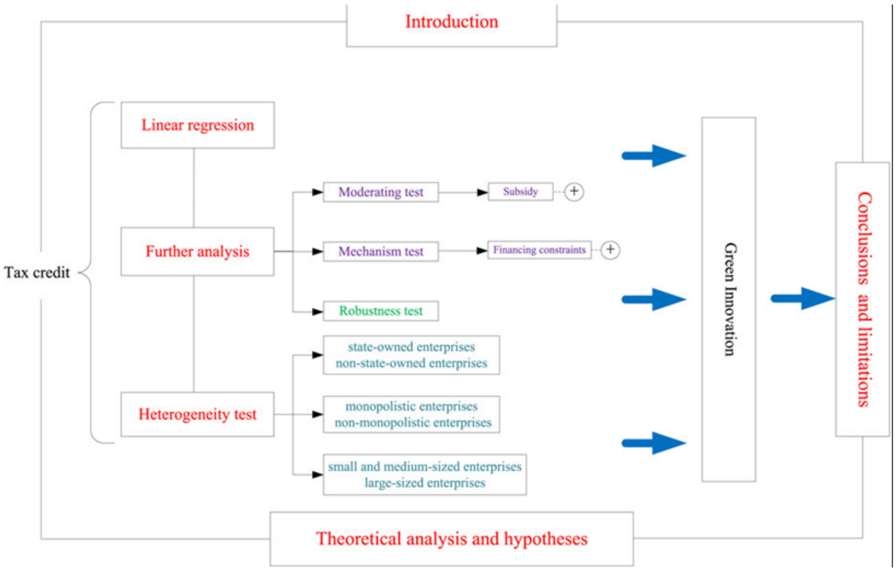

Figure 1: *Logic diagram*

IV. Discussion

3. Social Dimensions

Equity and Accessibility: While tax reforms can stimulate green entrepreneurship, it is vital to ensure that these initiatives are equitable. Small and medium enterprises (SMEs), which often lack the resources to navigate complex tax codes, should be prioritized. Simplified tax structures and targeted support can help ensure that all businesses, regardless of size, can access the benefits of green entrepreneurship.

Public Awareness and Engagement: For tax reforms to be effective, there must be public awareness and engagement regarding green entrepreneurship. Educating entrepreneurs about available incentives and the benefits of adopting sustainable practices can drive demand for green technologies and foster a culture of sustainability within the business community.

4. Challenges in Implementation

Bureaucratic Barriers: One of the significant challenges facing tax reforms in Russia is the existing bureaucratic framework. Complicated regulatory processes can deter entrepreneurs from pursuing green initiatives. Streamlining these processes and providing clear guidelines for tax incentives is crucial for encouraging participation in the green economy.

Infrastructure and Technological Gaps: The successful implementation of tax reforms to stimulate green entrepreneurship also depends on the availability of infrastructure and technology. Regions that lack adequate renewable energy infrastructure may struggle to attract investment, regardless of tax incentives. The government must invest in building the necessary infrastructure to support green initiatives.

Regional Disparities: The effectiveness of tax reforms may vary across different regions in Russia. Areas rich in natural resources may have better opportunities to develop renewable energy projects, while others may require more support and investment to foster green entrepreneurship. Policymakers should consider these regional disparities when designing tax incentives to ensure balanced development.

5. Global Comparisons and Best Practices

Learning from Global Experiences: Russia can benefit from examining global best practices in tax reforms aimed at promoting green entrepreneurship. Countries like Sweden and Germany have successfully implemented tax incentives that have led to significant advancements in renewable energy sectors. Adopting a tailored approach that considers Russia's unique context while incorporating effective strategies from other nations can enhance the effectiveness of tax reforms.

International Collaboration: Engaging with international organizations and participating in knowledge-sharing platforms can help Russia develop more effective tax policies for green entrepreneurship. Collaborative efforts can provide insights into successful case studies and innovative solutions that have been implemented elsewhere.

References

[1] Cao, J., Law, S. H., Samad, A. R. B. A., Mohamad, W. N. B. W., Wang, J., and Yang, X. (2022). Effect of financial development and technological innovation on green growth—analysis based on spatial durbin model. *J. Clean. Prod.* 365, 132865. doi:10.1016/j.jclepro.2022.132865

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Crowley, F., and Jordan, D. (2017). Does more competition increase business-level innovation? Evidence from domestically focused firms in emerging economies. *Econ. Innovation New Technol.* 26 (5), 477–488. doi:10.1080/10438599.2016.1233627

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Ullah A, Pinglu C, Ullah S, Abbas HSM, Khan S. The Role of E-Governance in Combating COVID-19 and Promoting Sustainable Development: A Comparative Study of China and Pakistan. Chinese Political Science Review. 2021; 6:86–118.

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

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THE INFLUENCE OF THE HUMAN FACTOR ON THE ECONOMIC GROWTH OF REGIONS AND COUNTRIES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract

In an era marked by pressing challenges such as climate change, environmental degradation, and social inequality, the influence of the human factor on the economic growth of regions and countries has become increasingly significant. Human capital, which includes not only education and skills but also health, creativity, and social cohesion, plays a pivotal role in determining the trajectory of economic development.

This paper examines the multifaceted relationship between the human factor and economic growth within the context of sustainable development, emphasizing the necessity for a holistic approach that integrates economic, social, and environmental dimensions. Human capital is a critical driver of innovation and productivity, influencing the competitiveness of economies at both regional and national levels. Regions that invest in education, vocational training, and health care are better positioned to foster skilled workforces capable of adapting to the demands of a rapidly changing global economy. Furthermore, social factors such as trust, community engagement, and cultural values significantly affect the effectiveness of economic policies and initiatives aimed at sustainable development.

This study analyzes various case studies from diverse regions, illustrating how the human factor has led to differing economic outcomes in the context of sustainable development. For example, regions that prioritize inclusive education and promote gender equality tend to experience higher levels of innovation and economic resilience. In contrast, areas with limited access to education and healthcare often struggle with persistent poverty and underdevelopment.

The paper also addresses the challenges and barriers that hinder the effective utilization of human capital, such as socioeconomic disparities, inadequate infrastructure, and a lack of supportive policies. It highlights the importance of creating environments that empower individuals and communities to contribute to sustainable economic growth.

The development of human potential is a vital component of Russia's strategic vision for the future. By focusing on education, healthcare, science and technology, social services, and regional development, the government aims to create a resilient and dynamic society capable of navigating the complexities of the modern world. However, addressing the inherent challenges and ensuring inclusive growth will be key to realizing these ambitious goals. As Russia moves forward, a holistic approach that considers the interplay of various factors will be essential in fostering sustainable human potential development and economic security.

Keywords: regional development, social aspects, ecological sustainability, policy recommendations, education, healthcare, community engagement, gender equality, socioeconomic disparities, inclusive development

I. Introduction

The relationship between the human factor and economic growth has garnered increasing attention, particularly in the context of sustainable development. Human capital—encompassing education, skills, health, and social capital—plays a pivotal role in determining a region's or country's ability to achieve economic growth while maintaining ecological balance and social equity. In an era where environmental concerns and social inequalities are at the forefront of global discourse, understanding how human factors contribute to sustainable development is essential.

Regions and countries that prioritize the development of human capital tend to experience more robust economic growth. A skilled and educated workforce not only drives innovation and productivity but also fosters adaptability in response to environmental changes and economic fluctuations. Moreover, the integration of sustainable practices into economic activities hinges on the willingness and ability of individuals and communities to embrace and implement these practices.

The influence of the human factor on economic growth manifests through various channels. First, education equips individuals with the necessary skills to engage in higher-value economic activities, leading to increased productivity. Second, health and well-being contribute to a more capable workforce, reducing absenteeism and enhancing performance. Third, social capital—characterized by networks, trust, and norms—facilitates collaboration and the sharing of knowledge, further driving innovation and growth.

However, the interplay between the human factor and sustainable development is not without challenges. Issues such as inequality in access to education and healthcare, migration, and demographic changes can hinder the potential benefits of human capital. Therefore, policies aimed at fostering human capital must also consider social inclusivity and environmental sustainability to create a holistic approach to economic growth.

In summary, recognizing and leveraging the human factor is critical for achieving sustainable economic growth. By investing in education, health, and social cohesion, regions and countries can enhance their resilience and adaptability, paving the way for a more sustainable future. This paper will explore the various dimensions of the human factor, its impact on economic growth, and the implications for sustainable development, providing a comprehensive understanding of this crucial relationship.

II. Methods

The study of the influence of the human factor on the economic growth of regions and countries in the context of sustainable development requires a comprehensive and interdisciplinary approach. The main methods used to study this problem are presented below.

1. Econometric modeling

One of the most common methods is econometric modeling, which allows you to assess the impact of various factors on economic growth. In the context of the human factor, models can be used that include the following variables:

- Education level.
- Life expectancy.
- Workforce skill level.
- Human Development Index (HDI).
- Fertility and mortality rates.

Econometric methods such as regressions, time series, and panel data help identify the relationship between human capital and economic growth.

2. Qualitative methods (interviews, focus groups)

Qualitative methods can be used to obtain in-depth data on the impact of the human factor on economic development. Interviews with experts in the field of economics, education, employment, or sustainable development provide information on practical aspects and barriers. Focus groups help to identify the opinions and expectations of different social groups.

3. Analysis of human capital indicators

Using human capital indicators such as:

- Human Development Index (HDI).
- Education index.
- Gender equality index.
- Income distribution.

Comparison of these indices with indicators of economic growth of a region or country allows for a detailed analysis of the relationship between human capital development and economic efficiency.

III. Results

The state may possess natural, technological, and financial resources, but all of this is insignificant without a highly qualified workforce and a high level of human development. In today's rapidly changing world, the importance of human capital is continually increasing. "In the era of digitalization and transformation of production processes, human capital is becoming the foundation for the development of the economy of any country" [12].

In a broad sense, human capital encompasses the abilities, knowledge, skills, intellect, and health of individuals utilized in production processes and to generate income for families and the nation as a whole.

The following types of human capital are identified in the economy:

1. **National human capital** refers to a portion of national wealth that includes intellectual, physical, and labor capabilities that aid in the economic development of the country.
2. **Organizational human capital** consists of the knowledge, skills, intellectual and professional abilities, as well as the physical and psychological well-being of personnel, utilized to achieve high performance in a specific organization.
3. **Individual human capital** comprises the knowledge, skills, health, and abilities of an individual that affect their standard of living and income.

The human capital of each country can be measured. Since 2018, the World Bank (WB) has been compiling the Human Capital Index (HCI) rankings by country. The HCI can help countries analyze problem areas in their socio-economic policies and assess their readiness to transition to a sustainable development model based on the growth of human capital.

The HCI is calculated based on three components:

- Survival;
- School life expectancy adjusted for learning outcomes;
- Health status.

The United Nations (UN) employs a different indicator to assess human development—the Human Development Index (HDI), which is a composite measure reflecting an individual's ability to lead a long and healthy life, gain knowledge, and achieve a decent standard of living.

The following factors are considered when calculating the index: health and longevity, access to education, and a decent standard of living.

The index categorizes countries into four groups based on their level of human development:

- Very high value—an index of at least 0.800;

- High value—an index of 0.700-0.799;
- Medium value—an index of 0.550-0.699;
- Low value—an index below 0.550.

In 2020, the HCI included data on health and education from 174 countries, representing 98% of the global population. According to the World Bank, Russia ranks 41st in the world HCI rankings, with an index of 0.68, or 68%. This indicates that a child born in Russia today can achieve 68% of the productivity of an adult with complete education and good health in the future. For instance, Russia's education indicators surpass those of many higher-income countries, but its health indicators fall short of the global average. The top-ranked countries in the index are Singapore (88%), Hong Kong (81%), and Japan (80%).

Furthermore, as demonstrated in other research, there is a strong positive correlation between subjective well-being (SWB) and the Environmental Protection Indicator (which covers a wide range of issues such as biodiversity, ecosystems, climate, energy, air and water pollution, agriculture, and sanitation). These findings suggest that well-being is linked to the long-term outcomes of environmental policies, even if it is not necessarily positively correlated with the short-term efforts required by these policies.

The challenge for policymakers is to overcome short-term trade-offs by decoupling improvements in human well-being from the consumption of natural resources and greenhouse gas emissions. A recent OECD report addresses this challenge by proposing climate change mitigation through a well-being perspective, placing people at the center of climate action. The countries identified in our analysis, that perform well on SDG 12 and SDG 13 while also achieving high levels of well-being suggest there may be pathways to enhancing well-being without compromising environmental sustainability. These countries include a mix of large and small nations. For instance, Germany has heavily invested in renewable energy infrastructure, creating 'green jobs' while simultaneously reducing emissions. The combination of carbon taxes, incentives for renewable energy, and ambitious social policies has enabled Nordic countries to transition away from fossil fuels without burdening low-income households with higher energy costs. Similarly, Costa Rica ranks among the top nations for investment in renewable energy relative to GDP and has committed to achieving carbon neutrality starting in 2021. It offers an alternative model for developing nations to avoid the carbon-intensive development path of the West.

According to the World Bank, human capital constitutes 64% of the world's wealth, estimated at $1,152 trillion. This highlights that human intelligence, health, and the development of professional and creative abilities—along with education—are becoming crucial resources, comparable to oil, gas, innovative technologies, and other assets of the national economy. A robust level of human capital fosters increased income, well-being, and quality of life not only for individuals but for the entire country. Therefore, "national programs should primarily focus on enhancing the education system, healthcare, and the social sector".

The contemporary world demands modern solutions. Innovations are now integral to every sector of economic activity. Currently, the advancement of high-tech industries represents a key competitive advantage for nations. According to Rosstat, there has been an increase in the contribution of these sectors to total GDP over the past decade. Consequently, producing high-tech products necessitates highly qualified professionals. As technological innovations expand within the country, the demand for human capital is set to rise accordingly.

Human development as a factor in ensuring the economic security of the EAEU countries. The Eurasian Economic Union (EAEU) is a growing integration association in the post-Soviet region, aimed at implementing a unified economic policy and facilitating the free movement of goods, services, capital, and labor resources [8]. One of its founding goals is the comprehensive development of modernization, cooperation, and enhancing the competitiveness of the member countries' economies within the global context. In today's environment, human potential has become a critical factor in ensuring the economic security of the EAEU.

An examination of population data from the EAEU countries over the last fifteen years indicates a notable rise in this metric. From the analysis of the data, several conclusions emerge. At the start of the study period (2005), Russia had the largest population, followed by Kazakhstan, Kyrgyzstan, and Belarus. Throughout this time, the population trends of these countries diverged. For instance, Russia exhibited relative stability, remaining close to its initial population level by 2020. In contrast, Kazakhstan showed positive growth, significantly increasing its population by 2020. Kyrgyzstan, however, maintained relative stability, with its population level staying near the initial figure.

Overall, the EAEU countries have experienced population growth over the past fifteen years, reaching notable increases by 2020. These developments underscore the significance of demographic factors in analyzing the region's socio-economic landscape and highlight the necessity of considering population trends when crafting development strategies.

Regarding age demographics, Russia, Belarus, and Armenia are characterized by a relatively low percentage of minors and a considerable elderly population, indicating that these nations are facing the challenges of population aging. This trend may diminish their economic and military influence, necessitating primary focus on ensuring the effectiveness of pension and healthcare systems, as the overall demographic burden on the working-age population is projected to nearly double by mid-century.

Thus, human potential plays a crucial role in all aspects of economic security, including production, food, foreign economic, and socio-demographic security, among others. Key destabilizing factors affecting human potential and economic security in the EAEU countries include significant disparities in human development and socio-demographic progress; gender inequality; increasing income disparities; and declining quality of life and well-being. Furthermore, Russia, Belarus, and Armenia continue to face issues of depopulation and aging, which directly result in a loss of labor resources.

Given the considerable challenges surrounding the levels and synchronicity of human potential development across EAEU nations, it is essential to reevaluate approaches to intra-integration interactions concerning the formation, development, implementation, and preservation of human potential. Strengthening cooperation should be prioritized, focusing on the following key areas:

1. Rapid advancement of digital transformation across all areas of human activity and society as a whole.
2. Enhancing collaboration in healthcare.
3. Emphasizing environmental sustainability in the creation of new joint projects aimed at achieving sustainable human development.
4. Boosting cooperation in education, science, and innovation.

Addressing these priorities and implementing them will enable the development of human potential, thereby ensuring a sufficient level of economic security for both individual EAEU countries and the entire Union.

Furthermore, Russia's national goals and strategic objectives for development until 2024 are supported by the national projects established in various sectors, including demography, healthcare, education, housing and urban development, ecology, safe and high-quality roads, labor productivity and employment, science, digital economy, culture, entrepreneurship, and more. These projects align with the principles outlined in the human potential development concept.

The Strategy of Economic Security of the Russian Federation identifies the development of human potential and the challenge of enhancing its quality as critical areas and significant threats to economic security in the social sphere.

The Russian government places particular emphasis on several key areas to promote the development of human potential:

1. **Education**: The Government of the Russian Federation is investing in the education system, focusing on improving the quality of primary and secondary education as well as vocational training. Additionally, there is increased funding for higher education and a push for greater international collaboration. Federal Law No. 273 establishes fundamental principles and regulations governing education in Russia, covering primary, secondary, and higher education, alongside provisions for preschool, vocational, and adult education.
2. **Healthcare**: The Government of the Russian Federation allocates funds to enhance the healthcare system, concentrating on improving medical care quality, increasing access to services, and encouraging healthy lifestyles among citizens. The government has also implemented measures to combat infectious diseases. Federal Law No. 323 outlines the fundamental principles and regulations for the healthcare system in Russia, including the organization of medical care, funding for services, and patient rights protection.
3. **Science and Technology**: The government invests in advancing science and technology, particularly focusing on fostering innovation, technology transfer, and the growth of high-tech industries. Funding for research and development is being increased, along with efforts to enhance international cooperation in this field. Federal Law No. 127 lays down the basic principles and regulations for science and innovation development in Russia, covering research funding, intellectual property protection, and the commercialization of scientific findings.
4. **Social Services**: The Russian government is committed to enhancing social services, prioritizing affordable housing, social security benefits, and assistance for those in need. Additionally, the government promotes cultural development and the preservation of Russia's cultural heritage. Federal Law No. 442 defines the key principles and regulations for social service provision in Russia, focusing on support for vulnerable groups, including the disabled and elderly, as well as affordable housing and social security.
5. **Regional Development**: The Russian government implements policies aimed at stimulating economic growth across its regions, particularly in job creation, support for small and medium-sized enterprises, and fostering regional cooperation.

In 2023, state initiatives for developing human potential in Russia will concentrate on these critical areas while also encouraging broader international cooperation.

IV. Discussion

Russia has established a comprehensive framework for its development until 2024, centered around national projects in key sectors such as demography, healthcare, education, and more. This multi-faceted approach reflects the government’s recognition of the interconnection between human potential and economic security, highlighting the importance of investing in various areas to foster sustainable growth and resilience.

Human Potential Development

The emphasis on human potential development is particularly relevant in today’s rapidly changing global landscape. By prioritizing education, healthcare, science and technology, social services, and regional development, Russia aims to enhance its human capital, which is essential for economic advancement and social stability. The government's commitment to these areas not only seeks to improve individual quality of life but also to bolster national competitiveness in an increasingly interconnected world.

Key Areas of Focus

1. **Education:** Investments in education are crucial for equipping the workforce with the necessary skills to meet the demands of the modern economy. By improving the quality

of primary, secondary, and vocational education, the government is laying the foundation for a skilled labor force that can adapt to technological advancements. The focus on higher education and international collaboration also suggests a strategic vision to foster innovation and attract global talent.

2. **Healthcare:** The enhancement of the healthcare system is vital for ensuring a healthy population capable of contributing to the economy. By improving access to medical services and promoting healthy lifestyles, the government addresses both immediate health concerns and long-term demographic challenges, such as population aging. Effective healthcare policies can significantly impact productivity and overall economic performance.

3. **Science and Technology:** Investing in science and technology is essential for driving innovation and economic diversification. By promoting research and development and protecting intellectual property, the government aims to create an environment conducive to technological advancements. This focus not only strengthens domestic industries but also positions Russia as a competitive player in the global market.

4. **Social Services:** Providing robust social services is integral to promoting social cohesion and stability. By ensuring affordable housing and support for vulnerable populations, the government addresses critical social needs that can otherwise hinder economic development. The emphasis on cultural preservation also reflects an understanding of the importance of social identity in fostering national pride and unity.

5. **Regional Development:** Stimulating economic growth in various regions is crucial for balanced national development. By supporting small and medium-sized enterprises and fostering regional cooperation, the government seeks to reduce disparities between urban and rural areas. This approach not only enhances local economies but also contributes to overall national resilience.

Challenges and Considerations

While the strategic objectives set forth by the Russian government are ambitious, several challenges may impede their successful implementation:

- Resource Allocation: Ensuring adequate funding and resources for these initiatives may pose difficulties, especially in times of economic uncertainty or budget constraints. Prioritizing investments will be crucial for achieving desired outcomes.
- Social Inequalities: Addressing social inequalities and ensuring that all populations benefit from development efforts will be essential. Failing to do so could lead to social unrest and undermine national unity.
- International Collaboration: Strengthening international cooperation can bring about opportunities for knowledge exchange and technological advancements. However, geopolitical tensions may hinder collaborative efforts, particularly in science and technology.
- Demographic Trends: Russia faces demographic challenges, including an aging population and declining birth rates. Addressing these trends will require comprehensive policies that encompass family support, immigration, and workforce development.

The development of human potential is a vital component of Russia's strategic vision for the future. By focusing on education, healthcare, science and technology, social services, and regional development, the government aims to create a resilient and dynamic society capable of navigating the complexities of the modern world. However, addressing the inherent challenges and ensuring inclusive growth will be key to realizing these ambitious goals. As Russia moves forward, a holistic approach that considers the interplay of various factors will be essential in fostering sustainable human potential development and economic security.

References

[1] Wang Y, Yu L (2021) Can the current environmental tax rate promote green technology innovation? - Evidence from China's resource-based industries. J Clean Prod 278:123443

[2] Gromov E.I., Shatalova O.I., Tsutsieva O.T. Improving the mechanism for managing sustainable development of rural areas//Journal of Monetary Economics and Management.- 2023.- No. 4. - P.8-14

[3] Mezentsev D.A. Methods of increasing sales in the context of modern business development//Journal of Monetary Economics and Management.- 2023.- No. 4. - P.15-23

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Makkaeva R.S.A., Askhabaliyev I.Ch., Omarov M.M. Modern concept of "knowledge economy" in the context of a new paradigm of economic development//Journal of Monetary Economics and Management.- 2023.- No. 4. - P.34-40

[6] Karavaeva I.V., Lev M.Yu. New challenges to Russia's economic security (review of speeches by participants in the All-Russian scientific and practical conference "VII Senchag Readings. Russia's economic security: response to new challenges") // Bulletin of the Institute of Economics of the Russian Academy of Sciences. - 2023. - No. 3. - p. 177-193.

[7] Gulmagomedova G.A., Omarov M.M. Efficiency of budget and tax administration: world experience//Journal of Monetary Economics and Management. - 2023.- No. 4. - P. 41-47

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Ullah A, Pinglu C, Ullah S, Abbas HSM, Khan S. The Role of E-Governance in Combating COVID-19 and Promoting Sustainable Development: A Comparative Study of China and Pakistan. Chinese Political Science Review. 2021; 6:86–118.

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

"GREEN ECONOMY" AS A MEANS OF ENSURING ECO-FRIENDLY AGRICULTURAL PRODUCTION

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Abstract

In many countries, the deepening of the environmental problem and the increase of anthropogenic effects on the ecosystem makes it necessary to review the basics of traditional farming and transition to an ecologically oriented economy. This development is also strategically important in our country, so an unsoiled environment and "green" growth must be accepted as national priorities. In this paper, the characteristics of the green economy are studied, and the necessity of extension of the green economy is justified. The contemporary state of "green" evolution was clarified using the example of Azerbaijan's agro-food complex, and scientific reasons for ulterior progress in this domain were given. This research also displays the gravity of applying marketing concepts when producing eco-friendly agriculture and food products. The study shows that the provision of development under the condition of expecting the interests of consumers, businesses, and society applies the socio-ethical concept of marketing. The article clarified the ecological quality of life and the economy's environmental and resource efficiency. The factors of the transition of the country's economy to "green" development tracks have been clarified. This article also tested the hypothesis that an increase in energy resource prices during the energy crisis entailed, in the short term, an increase in the share of renewables combustible in net electricity production in Europe. The study proved that the energy crisis is not an obstacle to the development of both green energy and the green economy. Based on the study's results, stages of transition to green development were elaborated to ensure eco-friendly agricultural production.

Keywords: green economy, green development, greening, environmental efficiency of the economy, resource efficiency

I. Introduction

The problems faced by our civilization in the present period led to severe changes in almost all spheres of society's life activity. These problems include global climate change, loss or disappearance of biodiversity, economic and social tensions, and the emergence and spread of viral infections. Recently, among the listed problems, the effects of virus infections on society and economic development have been more significant. However, implementing purposeful measures to solve the mentioned problem has made it feasible to reduce its effects on society significantly (Rakhmanov et al., 2020). We observe this situation in the example of our country.

However, among the global issues, solving the environmental problem remains relevant in many countries, and there is the potential to achieve stable economic and social development by solving this problem. To ensure stable economic growth, all sectors of the economy must be constantly improved. At the same time, every sector of the economy depends on the resource extraction industry. Transitioning to a green economy is one rational way out of this situation. *First of all, to ensure food security and the lasting development of the agro-food complex, it is necessary to focus on the agro-industrial complex and green energy during the transition to a green economy.*

Research shows that solving an environmental problem would take a long time. Our country's transition to a "green" economic development model will benefit society and is a reliable way to achieve persistent economic development.

In the current conditions, the world's countries are looking for ways to achieve sustainable development and try to implement it. The concept of lasting development is a qualitatively new approach from a socio-economic and ecological point of view, and it combines the following three main problems:

- The lasting development of the economy must correspond to the environmental system of people's life support.
- Rational and fair distribution of current natural resources (including energy resources) and material opportunities should be provided for the current generations and future generations.
- Natural capital should be equally distributed in society, and the needs of social groups should be met (Unesco, 2022).

The concept of lasting development is based on two main principles:

1. Humanity can give development a sustainable character for its long-term well-being.
2. Without creating conditions for realizing everyone has a better life in the future, lasting development is simply impossible. Poverty is one of the leading causes of ecological and other disasters, and it has become a common phenomenon worldwide. Therefore, poverty alleviation is one of the main tasks (State Statistics Committee, 2023).

Scholar studies show that applying the Green Economy (GE) model is necessary for contemporary conditions to move to lasting development in our territories (Vukovich, 2018). The GE model has attracted the attention of scientists and international organizations as an essential tool for realizing lasting development. For this reason, in 2012, most countries switched to a GE model at the UN conference dedicated to lasting development (RIO-20). The countries that are the main initiators of programs related to the GE, which should be especially mentioned, are Australia, Denmark, Germany, Israel, Norway, Spain, Sweden, etc.

This study relates to interdisciplinary research. Its research subject is green economic development. The main goal is identifying how the Azerbaijani economy should transition to "green" development to ensure environmentally friendly agricultural production. When setting specific objectives, the authors did not limit themselves only to studying the green development of the agro-food complex but also tested the hypothesis of whether the energy crisis led to an increase in the share of green energy in net electricity production. Thus, crises are not always an obstacle to developing a green economy.

II. Literature review

As defined by the United Nations Environment Program (UNEP), the green economy covers economic growth, environmental sustainability, and social justice (UNEP, 2011). However, there are contradictions between all three to one degree or another. Firstly, all three aspects require investment. Nevertheless, the budget of no country, even the most developed and prosperous, can provide funding in the required volumes. Each state sets the investment volume for each listed purpose, considering the opportunity cost.

Secondly, there are contradictions between economic growth and environmental stability since economic growth requires increased use of natural resources, which are mainly exhaustible.

Not only is the world's population growing, but so are their needs. An increase in demand leads to an increase in supply. The expansion of production leads to the release of pollutants and contributes to global climate change, which harms not only nature but also humans. That is, on the one hand, social justice can be ensured by economic growth. On the other hand, economic growth and expansion of production leave a carbon footprint, leading to an increase in emissions of carbon dioxide and other greenhouse gases.

Although contradictions exist, they can be mitigated with well-thought-out policies and government strategies. However, it is impossible to minimize the described contradictions without investment. Table 1 presents the main approaches to the green economy, which involve minimizing the described contradictions but have their own disadvantages.

Table 1: *Main characteristics of fundamental theories of green economy and their disadvantages*

Fundamental theories of green economy	**Main characteristics**	**Disadvantages**
Circular economy theory	In a circular economy, resources are reused and recycled to minimize waste and pollution.	The high costs of transitioning to a circular economy require significant investments. Repeated recycling of materials can decrease quality. Not all materials can be recycled. It is not economically feasible for manufacturers to produce products with a long service life.
Theory of sustainable development	Sustainable development of the national economy ensures a balance between economic growth, social inclusion, and environmental protection.	There is a high level of investment in renewable energy sources. New expensive technologies and equipment with a long payback period must be introduced. High costs can lead to decreased competitiveness, which is not profitable for entrepreneurs.
Ecological Economics	According to this theory, the economy should be a subsystem of the ecosystem.	Significant investments are needed to implement the green economy. It is difficult to achieve an economic model that considers all environmental and social factors, and there is a conflict of interest between business and environmental protection.
Theory of sustainable consumption and production	The essence of this theory is to change consumption and production patterns to reduce the negative impact on the environment.	Changing the consumption and production model may encounter the following obstacles: significant financial investments beyond the reach of small businesses, consumers' reluctance to change their habits and preferences, and the lack of green technologies in some industries.
Bioeconomy	Bioeconomy involves transitioning from fossil resources to renewable biological resources and developing biotechnology.	Biological resources are limited, leading to increased competition for their use. The development of the bioeconomy is impossible without significant financial investments. At the same time, some bioeconomic activities' economic efficiency is lower than traditional ones, which will decrease competitiveness.
Ecological modernization theory	According to this theory, environmental problems can be solved through innovation, reform, and institutional changes that do not impede economic development.	One of the assumptions of this theory is that economic growth and environmental sustainability can coexist and complement each other. However, limited natural resources indicate the opposite and are a prerequisite for reducing overall consumption.

Source: Authors' systematization.

Modern society is a society of consumers, so difficulties arise when promoting a circular economy (Figge et al., 2022). Consumers should change their habits, use the same product for a long time, and not regularly change, for example, phones and other electronics. Great difficulties will arise when manufacturers reformat since they are not interested in producing goods with a long service life. For example, if the light bulbs do not burn out regularly, and if we do not offer consumers new versions of iPhones, how can manufacturers generate revenues in volumes that would provide them with the wealth they strive for? An entrepreneur is not an altruist. Another disadvantage of the circular economy is that there are technological limitations since not all materials can be reused or easily recycled, or there are restrictions on the number of recycling cycles.

Reformatting producers is also necessary to promote sustainable development (green economy) (Ogryzek, 2023). Some sustainable technologies are less cost-effective, making them less attractive to entrepreneurs. Less efficiency combined with high costs makes production less competitive.

The main characteristics of ecological economics are sustainable resource management and the consideration of natural capital, environmental, and social factors in the economic model (Omer, 2023). Introducing environmental technologies often increases costs, which decreases revenues and profits. Thus, businesses are not interested in promoting ecological economics.

Promoting sustainable consumption and production may cause conflicts between economic, environmental, and social goals. For a massive transition of the population and business to sustainable consumption and production, the state must introduce a system of economic incentives (Goel & Baral, 2023). However, not all states can subsidize all enterprises to ensure the transition to sustainable production.

The main goal of the bioeconomy is the transition to using biological resources to produce products and services (Pan, 2023). As shown in Table 1, the limited availability of biological resources leads to increased competition for their possession and use, negatively affecting food security. It also leads to their intensive use, which can lead to monoculture practices and biodiversity loss.

The connection with green energy can be traced with all six theories listed in Table 1. Green energy is a crucial component of sustainable development.

The concept of a “green” economy is based on the awareness that all sectors of the national economy must rationally use natural resources, including energy. Thus, the green economy cannot be isolated from “green” energy. However, the research subject in most modern scientific works is either a “green” economy or a “green” energy.

The researcher M.V. Chkhan notes that the “green” economy (GE) is closely related to lasting production, consumption, energy efficiency, and renewable energy sources, which creates new jobs and improves people's well-being (Chkhan, 2021). This new economic concept, the GE, aims to unlock the value of people and nature and improve the population's well-being (Zenchanka et al., 2015). Poverty reduction and efficient and optimal use of limited natural resources form the basis of this concept (State Statistics Committee, 2022).

Researcher N. A. Khutorova believes that “green growth is a new vector of economic development,” which indicates the close interrelation of the country’s national priorities. “The GE must be viewed in continuous connection with the concept of lasting development of national and global economies” (Khutorova, 2015).

Numerous factors of green growth can be studied in more detail. Russian economists S.N. Bobylev, P.A. Kiryushin, and O.B. Kudryavtseva determine the factors of GE and lasting development within the framework of interaction between the state, society, and business and divide these factors into three categories (Bobylev et al., 2019). As E.B. Dorina and T.V. Bukhovets noted, these three factors relate to the state, society, and business (Dorina et al., 2017).

The specialized literature offers many approaches to the GE, which is oriented towards sustainable development. Some scholars argue that GE is based on transitioning to alternative resources and focuses on renewable energy sources (Gainsborough, 2018).

When studying green energy, one cannot ignore the mechanisms of energy price formation. Thus, researcher T. Gutium believes that gas pricing mechanisms influence the development of green energy, especially in periods when fossil fuel prices change considerably (Gutium, 2021). That is why this article tested the hypothesis that rising energy prices during the energy crisis led to an increased share of renewable fuels in net electricity production in Europe in the short term.

Summarizing all of the above, the authors in this study examined the "green" economy, not in isolation from "green" energy.

III. Materials and methods

This research's sources are scientific works published in the last ten years, national economic development programs, and a database of available data since 2010. The authors used the following methods: scientific abstraction, induction and deduction, static and dynamic analysis, and correlation and regression analysis. The hypothesis about the influence of energy resource prices on the share of renewable energy resources in electricity production during the energy crisis was tested using the software EViews 9.5.

EViews is a statistical package primarily used to analyze time series econometric data and build regression models. With its help, it will be proven or disproved that a significant increase in the price of energy resources leads to the growth of green energy. This package will also test the quality of the obtained regression equation.

To verify the quality of the obtained regression equation, the researchers rely on the following statistical tests: the coefficient of determination (R-squared), the coefficient of determination adjusted (Adjusted R Square), the F-statistic, Akaike Information Criterion (AIC), and Schwarz Criterion (SC).

Residuals checking for autocorrelation was performed using the Durbin-Watson Statistic test (d):

$$d = \frac{\sum_{i=2}^{n}(\xi_i - \xi_{i-1})^2}{\sum_{i=1}^{n}\xi_i^2} \tag{1}$$

$$\xi_i = y_i - \widehat{y_i} \tag{2}$$

Where:

ξ_i – random member with "statistical noise" properties ("White noise" - time series with zero expectation),

y_i – the value of the endogenous variable,

$\widehat{y_i}$ – the adjusted value, obtained with the regression equation.

Depending on the value obtained, we can highlight the following general cases:

if d=0, then there is perfect positive autocorrelation;

if d=4, then there is perfect negative autocorrelation;

If d≈2, we consider the deviation from the regression line to be random. This means that the constructed linear regression probably reflects the actual dependence.

The Breusch-Pagan-Godfrey test was used to check the heteroscedasticity of the residuals. The number of observations is 24. The observations represent monthly data for the years 2021-2022.

IV. Results

Recently, the concept of GE has been increasingly used in the scientific community. "The GE is no longer a new concept; it is used to explain a particular type of economic development, and at this time, the main goal is to improve the material well-being of people with the expectation of social justice and the reduction of anthropogenic impacts on the ecosystem (Khutorova, 2015).

Our country has no universally accepted and unambiguous definition of a GE. We do not observe that this concept is defined explicitly in the normative documents of the Republic of Azerbaijan. The most comprehensive description of this concept appears in the UN Environment Program. According to this document, the GE model is an economy that ensures a decent standard of living for people while protecting the environment without creating risks for future generations.

The deepening of environmental problems worldwide and the anthropogenic effects on ecosystems are reaching a dangerous level, making it necessary to review the foundations of traditional farming and transition to an ecologically oriented economy. "Economic growth is constantly creating unwanted and dangerous changes on our planet. The main reason is that carbon-based fuel products are the main energy resources to ensure economic development worldwide" (Gasimli et al., 2022). The type of ecologically oriented economy is called GE. The complex transformation strategy for a GE is called "green growth." Preserving ecological balance and improving the environment is impossible without "green" economic development. In this regard, "green development" is the most important means of lasting development.

In the document "Azerbaijan 2030: National Priorities for Socio-economic Development," adopted by the Decree of the President of the country on February 2, 2021, a lasting, growing, competitive economy, a clean environment, and a country of "green" growth were accepted as national priorities in our country. Until now, specific work has been done to transition our country's economy to green development tracks, and these measures are continuous. As a result of these measures, reductions in the volume of pollutants released into the atmosphere and significant improvements in some indicators characterizing the ecological quality of life are observed in our country.

As can be seen from the statistical analysis, the volume of pollutants released into the atmosphere from stationary sources in 2022 decreased from 170.9 thousand tons to 158.4 thousand tons, or by 7.3%, compared to 2018. During the analyzed years, the volume of pollutants released into the atmosphere from mobile sources decreased from 950.2 thousand tons to 772.2 thousand tons (18.7%) (Figure 1).

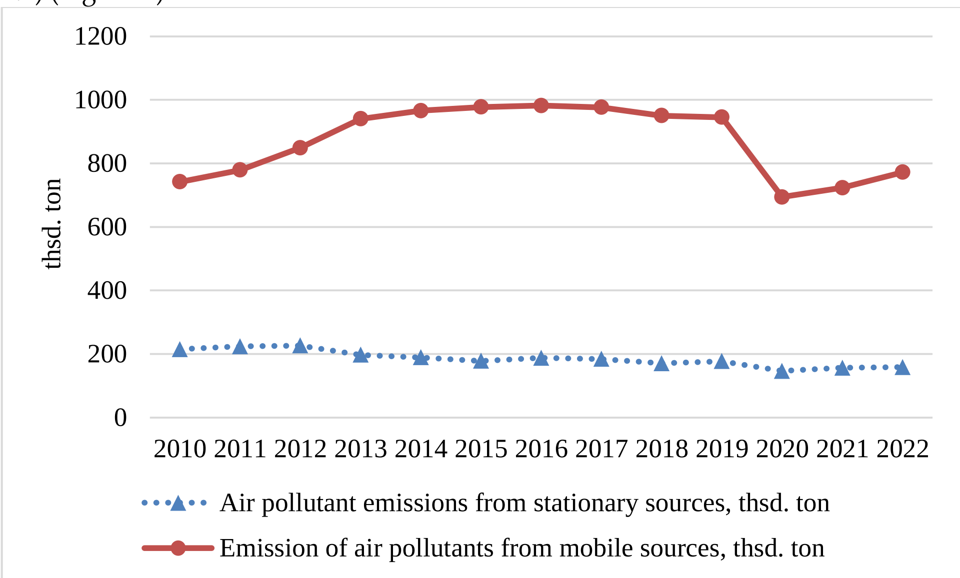

Figure 1: *Evolution of air pollutant emissions*
Source: The State Statistical Committee of the Republic of Azerbaijan

Currently, special attention is paid to developing the "green" agro-food complex to improve the quality of life in our country. To ensure the green development of the said complex, specific works have been done to create a legal framework and form its institutional foundations. Thus, the laws of the Republic of Azerbaijan "On ecological agriculture," "On food products," and "On the protection of consumers' rights" were adopted, and the Food Safety Agency was established.

In addition to all this, ensuring the coordination of activities on the production of ecologically clean agricultural products, expanding social and economic incentive measures that will help the development of the environmentally clean agricultural system, organizing fairs for producers of these products, and creating a product certification mechanism, the production of ecologically clean products it is planned to multiply and increase the number of people engaged in the production of these products by 50%.

These measures stipulated in the "Strategic Roadmap for the Production and Processing of Agricultural Products" have been almost implemented. As a result, the ecologically clean agricultural products market has developed to some extent as one of the critical segments of the food market. The research shows that specific improvements in some ecological and economic indicators in agriculture, forestry, and fishing (for example, reduction of wastewater discharge into surface water bodies, prevention of water loss used for irrigation, etc.) increase to a certain extent.

These opportunities can facilitate the growth of environmentally friendly products in domestic and foreign markets. The capacity of ecologically clean agricultural and food products is increasing yearly, and these products are among the dynamically developing markets. Thus, research shows that between 2000 and 2019, sales of organic agricultural products worldwide increased more than sevenfold. According to experts in this field, the market's growth for environmentally friendly products will continue from year to year, and in 2025, the volume of this market will reach 212-230 billion dollars. This means up to approximately 5% of the capacity of the world agricultural and food products market in terms of value.

The number of people who prefer organic products in the farming and food market worldwide is constantly increasing. The number of consumers of these products has increased approximately four times between 2005 and 2020, exceeding 700 million. According to data from the last few years, Switzerland is the leader among the countries that spend the most on organic products. Thus, in this country, the expenses incurred for acquiring organic products per person during the year amounted to 210 euros. This indicator was equal to 163 euros for Denmark, 157 euros for Luxembourg, 129 euros for Liechtenstein, 127 euros for Austria, 106 euros for Sweden, 93 euros for Germany, 77 euros for the USA, 71 euros for Canada, and 44 euros for Norway. The United States is the leader in terms of the capacity of the organic products market (44.7 billion euros). Germany ranks second, and France is third.

The production of these products and the actual capacity of the organic products market are expected to increase. Therefore, it is essential to focus on improving the production of these products, which also means raising the standard of living and preserving the national gene pool. Considering what has been said, attention to the production of environmentally friendly products has increased in recent years in our country.

In Azerbaijan, ecologically clean products are produced and offered to the market, which are directly consumed without processing, as well as those that undergo deep processing. These products include grapes, vegetables, subtropical plants, pasta, rice, milk, dairy products produced on family farms, and honey. These products offered to the market are positioned in the eyes of their buyers as ecologically clean products compared to products made traditionally, leading to buyers' preference for those products, thus ensuring their high competitiveness. Unfortunately, there is no accurate information on the listed products' production volume. Therefore, analyzing the conjuncture of ecological agriculture and food products is tricky.

Through market observation, it is possible to get a specific idea about the sale of the listed products and the buyers' satisfaction (Gutium et al., 2023). All this shows that the market of ecologically clean agriculture and food products in our country is experiencing its formation period. In addition to the so-called growth of the production of organic products in our country, it can allow the development of the export of those products and increase the profitability level of producers. This is because organic agricultural and food products are several times more expensive than conventionally produced products of the same name. Indeed, the costs involved in making these products are also high. Still, the income from the sale of the products allows them to cover the costs and ensure the necessary level of profitability for the producers. From this point of view, foreign organic agricultural and food products markets are pretty attractive for producers. Several principles must be observed in the production process for product development for those markets.

The document "Concept on the restoration and development of the liberated territories of the Republic of Azerbaijan" was prepared to realize the economic potential of the region based on the methodological approaches and advanced international practices on the restoration and reconstruction of the territories from Karabakh, ensuring lasting development in these territories (Gasimli et al., 2022). This document defines the principles of keeping the territory restoration process in focus. These principles are as follows:

- Achieving high population density when returning to restored areas;
- Involvement of private and state, as well as local and foreign investments in the recovery process to reduce state costs, in particular, wide use of public and private sector partnership;
- The process of restoration of territories consists in creating more demand for new production and thus stimulating the growth of the country's economy.

The principles mentioned above, in turn, envisage the preparation and implementation of political measures, including complex programs, related to the territories' restoration, reconstruction, and lasting development.

As noted above, organic agricultural and food products are several times more expensive than traditional analog products. Rising energy prices can become an obstacle to developing a green economy. However, as we will prove below, the energy crisis has led to the growth of green energy, which is an integral part of the green economy. So, the crisis is not an obstacle to developing both "green" energy and the "green" economy.

A regression analysis method was used to test the hypothesis about the influence of world natural gas and oil prices in Europe on the share of green energy in electricity production during the energy crisis. As a result, the following regression equation was developed using the software EViews 9.5:

$$\ln(share_{green}) = 2 - 0.1 \times \ln(price_{gas}) + 0.43 \times \ln(price_{oil}) + 0.13 \times d05 - 0.12 \times d11. \quad (3)$$

Where:

$share_{green}$ – the share of green energy in electricity production in Europe;

$price_{gas}$ – the natural gas price in Europe;

$price_{oil}$ – the oil price in Europe;

$d05$, $d11$ – dummy variables (05 – value "1" for May 2021; 11 – value "1" for November 2021).

The results of testing the null hypothesis H0 according to which the regression parameters of the regression equation (3) are equal to zero is presented in Table 2.

Table 2: *Testing the null hypothesis H0 that the regression parameters are equal to zero*

Variable	standard error	t-statistic	p-value
C	0.285909	7.066672	0.0000
$\ln(price_{gas})$	0.022222	-4.548545	0.0002
$\ln(price_{oil})$	0.076330	5.625145	0.0000
$d05$	0.049024	2.577127	0.0185
$d11$	0.047761	-2.591611	0.0179

Source: Authors' estimation using EViews 9.

The quality of regression equation (3) was verified, and the results are presented in Table 3.

Table 3: *The results of testing the quality of the regression equation*

Statistical tests	Value
R-squared	0.730786
Prob(F-statistic)	0.000031

Durbin-Watson statistic	2.1720
Akaike info criterion	-3.126022
Schwarz criterion	-2.880594
Hannan-Quinn criterion	-3.060910

Source: Authors' estimation using EViews 9.

The residuals do not autocorrelate according to the value of the Durbin-Watson statistic. The Breusch-Pagan-Godfrey test results showed that the regressions' random residuals are homoscedastic (Table 4).

Table 4: *Results of the Breusch-Pagan-Godfrey test*

	Value
F-statistic	0.6395
Obs *R-squared	2.8477
Scaled explained SS	2.4490
Prob. F (4,19)	0.6408
Prob. Chi-Square (4)	0.5836
Prob. Chi-Square (4)	0.6538

Source: Authors' estimation using EViews 9.

The obtained result indicates that only the price of oil had a direct positive impact (in the short term) on the share of green energy during the energy crisis in Europe. However, according to previous studies (Gutium, 2022), the price of natural gas directly impacts the share of green energy in energy-importing countries in the long term. The found cause-and-effect relationship shows that developing one's green energy is necessary to reduce the impact of volatility in world energy prices.

V. Discussion

The International Federation of Organic Agriculture (IFOAM) has defined the following principles that must be followed during the production of organic agricultural products: principles of ecology, health, care, and fairness. Many world countries have adopted the listed principles, and according to the latest information, their number has exceeded 180. The area of land devoted to organic farming in these countries has also increased yearly and, according to 2019, was equal to 72.3 million hectares.

In the last twenty years, the area of land certified for producing environmentally friendly products has increased up to seven times. Australia has the leading position worldwide in terms of cultivated area devoted to making organic products (35.7 million hectares). The following places are occupied by Argentina and Spain (respectively 3.7 and 2.4 million ha). According to 2020 data, the number of organic product producers worldwide is 3.1 million. Studies show that the area allocated for organic product production in Azerbaijan is 0.8% of the total land area. It should be noted that the level of this indicator varies around 1.5-1.6% worldwide.

Organic products produced in our country are rarely found in large trade networks. In trade networks of foreign countries (Russia, Belarus, etc.) are observed more on imported organic food products (for example, pasta products, cereals, etc.). This is because local producers establish relationships with consumers directly through social networks. This in itself should be considered admirable. Thus, forming relations with these products' direct consumers means removing intermediaries from the sales channel. In this case, the prices of the products become fairer, satisfying both producers and consumers.

In addition to all this, direct sales of products allow producers to have more income and, therefore, more efficient market operations than the intermediary sales channel. This essential factor encourages the development of the organic products market. However, in the future, the formation of a multi-channel system of organic products in our country will be inevitable. This will allow product manufacturers to increase the channel selection opportunities in product realization and to realize their products on the desired channel. Direct and indirect sales channels of organic products are active in developed foreign countries. It should also be noted that most of the products produced in those countries are sold through indirect sales channels. So, for example, according to data from recent years, 90% of organic products in Denmark, 72.3% in Great Britain, 54.0% in the USA, and 50% in Russia are sold through supermarkets.

Specialized stores are selling organic products in the listed countries. In these countries, the sale of products made by Denmark through specialized stores accounts for around 4% of the total volume of organic products. The mentioned indicator is 12% in France, 13.5% in Italy, 15% in Great Britain, and 25% in neighboring Russia. The high level of organization in the sale of organic products in the extensive trade networks of our country requires paying attention to solving the issues related to the marketing of these products. This is because, in the conditions of market relations, the competition between products and enterprises is based on marketing factors. Among these factors, packaging and certification of products at a level that can appeal to the consumer's taste in the current conditions can lead to the preference of those products compared to competing products and, thus, to the strengthening of the market positions of local producers.

In general, to ensure "green" development in the agro-food complex, it is necessary to apply the social-ethical marketing concept of marketing by business structures operating in this complex. During the application of this concept, not only the interests of consumers (this is ensured by offering consumers environmentally friendly products) but also producers (the interests of the manufacturing enterprise are manifested by obtaining sufficient profit to continue its market activity, and this is justified for the long-term period) and society as a whole interest (which manifests itself in the form of prevention of pollution of the environment and thus preservation of ecological balance) is protected.

Thus, lasting development is ensured. Transferring our country's development to the tracks of "green development" does not end with the measures mentioned above. The construction works in Karabakh are being implemented based on the principles of green development. We believe implementing intelligent village and city projects in Karabakh will significantly contribute to development based on the GE model.

The transition to "green" development to ensure environmentally friendly agricultural production requires an integrated approach, including the stages presented in Figure 2.

Figure 2: *Stages of transition to green development to ensure environmentally friendly agricultural production*
Source: Authors' elaboration

The passage of all these stages helps Azerbaijan create a sustainable and environmentally friendly agricultural complex that protects the environment, improves product quality, and improves the well-being of the rural population.

VI. Conclusion

The green economy theories examined in this study reflect a scientific approach to sustainable development that considers economic, environmental, and social factors. None of the theories is perfect; each has shortcomings. The main disadvantages are high initial costs and resistance from businesses due to the risk of reducing profits and competitiveness of production. All these obstacles can be overcome provided the state subsidizes the transition to a green economy and develops and applies a system of economic incentives.

The GE is interpreted as a concept that provides environmental sustainability, production and consumption of products and services, and investments in green development. When this issue is approached from a philosophical-sociological point of view, socio-economic development, income growth, employment, and poverty reduction are considered while ensuring environmental sustainability. There is no well-defined and universally accepted definition of what the concept of GE covers. For this reason, different countries come up with various definitions within their specific conditions. In fact, in the current conditions, the understanding of the GE, its scientific definition, and social-philosophical investigation differ in different countries.

Because the degree of socio-economic development of different countries is different, for example, there is considerable variation in lasting development between developed, developing, and newly industrialized countries. These differences are also reflected in the respective countries' GE levels and the steps taken in this direction.

In our opinion, the following can be attributed to the main ways of moving Azerbaijan's economy to the tracks of "green development":

- reducing the energy capacity of the economy (this can be achieved by reducing the share of non-productive sectors of the economy),
- extensive use of non-traditional energy resources, including renewable energy resources (solar, wind energy),
- reduction of anthropogenic (related to human activity) impacts of the energy sector on the environment,
- improvement of normative legal documents in the field of GE,
- create an efficient system of personnel training in energy-saving technologies, etc.

Factors related to society include the formation of an ecological lifestyle culture, the development of eco-activism, and the popularization of the eco-volunteer movement. Factors related to the state include the need for modernization of the economy, international cooperation in the sphere of lasting development, the implementation of internationally essential state projects, and the expectation of lasting development in the development of cities from an ecological point of view. Finally, factors related to business include improvement of environmental regulation, detection of "green" opportunities for business, and norms and standards for lasting development in business management.

In addition to the above, green economic development is influenced by using new and advanced technologies and actualizing environmental problems. To achieve this goal, factors affecting green economic development should be considered in a complex and systematic manner, thus ensuring lasting development.

References

1. Bobylev, S.N., Kiryushin, P.A., & Kudryavtseva, O.B. (2019). *Green economy and sustainable development goals for Russia*. Faculty of Economics, Moscow State University.

2. Chkhan, M.V. (2021). Green Economy as the Instrument of Providing Sustainable Finances in the EU. *MGIMO Review of International Relations*, *14* (5), 224-231.

3. Dorina, E.B., & Bukhovets, T.V. (2017). *Management of Green Development in the National Economy*. BELSENS.

4. Figge, F., Thorpe, A., Manzhynski, S., Gutberlet, M. (2022). The us in reUSe. Theorizing the how and why of the circular economy. *Business strategy and the environment*, *31* (6), 2741-2753.

5. Gainsborough, M. (2018). Transitioning to a green economy? Conflicting visions, critical opportunities and new ways forward: review essay: Transitioning to a green economy? *Development and Change*, *49*, 223–237.

6. Gasimli, V.A., Huseyn, R.Z., Huseynov, R.F., Hasanov, R.B., Jafarov, C.R., & Bayramova, A.B. (2022). *Green economy*. Azprint publishing house.

7. Goel, R., Baral, S.K. (2023). *Handbook of Research on Sustainable Consumption and Production for Greener Economies*. IGI Global, 481 p.

8. Gutium, T. (2021). Gas Pricing Mechanisms: Overview, Comparative Analysis and Recommendations. *2021 International Conference on Electromechanical and Energy Systems (SIELMEN)*, 45-50.

9. Gutium, T. (2022). The impact of the energy crisis on the economy and on the standard of living of the population of the Republic of Moldova. *Information and Innovations, 17* (1), 6-18.

10. Gutium, T., Gojaeva, E., & Huseynova, S. (2023). Social exclusion and poverty in the European Union and candidate countries. *Cogito Multidisciplinary Research Journal, XV* (2), 124-145.

11. Khutorova, N.A. (2015). Green growth as a new vector of development of the Russian economy. *Vestnik MGUL - Lesnoy Vestnik, 19* (1), 190-198.

12. Ogryzek, M. (2023). The sustainable development paradigm. *Geomatics and environmental engineering, 17* (1), 5-18.

13. Omer, A.M. (2023). Environmental and Ecological Economics. *Journal of Environmental Science Current Research*, *6*, 042.

14. Pan, A. (2023). *Bioeconomy Theory and Practice*. Springer Singapore, 294 p.

15. Rakhmanov, F.P., Suleymanov, E.B., & Gojaeva E.M. (2020). Consequences of the impact of the coronavirus pandemic on the development of tourism in Azerbaijan. *Tourism and Hospitality*, *2*, 76-88.

16. State Statistics Committee. (2022). *Green economy*. https://www.stat.gov.az/menu/6/statistical_yearbooks/?lang=en

17. State Statistics Committee. (2023). *Sustainable development goals*. https://www.stat.gov.az/menu/6/statistical_yearbooks/source/DIM_stat_2023.zip

18. UNEP. (2011). *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. http://www.unep.org/greeneconomy

19. Unesco. (2022). *Azerbaijan 2030: National priorities for socio-economic development*. Policy Monitoring Platform. https://www.unesco.org/creativity/en/policy-monitoring-platform/azerbaijan-2030-national-priorities-socio-economic-development

20. Vukovich, N.A. (2018). "Green" economy: definition and modern environmental-economic model. *Bulletin of UrFU. Series: Economics and Management*, 8-15.

21. Zenchanka, S., & Korshuk, E. (2015). The 'green economy' concept in Belarus: Today and tomorrow. *Progress in Industrial Ecology – An International Journal, 9* (1), 33-45.

BEHAVIOURAL ECONOMICS AND SUSTAINABILITY: ALIGNING HUMAN INCENTIVES WITH GREEN GROWTH STRATEGIES

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Abstract

This paper investigates the integration of behavioral economics into sustainability efforts, highlighting the critical role that human incentives play in promoting green growth strategies. As environmental challenges escalate globally, understanding the psychological mechanisms driving individual and collective decision-making becomes essential for crafting effective policies. The research identifies key behavioral insights, such as cognitive biases, heuristics, and the influence of social norms, which can be harnessed to encourage sustainable practices. It emphasizes the importance of designing interventions, including nudges and economic incentives, that align with human behavior to foster environmentally friendly actions among individuals and businesses. Through the examination of various case studies, the paper showcases successful implementations of behavioral interventions that have led to measurable improvements in sustainability outcomes. Ultimately, this study aims to equip policymakers and practitioners with practical tools and strategies to enhance the effectiveness of green growth initiatives, ensuring that they resonate with human behaviors and contribute to long-term sustainable development goals.

Keywords: behavioral economics, sustainability, green growth, human incentives, environmental policies, decision-making, nudges, social norms

I. Introduction

In recent years, the urgency of addressing climate change and environmental degradation has gained unprecedented global attention. As governments and organizations seek to implement strategies for sustainable development, the challenge of aligning human behavior with green growth objectives has become increasingly apparent. Traditional economic models often overlook the complexities of human decision-making, leading to policies that fail to engage individuals effectively in sustainability efforts.

Behavioral economics provides valuable insights into the cognitive biases, heuristics, and social influences that shape human choices. By understanding these psychological factors, policymakers can design interventions that motivate individuals and businesses to adopt environmentally friendly practices. For instance, simple nudges—subtle changes in the way choices are presented—can significantly impact behavior, such as encouraging recycling or energy conservation.

Moreover, the concept of aligning incentives is critical for fostering a culture of sustainability. Economic incentives, educational initiatives, and community engagement strategies can work synergistically to promote green behaviors. This approach recognizes that humans are not solely driven by rational calculations; social norms, values, and emotional connections also play crucial roles in decision-making.

This paper explores the intersection of behavioral economics and sustainability, highlighting the potential for aligning human incentives with green growth strategies. It aims to provide an in-depth analysis of how behavioral insights can inform policy design, enhance individual and collective actions, and ultimately contribute to a more sustainable future. By examining successful case studies and effective interventions, this research seeks to equip policymakers, businesses, and communities with actionable strategies that foster sustainable development and combat the pressing environmental challenges of our time.

The following sections will outline the key principles of behavioral economics, discuss their application in sustainability contexts, and propose recommendations for integrating these insights into green growth strategies.

II. Methods

This study employs a mixed-methods approach to explore the intersection of behavioral economics and sustainability, focusing on how human incentives can be aligned with green growth strategies. The methods are designed to gather quantitative data and qualitative insights, enabling a comprehensive understanding of the behavioral factors influencing sustainability practices.

1. Literature Review

An extensive literature review was conducted to establish a theoretical foundation for the study. This review encompasses scholarly articles, books, and case studies related to behavioral economics, sustainability, and green growth strategies. The review aims to identify key concepts, frameworks, and existing interventions that illustrate the application of behavioral insights in promoting sustainable behaviors.

2. Quantitative Analysis

Quantitative data were collected through surveys distributed to a diverse sample of individuals and businesses across various sectors. The survey aimed to assess attitudes toward sustainability, perceived barriers to adopting green practices, and the effectiveness of different incentives (e.g., financial rewards, educational campaigns) in promoting eco-friendly behaviors. Key metrics included:

- Behavioral Intentions: Measures of participants' intentions to engage in sustainable practices, such as recycling, energy conservation, and sustainable consumption.
- Perceived Effectiveness: Ratings of how effective participants believe different incentives and nudges are in influencing their behaviors.
- Demographic Variables: Data on participants' age, gender, education level, and geographic location to analyze potential differences in attitudes and behaviors.

Statistical methods, including regression analysis and correlation tests, were employed to identify relationships between variables and assess the impact of incentives on sustainable behaviors.

3. Qualitative Case Studies

In-depth qualitative case studies were conducted to explore successful implementations of behavioral interventions aimed at promoting sustainability. These case studies involved:

- Interviews: Semi-structured interviews with key stakeholders, including policymakers, business leaders, and community organizers, to gain insights into the design, implementation, and outcomes of specific initiatives.
- Document Analysis: Review of program materials, reports, and evaluations related to the selected case studies to gather contextual information and assess effectiveness.

The qualitative data were analyzed using thematic analysis to identify common themes, challenges, and best practices associated with behavioral interventions in sustainability.

4. Integrative Framework Development

Based on the findings from both quantitative and qualitative analyses, an integrative framework was developed to guide policymakers and practitioners in aligning human incentives with green growth strategies. This framework synthesizes behavioral economics principles, effective interventions, and actionable recommendations tailored to various contexts and stakeholder groups.

Summary

The combination of literature review, quantitative analysis, qualitative case studies, and integrative framework development provides a robust methodology for examining the complex relationship between human behavior and sustainability. By leveraging insights from behavioral economics, this study aims to contribute to the design of effective green growth strategies that resonate with individuals and promote a culture of sustainability.

III. Results

Human impact on the planet has been tremendous since the last century, leading to a 60% loss in global biodiversity. The mid-twentieth century's Great Acceleration of unsustainable growth marked the onset of a new geological era known as the Anthropocene, characterized by rapid increases in population, production, consumption, greenhouse gas emissions, waste, and pressure on ecosystems. Research indicates that as the global middle class expands, climate change and resource scarcity pose urgent threats that necessitate changes in individual consumption patterns, such as reducing fossil fuel use and meat demand (see Appendix – Case Study: Reducing Meat Consumption in Developed Countries).

To achieve green growth, policies should incentivize more sustainable consumption and production behaviors. Policies that positively influence everyday behaviors and social norms are crucial in decoupling economic growth and human well-being from their detrimental effects on the environment. Insights gained from observation and experimentation in behavioral and social sciences—such as psychology, cognitive science, neuroscience, and organizational behavior—provide powerful guidance for designing impactful and cost-effective green growth policies aligned with human decision-making.

Human behavior has various dimensions, dynamics, and drivers at all levels of the economy. At the microeconomic level, this encompasses individuals, households, and communities. At the meso and macro levels, organizational actors, such as governments and corporations, shape the choice architecture for citizens, employees, and consumers.

Green growth policy frameworks need to be more informed by behavioral insights. Currently, these policies are formulated under the assumption that citizens act rationally. However, advancements in behavioral sciences have illuminated the complexities of human decision-making, introducing concepts such as "bounded rationality" and "information-processing biases." Policies that acknowledge the limits of rationality can facilitate a shift in behaviors and societal norms toward green growth.

Behavioral science has made significant strides in analyzing and crafting behaviorally-informed policies. Today, governments from the United Kingdom to Singapore and Colombia are incorporating behavioral insights into their policymaking to find cost-effective solutions to governance challenges. Achieving the targets set out in the 17 Sustainable Development Goals (SDGs) and the Paris Agreement on Climate Change cannot occur without incentivizing sustainable behaviors and attitudes at scale.

IV. Discussion

The factors influencing green growth behavior can be examined across various levels (see Fig. 1). At the microeconomic level, research typically focuses on individuals, households, communities, small and medium-sized enterprises, and local governments. Meanwhile, the meso and macroeconomic levels encompass organizations such as economic sectors, large corporations, and provincial and national governments.

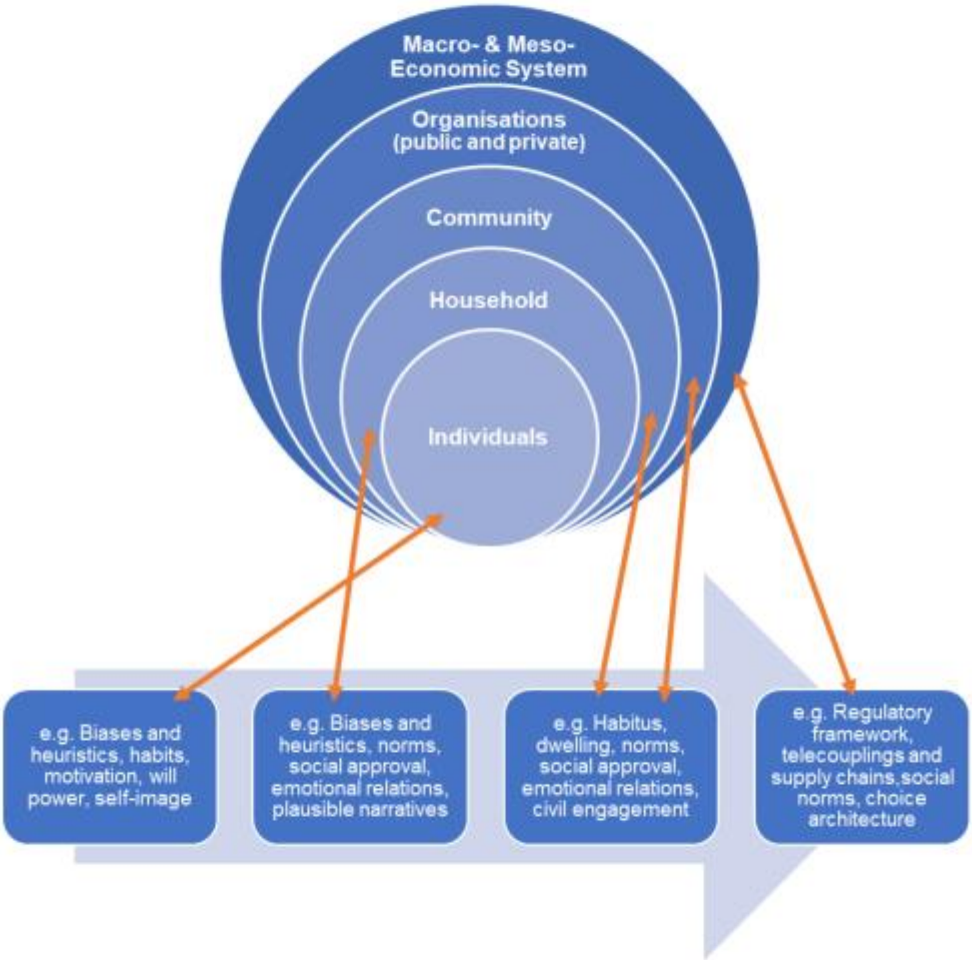

Figure 1: *Drivers influencing behaviour and where they originate*

Factors influencing individual behavior encompass prices, available options, and information; cognitive heuristics, biases, and habits; as well as community, regulatory, and socio-economic contexts. Decision-makers can modify the choice architecture in which individual behaviors occur to promote sustainable decisions. Recent studies have identified the most significant individual behavioral changes that can contribute to green growth. Choices affecting green growth include personal investment decisions (see Appendix – Case study: Sharing and rental opportunities for physical assets), modes of transportation (Case study: Switching from cars to walking and biking), adoption of low-carbon technologies (Case study: Fuel-efficient and clean stove uptake), farming practices, and compliance with environmental laws and regulations.

A recent study focusing on developed nations highlights behavioral changes that can lead to the largest reductions in individual greenhouse gas footprints, such as living without a car or avoiding transatlantic flights (Figure 2).

Organizations influence individual green growth behaviors in at least three key ways. First, they shape the work environments in which individuals make decisions and earn their incomes.

Second, they produce, offer, and regulate the product options available for individual consumption. Third, they generate many of the externalities that affect individuals and the ecosystems surrounding them. Although this topic is outside the scope of this paper, further research is necessary to explore organizational behaviors and their implications for individuals.

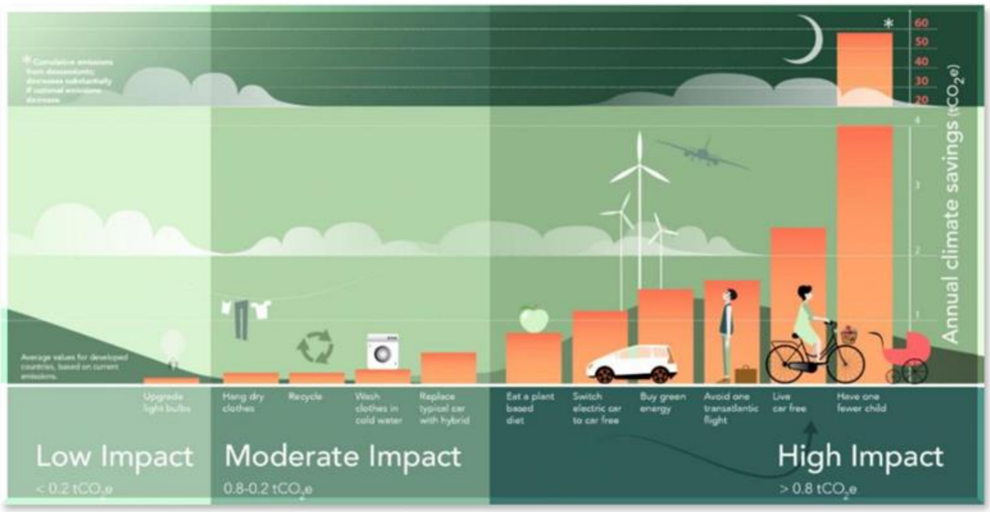

Figure 2: *Key individual behaviour choices ranked by impact on climate change*

Mainstream economics, in contrast to behavioral economics, primarily adheres to the rational choice theory of human behavior, viewing environmental challenges as market failures. This prevailing perspective assumes that market participants possess clear preferences, are informed about all relevant information, and make impartial decisions within their budget constraints. Based on this framework, mainstream economists advocate for market-based and regulatory solutions to address environmental market failures, such as Pigouvian taxes, contingent valuation, and tradable permits. They also employ Bayesian statistics and discounting to account for individual preferences.

Despite its limitations, traditional economics has provided two significant insights into individual behaviors related to green growth. First, it has highlighted that people make decisions by weighing various types of values, not solely price. These values are often difficult to compare. Classic economics identifies monetary benefits (like income and profit), monetary costs, opportunity costs, and non-monetary benefits (and costs). Non-monetary benefits often occur outside of markets and lack a standardized monetary value; for instance, the enjoyment of spending time with family or doing household chores. Traditional economics has explored various forms of non-monetary environmental values. This recognition of multiple forms of value helps to explain the phenomenon of choice overload, which can lead to suboptimal environmental decision-making.

Second, traditional economics has demonstrated that market failures—especially externalities and the tragedy of the commons—promote unsustainable behaviors among rational actors. Externalities incentivize price-sensitive individuals and groups, including businesses, to engage in unsustainable practices by evading the full costs of their economic decisions. The tragedy of the commons arises when resources are held in common without appropriate incentives for protection, leading to over-exploitation and degradation of those resources.

Behavioral insights provide new, cost-effective policy tools to facilitate green growth. While traditional economics continues to contribute to encouraging rational actors to adopt more sustainable behaviors, a closer examination of human behavior, including its deviations from rationality, reveals valuable insights for developing important new policy instruments.

References

[1] Podkolzina I.M., Gladilin A.V., Reshetov K.Yu., Taranova I.V., Gladilin V.A. Building a financial security system to ensure russia's food security// The Challenge of Sustainability in Agricultural Systems. Heidelberg, 2021. C. 539-548.

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. C. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

ECONOMIC RISKS IN THE CONDITIONS OF DIGITAL TRANSFORMATION

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Abstract

The development of the modern world is taking place against the background of the introduction of digital technologies, which is an objective and irreversible process that opens up opportunities for all spheres of society.
At the same time, digitalization is accompanied by negative consequences, generating many threats to the sustainability of economic systems.
The article considers the most significant problems of digital transformation and related economic risks. It is noted that, in general, digitalization provides society with many benefits and opportunities for intensification and efficiency of development, increasing the welfare of the population. But there are new risks that lead to structural changes in socio-economic and political-administrative systems that pose a threat to the economic security of the world's countries.
These risks include: technological disruption, cybersecurity and data vulnerability, digital skills deficit, labor migration, legal vulnerability, and economic inequality. Preventive measures to avoid negative development scenarios based on the use of modern technologies are proposed.

Keywords: disruption, market dynamics, innovation, cybersecurity, digitalization, economic risks

I. Introduction

The beginning of the 21st century is marked by the progressive movement of digital technologies, against the background of which economic and social systems, forms of international cooperation and business processes began to transform. This led to a reformatting of world economic and social relations, moving into the virtual space.

Digitalization continues to revolutionize the way businesses operate, business and interpersonal communication, and value creation. The new era of the digital economy has opened up unique opportunities for economic growth and increasing the efficiency of the global economy based on innovation and artificial intelligence. At the same time, digitalization, while creating broad opportunities and prospects, also has a negative effect since any development under conditions of uncertainty entails inevitable risks that are poorly studied and practically not calculated or assessed.

In the context of the dynamic digitalization of all life processes, society finds itself in a state of permanent risks, which aggravates the problems of making rational management decisions, both at the state level and at the level of economic entities (companies and citizens).

II. Methods

The concept of “Risk Society”, described in scientific works by Ulrich Beck (1984), takes the concept of risk beyond the scope of exclusively social problems [2]. Having described the universality and scale of risks, U. Beck came up with a definition of a “risk society”, which develops in conditions of uncertainty and unpredictability, and hypothetical losses are difficult to calculate and evaluate. Under these conditions, the implementation of current activities and decision-making, as defined by U. Beck, occurs reflexively and has a dual character. On the one hand, the increase of the role of public institutions in assessing the probability of developments and taking appropriate regulatory measures are aimed at minimizing risks. On the other hand, the changes introduced create new risks, expanding the range of uncertainty and unpredictability.

It is known that any decision made is associated with or entails certain risks, the fact of the occurrence of which can lead to identification of their form. The development of socio-economic systems is always accompanied by risks, which is the norm and at the same time a trigger for the rationalization of subsequent actions.

In 2017, The Global Risks Report [2] was presented in Davos (Switzerland), in which, on the basis of large-scale research work, 30 global risks of the most common nature were presented, and also 13 trends in the development of the world community for 10 years perspective in the context of the transition to a digital development model were described. Potential risks and threats were aggregated into five main groups: geopolitical, economic, technological, social and environmental.

In the annual report of the World Economic Forum 2024, these risks were confirmed, with clarification and emphasis on disinformation and polarization of society as the main modern threats [3].

The scientific research is based on a number of works of modern domestic and foreign authors, considering the issues of threats of economic nature in the period of digital transformation. This allowed, on the one hand, to generalize the accumulated experience of scientific thought, on the other hand, to identify and present new challenges arising in the conditions of digitalization in such a rapidly changing environment.

The purpose of the article is to identify the main economic risks of the digital format of society development, the factors that determine their impact on the socio-economic system.

The work used traditional methods of scientific cognition: generalizations and characteristics, observation and comparison, as well as information-analytical and statistical methods of research.

III. Results

Economic threats against the background of digital transformation create serious challenges to the stability of economic systems, their level of safety and security. This characterizes the main risk of an economy developing and operating on the basis of digital technologies. Digitalization leads to increased openness of national economic systems, making them more vulnerable to the negative impact of external factors. This problem is not only economic, but also political, ideological, social and other in nature, since information technologies reduce the security of the national system from negative external influences (the forms of manifestation are financial espionage, information and psychological pressure, manipulation with financial assets and instruments, and many others).

Also, the use of digital technologies increases access to companies' commercial and financial data, increasing the vulnerability of their financial stability and competitiveness. Thus, there is a scaling of criminal activity in the financial and economic sphere, against the background of which the threat of loss of control over the activities of companies increases, the likelihood of loss of

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property arises, etc.

High risks also arise for each individual in the field of personal finance management, regarding the use of personal data for criminal purposes, the threat of losing jobs, and, consequently, a source of income.

Thus, the composition of probabilistic risks in the context of digitalization is quite extensive and affects all spheres of society: government, commercial and personal interests.

Currently, there is a growing debate in the scientific community regarding possible risks that have already become obvious and that are possible in the future. At the same time, the opinions of experts differ regarding the real threats and assessments of their impact on socio-economic processes.

One of the main economic risks associated with digital transformation is the disruption of traditional markets, business models and business processes. Indeed, the rapid implementation of new technologies, such as artificial intelligence (AI), blockchain and the Internet of things (IoT), have the potential to disrupt a number of economic sectors, the products and services of which, as well as their business processes and logistics systems, are beginning to become obsolete quite quickly , and competition intensifies. Against the background of dynamic technological development, the pace of which is accelerating, market volatility is increasing, to which companies cannot respond quickly and adequately, thereby losing profits and competitiveness

To avoid this, or mitigate the negative consequences, companies need to increase investment in research and development, promoting a transformative culture of innovation and flexible management decision-making methods to meet increasing market dynamics.

But not all companies can afford this, but only those ones that have accumulated stability in their segment for years, have a high or sufficient level of capitalization and reserve resources. Unfortunately, the changes taking place will lead to a selection of the business community, with the strongest companies remaining “afloat”.

The consequence of these processes in a negative context will be a sharp reduction in jobs, and, consequently, it will lead to a reduction in income due to stagnation of wages [2]. The problem of job loss is one of the most urgent and most widespread among those discussed and studied. In addition, the threat of job losses, caused by the processes of replacing human labor with information and digital technologies, is incomparable with any economic and financial crisis of past years in scale and consequences.

In the context of the introduction of digital technologies, the labor market is undergoing a structural transformation, when traditional employment is replaced by platform forms and methods of using labor resources, which has the potential for global qualitative changes, simultaneously associated with the risks of intensification of competition and increased restrictions for a significant part of those employed in the economy.

On the one hand, digital transformations, provided they are managed well, lead to increased diversification of employment and improved quality of life [1], on the other hand, they put forward new qualification requirements, increasing competition and competency gaps in the labor market. Platform employment is growing rapidly, but is not uniform across countries, leading to global inconsistency in its regulation. Currently, there are several approaches to regulating platform qualifications and employment. Some countries are taking a wait-and-see attitude regarding the introduction of regulations, while others are actively introducing legal initiatives to regulate platform employment.

By now, a unified approach to the regulation of the digital labor and employment market has not been developed; there is no scientific basis for the concept of its development, which stagnates the processes of its functioning both within national systems and on a global scale. The complexity of managing migration processes arises.

The migration policy of states in a traditional economy was focused mainly on regulating the movement of labor, which historically consisted of workers engaged in non-standard forms of labor and having predominantly temporary employment. However, in the context of digital transformations, new forms of labor, demonstrating high growth rates, lead to a change in the classical nature of the labor market, when standard (traditional) forms of employment, prevailing in the main market segments, are replaced by other forms of organization and implementation of labor activity (platform labor based on information-communication technologies). Traditional migration is being replaced by virtual and telemigration [5], a new digital labor market with a changing structure and qualitative content of the demand and supply of labor resources is being formed. Its main characteristics are the rapid flow of labor from one area to another, the rapid growth of new professions and specialties.

According to MasterCard forecasts, the global platform economy will double in size by 2023 compared to 2018 and by 2027, the volume is predicted to be $864.7 billion [8].

Thus, in the near future, platform employment will replace traditional forms of labor organization, which in many ways has positive effects such as expansion of jobs, employment flexibility, transformation of migration into the integration of highly qualified labor. At the same time, gaps between countries in the speed of entry into the digital world and the use of advanced technologies, including gaps in the development of the labor market, can lead to negative effects, which include instability or loss of income, insufficient qualifications to work in new conditions, and social isolation. Countries need consolidation in regulating migration and labor employment processes.

Cyber security and data vulnerability are another one of the most common problems among researchers, which has now received more evidence of its reality and danger. Digitalization has the property of total and rapid spread, the tools of which are available to the criminal world, sometimes to a greater extent than to institutions regulating life processes. The risk of cyber attacks and identity theft has already become an obvious reality: infection with malicious software; fraudulent attacks and extortion leading to financial losses, causing damage to the population and companies (loss of trust and reputation among consumers); loss of confidentiality and protection of personal and corporate data.

Prevention of these actions also requires significant financial investments in their own security through the implementation of reliable cyber security measures (encryption, multi-factor authentication and regular security audits) on the part of companies and ensuring cyber security for all market participants on the part of the state.

The use of digital technologies to ensure cyber security in all areas not only requires high financial investments, but also significantly complicates the processes of interaction both within companies and in society as a whole.

On the one hand, companies that implement authentication systems in order to protect the personal data of their clients (for example, banks) greatly complicate the processes of interaction between employees and clients, when in order to make a decision on the requested service they have to overcome a multi-stage system of verification, approvals, confirmations, etc. On the other hand, the state also has to use the same complex algorithm of actions in all executive institutions, and in cases of failures, be the guarantor of the preservation of the rights and property of citizens. In addition, being the main guarantor of the rights and freedoms of its citizens, the state is obliged to significantly expand its participation in the creation of training platforms for the population, business entities of various forms of ownership, scale and type of activity and in this direction to closely interact with business, research centers and individuals to create a cyber security-oriented culture under the new conditions.

The peculiarity of digitalization, which distinguishes it from all previously historically important processes, is the speed of its spread and penetration, which greatly complicates the development of regulatory measures for the effective management of digital activities. As a result, organizations and citizens often face uncertainty regarding compliance with existing regulations and are unable to anticipate future changes in the regulatory environment. Failure to comply with regulatory requirements can result in unexpected legal and fiscal liabilities, fines and damage to reputation.

To mitigate this risk, it is necessary to monitor changes in legislation by creating and using appropriate software (information and consulting), companies need to conduct a thorough legal audit in real time, and the population needs to improve legal literacy, or seek help from specialists. Yet again, this is costly, more labor-consuming in terms of the intensity of actions and attention on the part of all users.

Of course, digital transformation, which has become a reality and inevitability, requires certain skills for all members of society. In the public and corporate sectors of the economy, there will be a growing demand for qualified personnel capable of using advanced technologies to make management decisions, stimulate innovation and increase productivity. However, many government agencies and private companies have difficulty finding staff to meet current demands, leading to a widening digital skills gap. In addition, automation and artificial intelligence may displace traditional jobs, causing unemployment and income inequality (this problem was outlined above). To solve this problem, organizations of all ownership types must invest in digital skills development, reskilling and upskilling to ensure their workforce has the capabilities to thrive in the digital economy.

For citizens, the presence of digital skills becomes a determining condition for strengthening their personal potential and the ability not only to use it as a means of managing personal income, but also as a means of personal identification in the digital space (the use of digital platforms and tools for life support). At the same time, digital qualifications require constant learning, since they are being transformed too rapidly, new digital products and services are appearing, and new digital conditions are being created to ensure economic and everyday issues.

The problem described is of a more pronounced social nature but its economic component consists in danger of losing its usual way of life due to the loss of income received under the traditional economic model.

To solve this problem, all organizations (in the state and private sectors) must increase investment in digital skills, reskilling and upskilling to ensure that their employees have the opportunities to thrive in the digital economy, and the government should do the same for the unemployed population. Besides, encouraging a culture of lifelong learning and career development can help employees adapt to changing work roles and new technology trends.

IV. Discussions and conclusions

Digital transformation poses a real threat of deepening socio-economic inequality and growth of the digital divide. Digital access, internet use and digital skills are not evenly distributed across the population, leading to differences in economic opportunities and access to vital services. In this regard, for all countries around the world, bridging the digital divide and ensuring equal access to digital technologies is critical to stimulate economic growth and reduce inequality.

Investing in digital infrastructure will become a universal and very large-scale task, the solution of which can only be achieved through joint efforts on the part of national systems, businesses and citizens; international institutions are also needed to regulate these processes.

A strategy for reducing inequality as a result of digital influence should be developed at the level of interstate interaction and implemented through the expansion of digital infrastructure, open access to broadband Internet and advanced software, supported by large-scale training and retraining programs for citizens of all social categories. But its implementation depends on coherency between the world's leading countries regarding to the negative effects of the digital world.

The problems described above are far from being solved; their number, degree of negative impact and possible destructive consequences are wider and more diverse in many ways. We have described some of them that, in our opinion, are the most acute and have already become a reality in a changing world.

Among them:

1. Technological disruption and market dynamics.
2. Cyber security threat and data vulnerability.

3. Complications of compliance with regulatory standards and other legal challenges.
4. Deficit of digital skills among economic entities and the population, movement of labor.
5. Economic inequality and digital gap

To summarize all of the above, we`d like to note that the identified economic risks and threats of digital transformation have one common property – you can only resist them if all economic entities work on a large-scale and permanent basis to adapt to the changes that are taking place. This work requires significant financial costs, personal, corporate and organizational efforts, readiness to accept reality, self-development and self-learning.

In conclusion, we note that digital transformation has many advantages and opens up wide opportunities for personal growth and self-development, expands the range of innovations and investments, creating new products and services. At the same time, it poses significant threats to national economic security, giving rise to new risks that have no analogues in scale and consequences. Moreover, negative consequences are difficult to assess and calculate, which makes it difficult to take preventive measures to fight them, both at the government level and in the corporate and private sectors.

Understanding of current changes, the ability to accept and adapt to them will greatly contribute to the right attitude towards proactive action in all areas.

Acceptance of digital transformation and understanding its benefits, will allow using them for driving sustainable economic growth and creating value for stakeholders. This requires new mechanisms for proactive risk management, investment in cyber security, and the development and strengthening of digital skills by all members of society. Coordination of actions within national systems and at the interstate level will make it possible to mitigate the entry into new conditions without significant losses. Countries need to consolidate joint actions in the areas of scientific research, legal initiatives and advanced technological achievements, despite existing geopolitical differences and contradictions.

References

[1] Gerbina T.V., Danilina Ya.V., Chavykina M.A. Labor and employment in the digital economy: Deposited manuscript No. 64-B2021. 08.11.2021.

[2] Zvereva T.V. Economic risks of the digital economy // Problems of risk analysis. No. 6 (V.14). 2017. pp. 22-29.

[3] Kichemaykin K. WEF named the main global risks for the next 10 years. [Electronic resource], access mode: https://www.gazeta.ru/business/news/2024/01/11/22092667.shtml, (access date: 06/15/2024).

[4] Sazonova O.A., Solovyov A.B., Sazonova N.V., Martsinevskaya L.V. The influence of digital technologies on state migration policy // Matters of Russian and International Law. 2022. V. 12. No. 5A. pp. 68–76.

[5] Tsapenko I.P., Grishin I.V. Virtualization of cross-border labor migration // Bulletin of the Russian Academy of Sciences. 2022. V. 92. No. 9. pp. 849–859.

[6] Chavykina A.V., Veselko A.A. Migration in a platform economy: main factors, analysis of international trends // RSUH Bulletin. Series Economics. Management. Law. 2023. No. 3. pp. 87-102.

[7] Yugay Yu.V. Labor migration from Central Asian countries to Russia // Post-Soviet Studies. 2022. V. 5. No. 2. pp. 206–219.

[8] Radoushinsky D. A. , Radushinskaya A. I., Khaykin M. M. Improving the quality of implementation of the container transportation project along the NSR based on the environmental and energy transition agenda Polar Science. 2023. №35. pp. 100923-100923. https://doi.org/10.1016/j.polar.2022.100923

[9] Radoushinsky, D.; Gogolinskiy, K.; Dellal, Y.; Sytko, I.; Joshi, A. Actual Quality Changes in Natural Resource and Gas Grid Use in Prospective Hydrogen Technology Roll-Out in the

World and Russia. Sustainability 2023, 15, 15059. https://doi.org/10.3390/su152015059

[10] Digitalization of the Social Sphere in Russia During the COVID-19 Pandemic: Analysis, Risks, Prospects / V. Dzobelova, N. Davletbayeva, O. Tegetaeva [et al.] // Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East (AFE-2022) : Agricultural Cyber-Physical Systems, Tashkent, 25–28 января 2023 года. Vol. 733-1. – Zug: Springer Cham, 2024. – P. 323-332. – DOI 10.1007/978-3-031-37978-9_31. – EDN CIFHRE.

[11] Digitalization and Industry 4.0-Changes Caused by COVID-19 / M. S. Rysalieva, V. B. Dzobelova, A. V. Olisaeva [et al.] // Strategies and Trends in Organizational and Project Management, Rostov-on-Don, 19–20 мая 2021 года / Editors: Pavel V. Trifonov, Marina V. Charaeva. – Rostov-on-Don: Springer Nature, 2022. – P. 12-20. – DOI 10.1007/978-3-030-94245-8_2. – EDN ZVSEKQ.

INVESTING IN SUSTAINABLE DEVELOPMENT: ECONOMIC BENEFITS AND RISKS FOR STATES AND CORPORATIONS

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Abstract

This paper explores various economic models and strategies that have successfully facilitated transitions toward sustainable development in different regions around the world. By analyzing the mechanisms employed in these transitions, the study identifies key economic, policy, and institutional factors that contributed to success. The analysis spans different sectors, including energy, agriculture, and manufacturing, with a focus on green technologies, circular economy practices, and renewable energy integration. The paper also reviews international cooperation efforts, regulatory frameworks, and the role of innovation in driving sustainable growth. The findings suggest that a combination of public policy incentives, private sector engagement, and social inclusivity is crucial for achieving long-term sustainability. Case studies of countries such as Sweden, Germany, Costa Rica, and China illustrate the diversity of approaches and the lessons that can be drawn from them. The research contributes to a better understanding of the pathways and tools necessary for a global transition toward a sustainable economic model.

Keywords: green economy, circular economy, renewable energy, policy incentives, innovation, international cooperation, environmental sustainability, transition strategies

I. Introduction

In recent decades, the global community has increasingly acknowledged the necessity of sustainable development as a fundamental principle for economic growth. Sustainable development involves pursuing economic progress while addressing environmental protection and social equity, ensuring the well-being of both current and future generations. As societies face the impacts of climate change, resource depletion, and social inequality, understanding the economics of sustainable development has become critical. This research paper explores the complex interaction between economic principles and sustainable development goals, highlighting the challenges impeding progress and examining potential solutions. By synthesizing existing literature and empirical evidence, the paper aims to illuminate the intricacies of achieving sustainable development from an economic standpoint. The urgency of addressing sustainability issues is evident in the rising frequency of environmental disasters, increasing income inequality, and ecosystem degradation. In this context, policymakers, businesses, and civil society are being urged to adopt comprehensive approaches that balance economic growth with environmental care and social inclusivity. Through a multidisciplinary perspective, this paper seeks to dissect the economics of sustainable development, shedding light on the trade-offs, synergies, and policy measures required to build a more equitable and resilient future. By critically examining existing frameworks, identifying knowledge gaps, and proposing innovative strategies, this paper aims to contribute to the ongoing dialogue on sustainable development and stimulate action toward a more sustainable and prosperous world. Sustainable development has become a critical concern in today's world, as societies face the pressing challenge of balancing economic growth with environmental protection and social equity. Popularized by the Brundtland Commission in 1987, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Since then, it has served as a guiding framework for governments, businesses, and communities worldwide. The pursuit of sustainable development is complex, involving the interconnectedness of economic, environmental, and social factors. Economists play a key role in addressing these challenges by analyzing trade-offs, creating incentives, and developing policy frameworks to support sustainable practices. The economics of sustainable development covers a broad spectrum of topics, including resource management, the transition to clean energy, poverty reduction, and climate adaptation. Despite widespread acknowledgment of the need for sustainability, significant challenges remain. Economic systems often prioritize immediate profits over long-term sustainability, leading to resource depletion, worsening inequality, and environmental degradation. Furthermore, many sustainability issues are global in scope, requiring international collaboration, which is often hindered by political and economic conflicts. In this context, the demand for innovative solutions is more urgent than ever. This review paper aims to provide an in-depth exploration of the economics of sustainable development, focusing on the obstacles to achieving sustainability and the possible ways forward. By integrating existing research and identifying areas where further study is needed, the paper seeks to enhance understanding of the economic forces at play in sustainable development and to guide the creation of policies that foster a more inclusive, resilient, and environmentally conscious global economy.

II. Methods

This paper employs a qualitative research design to investigate the economics of sustainable development, focusing on identifying challenges and exploring potential solutions. Qualitative methods are particularly well-suited for an in-depth analysis of the complex interactions between economic factors and sustainable development objectives, allowing for a nuanced understanding of the topic.

Data will be collected through an extensive literature review, drawing from academic journals, books, reports, and other scholarly materials that address the economics of sustainable development. The review will utilize online databases such as Google Scholar, JSTOR, and PubMed to access relevant research. Additionally, reports from governmental and non-governmental organizations, as well as industry white papers, will be included to provide a broad perspective on the subject.

The inclusion criteria for the literature review will focus on sources that discuss key aspects of sustainable development economics, such as economic growth, environmental sustainability, social equity, poverty reduction, and technological innovation. Only peer-reviewed articles and reputable sources published within the last ten years will be considered to ensure that the research is both up-to-date and credible. Exclusion criteria will include studies that do not directly address the economics of sustainable development or lack empirical evidence to support their findings. Non-English language publications will be excluded due to language constraints.

Ethical considerations in this research involve proper citation and acknowledgment of all sources to avoid plagiarism. The accuracy and relevance of the information will be critically assessed, with attention given to respecting diverse viewpoints in the literature. Care will be taken to avoid bias in both the selection and interpretation of data, ensuring an objective and balanced analysis of the economics of sustainable development.

III. Results

A series of recent crises and growing instability in the global economy and politics, as well as an increasing number of global risks and challenges, force us to reconsider the concept of sustainable development. Previously perceived as an abstract theoretical construct, the system of global goals and objectives that seemed distant from everyday problems has been seriously tested for viability and relevance in recent years. For everyone who has lived through the COVID-19 pandemic with its profound socio-economic consequences, and who is now observing fundamental changes in the economy and geopolitics, the term "sustainable development" takes on new meaning and significance.

Attempts to question the need to follow the UN Agenda for Sustainable Development until 2030, adopted in 2015, against the backdrop of intensifying crises have quickly given way to an awareness of the importance of joining forces to achieve the 17 Sustainable Development Goals (SDGs). This requires efforts at all levels - from states and regional associations to municipalities, companies and individuals representing society as a whole.

Increased attention to the topic of sustainable development is also due to worsening climate problems. Experts once again emphasize the imbalance in the climate system and the onset of irreversible consequences for the climate. Global environmental and climate risks have been leading the annual World Economic Forum (WEF) global risk reports for several years in a row, which only confirms the need for urgent action.

IV. Discussion

The concept of sustainable development is a process of economic and social transformation, in which the use of natural resources, investment direction, scientific and technological progress, personal development and institutional changes are coordinated in such a way as to strengthen the current and future potential to meet human needs and aspirations. At the corporate level, this concept covers a system of principles, processes and results aimed at maintaining a balance between economic, environmental and social aspects both in companies and in society as a whole. Maintaining this balance contributes to the preservation of vital systems and long-term well-being. The concept is closely related to the ESG approach (environmental, social, governance - the environment, society and corporate governance), which is aimed at managing non-financial risks taking into account the impact on the environment, society and the principles of effective management. This approach includes such processes as ESG rating, ESG investing and ESG transformation, and represents a continuous improvement of business processes. Current economic and political crises have only increased the importance of strengthening the sustainability of companies and made it urgent to develop more relevant ESG criteria for long-term development.

In the post-pandemic era, not only institutional investors, but also politicians in developed countries are declaring their commitment to ESG principles, paying attention to the implementation of "green" technologies, human-oriented corporate practices and improving the quality of life. The concept of the "green" economy, which emerged at the end of the 20th century, remains important, focusing on the need to minimize the negative impact of economic activity on the environment, placing sustainable development and environmental safety above simple economic growth at any cost.

The process of aligning the Decision Support System (DSS) to sectoral modeling varies based on the capabilities and flexibility of the selected modeling methodology. This section, along with the following one, details how this alignment is conducted for the Global Energy Model (GEM).

The integration of thematic results into GEM, as well as the alignment of outcomes, is influenced by the degree to which each sector experiences endogenous feedback loops.

Soft Coupling of Methods

The soft coupling of methods can be achieved either through direct input or calibration:

- Direct Input: This involves importing the results from thematic modeling as data time series into GEM. When there is limited or no relevant structure in GEM or when the parameters are not influenced by endogenous feedbacks, the outputs from sectoral models are fed into time-based table functions within GEM.
- Calibration: This approach is utilized to align GEM results with sectoral modeling outputs when the relevant indicators are influenced by GEM's endogenous feedback structure. Calibration requires several steps, which will be demonstrated using the example of total energy demand.

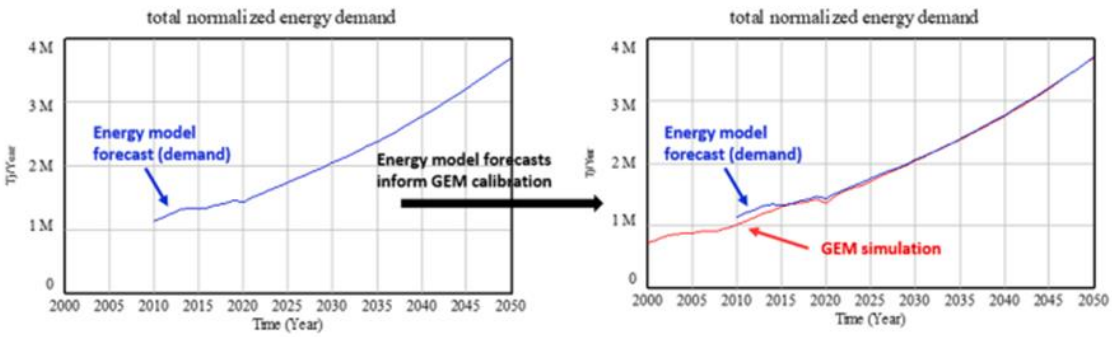

Figure 1: *Illustration of reference mode and the alignment of behavior in GEM*

Steps for Calibration

1. Creating an Artificial Simulation:

- The first step involves generating a simulation specifically for calibration purposes. In this case, the energy demand data for alignment is sourced from the Low Emissions Analysis Platform (LEAP) (SEI, 2018).
- The System Dynamics (SD) modeling software enables the importation of data from sectoral models into GEM and the creation of a simulation file that can be visualized. This imported data is termed "reference modes" and is utilized to conduct behavioral validation tests.
- The left graphs in Figure 3 illustrate the reference data from the LEAP model, specifically total energy demand and energy-related CO2e emissions, which are essential for calibrating these parameters within GEM.

2. Importing Baseline Real GDP Data:

Since LEAP does not account for feedback mechanisms affecting macroeconomic productivity, baseline real GDP data is imported as time series. This is necessary because GEM incorporates feedback loops that treat real GDP as a driver of energy demand and related costs. These factors subsequently impact sectoral real GDP through total factor productivity.

The interplay between real GDP and energy demand is reciprocal; thus, a change in real GDP influences energy demand and vice versa. To facilitate calibration of GEM in line with LEAP projections, it is crucial that real GDP remains exogenous during the calibration process to replicate the conditions (ceteris paribus) present in the LEAP model.

This calibration process ensures that the energy demand and CO2e emissions in GEM are accurately aligned with the projections and feedback mechanisms represented in the LEAP model, thereby enhancing the reliability of the model's outputs.

The events of 2022–2023 are increasingly raising doubts about the comprehensive achievement of the Sustainable Development Goals (SDGs) within the framework of Eurasian integration. The destruction of supply chains, rising prices for raw materials and commodities, including food, are creating difficult conditions for achieving the SDGs, especially those related to ending hunger (SDG 2) and ensuring health and well-being (SDG 3). Sergey Glazyev, Minister for Integration and Macroeconomics of the EEC, notes the trend towards chaos in food markets, emphasizing that global resources and technologies make it possible to produce food for 20 billion people — twice as many as the current population of the planet. However, the problem lies in the unfair distribution of resources, unequal international economic relations, and rising prices caused by the quantitative easing policy of reserve currency issuers.

For an effective transition to sustainable development, it is necessary to develop an adequate system of goals and indicators. It is necessary to improve the methodology for selecting statistical indicators reflecting the achievement of SDGs in the EAEU countries, as well as to create new indicators for missing areas. It is also important to implement international standards and take into account recommendations, such as the OECD recommendations, to improve the quality and comparability of economic statistics. This is critical for the formation of the EEC's own dossier on sustainable development and the preparation of a new report. Of particular importance is the coordination of statistical activities in the EAEU region, strengthening professional and research potential, as well as the introduction of advanced international standards in methodology and data classification.

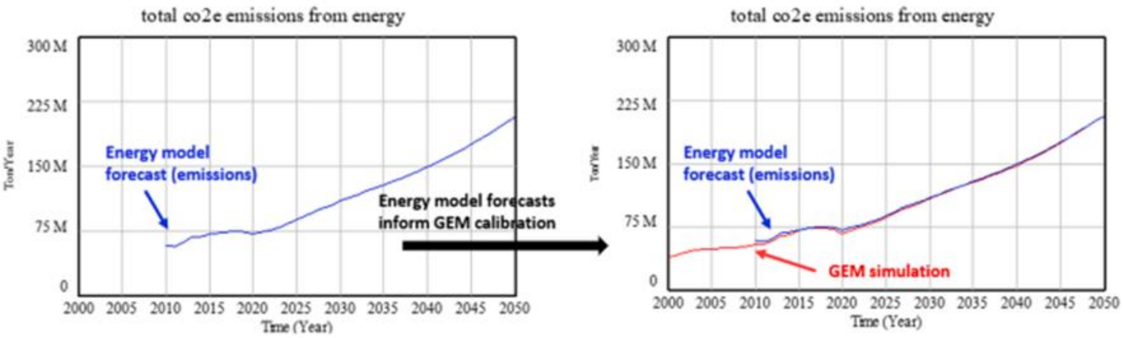

Figure 2: *Illustration of reference mode and the alignment of behavior in GEM*

The demand aligns with the results from LEAP, and closing the endogenous feedback loops enables us to (i) examine how macroeconomic indicators evolve under LEAP projections and (ii) subsequently adjust the energy demand trajectory forecasted by LEAP. Figure 4 illustrates a comparison of simulations with and without the endogenous feedback effects through total real GDP. The findings indicate that the energy mix derived from the sectoral model contributes to increased economic growth (for instance, through lower costs). This additional growth results in greater energy demand and related emissions than what LEAP initially predicted.

This process is conducive to iterations. Specifically, the updated total real GDP forecast from GEM can be integrated back into LEAP. This integration aids in assessing whether the anticipated emission reductions remain achievable or if the increased demand necessitates more robust mitigation efforts. This methodology is applied across all modules except for ecosystem service provisioning. The exception arises because modeling current and future ecosystem service provisioning requires iterative processes among GEM, GIS, and ecosystem services models like InVEST.

References

[1] Daukaev, A. Main trends in climate change in the Holocene epoch of the antropogenic

period in the world and in the Caucasus / A. Daukaev, R. Gakaev, T. Bachaeva // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 387-390. – DOI 10.24412/1932-2321-2023-575-387-390.

[2] Podkolzina, I.M., Gladilin, A.V., Reshetov, K.Y., Taranova, I.V., Gladilin, V.A. Building a Financial Security System to Ensure Russia's Food Security // Lecture Notes in Networks and Systems, 2021, 205, страницы 539–548

[3] Gakaev , R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[12] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144

GREEN ECONOMY AND SUSTAINABLE DEVELOPMENT: A NEW PARADIGM FOR TRADITIONAL BUSINESS MODELS

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Abstract

In the context of global climate change and increasing environmental challenges, the concept of a green economy has emerged as a crucial framework for achieving sustainable development. This paper examines the transformation of traditional business models within the framework of a green economy, emphasizing the imperative to integrate environmental and social considerations into strategic planning. By analyzing the key principles of a green economy—such as carbon emission reduction, resource efficiency, sustainable production and consumption, and biodiversity support—this study explores how these principles influence the adaptation of business practices. The paper further investigates the role of innovation in facilitating this transformation, highlighting how new technologies and business practices can lead to reduced environmental impact while also enhancing economic performance. Through case studies of successful transitions to sustainable business models, the research illustrates the diverse approaches organizations can take to align their operations with green economy principles. Moreover, the paper addresses the challenges enterprises face in implementing eco-friendly technologies, including regulatory barriers, financial constraints, and the need for a cultural shift within organizations. It argues that overcoming these challenges is essential for the successful transition to a green economy, which not only promotes ecological sustainability but also creates new opportunities for growth, resilience, and competitive advantage.

The findings underscore the importance of collaboration among stakeholders, including governments, businesses, and communities, to create an enabling environment for sustainable practices. Ultimately, this research contributes to the understanding of how a green economy can serve as a new paradigm for traditional business models, fostering a harmonious relationship between economic development and environmental stewardship.

Keywords: green economy, sustainable development, traditional business models, ecological sustainability, innovation, resource efficiency, biodiversity, climate change, eco-friendly technologies, strategic planning

I. Introduction

The United Nations Conference on Sustainable Development, commonly referred to as Rio+20, was initiated amidst significant concerns regarding the global economic landscape. Within this context, "green economy" was selected as one of the two primary themes of the conference, drawing from an expanding body of literature focused on green economy and growth. This research investigates the interplay and impact of the dual crises on the emergence of "greening" as a potential solution. The objective is to analyze what defines and differentiates the proposals found in twenty-four sources on the green economy, which include policy documents from international organizations and think tanks, as well as academic research papers. It also aims to explore the implications and meanings of the burgeoning greening agenda for sustainable development as we progress into the 21st century.

Using a systematic qualitative analysis of textual materials, the study identifies three categories of discourse that shed light on the meanings and implications of greening: "almost business as usual," "greening," and "all change." By examining these categories in relation to Dryzek's classification of environmental discourse, the research reveals three interconnected patterns: (1) scarcity and limits, (2) means and ends, and (3) reductionism and unity. These patterns enhance our comprehension of the tensions that arise among emerging propositions related to greening.

Furthermore, the patterns elucidate the significance and implications of greening for sustainable development, highlighting a trend toward the economization and polarization of discourses. The analysis also points to an enduring weak interpretation of sustainable development and a conflict between the stabilization or transformation of the dominant socioeconomic paradigms that shape its conceptualization.

As the world grapples with the escalating impacts of climate change, environmental degradation, and resource depletion, the traditional paradigms of economic growth are being increasingly scrutinized. The need for a transformative approach to development has given rise to the concept of a green economy, which seeks to promote economic growth while simultaneously addressing environmental and social challenges. Defined broadly, a green economy is one that is low in carbon emissions, resource-efficient, and socially inclusive. It emphasizes sustainable practices that support human well-being while protecting the planet’s ecosystems.

The traditional business models that have dominated economic systems for decades often prioritize short-term profits over long-term sustainability, leading to significant negative externalities, such as pollution, loss of biodiversity, and climate-related disasters. These practices not only threaten the health of the environment but also jeopardize the very foundations of human society by undermining the resources upon which livelihoods depend. In contrast, the principles of a green economy advocate for a systemic shift toward sustainability, encouraging businesses to rethink their operational frameworks and strategies.

This paper seeks to explore the transformation of traditional business models in light of the green economy paradigm. It will examine how organizations can adapt their practices to align with sustainability goals, highlighting the essential role of innovation and strategic planning in this transition. By integrating environmental and social considerations into their business operations, companies can not only mitigate their impact on the planet but also unlock new avenues for growth, resilience, and competitive advantage.

Furthermore, this introduction sets the stage for a detailed analysis of the key principles underlying the green economy, the challenges organizations face in adopting these principles, and the potential benefits of embracing a more sustainable approach to business. Ultimately, the paper aims to illustrate that the shift towards a green economy is not merely a trend but a necessary evolution that can redefine the relationship between economic development and environmental stewardship, ensuring a viable future for generations to come.

II. Methods

This study employs a multi-faceted research approach to analyze the transformation of traditional business models within the context of the green economy. The methodology comprises several key components designed to gather comprehensive data and insights into the subject matter:

1. **Literature Review**: A thorough review of existing literature on green economy principles, sustainable development, and traditional business models was conducted. This review

includes academic articles, books, reports from international organizations, and case studies that provide foundational knowledge and context for understanding the intersections between economic practices and environmental sustainability. The literature review serves to identify key themes, challenges, and opportunities that characterize the transition to a green economy.

2. **Case Studies**: Selected case studies of organizations that have successfully transformed their business models in alignment with green economy principles were analyzed. These case studies were chosen based on their relevance to various industries and their demonstrated commitment to sustainability. The analysis focuses on the strategies employed, the challenges encountered, and the outcomes achieved, providing real-world examples of how businesses can implement sustainable practices.
3. **Interviews and Surveys**: Semi-structured interviews and surveys were conducted with key stakeholders, including business leaders, sustainability experts, and policymakers. These discussions aimed to gather qualitative data on the motivations, barriers, and best practices associated with transitioning to a green economy. The insights gained from these interviews and surveys offer a deeper understanding of the subjective experiences and perspectives of those directly involved in the transformation process.
4. **Comparative Analysis**: A comparative analysis of different business models was performed to identify the factors that contribute to successful implementation of green economy principles. This analysis involved examining the differences and similarities in approaches taken by businesses across various sectors, such as manufacturing, agriculture, and services. By comparing these models, the study aims to highlight the adaptability of green economy principles and their applicability in diverse contexts.

III. Results

In light of the uncertain recovery of the global economy, governments from both mature and emerging economies, various international organizations including the UN, and stakeholders from civil society and academia have all played a role in advocating for a green economy or green growth as a means to address the ongoing crises. These terms are frequently used interchangeably, encompassing a spectrum of ideas related to low-carbon development. This range spans from the specific focus on eco-industry and environmentally friendly production to a comprehensive redefinition of an entire country's or region's economy. Between these two extremes lie policies aimed at promoting low-carbon economies or enhancing efficiency and productivity, which often overlap.

These approaches emphasize varying degrees of concepts such as dematerialization, decoupling resource use, valuing ecosystem services, and improving energy efficiency, all propelled by technological innovation. The notion that undervaluing natural capital impacts not only economic efficiency but also both growth and the quality of that growth concerning human welfare has gained recognition from international and national organizations since the influential Millennium Ecosystem Assessment was published. Additionally, scholars connect green growth and green economies to positive shifts in the eco-industry sector, which is transitioning from downstream environmental protection technologies to resource-saving technologies driven by innovation and competitive markets. They also highlight a growing interest in re-evaluating lifestyles beyond the traditional sustainable consumption agendas and the need to transcend the classic divide between individualistic and systemic methodologies, as well as the role of technological and cultural factors.

Consequently, a substantial portion of the policy and academic literature on greening growth and economies merges environmental and sustainability discourses with industrial and economic policy discussions, aiming for win-win solutions and positive cycles of progress and prosperity.

Among international organizations, the United Nations Environment Programme has taken a leading role in shaping and promoting the green economy as a driving force for growth, job creation, and poverty alleviation. It defines a green economy as one that enhances human well-being and social equity while significantly reducing environmental risks and ecological scarcities.

Against this backdrop of multiple crises and the emergence of new ideas for economic growth, 191 UN member states convened in Rio de Janeiro from June 20 to 22, 2012, for the UN Conference on Sustainable Development, known as Rio+20. This event marked the twentieth anniversary of the UN Conference on Environment and Development, which elevated sustainable development to an internationally recognized concept and normative goal, as well as the fortieth anniversary of the UN

IV. Discussion

The theme of a "green economy in the context of sustainable development and poverty eradication" was introduced as one of the emerging challenges during the UNCSD's first preparatory committee meeting in May 2010. Several intersessional and preparatory meetings at the UN headquarters in New York, along with country-led initiatives and reports, contributed to the development of the "zero-draft" outcome document in December 2011. Tariq Banuri, who was the Director of the Division for Sustainable Development at the UN during the lead-up to Rio+20, provided insight into the reasoning for focusing on the green economy in an interview. When asked if the green economy might "minimize" sustainable development, Banuri clarified that the green economy was firmly positioned within the context of sustainable development, aiming to align economic policies with social and environmental needs. He emphasized that focusing on the economy is essential, as it is an area requiring action.

In response to concerns about differing agendas between developed and developing nations and the fear that greening might hinder growth, Banuri acknowledged the crisis-driven nature of the agenda, explaining that the consensus was not about obstructing development but ensuring its possibility during times of crisis. This view was shared by both developing and developed countries. Banuri further addressed the idea that achieving sustainable development would require an economic paradigm shift, confirming the presence of an emergency mindset. He stressed that the goal was to find practical solutions rather than seeking a completely new paradigm.

A summary of national reports for Rio+20 highlighted concerns about the lack of clarity surrounding the green economy and the perceived risks, such as imposing conditions on aid and creating trade barriers. A detailed account of the process leading up to Rio+20 in the Earth Negotiations Bulletin underscored the controversy surrounding the UNCSD's decision. The green economy, though championed by UNEP as a key theme, encountered strong resistance from the G-77/China, resulting in a highly defensive and qualified text in this section of the document.

To discuss the idea of the green economy, its relationship to sustainable development, and the significance of its adoption within the Rio+20 agenda, it is essential to view it in a broader historical and economic context, especially considering the ongoing multiple crises. An initial qualitative analysis of the content from the 24 sources, along with reports on stimulus packages quickly passed by governments across the Atlantic, indicates that responses to these crises can be grouped into three main categories: (1) national stimulus packages, representing "almost business as usual" (BAU); (2) proposals to green the economy, labeled as "greening"; and (3) calls for socioeconomic transformation, described as "all change." Each category is characterized by its primary objective, its socioeconomic paradigm, and its vision of progress.

The "almost BAU" category refers to the stimulus packages, recovery programs, and bailouts implemented by major economies to mitigate the effects of the near-global financial collapse.

These measures often included "green stimulus measures," with large economies focusing on environmental initiatives within the broader context of their recovery efforts. Countries such as China, South Korea, the United States, Japan, and the European Union led the way in green investment packages, allocating significant funds to energy efficiency, infrastructure upgrades, clean technology markets, and research and development. The core of these responses was to reactivate the global market economy while addressing unemployment issues.

The greening efforts viewed the economic crisis as an opportunity for investment in the ecoindustry. Governments committed substantial funds to green projects, with a reported $512 billion being allocated globally, 22% of which was to be spent in 2009 alone. While these green stimulus packages were part of broader recovery strategies, they also demonstrated a shift towards greener policies. The overarching economic paradigm in this category remained tied to growth, framed within neoclassical economics, and reinforced by Keynesian approaches that emphasized state intervention in the economy.

The vision of progress within the "almost BAU" category was rooted in economic growth, with the assumption that growth would eventually benefit society as a whole. This incremental shift represented a move away from market fundamentalism toward a more active role for the state in shaping economic recovery and addressing both social and environmental needs.

The "greening" category refers to national and international efforts aimed at comprehensive strategies for greening economies. This approach is best exemplified by documents like the OECD's *Green Growth: Overcoming the Crisis and Beyond* (2009) and UNEP's *Global Green New Deal* (2009). The primary objective is to achieve resource-efficient, low-carbon growth. The socioeconomic paradigm is rooted in a technoscientific framework, with progress defined as efficient growth that benefits society as a whole and reduces poverty. This includes various shades of green, reflecting a gradual shift away from mainstream economic models toward propositions inspired by thinkers like Karl Polanyi. This shift reasserts the connection between the economy and society, moving beyond the state's rediscovered role in economic intervention, and incorporates ecological economic theories, which emphasize environmental limits and the need for equity across generations.

As we move further along the spectrum, the "all-change" category represents more radical approaches proposed by NGOs, think tanks, and heterodox economists. This category lacks a cohesive set of policies, but key documents like *World in Transition* (WBGU, 2011), *The Great Transition* (NEF, 2009), and the *Degrowth Declaration* (2010) embody the core ideas. The primary goals here include prosperity beyond traditional economic growth, the creation of steady-state economies, and the fostering of societies that prioritize well-being and sustainability. The degrowth movement, part of this category, critiques the primacy of economic growth, even in its sustainable forms, and calls for a reorientation towards human well-being and happiness. These proposals reflect a transformative socioeconomic paradigm that draws from natural sciences, social sciences, and humanities, rather than the more economic-centric approaches of previous categories. They also highlight the paradoxes of growth and efficiency, such as Easterlin's and Jevons' paradoxes.

In exploring these categories through the lens of John Dryzek's classification of environmental discourses, we see how each category aligns with varying degrees of reformist and radical thinking. Dryzek identifies two dimensions of human-nature interaction: reformist-to-radical changes and prosaic-to-imaginative alternatives to dominant political-economic structures. The "almost business as usual" (BAU) category aligns with Dryzek's reformist-prosaic "problem-solving" discourse, representing conservative and gradual approaches to change. The "greening" category overlaps with Dryzek's "sustainability" discourse, blending prosaic and imaginative elements. Finally, the "all-change" category fits with Dryzek's "green radicalism," representing a more imaginative and radical departure from current economic and environmental norms.

These distinctions help clarify the diverse responses to the green economy debate, from incremental reforms to more transformative visions of a sustainable future. Rio+20 fits into this framework primarily within the "greening" category, reflecting a reformist and moderate approach to sustainable development that aligns with the weak conception of sustainability. Held during the height of the global financial crisis, the agenda was shaped by both economic instability and growing environmental concerns. However, the emphasis at Rio+20 on the green economy—framed as a pathway to both economic recovery and environmental sustainability—largely mirrors the discourse of *ecological modernisation*, which advocates for more efficient, low-carbon growth without fundamentally questioning the dominant socioeconomic paradigm. This perspective seeks to "fix" the existing system through technological innovations and market-driven solutions, rather than shift to more radical alternatives.

The implications of Rio+20 for sustainable development, 20 years after the first Rio Summit (UNCED, 1992), suggest a continuation of the weak paradigm. While Rio+20 embraced green economy strategies, these strategies remain focused on efficiency improvements, resource management, and ecological modernisation rather than addressing deeper systemic issues, such as unsustainable consumption patterns or the need for a more transformative socioeconomic shift.

This is consistent with the broader literature on sustainable development, which critiques the weak version for prioritising economic growth and technological solutions over more profound social or environmental changes. Rio+20’s proposals, despite the green rhetoric, fall short of the more radical–imaginative dimensions represented by the "all-change" group, which advocates for paradigm-shifting transformations that prioritize well-being, equity, and ecological sustainability over economic growth.

Thus, Rio+20’s approach remains within the "reformist–prosaic" category of John Dryzek’s environmental discourse classifications, focusing on incremental changes and technocentric solutions. Its agenda, while progressive in terms of advocating for a greener economy, reinforces existing structures rather than challenging the global economic system in a way that the more radical discourses in the "all-change" category would demand. This is reflected in the underlying tension between the need to address immediate economic concerns and the more pressing, long-term sustainability challenges that still remain largely unaddressed.

References

[1] Taranova I.V., Kasaeva T.V., Shavrina J.O., Tekeeva H.E., Boeva K.Y. Methods of fraud management in the financial services market of the region// Business 4.0 as a Subject of the Digital Economy. Cham, 2022. C. 291-295.

[2] Mapar, M., Jafari, M. J., Mansouri, N., Arjmandi, R., Azizinezhad, R., & Ramos, T. B. (2020). A composite index for sustainability assessment of health, safety and environmental performance in municipalities of megacities. Sustainable Cities and Society, 60, 102164. http://doi.org/10.1016/j.scs.2020.102164

[3] Caeiro, S., Sandoval Hamón, L.A., Martins, R., Bayas Aldaz, C.E. (2020). Sustainability Assessment and Benchmarking in Higher Education Institutions: A Critical Reflection. Sustainability 2020, 12, 543.

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. C. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental

taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

TRANSITION TO INNOVATIVE METALLURGICAL TECHNOLOGIES – PRIORITY DIRECTION OF DECARBONIZATION

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Abstract

The article systematically analyzes the transition to innovative metallurgical technologies in the context of the priority direction of decarbonization. It is determined that at present the main direction of decarbonization can be considered the rapid development of electrometallurgy. Within the framework of this direction, oxygen blowing of liquid metal, extra-furnace treatment, the use of powerful transformers, automatic melting control, processing with synthetic slags, melting in induction furnaces, preliminary heating of the charge, and the widespread use of injection metallurgical processes are recognized as innovative technologies.
Reducing energy consumption in the production of electric steel has been put forward as the main task of metallurgical technologies. Two main directions of decarbonization in the steelmaking complex have been identified: intensification of smelting based on increasing the capacity of the furnace transformer and the introduction of modern "oxygen" technologies and a modular system in smelting.

Keywords: innovative technologies, decarbonization, priority areas, electrometallurgy, extra-furnace processing, injection processes

I. Introduction

It is known that the production of ferrous metallurgy is an industry with a large harmful impact on the environment and large-scale carbon dioxide emissions. Global climate change requires increased innovation activity in the metallurgical industry. The transition to innovative technologies can be considered as a priority direction of the decarbonization process in metallurgy. The main vector of this direction is electrometallurgy or the production of electric steel.

Current trends show that more than 80 percent growth in the use of the electric method in general steel production in recent decades is due to the introduction of innovations. Therefore, researchers propose to evaluate the criterion for accelerating innovative technologies in steel production as a derivative function of innovation growth (million tons/year), (million tons/year2) [1].

Researchers and specialists constantly analyze the role of innovative technologies in increasing the competitiveness of metallurgical products. It has been shown that innovative metallurgical technologies will play a decisive role in improving the quality of metal products in the coming decades and will ensure the protection of the leading positions of countries in the world market [2]. For example, in [3] the issue of removing hydrogen from the surface of liquid metal using a circulating vacuum as an innovative metallurgical technology is considered. It is shown that the removal of hydrogen from the metal surface in a circulating vacuum chamber is a long process and occurs at a very slow rate.

Analytical calculations have shown that removing hydrogen from the surface of liquid metal in the chamber of a circulation vacuum cleaner is not enough to obtain a low residual amount of hydrogen in the metal, and for this it is necessary to carry out additional technological measures.

II. The role of innovative metallurgical technologies in decarbonization of the environment.

In [4], promising innovative directions for the development of steelmaking were studied. It was shown that the share of electric steel in global steel production is more than 30%, in the USA this figure is approaching 40%. The main reasons are indicated as process flexibility, less dependence on the composition of primary raw materials, the possibility of producing alloy steels of various compositions and purposes, the use of large amounts of scrap metal, the possibility of automating processes and environmental aspects, and the rapid growth of electric steel production.

Based on the analysis of the current situation in metallurgical production, it has been determined that modern electric arc furnaces (EAF) have essentially become a smelting unit, significantly freed from the "dirty" metallurgical processing of steel.

Therefore, the priority development of electric steelmaking can be considered as the main direction of technical progress in metallurgical production. It is noted that the total energy consumption of EAF steel production is 1.5-1.8 times less than that of oxygen converters.

The study [5] presented the inevitable direction of development of electric smelting in the metallurgy of Russia, especially in the Ural region. It was shown that the technical and economic indicators of electric arc steelmaking furnaces (electrode consumption, melting time, energy consumption, etc.) have significantly improved in recent decades.

Out-of-furnace steel treatment processes are indicated as a major contribution to the achievements of electrometallurgy. Thus, out-of-furnace treatment allowed not only to abandon long cycles of melt reduction and oxidation and, therefore, to increase furnace productivity, but also to save energy and materials. Mainly, this allowed to significantly improve the quality of steel, to obtain steel with fundamentally new properties.

Thus, the conducted research allows us to consider the following processes as innovative in electrometallurgy: 1. Oxygen blowing. 2. Out-of-furnace processing. 3. Water-cooled panels. 4. High-power transformers. 5. Extended-arc welding. 6. Automated monitoring and control. 7. Foam plastic processing. 8. Use of water-cooled arcs. 9. Use of a new type of burner. 10. Tapping metal from the furnace bottom. 11. Ladle furnace processing. 12. Tapping liquid metal without residues ("swamp" melting). 13. Primary heating of the plate. 14. Injection methods or rubbing and blowing with gases.

In the context of the listed innovative technologies, methods for increasing the productivity of modern electric arc steelmaking furnaces were studied in [6]. It was shown that electric arc furnaces currently play an important role in steel production as the main metallurgical unit. EAFs, out-of-furnace processing units and continuous casting machines together make it possible to obtain high-quality steels with significantly lower energy costs and minimal impact on the environment.

It is shown that reducing the metal overheating temperature in the furnace is an effective method for increasing the EAF productivity. The necessity of such measures as high-temperature heating of furnace masonry, preliminary heating of materials added during the melting process, and the widespread use of heat-protective materials in the masonry of furnaces and fireboxes as methods for ensuring this process is substantiated.

The use of efficient energy-saving technologies in the steelmaking complex is considered in [7]. The analysis of technical and economic indicators of an electric steelmaking plant is carried out using an electric arc furnace as an example. Reducing energy costs in the production of electric steel is put forward as the main task of metallurgical technologies in our country.

The following are recommended as the main operations when implementing efficient energy-saving technologies:

1. EAF should be considered only for slag melting and obtaining liquid metal. All cleaning operations should be carried out using extra-furnace methods.

2. Steel smelting should be carried out using the advantages of liquid or "swamp" technology.

3. Only single-pass electric welding technology should be used in EAF. This technology involves increasing the capacity of the furnace transformer to 95 MVA and introducing a "furnace-ladle" device.

4. Minimization of heat losses in the furnace and firebox, preliminary heating of scrap metal, regular feeding of loading baskets into the furnace should be ensured.

5. To intensify the melting process, a modular system should be used. Here we consider such tricks as using fuel-oxygen burners, switching to oxygen injection and carbon blowing, and operating the furnace on long arcs.

6. It is necessary to ensure that the oven is constantly operating in foamed bags. This technology allows you to screen the electric arc operating in long arcs, protect the masonry and water-cooled panels of the furnace. Due to the injection of carbon, the technological advantage creates conditions for foaming of the resin during the reaction with oxygen.

It should be noted that in recent years much attention has been paid to the use of injection technologies in metallurgical production. Thus, in [8] it is shown that injection technologies are currently considered as a promising direction, widely used in metallurgy. This technology is used for processing alloys with materials similar to powders and for reducing heat-technical units.

The above studies showed that most metallurgical processes occur predominantly at the phase separation boundary, and the rate of these processes is determined by the total area of the contact surface. Intensification of the mixing of metal, resin and gases accelerates the course of physicochemical reactions in metallurgical furnaces.

This technology opens up wide possibilities for dephosphorization, desulphurization, deoxidation and alloying of steel, acceleration of slag formation, and carbonization of metal. Higher efficiency of this method is noted when feeding powder materials into the alloy in a gas flow.

The paper [8] also describes the characteristics of injection equipment for the implementation of injection technologies. The main process parameters determining the efficiency of injection technology are considered. As a result of experimental, calculation-analytical and design work, the main parameters of the powder gas flow in the injection metallurgical system were the carrier gas velocity, the mass density of the gas-dust mixture, the critical speed of pneumatic transport, the type of chamber blower (aerator and pneumatic-mechanical). It was determined that as a result of the use of this technology, a significant increase in the durability of the circulation vacuum cleaner pipes is observed.

In [9] the issue of reducing energy costs in the process of steel smelting in a large-tonnage electric arc furnace is considered. It is shown that at present the concept of steel production development is based on innovative technologies of energy-resource-saving and environmentally friendly production of electric steel.

Thus, modern metallurgical technologies include: utilization of heat from furnace gases; use of high-power electric transformers and alternative energy sources in the furnace; application of "oxygen" technologies to intensify smelting; foaming of pulp and combustion of process gases; synchronization of electrical energy and chemical energy of exothermic reactions

Studying the best practices of ferrous metallurgy enterprises allows us to identify two main areas of modernization of the steelmaking complex:

1. Intensification of the smelting process and application of modern "oxygen" technologies based on increasing the nominal power of the furnace transformer.

2. Application of a modular system (DANARC, Italy, DANIELI) in smelting processes.

The DANARC modular system combines maximum utilization of thermal energy, formation of foamed pulp and decarbonization of the liquid bath in one unit. The DANARC modular system has the following advantages over traditional equipment:

- blown coal dust is completely burned in the oxygen cylinder;
- efficient transfer of thermal energy is ensured in the bath;
- stationary placement of the module in the furnace frame is possible;
- ease of operation and minimal maintenance requirements.

It has been determined that the following results can be expected from the use of the DANARC modular melting system: increase in unit productivity - 17.3%; decrease in specific electricity consumption - 7.3%; reduction in defrosting time - 16.1%; decrease in specific electrode consumption - 39.4%; decrease in specific natural gas consumption - 14.8%.

The ways of increasing the productivity of electric arc furnaces are studied in [10]. It is shown that in the last 15-20 years the tendency of continuous increase in production of electrical steel in the world is clearly evident, and at present it makes up 40% of the total volume of steel production. The share of electrical steel in the USA is 45%, in Italy 60%, in Spain 72%, in Azerbaijan 80%.

The advanced development of electric steel production is associated with the direct application of advanced technical and technological developments and allows for a significant improvement in the technical and economic indicators of electric smelting. Increasing the productivity of electric arc furnaces is considered a complex task for metallurgists and power engineers and involves reducing the three main periods of smelting: preparatory, power and technological.

It has been established that further increase in EAF productivity can be ensured by better preparation of slag material for melting (slag scattering density 1.4-1.8 t/m2) and preliminary slag heating (400-500°C). These measures allow saving electricity by 70-75 kW.s/t, reducing melting time by 10-12%.

It is shown that after melting the slag, it is necessary to create and maintain a foamy pulp by blowing coke and oxygen to reduce radiation to the walls and roof of the furnace, as well as to ensure a "closed" arc combustion mode.

Increase in EAF productivity can also be achieved by conducting the melting process cycle in a single-pass mode, reducing the reduction cycle and conducting a number of cleaning processes with extra-furnace treatment.

Therefore, an important direction for increasing EAF productivity is increasing the capacity of the furnace transformer to 800-900 kVA/t. At this time, it is considered appropriate to increase the secondary voltage to 900-960 V.

In [11] it is shown that at present both rolled products and continuously cast blanks are widely used in the production of metal products. It is shown that the use of continuously cast blanks is more economically convenient, since in this case there is no need for additional rolling operations. In addition, the use of continuously cast blanks allows for a significant reduction in scrap metal, an increase in the output of healthy products, an increase in the productivity of rolling units and an improvement in working conditions.

In our country, the development of efficient technologies for the production of pipes and sheets from continuous casting is a pressing task for metallurgical enterprises. At the same time, the use of continuous casting machines allows reducing the cost of pipes by 10% and increasing the productivity of the pipe rolling unit by 15%.

A review of literary sources on the topic under study was conducted and the features of the change in the shape of the metal during radial sliding spreading of the works of Chekmarev A.P., Vatkin Yu.L., Potapov Yu.N., Polukhin P.Yu., Smirnov V.S., Fomichev Yu.A., Teterin P.K., Sveikin V.V., Kolikov A.P., Nikulin A.N. were determined and the works of other well-known scientists were analyzed.

Particular attention is paid to the advantages of the radial-sliding spreading method over other deformation methods. The intensity of compaction of the structure over the entire cross-section of the blanks, the possibilities and advantages of various schemes of the stress-strain state of the blanks are noted.

The conducted theoretical and practical studies allowed us to come to the following main conclusions in the analyzed work. The features of profiling the rear end of the workpiece in the form of a truncated cone and changing the shape of the cone of the workpiece during rolling on three-roll compression and piercing machines, based on the joint implementation of rolling processes on a compression machine, were determined.

Based on the products obtained during production tests and modeling using the Deform-3D program, it was established that smaller values of compression depth are observed when compressing a truncated cone blank 70 mm long.

During the physical and mathematical modeling of the process of profiling the end of the workpiece, it was found that as the profiling speed increases, the metal delaminates on the surface. Rational calibration and deformation modes have been developed, ensuring compression-free molding at the rear end of a truncated cone of a 70 mm long workpiece.

The process of profiling the tip of a workpiece with a cooled outer layer was simulated. It was found that cooling the outer layer at the end of the workpiece before profiling allows for a significant reduction in the depth of compression. In this regard, a cooling unit should be provided for in the working design for the reconstruction of the input section of a three-roll press machine.

In [12] it is shown that the fuel and energy complex of our country places serious demands on the products of the pipe industry. However, despite numerous theoretical and technological works, the problem of increasing the efficiency of seamless pipe production remains relevant.

The capabilities of pipe factories do not allow producing oil-quality pipes with a guaranteed level of properties that meet the technical requirements of developed countries. 95% of seamless pipes abroad are produced by continuous casting.

During the research work, the basic requirements for metal quality were scientifically substantiated and the following technological processes for the production of high-quality continuous casting blanks were developed:

- technology for the production of highly reliable oil and gas pipeline pipes operating at pressures up to 50 MPa;
- technology for the production of highly corrosion-resistant oil and gas pipeline pipes operated at low temperatures down to minus 60°C;
- technology for smelting carbon and low-alloy steels, furnace and out-of-furnace processing, continuous casting of square and round section pipe blanks.

III. Application of injection technology in metallurgy for decarbonization

Recently, interest in injection technologies has increased significantly, which are considered one of the most common technologies and one of the promising areas in metallurgy. These technologies are used for processing alloys with powder materials, as well as for gunning heating equipment units.

Shotcreting is a method of applying concrete mixture to a surface layer by layer under compressed air pressure [13].

It is known that most metallurgical processes occur at the phase boundary. The speed of these processes is determined by the total area of the contact surface. Intensification of the mixing of metal, resin and gases significantly accelerates the course of physical and chemical reactions [13].

A greater effect is achieved by accelerating alloy flows and simultaneously increasing the specific surface area of the reacting phases. These processes occur when using injection technologies. The high efficiency of this method is demonstrated when injecting powder materials into a metal alloy from a gas-bearing flow.

This method is used for dephosphorization, desulfurization, deoxygenation, acceleration of rust formation during steel alloying, and also for metal carbonization. In addition, injection of refractory materials can be used for twisting the mesh surfaces of metallurgical units [14].

Successful application of injection technologies depends on the use of injection equipment that provides a greater number of processes. In the 70-80s of the last century, work on the use of rapid carbonization of metal was carried out at various metallurgical plants.

At that time, pneumatic blowers manufactured in these establishments were used. The necessary scientific, technical and design research, operations and calculations were not carried out during the creation of these objects. Mainly for this reason, this promising method of metal processing has not yet found wide application [15].

In addition, work on improving injection technologies, especially on the design of powder blowing devices, has been developed abroad for many years.

The work carried out has led to the successful development of innovative metallurgical technologies in Japan, Germany, Austria, America and other countries. This promising direction has made it possible to intensify metallurgical processes, improve the quality of metal, and increase the service life of smelting units in these countries.

In the mid-90s of the last century, German injection devices were first used at the Serp and Molot plant (Moscow) with the participation of the Metallurgical Institute of the Russian Academy of Sciences.

In 1999-2000, the Institute of Metallurgy of the Ural Branch of the Russian Academy of Sciences completed the international project "Application of Casting Technologies at Metallurgical Enterprises of the Urals". As a result of studying the experience of applying casting technologies at European metallurgical plants, as well as research on the application of various powder materials to the alloy, it was recommended to continue work on equipping metallurgical enterprises with injection devices [16].

In this regard, there was a need to create casting equipment that is no different from foreign analogues in terms of quality, reliability and durability, but also meets the operating conditions of metallurgical enterprises in our country, and at the same time is significantly cheaper than imported ones [16].

For example, in the Russian Federation, experimental, computational-analytical and design work was carried out on the aerodynamics of powder-gas flows in injection-metallurgical systems and the influence of operating and design factors on the intensity of the output of sprayed materials from a pneumatic-mechanical feeder [17].

As a result of the conducted scientific research and experimental design work, the main parameters of powder gas flows in casting metallurgy systems were selected. The carrier gas velocity value is taken as the main parameter of the carrier gas flow mode.

One of the main characteristics of a two-phase flow is the mass density of the mixture, which is defined as the ratio of the mass flow rate of the solvent to the mass flow rate of the gas. At that time, gas-rubber mixtures with a mass flow rate of 2 to 60 kg/kg were used for blowing metal.

The critical speed of pneumatic transport was assessed as the main parameter ensuring the reliability of the blowing structure as a whole. One of the main and determining factors influencing the successful operation of injection equipment is the correct choice of the chamber blowing system.

Currently, two types of equipment are used for injection technologies: aeration and pneumatic-mechanical. Aeration-type chamber blowers are used for deep injection of powder materials and partially for reducing torque. In recent years, pneumatic chamber blowers have become increasingly widespread in the world. They are used for twisting stone surfaces, as well as shallow injection of powder materials into metal alloys.

Such blowers have a design more suitable for the operating conditions of metallurgical production in our country, are simple and reliable in operation, and have a wide range of applications. As a result of research and development work for injection metallurgy, a pneumatic-mechanical type design was chosen as a chamber blower [18].

This type of air blower is equipped with a tray dispenser, which is placed horizontally in the lower part of the working chamber. The dispenser has a separator ball wheel, the speed of which is regulated by an electric motor equipped with a frequency converter.

In 2001, the NIM-01-2 injection device for blowing powdered materials into a liquid alloy in an open-hearth furnace was put into operation at the plant in the Russian Federation. Work on the application and development of metal carbonization technology continues here. In 2002, an injection device for tightening pipes of a circulating vacuum cleaner of the NIM-01-4 type was put into operation. A new design was developed, manufactured and launched into production, cutting off the flow of gunite mass with the ability to adjust the angle of dispersion from 30 to 360 degrees for internal gunning of vacuum cleaner pipes. As a result of the device's introduction, the service life of the circulating vacuum cleaner pipes has increased significantly.

IV. Conclusions

1. The transition to innovative metallurgical technologies was systematically analyzed in the context of the priority direction of decarbonization. It was determined that at present the main direction of decarbonization can be considered the rapid development of electrometallurgy. In this direction, blowing liquid metal with oxygen, using physicochemical methods in extra-furnace (ladle furnace) processing, using powerful transformers in electric furnaces, automated control and management of melting, in the processing of synthetic resins. "Swamp" melting in induction furnaces, preliminary heating of slag, and widespread use of injection metallurgical processes were assessed as innovative technologies.

2. Reducing energy costs in the production of electric steel is put forward as the main task of metallurgical technologies. Two main directions of decarbonization in the steelmaking complex are defined: intensification of metallurgical processes based on increasing the capacity of the furnace-transformer and the introduction of modern

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References

[1] Ovchinnikov S.G. et al. Innovative acceleration as a factor of economic development (on the example of steel production) // Innovation, No. 3, 2006, 9 p.

[2] Flick Andreas (translated from English by Potapova M.V.). How innovation increases the competitiveness of products in steelmaking // Steel Metallurgy, No. 1 (18), 2016, pp. 26-29

[3] Metelkin A.A. et al. On the issue of removing hydrogen from metal in a circulation-type vacuum cleaner // Steel Metallurgy, No. 1 (18), 2012, pp. 29-31.

[4] Kazachkov E.A., Chepurnoy A.D. Prospective directions of development of electric steelmaking production // Chernye Metally, 1997, No. 4, pp. 50-53

[5] Roshin V.S. Electric smelting - an inevitable path of development of metallurgy in Russia and the Urals // Bulletin. MSTU, No. 1 (19), 2005, pp. 22-27

[6] Matochnik V.A. et al. Methods of increasing the productivity of modern arc steelmaking furnaces // Casting and Metallurgy. 2005, No. 3 (35), pp. 71-75.

[7] Vedybeda D.V. Implementation of energy-efficient technologies in the steelmaking complex // Casting and metallurgy, 2014, No. 2 (75), pp. 68-70

[8] Korneev S.V. Application of injection technologies in metallurgical production // Power Engineering and Industry of Russia, 2018, No. 22 (114), pp. 61-66

[9] Zazyan A.S., Terletsky S.V. Reducing energy costs during steel smelting for high-power large-tonnage EAF // Casting and metallurgy, 2010, No. 1-2 (54,55), pp. 239-242

[10] Kazachkov E.A., Chepurnoy A.D. Ways to increase the productivity of arc steel-making furnaces // Bulletin of the Priazovsky State Technical University, 2005, issue 5, 5 p.

[11] Pavlov D.A. Development and modeling of a new method for compression of continuously cast billets in the production of oil pipes // Abstract of diss. for associate professor of technical sciences, Ekaterinburg, 2013, 28 p.

[12] Arif Mammadov, Agil Babaev, Nizami Ismailov, Mukhtar Huseinov, Faiq Guliyev. Identification of the nature of defects arising in the production of continuously cast pipe bills for the oil and gas industry// Eastern-European Journal of Enterprise Technologies, 4/1(124), 2023, p.125 – 133. DOI: https://doi.org/10.15587/1729-4061.2023.284387,link https://journals.uran.ua/eejet/article/view/284387

[13] Chikalov S.G. Theoretical foundations, research, development and implementation of highly efficient technologies for the production of seamless pipes using continuously cast billets // Abstract of diss. for associate professor of technical sciences, Moscow, 2014, 48 p.

[14] Chikalov S.G. Production of seamless pipes from continuously cast billets. Volgograd, Committee for Printing, 1995, 416 p.

[15] Chikalov S.G. Main new types of products at the Volga Pipe Plant. Steel, No. 2, 2000, pp. 40-42.

[16] Bogatov A.A. et al. Development of a mathematical model for studying the processes of screw rolling and piercing of blanks // Rolled metal production, No. 7, 2013, pp. 28-33

[17] Bogatov A.A. et al. Modeling and optimization of a new method of reducing continuously cast billets // Ferrous metals, No. 11, 2013, pp. 26-31

[18] Zolya V.N.Study of technogenic waste in ferrous metallurgy and development of technologies for their processing. Abstract of diss. for. co-author of Ph.D., Moscow,2015, 27 p.

YOUNG SPECIALISTS EMPLOYMENT AS A FACTOR OF SUSTAINABLE RURAL DEVELOPMENT

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Abstract

The paper deals with the problems of employment of young in-demand specialists in rural areas. The development of rural areas is one of the priorities of our time, as there is a noticeable decrease in the number of both the rural population and those employed in public agricultural production. The need to attract young specialists to rural areas is becoming a task of national importance. The employment of young specialists is an important factor in the sustainable development of rural areas, since without young highly qualified personnel it is impossible to develop and bring to a new level the social infrastructure of rural areas and high-tech agriculture. As part of the study of this problem, we conducted a comparative analysis of the level of employment in urban and rural areas. A set of measures is proposed to improve economic, social and migration policy in rural areas in order to attract and retain in-demand specialists.

Keywords: young specialists, employment, rural areas, rural unemployment, living standards of the rural population

I. Introduction

Agriculture in the 21st century is an area of great opportunities. Stable growth of the rural economy contributes to the development of all regions of the country, therefore, solving issues of socio-economic development of rural areas are fundamental to the stable and sustainable development of any country. The agro-industrial complex is one of the priority sectors of the Russian economy. Today the task is to provide agricultural enterprises with the necessary number of competent, qualified personnel capable of organizing high yielding and efficient production. Recently, the land area has more than doubled. Labor productivity has increased due to the use of modern agricultural machinery. At the same time, staffing shortage have been and remain one of the key issues. And although our enterprise is not currently experiencing a large labor shortage, there is no personnel reserve in the farm business [1].

Modern agro-industrial complex is a high-tech industry that requires specialists of new generation. A modern stock-farmer is a highly qualified specialist who knows how to work with special computer programs, analyze data and make competent decisions based on them.

Today, the rural labor market is characterized by a shortage of young specialists in many sectors. The problem is relevant because as the demand for young specialists grows, competition between companies for their selection also increases.

If rural economy degrades, then rural areas do not develop.

II. Methods

In the course of writing this scientific work, we used the researches of Russian economists who made a great contribution to the science on the topic under consideration, as well as articles in periodicals and Internet resources.

Such methods as monographic, comparative and logical analysis, SWOT-analysis were used in the article.

The data of the Federal State Statistics Service and regulations were used as factual and analytical material.

III. Results

The state is taking all measures to support the development of the agro-industrial complex. In 2024 state support for the agro-industrial complex will amount to 558 billion rubles. Since the beginning of the main State program for agricultural development in 2013, more than 3.5 trillion rubles has been allocated to it. Landholders and processors have access to a wide range of support measures available to both large companies and small businesses, which has a positive effect on production output. Alongside with this, 68 billion rubles is envisaged for the comprehensive program for the development of rural areas and 40.7 billion rubles for the land reclamation program. Depending on climatic conditions differentiation of state support for agriculture in different regions of Russia will be preserved. Such differentiation already exists, preferences are provided for various regions, including the Far East, the North Caucasus, the Arctic zone and new territories.

Non-prestigious, low-paid work, mainly its greater part, is hard manual labor; life "without basic amenities" far from the city is the old Soviet stereotype about agriculture, formed by more than one generation, which has led to a paradoxical situation: the high-tech and modern sector of the agro-industrial complex, which is constantly modernizing and developing, introducing IT and other advanced technologies, experiences a constant shortage of personnel today. Decent work is increasingly recognized as an indispensable factor in sustainable development, capable of lifting an individual, his family and community out of poverty. Poverty is a predominantly rural phenomenon. The ILO estimates that in developing countries, more than 80 percent of the poor live in rural areas. In 2012, the rate of extreme poverty in rural areas was four times higher than in urban areas.

The state is interested in the development of the agro-industrial complex, because today this industry is the main source of export revenues. In 2023, the supply of agricultural products abroad in monetary terms amounted to 43.5 billion dollars, including grain exports - 16.5 billion dollars, which is a record value. And the higher the income the country receives from the agricultural sector, the more funds can be directed to the development of rural areas. Attention is also paid to the development of agricultural cooperatives, access to markets is expanded, and assistance is provided in organizing wholesale and retail trade. And the State program "Integrated development of rural areas" helps in this matter. During the period 2020-2025 the state will allocate almost 2.3 trillion rubles to improve the living and working conditions of rural population [2]. Trillions of rubles will be spent on all this. One way or another, the changes should affect 37 million people.

The main goal of State programs is to ensure sustainable development of rural areas. To achieve these goals, it is necessary to:

- conduct a detailed assessment of the real needs for rural development; improve the legal base for providing state support and ensuring the protection of interests,
- develop and more actively implement mechanisms for grant support for rural youth,
- attract investments for the creation and development of non-agricultural enterprises and social infrastructure in villages,
- develop public-private partnerships between local residents, agribusiness, civil society institutions and government agencies;

Rural areas across the Russian Federation are struggling to retain and attract young people for a variety of reasons. The twin demographic trends of youth outflow and population aging make it increasingly important for rural cities to implement youth retention and attraction strategies.

The share of the rural population in the constituent entities of the North Caucasus Federal District (NCFD) exceeds the Russian average indices, in some republics it is twice as high. Thus, as on January 1, 2023, in all seven constituent entities of the Russian Federation that are part of the NCFD, the actual value of the index of "Share of rural population in the total population of the Russian Federation" exceeds the Russian average index (25.1%)", the report says. It is noted that in the Republic of Dagestan the share of rural population is 54.8%, in the Republic of Ingushetia – 45.2%, in the Kabardino-Balkarian Republic – 48.2%, in the Karachay-Cherkess Republic – 58.6%, in the Republic of North Ossetia-Alania – 36.8% (see Table 1), in the Chechen Republic – 61.9%, in Stavropol Territory – 39.3% [3].

Table 1: *Population of North Ossetia by municipal districts and towns*

Region	2017	2018	**2019**	**2020**	**2021**
Ardonskiy MD	31 705	31 796	31 830	31 755	31 825
Digorskiy MD	18 372	18 356	18 265	18 283	18 341
Irafskiy MD	15 314	15 221	15 160	15 107	15 007
Kirovskiy MD	27 411	27 457	27 406	27 407	27 377
Mozdokskiy MD	87 164	88 018	88 123	88 222	87 718
Pravoberezhnyi MD	57 205	57 125	57 088	57 115	57 388
Prigorodnyi MD	104 103	103 531	103 132	102 285	101 655
Vladikavkaz (town)	325 410		323 998	322 481	321 106

*MD – municipal district

The state is developing strategies to attract and retain young people, assessing not only federal, but also regional factors. Over two years, almost 340 million rubles have been issued as part of a regional project to support farmers and develop rural cooperation in North Ossetia. The Cabinet of Ministers has made amendments to the rules for granting subsidies. The support was provided to 150 farms and cooperatives for the period of 2022-2023. Thus, farmers get an opportunity to expand their production; the volume of local products that reach the shelves increases and, accordingly, food security increases. Another issue is the development of the agro-industrial complex. This year, 215 million rubles have been allocated for the activities of the national project to support farmers and develop rural cooperation. This is 85 million rubles more than last year. In terms of the volume of allocated funds, North Ossetia-Alania is among the leaders in the country. Nevertheless, there are still a lot of drawbacks in the NCFD, i.e. a lot of manual labor, where you have to deal with animals and crops, working hours, which do not coincide with the working period, work greatly depending on natural factors, and, in addition, the problems of a low level of social and communal infrastructure. So, in August 2023 LLC Agro-Industrial Holding "Master-Prime, Beryozka" required a combine operator with a salary of 20 000 rubles, and with irregular working hours. In 2023, almost 900 thousand tons of grain crops were harvested in North Ossetia. Livestock breeding indicators are very good, both in dairy, poultry and cattle meat. Modern infrastructure and a qualitatively new living environment are being created: new schools, kindergartens, cultural centers, and communal networks.

However, as practice shows, rural areas use available human resources, equipment and technologies only by 50 percent. The remaining 50 percent is the key starting platform and at the same time a problematic growth zone for all Russian agglomerations. Weak economic infrastructure, outdated agricultural equipment and lack of modern technologies hinder the development of agricultural production. But perhaps the biggest problem is the shortage of personnel. Labor resources are moving to other industries, where earnings are higher. Moreover, young people, whose labor is especially needed in the village, are leaving for the cities first of all. The low level of incomes is confirmed by official statistics. According **to** Federal State Statistics Service, in the first quarter of 2024, the average accrued salary in agriculture amounted to 55.6 thousand rubles, while, for example, in the mining industry - 150.3 thousand rubles, in the processing industry - 150.3 thousand rubles, and in the agricultural sector - 150.3 thousand rubles.

Nowadays, one of the main factors constraining the innovative development of the economy, including agricultural production, is the shortage of personnel in the labor market. Now, it is necessary to focus on training a sufficient number of personnel in demand in agriculture, possessing modern competencies and skills for their effective use. Along with the general shortage in the industry, there is an increasingly acute shortage of highly qualified personnel, which is a consequence of the widening gap between the quality of their training and the ever-increasing qualification demands of the business community. For example, some of the most in-demand specialists in the NCFD are veterinary specialists – veterinarians and veterinary paramedics, livestock specialists. Among the working specialties there are vacancies for tractor operators and drivers, and machine milking operators. On average, about 12-15% of the positions of specialists and working professions of the agro-industrial complex remain vacant. For example, the first enterprise in North Ossetia-Alania with a full cycle of milk production and processing, which has its own raw materials, feed base and a milk processing plant for the production of natural dairy products with the brand "Master-Prime, Beryozka" in the village of Khataldon, Alagir district, the following employees were needed: an agronomist (with a salary of 20 000 rubles); veterinarian (with a salary of 20 000 rubles); stock-farmer (with a salary of 15 000 rubles); engineer (livestock engineer - breeder) - salary based on the results of the interview; combine operator (with a salary of 20 000 rubles); tractor operator (mechanizer) (with a salary of 20 000 rubles). Modern agriculture is a high-tech production employing highly qualified people.

According to the results of 2020–2022, about 65 thousand workplaces were created through the activities of the State program and additional investment projects [10]. Workplaces in rural areas are also being created as part of the State program for the development of the agro-industrial complex. The creation of a modern farm will ensure crop rotation and increase the yield of our main crop, i.e. soybeans, and will also help to create additional workplaces. Subsidies are provided for the development of family farms, agri-tourism, and cooperative farming. Due to these measures, more than 4 thousand new farms were created, more than 42 thousand farmers were involved in cooperative farming, and more than 10 thousand workplaces were already created in 2023 [3].

In the Nizhny Novgorod region, measures to support the agro-industrial complex and grant programs for farmers have been developed. Various government support measures were provided for agricultural enterprises: subsidies are provided for manufactured products (milk, meat, potatoes, grain, vegetables), subsidies for the purchase of machinery and equipment. There are also programs for favourable credit facilities. Grant programs "Agri-tourism", "Family Farm", "Agri-startup" have been developed for farm business. In total, in 2024, the budget provides 6.1 billion rubles to support the agricultural industry and the development of rural areas, of which 4.2 billion are funds from the regional budget, 1.9 billion are federal subsidies. As part of the "Integrated development of rural areas" program, social payments are provided for rural workers to improve housing conditions. The program also provides for the construction of housing, which the employee signs up under a rental agreement. In this case, housing construction is 80 percent financed from the federal and regional budgets, 20 percent comes from the employer and the municipality. This year under the program 22 houses are being built for rural workers and their families. In addition, within the framework of the regional law on the development of human resources, a payment of one million rubles is provided for young specialists to improve housing conditions.

The following Agricultural Support Programs are in effect in the Russian Federation:

Zemsky (country) teacher is a program that allows young specialists to receive one-time financial support. To attract qualified personnel to villages, the State offers incentive payments for various specialists. Teachers can participate in the Zemsky Teacher program, i.e. an annual competition whose winners are employed in rural schools for 5 years and receive 1 million rubles (or 2 million in the Far East).

According to the Ministry of Education of the Russian Federation despite the record number of program participants, the need for teaching staff in villages is still high – there are not enough teachers of mathematics, Russian language, foreign languages and some other subjects.

Zemsky Doctor is a Program to improve housing conditions for doctors under 50 years old, moving to rural areas. The program "Zemsky Doctor" operates for medical workers. Doctors who move to work in a village or small town receive a million rubles, and paramedics, midwives and nurses receive 500 thousand rubles each. In hard-to-reach areas, payments increase to 1.5 and 0.75 million, respectively, and in the Far North and Far East they reach 2 and 1 million rubles, correspondingly.

Data from the Accounts Chamber show that in some regions "zemsky doctors" work only for a short time and then quit. This reduces the effectiveness of the program. The auditors recommended strengthening control over compliance with the terms of labor contracts by participating doctors.

Besides, regions often attract specialists to agriculture through their own programs. Thus, in the Krasnoyarsk Territory, young workers of agricultural complexes can receive a million rubles in two stages – 500 thousand immediately and another 500 in three years (Resolution of the Krasnoyarsk Territory Government No. 198-p).

Rural mortgage is aimed at receiving a preferential loan from 0.1% to 3% for the purchase or construction of housing worth up to 3 million rubles. The maximum loan amount is 6 million rubles for one borrower and 12 million for couples. The initial contribution is 20% of the cost of housing for one borrower and 40% for couples. According to the Ministry of Agriculture, 16 banks including Rosselkhozbank and Sberbank participated in the program at the end of 2023.

The program of allocation of land plots for specialists needed by the village. Teachers, doctors, veterinarians and other necessary personnel can receive land for free use, and after 5 years of work, register it as property. Requirements for the area and location of plots are established by local authorities.

Another housing program is the Family Farm. For example, in the Novosibirsk Region it involves the creation of farm businesses on the basis of preferential land plots. The participant must be a peasant or farm business with 2 or more family members. The number of cattle should not exceed 400 heads, goats/sheep not more than 500 heads of broodstock.

Transport and tax benefits. The benefits associated with owning transport and agriculture are also important. Thus, owners of cars registered in rural areas pay less for a CMTPL insurance policy due to a lower territory coefficient (TC). This is explained by lower traffic intensity in villages.

Besides, citizens who run private subsidiary farms are completely exempt from paying transport tax on agricultural machinery – tractors, combines, milk tankers, etc. To receive the benefit, you need to submit an application to the tax office and an extract from the household book about the farming of private subsidiary farms.

Subsidies are also provided for self-employed farmers, i.e. reimbursement of part of the costs of seeds, feed, veterinary services, etc. The amount of subsidy rates varies from region to region. For example, in the Tyumen region there is a subsidy of 2.15 rubles for each kilogram of milk sold and 3 000 rubles per ton of vegetables and potatoes sold. To receive it, you need to be registered as self-employed and pay self-employment tax.

Labor guarantees and benefits for housing and utilities services. In addition to financial support measures, other benefits are available in rural areas. For example, women working in villages are entitled to a 36-hour work week instead of 40 hours. For exceeding this norm, the employer is obliged to pay extra as overtime.

In addition, once a month, rural women workers can take an additional paid day off at their discretion (Article 262 of the Labor Code of the Russian Federation). It is enough to obtain it by oral or written request of a female employee.

Increased pensions for rural residents. Finally, for those who have worked in agriculture for a long time, a considerable supplementary pension is provided. Non-working pensioners with over 30 years of experience in agricultural production receive a monthly increase of 25% to the fixed insurance pension payment. In 2024 this amounts to 2033.72 rubles.

So, attracting qualified personnel to the region's agriculture is an urgent and main task for the near future. Employers play an important role in staff retention. First of all, they should be interested in retaining specialists, creating favorable conditions for their work and rest, and providing them with decent wages and comfortable housing. To attract highly qualified workers, the Department of agricultural, together with the personnel services of agricultural organizations, currently visit rural schools, hold career guidance meetings, talk about job prospects, and inform about the possibility of concluding contracts for targeted training [3].

The issue of increasing the legal literacy of rural residents is urgent. It is necessary to create educational projects, for example, "Farmer's School", where it will be possible to become acquainted with legal aspects of farming, to improve financial literacy, to create a business model for a future business, to learn the basics of marketing as well as to get acquainted with the latest agricultural technologies and crops.

All young specialists are provided with social benefits stipulated by legislation (incentive payments, housing in the first place). Creating decent working conditions is only part of the work being done. It is important to know in what conditions young professionals live, to help organize their leisure time, to show an active citizenship, and to attract them to a healthy lifestyle. Then a number of issues related to retention of human resources in rural areas and many others will be resolved more easily. These issues are closely monitored by the government agencies. Monitoring of compliance with legislation in relation to young professionals and workers is carried out regarding the provision of vacations, compliance with work and rest regimes, compensation. If the approach is right, rural businesses can successfully attract and hire the best specialists.

Many agro-industrial complexes pay for staff training at universities and colleges, as well as training on advanced training courses in the central regions of our country [4].

Within the framework of the national project "Science and Universities", scientific and educational centers with an agricultural profile are created as functional units to ensure the scientific and technological transfer of the results of intellectual activity, youth laboratories that are engaged in research in the field of agricultural sciences are formed. Thus, the Far East State Agrarian University and the agricultural enterprise Dimskoye are currently working on a project aimed at creating a new Amur cattle breed adapted to local conditions. North Caucasus Federal University is expanding scientific projects related to the agro-industrial complex. For example, these are "smart greenhouses" for growing vegetables using robots. Such robotic assistants can plant, care for plants, and deliver crops to the warehouse. A robotic tomato grower with a pattern recognition system has already been created. It is able to determine the maturity of tomatoes and the need for their timely harvesting. In one medium-sized greenhouse, from 30 to 60 mechanical agrobots can work. In addition, NCFU scientists also work on the creation of organic fertilizers from low-value agricultural waste in collaboration with colleagues from other countries – Turkey, Iran and Uzbekistan [5]. In the food industry, healthy food products enriched with micro- and macroelements are being developed. One of the largest projects is the joint implementation with the Stavropol milk-processing plant of the first lactose (milk sugar) technology in Russia. This project is being implemented to replace the import of functional dairy ingredients for the medical, children's and veterinary industries. Modern digital solutions allow to significantly increase the economic indicators of agricultural areas. For example, Earth remote sensing data from space had already been successfully applied to identify possible risks and forecast crops. Major Russian agro-industrial enterprises are actively using solutions based on Internet of Things (IoT) and big data technologies. They enable farmers to obtain real-time information on temperature, humidity, soil condition and soils from each individual plot of land.

It is necessary to further develop the educational process from a model that primarily implements an educational function to a model that implements educational, research and technological functions [6].

It is also important to consider subjective factors that may not have been considered by previous generations, such as the ability to maintain a work-life balance, access to arts, culture, social and recreational opportunities, and fostering a sense of belonging to a place. If a business is focused only on making as much money as possible, without paying attention to social issues and without solving the problems of the territory in which it operates, sooner or later people will start to leave this territory. Besides work, young people need comfortable housing conditions, which in rural areas should be the same as in the city. In addition, employees of agricultural enterprises should be provided with health resort treatment, which could be obtained at the expense of the employer.

However, this problem can be solved in different ways:

• organization of a leisure center;
• creation of youth clubs;
• opening of sports and art clubs.

The social sphere at any time is the most susceptible to changes in the economic situation in the country [6].

Our study focused on young people (136 people from the villages of Elkhotovo and Zamankul) aged 23 to 30 years. The survey was used to collect data for subsequent assessment of the factors that youth face when deciding to stay or leave a particular village.

Thus:

1) 42% of participants expressed their desire to stay in their villages
2) 58% of young respondents named “work” as the main reason that they are going to leave
3) 61% noted Moscow and Krasnodar when asked where exactly those young people intended to migrate
4) respondents indicated the following reasons why they do not leave: “there are opportunities for professional growth”, “family circumstances”, “like the village”

Our research also showed the following values that would attract young people to rural communities:

1. Stable employment,
2. Work-life balance,
3. Digital information on the availability of culture/sports and recreational opportunities.

Our study results support the literature by indicating that youth's sense of belonging and perceptions of their home community may play an important role in their decision to stay or return to rural areas. The importance of “birthplace” (small homeland) is crucial when developing strategies for retaining and attracting young people [7].

Agricultural regions often have a reputation for being isolated and behind the times. In fact, many rural areas are home to businesses that are at the forefront of innovation. However, these businesses often find it difficult to attract and retain talent. This is partly due to the perception that job opportunities are limited in rural areas.

Businesses in rural areas need to offer higher wages and benefits than their urban counterparts to attract and retain young employees. There are also fewer job opportunities in rural areas, so workers are more likely to leave a company if they don't feel they are being paid a decent salary. To compete for talent, businesses in rural areas must offer wages and benefits at least at the level of urban areas [8]. In today's economy, it is more important than ever that businesses provide opportunities for career growth and development. By doing so, rural businesses can gain a competitive advantage.

Finally, businesses in rural communities need to focus on creating a positive working environment. This can be achieved by making sure the physical working environment is clean and comfortable and the company culture is the one that values teamwork, respect and communication. By creating a positive working environment, businesses in rural communities can ensure that they are able to attract and retain young workers.

Today, rural regions offer a unique set of challenges and business opportunities. By creating an environment that meets employee needs, businesses can increase their chances for attracting and retaining top specialists [9].

Most studies have shown that employees who feel stuck in an unpromising job are much more likely to leave their current position. Moreover, employees who don't feel like they're learning and growing are more likely to become disengaged and unproductive. On the other hand, employees who feel they have opportunities for career growth and development are more likely to be loyal and productive. Therefore, businesses need to provide opportunities for career growth and development. By doing this, companies will be able to retain their best employees and attract new talent.

Nowadays, there are all prospects for rural areas to become modern, comfortable, economically developed and promising ones. These are villages where the population has a job with decent pay, a school and a kindergarten, housing, and where social, sports and cultural life is supported. It is a village you will never leave.

IV. Discussion

In modern Russia, the employment picture is rapidly changing (entrepreneurship, remote work, etc.) Combined with the abilities of the younger generation as a tech-savvy cohort concerned with work-life balance, it is rural areas that can meet the needs of these young professionals in creating dynamic, prosperous places for both work and life:

- Provide quality vocational education and training and practical skills. Access to the labor market should be ensured through advanced training of employees and managers in vocational training and advanced training centers in agriculture.
- Promote the introduction of learning concepts divided into modules, with a focus on learners, as well as improved teaching methods (such as hybrid or e-learning models) and the creation of enterprises in agriculture (so-called agricultural enterprise) [8].

Thus, the importance of the agricultural sector as a potential source of employment is emphasized and various initiatives and reforms are encouraged to address this problem. It is important to highlight the need for targeted measures such as skills development, vocational training and economic empowerment of youth, as well as measures to stimulate workplace creation and promote sustainable development. Finally, there is a need for a holistic approach to solving the problem of rural unemployment, which combines both federal and regional efforts to stimulate inclusive growth and improve the well-being of rural communities.

Breaking away from the traditional employee-employer relationship by expanding employment opportunities, where remote work, self-employment and participation in new employment sectors offer rural areas more opportunities to attract potential residents. The importance of highlighting the balance between quality of life and employment can expand opportunities for young people considering making rural communities their home for the long term [10].

However, public services, transport and information and communication capabilities are still underdeveloped in rural areas. Employment is a decisive factor for young people to move, but it is not enough to maintain sustainable development of the territories in the long term. While cities are becoming increasingly inaccessible due to the high cost of living, rural areas provide an opportunity to realize one`s own creative and business ideas.

References

[1] Decree of the Government of the Russian Federation dated May 31, 2019 No. 696 "On approval of the State program of the Russian Federation "Integrated development of rural areas" and on Amendments to Certain Acts of the Government of the Russian Federation" [Electronic resource] Access mode: https://www.garant.ru/news/1275631

[2] Federal target program "Sustainable development of rural areas" [Electronic resource] Access mode: http://fcp.economy.gov.ru/cgi-bin/cis/fcp.cgi/Fcp/ViewFcp/

[3] In the North Caucasus Federal District, the share of the rural population exceeded the national average. https://news.rambler.ru/sociology/51511780/?utm_content=news_media&utm_medium=read_more&utm_source=copylink

[4] Sulimin V.V., Lyashenko E.A., Shvedov V.V. Regulation and organizational and economic mechanisms in the formation of investment attractiveness in the development of the agro-industrial complex of Russia // Moscow Economic Journal. 2017. No. 3. – pp. 38-42.

[5] The state of rural employment and staffing [Electronic resource] Access mode: sostoyanie-selskoy-zanyatosti-i-kadrovoe-obespechenie-v-selskoy-mestnosti-na-osnove-regionalnoy-statistiki

[6] Tokaeva B.B., Tokaeva A.B. Problems of small business in modern Russia// Economics and management: problems, solutions. 2020. Vol. 1. No. 3. pp. 19-25.

[7] Guseva D.A., Chebykina M.V., Shatalova T.N. Development of the regional economy: a technological aspect/In the collection: Models, forms and methods of financial analytics in the modern geopolitical situation. collection of materials of the International scientific and practical conference. Samara, 2024. pp. 21-32.

[8] Popova M.K. Management of innovative entrepreneurship development in Russia//The scientific result. Business and service technologies. 2023. Vol. 9. No. 2. pp. 122-130.

[9] Pyankov N.V. The impact of innovative technologies on the development of the regional economy//Bulletin of Eurasian Science. 2023. vol. 15. No. S2.

[10] Boldyreva S.B., Chadlaeva N.E., Idzhilova D.V., Sanzyrov A.V., Gojaev V.A. Digital transformation in the public sector of the subjects of the southern regions of the Russian Federation in the field of personnel training and recruitment //Economics and entrepreneurship. 2023. No. 2 (151). pp. 336-341.

ENSURING THE ECONOMIC SECURITY OF THE ENTERPRISE IN A MARKET ECONOMY

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Abstract

The modern market environment is characterized by a high degree of uncertainty, fluctuations in supply and demand, as well as the influence of various external factors, such as inflation, currency fluctuations and legal changes. In these conditions, the enterprise must develop effective strategies to protect its financial, material and intellectual resources. In practice, economic security is implemented through a set of measures aimed at protecting capital, increasing the financial transparency and improvement of operational efficiency. A set of measures to ensure economic security allows you to minimize potential risks and strengthen the company's position in the market.

Keywords: economic security, enterprise security, financial security, market economy, risks, microeconomics

I. Introduction

The modern market economy is characterized by an unstable state, which is expressed in serious fluctuations in the exchange rate, economic growth, inflation and unemployment. This state of the economy can be caused by various factors, including global economic crises, political instability, conflicts, natural disasters, etc. This makes it difficult to develop business strategies, financial planning, and make long-term investment decisions.

The business climate is becoming less attractive to investors, which can lead to a slowdown in economic growth, increased unemployment and increased social tensions. Thus, global economic uncertainty has a serious impact on the stability of the social system and forces governments to develop measures to stimulate business processes, regulate inflation, reduce unemployment and improve the investment climate in the country.

One of the most important tasks of companies in an unstable market economy is to ensure their own economic security. Economic security of an enterprise is a complex concept that has both a substantive and functional interpretation. From a substantive point of view, economic security is characterized as the ability of a company to maintain its economic stability and profitability in the face of uncertainty and risk. From a functional point of view, economic security is a set of measures aimed at supporting the stable functioning of a company in conditions of economic instability and ensuring cost reduction, increased profitability and protection from external and internal threats [6].

II. Methods

Mechanisms for ensuring the economic security of an enterprise are a system of measures and tools aimed at protecting the enterprise from internal and external threats that can jeopardize its stable functioning and financial stability. These mechanisms play a key role in maintaining the competitiveness of economic entities in a dynamic market environment, they ensure the stability of income and profits, help to maintain investment attractiveness and a good reputation in the market.

The system of ensuring the economic security of an enterprise in a market economy is presented in Fig.1.

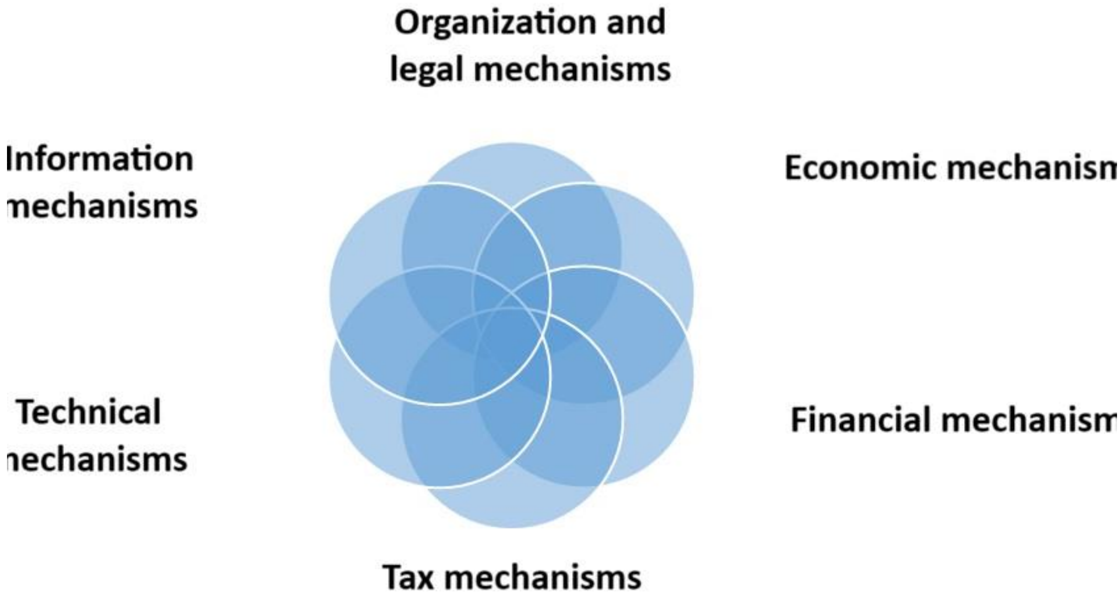

Figure 1: *Mechanisms for ensuring the economic security of the enterprise [6]*

Organizational and legal mechanisms for ensuring economic security are a set of measures aimed at creating a stable legal framework and management system that minimizes external and internal threats to the activities of the enterprise. The system of legal mechanisms for ensuring the economic security of an economic entity includes four levels:

- federal regulatory legal acts (the Constitution of the Russian Federation, the Civil Code of the Russian Federation, the Tax Code of the Russian Federation, the Labor Code of the Russian Federation, Federal Law No. 390-FZ of December 28, 2010 "On Security" and others);
- regional regulations (laws and regulations governing investment, tax and other aspects of the functioning of enterprises in the region);
- municipal regulatory legal acts (resolutions regulating the procedure for taxation by local taxes, the location of retail outlets and municipal support for small and medium-sized businesses);
- corporate regulatory legal acts (charter, internal regulations, staffing table, internal labor regulations, job descriptions, accounting policy, orders of the head, etc.).

Organizational mechanisms for ensuring the economic security of an economic entity can be differentiated by the frequency of their implementation into one-time, as well as implemented as necessary, periodically and systematically. An example of a one-time event is the development of the company's charter and other constituent documents that are formed at the stage of its foundation. Also, one-time mechanisms include the establishment of key internal procedures and regulations - anti-corruption policy, economic security policy, data privacy policy. Organizational measures for crisis management are implemented when the company faces financial difficulties or a sharp change in market conditions.

III. Results

Periodic organizational measures to ensure economic security include the distribution of encryption keys, tax audits, training of employees on security and compliance with corporate standards, revision and renewal of contracts with key partners to assess the relevance of the terms of cooperation. On an ongoing basis, companies monitor financial performance, assess business risks and control compliance with internal regulations for ensuring economic security.

An important aspect of ensuring economic security is the introduction of a corporate culture that contributes to the formation of a conscious attitude among employees to the issues of economic security. Supporting corporate values and stimulating responsible behavior of employees at all levels helps to strengthen loyalty and reduce the likelihood of information leakage, unauthorized actions and other internal violations.

Economic mechanisms for ensuring security make it possible to determine the strategic directions of the enterprise's development, as well as to form an effective system of financial, production and marketing management. They also allow to optimize production processes and reduce costs, which in turn increases the competitiveness of an economic entity in the market and ensures its security in an unstable economy [3]. Ensuring a stable position in the market requires the enterprise to constantly adapt to changing environmental conditions, primarily through the production of competitive products. The solution of this problem involves tracking consumer preferences, introducing innovative solutions, optimizing the use of material, human and financial resources.

Regular marketing research helps to reduce uncertainty in the process of making management decisions and allows you to determine the most promising directions for the development of the enterprise in a market economy. Reputation and brand management plays an important role in ensuring economic security, as a positive image of the company protects it from the negative influence of external factors. Consumer loyalty, formed through marketing activity and high product quality, reduces the sensitivity of the company to short-term economic shocks and helps to function stably in the market.

The lean manufacturing system includes three key subsystems, the interaction of which is based on the use of the tools of classical and flexible project management: "Management", "Production Organization" and "Continuous Learning". Each of the listed subsystems corresponds to a certain set of lean manufacturing methods. The most common lean manufacturing methods are Kaizen, 5S Technique, Rapid Equipment Changeover (SMED), TPM System, 5 Whys, Visualization, Fishbone Diagram, and many others. It should be noted that lean manufacturing methods demonstrate particular relevance when it is necessary to ensure business sustainability in the face of economic uncertainty. maintaining stability and improving the company's activities in conditions of economic uncertainty.

The introduction of automated control systems in production makes it possible to ensure the accuracy, flexibility and efficiency of production process management, minimize the impact of the human factor, and increase productivity and product quality. The listed optimization tools create a significant margin of safety for the enterprise, reducing its dependence on market fluctuations.

The key financial mechanism for ensuring the economic security of the enterprise is the formation of an effective financial management system, including budget planning, accounting and analysis of financial indicators, monitoring and control over the implementation of financial plans. The effectiveness of this mechanism is based on a comprehensive assessment of the current state and effectiveness of the company's activities using a variety of financial indicators - economic potential, profitability, liquidity, financial stability, profitability and business activity. The main source of information for the analysis of the financial and economic activities of the enterprise is the data of accounting (financial) statements, especially the balance sheet and the statement of financial results.

An integral structural component of financial planning is the formation of a financial strategy that allows the enterprise to ensure financial stability and efficiency.

The development and implementation of the financial strategy of the enterprise require an integrated approach and close integration with the overall development strategy of the organization. This allows you to effectively manage financial resources, reduce risks and ensure sustainable growth in a dynamically changing external environment.

Tax mechanisms for ensuring the economic security of an enterprise are a set of measures aimed at minimizing tax risks and ensuring compliance with tax legislation. Such mechanisms include, first of all, tax planning – the process of developing and implementing strategies to optimize the company's tax liabilities within the framework of the current legislation. and maximum use of tax benefits, deductions and other benefits provided for by law.

One of the most common tools for tax optimization is the use of tax benefits provided for by law. For example, from 2021 to 2023, the income tax rate for Russian IT companies was 3%, and in 2024 it was reduced to 0%. To receive this benefit, a company must be accredited by the Ministry of Digital Development of the Russian Federation, and income from the sale of IT products and services must be at least 90% of its total revenue. In many innovative industries, enterprises can use increased depreciation coefficients to reduce the amount of taxable profit.

The choice of the legal form of the company can significantly affect tax liabilities. For example, legal entities and individual entrepreneurs are taxed at different rates and methods, which allows you to choose the form depending on the volume and types of activity. In addition, holding structures allow you to distribute profits and losses between subsidiaries, which makes it possible to optimize tax payments in a group of companies. Many states offer special tax regimes for small and medium-sized businesses or certain sectors of the economy. For example, the simplified taxation system (STS) in Russia allows small businesses to pay a lower tax at a rate of 6% of income or 15% of the difference between income and expenses, while insurance premiums paid for employees are deducted from the tax amount. It also provides for a patent taxation system and a single agricultural tax, which significantly reduce the tax burden for the relevant types of activities.

IV. Discussion

As part of tax planning, companies can reinvest profits in business development, which allows them to reduce the tax base and postpone the payment of taxes to a later period. For example, profits can be used to finance new projects, modernize production facilities or expand the range of products. This tool reduces the amount of taxable profit and contributes to the growth of the company. Some companies use offshore jurisdictions or countries with low tax rates to register their subsidiaries or store assets.

The economic security of the enterprise also supports the use of measures to ensure the safety of property from man-made accidents, fires and intruders. Security and fire alarm systems ensure the safety of the enterprise, protecting it from unauthorized access and preventing damage from fires.

The company's security software includes a wide range of solutions aimed at protecting against cyber threats, data leaks and other risks that threaten information resources and business infrastructure (Fig. 2).

Antivirus software protects against viruses, malicious code, and spyware. Intrusion detection and prevention systems (IDS/IPS) provide network monitoring and detection of suspicious activity. Security information and event management (SIEM) systems aggregate and analyze security data from a variety of sources to help identify and respond to incidents in real time. Data protection tools (DLP systems) prevent unauthorized leakage and access to confidential information. Anti-spam and email protection programs fight phishing attacks, spam, and viruses that are distributed through email services.

Information mechanisms for ensuring the economic security of an enterprise are a set of measures and methods for the protection, processing and analysis of information aimed at preventing threats to economic stability and protecting confidential data of the company. Unlike technical mechanisms, information mechanisms are focused on the creation, processing and use of data that ensure the sustainable development of the company, prevent risks and increase the management efficiency.

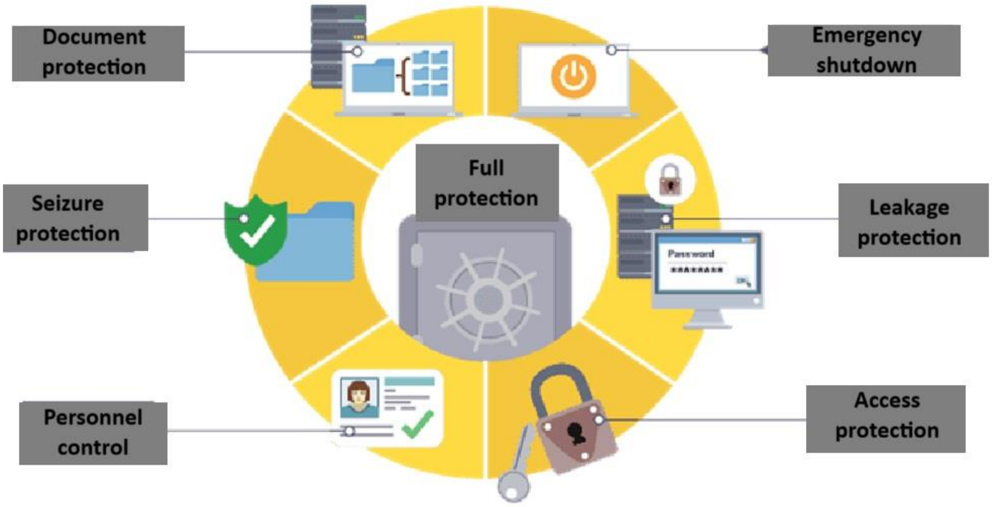

Figure 2: *Company security software*

Thus, the mechanism for ensuring the economic security of an enterprise is a set of organizational, economic, legal, technical and other measures aimed at reducing risks and ensuring the financial stability of the enterprise in conditions of uncertainty and competition in the market. It includes a comprehensive assessment of the economic situation, identification of threats and risks, analysis of the financial condition of the enterprise, management of financial flows, optimization of tax and personnel policies, control over resources and risks, as well as the development and implementation of a risk management strategy.

To implement the mechanism for ensuring the economic security of the enterprise, it is necessary to use modern methods of risk management, such as methods of modeling and analysis of financial flows, analysis of statistical data, as well as information and analytical systems. In addition, it is necessary to comply with legal and regulatory requirements, audit and control the financial activities of the company, as well as organize a system of training and advanced training of personnel.

In general, the mechanism for ensuring the economic security of a company is an important element of its long-term stability and success in the market. It allows you to prevent financial risks and ensure the competitiveness of business in an unstable economy.

References

[1] Blank I.A. Upravlenie finansovogo bezopasnosti predpriyatiya [Management of financial security of the enterprise]. – Kyiv: Elga, 2019. – 776 p.

[2] Lapaeva M.G., Lapaev S.P. Mirovozrencheskie i institutsional'nye osnovy rynoknogo ekonomiki [World Outlook and Institutional Foundations of Market Economy]. – Orenburg: OSU, 2022. – 111 p.

[3] Mirzoeva A.R. Strukturnye elementy sistemy ekonomicheskoy bezopasnosti predpriyatiya [Structural elements of the system of economic security of the enterprise] / A.R. Mirzoeva // In the collection: Development of modern agrarian science: actual issues, achievements and innovations.

Nalchik, 2024. Pp. 286-292.

[4] Sergeev, A. A. Economic security of the enterprise: a textbook and a workshop for universities / A. A. Sergeev. – 3rd ed. – Moscow : Yurayt Publishing House, 2024. – 275 p.

[5] Chkhutiashvili L.V., Chkhutiashvili N.V. Gosudarstvennoy rol' v usloviyakh rynoknogo ekonomiki [State role in the market economy] / L.V. Chkhutiashvili, N.V. Chkhutiashvili // Uchet i kontrol. – 2024. – № 7. – P. 84-88.

[6] Economic Security: A Textbook for Higher Educational Institutions / L. P. Goncharenko [i dr.] ; under the general editorship of L. P. Goncharenko. – 3rd ed., revised and supplemented – Moscow: Yurayt Publishing House, 2023. – 370 p.

ECOLOGICAL MINDSET IN EDUCATION: INTEGRATING SUSTAINABLE PRACTICES INTO EDUCATIONAL PROGRAMS

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Abstract

This paper delves into the critical role of ecological thinking in education and its potential to drive sustainable practices within educational programs. It begins by defining the concept of an ecological mindset, highlighting its significance in shaping a generation that is more aware of and responsive to environmental challenges. The paper discusses the theoretical foundations of ecological thinking, drawing from environmental psychology, sustainability studies, and educational theory to establish a comprehensive framework for integrating sustainability into educational curricula. Key strategies for embedding sustainable practices in educational programs are explored, including the use of interdisciplinary approaches that connect environmental issues with various subjects such as science, social studies, and the arts. The paper emphasizes the importance of experiential learning, where students engage in hands-on activities, community projects, and real-world problem-solving scenarios, fostering a deeper understanding of ecological principles. Through the examination of case studies from various educational institutions, the paper identifies best practices in implementing sustainability-focused curricula, showcasing successful initiatives and innovative teaching methods. Additionally, it addresses the challenges educators face in integrating ecological thinking into existing programs, such as curriculum constraints, lack of resources, and varying levels of institutional support.

Keywords: ecological mindset, education, sustainable practices, educational programs, interdisciplinary approaches, experiential learning, environmental awareness, curriculum development, sustainability education, best practices

I. Introduction

In recent decades, the urgency of addressing environmental challenges has escalated dramatically, driven by the alarming consequences of climate change, biodiversity loss, and resource depletion. As the world grapples with these pressing issues, the role of education in fostering an ecological mindset becomes increasingly critical. An ecological mindset encompasses a way of thinking that prioritizes sustainability, environmental stewardship, and an understanding of the interconnections within ecosystems. It empowers individuals to recognize their role in contributing to environmental health and encourages proactive engagement in sustainable practices.

Education serves as a powerful catalyst for instilling this mindset, shaping attitudes, values, and behaviors from an early age. By integrating sustainable practices into educational programs, institutions can equip students with the knowledge and skills necessary to navigate and address complex environmental challenges. This approach not only enhances students' understanding of ecological principles but also fosters a sense of responsibility and agency, motivating them to make informed choices that positively impact the environment.

Despite the growing recognition of the importance of ecological thinking in education, many educational institutions continue to prioritize traditional curricula that often overlook sustainability principles. This oversight limits the potential for students to engage meaningfully with environmental issues and undermines efforts to cultivate a generation of environmentally literate individuals. Therefore, it is imperative for educators and policymakers to actively seek ways to incorporate sustainability into educational frameworks.

This paper aims to explore the integration of ecological thinking into educational programs, examining effective strategies and best practices that facilitate this process. It will review theoretical perspectives on sustainability in education, highlight innovative pedagogical approaches, and present case studies that exemplify successful integration of ecological principles within curricula. By providing a comprehensive analysis of the current landscape of sustainability in education, this paper seeks to contribute to the ongoing discourse on fostering an ecological mindset among students and promoting sustainable practices within educational settings.

Ultimately, the goal is to inspire educators, administrators, and policymakers to recognize the transformative potential of ecological thinking in education and to take proactive steps towards embedding sustainability in their programs. As the world faces unprecedented environmental challenges, the need for a generation equipped with an ecological mindset has never been more urgent.

II. Methods

This study utilizes three primary methods to investigate the integration of ecological thinking and sustainable practices into educational programs: literature review, surveys, and case studies. Each method is detailed below with examples to illustrate its application.

1. Literature Review

The literature review serves as the foundational method for this study, providing a comprehensive analysis of existing research related to ecological thinking in education. This includes examining theoretical frameworks, pedagogical strategies, and empirical studies that highlight effective practices and challenges in sustainability education.

Example:

- The review may include key works such as “Education for Sustainable Development: A Guide for Educators” which outlines strategies for embedding sustainability in curricula and teaching practices.
- Additionally, studies documenting successful programs, like the Eco-Schools program, which integrates environmental education into schools globally, will be analyzed to extract best practices and lessons learned.

2. Surveys

Surveys are employed to collect quantitative data from educators across different educational levels. This method assesses the current state of ecological thinking in curricula and identifies barriers faced by educators in implementing sustainable practices.

Example:

- A survey could be distributed to teachers in primary, secondary, and higher education institutions, including questions such as:
  - o “How frequently do you incorporate sustainability topics into your lessons?” (Responses: Never, Occasionally, Often, Always)
  - o “What challenges do you face when trying to integrate ecological thinking into your curriculum?” (Response options might include lack of resources, insufficient training, or limited administrative support.)
- The collected data can then be analyzed statistically to reveal trends and correlations between educators' perceptions and the integration of sustainability practices.

3. Case Studies

Case studies provide in-depth qualitative insights into specific educational institutions that have successfully integrated ecological thinking into their programs. This method highlights innovative practices, strategies employed, and outcomes achieved.

Example:

- A case study might focus on a university that has implemented a Sustainability Studies program. This case would detail:
  - The curriculum changes made to include sustainability concepts across various disciplines (e.g., integrating environmental science into business courses).
  - Interviews with faculty and students about their experiences and perceptions regarding the program's impact on awareness and behavior related to sustainability.
  - Assessment of student projects that contribute to local environmental initiatives, demonstrating practical applications of ecological thinking.

Conclusion

These methods—literature review, surveys, and case studies—complement each other, providing a holistic view of the integration of ecological thinking in educational programs. By leveraging quantitative and qualitative data, the study aims to identify effective practices, barriers, and opportunities for fostering sustainability in education.

III. Results

Environmental education involves learning about the environment while gaining the knowledge, skills, values, and attitudes essential for understanding and tackling environmental challenges. It is vital for cultivating responsible and informed citizens capable of making sustainable decisions. With urgent environmental issues like climate change, pollution, and biodiversity loss becoming more prominent, the significance of environmental education is increasingly critical.

Strategies for Fostering a Sustainable Mindset

Integrating Environmental Education into the Curriculum

A highly effective approach to nurturing a sustainable mindset is the incorporation of environmental education into various subjects within the curriculum. This can encompass disciplines such as science, geography, social studies, and literature, covering topics like ecosystems, renewable energy, waste management, and conservation. By weaving environmental themes throughout the curriculum, students gain a well-rounded understanding of environmental issues and their potential solutions.

Hands-On Learning Experiences

Experiential learning serves as a potent method in environmental education. Engaging in hands-on activities such as field trips, nature walks, and outdoor classrooms allows students to make direct connections with their environment. These experiences may involve visits to nature reserves, botanical gardens, and sustainable farms. Through such hands-on learning, students can witness ecological processes firsthand, grasp the effects of human actions on the environment, and cultivate a deeper appreciation for nature.

Sustainable School Practices

Establishing sustainable practices within schools sets a strong example for students. Initiatives like recycling programs, energy conservation efforts, water-saving measures, and the use of eco-friendly materials contribute to this goal. Schools can also develop green spaces, such as gardens and outdoor learning areas, where students can interact with nature and learn about sustainable agriculture and biodiversity.

Project-Based Learning

Project-based learning (PBL) encourages students to explore real-world environmental issues and devise practical solutions. Projects might include developing a school recycling program or crafting a plan to reduce the institution's carbon footprint. PBL not only deepens students' understanding of environmental challenges but also hones their critical thinking, problem-solving, and collaborative skills.

Collaborations and Partnerships

Partnerships with environmental organizations, local communities, and government agencies can significantly enhance environmental education. Schools can collaborate with these entities to offer students expert knowledge, resources, and opportunities for community engagement. Such partnerships may also support involvement in environmental campaigns, clean-up initiatives, and conservation projects.

Incorporating Technology and Innovation

Technology plays a crucial role in environmental education. Digital tools and platforms can deliver interactive and engaging learning experiences. For instance, virtual simulations may illustrate the effects of climate change, while online resources provide current information on environmental issues. Furthermore, encouraging students to innovate and create eco-friendly technologies fosters a culture of sustainability and creativity.

IV. Discussion

One of the most impactful ways to cultivate a sustainable mindset is through the integration of environmental education across the curriculum. This can be applied in various subjects, including science, geography, social studies, and literature. Lessons can encompass themes such as ecosystems, renewable energy, waste management, and conservation. By weaving environmental topics into the educational framework, students can gain a holistic understanding of environmental challenges and potential solutions.

Experiential learning is an effective approach in environmental education. Engaging students in hands-on activities—like field trips, nature walks, and outdoor classrooms—enables them to connect with the environment in a tangible way. These experiences may include excursions to nature reserves, botanical gardens, and sustainable farms. Such immersive learning allows students to witness ecological processes directly, comprehend the effects of human activities on the environment, and develop a greater appreciation for nature.

Establishing sustainable practices within the school environment serves as a powerful model for students. This could involve initiatives such as recycling programs, energy-saving measures, water conservation strategies, and the use of eco-friendly materials. Additionally, schools can cultivate green spaces, like gardens and outdoor learning areas, where students can interact with nature and learn about sustainable agriculture and biodiversity.

Project-based learning (PBL) motivates students to explore real-world environmental issues and create practical solutions. Projects can vary from designing a recycling program for the school to developing a strategy for minimizing the school's carbon footprint. PBL not only deepens students' understanding of environmental matters but also enhances their critical thinking, problem-solving, and collaboration abilities.

Collaborating with environmental organizations, local communities, and government bodies can significantly enrich environmental education. Schools can work with these entities to provide students with expert insights, resources, and opportunities for community engagement. These partnerships can facilitate involvement in environmental campaigns, clean-up initiatives, and conservation projects.

Technology plays a crucial role in enhancing environmental education. Digital tools and platforms can offer interactive and engaging learning experiences. For instance, virtual simulations can illustrate the effects of climate change, while online resources can provide current information on environmental topics. Furthermore, encouraging students to innovate and develop eco-friendly technologies fosters a culture of sustainability and creativity.

Environmental education fosters awareness of environmental issues and their global implications. Students learn about the interconnectedness of natural systems and the effects of human actions on the environment. This awareness is crucial for cultivating a sustainable mindset and promoting responsible behavior.

Development of Critical Thinking Skills

Addressing environmental challenges requires critical thinking and problem-solving capabilities. Environmental education prompts students to analyze complex issues, consider diverse viewpoints, and formulate innovative solutions. These skills are essential not only for environmental stewardship but also across various life contexts.

Promotion of Sustainable Practices

By engaging with sustainability concepts, students are more inclined to adopt eco-friendly practices in their daily lives. This may involve reducing waste, conserving energy, choosing sustainable products, and supporting environmental initiatives. As students embrace sustainable habits, they can influence their families and communities, amplifying the positive effects.

Preparation for Future Careers

The increasing emphasis on sustainability is creating new career paths in areas like renewable energy, environmental science, and sustainable development. Environmental education equips students with the requisite knowledge and skills for these careers, fostering a passion for the environment that drives them toward professions that contribute to a sustainable future.

Improved Health and Well-Being

Engagement with nature has been linked to numerous health benefits, including reduced stress, enhanced mood, and improved cognitive function. Environmental education often incorporates outdoor activities, allowing students to reap these benefits. Additionally, learning about healthy eating and sustainable agriculture can promote better lifestyle choices.

Empowerment and Civic Engagement

Environmental education empowers students to take action on pressing environmental issues. By equipping them with knowledge and skills, it encourages active participation in their communities and advocacy for positive change. This civic engagement is vital for fostering collective efforts toward sustainability.

Incorporating environmental education into various aspects of learning is essential for developing a sustainable mindset among students. Through comprehensive curriculum integration, hands-on experiences, and sustainable school practices, we can prepare future generations to address environmental challenges effectively. By promoting awareness, critical thinking, and sustainable practices, we empower students to become engaged citizens committed to creating a more sustainable world.

Fostering a sustainable mindset through environmental education is essential for preparing students to address the environmental challenges of the future. As climate change, pollution, and biodiversity loss become increasingly pressing issues, it is crucial for educational institutions to equip students with the knowledge, skills, and values necessary to understand and tackle these challenges.

One of the foundational strategies for promoting a sustainable mindset is the integration of environmental education into various subjects. This approach ensures that students encounter environmental themes across the curriculum, allowing them to make connections between disciplines. For instance, science classes can explore ecosystems and renewable energy, while social studies can address the socio-economic implications of environmental degradation. Literature classes can analyze texts that reflect environmental themes, encouraging students to think critically about the narratives surrounding nature and sustainability. By embedding these topics into the curriculum, educators can help students develop a comprehensive understanding of environmental issues and their potential solutions.

Experiential learning is a powerful method for deepening students' engagement with environmental concepts. Hands-on activities such as field trips to nature reserves, community gardens, and sustainable farms allow students to connect with the environment in a meaningful way. For example, a class visit to a local wetland can provide firsthand experience of biodiversity and ecosystem dynamics. Nature walks can encourage observation and reflection on local flora and fauna, fostering a deeper appreciation for the natural world. Outdoor classrooms can serve as spaces for interactive learning, where students can participate in ecological monitoring, gardening, or conservation efforts. These experiences not only enhance knowledge but also cultivate a sense of responsibility toward the environment.

Schools can set powerful examples by implementing sustainable practices on their campuses. Initiatives such as recycling programs, energy conservation efforts, and the use of eco-friendly materials demonstrate the school's commitment to sustainability. Schools can create green spaces, including gardens and outdoor learning areas, where students can engage with nature and learn about sustainable agriculture and biodiversity. Moreover, schools can host workshops and events focused on sustainability, such as tree-planting days or clean-up drives. By fostering an environmentally friendly culture, schools encourage students to adopt sustainable habits that they can carry into their personal lives.

Technology plays a significant role in enhancing environmental education. Digital tools and platforms can facilitate interactive and engaging learning experiences. For example, virtual simulations can help students visualize the impacts of climate change on ecosystems, while online resources can provide current information on pressing environmental issues. Additionally, incorporating coding and robotics into environmental education can encourage students to design innovative solutions to sustainability challenges. By integrating technology into the learning process, educators can make environmental education more relevant and engaging for students.

Collaborating with environmental organizations, local communities, and government agencies can significantly enrich the environmental education experience. Schools can partner with these entities to provide students with expert insights, resources, and opportunities for community involvement. These partnerships can facilitate participation in environmental campaigns, clean-up initiatives, and conservation projects, allowing students to apply their learning in real-world contexts. For example, a partnership with a local conservation group might allow students to participate in habitat restoration efforts, reinforcing the importance of stewardship and active citizenship.

Project-based learning encourages students to engage with real-world environmental issues and develop practical solutions. Projects can range from designing a school recycling program to creating a plan for reducing the school's carbon footprint. PBL not only enhances students' understanding of environmental issues but also develops critical thinking, problem-solving, and collaboration skills. For instance, a project focused on reducing waste in the school cafeteria can involve students researching waste management strategies, conducting surveys, and presenting their findings to school administrators. This hands-on approach fosters a sense of ownership and accountability among students, motivating them to make a tangible difference.

Environmental education raises awareness about environmental issues and their global significance. Students learn about the interconnectedness of natural systems and the impact of human activities on the environment. This awareness serves as the foundation for cultivating a sustainable mindset and encourages responsible behavior.

Addressing environmental challenges requires critical thinking and problem-solving abilities. Environmental education encourages students to analyze complex problems, consider multiple perspectives, and develop innovative solutions. These skills are not only essential for environmental stewardship but also valuable in various life contexts.

By learning about sustainability, students are more likely to adopt eco-friendly practices in their daily lives. This can include reducing waste, conserving energy, using sustainable products, and supporting environmental initiatives. As students embrace these sustainable habits, they can influence their families and communities, amplifying the positive effects.

The increasing focus on sustainability is creating new career paths in fields such as renewable energy, environmental science, and sustainable development. Environmental education equips students with the necessary knowledge and skills for these careers while fostering a passion for the environment that drives them toward professions that contribute to a sustainable future.

Engaging with nature has been shown to provide numerous health benefits, including reduced stress, enhanced mood, and improved cognitive function. Environmental education often involves outdoor activities, allowing students to experience these benefits directly. Furthermore, learning about topics such as healthy eating and sustainable agriculture can promote healthier lifestyle choices.

Environmental education empowers students to take action on environmental issues. By equipping them with knowledge and skills, it encourages them to become active participants in their communities and advocates for positive change. This civic engagement is crucial for driving collective efforts toward sustainability.

At KR Mangalam School, one of the top IB schools in the NCR region, the implementation of a holistic approach to education serves as an exemplary model for fostering a sustainable mindset. The school integrates environmental education into its curriculum, offering students diverse opportunities to engage with environmental issues both inside and outside the classroom. Through hands-on learning experiences, sustainable practices, and community collaborations, KR Mangalam School cultivates environmentally responsible and informed citizens. By prioritizing sustainability in education, the school prepares its students to face future environmental challenges with knowledge, confidence, and commitment.

In conclusion, fostering a sustainable mindset through environmental education is crucial for empowering students to tackle future environmental challenges. By integrating environmental themes into the curriculum, providing hands-on learning experiences, and promoting sustainable practices within schools, educators can enhance students' understanding of environmental issues and encourage them to take action. With the support of innovative teaching methods and a commitment to sustainability, schools like KR Mangalam School are leading the way in shaping the next generation of environmentally conscious citizens.

References

[1] Mendoza, J.M.F. (2020). Self-perceived action competence for sustainability: the theoretical grounding and empirical validation of a novel research instrument. Environmental Education Research, 26(5), 742-760. https:// doi.org/10.1080/13504622.2020.1736991

[2] Mapar, M., Jafari, M. J., Mansouri, N., Arjmandi, R., Azizinezhad, R., & Ramos, T. B. (2020). A composite index for sustainability assessment of health, safety and environmental performance in municipalities of megacities. Sustainable Cities and Society, 60, 102164. http://doi.org/10.1016/j.scs.2020.102164

[3] Caeiro, S., Sandoval Hamón, L.A., Martins, R., Bayas Aldaz, C.E. (2020). Sustainability Assessment and Benchmarking in Higher Education Institutions: A Critical Reflection. Sustainability 2020, 12, 543.

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional

agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

DIGITAL SOLUTIONS IN CIRCULAR ECONOMY FRAMEWORKS

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Abstract

This paper provides a comprehensive examination of the role of digital solutions within the frameworks of the circular economy, focusing on their potential to enhance sustainability and resource efficiency across various sectors. As the world grapples with pressing environmental challenges—such as climate change, resource depletion, and waste management—the shift from a linear economy (take, make, dispose) to a circular economy (reduce, reuse, recycle) has become increasingly essential. Digital technologies play a critical role in this transition by facilitating innovative practices that can lead to a more sustainable and resilient economy.

The paper begins with an overview of the circular economy model, detailing its principles, objectives, and the significance of closing the loop in product lifecycles. This section highlights the differences between linear and circular approaches, illustrating the urgent need for systemic change in how resources are utilized and managed. The core of the paper delves into various digital technologies that underpin circular economy practices. Key technologies discussed include the Internet of Things (IoT), which enables real-time monitoring of resources and products, facilitating better inventory management, predictive maintenance, and efficient resource allocation, leading to reduced waste and improved operational efficiency. Blockchain technology provides transparency and traceability in supply chains, allowing businesses to verify the origin and lifecycle of materials, ensuring ethical sourcing and enhancing recycling processes while building consumer trust. Big data analytics plays a significant role by analyzing large datasets to gain insights into consumer behavior and resource usage patterns, crucial for designing products that meet sustainability criteria and for developing strategies to minimize waste. Additionally, artificial intelligence (AI) can optimize production processes and enhance decision-making by predicting demand, improving product design for longevity, and facilitating recycling processes through automated sorting and material recovery.

In summary, our study reinforces the notion that digital technologies are pivotal in enhancing resource efficiency and sustainability within the circular economy. By improving energy efficiency and reducing waste throughout the product lifecycle, these technologies not only contribute to environmental goals but also provide economic advantages. However, to fully realize the potential of digital solutions in CE frameworks, stakeholders must address the associated challenges, ensuring a collaborative and supportive environment for innovation and technology adoption. Ultimately, the integration of digital solutions into circular economy practices can drive meaningful change toward a more sustainable future.

Keywords: eco-friendly practices, innovation, environmental impact, smart technologies, economic opportunities

I. Introduction

The pressing challenges of the 21st century—ranging from climate change and resource scarcity to waste management—have underscored the urgent need for a fundamental transformation in how societies produce and consume goods. Traditional linear economic models, characterized by a "take, make, dispose" approach, are increasingly being recognized as unsustainable. In response, the concept of the circular economy has emerged as a viable alternative, advocating for practices that prioritize sustainability, resource efficiency, and waste reduction by promoting a closed-loop system where materials are reused, recycled, and regenerated.

Central to the successful implementation of circular economy principles is the integration of digital technologies. Innovations such as the Internet of Things (IoT), blockchain, big data analytics, and artificial intelligence (AI) are revolutionizing how businesses operate, providing new tools and methodologies to enhance sustainability throughout the supply chain and product lifecycle. These digital solutions not only optimize resource management and reduce environmental impact but also empower businesses to innovate and adapt to changing market demands.

This paper aims to explore the role of digital solutions within the frameworks of the circular economy. It will examine how these technologies facilitate more sustainable consumption and production practices, enhance transparency in supply chains, and support the transition toward a circular economic model. By showcasing successful case studies across various industries, the paper will illustrate the transformative potential of digital innovations in achieving circularity. Additionally, it will address the challenges and barriers to implementation, emphasizing the importance of policy support and collaboration among stakeholders.

In summary, the integration of digital solutions into circular economy frameworks represents a critical step toward achieving sustainable development and addressing the myriad environmental challenges facing our planet today. This exploration not only highlights the interconnectedness of technology and sustainability but also underscores the need for ongoing innovation and collaboration in the pursuit of a more resilient and sustainable future.

II. Methods

This paper employs three primary methods to examine the role of digital solutions in circular economy frameworks:

1. **Literature Review**: An extensive literature review was conducted to gather insights from existing research on the intersection of digital technologies and circular economy practices. Academic journals, industry reports, and relevant publications were analyzed to identify key themes, trends, and frameworks that highlight how digital solutions facilitate sustainable consumption and production.
2. **Case Study Analysis**: A selection of case studies from various industries was analyzed to showcase practical applications of digital technologies in promoting circular economy principles. Each case study examined the specific digital solutions implemented, the context in which they were applied, and the outcomes achieved, such as improved resource efficiency and reduced waste.
3. **Qualitative Interviews**: Qualitative interviews were conducted with industry experts and practitioners to gather firsthand insights into the implementation of digital solutions in circular economy practices. These interviews aimed to explore motivations for adopting digital technologies, challenges faced during implementation, and best practices that emerged from successful initiatives.

These methods collectively provide a comprehensive understanding of how digital solutions can enhance circular economy frameworks and contribute to sustainable development.

III. Results

After two rounds of coding, our study identified 13 digital functions from the existing literature that illustrate how digital technologies (DTs) can enhance circular economy (CE) performance, as shown in Table 4. This heatmap visually represents the most frequently discussed codes, with darker shades indicating stronger trends in the reviewed papers. We then classified the 13 digital functions into predefined categories.

From a technological standpoint, the Internet of Things (IoT) was frequently associated with functions like collecting and monitoring. This is because IoT connects wireless sensing devices, enabling effective data gathering and monitoring through internet connectivity. In contrast, big data analytics (BDA) showed an equal distribution of empirical and conceptual codes, while all other codes were weighted toward empirical evidence. Notably, in terms of implementation, artificial intelligence (AI) and general digital technologies exhibited nearly twice as many empirical codes compared to conceptual codes. The AI-related codes predominantly stemmed from papers published after 2020 and were primarily linked to generating insights through data analysis.

The most commonly discussed digital functions for enhancing circular economy practices were collection, monitoring, tracking and tracing, and optimization. Functions such as auto-planning, auto-control, and assessment were heavily grounded in empirical evidence, with auto-control displaying the highest concentration of empirical codes—16 compared to just three conceptual codes. Conversely, the functions of collect, monitor, and forecast had a similar number of empirical and conceptual codes.

Each digital function is discussed in detail below within the relevant categories. AI was predominantly applied in the data analysis category, leveraging its advanced data processing capabilities. BDA is effective in handling and analyzing vast and diverse volumes of data sourced from both the physical environment and human activities, especially at an accelerating pace (Gupta et al., 2019). Furthermore, AI facilitates a faster and more responsive learning process for data analysis based on extensive datasets (Kaplan & Haenlein, 2019; Kristoffersen et al., 2020). General digital technologies are linked with all digital functions due to their ability to integrate various technological capabilities. They showed a somewhat stronger correlation with two specific functions: sharing and auto-control, both of which necessitate the combined support of multiple digital technologies.

The differences between empirical and conceptual codes vary depending on the specific technology in question. For instance, IoT has an almost exclusive emphasis on empirical applications, reflecting its practical utility in real-world scenarios.

The analysis of the role of digital solutions in circular economy (CE) frameworks yielded several significant findings that illustrate the impact of various digital technologies on enhancing sustainability and resource efficiency. Through the literature review and coding process, 13 distinct digital functions were identified as critical in improving CE performance. These functions include collection, monitoring, tracking and tracing, optimization, auto-planning, auto-control, forecasting, data sharing, assessment, predictive maintenance, waste management, material recovery, and product lifecycle management.

The analysis revealed a notable distinction between empirical and conceptual codes associated with different digital functions. Functions such as auto-control, tracking and tracing, and optimization exhibited a significant concentration of empirical codes, indicating their strong grounding in real-world applications and effectiveness in enhancing CE practices. Conversely, functions like collection, monitoring, and forecasting showed a balance between empirical and conceptual codes, suggesting that while these functions are theoretically important, they are also increasingly supported by empirical evidence.

The results highlighted key insights into the technological aspects of digital solutions. IoT was consistently linked to data collection and monitoring functions, showcasing its critical role in enabling real-time tracking and improved decision-making. Artificial intelligence (AI) and big data analytics (BDA) were predominantly associated with data analysis functions, as their advanced capabilities allowed for handling vast datasets, leading to more informed insights and faster decision-making processes. General digital technologies displayed strong interlinkages with multiple functions, particularly in areas requiring integration across different systems, such as sharing and auto-control.

Several case studies were analyzed to illustrate the practical applications of these digital functions in various sectors. These case studies demonstrated how companies successfully implemented digital solutions to enhance their circular economy practices, achieving significant improvements in resource efficiency, waste reduction, and overall sustainability. The findings indicate that the integration of digital technologies within circular economy frameworks not only facilitates better resource management but also fosters innovation and collaboration among stakeholders, ultimately contributing to a more sustainable future.

IV. Discussion

The findings from our study illuminate the integral role that digital technologies (DTs) play in advancing the circular economy (CE) by enhancing energy and resource efficiency across the product lifecycle. The identification of reduction mechanisms as a central theme in the literature underscores the practicality and relevance of adopting digital solutions to achieve sustainable consumption and production.

Role of Digital Technologies

One of the most significant outcomes of this research is the emphasis on improving production and energy efficiency as a primary benefit of Industry 4.0. Enhanced process efficiency directly correlates with reduced waste in both materials and energy consumption. The digital functions identified—such as monitoring, optimization, and auto-control—are crucial in this regard. These functions allow for real-time adjustments and proactive management of resources, which are essential for minimizing waste generation.

The emphasis on logistics optimization further highlights how DTs can lead to sustainable practices. By collecting and sharing data regarding transportation logistics, companies can optimize routes and reduce fossil fuel consumption. This is particularly relevant in today's context, where supply chain efficiency is increasingly scrutinized in light of environmental impacts. The ability to leverage real-time data not only optimizes operations but also contributes to a significant reduction in the carbon footprint associated with transportation.

Short-Term vs. Long-Term Benefits

The study also distinguishes between short-term and long-term benefits of digital technologies in CE practices. In the short term, real-time monitoring facilitates quick and responsive equipment management, which is crucial for enhancing energy efficiency. Self-controlling robotics and automated systems can lead to immediate improvements in production processes by minimizing human errors, thus enhancing operational reliability.

In the medium to long term, the implementation of tracking and tracing technologies offers deeper insights into process efficiencies. This can result in more accurate analysis and planning, ultimately reducing waste from operational errors. The ability to analyze trends over time allows organizations to make informed decisions that lead to sustainable practices and resource conservation.

End-of-Life Efficiency

The end-of-life stage of products is another area where digital technologies show substantial promise. The integration of AI and control technologies into disassembly processes can enhance efficiency significantly. AI-driven insights enable better decision-making regarding disassembly levels and sorting waste materials, which are critical for effective recycling efforts. The capacity for automatic sorting not only increases recycling rates but also minimizes labor costs, illustrating a clear economic advantage alongside the environmental benefits.

Moreover, the ability of AI to facilitate connections between waste generators and collectors enhances waste recovery efficiency. This interconnectivity is essential in closing the loop of the circular economy, ensuring that materials are recovered and reused rather than discarded.

Challenges and Considerations

Despite the numerous benefits associated with integrating digital solutions into CE frameworks, challenges remain. The reliance on advanced technologies raises concerns about data privacy, security, and the need for robust infrastructure to support these digital solutions. Additionally, organizations must navigate the complexities of integrating new technologies into existing systems and processes, which can be resource-intensive and require substantial investment.

Furthermore, the varying levels of technological readiness across different industries and regions can create disparities in the adoption of these solutions. To address these challenges, it is crucial for stakeholders—including policymakers, businesses, and academic institutions—to foster an environment that supports innovation and collaboration. Creating regulations that encourage data sharing while ensuring privacy and security will be essential in driving the widespread adoption of digital technologies in circular economy practices.

In summary, our study reinforces the notion that digital technologies are pivotal in enhancing resource efficiency and sustainability within the circular economy. By improving energy efficiency and reducing waste throughout the product lifecycle, these technologies not only contribute to environmental goals but also provide economic advantages. However, to fully realize the potential of digital solutions in CE frameworks, stakeholders must address the associated challenges, ensuring a collaborative and supportive environment for innovation and technology adoption. Ultimately, the integration of digital solutions into circular economy practices can drive meaningful change toward a more sustainable future.

References

[1] Abdul-Hamid, A.-Q., Ali, M. H., Tseng, M.-L., Lan, S., & Kumar, M. (2020). Impeding challenges on industry 4.0 in circular economy: Palm oil industry in Malaysia. Computers & Operations Research, 123, 105052. https://doi.org/10.1016/j.cor.2020.105052

[2] Akkad, M. Z., & Bányai, T. (2021). In K. Jarmai & K. Voith (Eds.), Applying sustainable logistics in industry 4.0 era. Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-15- 9529-5_19.

[3] Aziz, N. A., Adnan, N. A. A., Wahab, D. A., & Azman, A. H. (2021). Component design optimisation based on artificial intelligence in support of additive manufacturing repair and restoration: Current status and future outlook for remanufacturing. Journal of Cleaner Production, 296, 126401

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V.

Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Ullah A, Pinglu C, Ullah S, Abbas HSM, Khan S. The Role of E-Governance in Combating COVID-19 and Promoting Sustainable Development: A Comparative Study of China and Pakistan. Chinese Political Science Review. 2021; 6:86–118.

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

TAX REGULATION AND THE TRANSITION TO A GREEN ECONOMY: INTEGRATING SUSTAINABLE DEVELOPMENT INTO FISCAL POLICY

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Abstract

This paper delves into the critical role that tax regulation plays in advancing the transition to a green economy by embedding sustainable development goals within fiscal policy frameworks. The research investigates various fiscal instruments, such as carbon taxes, environmental levies, tax incentives for renewable energy, and subsidies aimed at promoting eco-friendly technologies. These tools are examined in terms of their effectiveness in encouraging businesses and individuals to adopt sustainable practices, reduce carbon emissions, and decrease overall environmental degradation. The paper also highlights the challenges that arise when governments attempt to balance economic growth with the need to reduce environmental impact. It addresses the difficulties in aligning fiscal policies with both short-term economic objectives and long-term sustainability goals. Moreover, the study emphasizes the importance of international collaboration in ensuring that green tax regulations are coherent across borders and support global efforts to combat climate change. Through an analysis of successful case studies and emerging trends in green fiscal policy, the paper offers recommendations for improving tax systems to better facilitate the shift toward a low-carbon, resource-efficient economy. These include the need for more robust tax incentives for renewable energy investments, the gradual phasing out of environmentally harmful subsidies, and the implementation of tax schemes that can simultaneously stimulate green innovation and economic resilience.

Keywords: green economy, sustainable development, carbon tax, environmental subsidies, renewable energy incentives, eco-friendly practices

I. Introduction

The global transition to a green economy has emerged as one of the most pressing challenges of the 21st century, as nations seek to balance economic growth with environmental sustainability (fig.1). Climate change, resource depletion, and environmental degradation have underscored the urgent need for a shift toward more sustainable modes of production and consumption. Central to this transition is the role of fiscal policy, particularly tax regulation, which has the potential to influence economic behaviors, promote eco-friendly practices, and reduce the environmental impact of industries.

Tax policies designed to incentivize sustainable development can be powerful tools for driving the green economy. By incorporating environmental objectives into fiscal frameworks, governments can encourage businesses to reduce carbon emissions, invest in renewable energy, and adopt cleaner technologies. Instruments such as carbon taxes, tax breaks for renewable energy investments, and subsidies for green innovation not only promote environmental goals but also create opportunities for economic growth in emerging sectors.

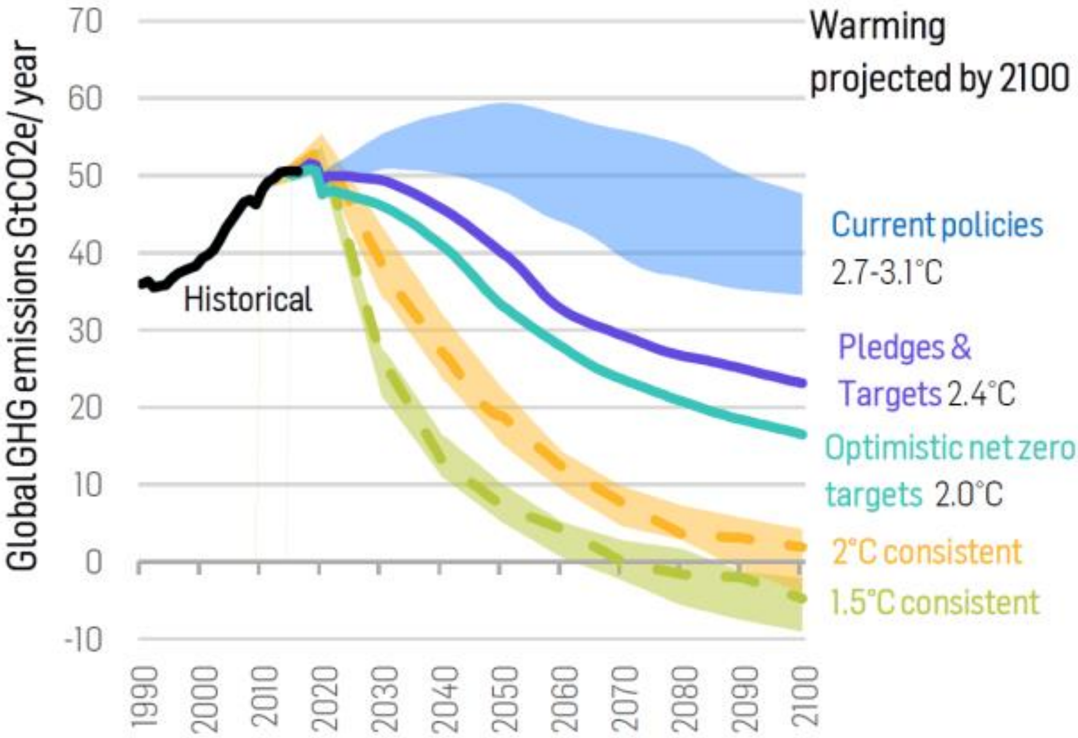

Figure 1: *Emissions and expected warming based on pledges and current policies*

The uncertainty surrounding future regulatory changes and the risks associated with climate change pose significant challenges for investors. These challenges can be broadly categorized into two main risk groups.

First, there are physical climate risks that directly affect the financial system. As climate change leads to more frequent and severe natural disasters, the realization of these physical risks can result in substantial financial losses. For instance, extreme weather events can damage assets, disrupt supply chains, and lead to increased insurance claims, impacting the financial sector directly.

Second, transition risks refer to potential financial losses or economic disruptions linked to the shift towards a low-carbon economy and the corresponding tightening of policies. These risks may affect the financial sector indirectly, manifesting through fluctuations in asset and collateral values or rising operational costs. Transition risks can arise from changes in consumer preferences, technological advancements, or stricter regulatory requirements aimed at reducing carbon emissions.

It's important to note that physical risks and transition risks can interact with each other. For example, failing to implement effective policies for transitioning to a low-carbon economy could exacerbate physical risks over time, as the effects of climate change intensify. Conversely, aggressive regulatory measures that accelerate the transition may incur short-term economic costs but could ultimately decrease the likelihood of experiencing severe physical risks in the future. This interplay underscores the complexity of climate-related risks and the need for investors to consider both types of risks in their decision-making processes.

However, implementing green tax regulations poses significant challenges. Governments must strike a delicate balance between fostering economic growth and addressing environmental concerns. In addition, tax systems need to be designed in a way that ensures fairness and does not disproportionately burden certain sectors or populations. The complexity of integrating sustainable development into fiscal policy also requires international coordination, as inconsistent policies across borders can undermine global efforts to mitigate climate change.

This paper explores the intersection of tax regulation and the green economy, examining how sustainable development can be integrated into fiscal policies to support a low-carbon, resource-efficient future. It analyzes the effectiveness of various green fiscal measures, the obstacles to their implementation, and the potential for international cooperation in achieving a sustainable economic transformation. By addressing these issues, the study aims to provide insights into how tax regulation can be leveraged to accelerate the transition to a greener economy.

II. Methods

This study utilizes three specific methods to analyze the integration of sustainable development into tax regulation and its role in transitioning to a green economy:

1. Comparative Policy Analysis:

The study compares the tax policies of three countries that have implemented significant green fiscal measures: Sweden, Germany, and South Korea. By analyzing the structure, implementation, and outcomes of their carbon tax systems, renewable energy tax incentives, and environmental subsidies, the study identifies effective strategies and challenges associated with these policies. This comparative approach helps to highlight best practices and lessons learned from diverse economic and regulatory environments.

2. Case Study of Carbon Tax in Sweden:

A detailed case study of Sweden's carbon tax policy was conducted to examine how a well-designed tax regulation can drive substantial reductions in greenhouse gas emissions. The study investigates the policy's design, including tax rates, coverage across sectors, and mechanisms for revenue recycling. The economic and environmental outcomes of the policy, such as its impact on emissions reduction and renewable energy adoption, are also evaluated using available data from government reports and environmental agencies.

3. Expert Interviews:

Structured interviews were conducted with tax policy experts, environmental economists, and government officials involved in the design and implementation of green tax regulations. The interviews focused on practical challenges in implementing green fiscal policies, the political and economic trade-offs, and future opportunities for integrating sustainability into national and international tax frameworks. These expert insights provide a deeper understanding of the real-world complexities of transitioning to a green economy through fiscal policy.

III. Results

In the era of transformative economics, the global shift toward green, low-carbon, and circular development is rapidly gaining momentum, establishing itself as a key trajectory for future economic growth. This paradigm shift not only reshapes environmental management strategies but also catalyzes the evolution of green tax systems. Green taxation, which targets polluters, aims to internalize external environmental costs, correct inefficiencies in market resource allocation, and enhance overall economic efficiency.

Despite the acknowledged importance of green taxation, theoretical research on its potential adverse effects on regional green development and innovation remains limited. Existing studies primarily concentrate on its macroeconomic impact and environmental benefits, leaving gaps in understanding the specific mechanisms through which green taxation influences regional innovation, particularly in terms of corporate resource allocation and the crowding out of limited financial and material assets.

This gap in theoretical research hampers a comprehensive evaluation of green taxation, affecting the efficiency and design of related policies. According to the Resource-Based View (RBV), the reallocation of resources toward green initiatives may reduce a firm’s ability to innovate and compete in non-green sectors. Furthermore, the innovation system perspective suggests that while green taxation can incentivize green technological advancements, it may divert resources from other innovation areas, thereby diminishing overall innovation capacity. The technological lock-in theory further posits that once certain technologies are adopted, economies of scale and learning effects make it difficult for systems to pivot away from established paths.

This study investigates the potentially negative effects of green taxation on regional green development and innovation. By analyzing how green taxation influences corporate behavior related to green innovation, the research introduces the novel idea that such taxes may inadvertently weaken a region's broader innovation capabilities. Through a unique heterogeneity analysis, the study examines the impact of green taxation on regions with varying innovation capacities, exploring how resource imbalances may lead to declines in overall innovation potential. This approach fills a critical theoretical void in the current literature and provides practical insights for policymakers aiming to refine green taxation to support high-quality green economic development.

Impact on Green Development and Green Innovation:

Green taxation, as a strategic policy instrument, plays a crucial role in advancing sustainable practices. By providing tax reductions on environmental equipment and eco-friendly technologies, green taxation incentivizes businesses to invest in and adopt clean and resource-efficient technologies. This approach helps lower resource consumption and environmental pollution, leading to significant improvements in regional green development. Moreover, green tax policies encourage companies to implement energy-saving and emission-reduction measures, which not only improve energy efficiency but also reduce emissions during the production process, ultimately enhancing productivity.

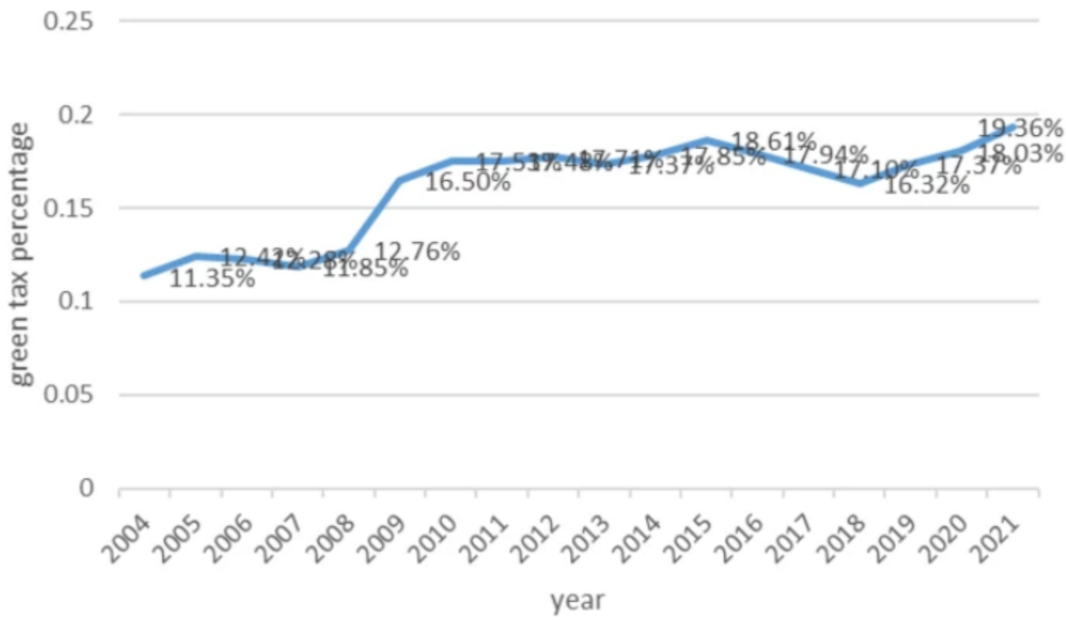

Figure 2: *National green tax intensity over time*

Broad green taxes, in contrast, take a more holistic approach by considering the synergistic development of ecological and economic systems. These taxes aim to regulate not only post-event outcomes but also provide preemptive guidance and control, as highlighted by the OECD (2010). Broad green taxes encompass a variety of fiscal measures, including environmental protection taxes, pollution fees, and specific environmental provisions found within various tax categories.

Due to difficulties in obtaining data related to tax incentives for environmental protection and energy conservation in value-added tax and corporate income tax, this study adopts a composite measure for broad green taxes. Specifically, broad green taxation is defined as the ratio of the total amount from environmental protection tax, domestic consumption tax, resource tax, urban maintenance and construction tax, farmland occupation tax, and vehicle and vessel tax to the total regional tax revenue.

This methodology enables a nuanced and comprehensive assessment of both narrow and broad green tax policies and their impact on regional green development and innovation capacity. The findings of this analysis are visually represented in Fig. 2, which illustrates a timeline of national green tax intensity, showcasing the evolution and implementation of these policies over time.

At the same time, imposing higher taxes on polluting activities pushes businesses to increase investments in environmental research and development (R&D). This shift drives innovation in green technologies and accelerates the transformation of traditional industries toward more sustainable practices. As a result, green taxation plays a key role in fostering the development and growth of green industries.

However, the positive effects of green taxation on innovation and development are not immediate. The adoption and implementation of new green technologies often take time, and there may be a delay in seeing the full impact of such innovations on regional green growth. Additionally, the introduction of green taxes can raise operational costs for businesses in the short term, which could slow down their ability to innovate and implement sustainable practices.

Given these dynamics, the following hypotheses are proposed:

- Hypothesis 1: Green taxation positively impacts regional green development by reducing resource consumption and pollution while improving energy efficiency.
- Hypothesis 2: Green taxation promotes green innovation by encouraging enterprises to invest in environmental R&D and adopt cleaner technologies.
- Hypothesis 3: The positive impact of green taxation on regional green development and innovation may exhibit a lagging effect due to the time required for technology adoption and the potential increase in operational costs.

IV. Discussion

The introduction of green tax policies, while increasing business costs, simultaneously incentivizes firms to invest in green technologies due to the tax benefits and reductions offered. This shift, however, may result in a reallocation of limited corporate resources, potentially reducing investment in research and development (R&D) and innovation in other critical areas. According to the Resource-Based View (RBV), a firm’s competitive advantage and innovation capacity stem from its unique resources and capabilities. Green taxation directs firms to focus their finite resources on green technologies in pursuit of tax incentives, which might undermine R&D efforts in non-green sectors, affecting their competitiveness and overall innovative potential.

Innovation system theory underscores that innovation is a collective process involving multiple stakeholders, such as enterprises, governments, and research institutions. Through interactions among these actors, new knowledge is generated and applied. Green taxation, by reshaping resource allocation and incentives, can enhance innovation in green technologies but may inadvertently divert resources from other areas of innovation (fig.3). This shift could dampen the region's overall innovation capacity, as resources become concentrated on green initiatives at the expense of broader technological progress.

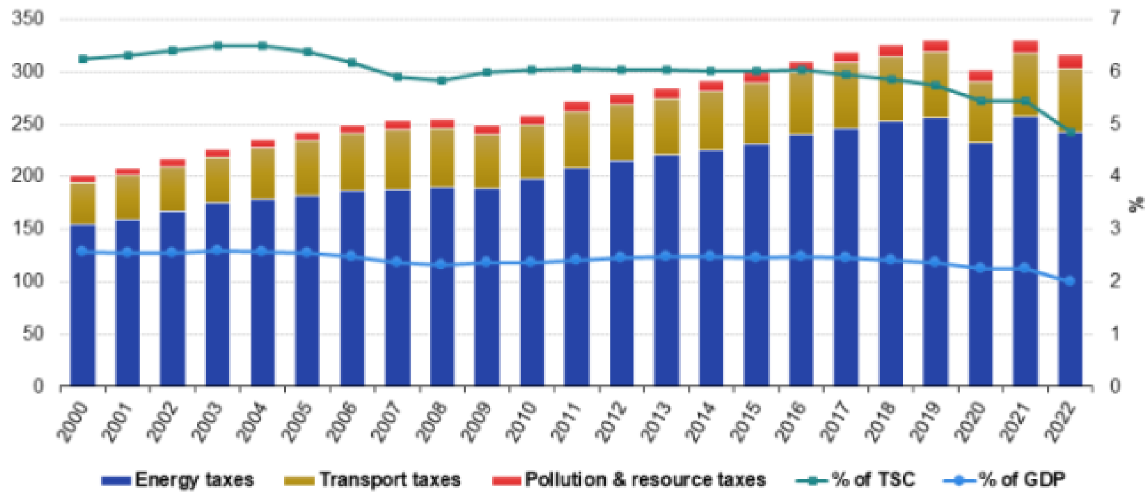

Figure 3: *Environmental tax revenue by type and total environmental taxes as share of TSC (total government revenue from taxes and social contributions) and GDP, EU, 2002-2022 (€ billion, %)*

Additionally, technological lock-in and path dependency theories suggest that once a specific technological trajectory is adopted, systems tend to become entrenched in that path due to factors like economies of scale, synergistic effects, and learning advantages. As a result, green taxation might lead businesses and regions to become overly reliant on established green technologies, limiting exploration of alternative or disruptive innovations. This dependence could hinder long-term innovation growth and adaptability to new technological paradigms.

In light of these dynamics, the following hypotheses are proposed:

- Hypothesis H3: Green taxation exerts an inhibitory influence on regional comprehensive innovation capacity, as it diverts resources from broader R&D efforts to green technology investments.

- Hypothesis H4: While advancing regional green development and reallocating corporate resources towards green technologies, green taxation impedes the enhancement of regional innovation capacity by limiting investment in non-green sectors and fostering technological lock-in.

Measurement of Green Taxation:

In this study, green taxation is categorized into two distinct types: narrow green taxes and broad green taxes.

1. Narrow Green Taxes: These taxes specifically target pollutant emissions and are designed to promote environmental protection and sustainable development. Narrow green taxes, such as environmental protection taxes, mark the shift from pollution fees to a formal taxation structure. Prior to the introduction of environmental protection taxes, pollution fees were used as a temporary solution.

2. Broad Green Taxes: These taxes encompass a more holistic approach, focusing on the integrated development of ecological and economic systems. Broad green taxes cover both post-event regulatory actions and proactive guidance for environmental management (OECD, 2010). This category includes a wide range of fiscal measures, such as environmental protection taxes, pollution fees, and specific environmental provisions within tax categories like value-added tax and corporate income tax.

Given the challenge of obtaining detailed data on tax incentives for environmental protection within broader tax categories, this study employs a composite measure for broad green taxation. Broad green taxation is defined as the proportion of total environmental protection tax, domestic consumption tax, resource tax, urban maintenance and construction tax, farmland occupation tax, and vehicle and vessel tax relative to total regional tax revenue. This composite measure allows for a comprehensive evaluation of both narrow and broad green tax policies' effects on regional green development and innovation capacity.

Most existing research primarily focuses on the economic effects of green taxation on enterprises, with comparatively less attention given to its implications for innovation capacity. The findings of this study align with prior research, indicating that green taxation can serve as a catalyst for green development and innovation. However, both narrow and broad green taxation have been shown to negatively impact the overall innovation capacity of enterprises. This result contrasts with some literature that suggests a positive influence on innovation, implying that green taxation may initially impose a burden on corporate innovation due to resource redistribution and resulting imbalances. The long-term effects of this taxation warrant further investigation.

Additionally, this research reveals significant regional disparities in the impact of green taxation on green development and innovation—an aspect that has not been sufficiently addressed in previous studies. Specifically, the study demonstrates a positive effect in Eastern regions, while the impact is either negligible or negative in Central and Western regions. This variation can be linked to differences in regional economic development, industrial structures, and innovation capacities, underscoring the necessity for region-specific green tax policies.

A key contribution of this study is the identification of a nonlinear relationship between green taxation and both green innovation and development. This insight challenges the linear assumptions present in some existing literature, suggesting that the effects of green taxation may vary with different tax levels. Future research should explore the optimal tax level that balances the promotion of green innovation against the potential negative impacts on corporate innovation capacity.

Ultimately, the study enhances traditional heterogeneity analysis by examining regions with varying innovation capabilities. The results emphasize the differing effects of green taxation across areas with different levels of corporate innovation. In regions with high corporate innovation capacity, narrow green taxation shows a delayed effect in fostering green development, potentially because enterprises need time to adjust their innovation strategies to new tax policies. Conversely, in regions with lower innovation capacities, narrow green taxation encourages a quicker adoption of green practices, suggesting that modest incentives may be sufficient to spur action among businesses in these areas.

This differentiation in impact highlights the importance of regional innovation capacities in policy-making. Identical policies may require tailored approaches across different regions. Notably, broad green taxation has not demonstrated significant positive effects on green development and innovation in either region type, indicating the need for a more nuanced approach in designing green taxation to effectively promote green innovation and sustainable development.

References

[1] Wang Y, Yu L (2021) Can the current environmental tax rate promote green technology innovation? - Evidence from China's resource-based industries. J Clean Prod 278:123443

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved

October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Ullah A, Pinglu C, Ullah S, Abbas HSM, Khan S. The Role of E-Governance in Combating COVID-19 and Promoting Sustainable Development: A Comparative Study of China and Pakistan. Chinese Political Science Review. 2021; 6:86–118.

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

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THE ROLE OF FORESTS IN THE CARBON CYCLE: MECHANISMS OF CARBON ABSORPTION AND STORAGE

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Abstract

Forests play a key role in the carbon cycle, acting as major carbon sinks and important carbon stores on Earth. This article examines how forest ecosystems perform photosynthesis, the process by which they capture carbon from the atmosphere and convert it into organic matter. Particular attention is paid to the various mechanisms of carbon assimilation, such as the transformation of carbon into biomass, roots and soil, as well as its long-term storage. One of the main factors influencing the efficiency of carbon absorption is the forest type. For example, tropical forests, due to their high biomass and species diversity, absorb significantly more carbon compared to temperate and boreal forests. The influence of climatic conditions, such as temperature and rainfall, on the process of photosynthesis and tree growth is also considered. Forest age also plays an important role: young forests accumulate carbon faster, while old forests can reach a state where carbon accumulation slows down. The article also highlights the importance of preserving and restoring forest ecosystems as a strategic approach to combating climate change. Increasing forest area and implementing sustainable forest management practices can significantly increase their capacity to absorb carbon, as well as improve other ecosystem services such as maintaining biodiversity and protecting soil from erosion. Importantly, forest destruction caused by logging and land tenure change releases significant amounts of carbon into the atmosphere, exacerbating the problem of climate change.

Keywords: forests, carbon cycle, carbon sequestration, carbon storage, climate change, ecosystem services, photosynthesis, sustainable forest management, forest restoration

I. Introduction

Despite the growing trend towards fragmentation of the global economy, the loss of influence of various international organizations and the weakening of previously concluded agreements, the idea of preventing catastrophic climate change, first enshrined in the UN Framework Convention on Climate Change (UNFCCC) in 1992, continues to be relevant and receives support from all countries of the world. Russia, although reducing its participation in various interstate initiatives in recent years, nevertheless emphasizes its commitment to decarbonization of the economy. The Low Carbon Development Strategy (LCDS) [1], adopted in October 2021, sets the goal of achieving carbon neutrality of the national economy by 2060. In accordance with this strategy, the transition to carbon neutrality is planned to begin only after 2030 (Fig. 1). An important role in this process is given not to measures in the energy sector, which might be expected, but to a more than twofold increase in carbon absorption by the country's forests in the area of land use, land-use change and forestry (LULUCF). This strategy, according to a number of forestry experts [2, 3], is based on rather unreliable foundations and is therefore considered risky.

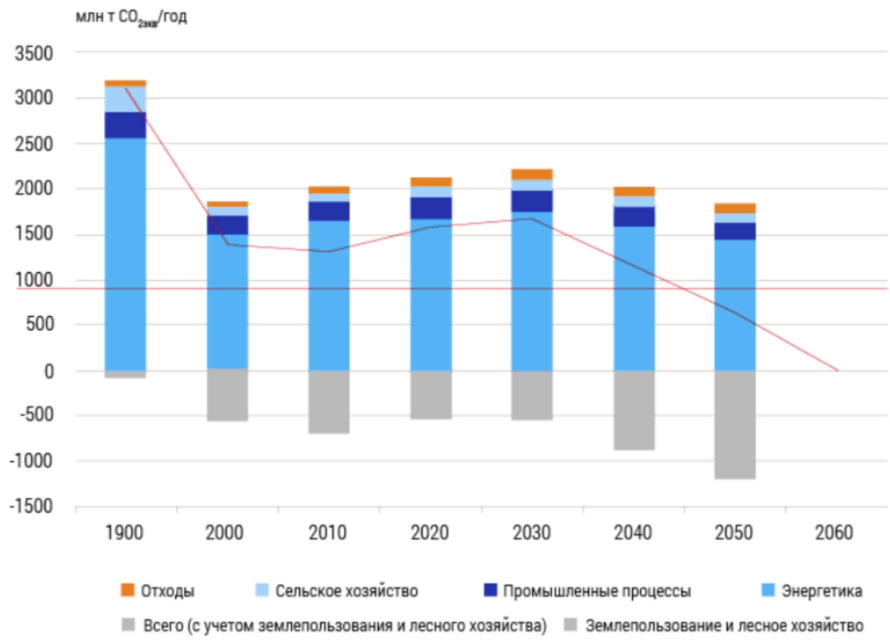

Figure 1: *Target scenario of the Low Carbon Development Strategy*

II. Methods

Low Carbon Development Strategy (LCDS) and its presentation at the UNFCCC Conference of the Parties in Glasgow in 2021 generated a great deal of interest and a number of publications devoted to various aspects of decarbonization of the Russian economy [4–11]. This work aims to assess the feasibility of achieving this goal, taking into account global historical experience, and to identify possible ways to solve this problem.

Over the past thirty years, two main periods have been distinguished in the dynamics of greenhouse gas (GHG) emissions in Russia: a sharp decline in the 1990s and a gradual increase in 2000–2020 (Fig. 1). The minimum net emission (taking into account the absorption of carbon dioxide by biota) was recorded in 2010, which is associated with an increase in the absorption capacity of forests due to a reduction in the volume of timber harvesting and the overgrowing of abandoned agricultural lands.

While the drop in emissions in 1990–2000 affected virtually all sectors of the national economy and affected emissions of all greenhouse gases (including carbon dioxide, methane, nitrous oxide, chlorofluorocarbons , and others), the subsequent partial recovery in emission volumes occurred primarily in the energy sector and, to a lesser extent, in industrial processes, where carbon dioxide emissions also increased (Fig. 1). A significant risk to Russia's long-term economic interests is the misconception that increasing the role of forests and properly accounting for this role can solve the practical tasks of the Paris Agreement and the Low Carbon Development Strategy (LCDS) to reduce greenhouse gas emissions without systematic actions to green the economy as a whole, especially in the energy sector. The temptation to rely on such a solution to the problem is great and is due to obvious geographic factors. According to the World Bank, about 20% of the world's forest cover is in Russia. These forests have the potential to become one of the key environmental donors in terms of greenhouse gas absorption and play a leading role in the formation of the carbon balance. Therefore, from the point of view of carbon regulation at the national level within the framework of the Paris Agreement and the goals outlined in the LULUCF [1], it is extremely important to correctly assess the net sink of the land-use change and forestry (LULUCF) sector in Russia and its dynamics in the coming decades. It should be emphasized that estimates of the current carbon balance in Russian forests and its dynamics in the coming decades vary significantly [2–3, 8-11]. Differences in estimates of even the current net flow, conducted by various institutions, can reach fourfold. There are diametrically opposed opinions on further changes in the net sink: from its dramatic reduction by more than five times [3] to a twofold increase by the middle of the century, which is directly reflected in the LULUCF concept [1]. For example, recent research by the World Resources Institute shows that between 2001 and 2019, net carbon sinks in Russia's forests averaged 1.79 billion tonnes of CO_2- eq per year, equivalent to 24% of the world's total forest sinks. These results are also consistent with Boston estimates. Consulting Group (BCG) [15], which record annual absorption by Russian forests in the range of 1.8 to 2.2 billion tons of CO_2- eq ., as well as data from Global Forest Watch , indicating similar removal values of 1.74 billion tonnes of CO_2- eq over the period 2001–2021.

From the point of view of Russia's official reporting under the United Nations Framework Convention on Climate Change (UNFCCC), according to the National Inventory Report of Anthropogenic Emissions by Sources and Removals by Sinks of GHGs [12], in 2021 the greenhouse gas balance in the land-use change and forestry (LULUCF) sector updated the minimum since 2000 and amounted to 484.8 million tons of CO_2-eq . per year, which is equivalent to a 13% decrease in net sink compared to previous estimates submitted to the UNFCCC. It is necessary to note not just an unprecedented decrease in absorption for lands classified as hayfields and pastures, for which the average absorption over a five-year period (2016–2020) was 44.5 million tons of CO_2- eq . per year, but a complete absence of runoff for this land category in 2021 and a total emission of 3.8 million tons of CO_2- eq . For forest lands, there is also a decrease in net runoff, but less significant on a category scale - by 3.8% compared to 2020, namely by 23.5 million tonnes of CO_2- eq , which may be associated with record forest fires in 2021 (Figure 2).

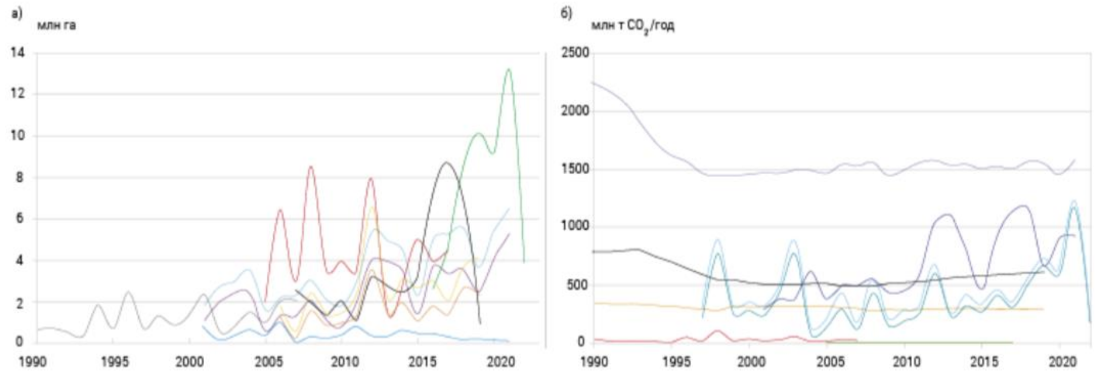

Figure 2: *Forest areas burned and forest loss from fires (a) and carbon dioxide emissions from forest loss compared to emissions from fuel combustion (b) in Russia*

The traditional methodology for assessing national anthropogenic greenhouse gas removals in the land-use change and forestry (LULUCF) sector is the guidelines for national greenhouse gas inventories developed by the Intergovernmental Panel on Climate Change (IPCC) [2] and their supplements [3]. The list of carbon pools and land-use categories remains classical and, without undergoing significant changes, is used by all researchers to assess the carbon budget.

Methods for estimating both removals and emissions of CO_2 equivalent are based on two main approaches. The first, the biomass gain and loss method, involves determining the annual change in carbon stock as the difference between annual carbon gains and losses in tonnes, and is a function of carbon changes and losses. The second approach, the stock difference method, is considered preferable due to its high accuracy and reliability, as it is characterized by the difference in carbon stocks in reservoirs at two specific points in time. However, regardless of the approach chosen, one of the main difficulties remains the identification of the age, stock, and species composition of forest areas, which are used as the main sources of data for the calculations.

In Russia, the official methodology approved by the Ministry of Natural Resources is the methodology of regional assessment of forest carbon budget (ROBUL), developed by the Institute of Global Climate and Ecology (IGCE) named after Academician Yu. A. Izrael and the Center for Forest Ecology and Productivity (CEPL) of the Russian Academy of Sciences (RAS) [5]. This methodology was verified within the framework of the UNFCCC and is intended to provide a unified approach to assessing the carbon budget in Russian forests.

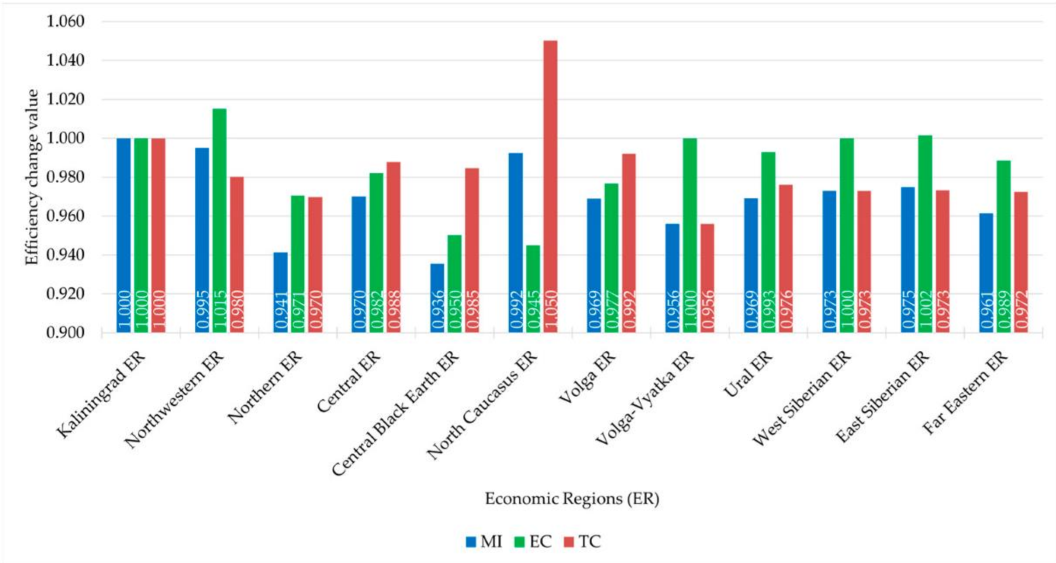

Figure 3: *Average total factor productivity and efficiency changes of forest carbon sinks among economic regions in Russia from 2009 to 2021.*

Further decomposition of the technical efficiency change values is presented in Fig. 3. As mentioned before, three regions, namely Kaliningrad, Volga-Vyatka, and West Siberian ERs, did not perform any efficiency improvements, therefore their PTE and SE values remained unchanged. Along with them, six DMUs (namely Central, Central Black Earth, North Caucasus, Ural, and Far Eastern ERs) kept their management regimes (PTEs) unmodified. During the study period, related improvements occurred in Northwestern ER (1.4%) and East Siberian ER (0.1%), while Northern and Volga ERs deteriorated by 3.5% and 2.3%, respectively. Therefore, these changes made a significant contribution to their performance. As stated before, deterioration in terms of scale efficiency is the main factor hindering the productivity of forest carbon sinks in Russia. In particular, the related value sufficiently decreased in the predominantly agricultural regions of Central Black Earth and North Caucasus ERs, accounting for 5% and 5.5%, respectively. Meanwhile, Central, Volga, Ural, and Far Eastern ERs decreased only by 1.8%, 0.1%, 0.7%, and 1.1%, respectively. Noteworthy, the scale efficiency increment in forest carbon sinks occurred in the Russian North, namely in Northwestern (0.2%) and Northern (0.5%) ERs. As stated in the report [7] by the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), high warming rates occurred in these territories, presumably contributing to local forests absorbing more carbon.

III. Results

Our estimates show a large, long-term persistent sink of 3.56 ± 0.37 Pg C yr−1 in global forests since at least 1990, with a statistically insignificant change, based on Monte Carlo simulations and Cohen's d (Supplementary Fig. 1). Although stable overall, the contribution to this carbon sink of different forest biomes has fluctuated greatly over time. In the tropics there has been a shift from equal contributions of intact and regrowth tropical forests in the 1990s to 65% of the sink being in regrowth forests in the 2010s, as the intact sink declined and the regrowth sink increased (Table 1). Boreal and temperate forests contributed similar carbon sinks in the 1990s, but by the 2010s the boreal sink had decreased to less than half of the temperate sink (Table 1). Carbon stock densities (Mg C ha−1) in all forest biomes in all climate zones steadily increased (Extended Data Fig. 2c), indicating that forest ecosystems across the planet continuously sequestered carbon, implying that a universal growth factor, or several factors, was enhancing forest sinks on continental scales. A suite of multidisciplinary evidence indicates that the global carbon-sink persistence and carbon-density increases were in part the result of CO2 fertilization contributing to substantially increased photosynthesis17,18, as well as to longer growing seasons in temperate and boreal regions26. These factors may have outweighed the negative effects on forest carbon from global heating, changing rainfall patterns and changes in the frequency and severity of natural disturbances in the remaining forests.

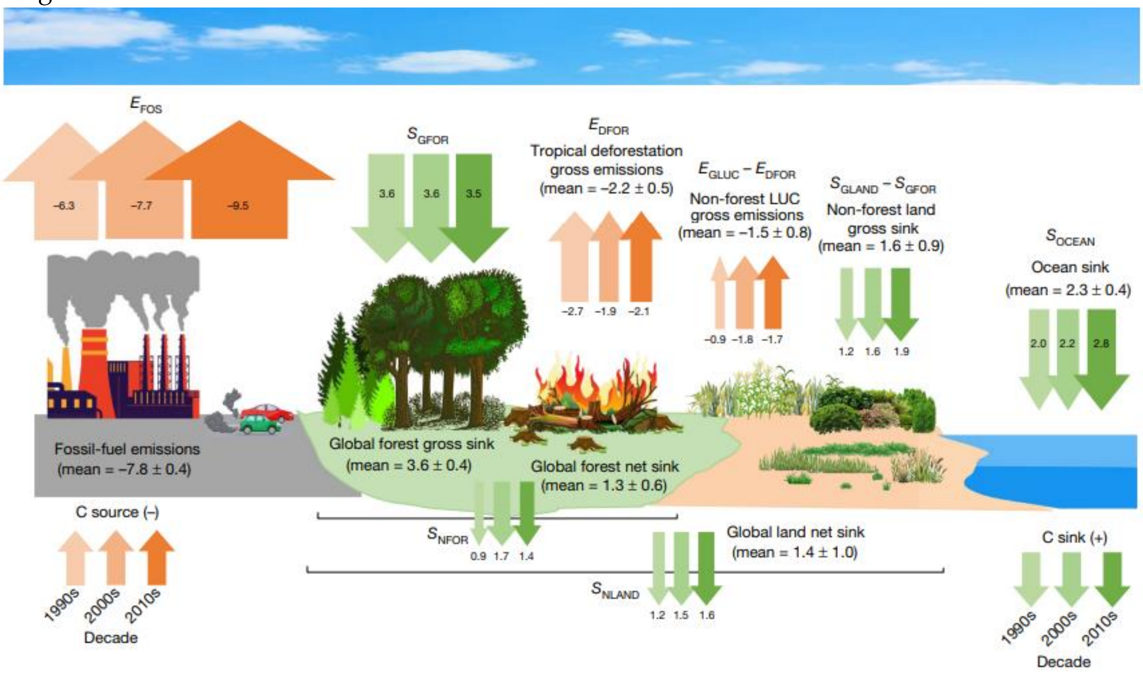

Figure 3: *Integration of inventory-based global forest carbon fluxes with the GCB*

The carbon pool of the world's forests is exposed to risks from deforestation, degradation, and disturbance caused or exacerbated by climate change. In intact tropical forests, the main threats are ongoing deforestation and degradation, which are the main drivers of reduced carbon sequestration (Extended Data, Figure 1). Increasing frequency and severity of droughts have also killed millions of trees, weakening the carbon pool in the Amazon. Given that the combined pool in intact and recovering forests remains stable, the net carbon sequestration for tropical forests as a whole is largely determined by the level of emissions from deforestation. Reducing deforestation and degradation is the only way to keep the carbon stored in forests from escaping into the atmosphere. Protecting tropical forests also helps to maintain their biodiversity and their capacity to sequester carbon into the future.

Boreal forests have been significantly impacted by climate change, including greater temperature increases and variations than other regions. Climate change has disrupted carbon cycling in vegetation and soils, and has increased the impacts of wildfires, pest outbreaks, and droughts. The high levels of carbon storage and sequestration in boreal forest necromass threaten to increase decomposition rates and wildfires during drought conditions. These impacts have made Canadian forests a carbon source, while forests in Asian Russia have lost 42% of their carbon sequestration capacity over three decades, particularly in the late 2010s. Future threats to boreal forest carbon dynamics also include northward shifts in bioclimatic zones, leading to permafrost thawing and megafires such as those that occurred in 2020–2022, as well as increased risks of major pest outbreaks and increased legal and illegal logging, which in turn releases methane and CO_2 .

Temperate forests include the most intensively managed forest ecosystems on Earth. Increased carbon sequestration in these forests is mainly due to past tree planting in China. Temperate forests regenerated on abandoned agricultural land or heavily logged forests in the first half of the 20th century are now approaching an age where their growth rates begin to decline, although growth trajectories and successional dynamics vary within the temperate forest biome. Climate change has increased the frequency and intensity of natural disturbances, which in turn has caused more severe bark beetle outbreaks after droughts in some European forests. In addition, increased deforestation in the temperate zone over the past three decades (+17%) has reduced carbon stocks.

IV. Discussion

To assess the possibilities of achieving carbon neutrality, a comparative analysis of the processes taking place in the economy, especially in the energy sector, in a number of countries was conducted. Both the leaders of decarbonization (the European Union, Japan, the United States and Canada) and the largest developing economies that are just beginning their path to the declared carbon neutrality (China, India, Turkey) are included.

In the energy sector, for the leading countries representing industrially developed economies, there is a transition to stabilization of specific (per capita) energy consumption with its moderate reduction. While in developing economies, including Russia, this indicator continues to grow.

When analyzing the carbon intensity of energy consumption, no significant division is observed. In most countries (EU, USA, Japan, China, Turkey) the trend towards decreasing specific emissions in the energy sector has been maintained over the past 50 years (with the exception of a three-year period in Japan, when there was a mass closure of nuclear power plants after the Fukushima accident in 2011). In Canada, this indicator stabilized back in 1985 at an unprecedentedly low level due to the widespread use of hydro and nuclear energy. In Russia, this indicator has stagnated since 2008, remaining slightly below the world average, while India's energy sector has demonstrated surprising constancy over the entire 50-year period due to the predominance of coal in the national energy balance.

The events of the last year have radically changed all previously existing forecasts of economic development, both for Russia and for many other countries. In this regard, for our study, which sets the task of risky extrapolation of the intensity of policy to curb greenhouse gas emissions for several decades ahead, the method of historical extrapolation was chosen instead of the traditional approach based on detailed assumptions about economic development. We are confident that historical extrapolation can yield useful results, which is confirmed by our experience in creating long-term forecasts for the development of global energy. For example, forecasts compiled in 1990 showed a coincidence with actual data on energy consumption in the world within 2% over a horizon of more than 30 years. However, taking into account the unusually high dependence of the final result on political decisions, we decided to consider two extreme scenarios of Russia's movement towards climate neutrality: an optimistic one and a real one, which takes into account, among other things, current turbulent events. The UN median scenario was chosen as the demographic scenario in both options, which assumes a gradual decrease in the country's population to 128 million by 2060.

The optimistic scenario is based on the assumption that ideas about the fight to preserve the climate will gain much greater influence in Russian society, comparable to that observed in developed countries over the past three decades. In this case, Russia will be able to count on decarbonization rates that correspond to the best world standards (see Table 2). In general, the parameters of the optimistic decarbonization scenario are as follows:

- The rate of reduction of specific (per capita) anthropogenic greenhouse gas emissions is 1% per year, which corresponds to the average value for developed countries in the period from 1990 to 2020.

- Forest management indicators follow the Strategy-2030 (2021) and assume full restoration of forests after all clear-cutting; the dynamics of carbon absorption by forests corresponds to high national estimates, which, it should be noted, significantly diverge from international recommendations.

- Additional carbon fixation by forests is taken into account, taking into account changes in climatic factors (temperature and precipitation), as well as the fertilization effect resulting from an increase in the concentration of carbon dioxide in the atmosphere.

- A 50% reduction in the area of forest fires is being implemented (in accordance with the Decree of the President of the Russian Federation) by 2030, with this indicator being maintained in the future.

The real decarbonization scenario takes into account the difficulties associated with the radical restructuring of all sectors of the economy - from energy to forestry - and is characterized by the following parameters:

- The rate of reduction of specific (per capita) anthropogenic greenhouse gas emissions corresponds to the moderate indicators achieved in Japan and Canada in the period from 1990 to 2020, and amounts to 0.5% per year, which is significantly better than current Russian indicators.

- Forest management indicators follow current international recommendations and are based on the results of official forest inventories and the Forest Strategy 2030, taking into account the real prospects for the development of the forest sector and the dynamics of carbon absorption by forest biota , according to which the net carbon sink shows a slight increase. In this scenario, ageing forests lose their bioproductivity , but technically and economically feasible forest climate projects are implemented in forestry , while the fight against forest fires achieves limited success.

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References

[1] Gakaev , R. Assessing Carbon Dynamics in Diverse Ecosystems: The Role of Carbon Polygons / R. Gakaev , L. Gatsaeva // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03013. – DOI 10.1051/e3sconf/202453703013. – EDN OOIDOS.p .

[2] Idrisov IA Climate change in Dagestan in the second half of the Holocene // Bulletin of the Institute of IAE. Makhachkala, 2010. No. 2

[3] Kornienko TV Questions of linguistic kinship, 2013. No. 9. P. 155-162.

[4] Munchaev RM, Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House, 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L. : Gidrometeoizdat , 1979. 408 p.

[8] Gakaev , R. Carbon sequestration in landscapes of the Chechen Republic / R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 193-196. – DOI 10.24412/1932-2321-2022-366-193-196. – EDN KHSSVY.

[9] Khotinsky NA, Savina SS Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin VI, Deniz DS Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11.No. 4. P. 1893-1904.

[11] Gunya , A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

GLOBAL CLIMATE CHANGE AND TEMPERATURE BALANCE: RISKS AND PROSPECTS

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Abstract

This paper focuses on global climate change and the balance of global temperatures. It has been established that CO_2 emissions and solar activity exert the greatest influence on changes in average temperatures.
The study explores the relationship between average temperature changes, the rate of solar energy input, CO_2 concentration, and cyclical periods. It was found that CO_2 emissions can be significantly reduced. The findings indicate that even with reductions and minimization of CO_2 emissions, such as on the European continent, the average temperature increase observed over the past 48–50 years will not decrease, and a return to the temperature levels of 100 years ago is not feasible. However, it is possible to project the stabilization of this increase at around 1.5°C.
Furthermore, this research highlights the critical link between CO_2 emissions, solar activity, and the broader natural and technological risks associated with climate change. These risks include extreme weather events, natural disasters, and impacts on industrial processes, underscoring the importance of innovative methodologies and practices for risk mitigation.

Keywords: climate change, CO_2 emissions, solar activity, temperature balance, sunspot activity, climate change, climate-related risks, and statistical model

I. Introduction

Climate change has a profound impact on people, the economy, and the environment. Extreme heat was recorded in 2023, leading to droughts and wildfires. In Europe, sea surface temperatures increased further, reaching record highs. Simultaneously, glaciers began to melt. The year 2023 was the warmest on record in Western and Southwestern European countries. The levels of carbon, nitrogen oxides, methane, and chlorofluorocarbons, which contribute to the greenhouse effect, are rapidly increasing due to emissions from industrial facilities and transportation. Consequently, the frequency of storms, blizzards, and floods has risen. According to the International Meteorological Organization (European Union Climate Change Program), the rate of warming in Europe has more than doubled compared to the global average since 1980. In 2023, the average temperature in Europe increased by 2.13°C. [1,2]. Climate change is one of the most significant challenges faced by scientists and engineers. A pressing scientific issue is whether the global rise in average temperatures could ever return to previous levels, what challenges and risks exist along this path, and what efforts will be required to achieve it. In other words, is it possible to achieve global climate equilibrium (temperature equilibrium)?

In light of the ongoing shifts in global energy strategies, particularly the transition from traditional fossil fuels to more sustainable chemical processes, it becomes increasingly important to consider the broader implications of these changes on climate dynamics. The evolution from "crude oil to chem" and emerging technologies like "carbon to chem" highlight how industrial innovations are responding to environmental pressures. These advancements underscore the necessity of integrating such forward-looking approaches into climate risk assessments, particularly when considering the potential impacts on CO_2 emissions and their role in global temperature regulation [3].The objective of this research is to investigate the emergence of global climate equilibrium. Atmospheric pollutants include greenhouse gases (GHGs) that block thermal radiation from the Earth while allowing heat from the Sun to reach the Earth's surface. Industrial greenhouse gases (IGHGs) refer to gases released into the atmosphere as a result of fuel combustion and other economic activities. The formation of IGHGs involves the following gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (CF_4, C_2F_6), halogenated hydrocarbons, sulfur hexafluoride (SF_6), and ammonia (NH_3). Additionally, indirect greenhouse gases, which are also pollutants, include nitrogen oxides (NOx) and other volatile organic compounds (VOCs).

The list of harmful substances polluting the atmosphere includes: carbon compounds (oxides); sulfur compounds (hydrogen sulfide, sulfur dioxide, and sulfur trioxide); nitrogen compounds (ammonia, nitrogen oxides, etc.); halogens (their chlorine, fluorine, bromine compounds, etc.); hydrocarbons (benzene, toluene, xylene); alcohols (methanol, ethanol, etc.); ethers; and aerosols of various origins—dust, smoke, and fog.These substances pollute the atmosphere both directly and through oxidation and conversion into other harmful compounds.The primary sources of atmospheric pollution are the metallurgical, cement, chemical, and petrochemical industries, thermal power plants, residential and industrial boilers, and transportation. Among these gases, carbon dioxide (CO_2 equivalent) was specifically mentioned in the study. Using this gas as an example, the study examines all gases contributing to the formation of the greenhouse effect [4-7].

It is well established that climate change is occurring and average temperatures are rising, as shown in Table 1. The primary factors influencing average temperature are the concentration of CO2 in the atmosphere (greenhouse effect) and solar activity. Other anomalous conditions may also arise during this time. Given these considerations, scientific research in this area is ongoing. Over the past 100 years, average temperature increases have been studied across different continents worldwide. Factors affecting the rise in average temperature have been identified, and statistical indicators have been used to analyze the annual average temperature increases across the continents of Europe, North and South America, Asia, Africa, and Oceania.

The factors most significantly influencing the rise in average global temperatures are primarily linked to human activities. These factors include:

1. Fossil fuel combustion:

- The burning of fossil fuels, such as coal, oil, and natural gas, releases large amounts of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere. These gases trap solar heat, leading to an increase in atmospheric temperatures.

2. Deforestation:

- Deforestation leads to the release of carbon into the atmosphere. Trees absorb carbon dioxide through photosynthesis, and a reduction in this process increases carbon levels in the atmosphere.

3. Industrial processes:

- Industrial activities, including metal production, cement manufacturing, and other processes, are significant sources of greenhouse gases.

4. Agricultural activities:

- Agricultural practices, particularly the raising of livestock and rice cultivation, are major sources of methane (CH_4) emissions. Methane is a very potent greenhouse gas, more effective than carbon dioxide.

5. Waste management:

- Methane and other greenhouse gases are released into the atmosphere due to improper waste handling and landfill operations.

6. Transportation:

- Vehicles such as cars, trucks, airplanes, and ships burn fossil fuels and emit greenhouse gases into the atmosphere.

7. Energy use:

- The production and use of electricity result in the emission of large quantities of greenhouse gases, especially when energy is generated from fossil fuels.

These factors are the primary contributors to the rise in average global temperatures. To combat climate change, it is essential to implement measures to manage and reduce these factors.

Heat (solar radiation) reaching Earth from the sun can vary depending on several factors. These changes can be short-term or long-term and are mainly associated with the following factors:

1. Solar activity:

- Solar activity changes in 11-year cycles. During these periods, the number of sunspots and the intensity of solar radiation fluctuate. When there are more sunspots, solar radiation slightly increases.

2. Earth's orbital parameters:

- These changes, known as Milankovitch cycles, are related to the eccentricity of Earth's orbit, axial tilt, and precession (the wobble of Earth's axis). These variations affect the amount of solar radiation reaching Earth over millennia and can lead to glacial periods.

3. Dust and aerosols in the atmosphere:

- Volcanic eruptions or large-scale wildfires release significant amounts of dust and aerosols into the atmosphere. These particles can block sunlight from reaching Earth's surface, causing a global cooling effect. For example, the eruption of Mount Pinatubo in 1991 led to a temporary decrease in global temperatures for several years.

4. Human activities:

- Aerosol emissions into the atmosphere from human activities (e.g., industrial processes and fuel combustion) can reflect solar radiation, but this effect is short-lived and does not fully offset the global warming effect caused by greenhouse gases.

5. The role of clouds:

- Clouds can both reflect and absorb solar radiation, altering the amount of solar energy that reaches Earth's surface. This cloud effect depends on the type, height, and density of the clouds.

6. Changes in Earth's albedo:

- The albedo of Earth's surface, or its ability to reflect sunlight, also affects how solar radiation is perceived. For example, snow and ice have a high albedo and reflect sunlight. As ice melts, darker surfaces (water and land) are exposed, absorbing more solar radiation and increasing temperatures.

The factors mentioned above determine the amount of heat that reaches Earth from the sun and its impact on the planet. Human activities, particularly the emission of greenhouse gases, disrupt Earth's energy balance and lead to global warming. While changes in solar radiation can cause short-term climate variations, the current trend of global warming is largely the result of human activity.

The statistical mathematical model was constructed based on statistical indicators using the example of the European continent. Climate change and its causes were studied through certain simplifications using these established statistical models. The average temperature increase from 1900 to 2023 was analyzed based on statistical data. A multifactorial experimental design matrix was developed using these indicators [8, 9]. The coded level values and the parameter variation intervals affecting the increase in average temperature, as determined by the coefficients, are described in Table 1.

Table 1: *Coded Levels and Parameter Variation Ranges Affecting the Increase in Average Temperature Across Factors*

Factor Names	Coded Levels			Variation Interval
	-1	0	+1	
X_1, CO_2 Concentration, ppm	1.4	2.3	3.2	0.9
X_2, Solar Activity, m/s	200	292	384	92
X_3, Duration, years	50	100	150	50

The multifactorial design matrix is presented in Table 2.

Table 2: *Multifactorial Design Matrix*

№	CO2 Concentration, ppm	Solar Activity, m/s	Duration, years	Output Parameter (Average Temperature),°C
1	1,4	200	50	0.1
2	1,4	200	50	0.2
3	1,4	200	50	0.3
4	1,4	292	100	0.4
5	1,4	292	100	0.5
6	1,4	292	100	0.6
7	1,4	384	150	0.7
8	1,4	384	150	0.8
9	1,4	384	150	0.9
10	2.3	200	100	1
11	2.3	200	100	1.1
12	2.3	200	100	1.2
13	2.3	292	150	1.3
14	2.3	292	150	1.4
15	2.3	292	150	1.5
16	2.3	384	50	1.6
17	2.3	384	50	1.7
18	2.3	384	50	1.82
19	4,6	200	150	1.84
20	4,6	200	150	1.86
21	4,6	200	150	1.88
22	4,6	292	50	1.9
23	4,6	292	50	1.95
24	4,6	292	50	1.98
25	4,6	384	100	2
26	4,6	384	100	2.1
27	4,6	384	100	2.15

Table 2 presents the results of the average annual temperature calculations depending on various factors. As a result, the following regression equation was obtained using the formula (2):

$$Y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{\substack{i.j=1 \\ i \neq j}}^{n} b_{ij} x_i x_j + \sum_{i=1}^{n} b_{ii} x_i^2 \quad (1)$$

Here, x_i – represents the factors in the climate change process; n - is the number of factor, *bi, bij, bii* - the coefficients in the regression equation represent linear, interaction, and quadratic effects, respectively. In this study, the number of factors is 3. The regression coefficients are determined using the following well-known formula:

$$b_i = \frac{\partial f}{\partial x_i};\ b_{ij} = \frac{\partial^2 f}{\partial x_i \partial x_j};\ b_{ii} = \frac{\partial^2 f}{2\partial {x_i}^2} \quad (2)$$

$$Y_{temp} = 1.2881 - 0,7881C_{CO_{2(1,4)}} + 0.01141C_{CO_{2(2,3)}} + 0.6741C_{CO_{2(4,6)}} - 0.2348G_{a(200)} - 0.0070G_{a(292)} + 0.2419G_{a(384)} - 0.0048P_{50} - 0.0604P_{100} + 0.0652P_{150} \quad (3)$$

Here, $C_{CO_2} - CO_2$ concentration, G_a - galactic solar activity, P – time (cycle period)

$$Y_{temp} = 17.333 - 0.305x_3 - 0.96x_1^2 - 0.757x_2^2 - 0.486x_3^2 \quad (4)$$

$$Y_{temp} = 13.4259 - 0.3204C_{co_{2(1,4)}} - 0.0370C_{co_{2(2,3)}} + 0.3574C_{co_{2(3,2)}} - 0.1859G_{a(200)} + 0.0263G_{a(292)} + 0.1596G_{a(384)} - 0.0470P_{10} + 0.0763P_{60} - 0.0293P_{110} \quad (5)$$

$$Y_{temp} = 15,4000 - 0,7444C_{co_{2(1,4)}} - 0.1444C_{co_{2(2,3)}} + 0.8889C_{co_{2(3,2)}} - 0.1644G_{a(200)} + 0.0089G_{a(292)} + 0.1556G_{a(384)} + 0.1800P_{0} - 0.0133P_{50} - 0.1667P_{100} \quad (6)$$

Equations (3) and (4) represent linear and nonlinear regression models of the change in average temperature over 100 years on the European continent. Equations (5) and (6) are regression models of the average temperature on the European continent as it stands now and 100 years ago [9].

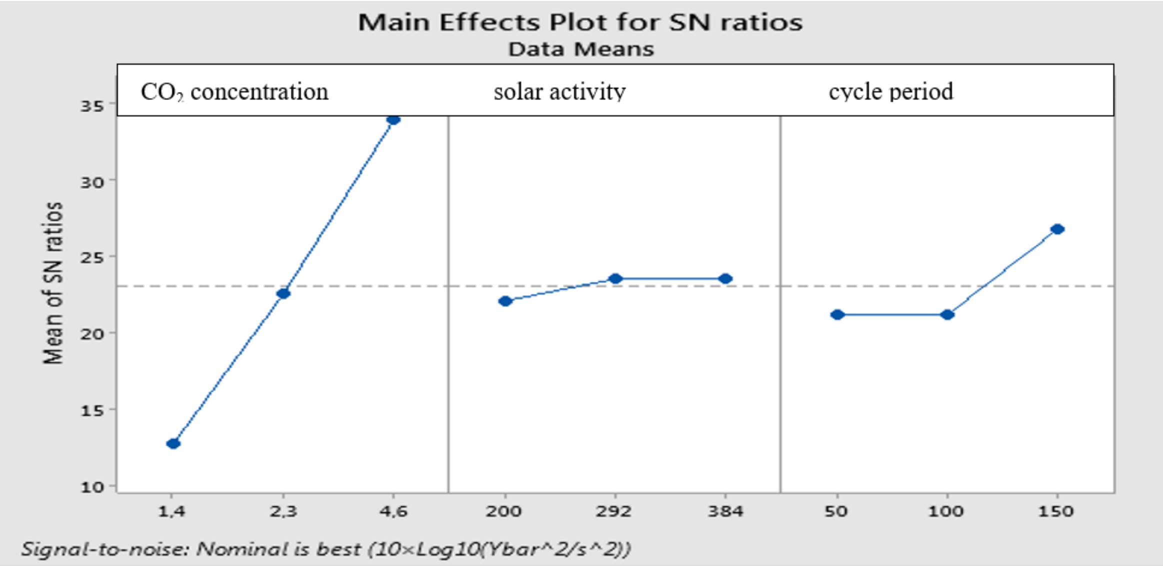

Figure 1: *Relationship between the increase in ambient temperature and CO_2 concentration, solar energy input rate (solar activity), and cycle period*

Processes in the environment, including continental temperatures, change according to nonlinear patterns [10, 11]. It is known from synergetic that nonlinear systems can be characterized by minimal energy dissipation [8]. Most natural processes are studied as nonlinear processes. Chaotic temperature fluctuations require the use of random functions. The method of E. Lorenz can be applied for the analysis of random functions [12, 13]. During this time, unstable harmonic oscillations (peaks) are separated, and the effects of other oscillations are ignored for simplicity.

$$\frac{dx}{d\tau} = k \cdot (y - x) \tag{7}$$

$$\frac{dy}{d\tau} = -x \cdot z + r \cdot x - y \tag{8}$$

$$\frac{dz}{d\tau} = x \cdot y - b \cdot z \tag{9}$$

Here, r = R, R - Rayleigh number, k - Prandtl number, b - constants

Preliminary calculations indicated that linear regression models, in comparison to nonlinear regression models, demonstrate certain minor inaccuracies. These inaccuracies are partially mitigated through the application of nonlinear regression. The relationships between atmospheric temperature, CO_2 concentration, and solar activity across different continents were analyzed. Earth's ecological systems are inherently complex, interconnected, and self-regulating. Addressing the challenges posed by these systems necessitates consideration of their intrinsic natural laws, suggesting that the study of complex ecological systems is fundamentally reliant on experimental calculations.

Research Results and Analysis

The results of the computational experiment examining the relationship between changes in ambient temperature, CO_2 emissions, and the period (time) of solar energy input, as the output parameter, are presented in Figure 1. The impact of all three factors on the outcome, as well as their interaction effects, was analyzed using the statistical software packages "Minitab" and "Origin" based on the obtained statistical data. An increase in CO_2 concentration led to a rise in ambient temperature. The temperature increased as solar activity intensified and then remained constant. Over a 50-year period, the temperature changed little when the CO_2 concentration remained constant. In the following 50 years, the temperature increased. Figure 2 shows a normal probability plot. Figure 3 presents a contour plot of temperature dependence on the rate of solar energy input and the cycle period. The figure shows that temperature significantly varies depending on solar activity and the time of year. Figure 4 illustrates the relationship between temperature and CO_2 concentration over time. In this case, CO_2 concentration and the cycle period greatly influence the temperature. Figure 5 depicts the relationship between temperature, CO_2 concentration, and solar activity. The figure shows that as CO_2 concentration and solar energy increase, the temperature change also increases significantly. During the study, CO_2 concentration was identified as the most harmful gas released into the environment. However, other gas emissions also have consequences. Figure 6 shows bubble charts of temperature changes. The images indicate that CO_2 concentration and solar activity have the most significant impact on temperature change [14, 15]. Here, synergistic processes become more pronounced.

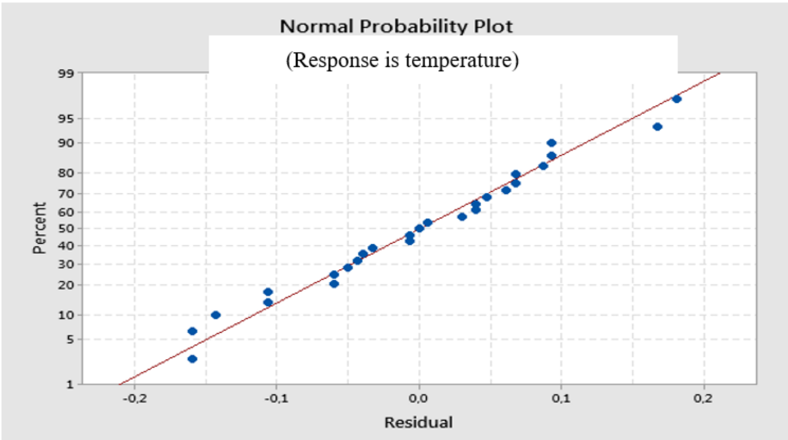

Figure 2: *Normal Probability Plot*

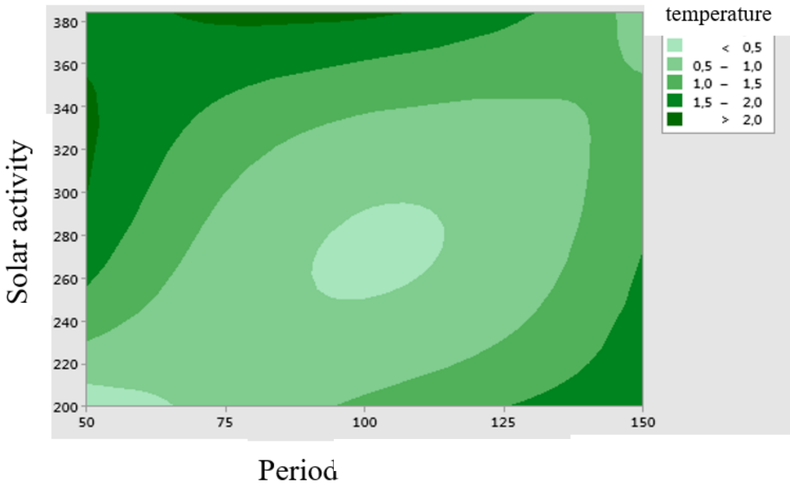

Figure 3: *Temperature Dependence on Solar Energy and Cycle Period*

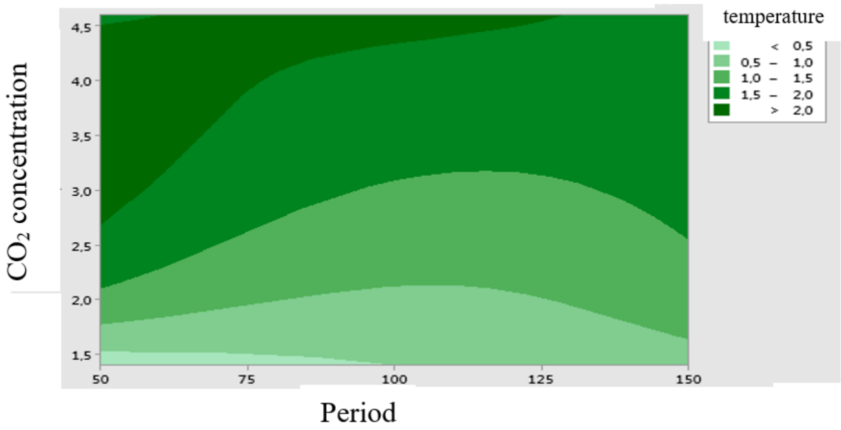

Figure 4: *Temperature Dependence on CO_2 Concentration and Period*

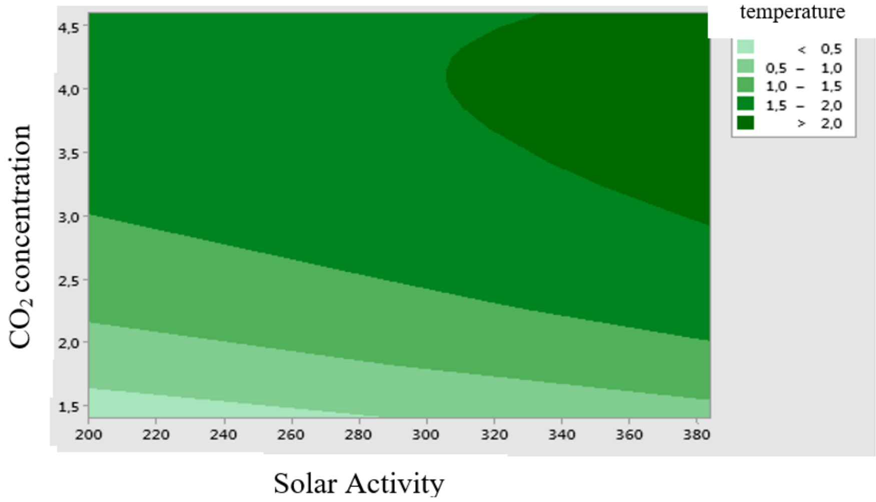

Figure 5: *Temperature Dependence on CO_2 Concentration and Solar Activity*

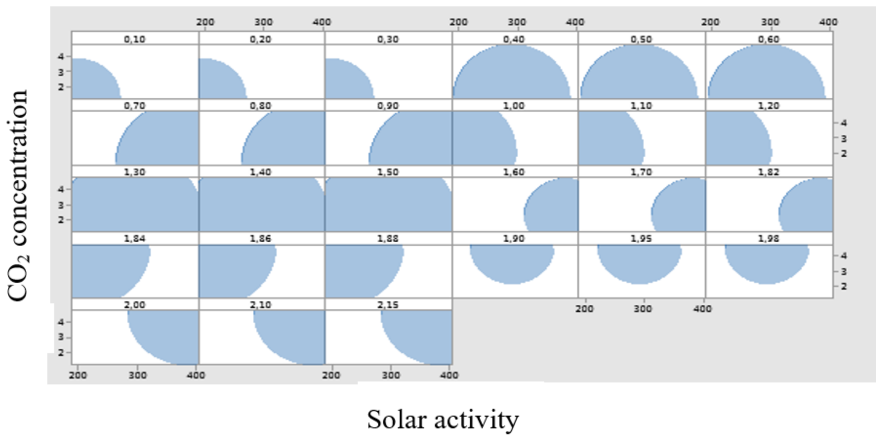

Figure 6: *Bubble Chart of Temperature Changes Depending on CO_2 Concentration and Solar Activity*

Environmental protection from harmful and hazardous industrial and transportation emissions is one of humanity's global challenges. Currently, scientists and engineers face the critical issue of preventing the pollution of the biosphere by CO_2 and other substances. Under these circumstances, it is necessary to develop a methodology for calculating harmful gases, including CO_2, emitted into the environment. The Department of Chemical Technology, Processing, and Ecology at Azerbaijan Technical University has developed a new methodology (using Python software) for calculating the quantity of harmful gases released into the atmosphere. Figure 7 shows the relationship between surface area temperature and solar activity and period. The figure reveals that the temperature variation is complex and has a specific volume depending on the cycle period and solar activity. Figure 8 illustrates the relationship between temperature variation area and CO_2 concentration and cycle period. The figure shows that the surface area does not have a complex structure but rather a convex surface. Figure 9 also shows the relationship between surface temperature variation, solar activity, and CO_2 concentration. In this case, the surface is convex and does not have a specific volume. Figures 7-9 demonstrate that temperature variation is highly dependent on the mentioned factors. However, as shown in Figure 7, the temperature variation surface has a specific volume depending on the cycle period and solar activity. This indicates that the relationship is complex and nonlinear.

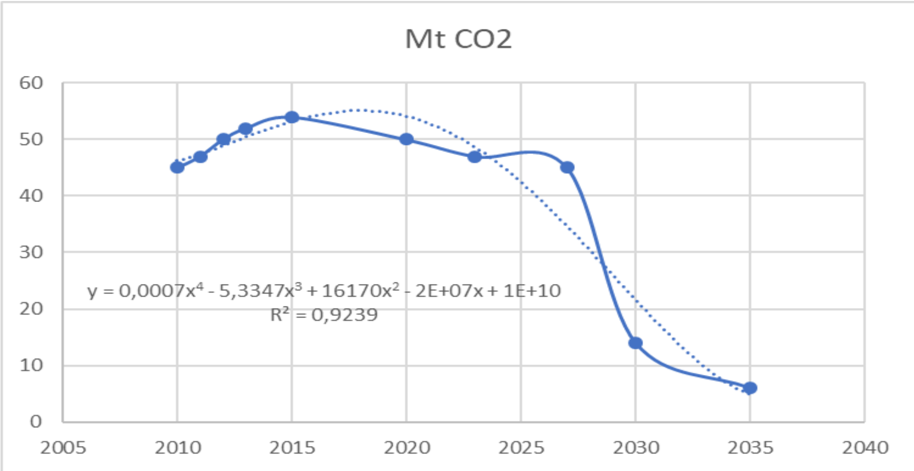

Figure 7: *Emissions from Fuel Combustion (million tons of CO_2 equivalent)*

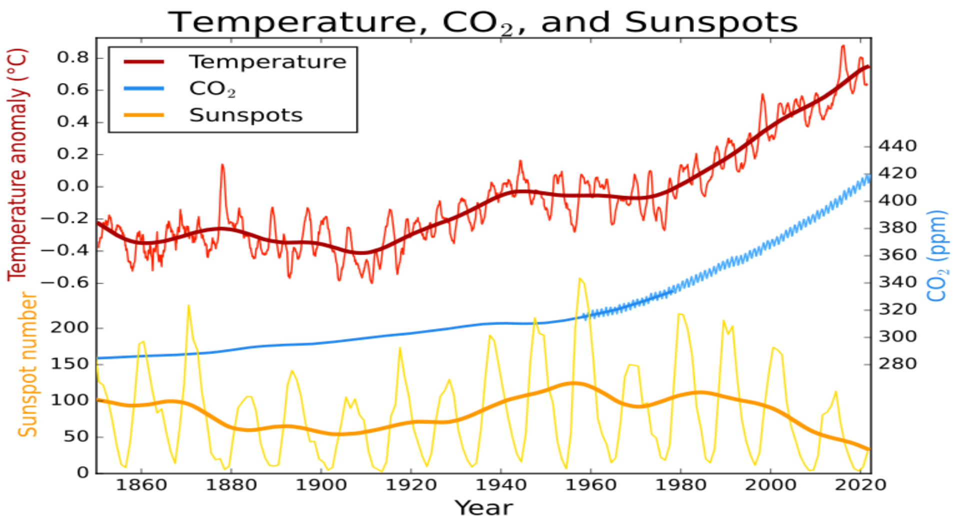

Figure 8: *Atmospheric CO_2, Average Surface Temperature, and Solar Activity (Sunspot Count) since 1850 [12]*

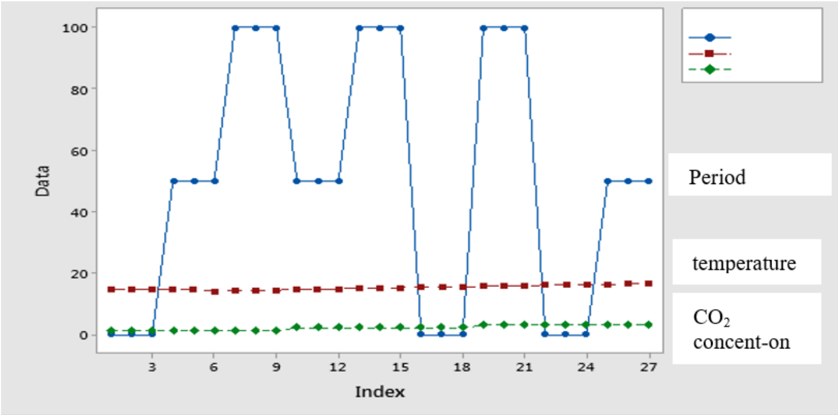

Figure 9: *Emergence of Temperature Equilibrium*

Results

CO_2 emissions and solar activity exert the greatest influence on global temperature changes. While humans cannot interfere with the Sun's activity, substantial reductions in CO_2, methane, and other IGHG emissions are possible. Other effects also depend on these two factors. Climate change is an extremely complex process, and there is a degree of randomness involved. The increase in CO_2 emissions is directly linked to human activities, including industrialization, wars, and other factors.

From the obtained graphs and calculations, it is evident that by reducing and minimizing CO_2 emissions, it is possible to forecast a likelihood of temperature reduction over the past 48-50 years and a return to the baseline temperature observed 100 years ago. However, this outcome underscores the broader principle that the more damage humanity causes to nature, the more severe the environmental consequences become.

Over the past 100 years, the Earth's average temperature has risen significantly. This increase is primarily attributed to the emissions of greenhouse gases (CO_2, CH_4, and others) resulting from human activities. Climate change has led to numerous severe consequences, including global warming, desertification, glacier melting, sea level rise, the destruction of small islands, and an increase in extreme weather events. The risk of progressive degradation of the global ecological system continues to grow.

Restoring the Earth's average temperature to its previous state is quite challenging and depends on several factors:

1. Reduction of greenhouse gas emissions: First and foremost, it is essential to significantly reduce the concentration of greenhouse gases in the atmosphere. This requires a rapid decrease in global carbon emissions and the implementation of technologies and policies aimed at removing greater amounts of carbon from the atmosphere.

2. Technological Innovations: Carbon capture and storage (CCS) technologies, methods for removing carbon from the atmosphere, and the widespread adoption of alternative energy sources are crucial.

3. Protection and Restoration of Natural Ecosystems: Natural methods, such as forest conservation, reforestation, and enhancing the carbon capture capacity of soil and oceans, also play a critical role.

4. Global Policy and Cooperation: Combating climate change requires global cooperation. Under international agreements like the United Nations Framework Convention on Climate Change (UNFCCC), the Paris Agreement, the Katowice Climate Package, and the Glasgow Climate Pact, it is crucial for countries to work together, adhere to their targets, and take significant steps in this direction.

Given these factors, the implementation of long-term strategies and systematic efforts is essential to attempt the restoration of global average temperatures to their historical norms. However, climatologists caution that some impacts may already be irreversible. At best, global warming might be limited and eventually halted, but achieving a full return to previous temperature levels will be an arduous, protracted, and costly endeavor.

References

[1] NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published April 17, 2024 from https://www.ncei.noaa.gov/access/monitoring/climate- at-a-glance/global/time-series

[2] Samarsky, A.A. Computers, Models, Computational Experiment. Moscow: Nauka, 1988. 170 p.

[3] Nasirov I.R., Upgrade of the Oil Refining Dialectics. OIL AND GAS VERTICAL, October 2020, No. 17 (476), pp. 20-26

[4] Yusubov F.V., Mansurov E.F. Optimization of the process of carbon dioxide extraction from flue gases. // Chemistry and technology of fuels and oils; 2020, No. 3. P. 31–33.

[5] Yusubov F.V., Bayramova A.S. İnvestigation and Computer Modeling of Separation of Gas Mixtures //Theoretical Foundations of Chemical Engineering; 2022, №4,Vol.56,pp.613-617

[6] Yusubov F.V. Aliev İ.A. Optimal design of adsorbers for separation of mixtures. // Chemistry and Technology of Fuels and Oils, №6, 2024, pp.63-69

[7] Yusubov F.V., İ.A. Aliev, S.N. Quliyeva Study of adsorption separation of gas mixtures under non- ststionary conditions. // Theoretical and Applied Ecology, №2, 2024, pp.101-107

[8] Introduction to Minitab® 16, Minitab Inc., 2010. 152 p.

[9] Nalimov V.V., Chernova N.A. Statistical methods forplanning extreme experiments. Moscow: «Nauka» Publ., 1965. 340 p.

[10] https://news.un.ora/ru/storv/2023/06/1442297

[11] https://habr.com/ruarticles/469259/

[12] Haken, G. Synergetics. Moscow: Mir,1980. 404 p.

[13] Nicolis, G., Prigogine, I. Self-Organization in Non-Equilibrium Systems. Moscow: Mir, 1979. 354 p.

[14] Ishkov, V.N., Kononovich, E.V. Solar Activity. http://crydee.sai.msu.ru/

[15] Vitinsky, Y.V. Solar Activity. Moscow: Nauka, Main Editorial Board of Physical-Mathematical Literature, 1983. 192 p.

[16] https://ru.wikipedia.org/wiki Variations of Solar Radiation. Available at: https://ru.-wikipedia.org/wiki/

CLIMATE CHANGE STATISTICS – A RESPONSE TO THE CLIMATE CHALLENGES OF MODERN TIMES: THE EXPERIENCE OF THE KYRGYZ REPUBLIC

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Abstract

This article focuses on the development and implementation of a system of climate change statistical indicators in the Kyrgyz Republic. It discusses the methodological approaches and practical results of the first experience of creating a systematic set of climate change statistics and integrating them into national decision-making processes for climate adaptation in the Kyrgyz Republic.

Keywords: statistics, climate change indicators, climate change adaptation, climate risks

I. Introduction

Climate change is one of the defining challenges of this decade, with both direct and indirect impacts on key services and infrastructure that affect human well-being and the economy including healthcare, water supply and sanitation, construction, and electricity. Climate change poses an immediate physical risk to the very existence of a facility or region. For example, the destruction of a production site due to an extreme weather event increases the likelihood of a default by the operating company. Climate change also presents a significant financial risk. Climate adaptation measures, as well as global responses to climate threats (such as reducing greenhouse gas emissions and adaptation programs), can have far-reaching consequences for the structure and functioning of global and national economies and financial system [1].

Climate risk encompasses a range of hazards, from extreme weather events to long-term shifts in weather patterns. According to a report by the WMO, the number of natural disasters has increased by five times since 1970, while economic losses have risen even more – by seven times [2].

The situation is especially tense in Central Asia, where warming is occurring faster than the global average, and its rate has almost doubled compared to the period from 1961 to 1990. Record-high temperatures and dry conditions in the Eastern Himalayas and most of the Tien Shan region have accelerated the mass loss of many regional glaciers, which will soon limit access to drinking and irrigation water, create problems in the hydropower sector, and affect agriculture. As the frequency of intense rainfall increases, mudslides and floods will become more common, while more frequent heatwaves will contribute to droughts and cause issues in the healthcare sector.

By 2050, Central Asia may see the emergence of 5 million climate migrants[1]. These climate-related risks exist alongside other challenges, such as misinformation, geopolitical competition, and inflation, and are key risks in 2024 and beyond[2]. It's also important to note that as the frequency and severity of natural disasters (e.g., floods, mudslides) increase, the costs of damage compensation continue to rise[3].

For these reasons, most countries (198 as of early 2022) have not only declared their willingness to adapt to climate change but also recognized the importance of achieving carbon neutrality. However, this progress has been slow and disproportionate to the growing climate risks. For instance, only 4.5% of countries have already achieved carbon neutrality, 10.6% have declared or committed to reaching carbon neutrality goals, 8.6% have enacted laws to achieve these goals, 29.3% have developed policies for achieving carbon neutrality, while the remaining 47% of countries are still discussing relevant documents [3].

The main reason for this situation is that climate risks are just one part of systemic risks. According to the UN Department of Economic and Social Affairs, if the transition to a zero-emissions economy is hastened without systemic changes (including in the field of information provision), the risks to financial stability could intensify [1].

These systemic consequences are essential to consider, as climate change is not an isolated issue – it has a substantial impact on all economic activities and efforts to ensure the well-being and quality of life for the population. The increasing climate risks require systemic changes across all areas of economic activity and the incorporation of climate concerns into national policies.

There is an urgent need for a new paradigm that combines traditional hydrometeorological research and data with climate adaptation studies, services, and assessments, reflected in national statistics. Given the importance of formalized government statistical data, the UN Department of Statistics even suggests that climate can be defined as the statistics of weather over a randomly determined period [1]. The value of reliable government statistical data becomes even more critical as the volume of fake news in the information space grows.

This article presents the methodological approaches and practical results of the first experience in developing a systematic set of reliable statistical data and integrating it into national climate adaptation decision-making processes in the Kyrgyz Republic[4].

II. Methodology

Modern climate management relies on accurate and accessible statistical and departmental data. The volume of climate data is growing exponentially due to the rapid expansion of both observation capabilities and computational power, driven by an improved understanding of climate processes, increased forecast accuracy, and advances in modeling.

Remote sensing data of the Earth's surface is also becoming more accessible for assessing long-term changes, complementing traditional climate observations and statistics (see Figure 1). Similar trends are observed in climate statistics, which have significantly expanded in recent years. Global sets of climate data and indicators, the UNECE set of climate change statistical indicators, the UN System of Environmental-Economic Accounting (SEEA) indicators, and international climate information databases are actively used.

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[1] https://kun.uz/ru/news/2022/11/28/k-2050-godu-v-tsentralnoy-azii-poyavitsya-5-mln-klimaticheskix-migrantov.
[2] https://www.weforum.org/agenda/2024/01/climate-risks-are-finally-front-and-centre-of-the-global-consciousness/
[3] https://climatedata.imf.org/pages/adaptation#ad2.
[4] The research was carried out within the framework of the UNDP project "Promoting the process of developing a National Adaptation Plan (NAP) for medium-term and long-term planning and implementation of adaptation measures to climate change in the Kyrgyz Republic"

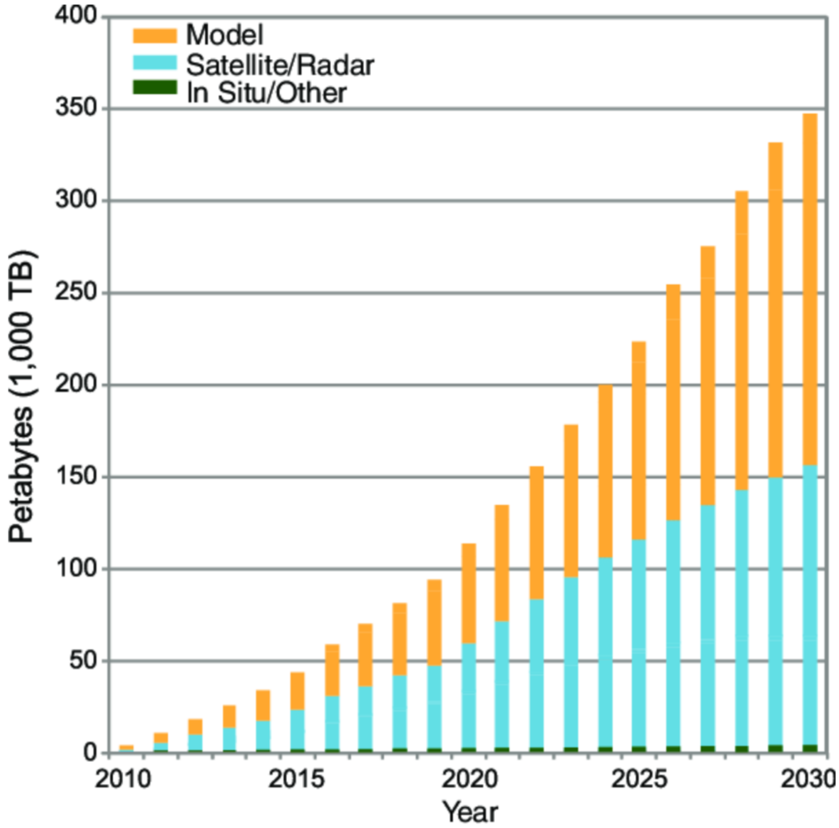

Figure 1: *Projected increase in global climate data for climate models, remote sensing data, and in situ instrumental/proxy data.*

Source: [4].

Understanding this, Infrastructure Panel (WIP) of the World Climate Research Programme (WCRP) and the Working Group on Climate Modeling (WGCM) were established 10 years ago. Their recommendations for global data infrastructure are based on several principles, starting with the need to separate requirements, implementation, and operations. Other important principles include considering the diverse needs of the data community (the data ecosystem), the importance of origin, the need for automation, and the commitment to measuring costs and benefits. WIP recommendations focus on requirements that take into account the diversity of the participating communities (model developers, analysts, software developers, and end-users). These requirements include the need for scientific reproducibility and accountability, as well as the need to register and track data usage. One key element is to focus on data sets rather than systems, aiming to make infrastructure less prone to systemic failures.

Despite this, climate data today are still full of gaps, hindering informed decision-making for managing climate risks. The rapid growth of global climate data also presents challenges in terms of physical archiving and sharing, as well as ease of access and search, especially for non-climate specialists.

A need for a new climate data paradigm is emerging in response to the constantly increasing volume of data, which should: (1) ensure free access to high-quality and reliable measurements for broad scientific research; (2) improve usefulness and clarity for a wide interdisciplinary audience; and (3) integrate climate risks into national and regional governance systems. Moreover, the channels through which climate shocks can be transmitted and amplified through the financial system are being actively studied [5].

In this new climate data paradigm, we believe that the focus should be on compressing information and converting it into indicators that are understandable to policymakers, government specialists, businesses, and the general public. Furthermore, these indicators should ideally have the status of official statistics, as today's global information network is overwhelmed with false information (up to 60%), much of which is generated by bots (up to 40%) [6]. In addition to traditional statistics, "diagnostics," which is used to assess the nature of climate changes over various time scales, is also useful [7].

As a methodological platform for implementing climate statistics in public administration and risk management, it is advisable to adopt the standardized and internationally recognized System of Environmental-Economic Accounting and Ecosystem Accounting (SEEA-EA) [8], which is actively being implemented in national statistical systems worldwide. With its network and hierarchical structure, SEEA can serve as the core of a territorial climate change information system. It includes data on greenhouse gas emissions, the turnover of low-carbon technologies in the national economy, the carbon footprint of national products, the size and condition of various ecosystems and their vulnerabilities, the mitigation and adaptation functions of ecosystems, the impact of ecosystems on the national greenhouse gas balance, and more. Additionally, the Global Set of Climate Change Statistics and Indicators is largely (14% of indicators) composed of SEEA-EA-generated data, and the UNECE set of climate change statistical indicators is almost entirely (more than 60%) made up of SEEA-EA indicators. The SEEA-EA is also being developed in relation to the Classification of the Functions of Government[5]. Furthermore, harmonized climate measurements with the SEEA-EA have been developed in recent years under the G20 Data Gaps Initiative (DGI-3). This is expected to provide policymakers with an expanded toolkit for developing economic and financial policies to address climate change issues in conjunction with financial innovations and inclusive growth. Therefore, the UN SEEA-EA Standard [9-11] can set the basic requirements for the development and implementation of climate statistics in public administration and risk management to better represent opportunities for sustainable investment, innovation, and insurance in an unstable and changing external environment.

III. Results

The interdisciplinary research on the formation and strengthening of climate-related information support was conducted as part of the development of the National Adaptation Plan (NAP) for medium- and long-term planning and implementation of climate change adaptation measures in the Kyrgyz Republic, on assignment from the UNDP office in the Kyrgyz Republic. This research included methodological developments and practical steps to establish a broad system of climate services in the country and to build the capacity of two governmental bodies: the National Statistical Committee and the Hydrometeorological Service of the Kyrgyz Republic, both of which are authorized to produce and disseminate climate information with official state status. The findings of the research, as presented in this article, initiated the establishment of climate change statistics in the Kyrgyz Republic. The key events and outcomes of the Project can be considered as milestones in the development of national climate change statistics (see Figure 2).

[5] The Classification of Functions of Government (COFOG), developed by the OECD, categorizes government expenditure data from the System of National Accounts by the purpose for which the funds are used.

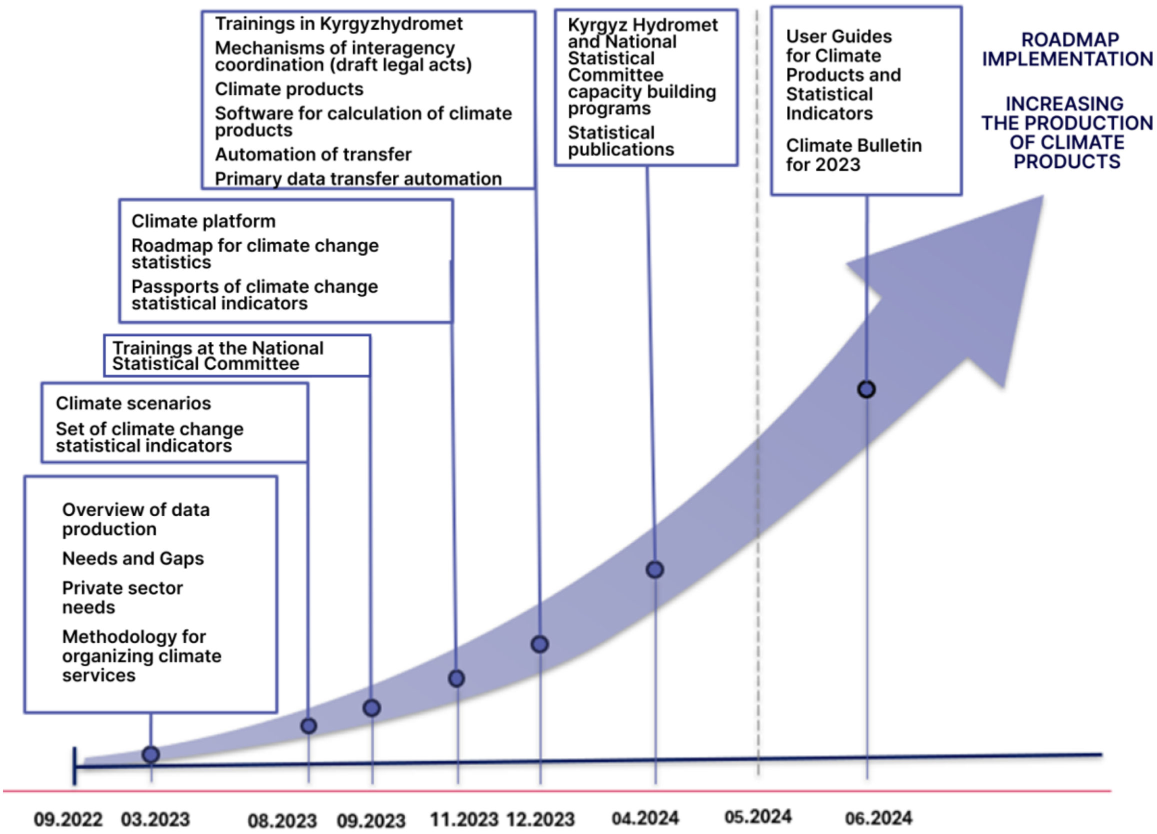

Figure 2: *The Process and Outcomes of the Project in the Establishment of New Climate Change Statistics in the Kyrgyz Republic*

Firstly, a significant characteristic of the Project was the development and implementation of a methodological approach aimed at effective planning that focuses on achieving specific outcomes[6] in improving the system of climate change statistical monitoring. This approach aims to increase the resilience of a wide range of stakeholders to climate change risks.

The systematic nature of the developed approach is defined by the complexity of climate change issues. The negative impacts and the risks they create affect the social, economic, environmental, and institutional aspects of sustainable development for regions and economic entities. An integrated "top-down" and "bottom-up" approach was implemented. Numerous meetings, trainings, and joint discussions identified the need to avoid the trap of system-bound analysis that relies solely on local knowledge, while also incorporating local institutional conditions, generational wisdom, and informal, socio-culturally driven factors and phenomena.

The research and decision-making were based on two planning principles: (1) an incremental approach, which is step-by-step progress, where decisions are made gradually as participants in discussions gather new information, and (2) a protective approach, prioritizing the interests of vulnerable and socially disadvantaged populations. Through mutual adaptation among stakeholders, actions were implemented progressively, considering all economic, environmental, social, political, cultural, and other conditions.

This methodological choice explains the significant number of interactive meetings involving the National Statistical Committee of the Kyrgyz Republic and the Hydrometeorological Service of the Kyrgyz Republic, with broad participation from government experts, members of the interagency working group on climate change indicators, and representatives from the real sector of the economy. These interdisciplinary discussions not only educated participants on the basics and specifics of climate statistics but also helped create indicators using the Global Set of Climate Change Statistics and other international recommendations. Over 500 people participated in 24

[6] The term "effective planning" currently refers to specific activities that lead to change [12].

training sessions, with more than 60% being women. The importance of women's traditionally strong role in Kyrgyz society and the need to formalize this role in public interactions were emphasized. Protecting the rights of rural widows to access water in conditions of water scarcity was also highlighted.

This approach enabled the gradual and multifaceted development of the set of climate change statistical indicators, their consideration by agencies and the private sector, and the formal development of each indicator and their metadata passports. As a result, by 2025, a significant portion of climate statistics will be published regularly. An important element of effective medium- and long-term planning was the creation of a Roadmap for the development of climate change statistics in the Kyrgyz Republic, which is essential for the successful introduction of new indicators into official statistics.

Secondly, a mechanism has been initiated in the Kyrgyz Republic for implementing climate change indicators within the institutional framework to enhance the resilience of climate-vulnerable sectors of the economy and a wide range of stakeholders to both current and future climate risks.

The availability of quality measurements for research and planning activities has improved, and the range of available hydrometeorological indicators has expanded. A new section in the official statistics of the Kyrgyz Republic has been developed – the "Climate Change Statistics" section, which includes 95 indicators grouped by specialized topics (drivers, impacts, vulnerability, mitigation, adaptation) and economic sectors (agriculture and irrigation, health, disaster risk management, biodiversity conservation and forestry, water management, urban areas, waste, industrial processes and product use, energy). This reflects various aspects of the climate agenda – hydrometeorological, environmental, socio-economic, demographic, and institutional. This is a foundational and pioneering step for many countries, not only in the development of official statistics but also in the national system of climate monitoring and services. Additionally, the project developed specialized climate indices and products. Before the project, only three hydrometeorological indicators were included in official statistics; now, there are 14.

As part of this project, research on current climate change and projections for the end of the century was conducted using two selected greenhouse gas emission scenarios, SSP5-8.5 and SSP2-4.5. Homogenized monthly temperature and precipitation data from 22 meteorological stations in Kyrgyzstan for the period 1980-2021 were used. Eleven climate products and methodologies for their calculation were developed to improve the quality of hydrometeorological data, and these were included in the national climate change statistical indicators by the National Statistical Committee of the Kyrgyz Republic. The basis for development was the WMO climate indices, which assess the impact of current climate and its changes on various socio-economic conditions in Kyrgyzstan. Climate products were calculated for the period 1980-2022 based on data from 13 meteorological stations in different climatic regions of Kyrgyzstan.

The development and first releases of the statistical publication "Climate Change Indicators in the Kyrgyz Republic" and the climate bulletin "Current State and Climate Change in the Kyrgyz Republic for 2023" will undoubtedly raise awareness among a wide range of stakeholders, with further editions planned on a regular basis. Additionally, two user manuals have been developed for the first time: a Climate Products User Manual and a Climate Change Statistical Indicators User Manual.

The priority focus is on expanding the understanding of climate vulnerability in the economic sectors of the Kyrgyz Republic. This ensures that a broad audience can comprehend the information and make relevant and rational decisions. During training presentations and open discussions, participants reflected on which physical climate threats hinder the development of vulnerable sectors and challenge public health and emergency systems. They were guided by an expanded understanding of the involved actors, considering the needs of government authorities, private sector representatives, and households. As a result, a set of statistical indicators was developed that covers a wide range of climate-related issues and phenomena, reducing climate vulnerability.

For example, despite data production challenges, the indicator "water reserves in glaciers" was adopted. It was recognized that as glaciers are predicted to melt, water scarcity issues will intensify, both for the Kyrgyz Republic and neighboring Central Asian countries. A gender-inclusive indicator was adopted: "The proportion of the population without access to centralized life-support systems (water supply, heating, cooling), including persons with disabilities and households that have lost a male breadwinner."

It is also significant that as a result of the project, the skills of the National Statistical Committee and the Hydrometeorological Service of the Kyrgyz Republic in constructive interaction with users of climate information have been enhanced, including their ability to listen to real needs and willingness to develop in response to those needs.

To ensure the integration of climate risks into the management system of the Kyrgyz Republic, a set of measures on institutional, organizational, technical, and operational support was implemented. Institutionally, the following were prepared: (1) Proposals to amend regulatory and legal acts of the Kyrgyz Republic in the field of hydrometeorology and official statistics in terms of climate information production and provision; (2) Draft regulatory and legal acts to establish interagency coordination mechanisms; (3) A roadmap for improving climate change statistics in the Kyrgyz Republic; (4) Institutional mechanisms for interagency cooperation to develop a climate change statistical database in the Kyrgyz Republic and maximize the use of available statistical and departmental information resources.

Organizationally, the following were developed: (1) Proposals for changes to the structure of the Hydrometeorological Service's departments related to climate data and index production and provision; (2) Proposals for changes to the structure of the National Statistical Committee's departments related to climate data and index production and provision; (3) Long-term capacity-building programs for the National Statistical Committee and the Hydrometeorological Service of the Kyrgyz Republic, which were approved by the heads of these agencies.

Technically, the following were proposed: (1) Software and databases for calculating climate products (indices) for the Hydrometeorological Service of the Kyrgyz Republic; (2) Software for calculating climate products; (3) Databases for climate information production.

To institutionalize operational processes[7], the following were developed: (1) Recommendations for climate product production and climate change statistical indicator data production; (2) Guidelines for interagency coordination in producing official climate change statistics; (3) Materials for creating and maintaining a platform for interaction with the private sector.

Thirdly, a significant step was taken in developing a broad climate service system in the Kyrgyz Republic to increase the resilience of a wide range of stakeholders to climate risks and uncertainties.

For the first time in Central Asia, methodological recommendations were made for the development of a national climate service system, covering providers, mainly the National Statistical Committee and the Hydrometeorological Service of the Kyrgyz Republic, and a wide range of consumers (see Figure 3). Climate service is defined as the provision of climate information for making the best decisions by individuals and organizations. The focus was on the chain of climate information production and provision, viewed as the subject of climate service and integrating climate data[8] and climate products[9].

[7] In this case, an operational process is a regularly repeated sequence of activities that transforms primary data into climate indices and climate data that are made available to stakeholders.
[8] Climate data are historical and real-time climate observations and direct model outputs covering historical and future periods. All climate data should be accompanied by information on how these observational data and model outputs were derived ("metadata")
[9] Climate products are summarized climate data. Products combine climate data with climate knowledge to enhance their value for adaptive management. Its use in the management process allows the climate factor to be adequately valued, thereby ensuring, as far as possible, that adaptive capacity is enhanced through climate informed decision-making [13].

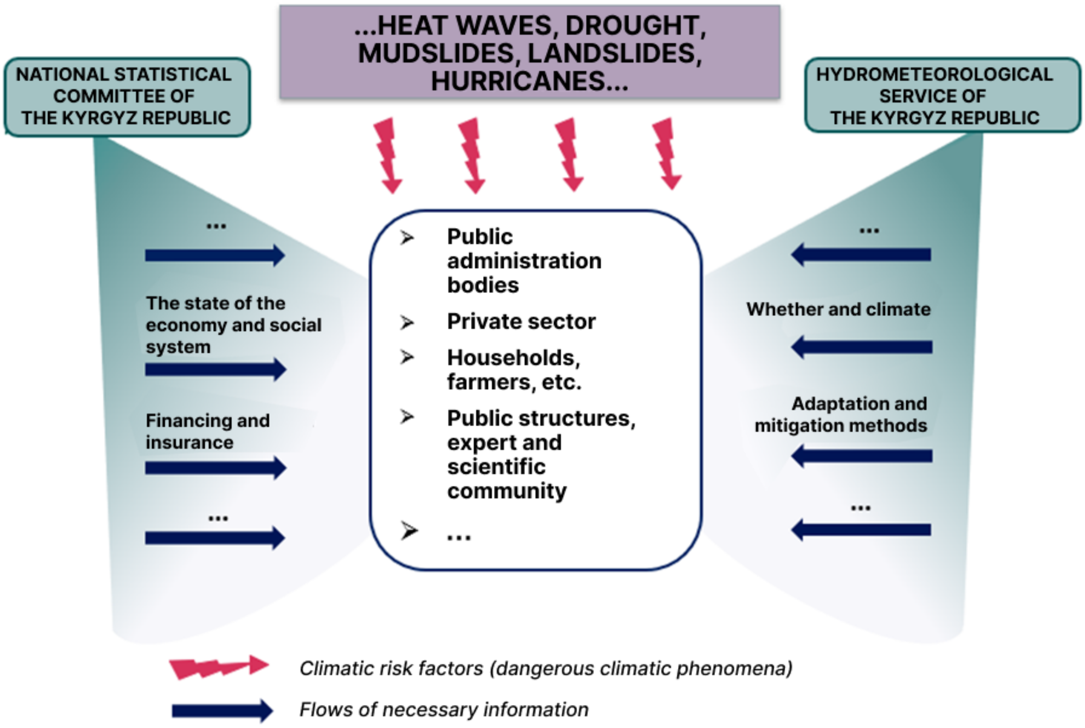

Figure 3: *Climate Service – A Necessary Factor for the Successful Implementation of the Climate Agenda of the Kyrgyz Republic*

A well-established and responsive climate service system creates the foundation for effective actions to reduce climate risks, adapt to climate change, and mitigate negative climate impacts. It is a broad yet targeted system addressing the problems and needs of a wide range of stakeholders. This includes diverse but crucial information – about weather and climate, past and future events, long-term trends, threats, and opportunities. This information is essential for making practical decisions regarding sector management, avoiding business losses, preventing threats to health and human life, and protecting material objects and infrastructure.

A significant focus during the project was on motivating and educating users about the relevance of climate information for various stakeholders – including specialists from territorial management bodies, sectors of the economy, representatives of large businesses and small producers, households, banks, credit organizations, insurance companies, public, and non-commercial entities. Each of these stakeholders has its own goals and perspectives on climate risks, but they all share a need for reliable and timely climate data.

All project activities were aimed at enhancing the capacity for producing and providing climate information by key climate service providers – the state agencies in meteorology and statistics. Their role as providers of reliable data is increasingly important in a world characterized by rising misinformation. The work of these agencies covers every link in the information production chain, including data collection, regular data processing, storage, provision, and the development and implementation of new climate indicators, all of which are legally and methodologically substantiated and supported by qualified personnel. Each stage of the process undergoes verification.

IV. Discussion

The climate agenda of the Kyrgyz Republic must be harmonized with global sustainable development goals (SDGs) and the overall systemic Concept of National Security of the country[10]. Defining and quantifying "climate change risk," with relevant measurement indicators, is central to analyzing development processes, as it is fundamental for assessing the socio-economic consequences of climate change. This, in turn, is crucial for planning effective, impactful, and fair climate adaptation and mitigation strategies. Extensive literature discusses the challenges, methods, results, and development of this fruitful research area, which has been evolving for nearly 40 years [14-18].

Today, the importance of creating effective climate statistics in every country is widely recognized. For example, in the Kyrgyz Republic, climate statistics have already been identified as a crucial and timely response to contemporary climate challenges. This significance is justified by the following premises:

- It is essential to improve the quality and availability of climate data, as the more we know about the climate crisis, the better we can identify and manage climate risks. Climate data will help analyze risks affecting the economy, monetary policy, price stability, and the financial system more effectively.
- The role of official government data needs to be strengthened; for instance, for the widespread adoption of climate insurance, which, according to UNDP, will become as significant as investments and innovations in the coming years.
- Transparency in climate-related issues must be ensured, and the quality of economic evaluation of targeted projects should be improved when transitioning to a green economy (cost-benefit analysis).

The special significance of the implemented project and its results lies in the initiation of a new trend in the development of statistics and meteorological support. The development of the indicator system and roadmap, and their integration into a unified statistical observation system in the Kyrgyz Republic, turned out to be a complex interdisciplinary and research-intensive task, as climate change impacts social, economic, environmental, and institutional aspects. Moreover, climate impacts are intertwined with increasing anthropogenic pressures on water, food, energy, biodiversity resources, inequality, and poverty.

The particular characteristic of the present time is that new concepts, terms, and institutions related to climate change and its impacts on various aspects of public life are becoming part of community and state life, expert discourse, official rhetoric, and decision-making systems. These are relatively new phenomena, yet climate challenges increasingly demand action, creating a need for new measurements and indicators. In this context, the project implemented comprehensive measures for institutional, organizational, technical, and operational support of new management actions within the climate agenda, ensuring that new "rules of the game" complement existing norms, rules, and practices without contradicting them. Thus, the following were ensured at each stage:

- Alignment with the needs of climate-vulnerable sectors and other stakeholders in the Kyrgyz Republic;
- Adherence to international recommendations and best practices;
- Consistency with existing local institutional and organizational conditions, including the ability to produce climate information and enable users to understand how to use it effectively.

Internationally, the project has localized the UN Global Statistical Indicators to the Kyrgyz

[10] Concept of National Security of the Kyrgyz Republic (Decree of the President of the Kyrgyz Republic of December 20, 2021 № 570).

Republic, adapting them to local needs and conditions for reducing climate risks and uncertainties. Each indicator has been developed with a metadata passport. Another significant result is the set of climate products developed with the help of international consultants on our project. Importantly, these climate products are included in the statistical set for the first time. This grants them high national status – at the level of official statistics, with regular production and publication of data, which undoubtedly indicates the systematic approach of the Kyrgyz Republic to assessing climate risks and threats, as well as to monitoring and transparency in climate actions. This represents an important innovative step in improving climate service formats.

V. Conclusions

The study of potential directions for the development and mechanisms of implementing climate change statistics in the Kyrgyz Republic, as an informational basis for reducing climate risks, led to several conclusions important both theoretically and practically.

Theoretically, with the increasing climate burden, defining and quantifying "climate change risk," as well as developing corresponding measurement indicators, is essential for analyzing the development processes of the Kyrgyz Republic. The reason is that without measuring risk reflection, planning climate risk reduction measures and conducting environmental and socio-economic assessments of climate change consequences are impossible.

The development of an adapted system of climate statistics indicators for the Kyrgyz Republic is the foundation for planning effective, impactful, and fair climate strategies (adaptation and mitigation). This indicator system should meet the basic requirements of the *new paradigm* of climate data in the context of growing volumes at global and national levels. The new system of climate change statistical indicators should: ensure free access to high-quality and reliable measurements for scientific research, enhance the utility and comprehensibility of climate information and data for a broad interdisciplinary audience, and integrate climate risks into country and regional management systems, covering a range of dangers from extreme weather events to long-term climate changes.

Since climate impacts affect systemic aspects of sustainable development, methodological approaches should combine "top-down" and "bottom-up" approaches, as well as incremental and protectionist approaches to planning.

Practically, new realities in the climate agenda in the Kyrgyz Republic, as in many other countries, involve increased demands and a transition to a new qualitative level for national statistical and meteorological services. These services are required to expand and strengthen their skills to provide adequate responses to new needs for reliable climate data, update their systematic scientific and calculation bases for producing climate data, and ensure regular publication. Enhancing the significance of these services on international platforms, such as the UN, WMO, and Eurostat, is also crucial. Such transformations will undoubtedly contribute to strengthening and substantively developing the Kyrgyz Republic's image as an active player in the international climate agenda.

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References

[1] Global Set of Climate Change Statistics and Indicators: Implementation Guidelines. ST/ESA/STAT/SER.M/101. Studies in Methods Series M No. 101 / UN. Department of Economic and Social Affairs. Statistics Division. New York, 2024.

[2] WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970-2019). Geneva, 2021.

[3] Chen, L., Msigwa, G., Yang, M., Osman, A., Fawzy, S., Rooney, D., Pow, S.Y. (2022). Strategies to achieve a carbon neutral society. Environmental Chemistry Letters, 20:2277-2310.

[4] Overpeck, J., Meehl, G., Bony, S., Easterling, D. (2011). Climate Data Challenges in the 21st Century. Science, 331:700-702.

[5] Implementation and Effects of the G20 Financial Regulatory Reforms: 2020 Annual Report / Financial Stability Board. 2020. 22 p.

[6] Human Development Report 2021/2022 / UNDP.New York, 2022.

[7] Shea, D.; National Center for Atmospheric Research Staff (Eds.). The Climate Data Guide: Statistical & Diagnostic Methods Overview. Last Modified 25 August 2014. Boulder, Colorado, USA.

[8] 9th Joint OECD/UNECE Seminar on the Implementation of the System of Environmental-Economic Accounting (SEEA) 18-20 March 2024, Palais des Nations, Geneva, Switzerland. URL: https://unece.org/sites/default/files/2023-11/SEEA_Seminar9_concept_note_final.pdf.

[9] System of Environmental Economic Accounting 2012 – Central Framework. Statistical Papers, Series F, No. 109. Sales No. E12.XVII.12 / United Nations. 2014.

[10] System of Environmental-Economic Accounting – Ecosystem Accounting. Final Draft. Version 5 / United Nations. 2021.

[11] System of Environmental-Economic Accounting 2012: Central Framework / UN. 2012.

[12] Benveniste G. Mastering Planning Policy / Edited by M. Kalantarova. M., 1994.

[13] Implementation plan of the Global Framework for Climate Services. WMO, 2014.

[14] Stern, N., Peters, S., Bakhshi, V. et al. Stern Review: The Economics of Climate Change. London: HM Treasury, 2006.

[15] Carleton, T.A., Hsiang, S.M. (2016). Social and economic impacts of climate. Science, 353(6304).

[16] Howard, P.H., Sterner, T. (2017). Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates. Environmental & Resource Economics, 68 (1):197-225.

[17] Tol, R.S.J. (2018). The Economic Impacts of Climate Change. Review of Environmental Economics and Policy, 12(1):4-25.

[18] Bosello, F., Parrado, R. (2020). Macro-economic assessment of climate change impacts: Methods and findings. Ekonomiaz, 97: 45-61.

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THE STUDY ON THE POTENTIAL OF SOLAR POWER TOWER AND SUPERCRITICAL CARBON DIOXIDE BRAYTON CYCLE TO REDUCE CARBON EMISSION IN AZERBAIJAN

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Abstract

The environmental challenges posed by conventional energy production necessitate a shift towards sustainable alternatives. This study explores the potential of solar power, particularly focusing on Solar Power Tower (SPT) systems utilizing the supercritical carbon dioxide (sCO_2) Brayton cycle, as a viable solution to reduce carbon emission in Azerbaijan. Through data collection and analysis, the study evaluates the efficiency and feasibility of SPT systems. Results indicate that the sCO_2 Brayton cycle offers a net cycle efficiency of 50.8%, surpassing traditional power generation methods. The Direct Normal Irradiance (DNI) analysis identifies the Nakhchivan Autonomous Republic as an optimal location for deploying SPT technology due to its high DNI levels. This transition to advanced solar technologies promises to meet rising energy demands, reduce carbon emissions, and mitigate environmental degradation, aligning with global efforts to address climate change and secure a sustainable future.

Keywords: solar energy, concentrated solar power, solar power tower, supercritical CO_2, photovoltaic, power cycles, sustainable energy

I. Introduction

Most current types of energy production and utilization cause environmental issues at local, regional, and global scales, reducing the quality of life and endangering human health. Fossil-fueled power plants produce large amounts of environmentally harmful emissions of gases such as carbon dioxide (CO_2). In 2023, the total CO_2 emissions from energy-related activities increased by 1.1% compared to the previous year. This rise pushed total CO_2 emissions to a record high of 37.4 billion tones [1]. Furthermore, worldwide energy demand is expected to rise approximately 1.5–3 times by 2050 [2]. By 2025, it is projected that the CO_2 intensity of global power generation will attain a level of 417 grams of CO_2 emitted per kilowatt-hour (g CO_2/kWh) [3]. This record-high level of emissions highlights the need for action to reduce carbon emissions, as these high levels significantly worsen global climate change. Thus, there is a pressing need to use renewable energy resources, such as solar, wind, hydropower, and biomass, instead of fossil fuels for energy generation. 26.49% of the world's electricity production comes from renewable energy sources [4], but for Azerbaijan, this figure is 20.3% [5].

The most developed form of renewable energy in Azerbaijan is hydropower, but in 2022, severe droughts recorded in several countries led to a decrease in confidence in hydropower [6]. On the other hand, solar energy has the highest economic potential among renewable energy sources. On average, each square meter of Earth receives roughly 342 watts of solar energy in a year [7]. This amounts to an enormous total energy input of 44 quadrillion (4.4×10^{16}) watts [7]. In Azerbaijan, the economic potential of solar energy sources is 23,000 MW [5], exceeding the economic potential of other renewable sources. Therefore, it is essential to develop solar energy, considering its vast potential globally and in Azerbaijan.

Solar energy stands out as an affordable renewable energy source with significant potential to generate clean and environmentally friendly energy. Solar radiation can be transformed into either heat or electricity through diverse solar conversion technologies. Solar energy conversion technologies can be classified into solar photovoltaic (PV) and concentrated solar power (CSP) systems. Solar photovoltaic systems directly transform solar radiation into electricity, whereas concentrated solar power systems convert solar radiation into heat energy. Solar power plants installed in Azerbaijan are all based on PV technology. However, CSP offers several advantages over PV systems. Thus, this study will focus on the potential installation of CSP technology in Azerbaijan.

Concentrated Solar Power (CSP) is a technology capable of large-scale electricity generation, providing reliable energy and the ability to deliver power on demand through thermal energy storage. CSP plants offer advantages such as high efficiency and the capability to accumulate heat, enabling operation nearly around the clock. Accumulating heat in CSP technology helps generate electricity when desired and stabilizes and controls power generation. CSP plants produce 33.3% more electrical energy compared to PV plants. [8]. Many positive aspects of CSP-type power plants make the installation and operation of this technology more appropriate. There are four distinct types of concentrated solar power systems: parabolic dish, parabolic trough, solar power tower, and Linear Fresnel reflector. They differ in how the sun's rays are concentrated in the receiver.

Solar Power Tower (SPT) technology is a promising option due to its wide temperature range, comparable cost per kilowatt, and longer storage durations [9]. SPT power plants work with the Rankine cycle. Rankin is pretty advanced, so there's little room for improvement. The simple Rankine cycle can achieve an efficiency of up to 29.6% [10], and specific studies indicate that this can potentially be improved to as much as 41% [11]. On the other hand, when supercritical carbon dioxide (SCO_2) is used as the working fluid in the Brayton cycle, the work efficiency appears to exceed 50% [12]. Supercritical CO_2 Brayton cycles can increase power plant capacity and efficiency, which will play a role in improving SPT technology [9].

In this paper, we investigate the potential of SPT power plants in reducing CO_2 emissions in Azerbaijan. We analyze the sCO_2 Brayton recompression cycle, develop a numerical model of an SPT plant, and propose a suitable region for its installation in the country. The results highlight the environmental benefits and feasibility of using SPT technology in Azerbaijan's shift towards renewable energy.

II. sCO_2 Brayton Recompression Cycle

Our study examines the sCO_2 (supercritical carbon dioxide) Brayton recompression cycle [13]. The recompression cycle reduces inefficiencies in the internal heat recovery process by using two recuperators and adding a secondary compressor. The cycle starts by compressing sCO_2 from low to high pressure with a compressor. As the sCO_2 is compressed, its temperature increases significantly due to its high heat capacity. Under these conditions, the sCO_2 enters the heat exchanger from the compressor, where it receives heat from an external source. In the heat exchanger, thermal energy from the Solar Power Tower heats the sCO_2, further increasing its temperature and pressure. The high-temperature, high-pressure sCO_2 then expands through a turbine, converting thermal energy into mechanical work. This turbine drives a generator to produce electrical power. After expansion, the sCO_2 enters the heat exchanger at a lower temperature and pressure to release the absorbed heat, reducing its temperature and preparing it for the next cycle. At reduced pressure and temperature, the sCO_2 is recompressed by the compressor to initiate the subsequent cycle.

Fig. 1 demonstrates a schematic representation of this cycle, which serves as the foundational framework for modeling an SPT power plant.

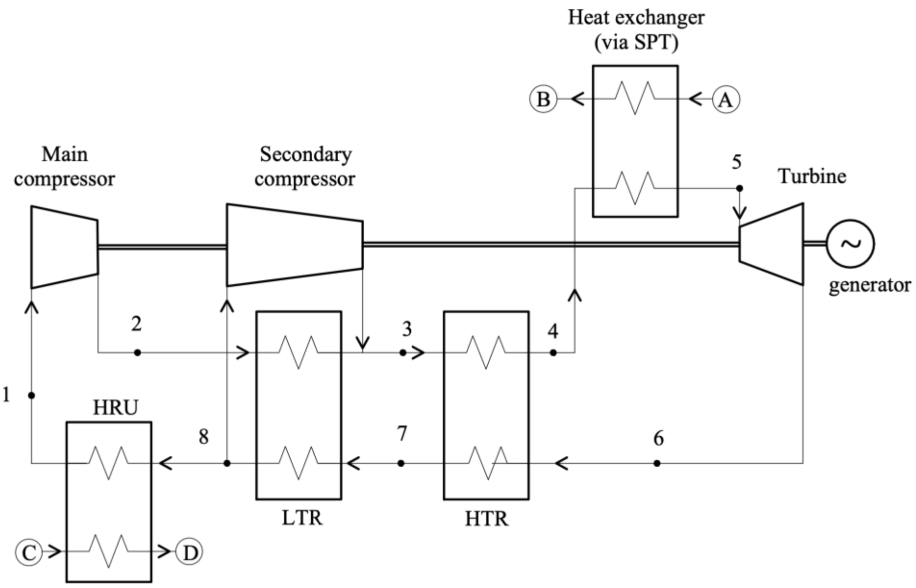

Figure 1: *Schematic of the sCO_2 Brayton recompression cycle [13]*

III. Methods

The numerical model of the sCO_2 cycle for the SPT power plant was constructed using Mathcad software. The numerical model uses primary assumptions outlined in Table 1.

Table 1: *Main assumptions for the sCO_2 cycle*

Parameter	Value	Parameter	Value
Heliostat field, F_H, m^2	67	Maximum cycle temperature, t_0, °C	650
Heliostat reflectance, R_H	0,82	Maximum cycle pressure, P_{max}, MPa	25
Maximum irradiance of the heliostat mirror E_H, W/m^2.	610	Minimum cycle pressure, P_{min}, MPa	10,5
Maximum receiver irradiance, E_i, MW/m^2	1,94	Relative internal turbine efficiency, η	0,84
Receiver absorption coefficient, A_{absorp}	0,95	Receiver emissivity ε_{em}	0,94

Direct Normal Irradiance (DNI) rates were analyzed to determine the optimal area for SPT implementation in Azerbaijan. This analysis was facilitated by utilizing geographic data provided by Solargis [14].

Additionally, we employed a comparative analysis approach to examine CO_2 emissions and technical parameters of the six most powerful non-renewable power plants in Azerbaijan: Shimal, Janub, Sumgayit, Gobu, Sangachal, and Azerbaijan. The parameters selected for this analysis are Capacity (MW), Cycle type, Cycle efficiency, and CO_2 emissions per kWh. Technical parameters were obtained through direct correspondence with the relevant power plant. This analysis was employed to evaluate the reduction in CO_2 emissions by replacing non-renewable power plants with SPT systems.

IV. Result and Discussion

I. Performance of power cycle

Our study began with an examination of the operational mechanisms of the sCO_2 Brayton recompression cycle. We based our calculations on the assumptions outlined in Table 1. We demonstrate the T-s diagram of the sCO_2 Brayton recompression cycle based on our results in Figure 2.

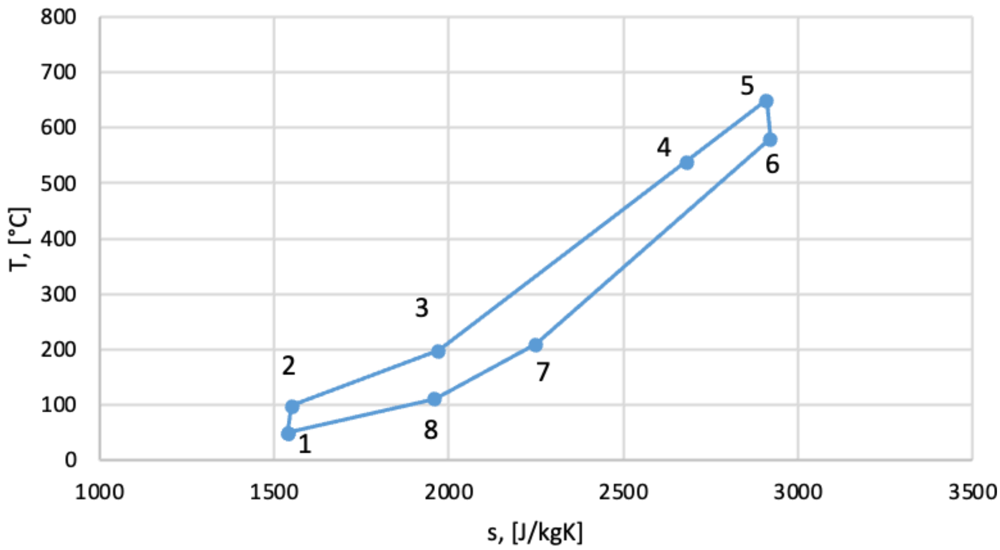

Figure 2: *T-s diagram of sCO_2 Brayton recompression cycle*

Additionally, we documented the outcomes of our calculations in Table 2. This table includes key performance metrics and design specifications such as sCO_2 mass flow, number of heliostats, heat exchanger characteristics, and operational parameters. These results provide a comprehensive overview of the system's performance under the specified conditions, demonstrating the feasibility and efficiency of using sCO_2 in SPT technology. The data in Table 2 are critical for validating the model and comparing the projected performance against conventional power generation systems. The efficiency of the cycle was determined to be 50.8%, indicating that the sCO_2 Brayton cycle is more appropriate for use in SPT plants than the Rankine cycle.

Table 2: *Main results for the sCO_2 cycle*

Parameter	Value	Parameter	Value
CO_2 mass flow at turbine inlet, D_0, kg/s	364	Turbine electric power, **MW**	72.8
Net heat input, Q_{ty} *KW*	107714	Main and secondary compressor electric power, **MW**	10/8
Receiver area, **m²**	57.5	Number of heliostats	3512
Capacity of Solar power tower, N_e, MW	54,8	Net Cycle efficiency, %	50.8

II. Identifying promising regions for Solar Power Tower deployment

Direct Normal Irradiance (DNI) is critical in analyzing a suitable area in Azerbaijan for an SPT. CSP systems, including SPT, concentrate sunlight on a small area to generate high temperatures. This concentration process is effective only with direct sunlight, making DNI an essential parameter for assessing the potential efficiency and viability of the system. High DNI values indicate a greater availability of direct sunlight, which is necessary for optimizing the performance of CSP technologies. The analysis of DNI levels in Azerbaijan, conducted using data from the Solargis [14], reveals several regions with significant potential for the deployment of SPTs. Upon analyzing the DNI maps, the Nakhchivan Autonomous Republic in Azerbaijan emerges as a particularly suitable location for the installation of an SPT power plant. The high DNI levels in this region indicate optimal conditions for the efficient operation of CSP systems, making it a promising site for harnessing solar energy effectively.

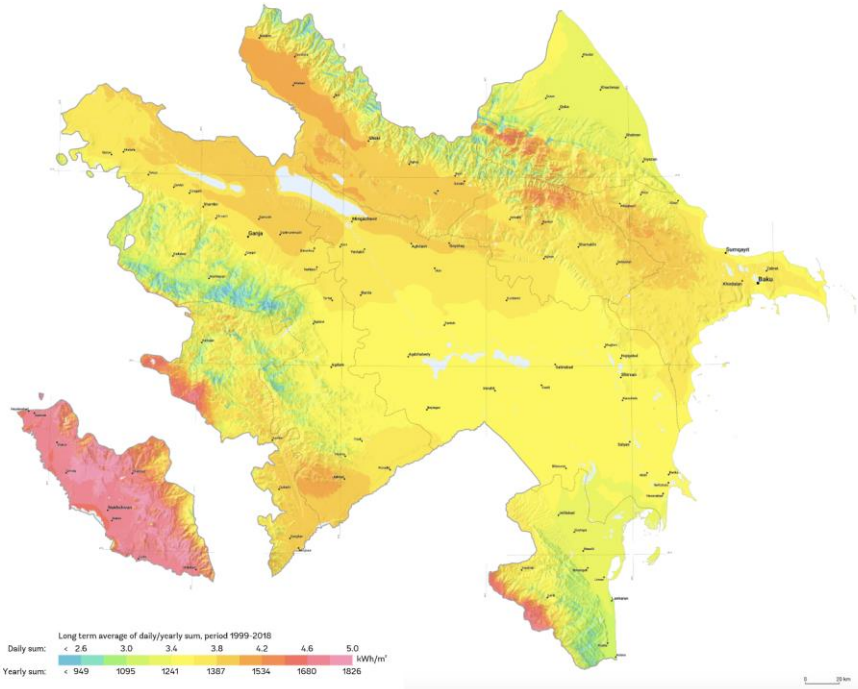

Figure 3: *Direct Normal Irradiation map of Azerbaijan [14]*

III. Potential for emissions reduction through Solar Power Tower

As previously discussed, energy production is a major contributor to environmental pollution. Therefore, it is essential to evaluate the carbon dioxide (CO_2) emissions produced by the operational non-renewable power plants in Azerbaijan. Table 3 provides the technical parameters of operational non-renewable power plants in Azerbaijan, including capacity, cycle type, cycle efficiency, and CO_2 emissions per kWh of electricity generated. The data highlights significant disparities in both capacity and efficiency among the power plants, with capacities ranging from 2400 MW for Azerbaijan TPP to 300 MW for the Sangachal Power Plant. Furthermore, variations in CO_2 emissions per kWh range from 0.414 kg for Shimal Power Plant to 0.538 kg for Azerbaijan TPP, underscoring the importance of technological efficiency in mitigating environmental impact in the energy sector.

Table 3: *Technical parameters of non-renewable power plants in Azerbaijan*

Name of the power plants	Capacity (MW)	Cycle	Efficiency of cycle (%)	CO_2 emitted per kWh (kg)
Azerbaijan TPP	2400	Rankine	37	0.538
Shimal Power Plant	800	Combined	55	0.414
Janub Power Plant	780	Combined	51	0.446

Sumgayit Power Plant	525	Combined	52	0.438
Gobu Power Plant	380	Otto	48	0.464
Sangachal Power Plant	300	Diesel	46	0.495

The data in Table 3 highlights that the Shimal Power Plant, with the highest efficiency, emits 0.414 kg of carbon per kWh of energy production. Replacing this plant with a SPT power plant would reduce CO_2 emissions by 331,200 kilograms per hour.

V. Conclusion

In conclusion, the urgent need to address environmental challenges stemming from conventional energy sources necessitates a transition towards sustainable alternatives. The exploration of solar energy, particularly through advanced technologies like the sCO_2 Brayton cycle, presents a promising pathway toward achieving this transition. By leveraging the efficiency and lower emissions offered by such innovative approaches, Azerbaijan can not only meet rising energy demands but also prevent environmental damage.

The comprehensive analysis conducted in this study underscores the viability and potential of solar power towers (SPT) utilizing the sCO_2 Brayton cycle in Azerbaijan's energy landscape. Through data collection, modeling, and analysis, we have demonstrated the feasibility of integrating advanced technologies into the energy infrastructure, thus opening avenues for a more sustainable future. With a net cycle efficiency of 50.8%, these systems offer a substantial improvement over traditional power generation methods.

Furthermore, the examination of Direct Normal Irradiance (DNI) levels in Azerbaijan reveals promising locations for the deployment of solar power towers, with the Nakhchivan Autonomous Republic emerging as particularly suitable. These regions boast high DNI levels, indicating optimal conditions for harnessing solar energy efficiently and effectively.

By adopting Solar Power Tower technologies with supercritical CO_2 cycles, Azerbaijan and other countries can fulfill their energy requirements while substantially contributing to global efforts to address climate change and safeguard the planet for future generations.

References

[1] CO_2 emissions in 2023. (2023). International Energy Agency: IEA.

[2] Dinc I, Zamfirescu C. Sustainable energy systems and applications. New York Dordrecht Heidelberg London: Springer; 2011. p. 823. http://dx.doi.org/10.1007/ 978-0-387-95861-3

[3] Electricity Market Report 2023. (2023). International Energy Agency: IEA. https://iea.blob.core.windows.net/assets/255e9cba-da84-4681-8c1f-458ca1a3d9ca/ElectricityMarketReport2023.pdf

[4] World – World Energy Balances: Overview – Analysis - IEA. (n.d.). IEA. https://www.iea.org/reports/world-energy-balances-overview/world

[5] Azərbaycanda bərpa olunan enerji mənbələrindən istifadə | Azərbaycan Energetika Nazirliyi. (2024, June 3). Azərbaycan Energetika Nazirliyi. https://minenergy.gov.az/az/alternativ-ve-berpa-olunan-enerji/azerbaycanda-berpa-olunan-enerji-menbelerinden-istifade

[6] 2022 was the year of drought. (2022, December 31). NBC News. https://www.nbcnews.com/science/environment/2022-was-year-drought-rcna62410

[7] The Balance of Power in the Earth-Sun System. (2005). National Aeronautics and Space Administration. https://www.nasa.gov/wp-content/uploads/2015/03/135642main_balance_trifold21.pdf

[8] Awan, A.B., Zubair, M., Praveen, R.P., Bhatti, A.R.: Design and comparative analysis of photo-voltaic and parabolic trough based CSP plants. Solar Energy. 183, 551–565 (2019). doi:1016/j.solener.2019.03.037.

[9] Mammadov, F., Kalbaliyev F. (2024). Analysis of Technical and Technological Parameters of Solar Thermal Power Plants. International Conference on Smart Environment and Green Technologies.

[10] Balmer, R.: Vapor and gas power cycles. In: Elsevier eBooks. pp. 447–534 (2011). doi:10.1016/b978-0-12-374996-3.00013-0.

[11] Reyes-Belmonte, M.A., Sebastián, A., Spelling, J., Romero, M., González-Aguilar, J.: Annual performance of subcritical Rankine cycle coupled to an innovative particle receiver solar power plant. Renewable Energy. 130, 786–795 (2019). doi:10.1016/j.renene.2018.06.109.

[12] Atif, M., Al-Sulaiman, F.A.: Energy and exergy analyses of solar tower power plant driven supercritical carbon dioxide recompression cycles for six different locations. Renewable & Sustainable Energy Reviews. 68, 153–167 (2017). doi: 10.1016/j.rser.2016.09.122.

[13] M. Binotti, M. Astolfi, S. Campanari, G. Manzolini, and P. Silva, “Preliminary Assessment of sCO2 Power Cycles for Application to CSP Solar Tower Plants,” in Energy Procedia, 2017, vol. 105, pp. 1116–1122.

[14] Solargis. (n.d.-b). Global Solar Atlas. The World Bank Group. https://globalsolaratlas.info/map?c=39.956912,47.04895,7&r=AZE

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THE ECONOMICS OF SUSTAINABLE URBAN DEVELOPMENT: HUMAN PARTICIPATION IN CREATING ECO-FRIENDLY CITIES

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Abstract

This study delves into the economic foundations of sustainable urban development, focusing on the active role of human participation in the transition toward eco-friendly cities. It investigates how sustainable cities balance economic growth, environmental conservation, and social equity, all while adapting to the challenges posed by rapid urbanization, climate change, and resource depletion. The research underscores the role of sustainable economic practices such as renewable energy integration, green infrastructure, and waste reduction in fostering urban resilience. A central theme of the book is the significance of human involvement in driving sustainability efforts. It explores how citizen engagement, policy-making, and community-driven initiatives shape eco-friendly urban landscapes. The book also highlights the economic benefits of public participation in decision-making processes, showing how informed communities can support green innovations and enhance city-wide efforts to reduce environmental impact. By exploring case studies and best practices from cities worldwide, the book demonstrates how human-driven policies and economic strategies can contribute to the development of cities that are environmentally sound, socially inclusive, and economically sustainable. This work serves as a guide for policymakers, urban planners, and citizens aiming to create more livable, sustainable urban spaces.

Keywords: Sustainable urban development, eco-friendly cities, human participation, green infrastructure, circular economy, renewable energy

I. Introduction

As urban populations continue to grow, cities around the world face unprecedented challenges, including environmental degradation, resource scarcity, and social inequality. The concept of sustainable urban development emerges as a critical framework to address these challenges, emphasizing the need for an integrated approach that harmonizes economic growth, environmental protection, and social inclusivity. This paradigm shift requires not only innovative economic strategies but also active human participation in creating eco-friendly urban environments.

Human involvement is crucial in the transition toward sustainable cities, as it fosters a sense of ownership and accountability among community members. Citizens play a vital role in shaping urban policies, influencing consumption patterns, and advocating for environmentally friendly practices. By engaging individuals and communities in decision-making processes, cities can harness local knowledge and foster a culture of sustainability that resonates with residents.

This study aims to explore the economics of sustainable urban development, highlighting the interplay between human participation and the creation of eco-friendly cities. It will examine successful case studies that illustrate how collaborative efforts can lead to innovative solutions, ultimately promoting urban resilience and a higher quality of life. The focus will also be on practical strategies and policies that can facilitate citizen engagement and foster sustainable economic growth in urban settings.

As we navigate the complexities of modern urbanization, understanding the economic implications of sustainable development and the critical role of human participation will be essential in building cities that are not only environmentally sustainable but also socially just and economically viable. Through this exploration, we aim to provide valuable insights for policymakers, urban planners, and community stakeholders striving to create sustainable urban futures.

II. Methods

This study employs three specific methods to investigate the economics of sustainable urban development and the role of human participation in creating eco-friendly cities:

1. Surveys: A structured survey will be administered to residents of selected urban areas. The survey will include quantitative questions designed to assess participants' awareness of sustainable practices, their attitudes toward eco-friendly initiatives, and their level of engagement in local decision-making processes. A sample size of approximately 500 participants will be targeted to ensure a representative cross-section of the urban population. Data from the surveys will be analyzed statistically to identify correlations between citizen participation and perceptions of sustainable urban development.

2. Case Studies: Detailed case studies will be conducted on three cities known for their innovative approaches to sustainable urban development—such as Copenhagen, Singapore, and Vancouver. Each case study will examine the specific policies implemented, the role of community involvement, and the measurable outcomes in terms of environmental sustainability and economic growth. Data will be collected through document analysis, interviews with local stakeholders, and site visits to assess the practical implications of these initiatives.

3. Focus Groups: Focus group discussions will be organized with diverse community members, including local residents, business owners, and representatives from environmental organizations. These discussions will aim to gather qualitative insights into community attitudes toward sustainable urban development, barriers to participation, and suggestions for improvement. Each focus group will consist of 8-10 participants, and sessions will be recorded and transcribed for thematic analysis, allowing for a deeper understanding of collective perspectives and shared experiences related to eco-friendly city initiatives.

III. Results

As the world confronts the growing challenges posed by climate change and environmental degradation, the construction industry has emerged as a key contributor to achieving a sustainable future. Eco-friendly building practices have become essential in this effort, providing innovative solutions that not only meet the immediate demands of urbanization but also protect the planet's long-term health. A core principle of eco-friendly building is the utilization of renewable energy sources. Since buildings are significant energy consumers and reliance on fossil fuels greatly contributes to carbon emissions, integrating technologies such as solar panels, wind turbines, and other renewable energy solutions allows structures to generate clean energy, thereby reducing their dependence on non-renewable resources and minimizing their ecological footprint.

The selection of construction materials is crucial to a building's environmental sustainability. Eco-friendly building practices prioritize the use of green materials, which are defined by their low environmental impact throughout their entire life cycle. This includes materials with recycled content, those sourced from sustainable forests, and products that exhibit a low carbon footprint. Such materials promote a more sustainable construction sector by conserving natural resources and decreasing the emissions associated with conventional materials.

Energy efficiency is central to eco-friendly building practices. Advanced technologies, such as smart building systems, energy-efficient HVAC (heating, ventilation, and air conditioning) systems, and superior insulation methods, optimize energy use within buildings. By implementing these technologies, buildings can significantly lower their energy consumption, which in turn reduces greenhouse gas emissions and reliance on non-renewable energy sources.

Eco-friendly building practices play a vital role in mitigating the carbon footprint linked to the construction and operation of buildings. The use of renewable energy sources and energy-efficient technologies contributes directly to the decrease of greenhouse gas emissions. Additionally, incorporating carbon sequestration strategies, such as green roofs and carbon-absorbing building materials, further helps offset the carbon impact of construction activities. Traditional construction methods typically involve the extraction and consumption of large quantities of natural resources. In contrast, eco-friendly building practices emphasize resource conservation. By utilizing recycled or reclaimed materials, minimizing waste through efficient construction techniques, and selecting materials with lower environmental impacts, these practices help preserve ecosystems and biodiversity. The resilience of the built environment in addressing climate change is a vital aspect of modern construction practices. Eco-friendly building methods enhance the overall resilience of structures by integrating features like climate-responsive design, resistance to natural disasters, and the adaptive reuse of existing buildings. This strategy ensures that buildings can endure the challenges posed by a changing climate, thereby contributing to the longevity and sustainability of the built environment.

In conclusion, eco-friendly building practices signify a transformative shift in the construction industry, moving beyond traditional norms to adopt a sustainable and environmentally conscious approach. The use of renewable energy sources, the integration of green building materials, and the implementation of energy-efficient technologies together redefine how buildings are designed, constructed, and operated. By reducing carbon footprints, conserving natural resources, and bolstering the overall resilience of the built environment, these practices stand as beacons of hope for a more sustainable and ecologically responsible future.

IV. Discussion

The transformative potential of Sustainable Urban Design goes beyond merely environmental aspects; it deeply influences community dynamics and significantly enhances the quality of life for urban residents. This examination delves into the multifaceted impact of Sustainable Urban Design on communities, highlighting its holistic approach to promoting community well-being, fostering a sense of belonging, improving residents' quality of life, and advancing social equity.

Sustainable Urban Design embraces a comprehensive perspective that prioritizes the overall well-being of communities. Recognizing the interplay between social, economic, and environmental factors, this approach shapes the urban experience by addressing the diverse needs and aspirations of community members. The goal is to create inclusive, resilient, and vibrant urban spaces that enhance the collective welfare of residents.

At its core, Sustainable Urban Design is committed to inclusive design principles that guarantee public spaces are accessible and usable for all. This commitment extends beyond mere regulatory compliance; it involves actively engaging with the varied needs of different demographic groups, including people with disabilities, seniors, and children. By incorporating universal design concepts, urban spaces become welcoming and inclusive, fostering a sense of belonging for all.

Moreover, Sustainable Urban Design emphasizes social cohesion and connectivity. The arrangement of urban spaces, the design of public gathering areas, and the creation of pedestrian-friendly environments encourage social interactions and community engagement. Integrating green spaces, parks, and communal areas acts as a catalyst for social cohesion, offering residents opportunities to connect, share experiences, and build a collective identity within their neighborhoods.

The design of sustainable urban environments significantly affects residents' health and well-being. Access to green spaces, walkable neighborhoods, and recreational facilities contributes to physical and mental wellness. Incorporating nature into the urban landscape improves air quality, reduces stress levels, and promotes overall health. Sustainable Urban Design advocates for designs that prioritize public health, acknowledging the link between a healthy environment and individual well-being.

Sustainable Urban Design also aims to enhance living conditions by optimizing resource use and creating comfortable, energy-efficient homes. Energy-efficient buildings that maximize natural light and ventilation not only minimize environmental impact but also provide healthier living spaces. Additionally, mixed-use developments ensure that essential services, educational institutions, and recreational amenities are conveniently located, improving residents' overall quality of life (fig.1).

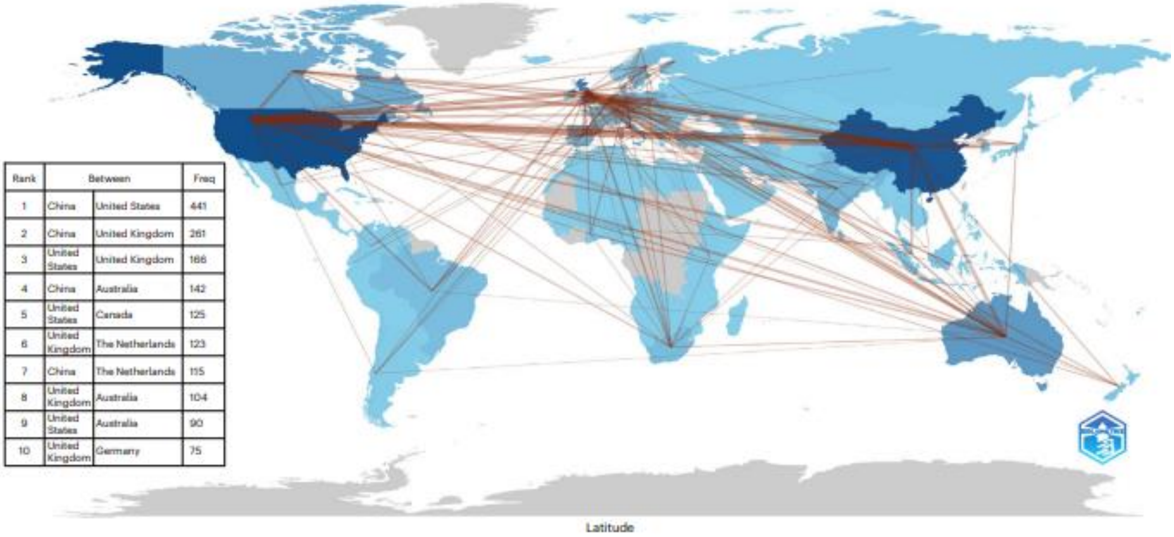

Figure 1: *10 collaborating countries in SDG11 research*

China followed by the United States and the United Kingdom dominates SDG11 research collaborations. There are significant connections among European, North American and Asian institutions, while Africa is less connected with Asia and Latin America and the Caribbean. Freq, frequently.

Equity is a key focus of Sustainable Urban Design, addressing issues of accessibility and affordability. Public infrastructure, including transportation systems and public spaces, is designed with the needs of all residents in mind, especially those with limited mobility or financial resources. Public transportation systems, cycling lanes, and pedestrian-friendly pathways enhance accessibility, ensuring urban amenities are reachable for everyone, regardless of socio-economic status.

Furthermore, Sustainable Urban Design actively tackles socio-economic disparities by promoting inclusive housing policies and equitable development strategies. This includes providing affordable housing, creating mixed-income neighborhoods, and implementing initiatives to prevent gentrification. By encouraging socio-economic diversity within urban areas, Sustainable Urban Design contributes to building resilient communities better equipped to face economic fluctuations and social transformations.

In conclusion, the community impact of Sustainable Urban Design extends beyond physical structures and environmental concerns associated with urban planning. By adopting a holistic approach to community well-being, fostering a sense of belonging, improving residents' quality of life, and promoting social equity, Sustainable Urban Design emerges as a powerful catalyst for positive social change. As cities evolve, the principles of sustainable urban design provide a roadmap for creating urban environments that prioritize the needs of diverse communities, ultimately leading to more livable, inclusive, and equitable urban spaces.

A significant trend of urbanization is unfolding worldwide, with nearly 55% of the global population currently living in urban areas. Projections indicate that this trend will continue, potentially doubling the urban population by 2050. Cities are also responsible for approximately 75% of carbon emissions, 70% of energy consumption, and 80% of global GDP, positioning them at the forefront of the fight for sustainable development and climate action. Effective urban management has the potential to promote sustainable development, leading to increased productivity and innovation. Data clearly illustrates the connections between planned urbanization and human development; however, the prevalence of informal settlements presents a major obstacle to the positive correlation between urban growth and improvements in income, health, and education conditions (see Figure 2).

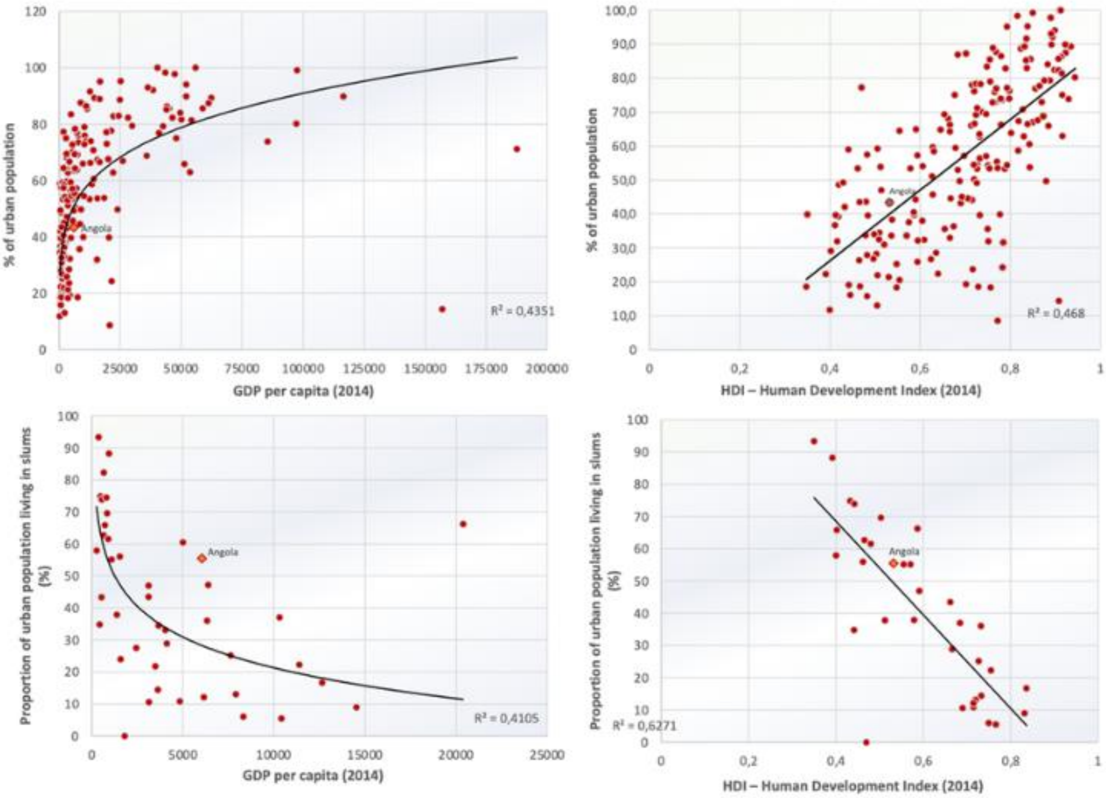

Figure 2: *Correlation between HDI and GDP per capita growth with unplanned urbanization*

There is a broad consensus within the development community regarding the significance of cities and urbanization in achieving sustainable development, as highlighted in recent global agendas. One of the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda is entirely focused on urban issues: SDG 11, which addresses sustainable cities and communities. This goal comprises 10 targets aimed at ensuring that cities and human settlements are inclusive, safe, resilient, and sustainable. However, urban issues extend beyond these specific targets and can be found across all 16 other SDGs, as shown in Figure 03. In addition to these interconnections, urbanization serves as a catalyst for achieving the SDGs, with cities functioning as engines of economic growth, innovation, and socio-economic opportunities.

Building local capacity for urban planning is essential to ensure that urbanization effectively contributes to sustainability. This need is highlighted in the 2030 Agenda under the SDG 11.3 target, which aims to enhance inclusive and sustainable urbanization and capacities for participatory, integrated, and sustainable human settlement planning and management in all countries by 2030. In response to this challenge, UN-Habitat launched a toolbox methodology called "Our City Plans" at the 2020 World Urban Forum. This initiative is designed to support cities in implementing the New Urban Agenda and localizing the SDGs at the community level in a participatory and incremental manner.

Figure 3: *The interconnectivity between SDG 11 targets and other SDGs targets*

The theories and concepts discussed above have shaped and influenced various urban agendas over the past two decades (see Fig.2). Among these, the sustainable city stands out as the most prominent and frequently referenced urban agenda. This concept, rooted in sustainable development (SD) and sustainable city development (SCD), first emerged with the 1994 Aalborg Charter and has been significantly influenced by the UN Agenda 21 and the 2002 Melbourne Principles on Sustainable Cities, which were sponsored by the United Nations Environment Programme (UNEP) and ICLEI.

Different scholars provide varying interpretations of what constitutes a sustainable city. Some view it as a framework for enhanced ecological and resource protection, while others see it as a means to ensure economic growth through greener technologies, balancing ecological stability and social equity—a perspective often referred to as “greener urban growth.” Additionally, some emphasize the importance of addressing all three pillars of sustainability.

Mori and Yamashita provide a comprehensive yet straightforward definition: a sustainable city maximizes socio-economic net benefits while considering environmental constraints and the limits of economic and social inequality. Similarly, Roseland defines a sustainable community, whether urban or rural, as dynamic and engaged in activities that sustain the environment, empower citizens, and ensure that the needs of both current and future generations are met. Scholars also highlight essential characteristics of sustainable urban form: inclusivity and accessibility, health and thoughtful planning, adequate density, energy efficiency, resilience to climate and other risks, economic competitiveness, affordability, protected ecosystems, eco-friendly transportation infrastructure, and robust regional linkages.

In addition to the sustainable city agenda, at least five other prominent urban agendas have been identified in the literature: Ecocity, low-carbon city, resilient city, knowledge city, and smart city. The concepts of green city and livable city are also present but are often regarded as subcategories of ecocity and sustainable city, respectively. Contrary to common assumptions among policymakers, these various agendas do not all share the same theoretical foundations, and their terminologies should not be used interchangeably.

The ecocity and green city concepts, rooted in long-standing principles of deep ecology and the humanities, gained traction in the late 20th century and were primarily operationalized within a broader eco-urbanism movement. Approaches such as eco-districts, zero-carbon cities, and low-impact urban developments align with this spirit of collective sustainability.

On the other hand, smart and digital city agendas focus on utilizing digital technology and infrastructure to enhance well-being, along with a greater emphasis on governance. However, in practice, the smart city agenda often lacks a holistic approach to sustainability, with initiatives that may not adequately address social equity or ecologically responsible resource management. Bibliometric and webometric analyses further reveal a lack of widely accepted definitions or coherent understandings of the smart city agenda, potentially leading to tensions and disconnections in research, policy, and practice.

References

[1 Cowley, R.; Joss, S.; Dayot, Y. The smart city and its publics: Insights from across six UK cities. Urban Res. Pract. 2018, 11, 53–77

[2] Naidoo, R., & Fisher, B. (2020). Reset Sustainable Development Goals for a pandemic world.

[3] Moore, S. A. (2020). Adventures in sustainable urbanism, by Robert Krueger, Tim Freytag and Samuel Mossner (eds.) Albany, NY, State University of New York Press, 2019.

[4] Zhou, L., ZHOU, C., CHE, L., & WANG, B. (2020). Spatio-temporal evolution and influencing factors of urban green development efficiency in China. J. Geogr. Sci, 30(5), 724-742.

[5] Duan, Y., & Yang, X. H. (2012). The Evolution of Chinese Social Ethos since the Reform and Opening Up. Theoretical Discussion, No. 4, 39-41.

[6] Gerrig, R. J., & Zimbardo, P. G. (2009). Psychology and Life. London: Pearson Education.

[7] Green, L., & Kreuter, M. (1994). Health Promotion Program Design (Translated by Huang J.T.). Shanghai: Yixing University Press.

[8] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[9] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[10] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[11] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/

E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[12] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[13] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[14] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144

METHODS FOR ANALYZING REGIONAL ENTREPRENEURSHIP WHILE INCORPORATING SUSTAINABLE DEVELOPMENT PRINCIPLES

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Abstract

This article explores the challenges of assessing local business activity through the lens of sustainability and innovation in success metrics. Current economic realities and environmental challenges have required the adaptation of traditional assessment methods to adequately reflect all aspects of business impact. The study begins with a critical look at outdated assessment approaches that neglect the long-term perspective and focus on immediate economic results. The paper emphasizes that such methods often ignore a wide range of factors, from the social environment to the environment. The author presents a new model of metrics that balance economic progress with environmental and social responsibility. These metrics place a particular emphasis on combining data on business impact on society and the ecosystem, allowing for a more accurate and comprehensive assessment. To implement the proposed model, attention is paid to the need to create information systems capable of collecting, analyzing, and interpreting data according to the new criteria. This will play a key role in providing regional political and economic leaders with the tools to make informed decisions. The article also illustrates how some regions are already successfully applying these metrics, demonstrating significant progress in their approaches to assessing entrepreneurial activity. These examples confirm the potential for achieving sustainability and well-being through the thoughtful application of these approaches. It concludes by highlighting that the shift to assessing entrepreneurial activity with a sustainable development perspective is not only important for the current state of regions, but also contributes to ensuring a better future.

Keywords: entrepreneurial activity, sustainable development, regional level

I. Introduction

There are over 5.7 million small businesses operating in Russia. These organizations form a critically important share of the country's economic structure, defined by the employment of 10 to 100 people and an annual income of no more than 800 million rubles. A comparison with the number of large (13.6 thousand) and medium (17.9 thousand) enterprises emphasizes their special role: the number of small firms reaches 213.8 thousand.

Over the past decade, the Russian small business segment has undergone a profound transformation and has emerged as a leading element of the economic system.

The prosperity and further development of such enterprises are closely linked to a number of conditions - from the economic to the technological situation both in the regions and in the country as a whole. In light of the above, the task of developing and implementing assessment strategies that will help small businesses meet the criteria for sustainable development is becoming more urgent. These approaches have broad potential: they not only ensure the stability of companies, but also provide tools for monitoring the impact of business processes on the environment and the social environment.

The concept of sustainable development emerged from the awareness of the environmental damage caused by industrialization. A striking echo of this was the London Smog Disaster of 1952, which killed over 12,000 people. This event had a significant impact on the growth of environmental awareness. Then, in 1972, the Club of Rome put forward The Limits to Growth, which outlined twelve prospects for global economic development and emphasized the rational use of resources and demographic regulation. The term "sustainable development" gained wide recognition after the publication of the UN report Our Common Future in 1987, which defined it as development that does not compromise the ability of future generations to meet their own needs. This document, prepared by a commission headed by Gro Harlem Brundtland, became a milestone in the promotion of global sustainability.

In modern Russia, the key importance of sustainability is relevant for small businesses, for which modernization and sustainable growth are becoming a matter of primary attention. The European Union, where about 25 million small and medium-sized enterprises operate, creating more than half of the bloc's GDP and providing jobs for almost 100 million people, can be considered a model for Russia. European SMEs are active in solving global problems, including climate change, rational use of resources and maintaining social sustainability.

Assessing the performance of small businesses based on sustainable development criteria helps not only to adapt to the changing market environment in Russia, but also to make a significant contribution to solving global problems, while strengthening the competitiveness of these enterprises.

II. Methods

This study aims to create a proven assessment approach that will enable small businesses to integrate sustainability principles into their strategies and operations. The analysis examined best practices and tools used in this area, including authoritative methodologies such as Acra, Common Sense, and the National Rating Agency, which specializes in ESG principles. In addition, an extensive review of academic literature and online sources was conducted to identify the most significant elements of sustainability.

Previous research shows that adhering to sustainable practices can increase financial returns by 80%, highlighting the critical importance of such strategic business reorientation. In the Russian context, voluntary adoption of ESG standards beyond statutory requirements is observed, highlighting the market's readiness for deeper integration of sustainable practices.

III. Results

In September 2024 A survey of 4.4 thousand organizations not related to small businesses was conducted. Its results showed that **entrepreneurial activity index** , characterizing the general state of entrepreneurial behavior of organizations, compared to August 2024:

- in extractive industries increased by 0.5 percentage points to 6.2%;
- in the manufacturing sector decreased by 0.1 percentage points to 6.8%.

In September 2023 In 2015, the index of business confidence in the extractive sector of the economy was 2.1%; in the manufacturing sector of the economy – 4.4%.

Entrepreneurial activity index (seasonally adjusted), %

Dynamics of the entrepreneurial activity index , %

	since 2017				
	minimum value		average value	maximum value	
	date	meaning		date	meaning
Mining	May 2020	-13.0	0.3	June 2018	7.8
Manufacturing industries	February 2017	-10.0	-1.0	June 2024	7.0

	2023				2024								
	Sept.	Oct.	Nov.	Dec.	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.
Mining	2.1	1.7	1.7	2.7	5.2	5.1	6.0	4.0	5.1	7.0	6.7	5.7	6.2
Manufacturing industries	4.4	4.5	6.4	5.1	5.8	5.4	6.1	6.8	6.6	7.0	6.9	6.9	6,8

An example of assessing entrepreneurial activity in the extractive and manufacturing industries demonstrates the importance of monitoring the entrepreneurial confidence index. In particular, significant fluctuations have been observed in these sectors since 2017. For example, the minimum value of the index in the extractive industry was recorded in May 2020 (-13%), which can be explained by the global economic consequences of the pandemic. The maximum was reached in June 2018 (7.8%), indicating economic recovery in the post-crisis period.

In manufacturing, the minimum index value (-10%) was observed in February 2017, which was associated with internal economic problems, and the maximum (7.0%) was recorded in June 2024. Such changes show how sensitive this sector is to external and internal factors.

To better understand the current state of regional economies and identify trends, it is necessary to take into account seasonal and structural fluctuations, as well as external factors such as international sanctions, commodity price fluctuations and changes in global trade.

Developing relevant metrics for sustainable development

Based on traditional methods of assessing entrepreneurial activity, it is necessary to supplement them with indicators reflecting sustainability. Such metrics should be adapted to the specifics of specific industries and regions. The following approaches are proposed for this purpose:

1. **Integrated sustainability indices** :
Introduction of indices that integrate economic, environmental and social indicators, allowing to assess not only current production activity but also long-term prospects.
2. **Environmental Performance Indices** :
Develop metrics that measure the impact of production activities on the environment, including emissions, resource use, and waste management.
3. **Social indicators** :
Assessing the impact of companies' activities on social conditions in the region, including job creation, wage levels, participation in social projects and human capital development.

The study and assessment of existing models demonstrates their value as tools for assessing ESG parameters in the activities of enterprises, with a special emphasis on the comprehensive approach proposed by the Acra methodology. Approaches based on the analysis of the processes of individual companies and their compliance with the set ESG goals are actively considered in the scientific community as some of the most promising for achieving results. The study by Shestakov A.B. and Gusev S.A. presents a comparative characteristic of various methods, most of which are based on economic models, while expert approaches presented by such authors as Shesterikov N.V. also find recognition. It is noted that more than two dozen methods for assessing the sustainability of enterprises are described in the scientific literature. Each of them has its own unique characteristics and requires a separate assessment in terms of practical applicability. The key features, advantages and possible disadvantages of these approaches are presented in the table for a clear comparison and ease of subsequent analysis.

The small size and flexibility of management in small businesses contribute to their quick response to market trends and ease of testing innovations. This makes a small enterprise an attractive choice for many citizens wishing to engage in entrepreneurial activity. However, in Russia, the practice of highly targeted use of the potential of small firms in terms of their impact on the sustainability and prosperity of both individual regions and the country as a whole has not yet been established.

Small businesses play a crucial role in stimulating the local economy, improving the social environment and addressing political issues. However, businesses in the Far East face serious economic challenges, including high costs, remoteness from economically developed centres, difficult climatic conditions and increased transport costs. This has traditionally made the region dependent on government subsidies, and the reduction of government support only worsens the situation, reducing the competitiveness of local businesses. Ultimately, this leads to the economic isolation of the Far East from the rest of the country.

The situation is critical in the small business sector, where many companies are in the crisis stage of their life cycle. The problems are exacerbated by their dependence on external financing, limited access to capital and ineffective state support. The high cost of capital and problems with securing ownership often lead to the insolvency of small enterprises, which highlights the need for reforms in this sector to improve their viability and support sustainable development.

To overcome the crisis of small business, a new course is aimed at improving state support and improving financial management within companies. In order for small business prosperity to become a reality, state aid measures must be carefully adjusted, and financial strategies must be fine-tuned to improve the overall efficiency of enterprises.

Managers of small businesses face the need to master strategic management skills, including the ability to deeply analyze both the internal and external business environment, find opportunities for development and sustainable progress. Small business should be considered an important component of the country's economic system, requiring development in harmony with national goals. Strategic management of small business has its own nuances and complexities, which is why there is a need to develop theoretical and methodological tools aimed at maintaining and strengthening the stability of this segment. This also involves the selection and adaptation of scientific and practical resources designed to ensure the successful functioning of small businesses.

In modern scientific literature, the issue of forming strategic directions for small business development has been touched upon relatively recently and is inspired by the experience of states with established market economies. The lack of a well-developed structure for supporting small business development at the regional level in modern Russia often leads to inconsistency in development strategies, undermining the potential for sustainable interaction with the country's economy as a whole.

IV. Discussion

In this regard, there is an urgent need for research aimed at establishing mechanisms for sustainable development in small businesses. This is understood as the ability to maintain positive, both qualitative and quantitative, changes in business activity, maintaining viability even under the influence of external changes (state of dynamic homeostasis), which in turn contributes to the economic growth of the Russian Federation, using available resources as efficiently as possible.

Structuring the sustainable development of small business involves the creation of a regulatory framework, the formation of conditions for activating entrepreneurial activity among the population, and the implementation of priority tasks to stimulate small and medium-sized businesses.

business, as well as the development of methods for assessing the current state and development prospects of enterprises in this sector. Sustainable development can be achieved through competent management and targeted forward movement of the system.

Important economic and social indicators for achieving sustainability in the sphere of small business are highlighted, including: formation of an optimal number of small business structures sufficient to create a critical mass; promotion of economic growth and encouragement of business initiatives; effective and efficient action aimed at fulfilling the set tasks and the most productive use of resources; improvement of the standard of living of both participants in the "small business" system and broader sections of the population.

Transformations in small business and strategic planning of its support pose multiple challenges due to its unique role in the economy. The lack of a comprehensive approach to supporting this sphere undermines the opportunities for sustainable economic development of regions. Therefore, it is important to improve and integrate theoretical and practical experience to create an effective model of sustainable development of small business in a specific area.

Given the importance of small businesses in creating jobs, maintaining competitiveness, and stimulating innovation, it is important to formulate a strategy that is oriented toward adapting to economic changes and challenges. This will allow resources to be used more consciously and ensure the long-term sustainability of small businesses, contributing to the overall economic well-being of regions.

Promoting sustainable development of small businesses requires a clear development of concepts and mechanisms for their implementation in practice, emphasizing the need for active actions to implement the established principles of sustainability. The key aspect here is the transition from a borrowing-oriented to a profitability model that brings positive effects to the whole society. This entails comprehensive state assistance, covering financial, property, insurance and credit support, as well as improving the information and legal framework. The need to improve legislation requires the development and implementation of such key bills as on small entrepreneurship, on investments and on insurance of small businesses, as well as on lending to small businesses.

$$\text{Sustainable development of small businesses} = \int_{t_0}^{t_1} (\alpha C(t) + \beta A(t) + \gamma S(t) + \delta L(t))\, dt$$

Where:

- $C(t)$ $A(t)$, $S(t)$, $L(t)$ are functions of time representing the dynamics of concepts, active actions, government support and legislative initiatives.
- α, β, γ, δ – weighting coefficients reflecting the importance of each factor for sustainable development.
- $\int_{t0}^{t1}$ −the integral over time from the initial moment t_0 to the final moment t_1, showing the accumulated effect of all factors on sustainable development over a given period of time.

This formula reflects the influence of various factors (concepts, actions, support, legislation) on the sustainable development of small businesses, taking into account their evolution over time. The integral emphasizes that business sustainability is a process that develops over time, and not a one-time phenomenon.

1.1. Resource efficiency index **(I_{res}):**

where P_{output} is the output of products (revenue, profit), P_{input} is the cost of resources.

$$I_{res} = \frac{P_{output}}{P_{input}}$$

1.2. Economic growth index (I_{growth}):

$$I_{growth} = \frac{B_t}{B_{t-1}} \times 100\%$$

This formula can be adapted and used to develop a method for assessing entrepreneurial activity at the regional level, taking into account the principles of sustainable development.

Each of the factors in the formula C(t),A(t),S(t),L(t) can be adapted to assess the specifics of regional entrepreneurial activity:

- C(t)— concepts and strategies of regional development. Each region may have its own characteristics that affect the sustainable development of small businesses (for example, access to natural resources, technological infrastructure, transport accessibility).
- A(t)— active actions of entrepreneurs in the region. This may include innovative projects, the number of new startups, and the dynamics of small business development.
- S(t)— regional support. This factor includes support measures provided by the regional government: subsidies, grants, tax breaks, and infrastructure projects.
- L(t)— regional legislative initiatives. Here, one can take into account the peculiarities of regional legislation aimed at developing entrepreneurial activity.

The recognition of the importance of small business as a driver of economic change has led to the desire to deepen the substantive-analytical understanding of its functioning and internal processes. Such analysis aims to activate entrepreneurial resources for the implementation of large-scale economic reforms. Strategically oriented management of small business should be aimed at strengthening the macroeconomic situation in the country and stimulating economic development in each region. Entrepreneurship existing at the local level significantly affects the socio-economic progress of the regions, their stable development is the cornerstone for the dynamic economic growth of the country.

Promoting sustainable development of small businesses requires a clear development of concepts and mechanisms for their implementation in practice, emphasizing the need for active actions to implement the established principles of sustainability. The key aspect here is the transition from a borrowing-oriented to a profitability model that brings positive effects to the whole society. This entails comprehensive state assistance, covering financial, property, insurance and credit support, as well as improving the information and legal framework. The need to improve legislation requires the development and implementation of such key bills as on small entrepreneurship, on investments and on insurance of small businesses, as well as on lending to small businesses.

In the context of reforming the Russian economy, new forms and methods of support are being sought, which increases the importance of government bodies at all levels and determines their role in the country's economic strategy. Assistance to small businesses consists of creating favorable conditions for the independence of citizens and providing support from the state, which will become the basis for sustainable economic growth. The tactics and strategy for developing entrepreneurship include developing government programs, providing investment financing, creating methodologies for assessing and supporting investment projects, and improving the tax system. Not only the success of individual entrepreneurs, but also the economic well-being of the country as a whole depends on these steps.

Modern small business management will call for innovative methods and the creation of a fundamentally new set of tools. Such tools, based on accurate diagnostics and differences in the operating conditions of small businesses in different regions, should allow for a separate assessment and improvement of the quality of financial management. An important element here will be specific indicators that will track and analyze business activity, profitability and solvency at the enterprise, as well as the possibility of comprehensive rating of enterprises taking into account their development and attractiveness for investment.

Within the framework of the strategy for sustainable growth of small business, special attention is paid to the economic liberalism of citizens, implying their active integration into the entrepreneurial sphere and strict assistance from government agencies. This is the path to consistent strengthening of the country's economic potential. The strategy involves the mobilization and adaptation of entrepreneurial abilities, the adoption of a balanced system of government support measures, the interaction of small and medium-sized businesses, as well as the expansion of foreign economic relations and the strengthening of the positions of small companies both locally and nationally.

The concept is based on a number of key principles:

- Initiative and creative activity of people in the business sphere, transforming material assets into profitable investments, instead of simple rent. This approach is aimed at creating social value and welfare.

- Develop a comprehensive strategy that involves small businesses interacting with the environment and directing limited resources where they can bring the greatest benefit to the regional economy.

- Application of reliable government incentive programs that are comprehensive in nature and take into account the unique features, economic conditions and potential changes in the development of business entities, regions and the country as a whole.

To implement this strategy for sustainable development of small businesses, it is essential to have effective tools to achieve the goals:

1. Develop a comprehensive government assistance program covering legal, financial and material assistance, which will include measures on registration, taxation, lending and protection.

2. Allocation of significant budgetary funds, their direction and monitoring of the effectiveness of investments for the benefit of small businesses, with subsequent assessment of the impact of these investments on the quality of life in the region.

3. Development and application of scientific methods for determining investment objects based on indicators of success and efficiency of working capital use.

4. Improving the legal and informational framework for providing access to economic resources, taking into account the need to focus them on priority tasks and strategic directions.

5. Using specialized approaches to planning and economic analysis, adapted to the unique conditions and characteristics of small business organization.

References

[1] Taranova IV, Kasaeva TV, Shavrina JO, Tekeeva HE, Boeva KY Methods of fraud management in the financial services market of the region // Business 4.0 as a Subject of the Digital Economy. Cham, 2022. P. 291-295.

[4] Blind K., Mangelsdorf A., Niebel C., Ramel F. Standards in the global value chains of the European Single Market // Review of International Political Economy. 2017. Vol. 25. P. 1–21. 10.1080/09692290.2017.1402804.

[5] Towards a Methodology of Sustainable Competitiveness of Organization / TA Salimova, LI Biryukova, AT Shilkina, EV Khakhaleva // International Journal of Civil Engineering and Technology. — 2018. — Vol. 9, issue 11. — Pp. 161–172. URL: https://www.researchgate.net/publication/329732083_Towards_a_methodology_of_sustainable_competitiveness_of_organization

[6] Podkolzina IM, Taranova IV, Paytaeva KT, Revunov SV, Abrosimova TF Innovative approaches in financial support for regional economic security // The Challenge of Sustainability in Agricultural Systems. Heidelberg, 2021, pp. 549-558.

[7] Tretyakova E.A., Alferova T.V., Pukhova Yu.I. Analysis of methodological tools for assessing the sustainable development of industrial enterprises // Vestnik PGU. Series: Economics. 2015. No. 4(27). URL : https :// cyberleninka . ru / article / n / analiz - metodicheskogo - instrumentariya - otsenkiustoychivogo - razvitiya - promyshlennyh - predpriyatiy (date of access: 09/24/2024).

[8] Svechnikova S.S. Relevance of integrating sustainable development priorities into a company's investment and financial strategies: theoretical and practical aspects, 2020. No. 2(8). URL: https://cyberleninka.ru/article/n/aktualnost-integratsiiprioritetovustoychivogo-razvitiya-v-investitsionnuyu-i-finansovuyu-strategiikompaniiteoreticheskie-i (accessed: 05.10.2024).

[9] Vavoura C., Vavouras I. Sustainable economic development in the European Union and COVID-19 // Evolutionary and Institutional Economics Review. 2022. No. 19. R. 455.

[10] Kantyukov R. R., Kolybanov K. Yu, Ravikovich VI Information technologies for preparing control decisions in automated systems of environmental monitoring, 2019.

[11] Busch T., Lewandowski S. Corporate Carbon and Financial Performance: A Meta-analysis // J. Industr. Ecol. 2018. 22 (4). P. 745–759. URL: https://onlinelibrary. wiley.com/doi/abs/10.1111/jiec.12591

THE IMPACT OF SUSTAINABLE DEVELOPMENT ON ECONOMIC GROWTH: BALANCING ENVIRONMENTAL, SOCIAL AND ECONOMIC FACTORS

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Abstract

This article delves into the intricate relationship between sustainable development and economic growth, highlighting the necessity of harmonizing environmental, social, and economic considerations to foster long-term prosperity. The study explores how sustainability-focused policies, such as promoting renewable energy, reducing carbon emissions, and enhancing social inclusion, can positively influence economic growth by increasing resource efficiency and driving innovation. It also addresses the complex trade-offs between immediate economic gains and the long-term benefits of sustainability, emphasizing the importance of aligning short-term policy goals with long-term environmental and social objectives. Through an analysis of key sustainability practices, including the adoption of green technologies, responsible resource management, and policies aimed at reducing inequality, the article demonstrates how sustainable development can mitigate the adverse effects of climate change, promote social justice, and create more resilient economies. The article draws on international case studies from countries leading in sustainable practices, providing insights into how governments, businesses, and communities can effectively balance economic development with environmental conservation and social well-being. Moreover, the paper highlights the growing role of global cooperation in sustainable development, underscoring how cross-border environmental impacts, financial markets, and technological innovation contribute to shaping the future of sustainable economic growth. The research argues that sustainable development is not only essential for safeguarding natural ecosystems and addressing social inequities but also crucial for ensuring long-term economic stability and competitiveness in a rapidly changing global landscape. By integrating sustainability principles into economic frameworks, nations can promote inclusive growth that benefits all segments of society while preserving the planet for future generations.

Keywords: climate change mitigation, social justice, inequality reduction, sustainable innovation, long-term economic stability, global cooperation, environmental conservation

I. Introduction

In recent decades, the concept of sustainable development has emerged as a critical framework for balancing economic growth with environmental protection and social inclusion. As global challenges such as climate change, resource depletion, and growing inequalities intensify, the traditional models of economic development that prioritize short-term gains over long-term sustainability are increasingly being questioned. Sustainable development, which integrates environmental, social, and economic dimensions, offers a more holistic approach to growth, ensuring that current needs are met without compromising the ability of future generations to meet theirs.

Economic growth has long been viewed as a primary driver of societal progress, leading to improved living standards, technological advancements, and job creation. However, unchecked growth can have severe environmental and social costs, including pollution, biodiversity loss, and widening wealth disparities. These consequences undermine the long-term stability of economies and exacerbate social tensions. Therefore, aligning economic growth strategies with sustainable development principles is essential to building resilient economies that can withstand future shocks while promoting social well-being and environmental stewardship.

This paper examines the impact of sustainable development on economic growth, exploring how policies that address environmental sustainability, social equity, and responsible resource management can foster long-term economic prosperity. The study also analyzes the potential trade-offs and synergies between economic growth and sustainability, offering insights into how nations can achieve balanced development. Through international examples, the research highlights best practices and innovative approaches that demonstrate the feasibility of achieving economic growth without sacrificing ecological health or social fairness. By fostering a green economy, promoting renewable energy, and encouraging inclusive social policies, sustainable development can serve as a pathway to a more stable, equitable, and prosperous global future.

II. Methods

This study employs a combination of qualitative and quantitative research methods to explore the impact of sustainable development on economic growth, focusing on the interplay between environmental, social, and economic factors. The methodological approach is designed to provide a comprehensive understanding of how sustainable policies influence economic outcomes and to identify best practices for balancing growth with sustainability.

1. Literature Review

A thorough review of existing academic literature, policy reports, and case studies is conducted to establish a foundation for understanding the theoretical and practical links between sustainable development and economic growth. The literature review covers various aspects, including environmental economics, green technologies, social inclusion, and sustainable policy frameworks. This provides context for the analysis and highlights the key challenges and opportunities associated with sustainable growth.

2. Comparative Case Studies

The study analyzes several international case studies from countries with leading practices in sustainable development, such as the European Union, the United States, and emerging economies like China and Malaysia. By comparing these cases, the research identifies the different approaches countries take to integrate sustainability into their economic growth strategies. The selection of case studies is based on the diversity of their policy frameworks, economic structures, and environmental challenges.

3.Quantitative Data Analysis

To assess the economic impact of sustainable development, statistical data on key economic indicators such as GDP growth, employment rates, and investment flows are analyzed in conjunction with sustainability metrics like carbon emissions, renewable energy adoption rates, and social equity measures. Data is sourced from reliable international databases, including the World Bank, OECD, and the United Nations. This quantitative analysis helps to identify correlations between sustainable development policies and long-term economic performance.

4. Policy Analysis

The study also conducts an in-depth analysis of sustainability-oriented policies, such as tax incentives for green technologies, environmental regulations, and social welfare programs. The focus is on understanding how these policies are designed and implemented to promote economic growth while minimizing environmental degradation and social inequality. Specific policies like carbon pricing, green bonds, and renewable energy subsidies are examined to evaluate their effectiveness in driving sustainable economic outcomes.

5. Expert Interviews

Interviews with experts in the fields of environmental economics, sustainable finance, and public policy are conducted to gain qualitative insights into the practical challenges and opportunities of implementing sustainable development strategies. These interviews provide valuable perspectives on the real-world impacts of sustainability initiatives on economic growth, as well as the barriers to their success.

6. Sustainability Index Analysis

Lastly, the study utilizes global sustainability indexes, such as the Sustainable Development Goals (SDGs) index and the Environmental Performance Index (EPI), to measure the progress of countries in achieving sustainable development. These indexes are cross-referenced with economic growth data to determine the effectiveness of various sustainability efforts in driving economic development.

By employing a mixed-methods approach, the study provides a robust analysis of the relationship between sustainable development and economic growth, offering both theoretical insights and practical recommendations for policymakers.

III. Results

Sustainable development has become a central concept in addressing the growing global challenges of environmental degradation, social inequality, and economic instability. The most widely accepted definition comes from the Brundtland Report, which describes sustainable development as growth that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Report, 1987). This concept embodies the balance between satisfying current societal expectations and protecting the long-term viability of our environment, economy, and social structures. Magis (2010) further emphasizes that sustainable development promotes individual well-being, fosters social cohesion and inclusion, and creates equal opportunities for all people, both now and in the future.

1. Sustainable Development and Food Security

In the context of agriculture and food production, sustainable development involves ensuring food security through the consistent and resilient production of food. Food security, a key pillar of sustainable agriculture, requires continuous monitoring and the implementation of policies aimed at protecting vulnerable farmers, pastoralists, and landless individuals. Agricultural reforms and incentives can help improve the production and distribution of food while safeguarding the interests of those most affected by food insecurity. These policies focus on creating systems that can withstand shocks such as climate change or economic disruptions, ensuring the global food supply remains robust.

2. Species and Ecosystems

From an environmental perspective, species and ecosystems represent essential natural resources that must be preserved for ongoing development. Sustainable development emphasizes the protection of biodiversity, including both living organisms (such as plants, animals, and microorganisms) and the non-living components of ecosystems that they rely on. The degradation of natural habitats and loss of biodiversity pose significant risks to agricultural productivity and ecosystem services, which are critical for human survival. Sustainable management of these resources ensures that development does not come at the cost of irreversible environmental damage, allowing future generations to benefit from the same resources.

3. Energy and Power

Energy is a fundamental component of development, particularly in agriculture, where it is necessary for powering machinery, irrigation, and transportation. The challenge lies in ensuring that energy sources are sustainable, reliable, and environmentally friendly. Today's energy demands are met through a variety of means, but the reliance on non-renewable resources such as fossil fuels has significant environmental consequences, including greenhouse gas emissions and pollution. Sustainable development encourages the transition to renewable energy sources that can support long-term agricultural productivity without harming the environment. Energy security is critical for maintaining the growth and resilience of agricultural systems, particularly in regions that are heavily dependent on energy for production.

These three elements—food security, species and ecosystems, and energy—are interrelated and form a nexus often referred to as the "water-energy-food nexus" (Borowski, 2020; Purwanto et al., 2021). This nexus highlights the complex interactions between these systems and emphasizes the need for integrated approaches to managing them. As shown in various studies, achieving sustainability in one area, such as increasing food production, can have negative consequences for others, such as depleting water resources or reducing biodiversity (Kasem & Thapa, 2012). Therefore, a holistic approach is necessary to ensure that agricultural practices contribute to overall sustainable development.

4. Agricultural Reforms and Productivity

In recent years, detailed research in both micro and macroeconomics has provided insights into how agrarian policies can promote sustainable growth. These studies reveal that while significant achievements have been made in boosting food production, much of this progress has come at the cost of environmental degradation and the depletion of natural resources. Intensive agricultural practices, such as monocropping and overuse of chemical inputs, have damaged ecosystems to the extent that some resources may be irretrievable for future agricultural use. A shift from destructive economic practices toward sustainable development is essential for ensuring long-term agricultural productivity.

Improving agricultural productivity is particularly crucial for addressing food insecurity in regions like Africa, where the agricultural sector plays a pivotal role in the economy and livelihood of millions (Pretty, Morison & Hine, 2003). Africa's agricultural productivity, though on the rise, still lags behind the global average. Initiatives to enhance private and public investments in agriculture, coupled with sustainable development policies, can help boost productivity, reduce food insecurity, and improve the resilience of agricultural systems in Africa.

IV. Discussion

Energy is fundamental to sustaining life and serves as the driving force behind economic development, industrial growth, and societal well-being. In today's world, various energy sources—such as fossil fuels, renewable energy, and even human and animal power—are critical for generating and transmitting the electricity necessary for daily life. As economies expand and energy demand grows, ensuring the availability of reliable, safe, and environmentally friendly energy sources for all is a significant challenge.

One of the most pressing issues of the 21st century is the gap between growing energy demands and the limited supply of conventional energy sources, which are predominantly nonrenewable. These sources, including oil, natural gas, coal, and nuclear power, are finite and environmentally detrimental. However, there is a growing shift towards renewable energy, such as solar, wind, hydropower, biomass, and geothermal energy, which offer nearly unlimited potential and are more sustainable (Shao, 2020). The transition to renewable energy is crucial for maintaining ecosystem balance while meeting the needs of an ever-growing population.

Economic development, urbanization, and increased industrial activity have driven energy consumption to unprecedented levels, especially in developed nations, leading to a global imbalance in energy resource distribution. Despite improvements in energy efficiency, total energy consumption continues to rise. This growing demand exacerbates environmental challenges, particularly in developing countries, where inadequate management of renewable energy systems and infrastructure poses significant social and environmental risks.

For example, the use of wood for cooking in rural areas can result in severe health issues, such as respiratory and eye diseases, due to smoke and harmful emissions. Similarly, emissions from the combustion of agricultural residues and exhaust from machinery contribute to air pollution. Poorly managed renewable energy systems, including the burning of biofuels and improper disposal of organic waste, can also lead to water and soil contamination, negatively impacting both human health and the environment.

These challenges illustrate that while renewable energy offers a path to sustainability, its production and implementation must be carefully managed to avoid unintended consequences. Agriculture, as a major consumer of energy, plays a crucial role in this transition. By adopting sustainable practices and integrating renewable energy systems, the agricultural sector can help mitigate the environmental impacts of energy consumption and contribute to global sustainability goals.

A clean environment is essential for ensuring human health and well-being, yet the relationship between environmental factors and the health of humans and other species is complex and multifaceted. The preservation and sustainable management of natural resources is a critical development issue, as adverse changes in the environment can surpass the adaptive capacities of organisms, reducing the survival chances of many species, including humans. One of the most pressing challenges is understanding the key factors driving species extinction and ecosystem degradation, particularly how government policies on natural resources contribute to these trends.

Climate change exacerbates this problem, leading to increased public expenses as governments compensate for damages from environmental disasters, such as those affecting private households and state infrastructure. Given these escalating costs, there is a growing need for governments to adopt new approaches and create innovative models for sustainable management. However, the intricate relationship between fundamental and applied sciences in sustainable development complicates this task. State institutions, even in developed countries, must play a more proactive role in research and development efforts aimed at sustainability.

The human body has adaptive mechanisms that can often cope with harmful environmental factors, but when these stressors become chronic or severe, the body's capacity to adapt is overwhelmed, leading to both physical and mental health issues. This highlights the urgency for governments to reassess their policies in sectors such as agriculture and forestry. They must ensure that both the environment and the population are protected from harmful impacts while contributing to national development goals.

A major challenge for most governments is the limited availability of resources dedicated to environmental conservation. The critical question is not only how to secure more resources but how to use existing ones most efficiently to achieve conservation priorities. Governments must balance immediate needs with long-term sustainability, ensuring that their actions promote health, protect ecosystems, and foster development for future generations.

References

[1] Agarkova L., Gurnovich T., Shmatko S., Podkolzina I., Filonich V. Priority directions of development of the cluster of innovative education in the regional agro-

industrial complex // International Journal of Monetary Economics and Finance. 2016. T. 6. № 2. C. 718.

[2] Gakaev , R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[3] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

NEW APPROACHES TO THE MANAGEMENT OF NATIONAL NATURAL PARKS IN THE CURRENT CONDITIONS OF INCREASING RISKS

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Abstract

The objective of this article is to identify and substantiate new approaches to the management of national parks (NP) under the current conditions of increasing risks. The study demonstrates that in order to preserve ecological capacity and valuable natural heritage, the primary trend in management is shifting towards risk management, particularly concerning climate change and increasing recreational pressures, which adversely affect ecosystem viability. The research conducted in 2023 focused on the territory of the "Curonian Spit" National Park and the adjacent coastal areas of the Curonian Lagoon on the southeastern coast of the Baltic Sea.

The study reveals that in a risk-prone external environment, national park management should be oriented towards ensuring strong sustainability through the use of a Sustainable Ecosystem Design (SED-NP) mechanism. This approach offers a systematic vision, flexible and pragmatic solutions, and methods that help to coordinate disparate efforts in sustainable tourism and biodiversity conservation with the aim of preserving the integrity of ecosystems and their capacity to generate ecosystem services in the face of external threats. The application of SED-NP approaches allows for the integration of data on ecosystem services, depletion/degradation and replenishment/restoration of ecosystems, benefits (income and advantages), and other characteristics into the NP management system.

The research justifies the conclusion that the studied territory – a narrow strip of land washed by the waters of the Baltic Sea and the freshwater Curonian Lagoon – is, due to historical circumstances, a product of the local population's climate and natural risk-reflection. The local population ensured their survival and well-being through continuous and deliberate protective actions to reinforce the spit and preserve the Curonian Lagoon, which sustained them. The analysis of the territory's condition identified two primary groups of risks to ecosystem viability and biodiversity: climate-related risks and recreational pressures, which require focused attention. The spatial localization of areas within the "Curonian Spit" National Park most susceptible to climate risks and recreational degradation was determined. A set of measures was developed to mitigate recreational degradation and climate risks. An ecological, social, and economic assessment of the effectiveness of measures to reduce risks to the ecosystem viability of the Curonian Spit was conducted in monetary terms. A mechanism for the ecological, social, and economic justification of decisions regarding *the development of the territory from the perspective of strong sustainability and reducing risks to ecosystem viability and loss of ecosystem services was developed and tested.*

New approaches to managing national parks under the current conditions of increasing risks were developed, which are implemented through a system of restrictions and regulations. The application of a decision-making justification mechanism for NP development, in accordance with the principle of strong sustainability, ensures qualitative control of tourist flows in time and space, the creation of zones for various types of tourism use, and the planning of necessary infrastructure adapted to individual needs, including those beyond the boundaries of specially protected natural areas.

Keywords: sustainability, national park, management, climate risks, tourism, natural capital, ecosystem services, recreational degradation

I. Introduction

In today's world, profound changes in ecosystems are happening in no time, accompanied by a decline in the ecosystem services provided to humans. According to the "Millennium Ecosystem Assessment" (2005), more than 60% of ecosystem services are currently degrading or transforming. The main factors exacerbating the crisis of protected natural areas (PNA) worldwide include: (1) increasing climate risks and their negative impact on biodiversity; (2) growing demand for nature-based recreation in increasingly urbanized societies; and (3) the destruction of relatively untouched natural habitats, transforming into other forms of land use as population grows, wealth increases, and more natural resources are used.

One of the primary contemporary challenges in the development of PNA is to achieve a sustainable balance between tourism development and the necessity of preserving valuable natural and cultural heritage under conditions of increasing climate and anthropogenic risks. According to the World Charter for Sustainable Tourism (UN, 1995), management of all resources in such a way that economic, social and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity and life support systems[1]. In Russia, the sustainable development of PNA and the creation of conditions for ecotourism in national parks are considered a key priority for achieving the national goal of "Ecological Well-being" (Clause 5) at the highest state level[2]. In the current context of high risks and uncertainties, national parks[3] represent the most effective form of territorial management aimed at preserving the social and economic significance of the ecosystem services provided by nature.

Many national parks have been established worldwide for the protection of nature. As of the end of 2022, Russia had 67 national parks of federal significance, alongside reserves, with a total area of 31.4 million hectares. However, as Fortin and Gagnon (1999) correctly pointed out, these parks were often created without adequate analysis of the consequences for neighboring communities [1]. Giving unique territories the status of a national park, in addition to strengthening nature conservation, leads to unexpected consequences. Protected scenic landscapes have become magnets attracting not only visitors but also numerous investors. This increases the risk of losing the integrity of natural ecosystems and biodiversity due to recreational degradation

[1] Adopted by the World Tourism Organization (UNWTO), the World Travel and Tourism Council (WTTC) and the Earth Council in 1995.

[2] Decree of the President of the Russian Federation of 07.05.2024 No. 309 "On the national development goals of the Russian Federation for the period up to 2030 and for the perspective up to 2036".

[3] According to the 2013 Guidelines of the International Union for Conservation of Nature, "national parks" refer to "large areas of natural or near-natural areas designed to protect large-scale ecological processes and associated ecosystem species and characteristics.

[2], and heightens the vulnerability of ecosystems to destructive climate impacts.

Our studies in the "Curonian Spit" NP and the adjacent coastal areas of the Curonian Lagoon in the Kaliningrad region on the Baltic Sea have shown that addressing this complex set of problems requires the application of risk-oriented management approaches when justifying decisions on the development of the NP territory and its buffer zone, as well as when refining visitor flow restrictions and regulations. For this, the traditionally collected data on the condition and trends of ecosystem and natural object changes, and visitor flow numbers are insufficient. This underscores the high relevance and practical significance of developing new approaches to NP management under modern conditions of increasing climate risks.

II. Methods and Data

In recent decades, the number of studies on the risks of decreasing ecosystem resilience under increasing external threats has grown. Not only ecological but also socio-economic impacts on national parks have been described [3], as well as the associated losses and benefits [4]. In the context of sustainable development, the view that national parks should be considered as investments in public goods has gained traction. De Groot et al. (2012) conducted the first global assessments of a range of ecosystems and services, including for coastal systems [5]. The multi-faceted consideration of the economic value of national parks has been reflected in the works of many scientists and specialists (R. Constanza, M. Wilson, S.N. Bobylev, G.A. Fomenko, R.A. Perelet, V.M. Zakharov, and others).

Numerous studies have also focused on sustainable tourism development [6-10]. To date, there is consensus on several fundamental issues related to the dependence of NP sustainability on stakeholder interactions, particularly the constructive interaction between NP management and local communities [11-17]. NPs should not be viewed as isolated natural ecosystems requiring unconditional protection, but rather as particularly complex anthropo-natural systems (ANS) that constitute a significant portion of a nation's and region's wealth due to their high proportion of non-depleting natural capital.

To effectively address these challenges, two fundamental aspects should be focused on: (1) ensuring, as much as possible, the resilience of ecosystems in the face of increasing destructive climate impacts; and (2) preventing the destruction and loss of ecosystems due to anthropogenic pressures in the form of increasing visitor numbers and changes in ecosystem use on adjacent lands, the buffer zone, and the NP territory itself by altering conservation status. Actions should be based on sustainable development principles, considering the interests of a wide range of stakeholders and conducting an analysis of the state of ecosystems and the flows of ecosystem services in the protected area and adjacent lands.

The task set in Russia to orient NPs towards sustainable development and create conditions for ecotourism[4] cannot be achieved through technical means alone. Significant adjustments to approaches to planning and spatial development design of protected areas are needed, following the inviolable ethics of Life, which recognizes the intrinsic value of all living things and strives to preserve it in an unstable external environment. Scientific discourse in this aspect is conducted in the context of moving sustainable development methodology towards a goal-oriented synthesis of natural, cultural, and socio-economic values, along with the corresponding system of restrictions and regulations on economic activities [18].

This vision is being implemented in NPs through the methodology of Sustainable Ecosystem Design (SED), which we are developing [19-21], considered as a special type of relationship with the high-risk and uncertain reality. The essence of SED in the context of NPs lies in an ethically-oriented, goal-rational, systematic approach to planning the development of national parks that reduces the likelihood of ecosystem destruction and the loss of natural wealth. The main focus is

[4] Decree of the President of the Russian Federation dated 07.05.2024 No. 309 "On the national development goals of the Russian Federation for the period up to 2030 and for the perspective up to 2036".

on minimizing risks through coordinated actions for biodiversity conservation in conjunction with climate adaptation[5]. A justified system of restrictions is applied based on special zoning of the territory, along with the verification of land-use decisions regarding NP development in accordance with the principles of sustainable development.

In the course of research we used: (1) materials of functional zoning of the territory of NP "Curonian Spit", information about the boundaries, areas and types of land cover of functional zones, information about the location, length and arrangement of eco-trails and tourist routes; (2) data on quantitative, spatial, temporal and cost characteristics of the flow of visitors, environmental constraints, the stability of the territory of the Curonian Spit to recreational loads; (3) information about existing and planned recreational facilities; about planned works on territory improvement; (4) information about economic entities providing services on the territory of the NP; (5) information about volumes of recreational fishing within the boundaries of the park's protection zone in the Curonian Lagoon and on the Baltic coast, about volumes of non-timber forest resources (mushrooms and berries) harvested by the local population and visitors; (6) information about prices for fish, mushrooms and berries in the markets of Zelenogradsk and Kaliningrad; (7) historical information about the Curonian Spit region.

III. Results

The research was conducted in the "Curonian Spit" National Park (NP) and on the coastal areas of the Curonian Lagoon in the Kaliningrad region, located in the southeastern Baltic region (see Figure 1).

Figure 1: *Situational map-scheme of the "Curonian Spit" NP location*

This coastal area, inhabited by humans for many centuries, is a product of the local population's climate and natural risk-reflection, ensuring their livelihood through thoughtful actions to protect the Curonian Lagoon, which provided their sustenance.

[5] Adapting to climate change means planning for and acting on the expected impacts of climate change. It involves making changes to how we live and what we do before the impacts of climate change occur (anticipatory action), and being prepared to respond to increasingly likely and frequent extreme events (response).

The unique character of the Curonian Spit is the result of various peoples' efforts to preserve it for future generations. The Curonian Spit represents a rare and successful example of the history of coexistence between nature and humans, with an abundance of both natural and cultural assets[6]. It is a unique cultural landscape with a system of protective engineering structures and forest plantations, formed and developed through the interaction of the sea, wind, and human activity. This is an example of the continuous process of self-development of a Living system, within which the activities of the "Curonian Spit" NP are integrated. To preserve the typical coastal communities of the Southeastern Baltic and the unique natural complexes of the Curonian Spit, as well as to protect spawning and nursery areas for commercially valuable fish species, marine mammals, and birds during migrations and breeding from adverse anthropogenic impacts, a protective zone of the national park has been established[7].

An analysis of spatial data from the "Curonian Spit" NP for the period 1991-2021 revealed that the ecosystems as a whole have undergone some changes (see Table 1).

Table 1: *Ecosystem change characteristics in the "Curonian Spit" NP for 1991-2021*

Ecosystems	Factors of Ecosystem Change		Quantitative Change (ha)	Comments on Causes of Change
	Anthropogenic	Climatic		
Forest	↑	–	954	Encroachment of forest on meadow ecosystems due to natural (development of fertile soil layer, natural afforestation, etc.) and anthropogenic processes (reforestation activities by the national park, adherence to restrictions on visiting certain particularly valuable areas)
Meadow	↓	–	-882	Sand movement due to wind, afforestation
Coastal (dunes and beaches)	↘	–	-82	Encroachment of grassy vegetation, including as a result of protective measures
Freshwater Internal (lakes and swamps)	–	–	0	–
Marine (Baltic Sea)	↗	↗	46	Shoreline erosion due to increased storm activity
Freshwater External (Curonian Lagoon)	↘	↘	-71	Expansion of dunes toward the lagoon due to intensified winds
Settlements	↑	–	35	Expansion of built-up area

The data in Table 1 indicate that the most significant changes in ecosystem areas occurred in forest (increase) and meadow (decrease) ecosystems. However, given the importance of stabilizing the sandy body of the Curonian Spit with forest plantations to preserve ecosystem services for beach recreation, these changes do not increase the risk of territorial degradation (reduction in natural capital), but rather contribute to its reduction. Climatic changes, such as the increased frequency of storm events in the southeastern Baltic and wind pressure on coastal areas from the Curonian Lagoon [22], have led to a decrease of the Curonian Spit's landmass by 46 hectares on

[6] The territory of the Kurshskaya Spit NP was included in the UNESCO World Heritage List in 2000 as part of the international Russian-Lithuanian site "Curonian Spit". URL: https://whc.unesco.org/ru/list/994. Date of reference: 12.03.2024.

[7] Order of the Ministry of Natural Resources of Russia No. 306 of 27.04.2022 "On establishing the boundaries of the protection zone of the Kurshskaya Spit National Park along the border with the Baltic Sea water area, as well as on approval of the Regulations on this protection zone".

the sea side and 71 hectares on the lagoon side. Retrospectively, the condition and characteristics of ecosystem assets (natural capital) fluctuated within acceptable levels, maintaining the potential to generate ecosystem services during the specified period and up to the present day.

The main climatic and anthropogenic vulnerabilities of the Curonian Spit's ecosystems and the coastal areas of the Curonian Lagoon. They include the increased frequency of storms, which damage economic and infrastructure facilities due to periodic breaches of the spit (when Baltic saltwater breaks into the freshwater Curonian Lagoon), and negatively impact biodiversity by disrupting ecosystem conditions. Another significant threat is the increase in the annual flow of tourists to the "Curonian Spit" NP, which rose from 200,000 visits in 2010 to 809,415 visits in 2021, more than fourfold[8]. This has substantially increased the threat of ecosystem degradation on the Curonian Spit, loss of biodiversity, and deterioration of the ecological integrity of the area.

In the "Curonian Spit" NP, its protective zone, and the coastal areas of the Curonian Lagoon, opportunities, methods, and means of organizing the activities of the "Curonian Spit" NP were explored using the Sustainable Ecosystem Design (SED) mechanism, with the aim of aligning current management practices with the task of preserving particularly valuable natural complexes of biodiversity and quality of life for people.

From this perspective, several conclusions were drawn that are important for reducing the risks of ecosystem integrity disruption on the Curonian Spit, the Curonian Lagoon, and its coastal areas, and for maintaining ecosystem service flows.

First, two main groups of risks were identified – climate and recreational – which require primary attention for mitigation. Climate risks are associated with changes in temperature regimes[9], precipitation patterns[10], increased storm frequency[11], and other factors. Recreational risks are linked to the growing number of visitors, recreational degradation, loss of habitats, and invasive species aggression.

Second, the spatial localization of areas within the "Curonian Spit" NP most susceptible to climatic risks and recreational degradation was determined. The areas identified as most vulnerable to climate (intensified storm events and wind pressure) and recreational (increasing tourist flow) impacts include:

- Areas of greatest vulnerability to tourist and natural-climatic impacts (foredunes, dune ridges, flat areas with pine forest plantations);
- Areas of concern for biodiversity (critical habitats for populations, locations of rare plant species, etc.).

Third, a comprehensive set of measures was developed to mitigate the risks of recreational degradation and climatic impacts. As part of the recreational activities plan of the "Curonian Spit" NP, a comprehensive set of measures was designed to reduce recreational degradation and climatic risks, including:

- Reducing recreational degradation risks, which involves (1) refining the zoning of the "Curonian Spit" NP to more fully encompass restrictions and prohibitions on visiting areas most vulnerable to recreational impacts and valuable for biodiversity conservation (foredunes, dune ridges, flat areas with pine forest plantations, critical habitats for populations, locations of rare plants, etc.); (2) constructing recreational infrastructure to prevent negative impacts from tourist flows on ecosystems (arranging parking lots,

[8] Information report of the FGBU "Kurshskaya Spit National Park" for 2021.

[9] Climate warming is felt in the Kaliningrad region, first of all, due to the increase in surface air temperature: for Kaliningrad - over a long period (168 years) at a rate of 0.01 °C per year, and for some other settlements of the region (Baltiysk, Sovetsk, Zheleznodorozhny) and Kaliningrad together - over a shortened period (56 years) at a rate of 0.03 °C per year [23].

[10] Average annual precipitation has been increasing by 4 mm every 10 years for the last 60 years; during the period of greatest warming (1980-2018), the rate of increase in precipitation has especially increased in July, with July precipitation increasing by 12.53 mm every 10 years; in the last 10 years, anomalous rainstorms have been occurring annually, with one or two days of monthly precipitation [24].

[11] Between 1966 and 1985, there was an average of 26 storm events per year; between 2004 and 2014, there were 254 storms, with an average of 28 storms per year; the number of days with high winds (>15 m/s) increased annually by 0.7 days and the average annual wind speed by 0.1 m/s [24].

sanitation sites, waste collection, and removal points).

- Reducing climatic risks, including constructing pathways across the foredune, reinforcing the foredune body, planting trees on dunes, and building shoreline protection structures in coastal areas most vulnerable to storm and surge impacts (foredunes, beach areas on the sea side).

Fourth, an ecological-social-economic justification mechanism for decision-making in the field of preserving natural complexes, unique and reference natural sites, and reducing the risks of their degradation was developed and tested. This mechanism is aimed at evaluating the ecological-social-economic consequences of various projects or specific intentions, documented as decisions that could be implemented in the "Curonian Spit" NP. The mechanism is based on the principle of "result-based management," widely used in public administration as an adequate and transparent method for assessing the implementation of state programs, mainly of a humanitarian nature, where purely financial assessment mechanisms have very limited use.

The developed mechanism is formulated as a sequence of actions, the results of which complement standard environmental impact assessment (EIA) procedures. The outcome provides comparable quantitative assessment indicators of the evaluated project's/program's/investment intention's impact on ecosystems, social and economic spheres, and summarizes these assessment data for compliance with the principles of strong sustainability.

The assessment is conducted using three evaluative characteristics: impact on (1) ecosystems, (2) the social sphere, and (3) the economic sphere. Each of the evaluative characteristics is specified by a group of corresponding assessment indicators (see Table 2). During the assessment, the projected state data (project line), expected as a result of the project's/intention's implementation, is compared with the baseline state (baseline) of the territory, without the project but under the influence of existing change factors (in our case, climatic and anthropogenic).

Table 2: *Evaluative Characteristics and Indicators for Assessing the Socio-Economic Significance of the Project*

No.	Evaluative Characteristics	Assessment Indicators
1	Impact on Ecosystems	1.1 Total area of ecosystems not significantly transformed by anthropogenic activity, ha
		1.2 Anthropogenic transformation coefficient of ecosystems, %
		1.3 Threat of anthropogenic degradation of ecosystem areas and objects, points
		1.4 Recreational load on the territory, person-days/day
		1.5 Maximum allowable recreational capacity of the territory, persons/day
2	Impact on Social Sphere	2.1 Approximate number of users of ecosystem services in the territory, broken down by types of ecosystem services, persons/year
		2.2 Number of visitors to the territory, including people with limited physical abilities, persons/year
		2.3 Number and list of main beneficiaries of ecosystem services in the territory, units/year
		2.4 Employment provided by ecosystem services in the territory, including for people with disabilities and local residents, persons/year
3	Impact on Economic Sphere	3.1 Potential gross income from the provision of ecosystem services, RUB/year
		3.2 Potential gross income from the provision of ecosystem services related to the tourism industry, RUB/year
		3.3 Approximate tax revenues to the budgets of all levels from the provision of ecosystem services and their use, RUB/year

Positive results were obtained from testing the Mechanism for Assessing the Compliance of Actions for the Development of the Curonian Spit National Park (NP) with the Principle of Strong Sustainability when developing activities for the recreational plan of the Curonian Spit NP. The assessment of activities showed that the projects with the highest ecological, social, and economic significance include the construction of pathways across the foredune near the tourist base (by reducing the risk of foredune destruction and degradation of the adjacent coastal ecosystems), the creation of a parking area at the park entrance (by reducing the risks of uncontrolled use of the territory by visitors), and the establishment of recreational routes in areas adjacent to the NP, which helps to reduce the recreational load on the protected areas of the Curonian Spit and significantly lowers the risks of recreational degradation.

The results confirmed the effectiveness of the proposed Mechanism in the development of programs and plans for the national park's territory, in decision-making regarding land use, and in reducing the risks of ecosystem degradation and loss of ecosystem services.

Fifth, an ecological, social, and economic assessment of the effectiveness of measures to reduce the risks to the viability of the Curonian Spit ecosystems was carried out in monetary terms. The viability of ecosystems is determined by the flow of ecosystem services they provide, its sustainable nature, and its value in ecological, social, and economic terms. From an economic efficiency standpoint, this value is expressed in monetary terms. In the case of the Curonian Spit, the key role in maintaining its integrity – and therefore the state and properties of ecosystems and the value of ecosystem services – is played by the activities of the Curonian Spit NP.

Thus, the effectiveness of measures to reduce climate and recreational risks was assessed based on the value of the existing flows of ecosystem services, which are largely ensured by the continuous efforts of the Curonian Spit NP to mitigate risks to ecosystems from climate and anthropogenic factors. The total value of ecosystem services in the Curonian Spit and the surrounding coastal and lagoon waters was estimated at 222.4 million rubles per year. The highest value is attributed to cultural ecosystem services for excursions and beach recreation – 71.3 and 72.8 million rubles per year, respectively; provisioning ecosystem services related to commercial fishing have a slightly lower value – 59.1 million rubles per year; the values of other provisioning services (amateur and sport fishing, mushroom and berry gathering, hay and wood harvesting), as well as regulating services (CO_2 absorption by the Curonian Spit ecosystems), range from 0.5 to 6.6 million rubles per year.

Additionally, the results of the ecosystem services assessment also reflect the contribution of the Curonian Spit ecosystems to the resilience capital of the region and the Russian Federation as a whole.

IV. Discussion and Conclusions

The study of potential directions for implementing the Curonian Spit National Park (NP) ecosystem services assessment (ESA) methodology to reduce climate and anthropogenic risks in the Curonian Spit and Curonian Lagoon has led to several important generalizations and conclusions.

Theoretical Considerations: In the face of increasing climate and recreational pressures, overcoming negative trends in regions that are attractive from a natural environment standpoint has shown that tourism management must be holistic. It must satisfy economic, social, and aesthetic needs while preserving cultural integrity, essential ecological processes, biodiversity, and life-support systems. This work should be based on the principles of the Charter for Sustainable Tourism, adapted to the geographical conditions of each region in the country.

It is essential to measure the impact of various human activities on protected ecosystems. Measuring the sustainability of a national park is the foundation of its management. However, monitoring the processes and phenomena occurring within the territory remains a significant challenge due to outdated approaches to measuring economic activity efficiency. The application of System of Environmental-Economic Accounting (SEEA) [12] can address this problem by

[12] Statistical Standard Central Framework of the System of Environmental Economic Accounting 2012 (System of Environmental Economic Accounting 2012 - Central Framework), in official translation 2017. URL: https://seea.un.org/sites/seea.un.org/files/seea_cf_final_ru_0.pdf Date of reference 12.07.2024

providing a comprehensive approach that aligns with existing data from state statistics and government funding structures. A key advantage of SEEA is its ability to understand the relationships between territorial development activities and the state of ecosystems through the flow of ecosystem services.

Managing the development of all forms of sustainable tourism in areas of high ecological value should primarily be based on the proper organization and control of tourist flows over time and space, the creation of zones for different types of tourism use, and the planning of necessary infrastructure. This infrastructure must support the viability of ecosystems and the flow of ecosystem services while being adapted to individual needs. Significant potential in this direction lies in the development of educational tourism in areas adjacent to the NP, with the possibility of integrating them into a single cluster. This approach allows for the diversification of tourist flows and reduces the risks of recreational degradation in protected areas.

For comprehensive analysis and comparative evaluation of potential directions and targets for the development of recreational flows, the results-oriented management[13] method and the Rapid Impact Assessment Matrix (RIAM) have proven highly effective. In our view, using this method in various geographical contexts will allow for determining the depth of analysis needed at different stages of spatial planning. This will provide government authorities, investors, and all stakeholders with timely and reliable information about the feasibility and priority of utilizing natural and cultural heritage sites in developing recreational flows.

Practical Considerations: A set of specific measures has been identified to reduce climate and anthropogenic risks to ecosystem viability and maintain ecosystem service flows. These measures include, first and foremost, refining the zoning of protected areas by identifying the most vulnerable sections to climate and anthropogenic impacts, with mandatory actions to mitigate these impacts (such as restrictions and access limitations, protective measures, etc.). In terms of preventing and avoiding future risks, the environmental, social, and economic justification mechanism for proposed projects, in addition to Environmental Impact Assessments (EIA), has proven effective. Additionally, it is important to develop tourism activities in areas adjacent to the national park.

In terms of monitoring, additional characteristics are important to reflect new risks and vulnerabilities, showing which actual services and in what quantities may be lost. The growing importance of sustainable monitoring of ecosystems in protected areas must be noted, as it forms the basis for creating ecological, economic, and social value through information and knowledge for public benefit. Monitoring should include not only the state and observed trends of ecosystems but also tourist flows. Moreover, accounting for the socio-economic conditions of the population living around the NP is increasingly recognized as essential for achieving ecosystem protection goals, as it facilitates constructive interaction between the NP and local communities.

References

[1] Fortin, M.-J., Gagnon, C. (1999). An assessment of social impacts of national parks on communities in Quebec, Canada. Environmental Conservation, 26, 200-211.

[2] Mayorova Yu.A. About the order of calculation and problems of regulation of permissible loads on the example of the national park "Curonian Spit" // Problems of study and protection of natural and cultural heritage of the national park "Curonian Spit": a collection of scientific articles. Issue. 16 / compiled by I.P. Zhukovskaya. I.P. Zhukovskaya. Kaliningrad: Izd-vo BFU named after I. Kant, 2020. 196 p.

[3] Pearce, D.G. Westland National Park: Economic Impact Study. New Zealand, Christchurch: University of Canterbury, 1982.

[13] This approach of multifunctional a priori analysis is widespread in the practice of public administration in many countries in various fields of activity, ranging from the AIDS program to forest management [25].

[4] Kerr, G.N., Sharp, B.H., Gough, J.D. Economic Benefits of Mt. Cook National Park. New Zealand, Christchurch: University of Canterbury and Lincoln College, 1986.

[5] de Groot, R., Brander, L., van der Ploeg, S., et al. (2012). Global Estimates of the Value of Ecosystems and Their Services in Monetary Units. Ecosystem Services, 1, 50-61.

[6] Hunter, C., Green, H. Tourism and the Environment: A Sustainable Relationship? London: Routledge, 1995.

[7] Hunter, C. (1997). Sustainable tourism as an adaptive paradigm. Annals of Tourism Research, 24, 850-867.

[8] Draper, D. (2000). Toward sustainable mountain communities: Balancing tourism development and environmental protection in Banff and Banff National Park, Canada. Ambio, 29, 408-415.

[9] Sharpley, R. (2000). Tourism and sustainable development: Exploring the theoretical divide. Journal of Sustainable Tourism, 8, 1-19.

[10] Saarinen, J. (2006). Traditions of sustainability in tourism studies. Annals of Tourism Research, 33, 1121-1140.

[11] McMinn, S. (1997). The challenge of sustainable tourism. Environmentalist, 17, 135-141.

[12] Byrd, E.T. (2007). Stakeholders in sustainable tourism development and their roles: Applying stakeholder theory to sustainable tourism development. Tourism Review, 62, 6-13.

[13] Liburd, J.J., Edwards, D. (Eds.) Understanding the Sustainable Development of Tourism. Oxford: Goodfellow, 2010.

[14] Mihalič, T. (2000). Environmental management of a tourist destination: A factor of tourism competitiveness. Tourism Management, 21, 65-78.

[15] Ceron, J.P., Dubois, G. (2003). Tourism and sustainable development indicators: The gap between theoretical demands and practical achievements. Current Issues in Tourism, 6, 54-75.

[16] Huete-Alcocer, N., López-Ruiz, V.R., Grigorescu, A. (2019). Measurement of satisfaction in sustainable tourism: A cultural heritage site in Spain. Sustainability, 11, 6774.

[17] McCool, S.F. Bosak, K. (Eds.) Reframing Sustainable Tourism. Dordrecht: Springer, 2016.

[18] Von Weizsaecker, E., Wijkman, A. Come On! Capitalism, Short-termism, Population and the Destruction of the Planet. Springer, 2018. 220 p.

[19] Fomenko G.A. Sustainable ecosystem design: prerequisites and approaches: teaching manual. Yaroslavl: ANO NIPI "Cadaster", 2021. 216 p. (Series "Planning and design of spatial development").

[20] Fomenko G.A. Sustainable ecosystem design: main features and peculiarities: educational and methodological manual. Yaroslavl: ANO NIPI "Cadaster", 2021. 136 p. (Series "Planning and design of spatial development").

[21] Fomenko G.A., Fomenko M.A. Sustainable ecosystem design: focus on ecosystem services: teaching manual. Yaroslavl: ANO NIPI "Cadaster", 2022. 260 p. (Series "Planning and design of spatial development").

[22] Stont J.I., Bukanova T.V., Krek E.V. Variability of climatic characteristics of the coastal part of the southeastern Baltic Sea in the early XXI century // Bulletin of the I. Kant Baltic Federal University. Kant. Ser. Natural and Medical Sciences. 2020. №1. PP. 81-94.

[23] Dvoeglazova N.V. Current state of the climate system of the Kaliningrad region against the background of global warming // Bulletin of the I. Kant Baltic Federal University. Ser. Natural and medical sciences. 2019. № 1. PP. 35-45.

[24] Climat razbolatel: Regional phenomena of global climate change in the Kaliningrad region. Kaliningrad: Ekopaschita, 2018. 32 p.

[25] Handbook on planning, monitoring and evaluation of development results / UNDP. New York, 2009.

DEVELOPMENT OF AGRICULTURAL INDUSTRY IN THE PARADIGM OF SUSTAINABLE DEVELOPMENT

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Abstract

The article explores and substantiates the theoretical and methodological foundations of the environmental component of resource conservation management of agricultural enterprises in the context of ensuring sustainable development. The main directions of the negative impact of the activities of agricultural enterprises on the environment are identified, including: land depletion and loss of soil fertility, soil erosion, soil compaction, loss of biodiversity, groundwater pollution. Indicators characterizing the environmental efficiency of resource conservation management of agricultural enterprises have been determined. It is noted that the culture of resource conservation should become a mandatory element of the general culture of behavior of employees of agricultural enterprises. The article defines the main stages of the formation of organizational culture at an agro-industrial complex enterprise, which contains a component of resource saving.

Keywords: agriculture, ecology, efficiency, management, resource conservation, sustainable development

I. Introduction

Agriculture is one of the largest economic sectors in the world. Farmland and grassland make up about 50% of the Earth's habitable environment and provide habitat and food for large numbers of people. Today, for most modern agricultural enterprises, it is relevant to identify areas of economic and management activity that will help to effectively use natural resources in the same way that a reasonable approach will help preserve and restore the habitat, protect and improve the quality of soil and water. In addition, the agro-industrial complex is the basis for the formation of food security of the state and has a significant impact on the state of the country's economy. In addition to providing enterprises and the population with raw materials and food, the agro-industrial complex provides employment opportunities for a significant part of the population. Thus, according to 2022 data, about 4 million people are employed in agriculture in the Russian Federation [5].

In the international arena, our country is positioned as an agrarian state. Over the past decade there has been a significant increase in agricultural production. At the same time, not all agricultural enterprises understand the importance of using resource-saving technologies and apply the principles of sustainable development in their activities. The current stage of development is characterized by an intensification of anthropogenic impacts on the environment, since the widespread use of new technologies in the activities of agricultural enterprises accelerates the need to meet the needs of the population for various types of resources and raises the issue of their conservation.

Considering the exceptional importance and priority of agriculture for the national economy, the issue of increasing the effectiveness of development of the agro-industrial sector of the domestic economy has always occupied a central place in the scientific works of domestic scientists. Scientists studied the directions and mechanisms for ensuring the efficiency of agricultural production and development of rural areas, determined strategic models and foundations for increasing the level of its competitiveness and improving the quality of life of the rural population, worked out mechanisms of state support for the industry and analyzed the results of agrarian reforms. All this ensured the emergence of a significant number of scientific and applied developments, which are extremely useful for the theory and practice of increasing the effectiveness of development of the agricultural sector.

II. Methods

Current problems in the development of the agro-industrial complex and the use of resource-saving technologies and techniques are reflected in the scientific works of domestic and foreign scientists, in particular V.V. Aleksashina [1], P.V. Druzhinin [4], D.A. Zimin [4], Kh.Z. Mantaev [2], S.A. Nikolskaya [3], Z.P. Okazov [2], O.V. Potasheva [4], Z.V. Totikov [2], E.S. Tskhovrebov [7], G.T. Shkiperova [4] and others. However, most domestic agricultural enterprises have significant shortcomings that relate to the formation of an effective resource-saving management system in the context of the environmental component, which necessitates the need to find ways to improve their activities.

The purpose of the article is to study the theoretical and methodological foundations of the environmental component of resource conservation management of agro-industrial complex enterprises in the context of ensuring sustainable development, as well as to determine the impact of agro-industrial complex activities on the environment.

In the context of modern trends and changes in the management paradigm towards socially responsible business, financial, in particular, investment markets are quite sensitive to companies that carry out corporate governance on the principles of sustainable development. Experts have a clear consensus that social, environmental and economic behavior of businesses can significantly improve the financial performance and performance of companies. The implementation of sustainable development goals into the corporate strategy of companies helps to obtain long-term value for owners and investors, improve the corporate reputation of the company, and ensure an increase in financial performance indicators. Since the 90s of the last century, the economic literature has examined and confirmed the connection between socially responsible business behavior and its financial results. Today, the concept of social responsibility of business is expanding, complemented by the principles of strategic programs for sustainable economic development and approved at the level of government in individual countries and their associations. Recognizing business opportunities based on factors that take into account the preservation of the natural environment and the company's concern for social issues is now seen as a strategic factor in increasing business productivity and competitiveness. Business ideas that arise and are implemented on the basis of sustainable development form the potential for a company’s competitive advantages (new technologies, resources, products, markets), which increases the ability to generate profits and improve financial performance.

The main benefits from the implementation and implementation of sustainable development goals in the strategic management of companies can be identified as follows: 1) improvement of corporate image, which leads to improved financial performance; 2) increasing the level of investment attractiveness and expanding the financial and production potential of the company; 3) maximizing profits through better satisfaction of consumer needs and the formation of a reserve of competitiveness; 4) obtaining non-financial (social and environmental) benefits for a wide range of parties.

III. Results

Sustainable development of agriculture is part of the overall global concept of sustainable development until 2030, which was adopted in 2015. The universal principle of the concept of "sustainable development" is to meet the needs of the modern generation without risks and threats for future generations to provide for their own. The main emphasis of the concept of sustainable development of agriculture is a focus on meeting the needs of humanity (in terms of improving the quality of life of the population) in the conditions of preserving and restoring bio and ecosystems.

The introduction and implementation of the concept of sustainable development in the practice of domestic agribusiness should be accompanied by the delineation of clear positions, principles and elements that will form a unified architecture for sustainable development of agribusiness not only at the level of individual economic entities, but also at the level of agriculture, rural areas, the agro-industrial sector, as part of the national economy as a whole.

Agricultural production is a priority for the economy of any country and is important for the three main elements of sustainable development: ecology, economy and society. Solving the strategic problem of ensuring food security both at the national level and in the context of the global dimension in modern conditions is accompanied by significant environmental and socio-economic compromises. In particular, the need to increase food production volumes leads to the emergence of the problem of disappearance of biological diversity, the widespread use of GMOs, the loss of natural characteristics of biological resources, their modification, the acceleration of the main biological processes of transformation of biological assets based on an increase in the level of intensity of agricultural production (the use of chemicals, mineral fertilizers, drugs stimulating the growth and maturation phase of biological assets, etc.).

The range of environmental challenges and threats is complemented by socio-economic factors, among which the low level of income and quality of life of the population of rural areas, underdeveloped social infrastructure, a high degree of unemployment in rural areas and the intensification of migration processes are characteristic, which actually leads to the destruction of certain rural areas.

Despite the fact that in recent years the domestic agro-industrial complex has demonstrated stable economic growth, the problem of food supply for the country's population remains relevant both at the national and global levels.

Agriculture is a basic sector of the domestic economy, the level of development and efficiency of which today determine the strategic priorities of foreign economic trade, the possibility of forming the country's budget, ensuring food security and the raw material basis for the development of technologically related types of economic activity. The agro-industrial sector in the domestic economy represents the basis of economic development, forms the strategic prerequisites for attracting investments, strengthening the level of competitiveness of the national economy and improving the level of well-being of the country's population. Solving these problems is impossible without ensuring the effective development of agribusiness, solving problems of improving the quality of life of the rural population and food supply for current and future generations.

Crop and livestock production have a major impact on the environment. They are the main source of water pollution with nitrates, phosphates and pesticides. The agricultural sector is also the main anthropogenic source of greenhouse gases methane and nitrous oxide, and also contributes to other types of air and water pollution [6]. Agriculture also has negative impacts on the environment due to land degradation, salinity, over-extraction of water and reduction in genetic diversity of crops [3].

Most modern farms have abandoned skilled farming, which was once the leading principle of land cultivation. Today the emphasis is solely on productivity - it's a big expense for a high return.

Agricultural business owners do not take into account what happens to the land, crops and people consuming agricultural products [6].

More than two-thirds of water used by humans is for agriculture. Groundwater contamination from agricultural chemicals and wastes is a serious problem in almost all developed countries and, increasingly, in many developing countries. Water consumption, in turn, tends to increase.

Fertilizer contamination occurs when more fertilizer is applied than crops need, or when it is washed off or blown off the soil surface. Excess nitrogen and phosphate may leach into groundwater or flow into waterways. This nutrient overload causes eutrophication of lakes, reservoirs and ponds, leading to an increase in algae that overwhelms other aquatic plants and animals [1].

Domestic agricultural enterprises widely use insecticides, herbicides and fungicides in their activities, which leads to contamination of fresh water with carcinogens and other poisons that have a negative impact on the environment. Pesticides also reduce biodiversity by killing weeds and insects and, therefore, food species of birds and other animals [4]. The use of pesticides has increased significantly over the past few decades. In some regions, recent growth rates ranged from 4% to 5.4%.

Agriculture is also a source of air pollution. The dominant anthropogenic source of ammonia is livestock farming, which accounts for about 40% of global emissions, mineral fertilizers – 16%, and biomass burning and crop residues – about 18% [3].

The burning of plant biomass is another major source of air pollutants, including carbon dioxide, nitrous oxide and smoke particles. Projections show that by 2030, ammonia and methane emissions from the livestock sector in developing countries could be at least 60% higher than currently. Ammonia emissions from agriculture, according to forecasts by ecologists and economists, will continue to grow in both developed and developing countries [4].

Agriculture, forestry and fisheries negatively impact land and sea biodiversity. Species richness is closely related to wild habitat range. As the area decreases, so does the number of species. Deforestation, consolidation of fields with accompanying reduction of edges and hedgerows, and drainage of wetlands for agriculture are reducing the total area available to wildlife [2; 4]. Pesticides and herbicides kill many insects and plants, thereby reducing food supplies for some animals. Pressures on biodiversity over the next decades will result from contradictory trends. Extensive methods usually give way to intensification, which in turn may give way to organic agriculture [1].

The main directions of the negative impact of the activities of agricultural enterprises on the environment are: soil depletion and loss of soil fertility; soil erosion; nitrate runoff; soil compaction; loss of biodiversity; air emissions; groundwater pollution.

By using more sustainable production methods, the negative impact of agriculture on the environment can be reduced. Among the areas for reducing the negative impact on the environment from the activities of agricultural enterprises, the following can be highlighted: increasing the efficiency of fertilizer use; distribution of rice varieties that emit less methane; improving livestock waste management; restoration of degraded lands; improving crop residue management; expansion of agroforestry and reforestation; supporting the mobility of livestock in pasture areas prone to drought, etc. In particular, the use of agricultural waste will help increase the energy autonomy of agricultural producers.

IV. Discussion

At the same time, part of the produced energy can be sent for sale to third-party consumers, which will help reduce greenhouse gas emissions into the atmosphere and strengthen energy independence. However, the effective use of biofuel to obtain energy in agricultural production, and especially from agricultural waste, requires optimization of technical and technological processes for the production and use of biofuel and scientific technical justification of the rational parameters of machines and equipment used for the production of biofuel and the production of energy based on it.

The transition of the agricultural sector to a new level of development is possible only under the condition of a radical change in the nature of the development of productive forces, a rejection of the extensive type of economic growth, and a transition to intensive factors. To do this, it is necessary to solve the problems of rational, economical use of resources. Therefore, the state and the managers of agricultural enterprises are faced with the task of ensuring effective resource conservation [2; 4].

Resource conservation management of agricultural enterprises should be a comprehensive process associated not only with improving economic and social efficiency indicators, but also contain an environmental component [7]. The group of indicators characterizing the environmental efficiency of resource-saving management of an agro-industrial complex enterprise includes the following coefficients (Table 1).

Table 1. *Main indicators of environmental efficiency of an agricultural enterprise*

Indicators of efficiency of resource-saving development	Characteristic	Possible threshold value/normative value
Nature intensity coefficient	Ratio of costs of used natural resources to net income from sales	Decrease
Natural resource productivity coefficient	Ratio of net income from sales to expenses of used natural resources	Increase
Ecological intensity coefficient	Characterizes the level of harmful effects on the environment per unit of useful product	Decrease
Resource intensity ratio	Characterizes the costs of energy, water, land and other resources per unit of useful product	Decrease
Eco-Friendly Factor	Ratio of purely beneficial effect to spent natural resources	≥ 1
Waste capacity coefficient	The ratio of the mass of waste reduced to a single volume, taking into account differences in the degree of their harmfulness per unit of production	Decrease
Ecological production factor	The difference between the cost of raw materials taken from 1 and the cost of waste produced	→ 1

It is advisable to calculate the integral indicator of management of environmental efficiency and resource saving using the formula:

$$\text{К экол.эф.} = \sqrt[7]{К1 * К2 * К3 * К4 * К5 * К6 * К7}$$

where K1 is the environmental intensity coefficient; K2 – coefficient of natural resource productivity; K3 – environmental intensity coefficient; K4 – process resource intensity coefficient; K5 – coefficient of environmental friendliness of the object; K6 – waste capacity coefficient; K7 – coefficient of environmental friendliness of production.

In conditions of limited resources and increased competition, resource conservation ensures the sustainable development of agricultural enterprises, which leads to the need to resolve issues of organizational and personnel support for business entities [4]. The formation of an effective management system for resource conservation of agricultural enterprises should include a number of components (management system; organizational support; financing; motivational programs) included in the culture of resource conservation.

The culture of resource conservation should become an obligatory element of the general culture of personal behavior and the culture of professional activity of employees of agricultural enterprises. The formation of resource-saving behavior of personnel should become an element of the corporate culture of a business entity [4].

The main stages of forming and adjusting the organizational culture at an agro-industrial complex enterprise, which contains a resource-saving component, are the following:

Stage I: analysis of the state and prospects of organizational culture regarding the presence of a resource-saving component.

Stage II: development of a resource saving strategy (defining priorities, principles, norms, patterns of personnel behavior, etc.).

Stage III: planning activities aimed at mastering the norms and values of resource conservation.

Stage IV: influencing the organizational culture in order to minimize ineffective methods of using resources, developing positive traits that will contribute to resource conservation.

Stage V: assessing the effectiveness of the impact on organizational culture and adjusting the necessary actions.

Today, agricultural production is witnessing a decline in productivity due to degradation of natural resources, increased biotic and abiotic stresses, low seed replacement rate, damage to the natural ecosystem due to excessive and indiscriminate use of pesticides, changes in soil microbial dynamics, lack of quality plasma, etc.

According to the forecasts of ecologists and economists, it is expected that in the coming decades, climate change will not lead to a decrease in global food availability, but it may increase the state's dependence on food imports and weaken the level of food security.

The implementation of the concept of sustainable development in the practical activities of agricultural enterprises today creates real economic benefits for all participants in the process of public agricultural production and development of rural areas. The beneficiaries of the results of activities based on the principles of sustainable development are: 1) agricultural producers who can improve the quality and competitiveness of products, maximize revenue and profit from the sale of environmentally friendly products and expand the sales market, attract additional financial flows in the form of investments in environmental agricultural production; 2) employees who are participants in social and labor relations, guaranteeing staff high standards of quality of working life; 3) residents of rural areas who receive bonuses from ecological land use, environmental improvement, conservation of natural resources, investments in the development of infrastructure for the implementation of investment projects for sustainable development, including those of a social nature; 3) food consumers who will be able to consume high-quality, environmentally friendly and safe food products; 4) regions, the state and society as a whole due to economic growth in the agro-industrial sector, which today appears to be the basis for economic development, solving the problem of ensuring food security, improving the quality of life of the country’s population, taking into account the interests and needs of future generations.

The development of the domestic agro-industrial complex at the present stage is characterized by the presence of a significant number of acute problems, but at the same time, domestic agricultural business remains one of the most effective and profitable types of economic activity. Preserving and increasing the development potential of agribusiness and rural areas today cannot be ensured without strategic initiatives to implement the concept of sustainable development, the foundations of which are now quite clearly outlined in domestic science and practice. Strategic priorities in the context of the concept of sustainable development should become a guideline for the domestic agricultural sector, not only to increase the level of competitiveness of the national agro-industrial complex, the level of quality of residents of rural areas and solve the problem of ensuring food security, strengthening the domestic economy, meeting the needs of the country's population and its future generations. The key tools for achieving the goals of sustainable development of agriculture and rural areas should be science, innovation and modern digital technologies, and sufficient financial support for strategic and current development programs.

Current problems of environmental protection and conservation of natural resources in today's conditions are of great importance. More and more domestic agricultural enterprises are concerned not only about making a profit, but also about how to minimize the negative impact on the environment. One of the effective directions for the development of agricultural enterprises is to increase the efficiency of resource conservation management not only in the context of the economic component, but also the environmental one.

References

[1] Aleksashina V.V. Prospects for the development of world energy and the problem of maintaining ecological balance in the biosphere // Urban Planning. – 2013. – No. 3. – P. 60-71.

[2] Mantaev Kh.Z., Okazov Z.P., Totikov Z.V. Rational environmental management. Monograph. – Grozny: ChSPU, Makhachkala: ALEF, 2020. – 250 p.

[3] Nikolskaya S.A. Ecology: textbook / S.A. Nikolskaya. – Ivanovo: IVSPU, 2015. – 160 p.

[4] Assessing the impact of economic development on air pollution / P.V. Druzhinin, G.T. Shkiperova, O.V. Potasheva, D.A. Zimin // Economic and social changes: facts, trends, forecast. – 2020. – T. 13. – No. 2. – P. 125–142.

[5] Agriculture in Russia. 2023: Stat. Sat. / Rosstat. – P. 29 M., 2023. – 103 p.

[6] Reduce greenhouse gas emissions. International Atomic Energy Agency. – URL:https://www.iaea.org/ru/temy/sokrashchenie-vybrosov-parnikovyh-gazov

[7] Tskhovrebov E.S. Resource saving: main stages of formation, theories and methods, trends and development prospects in the industry and construction industry of Russia // Bulletin of MGSU. – 2020. – T. 15. – Issue. 1. – pp. 112–158.

THE GLOBAL CLIMATE CHANGES AND ROLE OF NANOTECHNOLOGY IN AGRICULTURAL PRACTICE

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Abstract

Since the 18th century, as human activity intensified, climate changes on our planet became global. These changes create complications of different nature in different areas. There are three important categories of action for reducing the risk of global climate change: reducing emissions, adapting to climate impacts, and financing required adjustments. The plant world is the most important among the living systems affected by global climate changes. That is why adapting plants to these changes, in other words, increasing their durability, is one of the most important issues of modern horticulture. It has already been proven that nanotechnology plays an important role in increasing plants' resistance to environmental factors (temperature, salinity, drought, radiation, etc.). In the presented review article, the scientific articles of recent years have been analyzed and it has been shown that nanoparticles play an important role in plant development, productivity, important physiological and biochemical, molecular processes and resistance to stress factors. The number of studies and investigations dedicated to this field is observed with exponential growth. In the article, the research of recent years and the results obtained from our own experiences are highlighted. It has been shown that nanoparticles can produce both positive stimulatory and toxic effects in plants, depending on their type, physical and chemical properties, dose, exposure time and application methodology. It has been noted that nanoparticles play an important role in the mineral nutrition of plants, protection, and formation of effective responses to stress factors.

Keywords: nanotechnology, nanoparticles, plants, stress factors, drought, salinity.

I. Introduction

Since agriculture operates as an open system where energy and substances are freely exchanged, the production processes here are unique. The most affected by the consequences of global climate change is the agricultural industry. Therefore, concern about the potential effects of long-term climate change on agriculture has grown significantly in the past decade and has been the subject of many studies. These studies are mainly devoted to the elimination of possible physical effects associated with climate changes in crops and livestock. Although the methods and technologies used in agricultural production have an ancient history, each of them has always kept its relevance. Nanotechnology, determined to gain the status of technology of the 21st century, penetrates all areas of human activity in terms of its application. In recent years, the application of nanotechnology in agriculture has been noted as a major issue in the economic interests of all countries of the world from the point of view of investment. Research conducted by nanotechnology in the fields of plant physiology and biochemistry, agronomy, plant protection, productivity, product quality and packaging is giving positive results. To increase productivity in agriculture, nanotechnology offers new effective agrochemical agents, fertilizers, pesticides and herbicides, tolerance methods, smart packaging technologies.

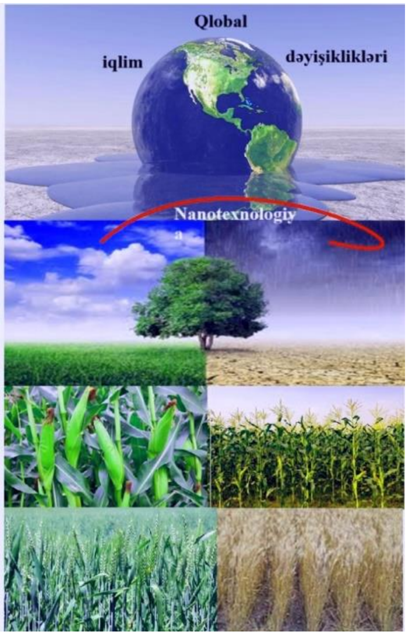

Figure 1: *Global climate change and nanotechnology*

The applications of nanotechnology in agriculture to increase productivity, improve production technologies, and modernize irrigation and agro technical methods include (1) the use of Nano forms of agrochemicals in the application of pesticides and fertilizers to improve and increase yields; (2) the application of Nano sensors in plant protection for identification of disease and chemical toxicant residues; (3) application of Nano devices for genetic engineering technology in plants; (4) application of Nano sensors in the diagnosis of plant diseases; (5) application of Nano technological methods in animal health, animal husbandry, poultry production; and (6) use of nanomaterials in post-harvest storage and packaging. What results of research conducted in the field of nanotechnology can be used in the application of intensive technologies in agricultural practice?

II. Interaction of nanoparticles with plants.

NPs can enter plants from air, soil, irrigation water, and seeds. NPs entering the organs and tissues and cells of plants cause many morphological and physiological changes depending on their characteristics. The effectiveness of NPs is determined by their chemical composition, size, surface coverage, reactivity and, most importantly, the effective dose. Studies have shown that NPs can have both positive and negative effects on plant growth and development, resistance to stress factors, and disease protection. In our experiments and the research of other scientists, it was determined that NPs can enter the seeds of plants, are absorbed from the endosperm layer of the embryo and migrate from the roots to the above-ground organs [1, 2].

From our experiments [2] and from the results of experiments by Lv. Christie and Zhang [3], it was clear that NPs penetrate the seeds and improve their water absorption, which leads to an increase in the intensity of seed germination. Nano hydrates can penetrate plant roots through osmotic pressure, capillary forces and pores (5-20 nm) in the cell wall [4]. The effects of some nanoparticles on plant development and important physiological processes are listed in Table 1.

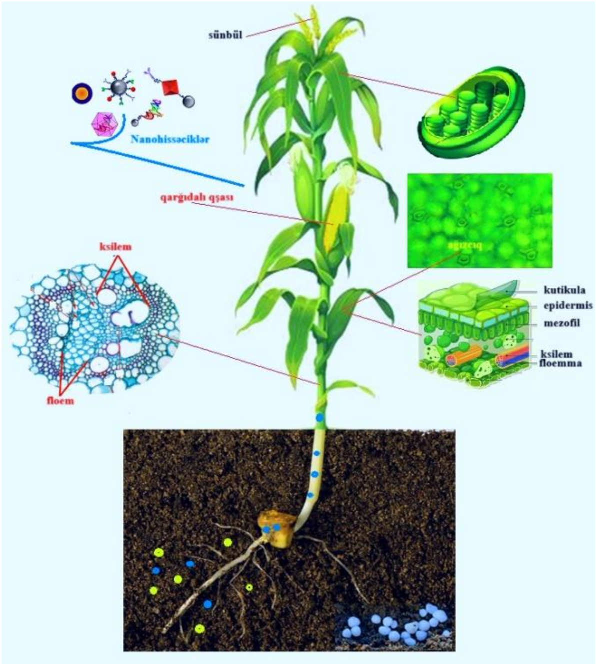

Figure 2: *The main areas of accumulation and action of nanoparticles in plants: root, seed, stem, leaf*

Table 1: *Effects of some nanoparticles on the plant developments and important physiological processes*

Nanoparticles	Plant variety	Possible effects and mechanism	References
Zn O	*Pennisetum americanum*	It increases the activity of certain enzymes	[5]
	Onion, Rice, Wheat	Disruption of cell metabolism, reduction of root length and reduction of plant biomass.	
Cu O	*Egeria densa*	Accelerates lipid oxidation, increases SOD and catalase activity	[6]
	Tomatoes, pigeon peas	It enhances root length, plant height, dry and fresh weight of seedlings, and intensity of photosynthesis	[7]
Ag	*Lactuca sativa*	It can accumulate in the leaves, it does not show any phytotoxic effect Accelerates the growth of sprouts Does not affect soil environment	[8]
	Phaseolus radiates *Sorghum bicolor* *Daucus carota L.*	Reduces germination rate, increases seed number, protein, chlorophyll content and H_2O_2 Strengthens root regeneration	
Au	*Xrizantema, gerbera & primrose*	Increases productivity, germination rate, growth and radical scavenging activity	[9]
	Arabidopsis thaliana	Increases germination, plant height, leaf length, diameter without showing toxicity at 5.4 ppm	
	Allium cepa L.	It increases the average length of roots, biomass, and reduces the number of leaves of seedlings	
Al_2O_3	*Nicotiana tabacum*	Reduces biomass but increases K+ uptake, increases macronutrient uptake	[10]

		in roots and leaves	
SiO_2	*Solanum lycopersicum* L.	It enhances the activity of a number of enzymes in the leaves and seeds, and also promotes the absorption of nitrate	[11]
TiO_2	Spinach	Increases Fe, P and K content in leaves, improves photosynthetic performance and Fe and P availability, accelerates plant growth	
Fe_3O_4	*Triticum aestivu*	Prolonging the exposure time accelerates plant growth, has a positive effect on VC content, and does not increase fruit weight.	[12]
γ-Fe2O3	*Cucumis melo*		

III. The role of nanoparticles in the resistance of plants to stress factors

The most serious problems caused by global climate changes in agriculture are related to drought and soil salinization. Both of these stress factors cause serious changes in plant organs, tissues, and important physiological processes (growth and development, photosynthesis, respiration, mineral nutrition, etc.) and ultimately stop the life activity of plants, reduce their productivity, and in most cases lead to their destruction. Experiments show that the application of nanoparticles in solving this problem can play an important role in plants' fight against stress factors. The results of experiments performed with the application of nanoparticles in recent years show that various metal-based nanoparticles, carbon nanotubes, and nitrogen oxide nanoparticles increase the resistance of plants to stress factors and are a promising field of research. In this type of experiment, it is possible to clarify the mechanism of the effect of nanoparticles on plants and the role of nanoparticles in the formation of responses to various stress factors. Plants develop early stress signalizing mechanisms to counter abiotic stressors and increase tolerance. When plant cells are stressed, they form and amplify secondary signals such as calcium, reactive oxygen species (ROS), phospholipids, and nitric oxide (NO), as well as various protein kinases. These signals include SnRk1 kinases that alter the expression of about 1000 stress-sensitive genes, ABA and ethylene plant hormones that act as key signals for stomatal closure and plant defense responses during drought stress [13]. These stress signals activate transcription factors, which further activate various stress-response genes to cope with the harsh effects of abiotic stress.

Salinity stress and nanoparticles. 20% of cultivated lands worldwide (35% in Azerbaijan) face salinity stress, which is the main type of abiotic stress factor, and this amount is increasing day by day due to global climate changes. Salinity is mainly caused by an excess of sodium chloride (Na Cl). High levels of Na Cl cause at least three types of problems for higher plants: 1) a higher osmotic pressure in the external environment (in solution), compared to the intracellular osmotic pressure, 2) high concentrations make it difficult to absorb and transport nutrient ions such as Na, K, and Ca, 3) Both Na and Cl ions can have direct toxic effects on membranes and enzyme systems. To combat salt stress, plants are well equipped with a defense system of various antioxidant enzymes including superoxide dismutase (SOD) and peroxidase (POD). Using the achievements of nanotechnology to reduce the negative effect of salt stress is one of the urgent issues of the day. The contribution of nanoparticles to the solution of this problem in the research of scientists is promising. From the results of our experiments with cotton plants, it is clear that when cotton seeds are treated (coated) with Al nanoparticles, they grow well in saline soils. In the initial stages of plant development, the amount of chlorophyll a and b pigments in the leaves increases, Al nanoparticles reduce the increased activity of key enzymes such as ascorbic peroxidase during salt stress. This decrease is slight in polyphenol oxidase but appreciable in guaiacol peroxidase enzyme. Hussain and Abu-Baker [14] sprayed a solution of Zn O nanoparticles on the leaves of a cotton plant irrigated with seawater to reduce the negative effect of salinity. It was clear from their experiments that application of Nano-Zn O reduced phosphorus (P) uptake and translocation to leaves, resulting in lower P/Zn ratio. They suggested that extra dose of P-fertilizer with Nano-Zn should be used to overcome P/Zn imbalance.

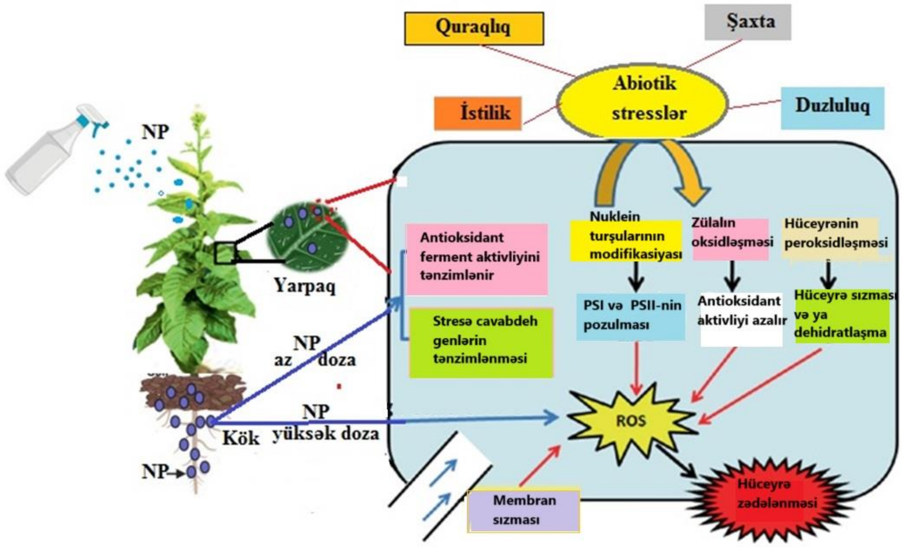

Figure 3: *Effects of nanoparticles on plants under stress conditions*

Avestan et al., [15] used SiO_2 nanoparticles to overcome the effect of salinity stress in their experiment. They managed to improve the morphological and physiological changes in strawberry plants during salt stress using SiO_2 nanoparticles. They found that nanoSiO_2 increased chlorophyll content in salt-stressed plants and maintained better leaf relative water content (RWC) and relative water conservation (RWP) compared to control.

Drought stress and nanoparticles. Plants on our planet have been constantly fighting water stress for millions of years, from the moment they emerged from water to land. As drought occurs, most higher plants are forced to adjust their life cycles to tolerate or avoid this stress. Therefore, drought has been the main driving factor for the evolution and diversification of arid plants. This important environmental factor always remains the main obstacle to agricultural production. For plant physiologists, the concept of "drought" does not simply mean lack of water, it means (1) low soil moisture; It means (2) high evaporation potential, (3) high-temperature conditions, (4) high solar radiation, (5) increased soil hardness, (6) lack of mineral elements, and (7) accumulation of salts in the topsoil.

Experiments show that as a result of the application of nanoparticles to plants in drought conditions, antioxidant enzyme activity increases, phyto hormone levels improve, and important changes in physiological properties occur, and as a result, the effect of drought on plants is reduced. The effects of Fe_2O_3, Zn O and TiO_2 nanoparticles on the development, productivity, biochemical and morpho-physiological parameters of plants under drought conditions were investigated in our experiments with corn plants grown in field conditions. It was determined that nanoparticles have a stimulating effect on plants grown in drought conditions. Plants whose seeds were treated with TiO_2 nanoparticles grew more intensively regardless of drought stress and plant height increased by 1.5 times compared to the control. The height increase was 1.6 times greater than the effect of Zn O nanoparticles, and 1.17 times greater than the effect of Fe_2O_3 nanoparticles. GPX activity significantly increased in the drought variant. This was 20-25 per cent higher than the activity under irrigated conditions. Nanoparticles also reduced GPX activity in the drought variant. At this time, the effect of Zn O nanoparticles was greater. Application of Zn O nanoparticles to soybean plants under drought conditions increases seed germination percentage, application of Cu and Zn nanoparticles to wheat plants increases relative humidity and antioxidant enzyme activity, stabilizes photosynthetic pigment content in leaves, reduces accumulation of thiobarbituric acid, reagents, and consequently reduces stress effects. Application of SiO_2 nanoparticles under drought stress reduces superoxide radical generation and membrane damage but increases shoot length and relative water content in barley. Application of Cu O nanoparticles to maize under drought conditions increases leaf water content, plant biomass, anthocyanin, chlorophyll and carotenoid content. Drought stress increases the negative effect of Cd element in wheat plant, but as a result of application of Zn O nanoparticles, the effect of both Cd and drought stress is weakened. The results of the experiments showed that the use of silver nanoparticles increases the germination percentage of lentil seeds and the growth rate of seedlings under drought conditions [16].

IV. Conclusion

A review of the scientific literature shows that nanotechnology, which has found many different fields of application in the last few decades, has begun to form a powerful scientific field. Nanotechnology is used in medicine, agriculture, industry, environment, engineering, and electronics, and is revolutionizing various fields. Nanotechnology is emerging as an important technology to strengthen and modernize agriculture in particular, which is an important tool to overcome food poverty and malnutrition, and the consequences of global climate change. A large number of extensive studies have determined that nanoparticles can provide beneficial effects on the development and growth of plants, increase productivity, and help eliminate biotic and abiotic stress factors. In perspective, the use of nanotechnology will create a powerful platform and enable a safe and stable future in sustainability, productivity, quality, diagnostics and smart packaging. It will be able to minimize product losses. The most effective way to understand the nature of the mechanisms of application of nanomaterials is to cooperate with such fields of science as molecular biology, plant physiology, plant biotechnology, cytology, soil physics along nanotechnology. Such collaborations can be useful for promoting multidisciplinary projects that can be implemented worldwide. In order to deepen the physiological research on nanotechnology, new ideas about the mechanism of tolerance to various abiotic stresses in plants are formed. The application of nanotechnology should be commercialized from the laboratory to the agricultural fields.

References

[1] Ismat S. Ahmadov 1,, Mahammadali A. Ramazanov , Eldar K. Gasimov, Fuad H. Rzayev , Solmaz B. Veliyeva. The Migration Study of Nanoparticles from Soil to the Leaves of Plants. Biointerface Research in Applied Chemistry. Volume 10, Issue 5, 2020, 6101 - 6111 https://doi.org/10.33263/BRIAC105.61016111

[2] Ismat Suleyman Ahmadov, Mahammadali Ahmad Ramazanov, Abel Mammadali Maharramov. The study of imbibition curves in the seeds of corn (Zea mays) and red kidney bean (Phaseolus vulgaris): effect of nanoparticles and salts. Bio interface Research in Applied Chemistry, volume 8, Issue 3, 3213-3218, 2018.

[3] Lv., J.; Christie, P.; Zhang, S. Uptake, translocation, and transformation of metal-based nanoparticles in plants: recent advances and methodological challenges. *Environmental Science: Nano.* **2018**, https://doi: 10.1039/c8en00645h .

[4] Li, C.C.; Dang, F.; Li, M.; Zhu, M.; Zhong, H.; Hintelmann, H.; Zhou, D.M. Effects of exposure pathways on the accumulation and phytotoxicity of silver nanoparticles in soybean and rice. *Nanotoxicology* **2017**, 11, 699-709, https://doi.org/10.1080/17435390.2017.1344740.

[5] J.C. Tarafdar, R. Raliya, I. Rathore. Microbial Synthesis of Phosphorous Nanoparticle from Tri-Calcium Phosphate Using Aspergillus tubingensis TFR-5. J. Bionanosci., vol. 6 (2) (2012), pp. 84-89, 10.1166/jbns.2012.1077]

[6] G.F. Nekrasova, O.S. Ushakova, A.E. Ermakov, M.A. Uimin, I.V. Byzov. Effects of copper(II) ions and copper oxide nanoparticles on Elodea densa Planch Russ. J. Ecol., vol. 42 (6) (2011), p. 458,

[7] F. Gao, *et al.* Was improvement of spinach growth by nano-TiO(2) treatment related to the changes of Rubisco activase? Biometals Int. J. Role Met. Ions Biol. Biochem. Med., vol. 21 (2) (2008), pp. 211-217, 10.1007/s10534-007-9110-y

[8] Larue C., Castillo-Michel H., Sobanska S., Cécillon L., Bureau S., Barthès V., Ouerdane L., Carrière M., Sarret G. Foliar exposure of the crop Lactuca sativa to silver nanoparticles: Evidence for internalization and changes in Ag speciation. *J. Hazard. Mater.* 2014;264:98–106. doi: 10.1016/j.jhazmat.2013.10.053.

[9] Park S., Ahn Y.-J. Multi-walled carbon nanotubes and silver nanoparticles differentially affect seed germination, chlorophyll content, and hydrogen peroxide accumulation in carrot (*Daucus carota* L.) *Biocatal. Agric. Biotechnol.* 2016;8:257–262. doi: 10.1016/j.bcab.2016.09.012.

[10] Burklew CE, Ashlock J, Winfrey WB, Zhang B (2012) Effects of Aluminum Oxide Nanoparticles on the Growth, Development, and microRNA Expression of Tobacco (Nicotiana tabacum). PLoS ONE 7(5): e34783. doi:10.1371/journal.pone.0034783

[11] González-Moscoso, N.V. Martínez-Villegas , D. Meza-Figueroa , M.C. Rivera-Cruz ,G. Cadenas-Pliego , A. Juárez-Maldonad. SiO_2 Nanoparticles Improve Nutrient Uptake in Tomato Plants Developed in the Presence of Arsenic. Revista bio ciencias vol.8 Tepic 2021 Epub 04-Oct-2021. https://doi.org/10.15741/revbio.08.e1084

[12] Yingming Feng et al., .Effects of Iron Oxide Nanoparticles (Fe3O4) on Growth, Photosynthesis, Antioxidant Activity and Distribution of Mineral Elements in Wheat (Triticum aestivum) Plants. Plants (Basel). 2022 Jul; 11(14): 1894. doi: 10.3390/plants11141894

[13] Cramer G.R., Urano K., Delrot S., Pezzotti M., Shinozaki K. Effects of abiotic stress on plants: A systems biology perspective. *BMC Plant Biol.* 2011;11:163. doi: 10.1186/1471-2229-11-163.

[14] Husseyn M.M. and Abou-Baker N.H. (2018). The contrubition of nanozinc to alleviate salinity stress on cotton plants. Royal Society open science, 5(8), 171809

[15] Avestan et al., (2019). Application of Nano-Silicon Dioxide improves Salt Stress Tolerance in Strawberry Plants. Agronomy, 9(5), 246

[16] Seyed Saeid Hojjat .The Effect of silver nanoparticle on lentil Seed Germination under drought stress . *International Journal of Farming and Allied Sciences.* **2016**, IJFAS Journal-2016-5-3/208-212/ 31 March, 2016

PROSPECTS FOR THE DEVELOPMENT OF DIGITAL CURRENCY IN THE CONTEXT OF AN INNOVATIVE ECONOMY

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Abstract

The historical method, abstract and logical methods, comparative and statistical methods were applied within the research. The characteristic of digital currencies of Central Banks, their differences from cryptocurrencies is presented, possible models of their functioning are considered in the article. Some regularities between the needs of consumers for which the digital currency is issued, and the features of its design are offered. The international experience of digital money introduction is analyzed and some conclusions are drawn on the advantages and prospects of this tool. The authors conclude that the transition to digital currencies will lead to faster innovative development of the bank and monetary-and-credit systems and the payment market as well. The conclusions and recommendations, drawn in the article, can be useful for the specialists occupied with the development of approaches to realization of digital national currencies, development of their design. The authors of the article consider an innovative form of money, digital monetary unit or digital currency.
The authors conclude that the transition to digital currencies will lead to faster innovative development of the bank and monetary-and-credit systems and the payment market as well. The conclusions and recommendations, drawn in the article, can be useful for the specialists occupied with the development of approaches to realization of digital national currencies, development of their design. The authors of the article consider an innovative form of money, digital monetary unit or digital currency.

Keywords: digital economy, innovation, payment market, digital currency, banking instruments

I. Introduction

In Russia the Central Bank of the Russian Federation started the development of the concept of digital rouble in 2020. In October, 2020 it published the special report for public consultations, in which the advantages of digital currency were described. In the conditions of the innovation economy new requirements to the communications, computing power, information systems and services appear. The innovation technologies development caused the emergence of a new form of money existence – digital currency (Plehova et al. 2020), (Bank for International Settlements, 2022; (Yakunina, 2022), (Imangozhina et al,2019), (Ivanova O. 2020), (Tutova V.A., 2024), (Yarovenko, 2021), (Khalilova, et al. 2022), (Kodasheva, G. et al, 2022), (Burkaltseva et al. 2022), (Rudyk et al,2022), (Petrova et al.,2022), (Niyazbekova &,Troyanskaya et al, 2021), (Patashkova, Y. et al.,2021), (Evmenchik, 2021), (Jazykbayeva, 2021), Niyazbekova, 2021), (Abramova et al.,2023), (Grekov, et al., 2016), (Niyazbekova et al., 2021;2023), Yakunina et al (2022), Mikhaylishin (2021) Kucherov I.I. (2018) Eskindarov M.A. et al. (2019) Andryushin S.A. (2019).

In April, 2021 the expert discussions took place in Russia; the discussion came to the end with the publication of the concept of digital rouble, which described the role, possibilities of application as well as the models and mechanisms of the use of digital currency (Bank of Russia, 2020; 2021; 2022)[1]. Converting of cash or non-cash rouble into digital rouble will be performed as 1:1. Client will be able to save his or her funds in case of bankruptcy of the financial institution working with digital currency. Funds will be available through other financial institution as the actually monetary unit belongs to the Central Bank of the Russian Federation.

Moreover, according to the glossary of Committee on payments and market infrastructure of Bank for International Settlements, electronic money is defined as "the cost stored in an electronic form on the device like the smart card or the hard drive of the personal computer" (Bank for International Settlements, 2020[2]).

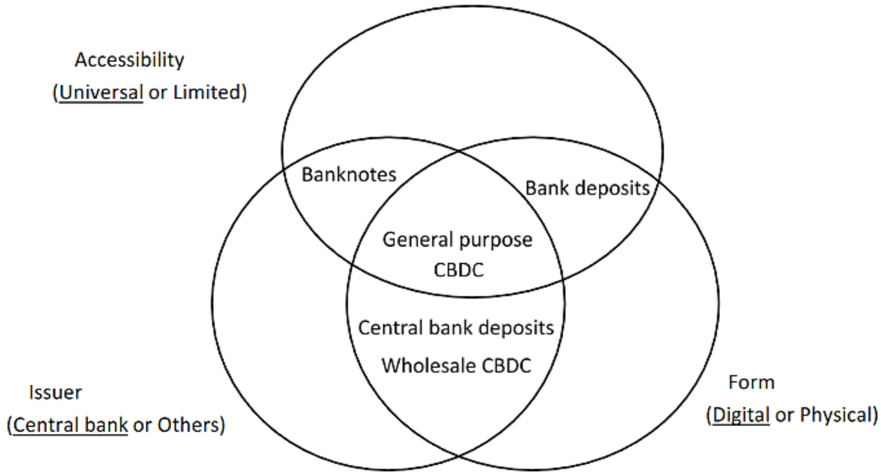

Figure 1: *Classification of Currency (according to Bank of Japan, 2020)*

Most representatives of Central Banks considered digital currencies of Central Banks (especially retail CBDC) negatively or scornfully up to 2019.

Many scientific works, devoted to digitalization of economy in general and the payment market in particular, were written from the moment of the beginning of work on the creation of digital rouble. The authors consider such Russian authors as Eskindarov M.A. (2019), Andryushin S.A.(2019), Serebrennikova et al. (2021), Mikhaylishin A.Yu. (2021), Kucherov et al. (2018), Tobin J. (1987) et al. to deserve attention. However, not all the matters have been taken rather up. For example, it is required to develop some recommendations on the choice of option of digital currency design, depending on the needs of their potential consumers.

II. Methods

Official data of Central Bank of the Russian Federation (Bank of Russia, 2020; Bank of Russia, 2021), Sveriges Riksbank (2022), Deutsche Bank (2022), People's Bank of China (2017)[3], Bank of Japan (2020)[4], etc. as well as the reports of analytical agencies served as epy materials for this research.

Historical method, abstract and logical methods, comparative and statistical methods were

[1] a) Bank of Russia (2020) Digital rouble. Report for public consultations. Moscow. 48 p. URL: http://www.cbr.ru/StaticHtml/File/112957/Consultation_Paper_201013.pdf (date of the address: 12.06.2024)
B) Bank of Russia (2021) Concept of digital rouble. Moscow. 31 p. URL: http://www.cbr.ru/Content/Document/File/120075/concept_08042021.pdf (date of the address: 12.06.2024)
C) Bank of Russia (2022) Digital ruble: testing start. URL: https://www.cbr.ru/press/event/?id=12685 (date of the address: 12.06.2024)

[2] Bank for International Settlements (2018) Central bank digital currencies, CPMI, Markets Committee Paper, 174, 1-34. URL: https://www.bis.org/cpmi/publ/d174.htm (date of address: 20.06.2024).

[3] Bank of China (2017) China Payment System Development Report 2016. China financial publishing house. 257 p.

[4] Bank of Japan (2020) The Bank of Japan's Approach to Central Bank Digital Currency. 19 p. URL: https://www.boj.or.jp/en/announcements/release_2020/data/rel201009e1.pdf (date of address: 20.07.2024)

applied within the research.

Official data of Central Bank of the Russian Federation (Bank of Russia[5], 2020; Bank of Russia, 2021[6]), Sveriges Riksbank (2022), Deutsche Bank (2022), People's Bank of China (2017), Bank of Japan (2020), etc. as well as the reports of analytical agencies served as epy materials for this research.

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Historical method, abstract and logical methods, comparative and statistical methods were applied within the research.

III. Results

In Russia the Central Bank created the prototype of the platform of digital rouble by the end of 2021. 2022 The first pilot group consisting of 12 banks which assets are 70.4% of the total assets of 328 credit institutions for the end of 2021 was created for its testing in January (Table 1).

Table 1: *Structure of pilot group on digital rouble testing (Bank of Russia, 2022)*

Bank	Position in the rating according to the volume of assets	Volume of assets in the end of 2021, trillion roubles	Western sanctions against the bank after 24.02.2022
Sberbank	1	38.284	Blocking
VTB	2	19.361	Blocking
Gazprombank	3	8.707	Absent
Alfa-Bank	4	5.612	Blocking
Promsvyazbank	6	4.045	Blocking
Rosbank	11	1.579	Absent
Tinkoff Bank	13	1.278	Absent
DOM bank.RF	16	0.913	Absent
Ak Bars Bank	20	0.66	Absent
TKB bank	37	0.208	Absent
Sinara bank	57	0.116	Absent

The analysis of the world practice showed that though many countries go to creation of the digital currencies in a similar way, they can choose different models for their realization.

Types of architectures of retail CBDCs (Fig.2).

[5] Bank of Russia (2021) Concept of digital rouble. Moscow. 31 p. URL: http://www.cbr.ru/Content/Document/File/120075/concept_08042021.pdf (date of the address: 12.08.2024)
[6] Bank of Russia (2021) Concept of digital rouble. Moscow. 31 p. URL: http://www.cbr.ru/Content/Document/File/120075/concept_08042021.pdf (date of the address: 12.08.2024)

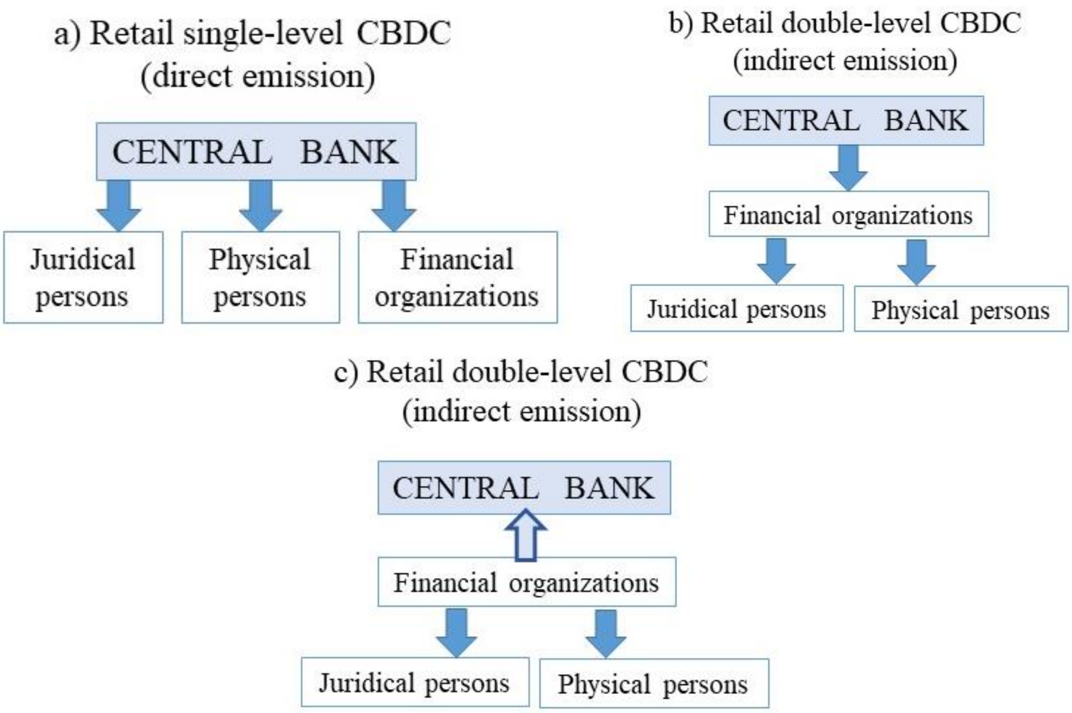

Figure 2: *Types of architectures of retail CBDCs (created by the authors)*

E-CNY has two-level structure, according to PBOC. But from the users' point of view, the model has more than the levels (Figure 3).

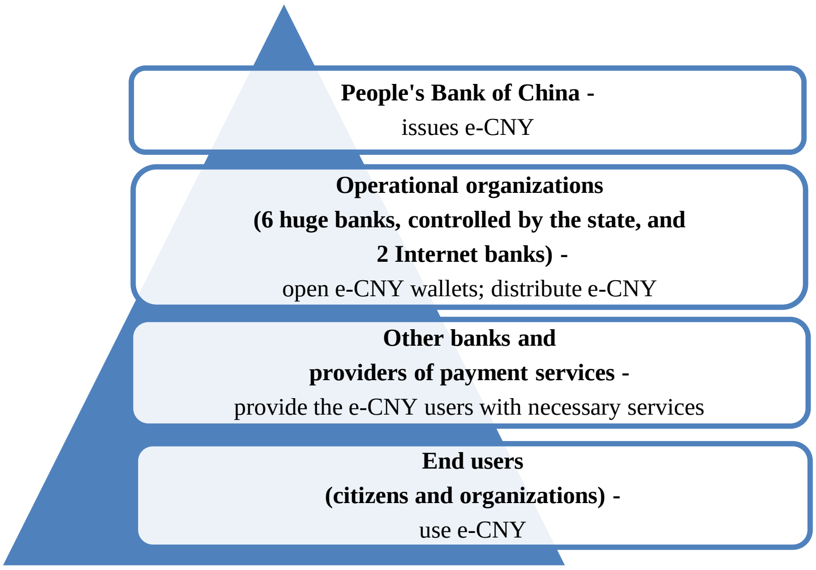

Figure 3: *Structure of the e-CNY model*

Source: created by the authors according to (Deutsche Bank, 2021)

The regulator of China considered the possible negative effect for "usual" national currency

The analysis of the world practice showed that though many countries go to creation of the digital currencies in a similar way, they can choose different models for their realization.

As for Russia, the two-level model, in which there are elements of the centralized system and the decentralized registers on the basis of blockchain technology was accepted. The first one provide large-scale data handling, and the second one allow to increase the efficiency, reliability and speed of transactions. The system of tracking and calculations among the participants (clearing) which maintains the register of the stream of means and their ownership is an important part of all process (Yakunina et al., 2022). Such model is most available to citizens and organizations and can be integrated into the bank infrastructure for customer service. The Central Bank allows to open virtual wallets for the users and allows financial institutions, Federal Treasury and other authoritiesto perform operations.

There is no universal option of the digital currency design. According to the authors of the article, the features of the digital currency design are determined by the consumers' needs. The authors' recommendations on the matter are provided in Figure 4.

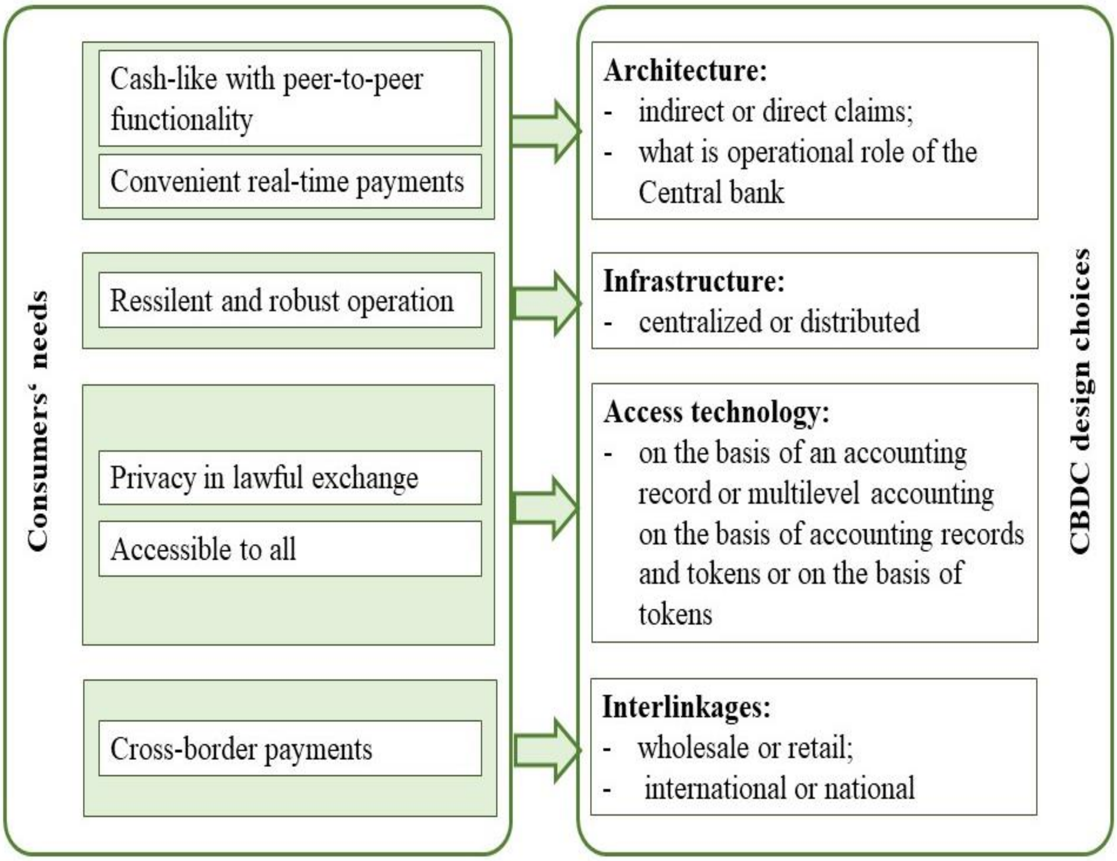

Figure 4: *Choice of Central bank digital currency according to the consumers' needs (drawn by the authors according to BIS Working Papers, 2020 and Kumhof & Noone, 2018)*

IV. Discussion

The accelerated digitalization was also strongly influenced by the coronavirus pandemic, which stimulated people to choose contactless and cashless payment.

Nevertheless, there is no consensus about the matter, how digital currencies are capable to perform the main and commonly accepted functions of money, among scientists and practicians.

Respectively, all three forms of Russian rouble will be absolutely equivalent (Bank of Russia, 2020). But this statement is debatable. According to other economists, digital money cannot be the store of value or to perform functions of means of accounting and payment (these two functions continue to be performed by official money) (Bouveret, Haksar, 2018).

However, digital currencies have to overcome some obstacles: their cost has to be stabler; they have to become convenient both to sellers, and consumers; their transition to the legitimate legal framework, legal regulation improvement are required; integration of digital currencies by leading companies in the field of payments (mobile applications, providers of bank cards) as well as large retail sellers.

At the same time payment and investment services are the kind of financial services. With respect thereto digital currencies can be considered not as money, but as a special financial instrument. According to other economists, digital money cannot be the store of value (Banque de France, 2018) or to perform functions of means of accounting and payment (these two functions continue to be performed by official money)

Studying of analytical reports and scientific works on CBDC proves that nobody among accounting or practicians knows definitely, what such innovation will lead to.

At the same time, reduction of dependence of users on certain providers will increase stability of a financial system of the country (Bank of Russia, 2020).

According to other economists, digital money cannot be the store of value (Banque de France, 2018) or to perform functions of means of accounting and payment (these two functions continue to be performed by official money).

Thus, this innovation is very perspective and capable to bring great benefit to modern economy. Soon we can expect transition from cash and traditional forms of non-cash payments to completely digital forms of money which will significantly change the payment market, bank and monetary-and-credit systems.

Besides, external restrictions and "freezing" of assets are not dangerous for such a form of calculation as digital currency. That is one of the reasons, why the sanctions of 2022 will even accelerate the introduction of digital rouble for the calculations in the Russian economy. There are all the reasons to expect, that digital currencies have great prospects.

References

[1] Bouveret A., Haksar V. (2018) What are cryptocurrencies? A potential form of money offers benefits while posing risks. Finance and Development. 26-27. URL: https://www.imf.org/en/Publications/fandd/issues/2018/06/what-are-cryptocurrencies-like-bitcoin-basics

[2] Dubyansky A.N. (2017) Theories of the origin of money and cryptocurrency. Money and credit, 12, 97-100.

[3] D'Urbino L. (2021) The digital currencies that matter. The Economist. URL: https://www.economist.com/leaders/2021/05/08/the-digital-currencies-that-matter (date of address: 20.09.2024).

[4] Kochergin D.A. (2017) Place and role of virtual currencies in the modern payment system. St. Petersburg State University Bulletin. Economy, 33-1, 119-140

[5] Plekhova Yu. et al. (2020) Digital money as a factor in the development of an innovative economy. StudNet, 8. URL: https://cyberleninka.ru/article/n/tsifrovye-dengi-kak-faktor-razvitiya-innovatsionnoy-ekonomiki (URL: 22.07.2024). Sitnik AA. (2020)

[6] Digital Currencies: Problems of Legal Regulation. Current problems of Russian law,15 (11), 103-113, DOI: 10.17803/1994-1471.2020.120.11.103-113.

[7] Tobin J. (1987) The case for preserving regulatory distinctions. Proceedings. Economic Policy Symposium. Jackson Hole, 167–205.

[8] Deutsche Bank. Official website. (2021) Digital yuan: what is it and how does it work? URL: https://www.db.com/news/detail/20210714-digital-yuan-what-is-it-and-how-does-it-work (date of address: 14.07.2024)

[9] Kunanbayeva, K. et al. Risk and Uncertainty in the Management System of a Commercial Bank. Approaches to Global Sustainability, Markets, and Governance, 2023, Part F643, P. 375–381. DOI:10.1007/978-981-99-2198-0_41

[10] Kunanbaeva, K, et al. Increasing the energy efficiency of the city-forming organizations of ferrous metallurgy. E3S Web of Conferences, 2021, 284, 0100.

[11] Kuzmina, M., er al. Environmental aspects of the public examination of the construction of an Incineration complex. E3S Web of Conferences, 2023, 458, 04019

[12] Jumabayeva, A. et al, 2023. Ensuring food security and competitiveness of the agro-

industrial complex | Garantindo a segurança alimentar e a competitividade do complexo agroindustrial. Brazilian Journal of Food Technology, 2023, 26, e2023079

[13] Rakhimova, S. et al, 2021. Development of an economic mechanism for creating sustainable regional infrastructure for supporting small businesses. E3S Web of Conferences, 2021, 258, 06063

[14] Niyazbekova Sh.U., Uspambayeva M.K., Moldashbayeva L.P. On institutional and legal problems of state audit and financial control // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2019. – № 3 (30). – Pp. 15-20. doi: 10.21777/2587-554X-2019-3-15-20

[15] Imangozhina Z.A., Niyazbekova Sh.U. International economic cooperation of the persian gulf countries in the gas sector // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2019. – № 1 (28). – Pp. 15-20. doi: 10.21777/2587-554X-2019-1-15-20

[16] Niyazbekova Sh.U., Bunevich K.G. Analysis of socio-economic development of Astana city // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2017. – № 3 (22). – Pp. 24-31. doi: 10.21777/2307-6135-2017-3-24-31

[17] Ivanova O.S., Niyazbekova Sh.U. Development of fintech and big data in the financial sector: features, problems, opportunities // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2020. – № 1 (32). – Pp. 30-36. doi: 10.21777/2587-554X-2020-1-30-36

[18] Tutova V.A., Niyazbekova Sh.U. Assessment of the effectiveness of marketing strategies of banking systems through the analysis of marketing activities of jsc tinkoff bank // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2024. – № 2 (49). – Pp. 42-51. doi: 10.21777/2587-554X-2024-2-42-51

[19] Yarovenko S.E., Niyazbekova Sh.U. COMPARATIVE ANALYSIS OF GLOBAL FINANCIAL CRISES, THEIR CAUSES AND CONSEQUENCES // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2021. – № 4 (39). – Pp. 48-57. doi: 10.21777/2587-554X-2021-4-48-57

[20] Niyazbekova Sh.U., Bunevich K.G. A BRIEF OVERVIEW OF THE DANISH FINANCIAL SECTOR // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2020. – № 3 (34). – Pp. 50-56. doi: 10.21777/2587-554X-2020-3-50-56

[21] Khalilova, M et al. P2P Lending as a New Model of Digital Bank. Studies in Big Data, 2022, 110, pp. 101–107 DOI: 10.13140/RG.2.2.33116.44167

[22] Kodasheva, G. et al, Innovative Banking Services in the Conditions of Digitalization. Studies in Big Data, 2022, 110, pp. 73–79 DOI: 10.1007/978-3-031-04903-3_10

[23] Burkaltseva, D. et al.Assessment of the Development of the Stock Market in the Russian Federation in a Crisis. Journal of Risk and Financial Management, 2022, 15(1), 4

DOI: 10.3390/jrfm15010004

[24] Burkaltseva, D.et al. Methodological Foundations of the Risk of the Stock Markets of Developed and Developing Countries in the Conditions of the Crisis.., Journal of Risk and Financial Management, 2022, 15(1), 3 DOI: 10.3390/jrfm15010003

[25] Rudyk, N.et al,Development and Regulation of the Digital Economy in the Context of Competitiveness.., Niyazbekova, S.U., Yessymkhanova, Z.K., Toigambayev, S.K. Lecture Notes in Networks and Systems, 2022, 245, pp. 167–174 DOI:10.1007/978-3-030-77000-6_20

[26] Petrova, L. et al Digital Transformation as a Strategic Direction Business Development in Modern Conditions. Lecture Notes in Networks and Systems, 2022, 245, pp. 183–192

DOI:10.1007/978-3-030-77000-6_22

[27] Niyazbekova, S. et al. Green bonds - A tool for financing green projects in countries. E3S Web of Conferences, 2021, 244, 10060 DOI:10.1051/e3sconf/202124410060

[28] Niyazbekova, S.,Troyanskaya, M.et al, Instruments for financing and investing the green economy in the country's environmental projects. E3S Web of Conferences, 2021, 244, 10054 DOI:10.1051/e3sconf/202124410054

[29] Patashkova, Y. et al. Dynamics of Bitcoin trading on the Binance cryptocurrency exchange. Economic Annals-XXI, 2021, 187(1-2), pp. 177–188 DOI:10.21003/ea.V187-17

[30] Evmenchik, O.S. The Role of Gross Profit and Margin Contribution in Decision Making. Studies in Systems, Decision and Control, 2021, 314, pp. 1393–1404 DOI:10.1007/978-3-030-56433-9_145

[31] Jazykbayeva, B., The Growth of green finance at the global level in the context of sustainable economic development. E3S Web of Conferences, 2021, 244, 10058 DOI:10.1051/e3sconf/202124410058

[32] Niyazbekova, S. Digital Economy Development as an Important Factor for the Country's Economic Growth. Studies in Systems, Decision and Control, 2021, 314, pp. 361–366 DOI:10.1007/978-3-030-56433-9_38

[33] Abramova M. Features of the mechanism for implementing sustainable development through the green economy. E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

[34] The influence of macroeconomic factors to the dynamics of stock exchange in the Republic of Kazakhstan. Niyazbekova, S.U., Grekov, I.E., Blokhina, T.K. Economy of Region, 2016, 12(4), pp. 1263–1273 doi: 10.17059/2016–4–26

[35] Niyazbekova S. Features of the "Green" strategies for the development of banks., Anastasia Zverkova, Natalia Sokolinskaya and Seyit Kerimkhulle. E3S Web of Conf., 402 (2023) 08029 DOI: 10.1051/e3sconf/202340208029

[36] Niyazbekova, S. et al. (2023). Analysis of Mortgage Lending in Conditions of Instability. In: Popkova, E.G. (eds) Sustainable Development Risks and Risk Management. Advances in Science, Technology & Innovation. Springer, Cham. DOI: 10.1007/978-3-031-34256-1_108

[37] Yakunina E., Yakovlevskaya A., Zhundrikov A. (2022) Than can help infrastructure digital ruble? InfraOne Research. 7 (77) URL: https://infraoneresearch.ru/87mpm9?8r51fq%5B0%5D=2&s1qtyk=1noixc (date of the address: 12.07.2024)

[38] Mikhaylishin A.Yu. (2021) Prerequisites of emergence and international experience of introduction of digital currencies of Central Banks. Russian Journal of Economics and Law. 2. URL: https://cyberleninka.ru/article/n/predposylki-poyavleniya-i-mirovoy-opyt-vnedreniya-tsifrovyh-valyut-tsentralnyh-bankov (date of the address: 20.07.2024).

[39] Kucherov I.I. (2018) Cryptocurrency (idea of legal identification and legitimation of alternative means of payment). Moscow. YURINFOR Center. 204 p.

[40] Eskindarov M.A. et al. (2019) Risks and chances of digital economy in Russia. Finance: theory and practice, 23.5 (113), 6-17.

[41] Andryushin S.A. (2019) Monetary and credit systems: from sources to cryptocurrencies". Moscow: Sam Poligrafist LLC. 452 p.

DEVELOPMENT OF THE AGRICULTURAL SECTOR AS AN IMPORTANT AREA OF EMPLOYMENT AND INCOME GROWTH FOR RUSSIANS

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Abstract

This article examines the problems of development of agricultural production in Russia. The author notes that the market processes of the last century in the Russian economy especially negatively affected those employed in the agricultural sector. There was a significant decline in the country's production of agricultural products, less sown areas, harvested grain, livestock, which were both the causes and consequences of the decline in the agricultural sector of labor remuneration and employment. The author found that the growth of employment in private subsidiary farming was a forced measure in the conditions of low wages of workers in the agricultural sector. The paper explores the possibility of developing many areas of agrarian production in the Chechen Republic, where there are not only natural and climatic conditions for this, but also a sufficient number of labor force. According to the author, the development of agricultural production in the region will provide jobs for a significant part of the local population. The necessity of material support from the state, the formation of appropriate legislative and tax systems in solving this problem is conditioned.

Keywords: agricultural production, employment, wages, Chechen Republic, rural areas, rural industrial enterprises

I. Introduction

Revival of the agrarian sector in the socio-economic development of the Russian state is considered among the main tasks of strategic nature. Agriculture as the basis of the agro-industrial complex in the country's economy plays a great role, since the food security of the state and the standard of living of rural residents depend on it. It is worth noting that Russian rural areas are home to up to 30% of its total population of more than 140 million people [1, c. 79]

Agricultural production, based on its ability to meet the needs of the country, is considered as an advanced sector of the Russian economy, which can meet domestic demand up to 90% for all major products. In the structure of Russian exports, agricultural products also account for a fairly significant share. Thus, in terms of wheat exports - 25 million tons, the country became the first in the world back in 2016, taking this place from the United States [2, c. 157]

II. Methods

Evstigneeva L. and Evstigneev R., note that one of the most important tasks facing Russia is the complication of its socio-economic structure as a prerequisite for the creation of a modern market economy. Such an economy is based on the tandem of large financial capital, which closely interacts with the state and regional markets. The more certain Russia's self-identity becomes in this respect, the more likely it will be a center of attraction for other CIS countries.

According to D. Samygin and A. Kudryavtsev, regions with favorable conditions for agricultural activity have a significant reserve for improving the efficiency of subsidies, which should be taken into account in the future when allocating state support funds.

According to Belousov R., the Russian economy was facing a challenge that had a “multidimensional” character: the growth potential was sharply decreasing due to external factors of development - high oil prices and increasing raw material exports; conditions for the development of non-resource sectors of the economy were deteriorating due to the expected opening of domestic markets; there was an urgent need for large-scale investments in the development of social and industrial infrastructure.

The work of Glazyev S.Y. and others is devoted to the study of the processes of market reforms development in Russia and their results. As the data analysis shows, by some indicators the country's economy was thrown back to the pre-revolutionary level, and even the war did not lead to such a long and deep decline in national production.

A. Emelyanov in his work analyzes the socio-economic structure of the Russian agrarian sector, developed in the course of its reform in the 1990s, determines the factors of improving the use of the potential of various forms of management, aimed at ensuring food independence of the country and the revival of the Russian village.

As Kashepov A. notes, institutions in the economy represent social norms, habits and behavior of subjects and at the same time large public, including state structures.

Basalaeva E. in her work focuses on such important problems of the agrarian sector as low incomes of the population employed in it, price disparity in industry and agriculture, reduction of the share of domestic food in the domestic market. The author pays much attention to the application of the most effective forms of distribution of funds allocated to the industry.

Uzun V. analyzes the processes of development of large and small businesses in Russian agriculture, determines the impact on their activities from natural, economic, ethnographic factors, as well as agrarian policy. The paper also presents the results of a comparative analysis of the efficiency of land and labor use by corporate, farm and private subsidiary farms.

Bogdanovsky V., studying the problem of employment in Russian agriculture in the years of market transformation, noted that there was a largely forced, large-scale transfer of labor from corporate farms to individual farms, as well as a significant decrease in labor profitability, actively developing underemployment, falling quality of human capital. Under such conditions, measures aimed at overcoming the industry's lag in labor profitability and developing alternative forms of employment for rural residents were important.

The work of Korotcheny V.M. notes the low efficiency of domestic agriculture compared to CIS countries and a relatively large technological gap with developed countries with a tendency to reduce. The author's calculations confirm the growth of efficiency of the Russian agricultural sector in the CIS beyond the time limit of the main study.

Buzdalov I., conducting socio-economic analysis of the nature and consequences of agrarian transformations in China and Russia, points to the presence of signs of a deep systemic crisis in the agrarian sphere of Russia in contrast to China. The author considers it important to use Chinese and foreign experience to achieve the priority of rural development in the country.

Bayrakov A.I. et al. study the natural landscapes of the Chechen Republic and their transformation under the influence of natural and anthropogenic factors as a prerequisite for a science-based approach to solving regional geo-ecological problems. The urgency of solving the existing problem is determined by ensuring environmental security and sustainable development of the region, which has long experienced anthropogenic impact, including military.

Abdulgalimov A.N. and Kurnosova T.I. consider very significant the problem of small innovative business development in the country, the solution of which depends on the possibility of transferring the economy to innovation rails.

Reshiev S.S., considering the nature and level of development of agriculture in the Chechen Republic, concludes that this production sector of the republic's economy still needs serious transformations and modernization, using the experience of successful analogues from the world and domestic practice.

Svetlov M.N. and others, analyzing the impact of state support of agricultural organizations on the revenue from the sale of agricultural products on the example of 14 Russian regions with significant differences in natural, institutional and technological conditions of agricultural production, emphasize the heterogeneity of state support effects for these territories.

Malyuk L.I. and others, studying the potential of non-agricultural employment, presented as a necessary form of employment of rural residents, believe that its development will largely solve the problem of unemployment in rural areas and increase the income of the rural population of the country.

When conducting this scientific research, such scientific methods as the method of comparative analysis, statistical analysis, comparative analysis, functional analysis, positive and normative analysis were applied. The scientific research was conducted in accordance with the problem-chronological principle, the principles of systematicity and scientific objectivity.

III. Results

The market transformation that took place in the Russian economy in the 1990s had a particularly negative impact on the situation of those employed in agricultural production. Thus, if in the agricultural sector of the country in 1990 there were about 8.3 million people, then in 1995 their number decreased to 6.7 million, in 2000 - to the mark of 4.7 million, and by the beginning of 2006 workers became 3 times less, i.e. 2.5 million. [3, p. 10] The number of cattle from 1990 to 1999 decreased by about 62% (from 45.3 million to 17.3 million); pigs - by 65% (from 27.1 million to 9.5 million); grain production decreased by 58%, i.e. 47 million tons instead of 113.5 million tons. 47 million tons instead of 113.5 million tons; the reduction in milk production reached 62% (from 41.4 million tons to 15.8 million tons); the area of agricultural land decreased by about 26% (from 202.4 million hectares to 152.7 million hectares), and of them the area under crops - by 35% (from 112.1 million hectares to 73.0 million hectares). [4, p. 56] If we consider the period 1990-2005, the plowed areas became less than 2 times less - only 51.4 million hectares instead of 112.1 million hectares; the number of cattle decreased more than 4 times, amounting to 10.9 million heads instead of 45.3 million [3, c. 10]

Employees of the agricultural sector in 1990 had an average labor remuneration reaching 95% of the average level in the economy as a whole, and compared to the same indicator in industry - up to 93%, but already in 2003 this indicator was only about 40% and 30%, respectively. [5, p. 125] Wages, as well as employment in the agrarian sector in the years under consideration decreased with a significant decline in agricultural production, reduction of livestock and cultivated areas, which can be considered both as a cause and as a consequence of these negative processes. The beginning of the 2000s was marked by the growth of wages in the agricultural sector, which increased by 46.6% in 2000-2001 and by 35.4% in 2002 relative to 2001. [6, p. 145] In 2004, of all those employed in the economy of the country, the workers of agricultural production accounted for 10.3% [7, p. 65], paid on average at the level of 43% of the similar indicator of urban residents. [8, c. 47]

During the period of market transformation of the 1990s and early 2000s, many people employed in the agricultural sector were forced to move to private subsidiary farms due to a significant drop in labor remuneration, which is not very high today. Thus, in 2002, the number of persons employed in their own farms of commodity orientation reached 3 million people, which could be compared with the number of employees of agricultural companies of large and medium-sized businesses, but still the vast majority of those working in private farms was noted in non-commodity production [9, p. 112]. Low incomes of agricultural workers could not but have negative consequences on the professional composition of the employed. Thus, at the beginning of 2003 only 16.9 thousand out of 86 thousand people who graduated in 2002 from agricultural universities, technical schools and colleges on a full-time basis, expressed a desire to work in the agricultural sector, i.e. every fifth person, only 18% were employed in their specialty, and this is with 30 thousand vacancies [10, p. 76]. This situation regarding employment in agricultural production and unemployment among rural residents is higher than in the city, required the state to develop certain measures for rural development, the purpose of which would be to increase the wages of agricultural workers, the growth of their professional level, increasing employment opportunities in rural areas, including through non-agricultural activities.

It is worth noting that only when agrarian policy is based on the special regularities of the development of agrarian relations and provides those employed in this production with the necessary socio-economic conditions, stimulates their labor productivity, it can be considered scientifically justified. Such a policy not only leads to the growth of food security of the country, but also makes it possible to have the status of a food power in the world. Here it is important to point out that neither crisis nor stagnation has practically no special influence on agrarian production.

IV. Discussion

How effective the country's agriculture should be determined based on comparative analysis with other countries on the basis of such, for example, non-parametric and parametric methods that establish the boundaries of production possibilities [11, p. 144]. Thus, for the development of social and engineering infrastructure in rural areas, the Chinese government implemented a protectionist "pro-peasant" agrarian policy, which attached importance to agro-industrial cooperation and integration. There were more and more national enterprises, which operated through "contract-orders" with family households, thus providing the opportunity to link together not only the processes of production, processing and marketing of the product, but also the supply of the necessary tools for this purpose. The structures that produce machinery and other equipment for the agricultural sector accounted for more than 130 million workers, producing products worth more than $500 billion [12, p. 138]. The implementation of these measures for rural development, in the implementation of which the state investment increased 30 times, provided China with a radical change in the socio-economic situation and to a greater extent in the agricultural sector, while before these reforms the country ranked only 125-130th in the world in terms of GDP per capita [12, c. 140].

To date, the following types of organizational and economic patterns can be distinguished in Russian agriculture:

- agricultural organizations hiring workers under contract;
- peasant (farmer) farms, where a contract may be drawn up when hiring workers or self-employment may be present;
- personal subsidiary farms that work on the basis of self-employment.

It should be noted that for the Chechen Republic the agricultural sector is one of the most important components of the regional economy, which can provide a significant part of its population with employment opportunities, thus reducing the number of unemployed, since the region has a fairly high proportion of rural residents - 62% as of January 1, 2021. [13] In agricultural production the decisive role is given to natural and climatic conditions, on which depends not only specialization, but also the very possibility for this activity. Accordingly, the location of various branches of this production in a certain territory requires taking into account the peculiarities of its soil and climatic zones. Although the Chechen Republic is small in terms of territory, it has a variety of climatic conditions for the development of many areas of agriculture. Thus, the region has nine soil-climatic zones with semi-deserts and sandy soils, steppes with chernozems, forests and mountain meadows. The soils are mostly chestnut, chernozem and meadow soils of good fertility; there are hot summers and short, rather mild winters against a background of different temperature conditions. Precipitation is uneven throughout the year, with more precipitation in June, while the least precipitation occurs between January and March. The region's river network is also uneven in distribution, with a densely branched river network in the mountainous part of the region and the adjacent Chechen plain, and almost none in the Tersko-Sunzhenskaya Upland and north of the Terek River [14].

In general, the natural and climatic conditions of the Republic allow to effectively develop not only the livestock industry, but also crop production, because with insufficient precipitation in most parts of the region, the presence of a developed network of rivers makes it possible to produce crops under artificial irrigation. For example, winter wheat yields well in mild winters, especially in the steppe and forest-steppe parts; the presence of plenty of heat ensures the production of grapes with a high sugar content, and the Naursky, Nadterechny and Shelkovsky districts are particularly suitable for this crop. Planting vineyards on the Zaterechnye stormy sands allows to use not only empty lands, but also to avoid many diseases of this crop. As experts note, in Soviet times in the republic collected up to 100 centners of grapes from one hectare, then sent it to different cities of the country by the day [15]. Also on the territory of the republic sunflower, gourds, especially in the farms of the Zaterezhnaya zone, have shown themselves to be highly profitable crops; good prospects for rice, the production of which requires the implementation of appropriate reclamation works. The high efficiency of production of cucumbers, tomatoes and herbs in greenhouses is confirmed by the example of "TC YugAroholding" LLC activity in the region, which gives an opportunity to both local residents and those from other regions to eat these vegetables of high quality in the winter season. Here it is important to note that among the main criteria of the efficiency of production activities of economic entities are the quality and quantity of products produced by them [16, c. 7].

It should be noted that there are geothermal sources in the republic, mostly in the foothills, the use of which in the production of greenhouse crops due to their cheap energy can be very profitable. Thus, in conditions of cheap energy, production of persimmons, pomegranates, oranges and other subtropical crops can be very profitable, but the problem is to solve the issue of purification of thermal water from the presence of highly corrosive substances. Natural and climatic features of terraces and sloping lands of mountainous areas are more suitable for mass production of various fruits and berries. Also alpine meadows of mountainous areas give all conditions for the development of meat cattle breeding, good conditions for honey production. In the stormy lands of the Shelkovsky and Nadterechny districts, fine-fleece sheep breeding gives good results. It is more desirable to use steppe and forest-steppe territories of the republic for dairy cattle breeding and poultry farming if there is a fodder base.

The development of agrarian production within the framework of the regional state program developed for this purpose provides for the creation of conditions necessary for the growth of living standards and employment of rural residents of the republic. The volume of agrarian production from all forms of agricultural producers - agricultural organizations, peasant (farmer) farms and households, calculated in current prices, in January-October 2023 in the republic, according to preliminary estimates, reached 39562.9 million rubles, exceeding by 14.8% the corresponding figure of the previous year [17]. Among the most priority areas of production within the framework of this program are considered vegetable growing, fruit growing, viticulture, which determine the overall sustainability of the entire agro-industrial complex and, to a large extent, the regional economy and import substitution; as a backbone sub-branch is presented cattle breeding, which provides for the production of milk, meat and uses significant areas of agricultural land [17].

The republic has been experiencing positive dynamics in the development of the livestock industry for a number of years. Thus, according to the results of calculations, the number of cattle for January-October 2023, attributable to the farms of all agricultural producers, amounted to 259.5 thousand heads, which was 0.8% higher than the same indicator of the previous year, of which the number of cows - 129.1 thousand heads, i.e. 1.7% more, and sheep and goats accounted for 299.3 thousand heads, indicating an increase of 1.7% compared to the corresponding values of the previous year [17].

It should be noted that for the growth of livestock productivity the most important is its pedigree composition. In the livestock industry of Russia, pedigree livestock occupies not too high a share, inferior to a similar indicator of developed countries, which contributes to the practice of buying highly productive animals, etc. abroad, although there is rich experience in the field of national breeding [18, c. 19].

The Chechen Republic has the appropriate specialized agricultural machinery and elite planting material for the development of the agro-industrial complex. Agricultural lands are enriched with the necessary mineral fertilizers, pesticides are used, new vines are planted instead of old vineyards, fishery reservoirs are restored, and fish farms are supplied with special fodder. But there are still problems regarding the provision of mineral fertilizers, pesticides, new machinery and equipment, etc. in different farms.

It is worth recalling that in the republic of the Soviet period, not only natural-climatic and soil conditions were taken into account in the allocation of agricultural production, but also the needs of the actively developing industry in the region, the specifics of transportation links with the areas of consumption of products of this sector. Comparison of the structure of modern agrarian production in the region and the early 1990s indicates their cardinal difference. So, today almost no sugar beet, grapes, tobacco are produced for sale in the market, not such large volumes of fruit and berry production, while these productions in the late 1980s and early 1990s gave the budget of the plant growing industry good income [19, c. 128].

Financial sustainability and modernization in the agricultural sector are considered important components in the framework of the implemented republican program for the development of the agricultural sector and regulation of markets of agricultural products, raw materials and food. The necessary condition for solving this problem can be the existence of a legislative and tax system that ensures the effective development of regional agrarian production sectors, as well as the provision of material support from the authorities.

It should be noted that the different results of state support in Russian regions may indicate the need for an individual approach in their analysis. Taking into account the practice of agrarian policy in European countries, when the federal level establishes instruments of state support and a single regulation for their application, while the regions are given the opportunity to choose from them for themselves, it would be possible to avoid complications of the state support system, which are possible in the conditions of granting greater powers to the regions [20, c. 20].

It should also be noted that, despite the government's extensive work on the development of rural areas in the country, the problem of the shortage of professional personnel in rural areas is still unsolved. At present, the most able-bodied and educated residents of rural areas, mostly represented by young people aged 18 to 35, are massively moving to cities for employment, while less than 10% of graduates of agricultural educational institutions prefer to live in rural areas. As evidenced by the data of the survey, the main reasons for this phenomenon include the low quality of housing and often its absence, many people do not recognize work in rural areas as appropriate for themselves [21, c. 15].

A big role in various state programs for the development of Russian rural areas is assigned to non-agricultural employment in rural areas. More return on both labor and other resources of rural territories can be expected from rural enterprises of industrial type, thus allowing to consider the creation of such structures as an important direction to increase employment and remuneration of rural residents. Such structures can be both small and medium-sized industries, which are engaged in various trades; processing of agricultural products, also carry out their transportation and storage; related to the recreational sphere and construction of various facilities; develop rural tourism, etc. In the conditions of interaction of agricultural processes with industrial processes, there is a multiple increase in production efficiency, also throughout the year there is a smoothing of unevenness in the use of labor of agricultural workers due to a more rational use of all types of resources involved in production.

Non-agricultural production is increasing in rural areas throughout the world. For example, up to 40-45% of the income of the rural population living in Central and Eastern Europe came from non-agricultural sources [21, p. 14]. The amount of non-agricultural income received by farmers in the states belonging to the Organization for Economic Cooperation and Development has now begun to exceed the income from purely agricultural activities [21, c. 14].

Thus, the available demand in the labor market in rural areas is affected not only by employment in the agricultural sector, but also by employment that is not related to it. At the same time, despite a significant decrease in employment in the agricultural sector, this sphere remains the main one for rural residents regarding the application of their labor. For the development of rural areas it is also important to have an appropriate legislative component of the process of preferential crediting and financing of rural companies of industrial type; to give them an opportunity, based on the industry specifics, not to pay taxes during the first 3-5 years of their activity, and later to pay them at the rate of 7-8%. It is also necessary for the state to insure the property of the participants of this process, as well as their personal funds and savings; to give them orders; to transfer the necessary production technologies, fixed assets and ownerless premises to them; to simplify the procedures related to the registration of relevant documents, etc.

References

[1] Evstigneeva L., Evstigneev R. Self-identification of Russia and the formation of a new regional union // Voprosy ekonomiki. - 2004. - № 10. - C. 70-88.

[2] Samygin, D., Kudryavtsev, A.. Strategic tools for the distribution of state support of the agrarian sector // Economic Policy. - 2018. - T. 13. - № 5. - C. 156-175.

[3] Belousov R. Russia's economy in the foreseeable future // The Economist. -2007. - № 7. - C. 3-11.

[4] Glazyev S.Y., Kara-Murza S.G., Batchikov S.A. White Book. Economic Reforms in Russia 1991-2001. - Moscow: Eksmo, 2003. - 368 c.

[5] Emelyanov A. Interaction of farm forms in agrarian economy // Voprosy ekonomiki. - 2003. - № 11. - C. 120-132.

[6] Kozlov M. Economic situation of agricultural commodity producers // Voprosy ekonomiki. - 2004. - № 5. - C. 141-146.

[7] Kashepov A. Social Policy: Labor Market and Employment // Social Policy and Social Partnership. - 2006. - № 8. - C. 61-68.

[8] Basalaeva E. Problems of formation of competitive agriculture // Voprosy ekonomiki. - 2006. - № 9. - C. 47-56.

[9] Uzun V. Efficiency of large and small business in agriculture // Voprosy ekonomiki. - 2005. - №6. - C. 109-118.

[10] Bogdanovsky V. Labor and Employment in Agriculture // Voprosy ekonomiki. - 2005. -

№ 6. - C. 72-83.

[11] Korotchenya V. Technical efficiency of Russian agriculture // Voprosy ekonomiki. - 2016. - № 4. - C. 144-155.

[12] Buzdalov I. On the experience and results of agrarian transformations in China and Russia // Voprosy ekonomiki. - 2014. - № 10. - P. 137-146 p.

[13] Comprehensive program of the Chechen Republic "Integrated development of rural areas" of 18.10.2022, No. 254. URL: http://publication.pravo.gov.ru/document/2000202210240018?index=6

[14] Bairakov A.I., Bolotkhanov E.B., Avtorkhanov A.I., Taimoskhanov H.E., Shakhtamirov I.Ya. The Chechen Republic: Nature, Economy and Ecology. - Grozny: Publishing House of the Chechen State University, 2006. - 375 c.

[15] The Bitter Fate of the Sweet Berry. The newspaper "Groznensky Rabochiy" of March 31, 2011.

[16] Abdulgalimov A.M., Kurnosova T.I. Development of the national innovation system of Russia // Bulletin of the Chechen State University. - 2023. - № 4(52). - C. 6-15.

[17] State program of the Chechen Republic "Development of Agriculture and Regulation of Markets of Agricultural Products, Raw Materials and Food" of December 26, 2023, № 339. URL: https://docs.cntd.ru/document/407030112?marker

[18] Aganbegyan A.G. Agriculture - the locomotive of socio-economic growth in Russia // EKO. All-Russian economic journal. - 2017. - № 5. - C. 5-22.

[19] Reshiev S.S. Agriculture of the Chechen Republic: state, problems and prospects of development // Bulletin of the Chechen State University. - 2017. - № 2(26). - C. 125-130.

[20] Malyuk L.I., Ignatov V.S., Pavlov A.Y. Transformation of the labor market of rural municipalities (by the example of Penza Oblast) // Regional Economics: Theory and Practice. - 2014. - № 32 (359). - C. 13-18.

[21] Svetlov, N.M.; Yanbykh, R.G.; Loginova, D.A. On the heterogeneity of the effects of state support of agriculture // Voprosy ekonomiki. - 2019. - № 4. - C. 59-73.

PARTNERSHIP FOR SUSTAINABLE DEVELOPMENT

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Abstract

The article is devoted to the study of the basic principles of forming sustainable development projects at enterprises, establishing cooperation between business entities and financial and credit institutions in order to ensure effective achievement of the goals of sustainable transformations of the state. The object of the study is the substantiation of methodological and applied recommendations for the creation of a special fund-intermediary between enterprises and financial and credit institutions for conducting scientific, technological and environmental preparation of production. Formation of projects for sustainable economic development by enterprises requires an integrated approach and should begin already at the stage of forming an innovative idea. The formation of a stage of scientific, technological and environmental preparation of production for enterprises conducting work on developing innovative projects is proposed.

Keywords: sustainable development, cooperation, business entities, innovation, environmental responsibility

I. Introduction

The environmental situation not only in our country but also throughout the world has worsened at the end of the 20th century so much that with the beginning of the 21st century the world's leading countries are forced to seek opportunities to influence all business projects to ensure environmental safety. Moreover, we are talking about achieving sustainable development, when, without giving in to competition in various markets, companies will implement environmentally friendly measures in the technological direction. The problem of ecology is an important aspect of the survival of each nation. In order to ensure normal environmental and economic living conditions for people, the concept of sustainable development was, as is known, developed, which has been tried to be implemented in most countries of the world for several decades.

As for sustainable development, domestic enterprises have only recently begun to pay attention to it. To a certain extent, this was not facilitated by various factors related to the peculiarities of the domestic economy. Recently, the problem of the pandemic has been added to the negative factors, that is, management has to not only ensure sustainable development, but also respond to people's requests for job preservation. The economic conditions for the functioning of enterprises were also not such as to force them to work towards solving environmental problems. The economy of enterprises was under pressure: tax, administrative, under the threat of bankruptcy. Environmental requirements were hardly considered significant when citizens simply needed to work to earn money to support their families. Thus, the main areas of activity of enterprises in previous decades were the production of products (services) at any price, making a profit and surviving in unfamiliar market conditions of competition.

Research on sustainable development covers the interaction of business and government, manufacturing enterprises and financial and credit institutions. Undoubtedly, world experience is extremely useful in terms of the results already obtained. At the same time, the results of research by domestic scientists best reveal the causes, factors and consequences of the implementation of various environmental measures in the conditions of the domestic economy.

The study of the problem of interaction between business and government bodies has long attracted the attention of scientists, entrepreneurs, officials at all levels, and most importantly, the public to issues of social responsibility of business. In our country, the aspect of corporate social responsibility in the scientific and practical plane has only recently begun to receive due attention. In particular, among the scientists who studied the role of human potential in the context of sustainable development, institutional mechanisms for reducing the negative impact on the environment, modern areas of corporate social responsibility should be named S.S. Ovsyannikova [5], V.M. Gilmundinova [1], T.O. Tagaeva [1], T.V. Divina [2]. Separately, it is necessary to highlight the researchers who raised the issue of banking responsibility in the process of sustainable development. These include, in particular, A.I. Osipova [6], etc. Among foreign publications devoted to sustainable development in recent years, one can highlight the work "Implementation of social projects in the context of digital transformation of the banking sector" [6]. According to the study, the author relies on the perspectives of the interest of national and international organizations in creating favorable conditions for sustainable development. He emphasizes the fundamental role of the financial system in mobilizing capital for a green economy.

The purpose of the study is to determine the organizational form of cooperation between financial and credit institutions and enterprises in the context of bilateral compliance by the parties with the requirements of sustainable development, environmental responsibility to society. It is important to justify the creation of an appropriate financial fund at enterprises or a separate fund operating for enterprises, which will accumulate the enterprises' own funds and receive the necessary loan funds for the implementation of sustainable development measures by enterprises.

II. Methods

Dialectical method and methods of analysis and synthesis - to study the features of the implementation of innovative work at the stage of scientific-technological-environmental preparation of production in the formation of sustainable development projects; structural-logical analysis - to develop theoretical and methodological principles for the functioning of the fund to ensure cooperation in financing sustainable development projects.

Sustainable economic development presupposes such changes in the technological re-equipment of production that will not affect the environment and will not have negative impacts on human life, and will not interfere with life and reproduction of the natural environment. To ensure these requirements, the world community has adopted a number of international agreements, to which our country has also acceded.

III. Results

One of the leading areas of sustainable development is the preservation of the environment, which is most affected by man-made factors, and their sources are industrial enterprises. The implementation of measures aimed at changing production flow charts taking into account the requirements of sustainable development undoubtedly requires significant financial resources. It is well known that enterprises themselves are not able to provide financial support for environmental protection programs. They perceive expenses on environmental protection measures as a diversion of working capital and the creation of prerequisites for a decrease in solvency. They need appropriate funds, which can be obtained, including through loans from banks or para-bank institutions. Instead, a problem usually arises, consisting in the unprofitability of environmental protection measures. Only a change in the production apparatus (equipment, composition of raw materials and materials, etc.) can simultaneously serve to generate profit and protect the environment.

The problem of preserving the human habitat is important for both current and future generations. Therefore, it is necessary to find a way out, for which it is worth paying attention not only to environmental protection measures, but also to replacing technological schemes. To protect against harmful emissions, there is no alternative to the need to implement treatment facilities, all kinds of filters, aerators, etc. However, the first direction is really unlikely to ever directly serve as a source of repayment to credit institutions. The second direction - lending for the technological process taking into account environmental protection requirements - can ensure profit and in this direct way serve as a source of funds for settlements with creditors. The specified directions of action to protect the natural environment require further research, including the search for some balance between them.

To find and solve the problem under study, the idea of creating a special fund between enterprises and financial and credit institutions for conducting scientific, technological and environmental preparation of production should be useful. Each enterprise that carries out work on developing innovative projects, and therefore organizes the preparation of production, should form a corresponding fund for the implementation of environmental measures, which should be responsible for the quality of product design projects and production flow charts that will guarantee environmental safety on the part of the enterprise. Such a fund, created directly at the manufacturing enterprise, would be an accumulator of funds received for the development of technologies taking into account the requirements of sustainable development. Accordingly, such a fund should act on behalf of the enterprise with the initiative to obtain the necessary credit resources and enter into relations with commercial banks. Fund employees should cooperate with credit institutions in order to obtain the necessary loans.

Of course, doubts may arise regarding the advisability of creating such a fund directly at the enterprise. Features of the technological process, other special factors in the vertical form of cooperation of the enterprise within the holding or financial-industrial group may testify in favor of this proposal. In the conditions of the horizontal form of cooperation, it is possible to assume the creation of a separate venture fund, which will work for a group of enterprises similar in technological scheme. Then the allocation of a venture fund will be justified. Having chosen a certain version of the technological scheme for one enterprise, the fund can subsequently find opportunities to improve the technology and gradually offer new versions of more environmentally advanced technological processes to other enterprises of the group. Instead, the venture fund should not necessarily be limited to the funds provided by the enterprises. Moreover, the search for the best options for technological processes will force the attraction of credit resources.

From the standpoint of the participation of individual credit institutions and their entire aggregate in lending to manufacturing enterprises, the environmental responsibility of the banking system should be considered in several dimensions.

Traditionally, the focus of scientific research is on the issue of environmental responsibility at the expense of manufacturing enterprises. In this context, researchers pay attention, first of all, to the prevention of harmful effects of manufacturing activities on the environment, the introduction of environmentally friendly technological processes, and thirdly, to the production of products that would have the least impact on the environment. This impact is considered in several aspects: from the point of view of means of production and transport - the elimination or minimization of harmful emissions, in particular into the atmosphere (for example, the accumulation of liquid and gaseous emissions and their disposal, the production of electric cars, etc.); from the point of view of consumer goods - the production of products whose residues are easily dissolved by natural factors (for example, replacing polyethylene bags with paper, hard plastics for the production of stationery with cardboard, etc.). The examples given are well-known and have already been sufficiently implemented in production. At the same time, there are significantly more environmentally friendly measures at enterprises, especially taking into account global experience.

V. Discussion

The development of production based on innovation necessarily implies the attraction of credit resources, which directly requires cooperation with credit institutions. In other words, credit institutions also participate in the process of sustainable development, perhaps indirectly, when it comes to the implementation of innovative technological processes, new types of goods or services. The indirect nature of the participation of credit institutions is determined only by the fact that they do not work directly on product and technology projects. This is done by the relevant design and engineering and technological institutes, bureaus and directly by the manufacturers' enterprises.

Of course, the question arises regarding the quality of the used material and technical resources and future products from the point of view of environmental safety. As practice shows, it is no less important for the creditor than for the enterprise-manufacturer of the products to know the prospects for the sales of goods, services, real estate, etc. After all, the return of the loan and the payment of interest on it, which constitutes the profit of the credit institution, will depend on how successful the production and sale of these objects will be. The need to conduct an environmental audit of credit activities is emphasized, in particular, by the authors of [4].

The solution to this problem should be facilitated by appropriate cooperation between manufacturing enterprises and credit institutions, subject to environmental responsibility. An important stage of this cooperation should be scientific, technological and environmental preparation of production. Design of new products and technologies occurs precisely at the stage of scientific and technological preparation. An environmental component should be added to the development of designs and technologies in the technical and economic aspect. That is, in the process of working on the design, when the composition of materials for the future product, the efficiency of future machines, devices, equipment are determined, it is necessary to conduct examinations for harmfulness not only in the production process, but also in the process of operation, and later - during the disposal of used production tools.

It is necessary for creditors to understand the very content of the process of designing products and technologies, which should serve as a guarantee for the provision of loans not only for serial production of products, when the receipt of profits by both the borrower - the enterprise, and the creditor - the bank is quite clear and fast.

In order to organize proper interaction between a credit institution and an enterprise, it is necessary for the enterprise to create a separate fund-intermediary for scientific, technological and ecological preparation of production under the department of production preparation. The fund should be subordinated to the linear-technical director (chief engineer), and functionally - to the director of economics and finance. Such dual subordination is aimed at effective technical management, when all technical decisions are made by a manager who is well versed in the technological schemes used at the enterprise. The technical director is the specialist who, even at a large enterprise with a significant number of production units located at various territorially isolated sites, knows the specifics of the functioning of each section and their needs for innovative solutions. The director of economics and finance is knowledgeable in the field of functioning of the financial resources that the said fund should accumulate, should influence the financial component of technical solutions. Decisions on the use of the fund's resources should be made jointly by the two directors together with the head of the production preparation department as the initiator of the innovation and the fund manager as the person responsible for the effective use of financial resources. If it is necessary to conduct an environmental assessment, in particular in projects for treatment facilities, the bank may propose to involve in the assessment an appropriate environmental institution that has a license to conduct such an assessment and provide the relevant conclusion.

In conclusion, it is worth emphasizing the importance of establishing cooperation between enterprises and financial and credit institutions in the process of ensuring the implementation of the country's sustainable development strategy. Since the implementation of the foundations of sustainable transformations requires significant funding, the effective implementation of sustainable development programs by business entities is impossible without established cooperation with financial institutions.

In addition, it is also worth noting that the formation of sustainable economic development projects by enterprises requires a comprehensive approach and should begin already at the stage of forming an innovative idea. Thus, it is proposed to form a stage of scientific and technological environmental preparation of production for enterprises working on developing innovative projects. It is also important to create a fund that should become an intermediary between enterprises and financial and credit institutions for financial support for the implementation of scientific and technical preparation of production.

References

[1] Gilmundinov V.M., Tagaeva T.O. Improving institutional mechanisms for reducing negative impact on the environment // Journal of the Siberian Federal University. Humanities. - 2023. - No. 16 (9). - P. 1510-1517.

[2] Divina T.V. Modern directions of corporate social responsibility // Social entrepreneurship and corporate social responsibility. - 2023. - Vol. 4. - No. 3. - P. 127-136.

[3] Makarov I.N., Osipova I.V. Corporate responsibility: environmental responsibility of business in the context of a green economy // Creative Economy. - 2022. - Vol. 16. - No. 2. - P. 449-462.

[4] Manukhin A.I. Improving the lending system for small and medium-sized businesses: abstract of dis. ... candidate of economic sciences: 5.2.4. / Manukhin A.I. - Moscow, - 2023. - 24 p.

[5] Ovsyannikov S.S. Social policy and development of human potential // Russian entrepreneurship. - 2007. - Vol. 8. - No. 7. - P. 148-152.

[6] Prokhorova T.V. Implementation of social projects in the context of digital transformation of the banking sector / T. V. Prokhorova // Business. Innovations. Economy: collection of scientific articles. - Minsk, 2021. - No. 5. - P. 157-164.

THE ROLE OF DIGITALIZATION AND SMART TECHNOLOGIES IN THE DEVELOPMENT OF A SUSTAINABLE REGIONAL ECONOMY

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Abstract

Digitalization and smart technologies play a decisive role in the transformation of the economy towards sustainable development at the regional level. The article analyzes the impact of digital tools such as the Internet of Things (IoT), big data, artificial intelligence and automation on increasing the efficiency of natural and economic resources. The use of these technologies allows for the creation of smart cities and sustainable infrastructure, ensuring the optimization of energy consumption, reducing CO_2 emissions and improving the quality of life of local populations. Particular attention is paid to areas where digitalization has the greatest impact on sustainable development: transport, energy, utilities and waste management. The article considers specific examples of the implementation of smart solutions, such as smart lighting systems, environmental monitoring, intelligent traffic management, which helps reduce costs and increase the economic sustainability of the region. In addition, the mechanisms of interaction between business and the state in the process of implementing digital solutions, as well as the impact on the creation of new jobs and strengthening the competitiveness of regions are studied. The analysis highlights that digitalization not only contributes to increased efficiency, but is also becoming an important factor in the formation of a sustainable and competitive economy capable of adapting to modern challenges and global changes.

Keywords: sustainable development, digitalization, smart technologies, regional economy, sustainable economic growth, Internet of things, artificial intelligence

I. Introduction

In recent years, sustainability has emerged as a core objective in regional development, driven by the recognition that economic growth must be balanced with environmental protection and social well-being. As global environmental pressures, such as climate change, resource depletion, and pollution, continue to intensify, regions are increasingly exploring innovative solutions to build resilient and sustainable economies. Digitalization and smart technologies have proven to be powerful tools in this transition, offering unprecedented ways to optimize resource use, reduce environmental impacts, and improve public services.

Digitalization, encompassing technologies like the Internet of Things (IoT), big data analytics, artificial intelligence (AI), and blockchain, is enabling regions to modernize key industries and infrastructure. IoT, for example, allows for real-time monitoring and management of resources, from energy and water to waste, contributing to more efficient systems and lower operational costs. AI and big data, meanwhile, provide actionable insights for better decision-making, helping governments and businesses predict demand, manage supply chains, and reduce waste. Through these advancements, digitalization supports the development of "smart" cities and communities—

places that actively use technology to manage resources responsibly, mitigate emissions, and promote sustainable lifestyles.

A major area of impact is energy management, where smart technologies, like renewable energy grids and smart meters, allow for precise control over energy production and consumption. These innovations enable regions to rely more on renewable sources, such as solar and wind, which can be integrated into existing grids to reduce dependency on fossil fuels and cut greenhouse gas emissions. In the transportation sector, smart systems improve traffic flow, optimize public transit, and reduce emissions, while in agriculture, digital tools aid in precision farming, optimizing water use, and minimizing chemical inputs. Each of these advancements contributes to building a regional economy that is both economically viable and environmentally sustainable.

However, the transition to a digitally driven, sustainable economy is not without challenges. Successful implementation requires coordinated efforts among government entities, private sector actors, and local communities. Investment in digital infrastructure and skills training is essential, as is the establishment of regulatory frameworks that ensure data security and privacy. Moreover, digitalization raises questions about social equity, as technology access and literacy vary significantly across different demographic groups. This digital divide must be addressed to ensure that sustainable development benefits are widely accessible.

II. Methods

To investigate the role of digitalization and smart technologies in promoting sustainable regional economic development, this study adopts a mixed-methods approach, combining quantitative data analysis, case studies, and expert interviews. This multi-dimensional methodology provides a comprehensive view of how digital technologies impact regional sustainability across various sectors, such as energy, transportation, waste management, and public services. Below is an outline of the specific methods used.

1. **Quantitative Data Analysis**

Quantitative data was collected from regional government databases, environmental agencies, and public economic records to measure key indicators of sustainability and economic impact. Indicators include energy consumption, greenhouse gas emissions, operational efficiency metrics, and cost savings attributed to the use of digital technologies. Statistical analysis was applied to examine correlations between technology adoption and improvements in these sustainability metrics, providing insight into the direct and indirect effects of digital solutions.

2. **Case Studies of Smart Technology Initiatives**

Case studies were selected from various regions that have successfully implemented smart technologies in key sectors. Each case study provides an in-depth analysis of specific projects, such as smart grid integration, IoT-based water management, and AI-powered public transportation systems. The case studies document the processes of project implementation, including the selection of technologies, stakeholder collaboration, financing, and regulatory support. Data from these cases helped to identify patterns, challenges, and best practices in leveraging digitalization for sustainable development.

3. **Expert Interviews and Surveys**

To understand the practical and strategic implications of implementing digital solutions, semi-structured interviews were conducted with experts from government agencies, tech companies, environmental organizations, and academic institutions specializing in regional development and sustainability. These interviews gathered insights on challenges in implementation, the role of policy, and the socioeconomic impacts of digital transformation on regional sustainability efforts. Surveys were also distributed to industry professionals to collect broader perspectives on the barriers and opportunities of digitalization in sustainable development.

4. **Comparative Analysis of Regional Digital Transformation Policies**

A comparative policy analysis was conducted to evaluate the role of government policies in driving digital and smart technology adoption for sustainable regional development. Policy documents, strategic frameworks, and government reports from regions with differing levels of digitalization were analyzed to assess the effectiveness of incentives, regulations, and public-private partnerships in fostering sustainable practices. This comparative approach helped to highlight the role of policy in overcoming challenges such as funding constraints, digital infrastructure needs, and technology literacy gaps.

5. **Impact Assessment Model**

Based on the findings from the quantitative analysis, case studies, and interviews, an impact assessment model was developed to evaluate the economic and environmental effects of digitalization across different sectors within regional economies. This model considered both direct impacts, such as cost savings and emission reductions, and indirect impacts, including job creation and social equity improvements. The model provided a framework for estimating long-term sustainability benefits and challenges associated with digitalization, offering a holistic view of its role in regional sustainable development.

By integrating these methods, this study presents a well-rounded analysis of how digitalization and smart technologies contribute to sustainable economic development at the regional level, identifying key success factors, limitations, and opportunities for scaling these initiatives.

III. Results

Digitalization plays a crucial role in enhancing the effectiveness and efficiency of cities concerning planning, management, and development. The ongoing digital transformation has revolutionized the business ecosystem, altering the value chain processes across various industries. This transformation presents a wealth of opportunities through the application of technologies and intelligent systems that offer smart solutions to urban challenges. Digitalization encourages innovation by fostering a collaboration between physical and digital realms among stakeholders within urban contexts and beyond.

In a broader sense, digital technologies significantly accelerate access to data and knowledge, thereby enhancing institutional accountability, improving the efficiency of scientific endeavors, and promoting innovation across numerous sectors. These data-driven technologies are pivotal in the development of smart cities, enabling the resolution of urban issues and facilitating better decision-making to elevate the quality of urban life. A smart city comprises an integrated system of six components: smart people, smart living, smart mobility, smart environment, smart economy, and smart governance. The effectiveness of these components can be further enhanced through the application of several key technologies, including Information and Communication Technology (ICT), the Internet of Things (IoT), sensor technology, geospatial technology, Artificial Intelligence (AI), and Blockchain.

ICT serves as the primary technology in smart cities, implementing smart initiatives through the integration of physical infrastructure and data processing tools. IoT devices enable cities to gather and analyze real-time data, helping to identify problems and improve service delivery. In the smart city framework, sensor technology measures various system metrics, including energy consumption, water quality, gas usage, traffic congestion, and pollution levels. AI technology is utilized to manage and control automated city infrastructures, while geospatial technology is applied across smart city subsystems—such as energy, transportation, public services, and governance—to enhance infrastructure management efficiency. Additionally, Blockchain technology provides a secure communication framework within the smart city.

While digital technologies are expected to improve the quality of life for individuals and communities, it is crucial not to overlook their environmental costs. Therefore, promoting the development of cyber-physical assets in conjunction with sustainability considerations is essential. This approach not only aims to enhance citizens' quality of life but also seeks to improve the overall urban environment. It is vital to ensure that the utilization of digital technologies contributes to long-term well-being across economic, social, and environmental dimensions.

In today's Information Society, the adoption and integration of smart technologies are increasingly driving growth and competitiveness, particularly within the realm of regional policy. The rapid evolution of digital technologies and Information and Communication Technologies (ICTs) has introduced significant challenges to achieving smart, sustainable, and inclusive growth, aligning with the objectives of the Europe 2020 strategy. A crucial aspect of this transformation is the ability to adapt digital tools and entrepreneurial strategies to the unique conditions of each region, thereby fostering knowledge-based innovation, setting clear priorities, and enabling informed decision-making.

As the adoption of ICT becomes central to national and regional policies, governments worldwide are formulating digital development strategies aimed at enhancing efficiency and transparency in public administration, stimulating innovation and entrepreneurship, and improving the overall quality of life. These new technologies are facilitating a shift toward a digital economy, which not only creates value-added opportunities but also contributes to economic growth in various dimensions.

For policymakers, it is vital to connect the penetration of ICT within companies and the development of relevant infrastructure with key economic outcomes such as job creation, improved competitiveness, and increased export activity. Investments in ICT, the enhancement of workforce digital skills, the promotion of demand-driven innovation from the public sector, and the reform of the regulatory framework are expected to serve as growth drivers at local, regional, and national levels, provided that they are supported by appropriate policies.

The focus of this study is on the role of smart technologies in regional development, specifically through the lens of the regional innovation system model. Innovation is not merely an isolated act within a single organization; it is embedded in a larger system that facilitates and enhances the innovation process. These processes are critical for the effective application of new technologies and the promotion of knowledge-sharing.

According to Lundvall, innovation systems are open, social, and dynamic. They are considered open because innovations emerge from interactions among various economic actors, meaning they are responsive to external influences. They are social because they are grounded in an institutional environment shaped by laws, social norms, cultural models, and technical frameworks. They are dynamic due to ongoing financial exchanges between public and private organizations, talent flows among universities, corporations, and government agencies, and regulatory influences from government bodies to innovation agencies. Innovation systems can be analyzed at several levels, including sectoral, regional, national, and international.

Regional Innovation Systems are typically composed of a network of private, semi-private, and public entities that operate within an institutional framework designed to encourage knowledge creation, transmission, and application. Research on Regional Innovation Systems has identified three primary dimensions: the interactions among innovation system actors for knowledge exchange, the role of institutions in supporting regional knowledge-sharing and innovation, and how Regional Innovation Systems influence regional innovation policies. According to Autio, the Regional Innovation System consists of five main dimensions:

1. A subsystem focused on the application and exploitation of knowledge through innovative industries and companies,
2. A subsystem for knowledge production and dissemination that includes higher education institutions and research centers,
3. High-intensity interactions between subsystems involving scientific and applied knowledge and human resource flows,

4. A robust infrastructure and institutional framework, with significant regional autonomy, and
5. Active regional policy actors who guide and support regional innovation initiatives.

Understanding the dynamics within regional innovation systems and the impact of smart technologies on regional economic development is essential for formulating effective strategies that lead to sustainable growth.

IV. Discussion

The integration of digitalization and smart technologies in urban environments has profound implications for enhancing the quality of life and the efficiency of city management. As cities continue to evolve into smart cities, it is essential to critically evaluate the multifaceted impact of these advancements. This discussion explores key themes related to the benefits, challenges, and future directions of digitalization in urban settings.

Enhancing Urban Efficiency and Quality of Life

Digitalization has transformed the way cities operate, leading to improved efficiency in service delivery and resource management. The adoption of technologies such as the Internet of Things (IoT) enables cities to collect real-time data, which can be used to optimize services such as waste management, public transportation, and energy consumption. For instance, smart traffic management systems can analyze traffic patterns and adjust signals in real-time, reducing congestion and emissions while enhancing mobility. These efficiencies contribute to a higher quality of urban life by making cities more livable and accessible.

Moreover, smart technologies facilitate greater citizen engagement and participation in governance. Through digital platforms, residents can access information, voice their concerns, and engage in decision-making processes. This transparency fosters trust between citizens and local governments, leading to more responsive and accountable governance. Enhanced communication frameworks, supported by technologies like Blockchain, can further improve data integrity and security, ensuring that citizens' information is handled responsibly.

Driving Innovation and Economic Growth

Digitalization also stimulates innovation and economic growth in urban areas. By creating a conducive environment for startups and tech firms, cities can become hubs of innovation that attract talent and investment. The emphasis on knowledge-based economies encourages collaboration among universities, research institutions, and businesses, driving advancements in various sectors.

However, the growth of a digital economy must be approached thoughtfully. The focus on technological innovation should be accompanied by policies that ensure equitable access to digital resources. This includes investments in digital infrastructure and education to improve digital literacy among all residents, particularly marginalized communities. Failure to address these disparities may exacerbate existing inequalities, hindering the overall benefits of digitalization.

Addressing Environmental Concerns

While the potential benefits of digitalization are significant, it is imperative to address the environmental costs associated with these technologies. The production and disposal of digital devices contribute to electronic waste, and the energy consumption of data centers raises concerns about sustainability. Therefore, integrating sustainability principles into digital strategies is crucial.

Cities should prioritize the development of cyber-physical assets that not only enhance urban efficiency but also promote environmental sustainability. This can include the implementation of green technologies, energy-efficient infrastructure, and sustainable urban planning practices. For

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instance, the use of smart grids can optimize energy distribution and integrate renewable energy sources, reducing reliance on fossil fuels and lowering carbon emissions.

Future Directions

Looking ahead, the successful integration of digitalization in urban environments will depend on a holistic approach that considers social, economic, and environmental factors. Policymakers must develop frameworks that encourage collaboration between public and private sectors, ensuring that digital initiatives align with broader sustainability goals.

Investments in research and development should focus on emerging technologies that have the potential to enhance urban life while minimizing environmental impact. Furthermore, continuous evaluation and adaptation of digital strategies will be essential in response to the evolving needs of urban populations and the challenges posed by climate change.

In conclusion, while digitalization and smart technologies offer significant opportunities for enhancing urban living, a balanced approach is necessary to ensure that these benefits are realized in an equitable and sustainable manner. By addressing the challenges and leveraging the potential of digitalization, cities can create resilient urban environments that improve the quality of life for all residents.

The transition toward Smart Sustainable Cities (SSCs) is significantly influenced by the implementation of innovative technologies. While these technologies offer promising benefits, they also pose notable environmental and social challenges. The following discussion explores both the advantages and the drawbacks of digital technologies in urban contexts, highlighting the need for a comprehensive evaluation framework to assess their net impact.

Advantages of Digital Technologies in Smart Sustainable Cities

Digital technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and big data analytics play a pivotal role in enhancing urban environments. The table below summarizes the key benefits associated with these technologies:

These technologies collectively enhance the efficiency of public services, reduce greenhouse gas (GHG) emissions, and improve citizens' quality of life by enabling better resource management and decision-making. They also facilitate greater citizen engagement in governance, promoting transparency and accountability within urban administrations.

Environmental and Social Risks Associated with Digital Technologies

Despite the benefits, the application of digital technologies in urban environments can lead to significant environmental and social challenges. The following outlines some key risks:

Environmental Risks:

1. High Energy Consumption: Many digital technologies are energy-intensive, leading to increased GHG emissions.
2. Pollution from Connected Devices: The proliferation of IoT devices can contribute to environmental pollution.
3. Exploitation of Rare Earths: Increased demand for technological devices results in the depletion of rare earth materials and the use of plastics, which are difficult to recycle and contribute to environmental degradation.
4. Difficulties in Recycling: The end-of-life phase of technological products poses challenges for recycling raw materials, exacerbating environmental issues.

Social Risks:

1. Privacy Concerns: The use of AI and IoT can compromise citizens' privacy when personal data is processed without consent.
2. Data Governance Issues: The complexity of new technologies often leads to the delegation of data governance to private entities, raising concerns about oversight.
3. Cybersecurity Risks: Increased reliance on digital technologies heightens the risk of cyberattacks, endangering data protection.

4. Discrimination and Marginalization: The implementation of new technologies may inadvertently marginalize older populations or those in rural areas, limiting their access to digital services.

These environmental and social risks pose significant challenges to the development of truly sustainable smart cities.

Table 1: *The key benefits associated with these technologies*

Technology	Description	Benefits for SSC Development
AI	Training of AI systems	- More efficient resource utilization for public services - Reduced consumption and emissions - Pollution level monitoring and targeted policy support - Enhanced provision of essential public services (e.g., healthcare, transportation)
Big Data Analysis	Collection and analysis of large urban data	- Prediction of environmental catastrophes - Data-driven initiatives against environmental events - Optimization of decision-making based on citizen needs - Effective public fund allocation
Data Platform	Real-time analysis and control of urban data	- Real-time monitoring of environmental conditions - Prompt disaster response - Support for decision-making activities - Enhanced citizen participation in governance
IoT	Sensors and intelligent devices	- Real-time interaction and monitoring of urban environments - Measurement of air pollution - Small-scale renewable energy production - Improved public services and security
ICT	Digital infrastructures for communication	- Reduced information transmission times - Quick emergency responses - Widespread network access - Democratization of technology and reduction of the digital divide

Evaluating the Net Impact of Digital Technologies

To effectively assess the net impact of digital solutions on the development of Smart Sustainable Cities, a risk assessment framework is essential. This evaluation should consider two scenarios for social risks:

1. Best Scenario: Implementation of all countermeasures by Public Administration to mitigate risks.

2. Worst Scenario: Failure to implement necessary remedies, leading to exacerbated risks.

For environmental risks, a quantitative approach is recommended, utilizing existing literature to gauge the potential harm caused by each technology. The impact of each solution can be measured on a scale from 1 (significantly positive impact) to 5 (significantly negative impact). The overall effect on the urban ecosystem can then be calculated as the sum of these values.

Conclusion

The path toward developing Smart Sustainable Cities is paved with opportunities and challenges posed by digital technologies. While the benefits are substantial, the potential environmental and social risks necessitate careful evaluation and proactive management. A comprehensive risk assessment framework, coupled with strategic policy interventions, is vital for ensuring that the transition to smart cities enhances urban sustainability while safeguarding the rights and well-being of all citizens. By addressing these risks thoughtfully, cities can realize the full potential of digital technologies in fostering sustainable urban environments.

References

[1] Nazarova I. T., Gurezov Z.Ways of managing innovative organizations in Russia.//Journal of Monetary Economics and Management. -2022-№1-C.18.

[2] Altsybeeva I. G., Andreeva L. O.Financial strategy in the management of the enterprise.//Journal of Monetary Economics and Management. -2022-№1-C.6.

[3] Shmatko S.G., Agarkova L.V., Gurnovich T.G., Podkolzina I.M. Problems of increasing the quality of raw material for wine in the stavropol region // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2016. T. 7. № 2. C. 725-730.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Aliyeva M. L., Misirli R. R. Advantages and problems of big data management// Journal of Monetary Economics and Management. - 2023. - No. 1.- P.8-14

[6] Mezentsev D.A. Methods of increasing sales in the context of modern business development//Journal of Monetary Economics and Management.- 2023.- No. 4. - P.15-23

[7] Babaeva Z.Sh., Pogorelova L.A. Differentiation of the standard of living of the population as a reflection of socio-economic development//Journal of Monetary Economics and Management.-2023.-№2. - P.50-58

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

RESOURCE-SAVING TECHNOLOGIES IN AGRICULTURE AS A WAY TO REMOVE FOOD SECURITY RISK

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Abstract

The article deals with the possibility of reducing the food security risks by creating optimal conditions for plant growth and development in accordance with climatic conditions. To do this, it is necessary to know the evapotranspiration of plants for the studied period of times. On the example of the study of on apple's seedlings evapotranspiration depending on meteorological and biological conditions under different watering schedule with drip irrigating in central region of Russia, the obtained regression equations for definition of evapotranspiration are given.

Keywords: resource-saving technologies, risk, food security, evapotranspiration, differentiated irrigation schedule, drip irrigation, apple seedlings, irrigation rate

I. Introduction

The Decree of the President of the Russian Federation "On the approval f the Doctrine of food security oa the Russian Federation" is indicated that ensuring the country's food security involves risks that can significantly affect it.

With the existing climate change, which is characterized by global instability, new risks are emerging in all areas of human activity and, as a first - in agriculture. This is due to increasing frequency of hurricanes, floods, and droughts, which can lead to a sharp decrease in gross output or complete loss, which is directly related to the risk of food security. One of the mechanisms for managing climate risks is to maintain an optimal water-air regime of the soil during the crop's cultivation throughout the growing season in accordance with the changing requirements of plants according to the phases of their development.

Resource-saving technologies aimed at rational nature management and environmental protection play an important role in such conditions, which ensure the saving of irrigation water, protection of soils, as well as surface, groundwater and water resources from pollution. A scientifically based irrigation regime developed in accordance with plant water requirements, as well as rational irrigation techniques meet the principles of resource saving.

The main indicator used in the justification of irrigation schedule is the evapotranspiration of crops, which serves as a measure of the moisture need of plants. This indicator allows determining the irrigation quantity and rate in specific condition and therefore this is the basis of plants water management. There are experimental and calculated methods of evapotranspiration determination [2,3,4].

Evapotranspiration, or total water consumption, is a function of external and internal factors. External factors include meteorological conditions, the level of agricultural technology, soil moisture; internal factors include the physiological characteristics of the plant (type and phase of development). With optimal moisture reserves in the soil, evapotranspiration is more dependent on the temperature regime of the external environment and the influx of solar radiation, that is, it has a bioclimatic character [1, 14].

During the growing season, evapotranspiration changes in accordance with the changing requirements of plants to the water regime due to the passage of different phases of development, as well as meteorological conditions. The greatest intensity of evapotranspiration is observed when the periods of maximum plant water demand coincide with the most intense meteorological conditions [1,3,12].

Since evapotranspiration largely depends on the type of crop, the phase of its development, and growing conditions, it is necessary to determine its values experimentally for certain types of crops grown in various soil and climatic conditions over the required period of time [13]. It is especially important to know the daily water consumption of a crop with drip irrigation, which makes it possible to accurately regulate soil moisture and maintain it within the required limits for a given crop throughout the growing season. In this case, the irrigation rate for drip irrigation should correspond to evapotranspiration for a certain period, which will allow maintaining soil moisture in the required range.

The existing methods for determining evapotranspiration are divided into experimental (direct measurement methods) and computational methods based on establishing the relationship of water consumption with climatic and biological factors [14]. Experimental methods make it possible to obtain the most accurate result, but are characterized by high labor intensity and low efficiency, which is due to the influence of many external and internal factors. It is the great variability of evapotranspiration over time and in accordance with natural and climatic conditions that has led to the creation of a large number of computational (empirical) methods. To be able to use computational methods, it is necessary to experimentally obtain additional coefficients or coupling equations that correspond to specific conditions and the cultivated crop.

II. Materials and methods

As a result of studies of the water regime of apple seedlings grown under drip irrigation in the conditions of the Moscow region under various irrigation regimes, the values of evapotranspiration of seedlings for three years with different availability of temperature and precipitation were obtained.

In the nursery of the Michurinsky garden of the Russian State Agricultural Academy named after K.A.Timiryazev in 2011-2013, studies were conducted on the formation of seedlings of apple trees White infusion and Honeydew under various irrigation regimes. The following humidification regimes were studied: option I – soil moisture was maintained in the range of 70-95% HB; II – humidity was maintained in the range of 60-85%HB; III variant is differentiated – in the first year of sapling development, humidity was similar to option I, and in the next two years, similar to option II; IY variant (control) – without irrigation [7]

The soils of the pilot area are sod-podzolic on the cover loam, medium loamy. Watering was carried out by drip lines arranged according to the scheme 0.9x0.3m with built-in droppers with an auto-compensation system, which made it possible to maintain a constant flow rate of 3.8 l/h droppers. The moisture layer changed over the years in accordance with the depth of development of the root system. In the first year it was 30cm, in the next two years it was 40 and 50 cm. Soil moisture was determined using tensiometers, the readings of which were compared with the humidity determined by the thermostatic-weight method.

Evapotranspiration of apple seedlings was calculated based on changes in moisture reserves in the active soil layer. It is quite difficult to plan irrigation with drip irrigation according to the evaporometer data in humid regions, this is due to the uneven distribution of precipitation in time and space, which does not allow considering their effect on the available moisture content in the soil. In this regard, in humid areas, it is advisable to use a method for calculating water consumption based on measuring the actual soil moisture, which eliminates the need to consider the amount of precipitation [5]. Then evapotranspiration for the estimated period E will correspond to the difference in the values of moisture reserves in the soil at the beginning and end of the period under consideration (W_H-Wk) plus precipitation (P) and groundwater recharge (Vg)

Knowing the actual values of soil moisture, it is possible to calculate moisture reserves at the beginning and end of the decade and determine evapotranspiration using the water balance equation [3, 4, 6, 7, 8, 9, 10]:

$$W_k = W_н + P + Z - E \pm V_g,$$

где W_k и $W_н$ – moisture reserves in the soil layer at the end and beginning of the calculation period, m3/ha;

P – precipitation, m3/ha;

Z – condensation of water vapor during the calculation period, m3/ha, with a decadal calculation of soil moisture dynamics, condensation of water vapor is insignificant;

E – evapotranspiration, m3/ha;

Vg– groundwater recharge, m3/ha. (This value was insignificant due to the deep occurrence of groundwater and the light granulometric composition of the soil.

III. Research results

The obtained values of evapotranspiration of one-, two- and three-year-old apple seedlings for three years of different availability are shown in Table 1. The table data confirm the direct dependence of evapotranspiration on the degree of soil moisture: thus, the highest values were obtained in 2013, as the wettest, in all variants. Over 3 years of research, the maximum values were noted in the most humidified variant I, where evapotranspiration increases from 3,561 in 2011 to 4,239 m3/ha in 2013. The minimum values of evapotranspiration were obtained in 2012: in the II variant – 3068 m3/ha, in the III – 3056 m3/ha (soil moisture within 60-80% HB) and in the control – 2301 m3/ha. This is due to the fact that in 2011, in all variants, survival irrigation was carried out at a rate of 410 m3/ha, and 2012 was characterized by a lower amount of average daily temperatures, more precipitation and a lower inflow of total solar radiation.

Changes in evapotranspiration during the growing season are determined by both climatic factors and the phase of apple seedlings growing. The maximum value of evapotranspiration of annual seedlings was obtained in the 3rd decade of July: from 183 m3/ha to 355 m3/ha in accordance with variants. During this phase, the leaf surface area is still small, and moisture evaporates intensively from the soil surface. The second peak of evapotranspiration is observed in the 3rd decade of July, which is associated with the development of the maximum leaf surface area, which contributes to intensive transpiration against the background of high average daily temperatures and a large inflow of solar radiation.

It should be noted that the control variant, in which did not consider the first two decades of May in connection with engraftment irrigation. In 2012, the maximum water consumption was also noted in the 3rd decade of July: from 234 m3/ha to 382 m3/ha. In the third year of research, the greatest importance of evapotranspiration was in the 2nd decade of May, when a combination of high temperatures and an inflow of total solar radiation was observed. In addition, this period is characterized by an intensive growth of seedlings. It is necessary to pay attention to the III differentiated variant, where, compared with the I variant, water consumption for three years of research was 1519 m3/ha less, and the quality and yield of seedlings are the same as in the I variant [7]

After irrigation is stopped, evapotranspiration levels out in all variants and reaches minimum values.

Table 1: *Evapotranspiration of apple seedlings under various soil moisture conditions for one, two and three-year-old seedlings, m3/ha*

Month	Decads	I variant (70–90% HB)	II variant (60–80% HB)	III variant (differ.)	Control (without irrigation)
1-st year					
May	1	223	220	220	219
	2	249	253	253	251
	3	312	282	316	158
June	1	303	268	301	154
	2	256	225	254	128
	3	295	259	293	150
July	1	272	244	270	151
	2	318	275	309	162
	3	355	312	354	183
August	1	226	198	224	114
	2	257	226	255	141
	3	152	157	158	153
September	1	137	132	131	133
	2	108	103	105	107
	3	99	97	96	96
Total		3561	3252	3538	2301
2-nd year					
May	1	268	199	196	150
	2	289	221	218	161
	3	322	277	274	209
June	1	266	197	194	145
	2	322	255	252	187
	3	337	258	255	192
July	1	357	281	278	212
	2	310	242	239	174
	3	382	313	311	234
August	1	348	273	270	199
	2	254	182	179	123
	3	109	111	117	111
September	1	115	113	115	106
	2	83	80	87	78
	3	65	66	71	62
Total		3828	3068	3056	2344
3-nd year					
May	1	287	234	233	182
	2	381	314	313	244
	3	284	231	232	180
June	1	364	305	300	241

	2	365	307	299	238
	3	377	305	310	234
July	1	372	303	306	233
	2	343	280	282	219
	3	271	221	222	172
August	1	330	269	272	210
	2	332	271	271	212
	3	276	225	226	175
September	1	103	106	103	99
	2	105	98	99	93
	3	49	51	47	44
Total		4239	3519	3515	2777

The general character of evapotranspiration dynamics for seedlings of the second year of growing is described by a polynomial trend line (Fig. 1). As can be seen from the figure, evapotranspiration, reaching its peak in the 2-nd decade of July, gradually decreases by the end of the growing season.

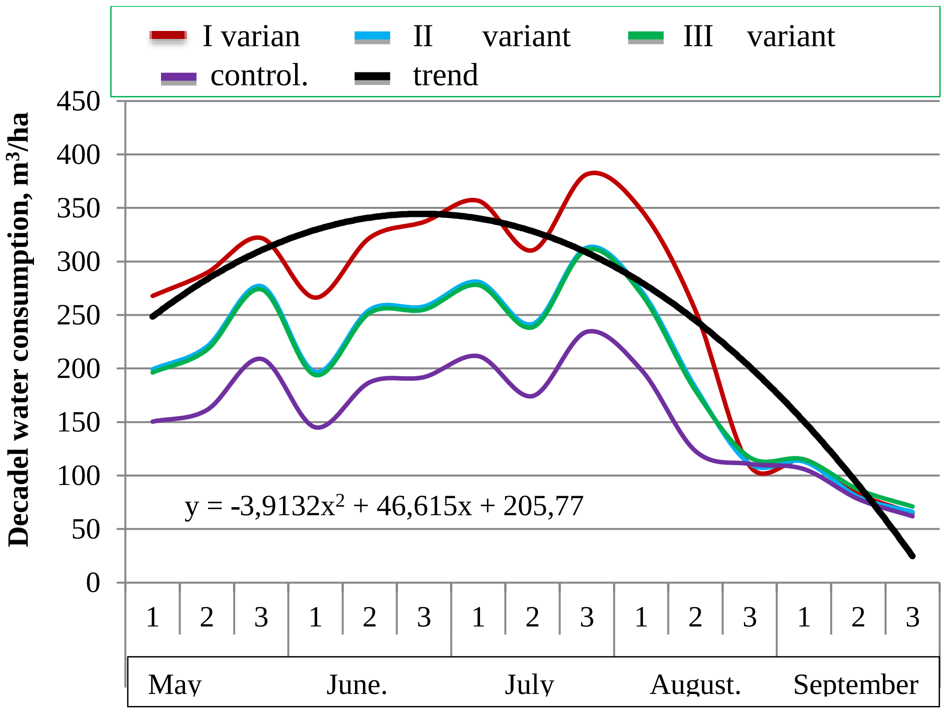

Figure 1: *Dynamics of decadal evapotranspiration of two-year-old apple seedlings described by a polynomial of the second degree*

IV. Discussion

During studies for three years of different security and seedlings of different ages, a linear dependence of evapotranspiration on such meteorological factors as the inflow of total solar radiation and the sum of average daily temperatures was established [11], which is described by the following regression equation (tab.2). In the equations under consideration E – evapotranspiration per decade, m^3/ha, t – sum of average daily temperatures per decade, Q – inflow of per decade, M j/m^2. It should be noted that these equations are valid only for the irrigated period. Evapotranspiration at the end of the vegetation is difficult to describe by these equations, as the average daily temperature, inflow of total solar radiation decreases significantly, and the amount of precipitation increases significantly.

On the basis of the obtained equations, a three-dimensional graph of the dependence of evapotranspiration on climatic factors for 1 variant of three-year seedlings according to the equation E=*7,4+0,81Q+0,91t* (*Fig*.2)

Table 2: *Dependence of evapotranspiration on the sum of average daily temperatures and inflow of total solar radiation*

Year	Experience option	Regression equation	Determination factor, R^2	Model error
2011	I (70–90% HB)	$E = -24{,}9 + 0{,}77t + 0{,}69Q$	0,89	± 4,4
	II (60–80% HB)	$E = -20{,}9 + 0{,}65t + 0{,}64Q$	0,83	± 0,5
	Control	$E = -10{,}2 + 0{,}46t + 0{,}29Q$	0,98	± 2,3
2012	I (70–90% HB)	$E = 30{,}2 + 0{,}76t + 0{,}73Q$	0,77	± 6,5
	II (60–80% HB)	$E = -42{,}3 + 0{,}64t + 0{,}86Q$	0,81	± 4,5
	Control	$E = -50{,}9 + 0{,}41t + 0{,}80Q$	0,74	± 2,5
2013	I (70–90% HB)	$E = 7{,}4 + 0{,}81t + 0{,}91Q$	0,89	± 0,5
	II (60–80% HB)	$E = 4{,}0 + 0{,}62t + 0{,}81Q$	0,92	± 2,9
	Control	$E = 1{,}3 + 0{,}44t + 0{,}63Q$	0,73	± 4,4

For annual apple seedlings, a general model for calculating evapotranspiration has been developed depending on the total solar radiation (Q), the sum of average daily temperature (t) and soil moisture (γ)

$$E = -101{,}3 + 0{,}62Q + 0{,}54t + 1{,}9\gamma \pm 11{,}4,\ R = 0{,}81.$$

The soil moisture parameter is set as follows: 70 - in the irrigation mode of 70-90% FC, 60 - in the irrigation mode of 60-80% FC and 0 - in the absence of irrigation.

Similar equations were obtained for two- and three-year-old seedlings, respectively.

$$E = -137{,}8 + 0{,}56Q + 1{,}09t + 1{,}5\gamma \pm 30{,}7,\ R = 0{,}74;$$
$$E = -56{,}6 + 0{,}62Q + 0{,}78t + 1{,}5\gamma \pm 20{,}8,\ R = 0{,}78$$

However, the best result was shown by a simple linear dependence of evapotranspiration on the total solar inflow radiation for 3 years of research on all irrigated variants (Tab.3, Fig.3)

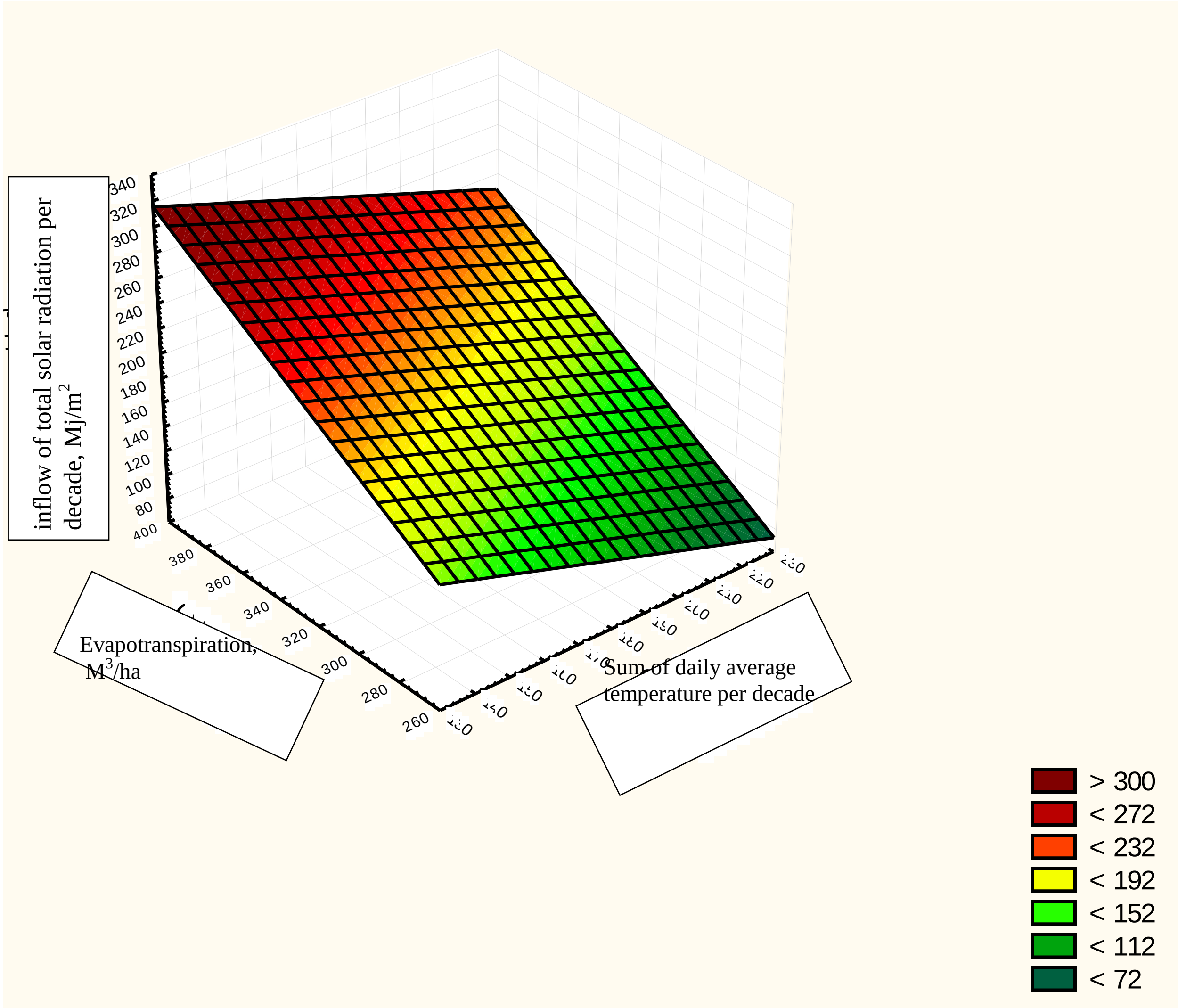

Figure 2: *Three-dimensional graph of the dependence of evapotranspiration on climatic factors for 1 variant of three-year seedlings*

Table 3: *Dependence of evapotranspiration (E) on the total solar radiation inflow (Q)*

Experience option/Year	2011	2012	2013
I	E=1,21Q+23,9 R^2=0,91	E=1,97Q – 81,7 R^2=0,87	E=1,68Q+14,49 R^2=0,94
II	E=1,00Q+37,9 R^2=0,91	E=1,48Q-48,3 R^2=0,91	E=1,31Q+26,1 R^2=0,95
III	E=1,21Q+23,9 R^2=0,91	E=1,21Q+23,9 R^2=0,91	E=1,31Q+25,3 R^2=0,94

The obtained equations allow to maintain soil moisture in accordance with required irrigation regime (tab.4) and the period of development of seedlings, as each equation is valid for a specific period. This is especially true for drip irrigation, when frequent irrigation norms mainly correspond to evapotranspiration over the past period (2 – 7 days), i.e.

$$m = E, \quad m^3/ha$$

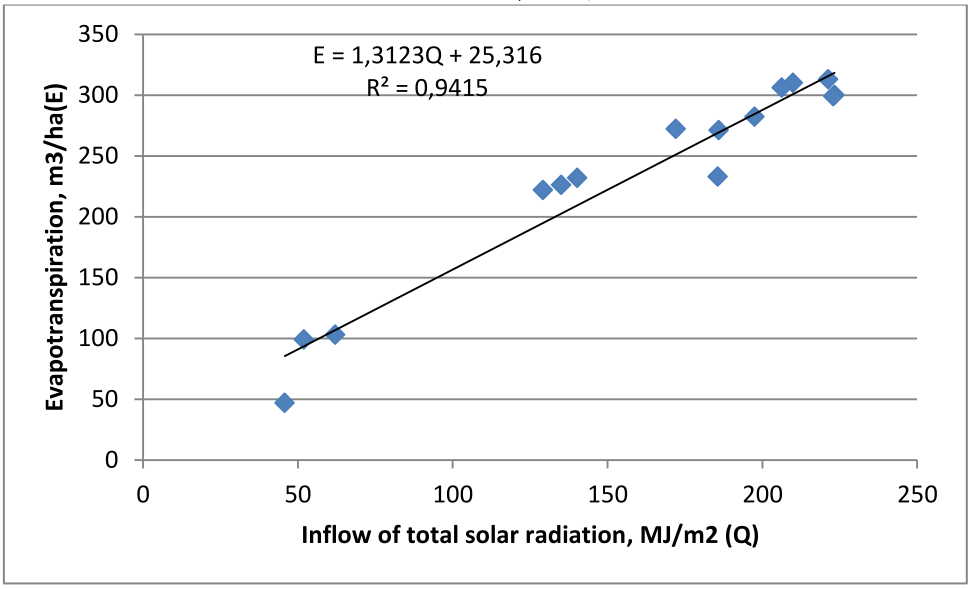

Figure 3: *Graph of the dependence of evapotranspiration (E) on the inflow of total solar radiation (Q)*

For maintenance the specified soil moisture ranges, the irrigation norm was: for 1 variant – 1665, 1481, 1463 m³/ha for years of research, for II variant 1362, 731,748 m³/ha, for III variant -1644, 725 and 741 m³/ha, respectively (Tab. 3). Irrigation water were regularly fed to the site with small norms, thus ensuring constant and uniform moisture of the active soil layer.

Table 4: *Comparative characteristics of different modes of irrigation of apple seedlings.*

Indicator	Experience options								
	I variant (70-90 % FC)			II variant (60-80 % FC)			III variant differentiated		
	Year of research								
	2011	2012	2013	2011	2012	2013	2011	2012	2013
M (irrigation norm, m^3/ha	1665	1481	1463	1362	731	748	1644	725	741
m (norm of watering,m^3/ha	41	49	59	41	46	58	40	45	57
Number of waters	41	30	25	33	16	13	41	16	13
T (The period between watering, day)	2	3	4	3	5	7	2	5	7

Irrigation norms increased annually in accordance with the increasing of roots zone from 30 to 50 cm and amounted to 40, 49, 58 m^3/ha years research respectively. The number of waterings depended on the experience and meteorological conditions of the year and varied from 16 to 30. The period between watering varied according to years of research and depending on soil moisture regime (experience options) from 2 to7 days, which ensured uniform moisture during drip irrigation.

V. Conclusions

1. Resource-saving technologies that contribute to reducing food security risks include the development of scientifically based §rational irrigation regime based on knowledge o plant evapotranspiration by development phases.

2. The maximum value of evapotranspiration during the vegetation period is typical for the most humid variant (1) – 3561,3828 and 4239 m^3/ha years of research, respectively, the minimum – for control (without irrigation) – 2301,2344 and 2777 m^3/ha. The highest values of evapotranspiration were recorded in the 2nd and 3rd decades of May (I variant - 355 -382 m^3/ha, II variant – 312 – 314 m^3/ha, control – 182- 244 m^3/ha)

3. Differentiated irrigation regime contributes to the saving of irrigation water, which in two years reached 777 m^3/ha, in three years - 1500 m^3/ha and decrease in evapotranspiration by 795 and 1519 m^3/ha, respectively.

4. Regression equations describing the dependence of evapotranspiration on the inflow of total solar radiation and the sum of average daily temperatures have been obtained, the use of which will allow to quickly manage the water regime of plants in accordance with changing climatic factors and resource saving requirements.

References

[1] Akutneva E.V. Coefficient of water consumption of fruit crops depending on the irrigation regime // Agronomy and forestry / Izvestiya Nizhnevolzhsky Agrouniversitetskiy complex. № 4 (12), 2008

[2] Likhatsevich A.P., Vaga A.V. The influence of air temperature on water consumption of seedlings of agricultural crops // Bulletin of the National Academy of Sciences of Belarus / 2012. No. 2. pp.65-71.

[3] Melioration and water management. Irrigation: Handbook / edited by B.B. Shumakov. – M.: Agropromizdat, 1990. 415 p.

[4] Khitskov I.F. The system of gardening in agricultural enterprises (On the example of the Central and Central Chernozem regions of the Russian Federation) / edited by I.F. Khitskov, I.M. Kulikov. Voronezh : Center for Spiritual Revival of the Chernozem region, 2007. 296 p

[5] Ionova Z.M., Boyko S.I. The main achievements in the application of drip irrigation. M., 1985. 68c.

[6] Akhmedov A.D. Analytical approach to determining some water-physical characteristics of soils / Materials of the international scientific and practical conference. M.: 2008. Access mode:
http://www.msuee.ru/science/1/sb-08/sb-08_1_5.pdf

[7] Burmistrova A.Yu. Regulation of the water regime of the soil during drip irrigation of a fruit nursery in the Non-Chernozem zone. Dis. candidate of agricultural Sciences, 2013. 229s.

[8] Elsayed A.M. Justification of drip irrigation regimes of strawberries on sod-podzolic soils. Dis. Candidate of Agricultural Sciences, 2011. 192s.

[9] Parfenova N.I., Reshetkina N.M. Ecological principles of regulation of the hydrochemical regime of irrigated lands / Edited by B. B. Shumakov; Russian Academy of Sciences, All Russia. A. N. Kostyakov Research Institute of Hydraulic Engineering and Land Reclamation. St. Petersburg: Hydrometeoizdat, 1995. 359 p.

[10] Shumakov B.B., Kuznetsova E.I. Conceptual issues of irrigated agriculture. Materials of the scientific and practical conference. Tver, 1998.

[11] Puzachenko Yu.G. Mathematical methods in ecological and geographical research. M.: Publishing center "Academy", 2004. - 416 p.12. Farag, A.A.; Abdrabbo, M.A.A.; Maharik, Z.Y.; Rasha El-Morshedy

Water Footprint for Garlic under Irrigation Levels and Agrispon Application, International Letters of Natural Sciences, (2021)Vol. 84, pp. 12-24

[13] Stulina G.V., Solodky G.F. The use of the improved FAO methodology for assessing water consumption of agricultural crops in the irrigation process in Central Asia; /SIC ICWC, Tashkent, 2020

[14] Cheremisinov A.A., Cheremisinov A.Yu. Review of computational methods for determining the total evaporation of irrigated agricultural fields/ Scientific journal of the Russian Research Institute of Land Reclamation Problems No.1, 2016, pp.113-133

CONTRIBUTION OF REGIONAL INTEGRATION ASSOCIATIONS TO SUSTAINABLE DEVELOPMENT

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Abstract

Regional integration associations play a crucial role in promoting sustainable development across member states by fostering economic collaboration, social cohesion, and environmental sustainability. These organizations facilitate the exchange of best practices, harmonization of policies, and mobilization of resources to address common challenges such as poverty reduction, climate change, and social inequality. By implementing regional strategies and frameworks, these associations can enhance infrastructure development, improve trade and investment flows, and support sustainable resource management. Furthermore, regional integration promotes dialogue and cooperation among diverse stakeholders, including governments, businesses, and civil society, to create a shared vision for sustainable development. This paper examines the contributions of various regional integration associations, highlighting successful case studies and identifying key challenges and opportunities for enhancing their impact on sustainable development goals (SDGs). Ultimately, the findings underscore the importance of collaborative approaches in achieving sustainable development and emphasize the need for continued investment in regional integration initiatives.

Keywords: economic collaboration, social cohesion, environmental sustainability, resource management, trade and investment, sustainable development goals (SDGs)

I. Introduction

In an increasingly interconnected world, regional integration associations have emerged as vital entities in advancing sustainable development. These organizations—formed by countries within specific geographical areas—aim to foster economic cooperation, promote social inclusion, and address environmental challenges collectively. As globalization continues to reshape economies and societies, the role of regional integration becomes increasingly significant in facilitating cross-border collaboration and creating synergies among member states.

Regional integration associations encompass various forms, including economic unions, political alliances, and trade blocs, each tailored to the unique contexts and needs of their member countries. By establishing common frameworks and policies, these associations enhance collective action toward achieving the Sustainable Development Goals (SDGs), which were adopted by the United Nations in 2015 as a universal call to end poverty, protect the planet, and ensure prosperity for all by 2030.

The contributions of regional integration associations to sustainable development are multifaceted. They help streamline trade and investment, enhance infrastructure development, and promote sustainable resource management practices. Additionally, these associations facilitate knowledge exchange, enabling member states to learn from one another's successes and challenges in implementing sustainable policies.

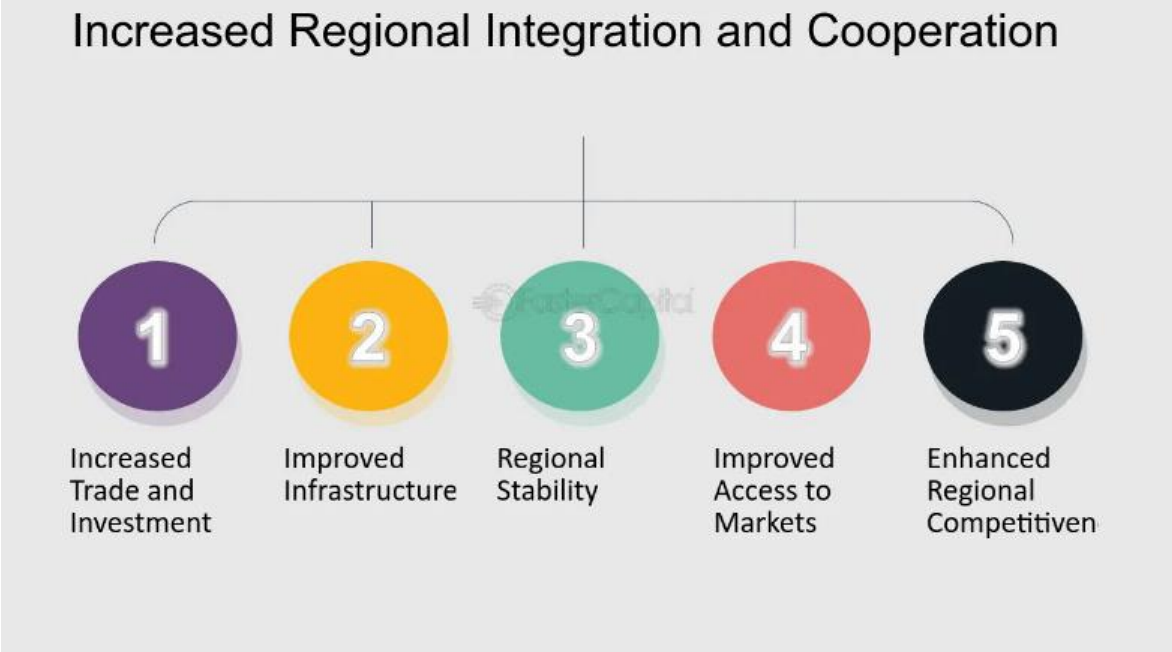

Figure 1: *Increased Regional Integration and Cooperation*

Regional integration and cooperation are fundamental to the success of the East African Community (EAC) Customs Union, which has established a single market by removing trade barriers and harmonizing trade policies. This integration is essential for promoting economic growth, creating jobs, and improving living standards across the region. The following sections explore the key benefits of enhanced regional integration and cooperation within the EAC Customs Union.

1. Increased Trade and Investment

The removal of trade barriers and the alignment of trade policies within the EAC Customs Union have facilitated cross-border business, resulting in a significant boost to trade and investment. With clearer regulations governing trade, businesses find it easier to invest in the region, further stimulating economic growth.

2. Improved Infrastructure

Regional integration has led to major infrastructure developments, such as the Standard Gauge Railway, which has enhanced connectivity and reduced transportation costs for goods across the region. This improved infrastructure not only supports smoother trade but also attracts further investment, as businesses benefit from better logistical networks.

3. Regional Stability

Collaboration among EAC member states has contributed to regional stability by fostering peace and resolving conflicts. This stable environment provides businesses with greater confidence to invest, which in turn drives economic growth and development.

4. Improved Access to Markets

The EAC Customs Union's creation of a single market has made it easier for businesses to access markets across member states. This improved market access has facilitated increased trade and investment, allowing businesses to expand beyond their home countries and tap into broader regional opportunities.

5. Enhanced Regional Competitiveness

The harmonization of trade policies has leveled the playing field, enabling businesses to compete more fairly within the region. This heightened competition encourages innovation and quality improvement, driving the region's overall competitiveness in global markets.

Increased regional integration and cooperation are crucial for the continued success of the EAC Customs Union. The benefits, including higher levels of trade and investment, improved infrastructure, greater regional stability, better market access, and enhanced competitiveness, all contribute to economic growth and improved living standards. EAC member states must maintain and strengthen their commitment to integration and cooperation to achieve long-term prosperity for the region.

However, while the potential of regional integration to advance sustainable development is significant, challenges remain. Issues such as political instability, economic disparities among member states, and the complexity of coordinating policies can hinder effective collaboration. Moreover, regional integration must navigate the tensions between national sovereignty and collective decision-making to achieve meaningful progress.

This paper aims to explore the contributions of regional integration associations to sustainable development, highlighting successful initiatives, identifying key challenges, and offering recommendations for enhancing their impact. By examining case studies from various regions, this research seeks to provide insights into the mechanisms through which regional integration can support sustainable development objectives and contribute to building a more equitable and resilient global community.

II. Methods

To investigate the contributions of regional integration associations to sustainable development, this study employs a mixed-methods approach, combining qualitative and quantitative research methodologies. The following steps outline the research methods used to gather and analyze data:

1. Qualitative Case Studies

This method involves in-depth analysis of selected regional integration associations (e.g., the European Union, African Union, ASEAN) to explore their initiatives aimed at sustainable development. The process includes:

- Selection of Case Studies: Identify associations with varying degrees of success in achieving sustainable development goals.
- Document Analysis: Review strategic plans, policy documents, and reports published by the associations to understand their objectives and measures related to sustainable development.
- Interviews with Key Stakeholders: Conduct semi-structured interviews with policymakers, experts, and representatives from member states to gather insights on the challenges and successes of regional initiatives.

2. Surveys of Member Countries

This quantitative method involves distributing surveys to assess perceptions and impacts of regional integration on sustainable development among member countries:

- Survey Design: Develop a structured questionnaire targeting various stakeholders, including government officials, NGOs, and private sector representatives.
- Data Collection: Distribute the surveys to a diverse sample of stakeholders within member countries of the regional integration associations. Ensure a mix of countries to capture different perspectives.
- Statistical Analysis: Analyze survey data using statistical software to identify trends, correlations, and significant differences in perceptions regarding the contributions of regional integration to sustainable development.

3. Comparative Analysis of Key Indicators

This method involves a comparative analysis of economic, social, and environmental indicators before and after the establishment of regional integration associations:

- Data Collection: Gather data on relevant indicators such as GDP growth, poverty rates, environmental sustainability measures, and social inclusion metrics from sources like the World Bank and regional statistical agencies.
- Timeframe Selection: Define a timeframe for analysis, focusing on periods before and after the formation of the regional integration association.

- Comparative Metrics: Use statistical methods (e.g., t-tests, regression analysis) to compare changes in key indicators, assessing the impact of regional integration on sustainable development outcomes across different member countries.

These methods collectively provide a robust framework for assessing how regional integration associations contribute to sustainable development, incorporating both qualitative insights and quantitative data.

III. Results

Regional integration associations make a significant contribution to achieving the Sustainable Development Goals (SDGs) by coordinating the efforts of member states in various sectors.

For example, in the Eurasian Economic Union (EAEU), integration helps strengthen economic ties between countries, promoting sustainable economic growth and improving the population's quality of life. According to Sergey Glazyev, Minister of Integration and Macroeconomics of the Eurasian Economic Commission, the focus on integration in areas such as sports, healthcare, and education contributes to achieving several SDGs aimed at enhancing social well-being.

In the Association of Southeast Asian Nations (ASEAN), regional cooperation also plays a key role. ASEAN Deputy Secretary-General for the Socio-Cultural Community, Ekkaphab Phanthavong, emphasizes that joint efforts allow countries to mobilize resources efficiently and attract investments into critical economic sectors, ultimately promoting sustainable development in the region.

By stimulating trade and economic growth, regional integration processes create conditions for more sustainable and inclusive development, which aligns with the SDGs. These efforts help reduce poverty, improve working conditions, and ensure equitable access to development benefits.

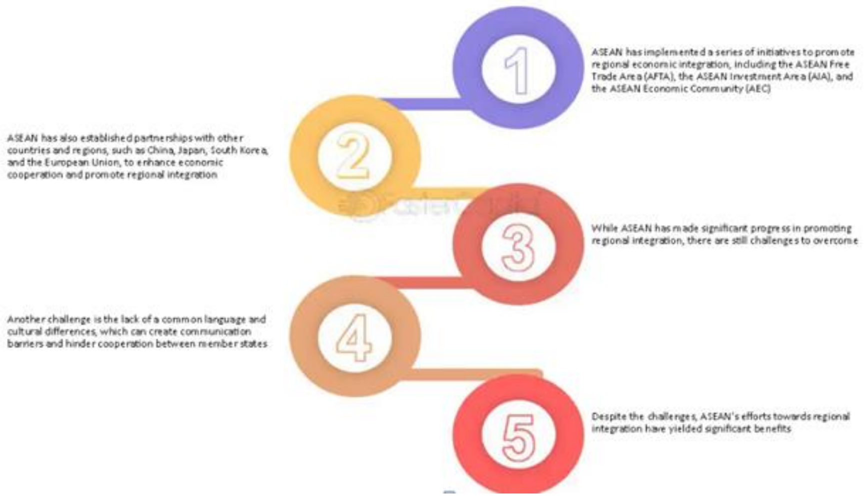

Figure 2: *The Association of Southeast Asian Nations (ASEAN)*

The Association of Southeast Asian Nations (ASEAN) is a regional intergovernmental organization comprising ten Southeast Asian countries, with the goal of fostering economic growth, social progress, and cultural development in the region. Its member countries include Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. The organization has played a key role in creating a more integrated regional economy, with a combined population of over 640 million, a total GDP of $2.8 trillion, and a trade volume of $2.6 trillion, making it the world's seventh-largest economy.

Key aspects of ASEAN regional integration:

1. ASEAN has introduced several initiatives to promote regional economic integration,

including the ASEAN Free Trade Area (AFTA), the ASEAN Investment Area (AIA), and the ASEAN Economic Community (AEC). These initiatives aim to reduce trade barriers, encourage investment, and develop a more competitive and integrated regional economy.

2. ASEAN has also built partnerships with other countries and regions, such as China, Japan, South Korea, and the European Union, to strengthen economic cooperation and enhance regional integration. For example, the ASEAN-China Free Trade Area (ACFTA) has significantly boosted trade between ASEAN and China, with bilateral trade reaching $587 billion in 2019.

3. Despite significant progress, ASEAN still faces challenges in promoting regional integration. One major issue is the development gap among member states, with some countries being more economically advanced than others. This disparity can slow the implementation of regional initiatives and lead to uneven economic growth.

4. Another challenge is the lack of a common language and the cultural differences across member countries, which can create communication barriers and hinder cooperation. However, ASEAN has taken steps to encourage cultural exchange and language learning to address these obstacles.

5. Despite these challenges, ASEAN's efforts towards regional integration have yielded notable benefits. The creation of AFTA, for instance, has increased trade and investment within the region, contributing to economic growth and job creation. Additionally, the "ASEAN Way," which emphasizes consensus-building and non-interference in member states' domestic affairs, has helped to maintain regional stability and prevent conflicts.

In summary, ASEAN's regional integration has been key in building a more cohesive and competitive regional economy. While challenges remain, ASEAN's initiatives have brought significant advantages to its member states and the region as a whole.

IV. Discussion

The concept of the "risk society," introduced by Ulrich Beck in the 1980s, is being reinterpreted in new ways today. Global crises, military-political conflicts, hybrid threats, and futurological alarmism are shaping the current agenda of social sciences. The fundamental socio-natural contradiction—the inability of the biosphere to meet the demands of a growing population—has been compounded by economic, social, and geopolitical crises. In the context of "ecological urgency" and widespread negative changes that threaten global destabilization, humanity is facing the necessity of finding collective solutions to a complex set of interrelated problems or, at the very least, minimizing their consequences.

The limits to growth, outlined nearly half a century ago in the reports of the Club of Rome, now seem more utopian, and the primary task has become the preservation of the integrity and sustainability of the planetary ecosystem amidst increasing anthropogenic pressure and destructive climate changes. While the paradigm of "sustainable development" remains highly debated, a growing consensus has emerged regarding its lack of alternatives. This characteristic distinguishes it from other political-economic models of the future, which continue to offer multiple variants. The political concept of sustainable development, despite numerous contradictions, has not yet exhausted its potential and continues to be recognized as one of the core doctrines of the international community.

The Sustainable Development Goals (SDGs), adopted by the UN, represent an ambitious program aimed at creating a better future by 2030. Following the Millennium Development Goals (MDGs), introduced in 2001, the number of SDGs was increased from 8 to 17, and the number of tasks rose from 21 to 169. The regional contribution to achieving these goals, including efforts by regional integration organizations (RIOs), plays a significant role. The growing influence and capabilities of RIOs are evident as they impact socio-economic development, especially in the context of the restructuring of the global economic architecture. They are becoming important actors in international relations and are expected to make global governance more systematic and effective in the future. Modern regionalization, accelerated by ongoing crises and unpredictable risks, is transforming the world into a decentralized networked space, intensifying competition among various actors, with RIOs playing a key role in shaping the global future.

Research is focused not only on the sustainability of RIOs themselves but also on their potential to stabilize the global political landscape. The events of 2022–2023 have raised skepticism about the comprehensive achievement of the SDGs within the Eurasian integration region. Disruptions in supply chains, rising prices for raw materials and commodities, including food, create significant obstacles, particularly in meeting goals related to eradicating hunger (SDG 2) and ensuring health and well-being (SDG 3). As noted by Sergey Glazyev, Minister for Integration and Macroeconomics of the Eurasian Economic Commission (EEC), global resources and technologies have the capacity to produce food for 20 billion people, twice the current global population. However, the problem lies in the fair distribution of these resources, the development of equitable international economic relations, and the regulation of prices driven by quantitative easing policies of countries that issue reserve currencies.

Ensuring the effectiveness of the transition to sustainable development requires the development of an adequate system of goals and indicators. This involves improving existing statistical measures that reflect the achievement of SDGs within the Eurasian Economic Union (EAEU), as well as creating new indicators in areas that are not currently covered. It is also essential to implement international standards and recommendations to enhance the quality and comparability of economic statistics. This is particularly relevant for the creation of the EEC's own "sustainable development dossier" for the EAEU and for preparing new reports. Additionally, coordination of statistical activities within the EAEU region, capacity building in research and professional expertise, and the adoption of advanced international standards in methodology and classification are gaining increased significance.

Human development encompasses key dimensions such as governance, health, life expectancy, education (mean and expected years of schooling), and per capita income, all of which contribute to a stable standard of living (fig.3). However, without sustainability and empowerment, human development faces challenges in promoting long-term progress. The relationship between human development and sustainable development is well-established, with studies consistently showing that improvements in human capital positively influence sustainable growth and global integration.

Figure 3: *Human Development for everyone*

Human development focuses on creating a sustainable society by enhancing health, knowledge, and well-being. It emphasizes a healthy, long life, access to knowledge, and a decent standard of living, all of which are critical for assessing progress over the long term. Research shows a positive and significant relationship between human development and sustainable development, with improvements in human capital contributing to sustainability.

For instance, Hess (2015) studied sustainable development by examining the Human Development Index (HDI) as an independent determinant, using adjusted net savings as a proxy for sustainable development. His work extended the Solow growth model and found that while initial HDI levels can present ambiguous effects on economic growth, components like life expectancy and literacy positively impact long-term economic development. HDI has been shown to have a significant positive impact on sustainable policies and outcomes.

Similarly, Boyacıoglu (2008) investigated the relationship between health indicators and sustainable development in Turkey, comparing it with other countries between 1980 and 2008. The study demonstrated that increased health expenditure in Turkey led to a decrease in the mortality rate and a rise in life expectancy, highlighting the link between health investment and human development.

Chikalipah and Makina (2020) further support the co-integration of human development and sustainable growth. They suggest that improving human capital creates a more sustainable society, consistent with the principles of social welfare theory, which focuses on the collective well-being of society as a foundation for sustainable development.

When analyzing the alignment of countries' and regional integration organizations' positions on achieving Sustainable Development Goals (SDGs), it is crucial to consider the persistent macroeconomic inequalities on a global scale. For instance, most African Union countries, as well as some members of MERCOSUR and ASEAN, fall into the category of aid recipients. In global discussions, including within the Group of 77 format, they have frequently emphasized the inadequacy of resources to achieve SDGs. Therefore, essential components of addressing these issues must include investments, financial assistance, and technology transfers from developed to developing countries ("North-South" cooperation).

For these countries, achieving not only SDGs 1 and 2, but also combating drought, reducing subsidies in the agricultural sector of developed countries, adopting a sustainable ecosystem approach to land resource management, and technology transfer (particularly pertinent for the African Union) for agriculture, infrastructure, and communications development are of critical importance. Even with SDG 9, the implementation of the Bali Strategic Plan to provide technical support to developing countries and ensure the full functioning of a "technology bank" to support the innovation potential of less developed countries remains relevant.

Regarding SDGs 16 and 17, developing countries and recipient countries stress the importance of further democratizing international institutions, ensuring these countries' access to decision-making, strengthening the regulation of financial markets and institutions for global financial stability, and reforming the international monetary system. For ASEAN, MERCOSUR, and the African Union, eliminating trade protectionist measures, de-offshoring, combating aggressive tax planning, participating in developing an open, predictable, and non-discriminatory trade and financial system, regulating financial markets for a fairer and more stable financial system, and reforming major global financial organizations such as the World Bank and IMF for balanced and democratic regional representation are crucial.

Low-income countries (LICs) still lack sufficient financial space to respond to crises and invest in sustainable development due to limited international financing opportunities on acceptable terms. Unequal access to COVID-19 vaccines and the side effects of geopolitical and economic policies of the global North have negatively impacted humanitarian, social, and food crises in poor countries of the global South.

Differences persist between developed (donor) and developing (recipient) countries in achieving SDGs, which also need to be analyzed considering the interests of the Eurasian Economic Union in this context. It is conceivable that goals and objectives should be indicative and established in a "soft" regulatory framework. Their mandatory, prescriptive nature would likely face rejection from most developing countries and integration blocs. Such an approach could potentially facilitate successful goal attainment in the future and allow countries and integration blocs to benefit from global development within the triple paradigm of SDGs that integrates environmental, economic, and social factors.

Introducing a range of new variables and indicators of key SDG parameters at the regional integration organization (RIO) level and considering the feasibility of creating corresponding supranational platforms are also noteworthy. The list of priority SDGs and indicators should be reviewed based on the characteristics of RIOs (geographical, demographic, socio-economic, etc.). For example, indicators could include the well-being of the average citizen or the overall environmental impact of population activities.

At the supranational level, establishing an information system on environmental and social conditions, signs of growing inequality, failures in responsible consumption and production models—all warning signals indicating societal and environmental strain—should be considered. Information should flow promptly not only from national governments but also from representatives of NGOs and civil society agents.

A crucial aspect of this work should be the creation of regulatory acts harmonizing various areas of legislation, primarily economic, environmental, anti-offshore, anti-monopoly, and social laws. Achieving SDGs at regional levels should contribute to the political, economic, and social consolidation of the global space, significantly enhancing the international relevance of RIOs and their global institutionalization in a post-conflict world, including on democratic principles, integrating regional civil communities in line with SDG 16 (Peace, justice, and effective institutions).

Currently, the discourse accompanying the movement towards sustainable development in integration blocs plays a critical role in strengthening their resilience, particularly vital during acute phases of crises and conflicts. Ultimately, the journey towards SDGs can organize political processes, organizational structures, and ideological solidarity at a supranational integration level. Efforts must unite to reduce risk, transform the modern "risk environment" into a space for cooperation to eliminate major threats to civilization's further development.

Regional integration has recently gained prominence, especially following the Belt and Road Initiative (BRI), playing a crucial role in connecting over 65 countries through the lens of regionalism and development theory. The objective is to foster progress across social, economic, and environmental dimensions of sustainable development. The growing interconnection of national economies through BRI exemplifies how regional integration can function as a catalyst in several ways, such as advancing trade, digital transformation, expanding markets, fostering regional cooperation, and promoting sustainable socio-economic growth. According to Yu and Chang, the BRI, grounded in regional integration and development theory, aims to enhance global collaboration and connectivity, facilitating sustainable growth and reinforcing regional ties. Such initiatives can improve human development and healthcare, creating employment opportunities and reducing the burden of old-age dependency by enabling financial savings for retirement benefits.

Obere and Muthoga investigated the impact of regional integration on economic development using the generalized method of moments (GMM) and found that regional integration significantly stimulates economic growth, highlighting the relationship between regionalization and a sustainable economy. Brautigam and Tang emphasized that China addressed sustainable economic development by offering the BRI as a proposition to achieve shared goals in human development, healthcare, and economic growth through trade, connectivity, investment, and infrastructure. Furthermore, Wang and Selina suggested that the BRI may act as a moderating force in the global application of development theory, with bilateral cooperation potentially mitigating political instability and boosting local development through regional progress.

Based on these findings, the proposed hypothesis (H4) is that there is a significant moderating effect of regional integration on the relationship between sustainable development and its determinants.

References

[1] Zhang C, Rahman MS, Rahman MM, Yawson AE, Shibuya K. Trends and projections of universal health coverage indicators in Ghana, 1995–2030: A national and subnational study. PloS one The Lancet Global Health. 2019; 14(5):e0209126. https://doi.org/10.1371/journal.pone.0209126 PMID: 31116754

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] Nilsson K. A sustainable working life for all ages–The swAge-model. Applied Ergonomics. 2020; 86:103082. https://doi.org/10.1016/j.apergo.2020.103082 PMID: 32342898

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Cep. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. C. 239-245.

[7] European Commission (2022a) Communication from the Commission. Guidelines on the application of the Regulation (EU, EURATOM) 2020/2092 on a general regime of conditionality for the protection of the Union budget. Brussels, 2.3.2022 C (2022) 1382 final.

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Ullah A, Pinglu C, Ullah S, Abbas HSM, Khan S. The Role of E-Governance in Combating COVID-19 and Promoting Sustainable Development: A Comparative Study of China and Pakistan. Chinese Political Science Review. 2021; 6:86–118.

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

GREEN ECONOMY AND SUSTAINABLE DEVELOPMENT: TRANSFORMING TRADITIONAL BUSINESS MODELS

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Abstract

The transition to a green economy is pivotal for achieving sustainable development in the face of escalating environmental challenges. This paper explores the transformation of traditional business models to align with green economy principles, emphasizing the integration of sustainability into core operations. By analyzing various case studies, we demonstrate how businesses can adopt innovative practices that reduce their ecological footprint while enhancing economic performance. The research highlights key strategies, such as circular economy approaches, renewable energy adoption, and sustainable supply chain management, which not only mitigate environmental impacts but also drive competitive advantage. Furthermore, we discuss the role of policymakers in fostering an environment conducive to green investments and the importance of stakeholder engagement in this transformative process. Ultimately, this paper aims to provide insights for businesses looking to navigate the complexities of sustainable development while contributing to a resilient and equitable economy.

Keywords: sustainable supply chain, environmental impact, innovation, competitive advantage, stakeholder engagement, policy framework, eco-friendly practices

I. Introduction

As global environmental challenges intensify, the need for a transition to a green economy has never been more urgent. A green economy is defined as one that results in improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities. This paradigm shift is essential for addressing issues such as climate change, resource depletion, and biodiversity loss, which pose significant threats to sustainable development.

Traditional business models often prioritize short-term profits over long-term sustainability, leading to practices that are harmful to the environment. However, an increasing number of businesses are recognizing the importance of integrating sustainability into their operations. This transformation not only addresses ecological concerns but also opens up new avenues for innovation and competitive advantage. By adopting green practices, companies can enhance their brand reputation, attract environmentally conscious consumers, and achieve operational efficiencies.

This paper explores how businesses can successfully transition to more sustainable models by examining key strategies, including the circular economy, renewable energy integration, and sustainable supply chain management. It also emphasizes the critical role of policymakers in creating an enabling environment for green investments and fostering collaboration among stakeholders. Through this comprehensive analysis, we aim to provide insights and practical recommendations for businesses seeking to thrive in a green economy while contributing to sustainable development goals. This study delves into the concept of the green economy and its impact on economic development and operational practices. It is based on the premise that traditional linear business models have become unsustainable due to their detrimental effects on the environment, the depletion of natural resources, and the decline in living standards. In light of these challenges, the green economy, which is intricately linked to the principles of the circular economy and bioeconomy, emerges as a crucial framework for fostering sustainable development. The primary objective of this exploration is to establish a balance among the enduring social, environmental, and economic goals of humanity.

Figure 1: *Inclusive Green Economy*

The Inclusive Green Economy (IGE) model, illustrated in Fig. 1, distinguishes itself from traditional economic models by integrating three core components: environmental, social, and economic factors. Emerging from the green economy concept, IGE emphasizes a low-carbon, efficient, and clean production process, while also highlighting aspects of consumption and outcomes centered around sharing, circular practices, collaboration, solidarity, resilience, opportunity, and interdependence. The IGE framework posits that there are multiple pathways to achieving environmental sustainability. Transitioning to an inclusive green economy necessitates the promotion and support of sustainable lifestyles, the enhancement of sustainable consumption and production (SCP), and the encouragement of eco-innovation and resource efficiency. This green economic approach, which includes Corporate Social Responsibility (CSR), offers numerous advantages, including economic, health, safety, social, and environmental benefits. Integrating a green economy within an existing organization presents challenges, but one effective strategy is to manage the business model in a way that incorporates green management principles, ultimately enhancing Corporate Social Responsibility.

By examining the core components of the green economy, this paper presents an innovative development framework that encourages the integration of green, circular, and bioeconomic principles. Such integration is essential for promoting future economic and social progress while ensuring environmental sustainability. Through this analysis, we aim to highlight the potential pathways for businesses and policymakers to transition towards more sustainable practices, ultimately contributing to a resilient and equitable economy. Over the last decade, a frequent claim has been that traditional economic models need to be reformed to address climate change, biodiversity losses, water scarcity, and other pressing challenges while simultaneously tackling key social and economic issues. The global financial crisis of 2008–2009 intensified this debate, leading to the emergence of the vision of a 'green economy'. In 2015, countries worldwide adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs).

These goals recognize that ending global poverty must go hand-in-hand with strategies for economic growth while addressing various social needs, including education, health, social protection, and job creation, all while tackling environmental pollution and climate change.

The SDGs establish a real link between ecological and economic systems and reinforce the necessity for a transition to a green economy, which implies a fundamental transformation toward more sustainable modes of production and consumption. This article focuses on a particularly critical aspect of such a transition: the development of sustainable technological change. This change refers to production and consumption patterns that result in significantly reduced negative impacts on the natural environment, including global climate change.

Specifically, the article discusses several key challenges in supporting sustainable technological change and overcoming the barriers to it. These challenges aim to communicate essential lessons from academic research to policymakers, professionals, and the general public. Addressing climate and environmental challenges requires not only natural scientific knowledge and engineering expertise regarding various technical solutions (such as carbon-free energy technologies) but also recognition that pursuing sustainable technological change is a societal, organizational, political, and economic endeavor involving several non-technical challenges.

Our planet is currently confronted with significant economic, social, and environmental challenges. In response to these issues, the Sustainable Development Goals (SDGs) outline global priorities and aspirations for 2030, presenting an unparalleled opportunity to eradicate extreme poverty and guide the world toward a sustainable future.

Governments around the world have already committed to these goals, and it is now imperative for businesses to take action. The SDG Compass provides insight into how the SDGs impact your business, equipping you with the tools and knowledge needed to embed sustainability into the core of your business strategy.

The guide outlines five steps that companies can take to enhance their contributions to the SDGs. Organizations can use these steps to either set new goals or align their existing strategies, depending on their current stage in integrating sustainability into their core business practices.

Figure 2: *The SDG Compass*

For instance, the transitions literature identifies many sectors—such as energy generation and water supply—as socio-technical systems and innovation systems. These systems consist of networks of actors (individuals, private firms, research institutes, government authorities, etc.), the knowledge these actors possess, and the relevant institutions (legal rules, codes of conduct, etc.). The development of new carbon-free technologies often necessitates the establishment of new value chains involving actors that may not have previously interacted. This process can be lengthy and transformative, resulting in legal amendments, changes in consumer behavior, distributional effects, infrastructure development, and the emergence of novel business models.

II. Methods

Literature Review

- Description: A systematic literature review will be conducted to synthesize existing research on green economy principles, circular economy, bioeconomy, and sustainable development. This will include academic journals, policy papers, and reports from international organizations (e.g., UNEP, EU, World Bank).
- Process:
  - Identify key themes, frameworks, and case studies relevant to the green economy.
  - Analyze previous findings to understand the evolution of the green economy concept and its implications for business models.
  - Summarize the benefits and challenges associated with implementing green economy practices in various sectors.

Case Study Analysis

- Description: This method will involve in-depth case studies of specific countries or regions that have successfully transitioned to a green economy, as well as those still in the early stages of this transition.
- Process:
  - Select case studies from both developed (e.g., EU countries) and developing regions (e.g., Western Balkans) to provide a comparative analysis.
  - Examine policies, initiatives, and business practices that illustrate the transformation from traditional models to green economy practices.
  - Evaluate the outcomes, focusing on economic, environmental, and social impacts, and derive best practices and lessons learned from each case.

Stakeholder Interviews

- Description: Semi-structured interviews will be conducted with stakeholders involved in the implementation of green economy initiatives, including policymakers, business leaders, environmental NGOs, and academic researchers.
- Process:
  - Develop an interview guide with open-ended questions aimed at understanding stakeholders' perspectives on the challenges, opportunities, and effectiveness of green economy initiatives.
  - Conduct interviews with a diverse range of stakeholders to capture various viewpoints and insights.
  - Analyze the interview data using thematic analysis to identify common trends, barriers, and recommendations for enhancing the transition to a green economy.

III. Results

The term "green economy" is defined by the United Nations Environment Programme (UNEP) as an economy that enhances social well-being and reduces inequalities while significantly decreasing environmental risks and ecological scarcities (UNEP 2011) (fig.3). The fundamental components of green economies include the circular economy, bioeconomy, clean technologies, waste management hierarchy, industrial ecology, and strategies focused on environmental conservation and restoration. Numerous international organizations, such as the UN, IMF, World Bank, and World Trade Organization, support the effective implementation of green economy practices.

The European Union's "European Strategy for the Bioeconomy," adopted in 2012, defines the bioeconomy as a process involving the use of renewable biological resources to produce food, biomaterial-based products, and bioenergy. This strategy highlights the potential for utilizing renewable biological resources, emphasizing the need for sustainable manufacturing and bioenergy generation. However, transitioning to these new production methods requires the adoption of innovative and often significantly different technologies. Thus, the successful implementation of these emerging development paradigms calls for innovative solutions across various sectors, including product development, materials, and technological and organizational processes.

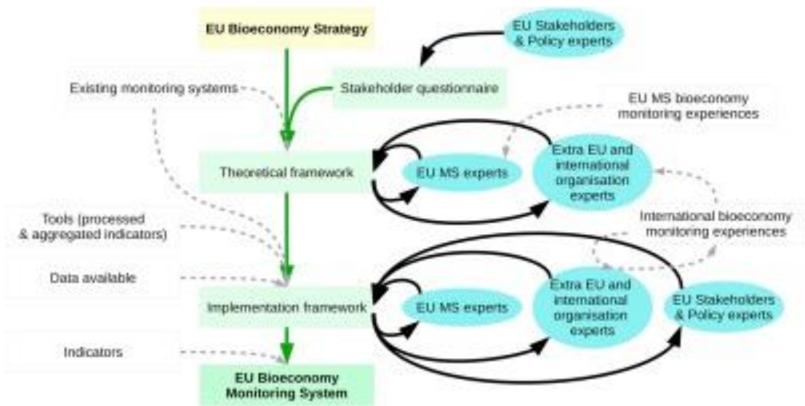

Figure 3: *Development of a bioeconomy monitoring framework for the European Union*

Technological and metallurgical innovations play a crucial role in this transition, facilitating the creation of products and services and adopting processes that are economically viable while minimizing environmental degradation. The metallurgy sector, which is fundamental to civilization's advancement, must embrace the principles of the green economy. The sector's significant growth has presented considerable energy and environmental challenges. Transitioning from traditional to green metallurgical processes offers substantial benefits, as conventional practices heavily depend on fossil fuels, resulting in considerable CO_2 emissions. There is an urgent need for innovative strategies to replace fossil fuels with renewable energy sources while also reducing energy consumption and CO_2 emissions.

As a result, topics such as the substitution of renewable energy for fossil fuels, the utilization of metallurgical slag as a resource, low-carbon smelting technologies in the steel industry, and the mechanisms and control processes for producing non-quenched and tempered high-strength steel for automotive applications have gained significant attention for their potential in energy recovery and technological advancement within the metallurgy sector.

The European Union employs the ecological innovation index to measure the progress of ecological innovations among its member countries. This index comprises sixteen indicators organized into five thematic categories: resources essential for developing ecological innovations, activities conducted during the ecological innovation process, outcomes of ecological innovations, achieved resource use efficiency, and socio-economic impacts.

IV. Discussion

One of the fundamental principles of the green economy is the bioeconomy, which emphasizes the utilization of renewable biological resources for producing materials, chemicals, and energy . This methodology converts sustainable biological resources into value-added products. Perspectives on the bioeconomy vary depending on its focus, which includes resources such as biomaterials and energy derived from agriculture, oceans, and forests, as well as biotechnology with an emphasis on the commercialization of biotech innovations and ecological processes coupled with territorial adaptation. EU documents highlight the importance of integrating the bioeconomy with the circular economy, focusing on concepts such as value chain oversight, sustainability, biorefining, efficient resource use, and cascading biomass utilization. They underscore the crucial role of research, innovation, and societal shifts towards sustainability.

The concept of the circular economy promotes a business model that facilitates the cyclical movement of materials and energy. The primary objective of this initiative is to enhance the durability of materials and energy through inventive design strategies and recycling practices. This approach aims to reduce waste, promote the adoption of renewable energy sources, and ensure that pricing accurately reflects actual costs. Implementing the principles of the circular economy requires a holistic approach across macro, meso, and micro levels. At the macro level, it necessitates reconfiguring the entire industrial framework of an economy. The meso level focuses on regional economies, particularly eco-industrial parks, whereas the micro level deals with individual businesses, consumers, and products. Essentially, the circular economy aims to create a closed loop that encompasses the procurement of raw materials, their conversion into products, and the recycling of resources for use in subsequent production cycles.

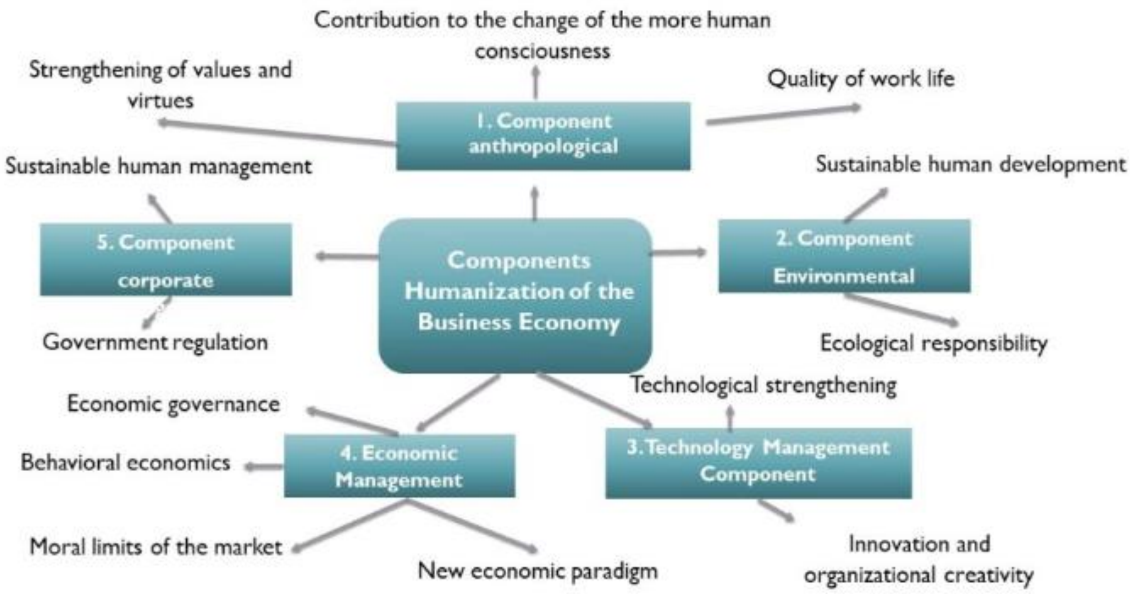

Figure 4: *Hybrid model for the humanization of the business economy and corporate social responsibility*

The model developed, drawing on both classical and modern economic theories, aims to identify and understand potential gaps in knowledge among companies regarding various critical topics. These topics include the strengthening of values and virtues, shifts in human consciousness, sustainable development, technological advancement, innovation and creativity, quality of work life, ecological responsibility, economic governance, behavioral economics, moral limits of the market, and the emergence of a new economic paradigm emphasizing more humane management.

The underlying concern is that ignorance in these areas can hinder companies from implementing humanization policies within the business economy. The strength of this hybrid model lies in its integration of components and principles derived from the theories and authors studied. By addressing these gaps, the model aims to foster more sustainable businesses and environmentally conscious consumers.

Furthermore, the application of this model is anticipated to enhance companies' competitiveness, productivity, research capabilities, innovation, and technology, all within a framework of social responsibility. Ultimately, the purpose of this model is to engage stakeholders—including business leaders, employees, and consumers—in adopting best practices for humanizing the business economy, thereby promoting sustainability and long-term viability.

The mission of the circular economy is to maximize the conservation and enhancement of natural capital by keeping materials and components in use for as long as possible and extending product lifespan.. This approach aims not only to boost business efficiency but also to mitigate and eliminate external economic impacts harmful to human health, natural environments, and ecological systems.

The analysis of the principal characteristics of the green, bioeconomy, and circular economy reveals that, although distinct, these concepts complement each other. For long-term sustainable development, it is essential to apply all three concepts simultaneously. Systemically, the bioeconomy and circular economy act as subsystems within the green economy framework. The circular economy utilizes both renewable and non-renewable resources, while the circular bioeconomy exclusively employs renewable resources to transform waste into value-added products.

Implementing the green economy concept is vital not only for meeting economic objectives but also for addressing environmental and social goals. This approach can lead to numerous positive outcomes, including:

- Enhanced well-being for individuals
- Reduction of poverty
- Achievement of social equality
- Minimization and elimination of environmental damage
- Decrease in carbon emissions
- Complete elimination of pollution
- Primarily utilizing renewable energy sources
- Creation of new green employment opportunities
- Mitigation of biodiversity loss
- Proper waste management.

Thanks to their advanced economic and technological progress and available resources, developed nations have been the pioneers in adopting green economy principles. In contrast, countries in the Western Balkans, including our own, are just beginning to undertake this endeavor, embracing it at a significantly slower rate.

The primary challenges hindering a smooth transition to these new "green" development models include a low level of economic development, an inadequate economic structure, and a scarcity of necessary resources. The adoption of the "Action Plan for the Common Regional Market of the Six Western Balkan Countries for the Period 2021-2024" at the Berlin Process summit in Sofia, along with the document "Common Regional Market - A Catalyst for Deeper Regional Integration, Economic Integration, and a Step Towards the EU Single Market," addresses the development challenges of underdeveloped countries that impede the progress of developed nations. These documents underscore the necessity for Western Balkan countries to enhance their economic competitiveness and expedite their integration into the single European market.

Establishing a digital, investment, and industrial innovation zone in the region, aligned with EU regulations, is highlighted as a significant factor in achieving this objective more swiftly. The "Green Agenda for the Western Balkans for the Period 2021-2030" outlines the commencement of the transition towards "green" economic practices within the Western Balkan countries. This agenda identifies the primary pillars for these countries' long-term green economic transition as follows:

1. Climate, energy, and mobility
2. Circular economy
3. Reduction of environmental pollution
4. Sustainable agriculture and food production
5. Biodiversity conservation

References

[1] Mrochko L.V., Spiridonova G.V., Kuznetsova M.I., Solovieva E.A. Ecological worldview as the basis of modern business in the ESG concept//Economic and social-humanitarian research. 2023. No. 1 (37). P. 83-92.

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] N. Dobbeling-Hildebrandt, ¨ K. Miersch, T.M. Khanna, M. Bachelet, S.B. Bruns, M. Callaghan, O. Edenhofer, C. Flachsland, P.M. Forster, M. Kalkuhl, et al., Systematic review and meta-analysis of ex-post evaluations on the effectiveness of carbon pricing, Nat. Commun. 15 (1) (2024) 4147, https://doi.org/10.1038/ s41467-024-48512-w.

[5] Santikarn M; Churie Kallhauge AN; Bozcaga MO; Sattler L; Mccormick MS; Ferran Torres A; Conway D; Mongendre L; Inclan C; Mikolajczyk S; et al.; Washington, D. C.: World Bank Group, 2021.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] European Commission (2022a) Communication from the Commission. Guidelines on the application of the Regulation (EU, EURATOM) 2020/2092 on a general regime of conditionality for the protection of the Union budget. Brussels, 2.3.2022 C (2022) 1382 final.

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 2137-2144.

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

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MORPHODYNAMICS OF THE BLACK SEA COASTAL ZONE OF ADJARA AND MODERN APPROACHES

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Abstract

The coastline of Adjara, especially the Cape of Batumi, is an active area, which is caused by the underwater canyon of Batumi. It was influenced by the construction of Batumi port in 1878. To protect the port from the impact of storm waves and flooding, a 170-meter-deep dam was built, which eventually caused the Batumi Accumulation Basin to rise sharply, causing it to approach the Batumi Underwater Canyon. The average width of the beach today is 70-80 meters and the threat is growing, as already happened on January 14, 1999, when a beach of about 200 meters long with a total area of 11000 m² washed ashore and sank into the Batumi Canyon. The incident reportedly occurred during the night, triggered by a small earthquake in the city of Trabzon. the construction of dams in the river Chorokhi basin, since the 1990s, had an extremely negative impact on the southern section of the Black Sea coast. (These references are taken from examples of coastal hazard along the Georgian black sea coast: "Examples of coastal hazard along the Georgian black sea coast" Gelovani, I., Lominadze, G., Kavlashvili, G., Russo, G. NATO Science for peace and Security Series C: Environmrntal security, 2021, pp.317-326.)

The innovative project of the company "Ambassador Batumi Island" involves the construction of two artificial peninsulas and an island at the entrance of Batumi, in the settlements of Barchan and Tamar. An area of 144.3223 m² has been allocated for the project, of which 108.50632 m² will be used for various purposes, of which 84 m² will be artificially created area, while the rest will be devoted to protective moles and artificial island aquarium.

The project was preceded by two years of preparatory work, a detailed study of the Black Sea coast. More than 30 local and international studies have been conducted. Three alternative sites were selected for the construction. Eventually, after laboratory findings and expert advice, the Cape of Batumi was chosen for artificial development. More than five hectares of land has already been developed, and work is underway to improve the waterfront. A bridge was constructed to carry heavy equipment, and the necessary infrastructure was put in place. It is worth noting that the seven-ball storms in Batumi in 2023 and 2024 had no impact on the ongoing construction in the Gulf, which confirms that the geographical location for the project was selected with caution by qualified specialists. Planning takes into account an eight-point seismicity and the global warming-related tendency for water to rise.

The EIA (Environmental Impact Assessment) concludes that the environmental impact of a construction site can be reversed in 5 to 10 years. The island will have a well-developed blue-green infrastructure that will create a new landscape and integrated ecosystem for the population. The territory of the island should be created an outstanding architectural example of world importance, which will make the city of Batumi more distinctive and attractive. The work carried out along the Black Sea coast may lay the foundation for new modern approaches that are important and necessary for us as a maritime country.

Keywords: Black Sea, future project, artificial island

Introduction

The coastline of Adjara, especially the Cape of Batumi, is an active area, which is caused by the underwater canyon of Batumi. It was influenced by the construction of Batumi port in 1878. To protect the port from the impact of storm waves and flooding, a 170-meter-deep dam was built, which eventually caused the Batumi Accumulation Basin to rise sharply, causing it to approach the Batumi Underwater Canyon.

Figure 1: *Completed "Ambassador Batumi Island"*

The average width of the beach today is 70-80 meters and the threat is growing, as already happened on January 14, 1999, when a beach of about 200 meters long with a total area of 11000 m² washed ashore and sank into the Batumi Canyon. The incident reportedly occurred during the night, triggered by a small earthquake in the city of Trabzon. the construction of dams in the river Chorokhi basin, since the 1990s, had an extremely negative impact on the southern section of the Black Sea coast. (These references are taken from examples of coastal hazard along the Georgian black sea coast) "Examples of coastal hazard along the Georgian black sea coast" Gelovani, I., lominadze, G., Kavlashvili, G., Russo, G. NATO Science for peace and Security Series C :Environmrntal security, 2021, pp.317-326

Method

In order to better solve the problem, joint work of the state and private investors is necessary. As an example of modern approaches, I have cited the project of "Ambassador Batumi Island" LLC, which envisages the construction of two artificial peninsulas and an island. [Fig.1] An area of 1 443 223 m² has been allocated for the project, of which 108.50632 m² will be used for various purposes, of which 84 m² will be artificially created area, and the rest will be reserved for protective moles and artificial island aquatoria.

The settlements of "Bartskhani" and "Tamar" at the entrance of Batumi have been selected for construction, the infrastructure is currently in place, appropriate equipment has been purchased, a connecting bridge has been built, and an area of more than 5 hectares of land in the water has been arranged.

The big storms of Batumi in November-January 2023-24 did not affect the area under construction, which proves that the geographical location of the island was chosen correctly. The project was preceded by two years of more than 40 local and international studies. 8-point seismicity and global warming-related rising water trends are considered. In the framework of the Ambassador Batumi Island project in Ankara, Republic of Turkey, testing and additional studies were conducted in the hydraulic laboratory, the purpose of which is the engineering stability of the two peninsulas and the island structure. The intersection of the two waves and the speed of the wave were checked. The terrain, geological structure, landscape, hydrology, wave regime, morphodynamics of the construction area of the artificial island were studied by joint researches of local and foreign scientists

As a result, it was concluded that the implementation of the artificial island project will not have a negative impact on the sustainability of the sea coast. Soil settlement estimation was done using Settle3 software. Various preventive measures will be implemented during the construction period. The project envisages the arrangement of pumping equipment, which ensures the pumping of water from the internal aquarium to the external aquarium. Monitoring of water pollution and quality in the relevant catchment basin will be carried out systematically. Observation of the biological environment of the sea will be conducted twice a year and additional mitigation measures will be implemented if necessary. According to the results of the research of water and bottom sediments of the marine aquaria, it was established that at a distance of 60-70 m, there is a high level of historical pollution of the sediments of the bottom slope of the underwater slope with oil and oil products. In the coastline, the river Bartskhana and river Kubistskal used to discharge water contaminated with petroleum products into the sea. The construction of the artificial peninsula and island will permanently cover the historically polluted seabed. As a result, the risk of contamination is eliminated. In case of contamination of sea water and bottom sediments, mitigation measures will be implemented. In order to study the background condition of the bottom sediments quality, field work and laboratory research of the taken samples will be conducted twice a year. The island will have a well-developed blue-green infrastructure that will create a new landscape and an integrated ecosystem for the population. Stones, concrete inert material required for the purposes of the project will be brought in ready form from licensed quarries. This will certainly reduce the risks of environmental impact, such as the spread of dust in the ambient air, the spread of noise and the impact on the water environment. (Fig. 2 and 3.)

"Ambassador Batumi Island", at the stage of development of the technical-economic study, design and development of the master plan of the artificial island, cooperates with the largest international corporations such as Colliers (Great Britain), Arup GROUP (Great Britain), Yuksel Proje (Turkey) SHOP Architects (USA) etc.

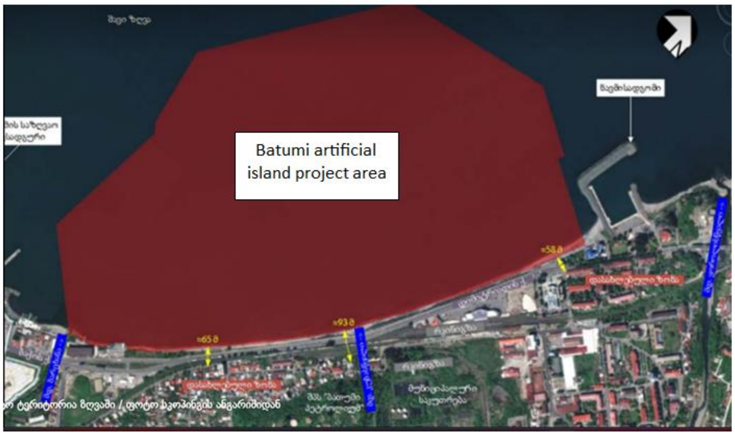

Figure 2: Artificial island project area

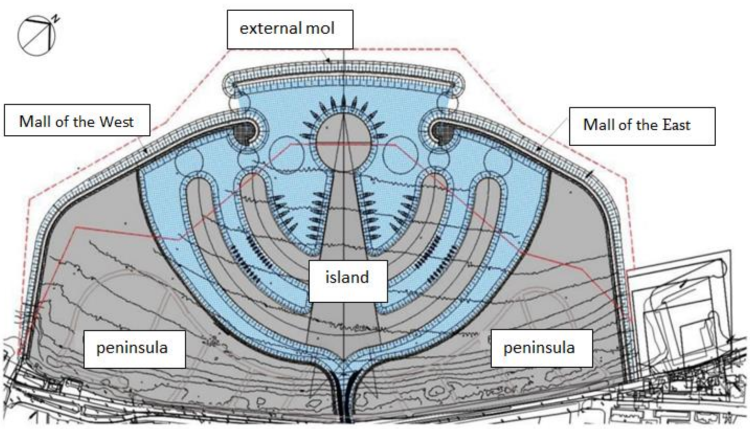

Figure 3: *Gen plan*

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Conclusion

The Ambassador Batumi Island is an important project for the region. In the course of the planned activities, mitigation measures will be taken to reduce the negative impact on the environment. Geological engineering studies indicate that geological processes are not expected to have a high risk of impacting newly constructed infrastructure. It is also worth noting that the company's management gives students the opportunity to participate in this project and receive qualified education with foreign specialists. The territory of the island should be created an outstanding architectural example of world importance, which will make the city of Batumi more distinctive and attractive. The work carried out along the Black Sea coast may lay the foundation for new modern approaches that are important and necessary for us as a maritime country.

References

[1] Metreveli G., Machavariani L., Gulashvili Z., positives and negatives of reservoirs. (book) Tbilisi 2022. 122-123 p.

[2] Makalatia I., Bilashvili K., Kereselidze D. Changes caused by Chorokhi river sediment and modern approaches in Adjara coastline. Proceedings of the Institute of Geophysics named after Mikheil Nodia of Tbilisi State University. Tbilisi. 2023. 102-104 p.

[3] Russo G., The modern situation and development forecasts of Batumi Cape, Tb., 2007.

[4] Russo G., Batumi cape morphodynamics and development forecasts, 2000.

[5] LLC "Ambassador Batumi Island" st. Batumi Artificial Island Development and Operation Project. Environmental Impact Assessment Report. Executor LLC "Gama Consulting" Tbilisi 2023.

[6] Tsivtsivadze N., problems of the defacto coast of the Black Sea of Georgia and ways to eliminate them. (book) Tbilisi 2023.

[7] https://islandambassadori.com/ka/memorandumi/

[8] https://batumelebi.netgazeti.ge/batumelebi/530324/

[9] https://www.facebook.com/Islandambassadori/

THE ROLE OF LEGAL MECHANISMS IN THE IMPLEMENTATION OF THE SUSTAINABLE DEVELOPMENT GOALS (SDGs)

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Abstract

This article examines the pivotal role that legal frameworks play in achieving the United Nations' Sustainable Development Goals (SDGs). The SDGs, established in 2015 as part of the 2030 Agenda for Sustainable Development, represent a global commitment to addressing social, economic, and environmental challenges.

The implementation of these goals requires a coordinated effort across national, regional, and international levels, where legal mechanisms are key enablers of effective action. The text explores how laws, regulations, and policies can help institutionalize the SDGs by embedding sustainable development principles into legal systems. This includes integrating international agreements into national legislation, ensuring accountability through judicial and non-judicial bodies, and creating enforcement mechanisms to monitor compliance. Specific examples of legislation that support SDG implementation include environmental protection laws (SDG 13: Climate Action), gender equality policies (SDG 5: Gender Equality), and economic regulation aimed at reducing poverty and inequality (SDG 1: No Poverty, SDG 10: Reduced Inequalities). Moreover, the article discusses the challenges that arise in the harmonization of legal systems across different jurisdictions, particularly in developing countries with limited legal infrastructure. It highlights the need for legal capacity building, effective governance structures, and international cooperation to strengthen the legal enforcement of SDG-related commitments.

In conclusion, legal mechanisms are essential for translating the SDGs from global aspirations into tangible actions. They provide the structure for implementing sustainable policies, ensuring accountability, and fostering an environment where sustainable development can thrive. By supporting a rule-based approach, legal systems play a crucial role in advancing the global sustainability agenda.

Keywords: sustainable development goals (SDGs), legal mechanisms, international law, national legislation, environmental protection, accountability, governance, legal frameworks

I. Introduction

The UN Sustainable Development Goals (SDGs) (Fig.1) were established by the United Nations as a "universal call to action" to eliminate poverty, safeguard the environment, and guarantee that by 2030, everyone can experience peace and prosperity. These goals have gained significant traction among managers in both public and private sectors. Many organizations have begun including their contributions to specific SDGs in formal reports to stakeholders, such as annual reports. Although not originally intended for this purpose, the SDGs are increasingly being used as a tool for accountability. However, their use in this capacity comes with challenges. One issue is that organizations may—either deliberately or unintentionally—report only on activities that align with a limited set of goals, which fails to provide the comprehensive information necessary for the SDGs to function effectively as an accountability mechanism.

Figure 1: *Sustainable Development Goals (SDGs)*

Despite their widespread appeal, little is known about the broader implications (both positive and negative, intended and unintended) of incorporating SDGs into organizational management practices. This leads to the central question of the research: "What is the potential role of the SDGs as an accountability mechanism?" While some studies have examined the drivers and outcomes of SDG reporting, they have predominantly been quantitative. To better understand the SDGs' potential as an accountability tool, qualitative research is essential, as it allows for deeper exploration of new phenomena without imposing pre-existing frameworks. This study focuses on the infrastructure sector, where many organizations have adopted and reported on the SDGs. This sector is especially relevant due to its critical role in providing essential services, such as electricity, heating, transportation, and water, which are foundational to society. As a result, infrastructure agencies operate in a highly regulated environment. This raises an important question: How can accountability to societal needs be effectively ensured for organizations responsible for vital infrastructure? Changing the mindset of organizations that manage key technological systems, such as power grids, water supply systems, or rail networks, is crucial for broader accountability. However, these organizations face challenges in implementing societal needs, as they are constrained by legal requirements and shareholder expectations. This article explores how infrastructure organizations are using the SDGs as an accountability mechanism. It first provides an overview of the SDGs and the concept of accountability, followed by a case study methodology. The research is based on interviews with employees from three infrastructure organizations. Through this case study, the authors analyze the key tensions that arise when using the SDGs for accountability. In conclusion, the article argues that while the SDGs offer a useful tool for making organizations more accountable to societal needs, significant changes in the design of accountability mechanisms are required to achieve meaningful accountability.

II. Methods

To investigate how the SDGs function as an accountability mechanism in the infrastructure sector, this study employs a qualitative case study approach. This method allows for in-depth exploration and understanding of complex phenomena in their real-life context. The research focuses on three organizations within the infrastructure sector, chosen for their critical role in providing essential services (electricity, water, and transportation) and their adoption of SDG reporting.

The study uses semi-structured interviews as the primary data collection method, targeting key employees involved in SDG implementation and reporting. These interviews provide insights into how these organizations integrate the SDGs into their management practices, how they report on their contributions, and the challenges they face in using the SDGs as an accountability tool. The semi-structured format allows flexibility in exploring new themes that arise during the interviews.

In addition to interviews, document analysis is conducted on relevant organizational reports, including annual reports and sustainability documents, to understand how these organizations publicly communicate their alignment with the SDGs. This analysis helps verify the consistency between the organizations' internal practices and their external communication.

The data collected is then analyzed using thematic analysis, which involves coding the interview transcripts and documents to identify recurring themes and patterns related to SDG reporting and accountability. This method facilitates the identification of key tensions and challenges, as well as the broader implications of using the SDGs as an accountability mechanism.

The results of the case study are presented in a narrative format, discussing the specific findings from the infrastructure sector while drawing broader conclusions about the use of SDGs in organizational accountability.

III. Results

On 25 September 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development, an ambitious action plan aimed at improving the lives of individuals, protecting the planet, and fostering prosperity. This agenda, which also strives to promote universal peace and freedom, was introduced as a means to achieve targets that the Millennium Development Goals had failed to meet. The agenda includes 17 Sustainable Development Goals (SDGs) and 169 specific targets, with a strong focus on realizing human rights for all, promoting gender equality, and empowering women and girls.

The 2030 Agenda is more ambitious than its predecessor, extending its objectives beyond poverty reduction and environmental protection. It emphasizes five key areas of action, often referred to as the 5Ps: people, planet, prosperity, peace, and partnership. These areas work together across the three dimensions of sustainable development: economic, social, and environmental. The SDGs are seen as a potential new social contract for the era of globalization, offering a framework for security and freedom worldwide.

Figure 2: *The 5Ps of Strategy*

Although the SDGs are not legally binding, the countries that have adopted them are expected to establish national or transnational frameworks to support their implementation. At the European level, the agenda aligns with existing sustainable development initiatives. The European Union was already well-positioned in terms of sustainability and played a key role in advocating for SDG 16, which focuses on promoting peaceful, inclusive societies. The agenda encourages a holistic approach, where policies at international, EU, and member state levels should address the interconnected areas of the 5Ps, avoiding compartmentalization and promoting integration across different policy areas to achieve progress in all SDGs simultaneously. The responsibility to understand and implement the SDGs is universal, as all individuals and entities are regarded as key actors in this global effort. Public authorities and civil society are called upon to be both active participants in achieving the goals and beneficiaries of the progress made across the 17 SDGs. However, the 2019 Progress Report by the UN Economic and Social Council highlights that progress has been slow, with the most vulnerable populations and countries continuing to face the greatest challenges. The report emphasizes that the global response has not been ambitious enough.

To address the slow progress, there is a growing emphasis on collaborative efforts in research and education, particularly in the field of law. Universities, through legal research and teaching, play a crucial role in advancing the SDGs. The academic and scientific communities have recognized the importance of contributing to these goals. This paper aims to explore how civil law and procedural law have created mechanisms to protect rights, reduce inequalities, and promote legal sustainability. The study will also identify existing gaps and challenges in ensuring that legal frameworks support the achievement of the SDGs.

IV. Discussion

The goal of eradicating poverty, outlined in SDG 1, must be approached at both the international and national levels. This involves developing policies focused on poverty eradication and ensuring that states take concrete legislative actions. Poverty has numerous consequences that affect various aspects of life, which is why legal frameworks must address the tools available to mitigate its effects. These frameworks also support a sustainable approach by aligning with SDG 10, which aims to reduce inequality within and among countries. Poverty serves as a condition of vulnerability that perpetuates inequality, and thus, legal systems' interventions serve to address both issues simultaneously.

The vulnerability associated with poverty often leads to difficulties in asserting the rights and interests of those affected, particularly in instances of rights violations. The EU has been actively implementing actions and strategies to combat poverty and social exclusion. In November 2017, the European Parliament, the Council, and the Commission proclaimed the European Pillar of Social Rights, which articulates 20 principles designed to support effective and equitable labor markets and welfare systems. These principles emphasize equal opportunities, access to employment, fair working conditions, and comprehensive social protection and inclusion.

Among these principles, Principle 11 specifically addresses children's right to protection from poverty and outlines measures aimed at enhancing equal opportunities for children from disadvantaged backgrounds. The European Commission has also put forth an Action Plan for the Pillar, detailing specific actions required for its implementation. This Action Plan aims to revitalize efforts to tackle poverty and social exclusion within the EU, with a target of reducing the number of people at risk of poverty or social exclusion by 15 million by 2030, or at least by 5 million.

Furthermore, the EU Strategy on the Rights of the Child emphasizes that "children will have access to quality education and healthcare, and families will have sufficient resources to meet their children's needs." The Council Recommendation establishing a European Child Guarantee underscores the EU's commitment, alongside its Member States, to lead in implementing the UN 2030 Agenda and the Sustainable Development Goals, including those focused on eradicating poverty. The aim of this Recommendation is to prevent and combat social exclusion by ensuring access for children in need to essential services. This includes integrating a gender perspective to address the different circumstances of girls and boys, combating child poverty, and promoting equal opportunities.

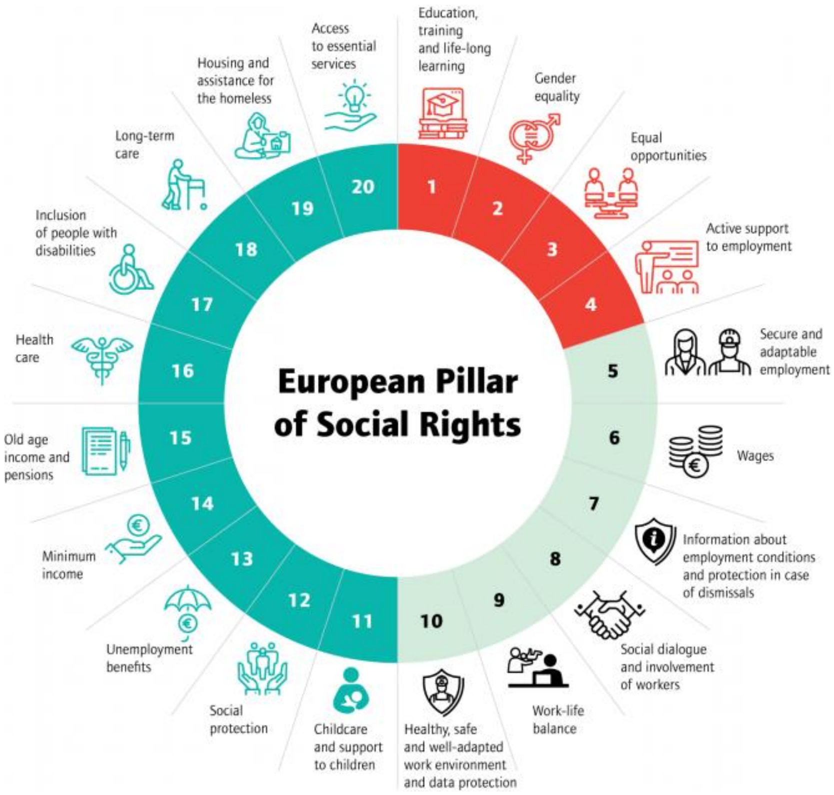

Figure 3: *The 20 principles of the European Pillar of Social Rights*

Lastly, the European Platform on Combating Homelessness has introduced a series of actions to ensure meaningful progress in the efforts of Member States to combat homelessness.

Objective 10 of the Sustainable Development Goals (SDGs) emphasizes the need to reduce inequality both within and among countries. This commitment begins with the elimination of all forms of discrimination, as articulated in various Declarations of Rights. A pertinent example is the Charter of Fundamental Rights of the European Union which prohibits discrimination on several grounds, including disability. Specifically, target 10.2 seeks to "empower and promote the social, economic, and political inclusion of all, irrespective of disability."

Disability often constitutes a unique vulnerability, exacerbated by legislative frameworks that have historically denied legal capacity to individuals with mental or psychological impairments. Recognizing legal capacity is essential for achieving target 10.3, which focuses on ensuring equal opportunity and reducing inequalities in outcomes. This includes eliminating discriminatory laws and practices while promoting appropriate legislative measures.

The Convention on the Rights of Persons with Disabilities (CRPD) marked a significant advancement in recognizing disability as a human rights issue on a global scale. The Preamble of the CRPD underscores the importance of individual autonomy and independence for persons with disabilities, emphasizing their right to make personal choices. The Convention defines persons with disabilities as those who experience long-term physical, mental, intellectual, or sensory impairments, which may hinder their full and effective participation in society due to various barriers.

The CRPD obligates signatory states to "promote, protect, and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to respect their inherent dignity." Notably, Article 12 of the Convention mandates that states recognize that persons with disabilities enjoy legal capacity on an equal basis with others in all aspects of life and that they are entitled to the support necessary to exercise this capacity, accompanied by safeguards that respect their rights, will, and preferences.

Furthermore, SDG 9, which focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation, is particularly relevant to industrial property regulations, specifically patents. Targets 9.4 and 9.5 advocate for specific adaptations within the regulatory framework of industrial property to facilitate innovation and sustainable industrial practices.

SDG 12.a calls for support to developing countries to enhance their scientific and technological capacities towards more sustainable consumption and production patterns. This necessitates robust protection of exclusive rights, along with the flexibility and speed required for fostering innovation and research. Industrial property rights are enshrined in Article 17(2) of the Charter of Fundamental Rights of the EU, and numerous Directives reflect the significance attributed to these rights.

The EU's legislative framework regarding industrial property is largely encapsulated in the European Patent Convention, established on October 5, 1973, and the Directive 98/44/EC on the legal protection of biotechnological inventions, enacted on July 6, 1998.

Regarding SDG 3, specifically target 3.8, which aims to achieve universal health coverage—including financial risk protection and access to quality essential health care services—there are EU regulations that address patent systems to support disadvantaged countries. Notably, Regulation (EC) No 816/2006 outlines the framework for the compulsory licensing of patents concerning the manufacture of pharmaceutical products for export to countries facing public health challenges. This Regulation aims to alleviate public health problems in least developed and other developing countries by improving access to safe, effective, and affordable medicines, ensuring their quality is guaranteed.

The rule of law is essential for the effective functioning of any society. Despite its universal importance, it remains a complex and multifaceted concept, interpreted and applied in diverse ways. This contribution delves into the intricacies of the rule of law, focusing on its role as a foundational value in the European Union's (EU) political and legal framework. It seeks to address the challenges associated with educating students on the core components of the rule of law and proposes effective teaching methods for enhancing their understanding.

Figure 4: *Fighting for Human Rights: Social Entrepreneurs Advocating for Equality and Justice*

The Complexity of the Rule of Law.

1. Empowering Marginalized Communities: Kiva.

Kiva is a pioneering social enterprise that facilitates global connections through micro-lending. By providing small loans to entrepreneurs in underserved communities, Kiva enables them to start or expand businesses, lifting themselves and their families out of poverty. This approach fosters economic development and empowers marginalized individuals to achieve self-sufficiency, actively participating in their local economies.

2. Promoting Education for All: Teach for All.

Teach for All is a global network of social enterprises dedicated to providing quality education universally. By recruiting and training talented young leaders as teachers, Teach for All addresses educational disparities and empowers students to reach their full potential. Through innovative teaching methods and community engagement, these initiatives are transforming children's lives worldwide, fostering a more equitable and just society.

3. Breaking the Cycle of Poverty: BRAC.

Originally founded in Bangladesh, BRAC is now among the world's largest development organizations, exemplifying effective social entrepreneurship. With a holistic approach to poverty alleviation encompassing education, healthcare, microfinance, and social empowerment, BRAC empowers individuals and communities with resources and skills to break the cycle of poverty, fostering inclusivity and sustainable progress.

4. Advocating for Gender Equality: Global Fund for Women.

The Global Fund for Women is a leading advocate for women's rights globally. Through grants to grassroots organizations and activists, it supports efforts to combat gender-based violence, promote economic empowerment, and ensure women's full participation in decision-making processes. These initiatives drive systemic change toward a more equitable world.

5. Protecting the Environment: Patagonia.

Patagonia, a renowned outdoor company and certified B Corporation, leads in environmental stewardship. Through initiatives like donating 1% of sales to environmental causes via the 1% for the Planet program, Patagonia showcases how social entrepreneurship can mitigate ecological impact and advocate for climate justice.

6. Providing Access to Clean Water: charity: water.

Charity: water revolutionizes global water access by funding sustainable projects in developing nations. Through transparent practices and accountability, it ensures communities gain reliable access to clean drinking water, inspiring a new generation of social entrepreneurs to address urgent global challenges.

7. Fighting Food Insecurity: The Hunger Project.

The Hunger Project mobilizes a global movement to end hunger and poverty. By empowering communities with sustainable solutions and strategic partnerships, it enables self-reliance and tackles the root causes of food insecurity, exemplifying the transformative power of social entrepreneurship.

8. Promoting Accessible Healthcare: LifeSpring Hospitals.

Life Spring Hospitals in India innovatively provides affordable, quality healthcare to underserved communities. Through a sustainable business model, it demonstrates that healthcare can be accessible and financially viable, improving health outcomes and reducing disparities.

9. Supporting Fair Trade: Ten Thousand Villages

Ten Thousand Villages is a nonprofit promoting fair trade by empowering artisans worldwide. It provides market access and ensures fair wages, enabling artisans to build sustainable livelihoods and raising awareness about ethical consumerism.

10. Empowering Refugees: Re

Empowers refugees through skills training and employment opportunities. By harnessing refugees' talents and fostering integration, Re

challenges stereotypes and promotes inclusivity, showcasing the transformative impact of social entrepreneurship.

These examples highlight how social entrepreneurship addresses critical societal issues, promoting equality, justice, and sustainability to create a more inclusive global community.

The rule of law transcends mere compliance with legal rules; it embodies the principle that law governs everyone, including the state and its citizens. Its primary rationale is to safeguard individuals from arbitrary power, ensuring that governmental authority is limited and accountable. Given its context-dependent nature, the interpretation of the rule of law varies based on historical, geographical, and cultural factors. Consequently, while the concept of the rule of law is globally recognized as essential, various approaches—such as formal versus substantive interpretations—have emerged, influenced by differing compliance levels with the rule of law.

Formal vs. Substantive Rule of Law.

The formal dimension emphasizes adherence to legal norms and the characteristics of law itself, including clarity, stability, and non-contradictory rules. This aspect is crucial for the functioning of political systems and underpins civil and political rights fundamental to democracy. However, it is essential to recognize that a robust rule of law does not automatically equate to a healthy democracy. For instance, democracies can still exhibit significant deficiencies in their rule of law—exemplified by Hungary's 'illiberal democracy'—while established democracies may also face rule of law challenges.

In the EU, the rule of law stands as a cornerstone of its political and legal order, serving as both a guiding principle and a measure of member states' adherence to democratic norms. Recent developments, particularly instances of rule of law backsliding in certain member states, have highlighted the EU's unique challenge of safeguarding this foundational value against systematic violations. This situation creates an imperative for educators teaching the rule of law within the context of EU values, necessitating effective communication of the importance and implications of the rule of law to students.

Educational Approaches to Teaching the Rule of Law:

1. Pedagogical Framework.

The contribution emphasizes the need for a comprehensive pedagogical framework that encompasses the complexity of the rule of law. Educators should adopt a multidimensional approach that integrates historical, theoretical, and practical perspectives, allowing students to appreciate the nuances of the rule of law in various contexts.

2. Methodological Strategies.

Methodological tools for teaching should be tailored to promote active learning and critical thinking. This could include case studies that illustrate real-world applications and challenges of the rule of law, simulations of legal processes, and discussions that encourage students to analyze and debate contemporary issues surrounding the rule of law.

3. Interdisciplinary Perspectives.

Integrating perspectives from political science, sociology, and ethics can enrich students' understanding of the rule of law. This interdisciplinary approach enables students to grasp how the rule of law intersects with broader societal values and the impact of political structures on legal frameworks.

References

[1] Alcaraz Ramos M (2023) Reflexiones generales sobre los Objetivos de Desarrollo Sostenible. In: Arrabal Platero P (dir) Los objetivos de desarrollo sostenible y la inteligencia artificial. Tirant lo Blanch. Valencia, pp 19–46

[2] Rahim F, Allen R, Barroy H, Gores L, Kutzin J. COVID-19 funds in response to the pandemic. Washington, DC, WA: International Monetary Fund, 2020.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fröhlich M (2023) Gender issues in European economic law. In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[7] European Commission (2022a) Communication from the Commission. Guidelines on the application of the Regulation (EU, EURATOM) 2020/2092 on a general regime of conditionality for the protection of the Union budget. Brussels, 2.3.2022 C (2022) 1382 final.

[8] A.S. Salamova, Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] Casey T (2021) Reflections on legal education in the aftermath of a pandemic. Clinical Law Rev 28:85–106

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

PRINCIPLES OF SUSTAINABLE DEVELOPMENT: REGIONAL ASPECT

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Abstract

The article is devoted to the comparative analysis of regional economic policy conducted in developed countries and in Russia. The processes of development and realization of the regional policy of developed countries are investigated, which include the correct choice of objects for which the stimulation or restriction of economic growth is envisaged. It is noted that the market processes of the 90s of the last century in Russia took place against the background of economic crisis, accompanied by a decline in the standard of living of society, the growth of the differentiation of the country's regions in terms of socio-economic development, which contributed to the emergence of depressive territories. The important components of the concept of "depressive region" are considered, as well as the established subtypes of depressive regions are presented, their features are highlighted. It is noted that the depressiveness of regional development had a direct dependence on the sharp decline in living standards in the years of market transformation. On the example of such a depressive region as the Chechen Republic the analysis of successful implementation of government measures to achieve sustainable socio-economic development of the region is carried out.

Keywords: regional policy, sustainable development, income, employment, Chechen Republic

I. Introduction

In modern domestic economic science there are different ideas regarding the definition of the content of regional policy. Thus, the regional policy conducted under the conditions of centralized management system in the Soviet Union, pursued the global goal of placing productive forces, solving the problems of creating large territorial-production complexes, accelerated development of the eastern regions, development of northern territories, equalization of the levels of economic development of the Union republics, etc. The nationwide character of this policy was its principal feature. The realization of national tasks, taking into account the location of the resource base and socio-economic characteristics of the country's territories was the main core of its content. [1]

Regional policy in foreign countries had some differences, providing for differentiated diagnostics of the country's economic regions in order to determine the directions of development. Along with the solutions of economic problems, considerable attention was paid to the problems of social, political and environmental nature, and although economic motives were given the greatest importance, their relative importance could be different depending on the country. It should be noted that it was only in the late 1950s and early 1960s that European countries began to emphasize economic issues in their regional economic policies, whereas previously the prerogative had been given to its social importance. In modern times, social factors play no less important role and their goal is to achieve full employment, to distribute the regional income received and to solve the problem of welfare [1].

II. Methods

According to S.S. Reshiev, in the development of effective policy much depends on the choice of the state strategy for the development of raw material industries and the form of ownership of them, as they represent the economic core that contributes to the successful economic growth of all regions.

In the work of Surkov S.A. and Shusharin V.V. it is noted that equalization of the levels of economic and especially social development of regions, which have far from equal opportunities, will contribute to leveling the processes of depressiveness of regional development.

N.D. Kondratiev considered it necessary to rely on a comprehensive study of regularities and trends of movement in the past and the possible direction of changes in the future, in contrast to the widespread teleological approach, which focuses on a priori set goals and predicts possible ways to achieve them.

Smirnyagin L. and Bylova G. note that the experience of Western countries facing the problem of structural reorganization and withdrawal from the crisis of depressed regions indicates a higher efficiency of the path of development aimed "upward" and the use of internal growth factors.

According to Volkov and other researchers, among the most conflictogenic factors influencing the socio-political and inter-ethnic situation in the North Caucasus, it was the factors of religiosity that stood out, and their role will not diminish given the unfavorable socio-economic situation.

According to the research of R.M. Sadykov, the growth of the physical volume of gross output of the personal sector was due to the inflow of labor force released from agricultural enterprises, land reform, which removed restrictions on the size of personal land use and livestock, etc.

In conducting this scientific research, such scientific methods as the method of comparative analysis, statistical analysis, comparative analysis, functional analysis, positive and normative analysis were applied. The scientific research was carried out in accordance with the problem-chronological principle, the principles of systematicity, as well as scientific objectivity.

III. Results

Regional economic policy or local planning absorbs all types of government intervention to improve the territorial distribution of economic activities. In fact, regional policies implemented in foreign countries seek to correct some spatial effects of free trade economy in order to achieve economic growth and improve the process of social distribution.

There are five periods in the development and implementation of regional policies of foreign countries:

- the first period is to identify regional problems and their origins;
- the second period is the definition of objectives and, if possible, in a quantitative way;
- the third period is the formation of an appropriate strategy;
- the fourth period is the selection of instruments to be used;
- the fifth period is the evaluation of the implemented policy [1].

Among the most important elements of the process of development and implementation of regional policy of developed states is the correct choice of objects for which it is envisaged to stimulate or limit economic growth.

During the realization of market transformation in Russia there was a deep recession in the economy, a decline in living standards of the population, increased differentiation of regions by level of socio-economic development, which resulted in the emergence of depressed territories. By the beginning of the XXI century, as a result of transition processes, 2/3 of the country's subjects, especially those located near or on the periphery of such leading industrial centers as the North-Western, Central, Volga-Vyatka, Volga economic regions, as well as the North Caucasus, Siberia, the Far East and the Urals were presented as depressive [2].

Depressiveness as an economic phenomenon in relation to the regions, according to the “theory of long waves” of N.D. Kondratiev, is presented as an objective consequence of the cyclical nature of their economic development [3]. “Depression” as an economic category is a stagnation in the economy, with a lack of growth in production and business activity, low demand for products and significant unemployment. This phenomenon is usually observed after or as a result of an economic crisis, indicating the final stage, after which we should expect the onset of the stages of economic recovery and recovery. Based on the existing ideas of both domestic and foreign economic theory, depression is characterized by a cumulative process, when the reduction of investment and consumer demand results in a decrease in production and production resources, thereby maintaining low demand [4].

It should be noted that the Russian depression, emphasizing its specificity in the form of a decline in production in the presence of inflation, gave reason, according to some authors, to consider it as “stagflation.” [2] In accordance with this context, “depressive region” is most accurately defined by L. Smirnyagin and G. Bylova as a territory that differs from others in terms of the main socio-economic indicators, which include the rate of development. [5]

At the legislative and regulatory level, the concept of “depressed regions” found application in the context of budgetary relations to determine the system of compensation for existing interregional differences. In the Resolution of the Government of the Russian Federation No. 639 dated 29.06.1995, the name “depressive” was first adopted in relation to the regions, despite the ambiguity of its interpretation, which in the future, especially in practice, had negative consequences. The draft Federal Law No. 91010-3 “On the Basis of Federal Support for Depressed Territories of the Russian Federation” adopted in the country on March 12, 2003 reflected the concept of “depressive region” more precisely. According to this provision, “depressed territory” was represented as a unit in the form of a district, city or it was a set of contiguous administrative units with a homogeneous economic structure, within one or more subjects of the Russian Federation, which due to the crisis was in a state of extreme economic decline [6].

In the traditional perception, a depressed region is characterized by a lower than average level of socio-economic development in the country, but in the earlier period it was a relatively stable developing territory, occupying high positions in the country by some indicators. Depressive regions, having a large accumulated scientific and technical potential, a significant share of industry in the structure of the regional economy, a fairly high level of qualification labor resources, while being characterized by decreased competitiveness in the main products, reduced investment demand, negative structural changes in the economy, depletion of mineral raw material base, low indicators of well-being of the local population. Such features define a depressed region as a territory in a phase of steady economic decline, in which there is no possibility of new stimuli for development and it is necessary to apply corrective measures on the part of the authorities to get out of the current state. In the 1990s, depressed regions, based on the duration and depth of territorial depression, largely due to the sectoral specifics of production, the crisis in which led to the spread of depression to the entire regional economy, began to be divided into old-industrial, extractive and agrarian-industrial types [2].

Among the more affected due to the reforms of the 1990s in the country were the old-industrial regions, on the territory of which were concentrated such enterprises of processing industry with a developed scientific, technical and technological base, belonging to the military-industrial complex, machine building, instrument making, light and food industries. The structure of the economy of these territories was formed throughout the period beginning from the late XIX century to the middle of the XX century, with different stages of industrial development [2].

The extractive depressive regions included localized resource-producing territories, especially mining and timber industries, located in sparsely populated areas. These regions, as well as old-industrial ones, were characterized by a fairly developed economic potential with a significant share of industry in the economic structure, highly skilled labor resources, but due to the disruption of supply and raw material relations or changes in the development strategy, as well as the low competitiveness of core industries had problems in the form of deep economic recession, high unemployment, especially structural unemployment, rather low indicators of investment activity of the level of financial and budgetary support of the economy. Depressive regions of the old industrial and extractive types belonged to the group of low-income regions with high poverty rates according to the level of per capita purchasing power of money incomes.

IV. Discussion

Regions of the Central Black Earth Economic Region, republics of the North Caucasus and South Siberia, where stagnation of socio-economic processes was noted as a consequence of a combination of typical agrarian specialization and industrial backwardness of the region, could be attributed to the number of agrarian-industrial depressive regions, despite some difficulties in classification due to the fact that the agricultural sector in most Russian subjects, neither in terms of production volume, nor in terms of share in the gross regional product, did not occupy leading positions [2].

It should be noted that in addition to the above classification of depressed regions, there were others. Thus, in 2005 the Ministry of Regional Development of the Russian Federation developed a new typology of Russian regions, in which all subjects, based on the basis of development, the degree of involvement in global development processes such as globalization, urbanization and neo-industrialization, were grouped into 4 main types and 7 groups based on expert assessment with the analysis of indicators of socio-economic development of the subjects of the Russian Federation. In depressive regions, according to this classification, there was a significant economic decline in the main branches of the economic sphere over the last 10 years and lower level compared to the average analogs in the country of many economic indicators, while in the past these territories were economically developed, occupying prominent places in some positions in the country's economy [7].

In general, in depressed regions there were observed:

- high unemployment rates and, as a consequence, a low standard of living of the population living in these territories;
- significant lag in socio-economic development compared to other regions of the country;
- poor infrastructure provision.

In turn, depressive regions were subdivided into such subtypes as background and crisis. While the background depressive regions had a low standard of living, backward technological base, insufficient market positioning, and a shortage of human resources, the crisis regions were characterized by a rather significant lag behind other regions in terms of socio-economic development, high unemployment rates, poor infrastructure provision and a higher level of social conflicts. Depressiveness of regional development had a direct dependence on the sharp decline in living standards during the years of market transformation.

At the beginning of 2000, the Chechen Republic could also be considered as depressive among the Russian regions that were among the last in the country in terms of socio-economic development, which is confirmed by the data in the table below.

Table 1: *Main socio-economic indicators (2005 results)*

Key indicators	Number of registered unemployed in % of economically active population	Area of housing stock per capita	Industrial output per capita, thousand rubles.	Share of pupils studying in the second shift, %	Number of hospital beds Number of hospital beds per 10,000 people.	Proportion of population with incomes below the flow minimum
Russian Federation	2,6	19.2 (18 is the norm)	78,1	19,8	116,0	17,8
Southern Federal District	5,9		24,8	25,2	105,2	37,3
Chechen Republic	78,9	11,7	9,7	54,8	68,9	90,0

Analysis of the data in the table shows that the Chechen Republic lagged far behind in all the most important socio-economic parameters in comparison with the all-Russian average and the average for the Southern Federal District (SFD), of which it was then a part. For example, by the end of 2005, the regional indicator of the number of registered unemployed was more than 30 and 13 times higher than the national average and the average for the Southern Federal District, respectively; the share of the population with incomes below the subsistence minimum was more than 5 and 2 times higher than in the country as a whole and in the Southern Federal District, respectively, etc.

The reasons for this negative socio-economic state of the Chechen Republic were to be found in the political and economic restructuring that began in the USSR and the anti-terrorist operations of the last decade of the 20th century, which resulted in the final destruction of the regional economy. The economic crisis in the republic began even before the anti-terrorist operations began, with the rise to power of new persons whose aims were far from the interests of the Chechen people. While the pre-war economic crisis was manifested by a decline in production and living standards, rising unemployment and crime rates, during the anti-terrorist operations many of the region's industrial and social infrastructure facilities were virtually destroyed.

The unemployment rate in the republic, which by the mid-2000s reached about 80% of the able-bodied population, was the highest compared to other regions of the country, and the situation was aggravated by the fact that there were positive dynamics of demographic processes due to the growth of the birth rate, as well as the return of refugees and forced migrants to their homeland due to the cessation of anti-terrorist operations. By the beginning of 2005, according to the data of the Ministry of Labor of the Republic, the number of unemployed able-bodied population reached 400 thousand people, i.e. 62% of the labor resources and almost 69% of the economically active population of the region. This situation, in which the labor market in the republic found itself, could be generally considered as a crisis. In August 2005, at a meeting of the Government, when approving the draft federal budget for 2006-2008, German Gref pointed out that 91% of the population of the Chechen Republic was officially below the poverty line. At the same time, according to the minister, in the Khanty-Mansiysk and Yamalo-Nenets Autonomous Okrugs this indicator was the lowest in the country - less than 7%, and the main reason for the extremely low incomes of the region's population was unemployment [9].

It is worth noting that the deficit of jobs was the most pressing problem for all regions of the Southern Federal District. This was especially true for the republics in which the number of working-age population was two to three times higher than the number of available jobs. In all the republics of the North Caucasus, the load of the unemployed population per vacancy was significantly higher than the national average. Thus, in 1999 in Ingushetia this indicator reached 184.4 people, in Dagestan ◎ 32.3, 20.3 ◎ in Kabardino-Balkaria, while the all-Russian ◎ 2.4 people per vacancy [10].

One of the sides of this problem for the Southern Federal District was the employment of graduates of higher educational institutions. Thus, in 2004, when analyzing the need for specialists with higher education it was revealed that for the last five years the labor market annually increased by about one hundred thousand only at the expense of university graduates, and most of them had humanitarian and socio-economic specialties, thereby worsening the already difficult situation in the sphere of employment of specialists of higher and middle levels. Thus, for example, in 2003 state and non-state higher education institutions of the Southern Federal District graduated 38.2 thousand people in these specialties, while the demand for them, according to the data of employment services, was only 14.5 thousand people. In some regions the spread was even higher: 9 times the excess was reached in Karachaevo-Cherkessia, 7 times in ◎ Ingushetia, 4 times - in Rostov region [11].

In the mid-2000s, the Chechen Republic lagged 7-8 times behind the Russian average in terms of per capita income. At the same time, the consumer market was only one-quarter supplied with local goods, and therefore the increase in incomes, including through allowances and compensatory payments, did not sufficiently stimulate the growth of production in the republic, and at the same time, despite the low incomes of the population, the cost of living here was noticeably higher. [11] Thus, in the 4th quarter of 2005, the minimum subsistence level for this region was set at 2793 rubles, which was slightly more than the size of the pension for disabled people of the second degree and noticeably lower than the subsistence level even in comparatively poor and small Ingushetia, while the average per capita income of the Chechen Republic was 512 rubles. And more than a third of Chechen families had to live on such an income [12].

Various social transfers such as pensions, allowances, compensations, etc., assistance from relatives, and income from subsidiary and personal homestead farms were of great importance in ensuring the livelihood of households in the region in the face of high unemployment in the period under consideration. Support from relatives, mostly from those who had managed to find good jobs outside the republic, both in other Russian regions and abroad, was also an important source of survival. As is well known, kinship ties are highly valued in Chechen society, and close ties with parents remain with children until the end.

As we have already mentioned earlier, employment in subsidiary and personal household farms contributed to the survival of the region's population. It should be noted that in the conditions of fragmentation and changes in the existing production structures, personal subsidiary (household) farms of rural residents begin to acquire great importance as a source of agricultural products and concentration of a significant part of production resources and activities. Personal subsidiary farms become for many rural residents the only way of life support and livelihood. Thus, according to researchers' calculations, if properly managed, a plot of land of 6 hectares can provide a family of four people with vegetables, potatoes and fruit and vegetable products, in this regard, the training of rural residents, especially young people, agricultural knowledge and improving the culture of agricultural production are considered as an important direction of social policy in rural areas. [13] Personal subsidiary farms are more resilient and adapted to the market compared to large-scale production. In conditions of economic crisis, home agricultural production is beginning to play an important role in the survival of the majority of not only rural but also urban residents.

On February 19, 2007, in the session hall of the Ministry of Finance of the Chechen Republic in the framework of the round table entitled "A New Economic Strategy for the Chechen Republic", it was pointed out that it was necessary to elaborate and start implementing a long-term development program for the republic based on the current socio-economic situation. Employment growth was the main condition for increasing the population's income, which, in turn, was impossible without the corresponding development of production and social infrastructure. Of great importance in improving the quality of life and the development of many industries, especially those based on the use of natural resources (oil production, agriculture, forestry, tourism, recreation) was the need to restore the natural environment and its protection [14].

The implementation of program activities in accordance with the planned goals and objectives allowed the leadership of the republic to increase real incomes of the population by the end of 2010 in 1.3-1.5 times, nominal average monthly accrued wages - in 1.7 times, the level of officially registered unemployment decreased by 2 times compared to 2005 [15].

The Russian Federation Government Resolution of April 15, 2014 approved the state program "Development of the North Caucasus Federal District until 2025", the main purpose of which was to improve the welfare and quality of life of the population of the republics that make up the North Caucasus Federal District, ensuring the reduction of their lagging behind the average Russian level

Necessary for the solution of this problem was the formation of a dynamically developing and competitive economy, which, in turn, provided for:

- increasing investment activity and attractiveness of the republics of the North Caucasian Federal District;

- formation of modern tourist infrastructure of tourist-recreational special economic zones on the territories of the republics of the North Caucasus Federal District, Krasnodar Krai and the Republic of Adygea;

increasing the number of beds in collective accommodation facilities in such a specially protected ecological resort region of the country as Caucasian Mineral Waters;

- creating new jobs in competitive sectors of the economy and reducing the unemployment rate;

- ensuring an increase in the population's monetary income and reducing the unemployment rate;

- modernization of health care, education, social protection and social services;

- Ensuring accessibility of medical care for the population at all stages and preschool education services;

- creating conditions for increasing the birth rate and life expectancy of the population, increasing the share of students studying in the first shift in general educational organizations. [16]

In general, it should be noted that the state measures to achieve sustainable socio-economic development of the region, taken within the framework of the noted program can be considered effective. Thus, the gross regional product in 2022 amounted to 268068,5 million rubles, which exceeded the 2005 figure by more than 11 times; the gross regional product per capita increased from 20038,4 rubles in 2010 to 177859,9 rubles in 2022, i.e. by almost 9 times; the volume of agricultural production in 2023 amounted to 50861,0 million rubles, which was more than 11 times higher than in 2005; investments in fixed assets increased 9 times since 2005, reaching the mark of 119515.31 million rubles; the number of officially registered unemployed from 332.7 thousand people in 2005 decreased to 51.8 thousand people in 2023, i.e. by 84%. [17] Based on the world experience, it can be noted that significant economic successes are achieved only by such territories, in which management mechanisms based on the principles of social justice, pursue the goal of creating equal conditions for sustainable human development, contribute to the development of his intellectual and physical abilities, the growth of the quality of life of the population as a whole.

References

[1] Reshiev S.S. Federal District as the Central Link of the State Regional Policy // Regional Economics: Theory and Practice. - 2009. - № 15 (108). - C. 7-15.

[2] Surkova S.A., Shusharina V.V. Depressed regions: typological features and mechanisms for overcoming depression // Regional Economics: Theory and Practice. - 2009. - № 1(94). - C. 25-37.

[3] Kondratiev N.D. Big cycles of conjuncture and the theory of foresight. Selected works. - Moscow: Ekonomika, 2002. - 765 c.

[4] Raizberg B.A., Lozovsky L.Sh., Starodubtseva E.B. Modern Economic Dictionary. - Moscow: SIC INFRA-M., 2024. - 512 c.

[5] Smirnyagin L., Bylov G. On the program of assistance to depressed regions // Regionology. - 1995. - № 3. - C. 31-43.

[6] Draft Federal Law No. 91010-3 "On the Basis of Federal Support of Depressed Territories of the Russian Federation". URL: https://base.garant.ru/3119695/.

[7] Website of the Ministry of Regional Development of the Russian Federation. URL: www.economy.gov.ru

[8] Concept of the Program of Social and Economic Development of the Chechen Republic for 2007-2010. "From Recovery to Development". - Grozny: Committee on Statistics of the Chechen Republic, 2007. - 282 c.

[9] Herman Gref. Over 90% of Chechens are below the poverty line // Grozny Worker newspaper, August 2005.

[10] Regional Studies. The South of Russia: a Brief Thematic Dictionary. ed. by Y. G. Volkov, A. V. Popov. Rostov n/D: SKNTs VS, 2004. - 689 c.

[11] Five years on the labor market // Southern Federal newspaper, No. 23 of 29.06. 2024

[12] Formula of poverty // Groznensky Rabochiy newspaper, February 2006.

[13] Sadykov R.M. Personal subsidiary farming in ensuring food security of the region // Regional Economics: Theory and Practice. - 2016. - № 1 (424). - C. 134-143.

[14] Round Table: New Economic Strategy for the Chechen Republic // Vesti Respubliki newspaper, February 22, 2007.

[15] Chechenstat data. URL: https://95.rosstat.gov.ru/folder/39445.

[16] State Program "Development of the North Caucasian Federal District". Resolution of the Government of the Russian Federation of April 15, 2014. No. 309 (in the current edition). URL: http://pravo.gov.ru/proxy/ips/?docbody=&prevDoc=102417383&backlink=1&&nd=102349751

[17] Chechen Republic in Figures 2024. Brief statistical compendium. - Grozny: Chechenstat, 2024. - 148 c. URL https://95.rosstat.gov.ru/folder/39258

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CARBON POLYGONS AND THEIR IMPACT ON LOCAL ECOSYSTEMS: INTERACTIONS AND CONSEQUENCES

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Abstract

Carbon polygons are areas where data are collected and accumulated to assess the carbon balance of ecosystems, as well as to implement measures to reduce carbon emissions and increase the absorption of greenhouse gases (GHGs). They play an important role in the context of the global fight against climate change, providing important information for improving the management of carbon cycles. However, their impact on local ecosystems is complex and multifaceted. The interaction of carbon polygons with the surrounding nature can vary from positive (e.g. restoration of biodiversity, improvement of soil and water conditions) to negative (including changes in vegetation structure, disruption of usual animal migration routes and possible displacement of local species). This paper considers the key ecological aspects of the functioning of carbon polygons, their interactions with local ecosystems, as well as possible socio-ecological consequences, including both environmental benefits and potential threats to biodiversity and the resilience of natural systems.

Keywords: carbon polygons, carbon balance, climate change, local ecosystems, biodiversity, greenhouse gases, ecosystem restoration, ecosystem services

I. Introduction

More than 160 countries around the world have committed to achieving carbon neutrality by 2030-2070 in one form or another. 1 The goal of achieving carbon neutrality no later than 2060 is formulated in the Climate Doctrine of the Russian Federation. However, many decarbonization plans lack specificity. As a result, they are being implemented too slowly, faced with increasing protectionism, complicated geopolitical problems (security, reliability of supply chains), which prevents the necessary pace of progress towards carbon neutrality. 2 In order for decarbonization actions to be understandable, coordinated at all levels of decision-making and implementation, and to receive broad public support, a clear and understandable action plan is needed - a roadmap - to transform the current raw materials model of economic and socio-political development of Russia into a model of an inclusive and fair innovative low-carbon economy.

The pilot project to create a network of carbon polygons in the Russian Federation is aimed at fulfilling the tasks within the framework of the national action plan for adaptation to climate change and ensuring environmental safety. The main goal of the project is to study the processes of emission and absorption of greenhouse gases (GHG) and develop technologies that help reduce their concentration in the atmosphere. Carbon polygons are experimental territories where comprehensive studies are carried out aimed at assessing the carbon balance of ecosystems and implementing solutions to reduce GHG emissions and increase their absorption.

The main objectives of the project:

1. Monitoring greenhouse gas emissions and absorption:

One of the key functions of carbon polygons is to monitor emissions and absorption of GHGs (carbon dioxide, methane, and others). Ground-based and remote measurement methods are used, such as installing sensors, detectors, and using satellite data. This helps to monitor the dynamics of carbon flows and identify sources and sinks of GHGs in different types of ecosystems.

Global carbon dioxide levels as of…

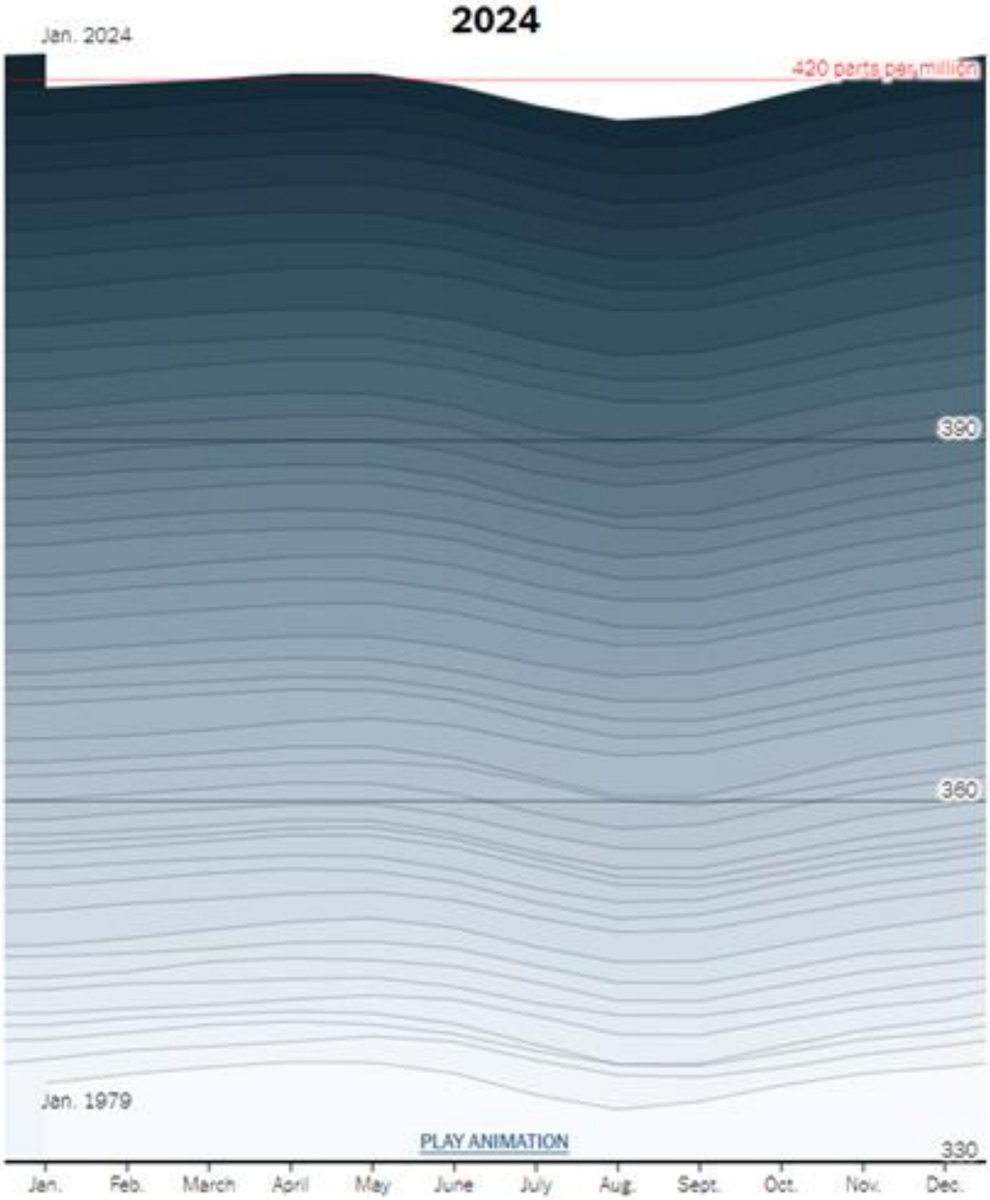

Figure 1: *The chart shows monthly numbers of carbon dioxide molecules per million molecules of dry air. Because of seasonal differences, levels are higher in May than in August.*

2. Assessment of spatial and temporal variability of carbon fluxes:

Regular measurements are taken at landfills to determine the spatial and temporal dynamics of carbon emissions and absorption. These data allow the creation of integrated carbon balance models, assessing how these flows change depending on the season, time of year, weather conditions and landscape features. As a result, conclusions can be drawn about how differences in climate and geography can affect the carbon balance of various ecosystems.

3. Development of technological solutions to reduce emissions and increase absorption of greenhouse gases:

One of the project's priorities is testing and verification of technologies aimed at reducing emissions and increasing absorption of GHGs by natural ecosystems. Such technologies include forest restoration, regulation of agricultural practices (e.g. minimizing the use of fertilizers and improving agricultural practices), water and soil management. In addition, polygons are used to test these technologies under conditions close to real ones and verify their effectiveness in different climate zones and ecosystems.

4. Development of technologies for remote monitoring of ecosystems:

To manage carbon flows, it is necessary to develop technologies for remote monitoring of the structure and condition of ecosystems (vegetation and soil cover, soil moisture, biomass). This is achieved by synthesizing ground-based measurement data with the results of satellite observations and mathematical modeling. The use of such technologies will allow for prompt assessment of the condition of ecosystems and forecasting changes in the carbon balance.

The carbon landfill project proposed by Ctrl2Go is a key initiative to address Russia's unsustainable production and reduce greenhouse gas emissions. With limited government resources to develop their own solutions, business participation is becoming a strategically important step. Ctrl2Go has provided a technology that can not only reduce Russia's gap in the green economy, but also make it one of the leaders in this field. With the European Union introducing a carbon tax from 2023, Russia faces additional challenges amid an economic crisis exacerbated by the COVID-19 pandemic. The carbon landfill project provides an opportunity to minimize risks to the economy and avoid a protracted crisis that could arise due to the complication of trade relations with the EU.

The authors of the project emphasize that carbon landfills are the only fast and effective way for Russian enterprises to reduce greenhouse gas emissions. This is a preferable way compared to the proposal to introduce taxes on excess carbon dioxide emissions, which, according to the authors, will not solve the problem of polluting industries, but will only increase the burden on them. The technology developed by Ctrl2Go is capable of providing real mechanisms for monitoring and reducing emissions, which makes this project a viable alternative to tax measures.

The scientific component of the project also plays an important role. Russia, which has long relied on traditional fuels such as oil and gas, risks falling behind in the field of new energy sources, which will negatively affect its industry and energy sector. Carbon polygons allow not only to implement emission control technologies, but also to create a scientific complex for automated measurement of the level of carbon dioxide absorption in various natural zones of the country. This is especially important in the context of international climate agreements and requirements. The European Union uses closed methods for calculating the carbon footprint, which take into account only the level of emissions, but do not take into account the absorption of carbon dioxide by nature. The carbon polygon project will allow Russia to develop an alternative system for assessing the carbon balance and propose its own adjustments to the international practice of calculating carbon duties, which will strengthen its position in international negotiations.

II. Methods

Carbon landfills are currently being considered as a possible tool to combat the effects of climate change. Their main advantage is that they can improve air quality by capturing and storing carbon dioxide emitted by industrial plants, which is especially important near large emission sources. These landfills also have the potential to reduce the amount of carbon dioxide released into the atmosphere, which helps slow global warming. In addition, the development of this technology can stimulate economic growth and create new jobs.

However, carbon landfills also have their drawbacks. Their implementation requires significant financial costs, which can become a serious barrier to large-scale use. It is also worth considering that the technology is still in the development stage, and there are many technical problems that need to be solved. In addition, the ability of carbon landfills to capture carbon dioxide is limited, and their effectiveness on a global scale remains questionable. Overall, despite the existing difficulties, carbon landfills play an important role in studying the mechanisms of CO_2 absorption by natural ecosystems and can become a significant element in the fight against climate change.

III. Results

The need to combat climate change remains important at the global level, and Russia continues to actively develop climate policy. Data on greenhouse gas (GHG) emissions and absorption play a key role, as they are used to formulate climate goals, compile country and company reports, implement climate projects, and develop carbon markets. However, the quality of this data is still far from ideal. According to the IEA, the uncertainty in estimates of global carbon dioxide emissions is 10%, methane - 25%, nitrous oxide - 30%, and fluorinated gases - 20%. Also difficult is the assessment of the ability of forests and other ecosystems to absorb carbon, which is of particular importance for the Russian climate strategy.

Russia's climate goal for 2030 is to reduce GHG emissions to 70% of 1990 levels, taking into account the maximum absorption capacity of forests and other ecosystems, subject to sustainable socio-economic development. Currently, absorption compensates for about 30% of GHG emissions in the country. The assessment methodology is based on recommendations from the Intergovernmental Panel on Climate Change, but discussions about the accuracy continue.

In February 2022, Russia approved the Federal Program for Environmental Development and Combating Climate Change until 2030, which includes the creation of a system for monitoring GHG flows and the carbon cycle. The law on limiting GHG emissions adopted in 2021 obliged large emitting companies to submit emissions reports and opened up opportunities for climate projects.

The report analyzes the role and current state of the carbon landfill network in Russia, including goals, objectives, regional characteristics, results, scientific research, technologies, educational programs and international cooperation.

IV. Discussion

Global averaged concentrations of carbon dioxide (CO2), the most important greenhouse gas, in 2022 were a full 50% above the pre-industrial era for the first time. They continued to grow in 2023.

The rate of growth in CO2 concentrations was slightly lower than the previous year and the average for the decade, according to WMO's Greenhouse Gas Bulletin. But he said this was most likely due to natural, short-term variations in the carbon cycle and that new emissions as a result of industrial activities continued to rise.

Methane concentrations also grew, and levels of nitrous oxide, the third main gas, saw the highest year-on-year increase on record from 2021 to 2022, according to the Greenhouse Bulletin, which is published to inform the United Nations Climate Change negotiations, or COP28, in Dubai.

“Despite decades of warnings from the scientific community, thousands of pages of reports and dozens of climate conferences, we are still heading in the wrong direction,” said WMO Secretary-General Prof. Petteri Taalas. “The current level of greenhouse gas concentrations puts us on the pathway of an increase in temperatures well above the Paris Agreement targets by the end of this century. This will be accompanied by more extreme weather, including intense heat and rainfall, ice melt, sea-level rise and ocean heat and acidification. The socioeconomic and environmental costs will soar.. We must reduce the consumption of fossil fuels as a matter of urgency,” said Prof. Taalas .

Just under half of CO2 emissions remain in the atmosphere. Just over one quarter are absorbed by the ocean and just under 30% by land ecosystems like forests – although there is significant year-to-year variability in this. As long as emissions continue, CO2 will continue accumulating in the atmosphere leading to global temperature rise. Given the long life of CO2, the temperature level already observed will persist for several decades even if emissions are rapidly reduced to net zero.

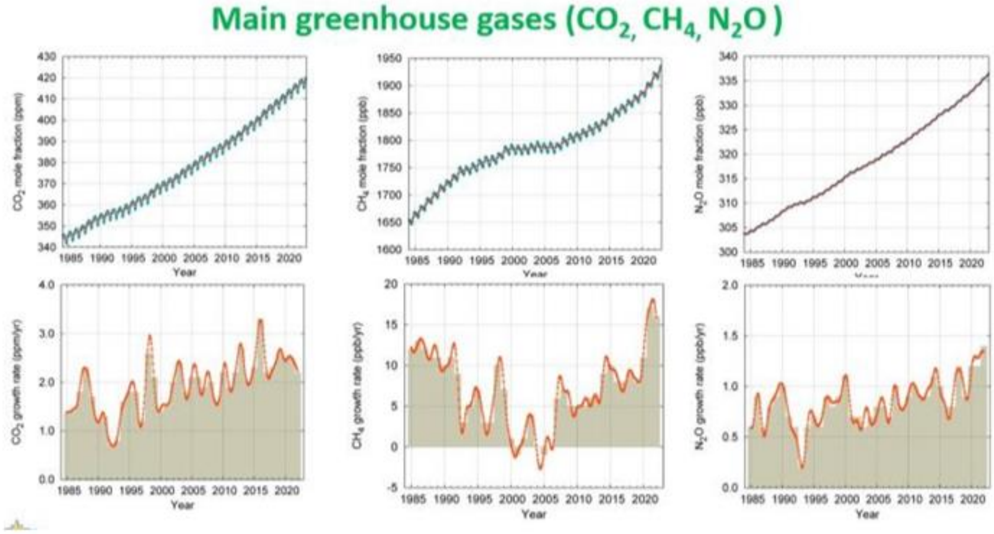

Figure 3: *Graphs - Main greenhouse gases*

The last time the Earth experienced a comparable concentration of CO2 was 3-5 million years ago, when the temperature was 2-3°C warmer and sea level was 10-20 meters higher than now.

The carbon measurement supersite at Kadyrov Chechen State University is distinguished for its scientific research aimed at developing regenerative animal husbandry technologies in mountainous and foothill regions. Regenerative grazing management, especially adaptive grazing across multiple pastures, helps to reduce soil degradation compared to continuous grazing, thereby potentially lowering carbon emissions from the soil. The integration of crop rotation and maintaining perennial cover crops with controlled grazing also contributes to the accumulation of organic carbon in the soil.

This work is being carried out as part of a project to develop a pasture management tool. To achieve these goals effectively, the university collaborates with climate and carbon experts from the Peoples' Friendship University of Russia, the Voronezh State Forestry University, the National Research University Higher School of Economics, the Institute of Geography of the Russian Academy of Sciences, and the Yu.A. Israel Institute of Global Climate and Ecology.

The project aims to identify the most efficient methods of regenerative animal husbandry to enhance carbon sequestration in pastures and study the effects of climate on ecosystems in mountain and foothill landscapes. The planned service will rely on a digital model of pasture sites, enabling the analysis of pasture conditions, degradation, forage production volume, and the detection of soil and grass cover damage, wind and water erosion, and signs of salinization. At each site (reference, intensive grazing, and average grazing sites), aboveground herbaceous vegetation is sampled to evaluate biomass volume and quality. The dominant plant species in each ecosystem are identified. In total, 62 species of vascular plants from 31 families have been cataloged on the southern slope of the Makazhoy Basin.

A mathematical model has been employed as part of the project to account for the physical stabilization mechanisms of soil organic matter. Parameter identification for this model is currently underway at regenerative animal husbandry test sites. The project aims to restore soil quality, increase soil carbon content, improve production profitability by increasing livestock density in the same areas, and reduce production costs through natural pasture restoration.

Figure 4: Carbon Polygon Territories of Kadyrov Chechen State University

Figure 5: *Carbon polygon Way Carbon*

The polygon is unique due to the diversity of landscapes on its territory, including steppe zones, forests and subalpine meadows. This allows for research to be conducted in various natural conditions, making climate research more comprehensive. Each of these zones conducts its own climate research aimed at understanding how different ecosystems respond to changes in the environment.

The key goal of the research is to create conditions for carbon neutrality. This means that scientists aim to ensure that the environment absorbs more carbon than it emits. To do this, strategies are being developed to reduce carbon dioxide emissions and increase its absorption by natural ecosystems such as forests, meadows and soils. Ultimately, this will help combat global climate change and preserve ecosystems.

This excerpt talks about carbon sequestration as one way to achieve carbon neutrality. Carbon neutrality means a balance between the emission of carbon dioxide into the atmosphere and its absorption by natural processes. One effective way to absorb CO_2 is to plant plants with high sequestration potential, i.e. the ability to actively accumulate carbon dioxide from the atmosphere.

Sequestration in this context means the absorption of carbon by plants or soil, which helps to offset CO_2 emissions, and carbon dioxide emissions and absorption are monitored at special landfills to determine how effectively this helps to achieve a carbon balance.

Carbon farms are plots of land where plants with a high potential for carbon sequestration are planted. For example, paulownia and poplar are mentioned as tree species that can actively sequester carbon because they grow quickly and effectively absorb CO_2 from the atmosphere.

Thus, with the help of such projects aimed at increasing the absorption of carbon dioxide, it is possible to offset carbon emissions and get closer to achieving carbon neutrality.

Carbon polygons are an important and promising area in Russia's climate policy. They not only contribute to the creation of a reliable system for monitoring carbon flows in the country's ecosystems, but also increase confidence in Russian climate initiatives, since foreign carbon farms face problems with the reliability of their results. According to the Center for Strategic Research (CSR), the polygons, sharing the goals and objectives of the Ministry of Education and Science of Russia, focus on the practical aspects of their work, including the search for optimal solutions for decarbonization. The presence of industrial partners enhances the practical focus of their activities. Although most Russian carbon polygons are in the initial stages of implementation, by September 2022 they have already achieved some success, especially in the field of education and scientific research.

Most of the current research at the sites is related to the development of scientific and methodological tools for climate monitoring, such as geographic information systems (GIS). The sites emphasize the importance of timely delivery of equipment to intensify scientific work, but most of the necessary equipment in Russia is imported, mainly from the United States. In the context of increasing geopolitical tensions, this creates risks for supplies. According to the Russian Ministry of Education and Science, deliveries continue, but the deadlines have increased, and prices have increased by 20-30%.

The educational activities of carbon polygons are also developing successfully. In 2021–2022, at least seven new educational programs for bachelors and masters were created, existing programs were updated, and new courses were introduced. More than 15 advanced training programs and courses were also prepared. In addition, the polygons actively conduct educational and outreach events.

The most challenging situation at present is international cooperation of carbon polygons, which is extremely important for the recognition of Russian research abroad. There is a breakdown in traditional ties with the West, a transition to more active cooperation within the EAEU and a reorientation towards Asian countries. The Russian Ministry of Education and Science is making efforts to support international cooperation by inviting foreign experts from friendly countries to the Expert Council. The survey showed that polygons almost unanimously recognize the potential for further development in all areas: scientific research, education and international cooperation, and plan to commercialize and scale up best practices in the future. However, they also note the existence of barriers, such as access to technology, funding, infrastructure and administrative difficulties, including difficulties with permitting procedures, lack of standards and unified methods. Among the potential barriers, access to funding and uncertainty with the verification of the obtained data are most often mentioned.

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References

[1] Gakaev, R. Assessing Carbon Dynamics in Diverse Ecosystems: The Role of Carbon Polygons / R. Gakaev , L. Gatsaeva // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03013. – DOI 10.1051/e3sconf/202453703013. – EDN OOIDOS.p .

[2] Gakaev, R. Assessing Carbon Dynamics in Diverse Ecosystems: The Role of Carbon Polygons / R. Gakaev , L. Gatsaeva // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03013. – DOI 10.1051/e3sconf/202453703013.

[3] Gakaev, R. Carbon capacity of gray forest soils in the Chechen Republic / R. Gakaev // BIO Web of Conferences. – 2022. – Vol. 42. – P. 02006. – DOI 10.1051/ bioconf /20224202006.

[4] Munchaev RM, Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House, 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L. : Gidrometeoizdat , 1979. 408 p.

[8] Gakaev , R. Carbon sequestration in landscapes of the Chechen Republic / R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 193-196. – DOI 10.24412/1932-2321-2022-366-193-196. – EDN KHSSVY.

[9] Khotinsky NA, Savina SS Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin VI, Deniz DS Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11.No. 4. P. 1893-1904.

[11] Gunya , A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

SUSTAINABLE CONSUMPTION PATTERNS: THE ROLE OF CONSUMER BEHAVIOR IN A GREEN ECONOMY

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Abstract

The concept of sustainable consumption patterns emphasizes the necessity for individuals and communities to shift towards consumption habits that minimize environmental impact, conserve resources, and support long-term ecological balance. In a green economy, consumer behavior plays a pivotal role in driving the demand for sustainable products and services, which in turn influences production systems and business strategies. This paper explores the intersection of consumer choices and sustainability, investigating how factors such as awareness, values, social influence, and policy interventions impact the adoption of eco-friendly behaviors. By highlighting the barriers to sustainable consumption—such as perceived costs, lack of availability, and knowledge gaps—the discussion delves into how consumers can be empowered through education, incentives, and corporate responsibility to foster a green economy. Ultimately, it advocates for a holistic approach, involving stakeholders across sectors to promote behaviors that support sustainability at both individual and societal levels.

Keywords: sustainable development, consumer behavior, environmental impact, eco-friendly products, resource conservation

I. Introduction

In recent years, the urgent need to address environmental degradation and climate change has driven the shift toward sustainable development and the promotion of a green economy. A green economy prioritizes low-carbon, resource-efficient, and socially inclusive growth. One of the critical elements underpinning the success of a green economy is sustainable consumption, which requires individuals to adopt behaviors and consumption patterns that minimize environmental impact, reduce waste, and conserve natural resources.

Consumer behavior plays a central role in shaping the trajectory of the green economy. The choices that individuals make regarding the products and services they purchase significantly affect the demand for environmentally friendly alternatives, encouraging businesses to innovate and adopt sustainable production practices. However, fostering sustainable consumption is not without its challenges. Numerous factors—such as consumer awareness, economic considerations, cultural norms, and availability of sustainable options—impact individuals' willingness and ability to make eco-friendly choices.

This paper examines the role of consumer behavior in promoting sustainable consumption patterns within a green economy. It explores the drivers and barriers to sustainable consumption, considering how public policies, corporate strategies, and social influences can facilitate the transition to more responsible and environmentally conscious consumption habits. The discussion underscores the need for a collaborative approach that involves governments, businesses, and consumers working together to promote a sustainable future.

By understanding the mechanisms through which consumer behavior can impact the green economy, this research aims to offer insights into how sustainable consumption patterns can be encouraged and adopted more widely. In doing so, it contributes to the broader dialogue on sustainability, emphasizing the importance of individual action as a catalyst for large-scale environmental progress.

Today's consumption is no longer just about using goods and services to meet immediate needs; it has also become a reflection of living standards, a marker of social structure, and a way for individuals to express their identity. In contemporary literature, many definitions of consumption emphasize its social, biological, and psychological dimensions, as well as the factors influencing the satisfaction of human needs. The evolution of consumption, driven by globalization, internationalization, innovation, and the rapid development of a knowledge-based economy, has led to consumption playing not only an important but perhaps a fundamental role, increasingly influencing modern economic processes and growth.

Today, even the youngest family members are becoming active participants in the shopping process, often acting as key advisors and decision-makers, especially when it comes to selecting and purchasing products for family enjoyment, such as modern and high-tech gadgets. In response to environmental degradation, a growing number of consumers are enthusiastic and committed to making significant changes in their daily lives to reduce their ecological footprint. As a result, they make purchasing decisions based on sustainable development principles, fully aware of the impact their choices have on their health and the environment.

Today's consumers, above all, are conscious of the effects of their decisions, largely thanks to greater access to information and active involvement in social life. They are knowledgeable about product quality and the price-to-quality ratio, making more responsible choices in shaping their consumption patterns and asserting their consumer rights. Pro-environmental consumer behavior involves the extent to which consumers engage in deliberate, rational actions to protect the natural environment. This environmentally friendly attitude is a product of knowledge and environmental awareness developed by informed individuals.

Fostering these attitudes and promoting healthy lifestyles in society through awareness-raising is one of the primary goals of education for sustainable development. Current research on the relationship between pro-environmental attitudes and behaviors, as well as the methodology used, requires a modern approach. While much of the literature links consumer behavior with these attitudes, empirical findings remain ambiguous regarding the nature, strength, and direction of these relationships.

Young consumers were selected for this study due to their growing influence and decision-making power within households. They tend to respond more actively to the evolving environment, globalization, and its impact on consumption, lifestyle, and emerging trends compared to other market participants. Understanding their motivations, behavior, and market attitudes can help businesses develop appropriate, innovative marketing strategies and identify the right paths for growth. This will enable companies to stay competitive and offer attractive products or services to new, particularly younger, customers, even amidst rapid changes in consumption patterns and the fast-paced development of mobile technologies and applications.

This article aims to identify the consumer attitudes and behaviors of young people that align with the principles of sustainable consumption. It is divided into three sections: theoretical, methodological, and empirical. The theoretical part explores the concept and essence of sustainable consumption and its link to Fair Trade. The methodological section briefly outlines the research design and sample selection. The empirical section investigates the pro-environmental behaviors of young consumers that can be characterized as sustainable consumption. The article concludes with a summary of key findings and insights.

II. Methods

The research was conducted using a custom-designed questionnaire created by the author, consisting of 50 closed-ended questions focused on alternative consumer trends, including sustainable consumption. The survey was carried out between February 1 and May 1, 2018. One of the challenges was accurately defining the target group, as the term "young consumer" lacks a universally agreed-upon definition in the literature. Different studies define the age range of young consumers in various ways, such as 15-29 years old [Szulce, 2009, p. 637], 15-34 years old [Olejniczuk-Merta, 2001, p. 40], 18-25 years old [Grønhøj, 2007, p. 243], 18-30 years old [Kumar, Kapoor, 2017, p. 218], and 18-35 years old [Phillips, Stanton, 2004, p. 8; Ofosu, Gyanewa, Boadi, 2013, p. 288]. For this study, the population was defined as individuals aged 18-34, in line with Polish literature, where 34 years is considered the end of youth.

Participants were recruited through the "ankietka.pl" platform and social media channels like Facebook, WhatsApp, Messenger, and email. To participate, individuals had to access a specific website containing the questionnaire, which was also shared on specialized forums and the fanpages of universities and private schools. The study focused on young consumers aged 18-34, belonging to Generations Y and Z, who made independent purchasing decisions. Importantly, the research targeted all young consumers, not just those engaged in sustainable consumption. A quota sampling method was applied, with gender and age being the key variables (quotas).

It should be noted that a primary methodological challenge in studying the sustainable behavior of young consumers stems from the non-random sampling approach and the use of an online survey. Incomplete or incorrect responses were excluded (17 cases), and out of the 606 initial questionnaires, 589 valid responses were retained, representing 97.19% of the total sample. These responses were coded, and the data were analyzed using the statistical software SPSS, version 23.

The main objective of the research was to explore sustainable consumption patterns among young Polish consumers. The study aimed to uncover the primary factors motivating young people to engage in sustainable consumption. To this end, three research hypotheses were proposed:

- H1: Sustainable consumption is more prevalent among well-educated young consumers living in large cities.
- H2: Disposable income significantly influences young consumers' positive attitudes toward sustainable development. The higher the income, the more favorable their views on sustainable consumption.
- H3: Young women demonstrate higher environmental awareness than young men, leading to consumer behaviors that are more closely aligned with sustainable consumption principles.

III. Results

The restrictions on both domestic and international transportation during the Covid-19 pandemic led to a significant reduction in travel demand, a near standstill in transportation infrastructure, and numerous serious socioeconomic impacts. On the other hand, reduced transportation activity also meant lower demand for oil and other fossil fuels, which brought environmental benefits, including improved air quality. For example, NO_2 emissions dropped by up to 30%, contributing to enhanced environmental quality (Muhammad et al., 2020). Water quality also improved as a result of people staying home and reducing travel and shipping activities.

However, the pandemic also brought environmental challenges, particularly due to the vast amount of medical waste generated daily. The sudden increase in the use of disposable masks, gloves, and hand sanitizers by millions of people contributed to a surge in waste. Additionally, as household organic waste increased and online purchases required more transportation and packaging, there was a dramatic rise in inorganic waste as well. The environmental consequences of the pandemic, both direct and indirect, continue to raise questions about new strategies and approaches that the global community is exploring to reduce future environmental impacts.

H1: Pandemics have a positive impact on environmental awareness.

Pandemics have had a significant influence on regulatory changes affecting global consumer behavior. At the onset of the Covid-19 outbreak, many countries implemented lockdowns or isolation measures, disrupting normal life and forcing the closure of local businesses. Concerns over product shortages triggered anxiety and led consumers to stockpile essential goods and medical supplies. However, as the pandemic persisted, with new variants emerging, financial instability became more pronounced. This resulted in rising unemployment, inflation, and an economic recession in many countries, all of which have affected consumer attitudes, perceptions, and behavior.

In response, consumers have become more cautious in their purchasing decisions, seeking to balance income and expenditure amid price fluctuations and uncertain wages. A 2021 survey of over 3,000 consumers across 15 countries revealed that the pandemic may have ushered in an era of healthier and more sustainable consumption that could last for the next decade (Accenture, 2021). It is clear that Covid-19 has had a profound impact not only on the global economy but also on the psychology of consumers, leading to notable changes in both short-term and long-term consumption patterns.

H2: Pandemics have a positive impact on consumer attitudes.

Subjective norms play an important role when individuals feel pressure to engage in certain behaviors. In response to unforeseen and potentially dangerous situations, like Covid-19, people often experience anxiety and negative emotions as a protective instinct. When feeling vulnerable, individuals may be more likely to accept negative judgments from others in order to safeguard themselves. For example, to prevent the spread of the virus, individuals may heed advice from their partners and maintain social distancing.

Cultural differences also influence responses to pandemics. Asian cultures, which emphasize social responsibility and collectivism, often encourage individuals to follow societal norms and suppress personal desires. In contrast, Western cultures place a greater emphasis on autonomy, independence, and self-regulation.

H3: Pandemics have a positive impact on subjective norms.

Perceived behavioral control refers to an individual’s assessment of how easy or difficult it is to perform a particular behavior. People are more likely to exert effort to carry out an action if they believe they have the resources and skills needed and expect fewer obstacles. The Covid-19 pandemic disrupted global supply chains and created a workforce crisis, limiting consumer access to sustainable products and services. This led to a surge in stockpiling, although supply capacity could not keep up with demand.

Consumers must also factor in the added costs of green products, which have risen due to market fluctuations caused by the pandemic's direct and indirect effects, along with income loss from job cuts and social distancing mandates. However, reduced spending provides an opportunity to promote sustainable consumption patterns. These include lowering energy use, increasing recycling, cooking at home more often, avoiding unnecessary purchases, and buying secondhand clothing to manage living costs.

H4: Pandemics promote sustainable consumption behavior by encouraging cost-saving and eco-friendly practices.

IV. Discussion

Green consumption has emerged as a popular and novel approach to consumption and lifestyle, gaining traction among a large number of consumers. This approach emphasizes environmental impact, resource efficiency, and consumer rights. Rooted in health protection and resource conservation, green consumption aligns with both personal well-being and environmental sustainability, with its core principle being sustainable consumption. According to the China Consumers' Association, green consumption encompasses three key elements: (1) encouraging consumers to choose eco-friendly products, (2) focusing on responsible waste disposal to prevent environmental pollution, and (3) promoting a shift in consumer attitudes towards valuing nature and prioritizing health. This approach aims to balance the pursuit of a comfortable life with the conservation of resources and energy, ultimately achieving sustainable consumption.

The concept of green consumption was first introduced in 1987 by British scholars Elkington and Hailes in their book *Green Consumer's Guide*. They defined green consumption as the avoidance of certain products, including: (1) goods harmful to health, (2) products that use excessive resources during their lifecycle, (3) items with unnecessary packaging or short lifespans, (4) products derived from endangered animals or natural resources, (5) items involving cruelty to animals, and (6) goods that negatively impact other countries, particularly developing nations (Lin & Xu, 2000; Xu, 2007).

Today, the "5R" principle of green consumption is globally recognized (fig.1): (1) save resources, (2) reduce pollution, (3) reuse and buy durable products, (4) recycle through proper waste sorting, and (5) protect and preserve nature (Wang, 2006). This broad concept covers not only consumer behavior but also the mindset and values behind consumption. Drawing from psychological theory, green consumption is characterized by three interconnected components: green consumption cognition (awareness and knowledge about green practices), green consumption attitude (a favorable or unfavorable psychological stance towards green consumption), and green consumption behavior (specific actions such as buying energy-saving products or avoiding disposable items). According to behavioral science, cognition influences attitudes, which in turn shape behaviors, creating a tightly linked cycle that forms the concept of green consumption.

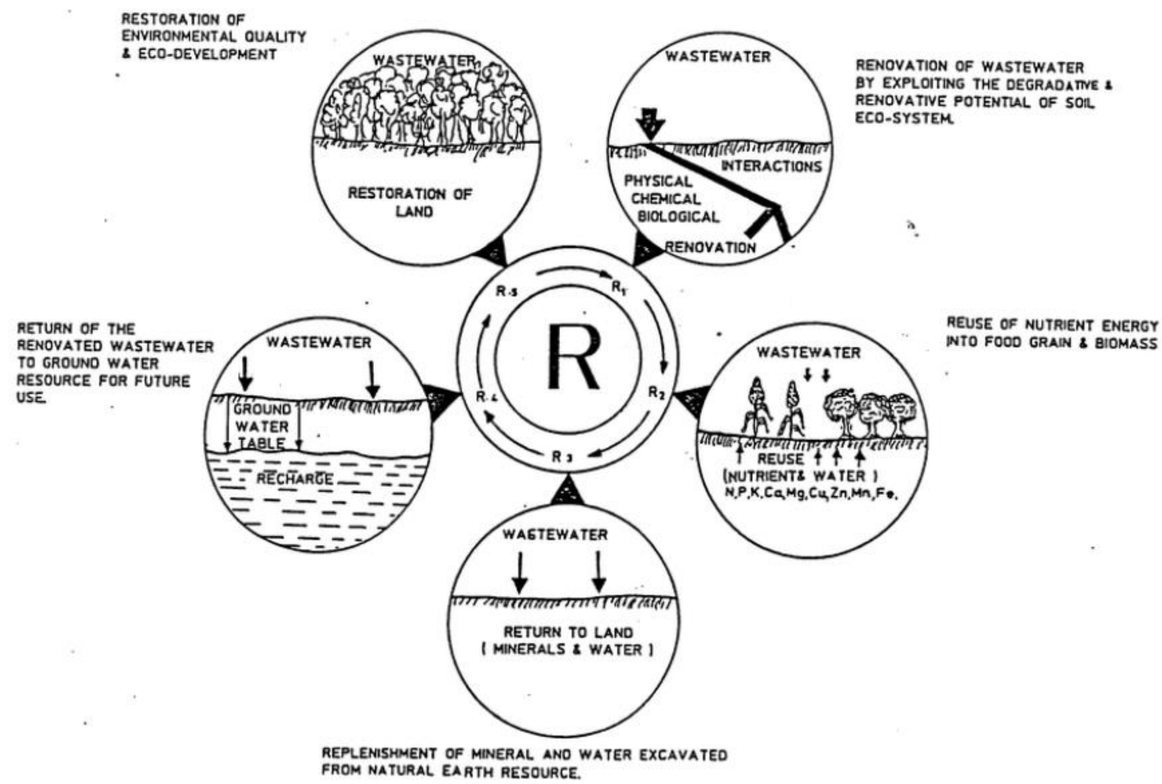

Figure 1: *5R concept of wastewater management and recycling, reuse and eco-development*

Furthermore, Si (2002) identified four core aspects of green consumption: (1) minimizing resource and energy usage (economic consumption), (2) reducing waste and pollutants (clean consumption), (3) ensuring that consumption does not harm health (safe consumption), and (4) avoiding consumption patterns that jeopardize future generations (sustainable consumption). Pan (2003a) proposed a hierarchy of green consumption, starting with moderate consumption, followed by the use of green products, then spiritual consumption, and ultimately leading to a simpler and easier lifestyle. Green consumption not only fosters sustainable development but also helps harmonize the relationship between humans and nature, promoting health, equity, and the long-term prosperity of human society.

Raukoff and Wu (2013) define green consumption behavior as the actions of consumers who aim to protect the environment and minimize the negative impacts of consumption throughout the entire lifecycle of a product—from purchase to use and post-use disposal. Similarly, Chen et al. (2013) describe green consumption as a responsible and sustainable mode of consumption, in which consumers, after recognizing environmental issues, seek to fulfill their purchasing needs while minimizing environmental harm. In reviewing the literature, the terminology for green consumption behavior varies, with some scholars using terms like "ecological consumption" and others using "green consumption." However, after analysis, these terms are found to be fundamentally consistent. This paper uses the term "green consumption behavior," although other sources may refer to it as "green purchasing behavior," with no essential difference between the two.

The prevailing definition of green consumption highlights rational consumption where individuals not only focus on their own health and interests but also emphasize environmental protection, reducing resource waste, preventing pollution, and fulfilling social responsibilities. Other researchers frame green consumption as a socially responsible behavior where consumers are aware of the broader consequences of their consumption choices.

Green consumption is also considered an environmental behavior. Scholars have studied the factors influencing environmental behaviors, offering valuable insights into green consumption research. Stern (2000) categorized environmental behaviors into four types: (1) activism, (2) public-level environmental behaviors (such as supporting environmental policies or paying higher taxes for environmental protection), (3) individual-level environmental behaviors (such as green consumption), and (4) environmental behaviors of organizations. Green consumption falls under individual-level environmental behaviors, setting it apart from other types.

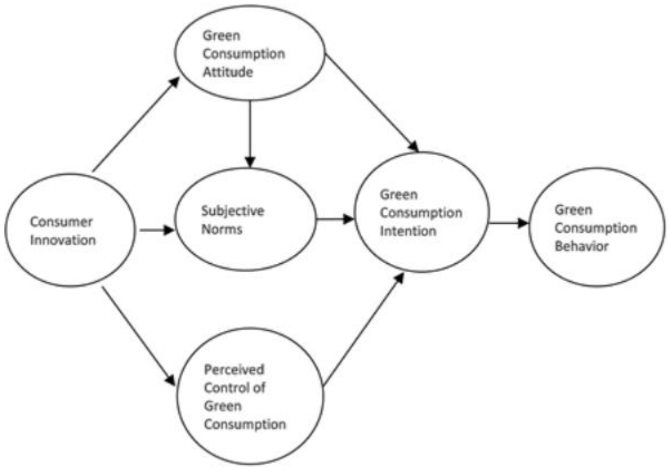

Figure 2: *The influence of consumer innovation on green consumption behavior*

Green consumption differs from other environmental behaviors in a few key ways. First, it is directly tied to consumer choices, where people consider factors like cost, quality, and environmental impact in their purchasing decisions. Second, consumers may use green products and brands as a way to express their values and identity. These distinctions between green consumption and other environmental behaviors suggest that different factors may influence green consumption compared to other types of environmental actions.

References

[1] Chang, Y.P., & Zhu, D.H. (2007). Research on Influencing Factors of Online Shopping Intention from the Perspective of Consumers’ Innovation. Chinese Journal of Management, No. 11, 820-523. (In Chinese with English Abstract)

[2] Chen, K., Guo, F., & Zhao, Z. B. (2013). Mechanism Analysis of Psychological Factors of Green Consumption Behavior: From the Research Perspective of Psychological Process of Green Consumption Behavior. Enterprise Economics, 32, 124-128.

[3] Chen, W. P. (2011). Relationship between Lifestyle, Consumer Innovation and New Product Purchasing Behavior. Economic Management, No. 2, 94-101.

[4] Chen, X. J. (2007). Environmental Perception Consumer Behavior and Ecological Marketing Research. Wuxi: Jiangnan University.

[5] Duan, Y., & Yang, X. H. (2012). The Evolution of Chinese Social Ethos since the Reform and Opening Up. Theoretical Discussion, No. 4, 39-41.

[6] Gerrig, R. J., & Zimbardo, P. G. (2009). Psychology and Life. London: Pearson Education.

[7] Green, L., & Kreuter, M. (1994). Health Promotion Program Design (Translated by Huang J.T.). Shanghai: Yixing University Press.

[8] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I.

Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[9] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[10] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[11] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[12] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[13] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[14] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144

AN INVESTIGATION OF THE DIGITAL FOOTPRINT OF INDIVIDUALITY IN RELATION TO ENVIRONMENTALLY RESPONSIBLE BEHAVIOR

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Abstract

The article presents a study that attempts to investigate the features of students' environmental behavior. The peculiarity of this work is the inclusion of some indicators of the digital footprint of individuality (openness/closedness) of the profile and the color scheme of the profile) in the analysis of the results obtained using valid methods characterizing students' attitudes to environmental issues. The authors trace the relationship between the indicators characterizing environmental behavior and the studied indicators of the digital footprint of students' individuality. Also, in the process of analyzing the results obtained, a relationship was revealed between the age characteristics of students and the features of their profile in VK.

Keywords: digital trace of individuality, integral individuality, environmental issues, digital environment, VK users, environmental behavior, student age

I. Introduction

Trying to analyze the digital trace of individuality, or as we propose from the point of view of the theory of integral individuality of V.S. Merlin and the theory of polymorphic individuality of V.V. Belous [1] - the supra-status (digital) level of individuality, it is necessary to evaluate its profile in the social network according to available open parameters. In this study, we attempted to analyze the characteristics of the attitude to environmental issues in the student environment, on the one hand, and, on the other hand, to link these characteristics with some parameters of the digital trace of individuality - the openness or closedness of the profile in the social network and the predominant colors in the photographs that are available in the profile. This approach is relevant, since the actively developing digital environment makes its own adjustments to the structure of individuality [2]. Not so long ago - in the early 2000s, psychologists considered this environment, the environment of the Internet space exclusively as a resource that negatively affects the psyche. In studies, the Internet environment was considered addictive.

II. Methods

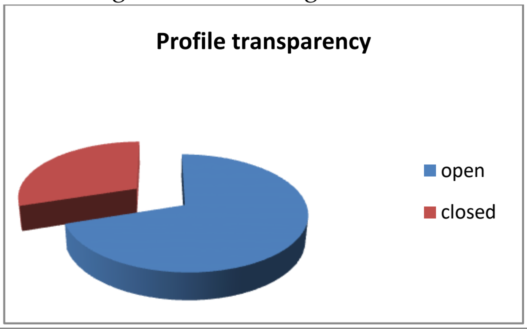
The study involved first-year students of the Institute of International Relations of the Federal State Budgetary Educational Institution of Higher Education "Pyatigorsk State University" - future journalists and specialists in international relations. The diagnostics were conducted in September 2024. We asked the subjects to provide a link to their profile on the social network during the diagnostic methods. Of the 123 students who passed the test, 98 provided this information. Another feature of this component of the study was that several students provided incorrect access to the profile. Thus, 86 people remained in the sample - 69 girls and 17 boys. The profile for analysis was characterized by 2 indicators - openness / closeness of the profile and the predominant color of photos, pictures, etc., which are available in the profile.

To diagnose attitudes towards environmental issues and manifestations of environmental behavior, we used valid diagnostic methods – the Method of Diagnosing Motivation for Interaction with Nature "Alternative"; the Scale of Environmental Concern and the Method of "Differential Emotions Scale" [3]. To process the obtained data, we used statistical data analysis.

At the final stage of the study, a comparative analysis of the obtained data and their interpretation was carried out.

III. Results

At the first stage, our goal was to characterize students' profiles on VK by two characteristics: openness or closedness of the profile and the predominant color scheme of the profile photo, which will indicate the emotional background of the digital trace of individuality.



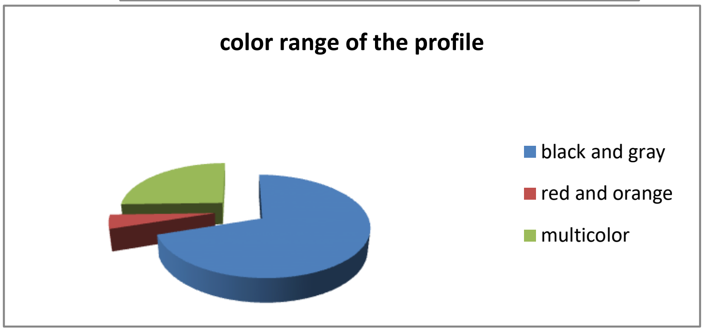


Figure 1: *Results of the analysis of profile openness/closedness and profile color scheme" (%)*

Of the provided VK profiles, 30% were closed. The remaining 70% are open and filled profiles. We assume that students exhibit extroverted behavior in the digital space - they are open to the digital environment and ready to interact. As for the color scheme, black or gray predominates in most profiles (77%). Red or orange predominates in 5% of cases, and in 28% of cases, there is a variety of colors and no dominance of any color. The predominance of black indicates an emotional state characteristic of the stage of adaptation to the university conditions, the presence of a certain stress characteristic of the transition from adolescence to young adulthood. Black in this situation is a desire for independence, resistance to external pressure and denial of any authorities. To this characteristic should be added the manifestation of aggression and depression.

In the further analysis, we will consider the results of diagnostics using methods that determine environmentally responsible behavior - the Method of Diagnostics of Motivation for Interaction with Nature "Alternative"; the Scale of Environmental Concern and the Method "Scale of Differential Emotions". In the analysis, we will trace the relationship between the obtained results and the features of the digital trace of individuality.

Fig. 2 shows the results of diagnostics using the Alternative method of diagnosing motivation for interaction with nature. In the sample under study, two types of motivation predominate: aesthetic and cognitive. This fact indicates that respondents perceive nature as an object of beauty when actively interacting with it. High rates of this type of motivation are demonstrated by 68% of students with an open VK profile.

Also, high rates are presented in the cognitive type of motivation, which indicates the attitude to the environment as an object of knowledge in interaction with it. This type of motivation prevails in 30% of students with an open profile. It should be noted that 89% of students have a multi-color profile photo.

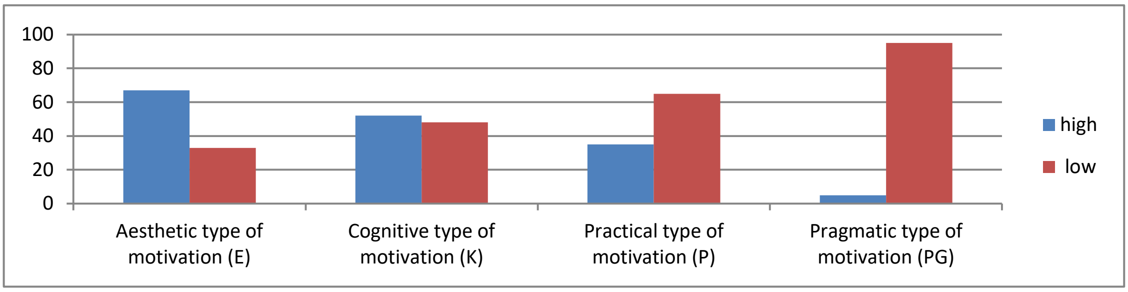


Figure 2: *Results of the Methodology for diagnosing motivation for interaction with nature "Alternative" (%)*

Fig. 3 shows the results of the "Scale of Environmental Concern" method. It is obvious that high scores were obtained for all scales, which indicates concern about the fate of animals, birds and the ecosystem as a whole, as well as concern about the impact of the consequences of environmental problems on children, people who live in the same region. A high level is also observed for the "Egoistic Concern" indicator - everything that concerns the consequences of environmental problems for one's own health, one's own lifestyle and future. Such scores indicate a high level of involvement in understanding the consequences of environmental problems in real life. Moreover, such data are shown by all representatives of this sample - students with open and closed profiles and with all types of color schemes in the profile.

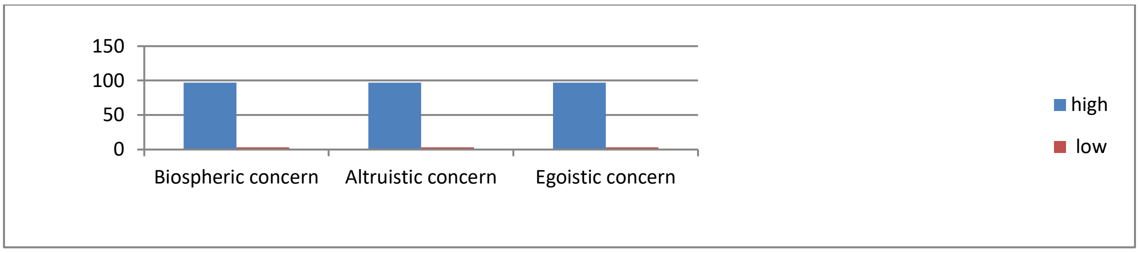


Figure 3: *Results for the Environmental Concern Scale Methodology (%)*

Based on the data obtained, we can state a high level of environmentally responsible behavior.

The results presented in Fig. 4 determine the level of emotion that the subjects showed regarding the current situation. In the block of positive emotions, there is a predominance of low emotion in all indicators: "Interest", "Joy" and "Surprise". Comparing the data with the manifestation of the digital trace of individuality, and specifically in the prevailing color scheme - black and gray, there is a connection between the emotional state and the prevailing color of the profile. In the block of negative emotions, low values are recorded for all four indicators, which once again confirms the closeness and some emotional instability inherent in first-year students. In general, the general index of positive emotions and negative emotions are distributed approximately in equal shares between high and low indicators. At the same time, the picture is complemented by the predominance of the low level of the indicator " Anxious and depressive emotions ", which characterizes the predominance of environmental features over individual ones in the manifestation of emotions regarding the situation associated with the attitude to environmental problems.

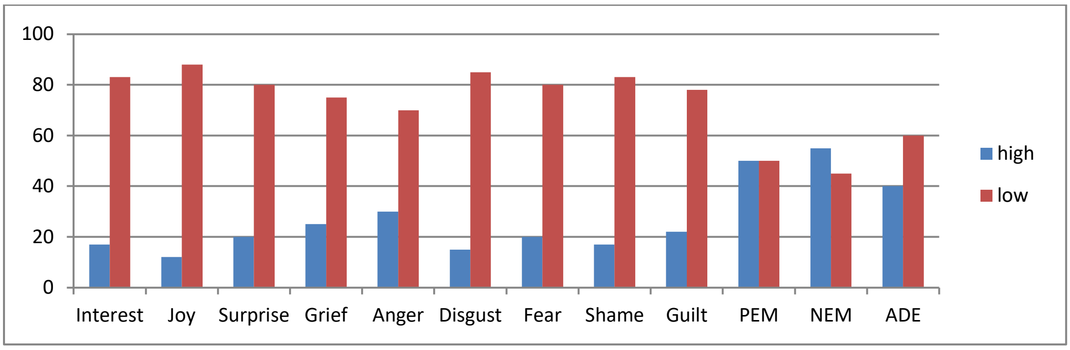


Figure 4: *Results for the "Differential Emotions Scale" method (%)*

IV. Discussion

The study by Ivanova I.V. and Konenkova N.V. examines the influence of the reflexive-value approach on the formation of environmentally responsible behavior of young people [4]. Scientists have proven the importance of interpersonal relationships and both general and environmental culture in the formation of environmentally responsible behavior. The study by Matovaya N.I and Shagarova L.M. highlights a very relevant and burning topic of our country's share - tourism and its development [5]. Their work examines the need for environmentally responsible behavior of tourists in nature conservation areas. This problem is considered within the framework of the contradiction between the need to develop domestic tourism and the need to preserve unique natural monuments of Russia. Demenshin V.N. in his "Review of Foreign Studies of Environmental Consciousness" [6] refers to the studies of I. Tilikidou and J. Zotos, who, based on the works of B. Schlegelmilch, developed an approach to describing environmental consciousness, in which they included all components of environmentally responsible consumer behavior, while the behavioral aspect includes pro-environmental purchasing behavior, pro-environmental behavior after purchase and environmental protection activities [7]. Summarizing the sources we have cited, we can state that environmentally responsible behavior in the student environment is not considered in psychological science.

In the aspect of the digital trace of individuality, Tulupyeva T.D. and Ivanova A.Yu. consider a psychological approach, which involves studying the manifestation of mental properties and characteristics of a person during communication and behavior on the network, taking into account that communication occurs within social groups, this approach is characterized as socio-psychological [8; 9; 10]. Gaidash O.V. in his study, describing modern approaches to the interpretation of the digital trace, states the fact that the features of these characteristics of individuality are used mainly by marketers [11].

From the point of view of the theory of integral individuality by V.S. Merlin and polymorphic individuality by V.V. Belous [12], the digital trace of individuality (the data that can be openly available in the digital environment) has not yet been considered as a supra-status level of integral individuality. In this paper, we postulate a new approach to the study of the holistic individuality of a modern person.

References

[1] Belous, V. V., & Boyazitova, I. V. (2008). Development of integral individuality of a person in objective space. Bulletin of the Peoples' Friendship University of Russia. Series: Psychology and Pedagogy, (1), 37-45.

[2] Marcinkowska, T. D. New methodology of digital everyday life / T. D. Marcinkowska // Questions of Psychology. - 2023. - Vol. 69, No. 2. - P. 3-13. - EDN NNHYYG.

[3] Ivanova Alexandra Andreevna, Shevel Tatyana Maksimovna, Agisova Fatiha, & Patrakova Natalia Alekseevna (2023). Schulz's environmental concern scale: adaptation and validation. Psychology. Journal of the Higher School of Economics, 20 (4), 699-717. doi: 10.17323/1813-8918-2023-4-699-717

[4] Irina Viktorovna Ivanova, & Natalia Viktorovna Konenkova (2023). Reflexive-value approach to the formation of environmentally responsible behavior of teenagers and youth. Innovative Scientific Modern Academic Research Trajectory, (3 (15)), 49-61. doi: 10.17853/2686-8970-2023-3-49-61

[5] Matova N.I., Shagarov L.M. Features of environmentally responsible behavior of tourists in protected natural areas // Modern problems of service and tourism. 2021. Vol. 15. No. 1. P. 93–106. DOI : 10.24412/1995-0411-2021-1-93-106.

[6] Demenshin V.N. Review of foreign studies of environmental consciousness // Internet journal "World of Science" 2017, Volume 5, Number 5 https :// mir - nauki . com / PDF / 18 PSMN 517.

[7] Tilikidou, I., Ecological consumer behavior: review and suggestions for future research / I. Tilikidou, Y. Zotos // Medit, 1999. – Vol 10. – No. 1. – P. 14-21.

[8] Flerov O.V. (2018). Human digital footprint on the Internet: basic humanitarian approaches. Educational resources and technologies, (4 (25)), 79-82.

[9] Tulupyeva T.V., Tafintseva A.S., Tulupyev A.L. An approach to the analysis of the reflection of personality traits in digital traces // Bulletin of Psychotherapy. - 2016. - No. 60 (65). - P. 124-137.

[10] Ivanova A.Yu., Malyshkina M.V. Psychological problems of communication and activities of the digital technology generation // Scientific notes of P.F. Lesgaft University. - 2017. - No. 7 (149). - P. 221-228.

[11] Gaidash O.V. (2020). The phenomenon of digital trace in modern society. Bulletin of Magistracy, (6 (105)), 10.

THE COVID-19 PANDEMIC AS A CATALYST FOR THE DEVELOPMENT OF SUSTAINABLE ENVIRONMENTAL PRACTICES AND THEIR IMPACT ON QUALITY OF LIFE

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Abstract

The COVID-19 pandemic has been an important catalyst for the adoption of sustainable environmental practices. Restrictive measures such as quarantines and curtailment of international travel have reduced greenhouse gas emissions and improved air quality in cities. This has provided an opportunity to rethink consumption and resource use patterns and accelerate the transition to greener and more sustainable approaches across sectors including transport, energy and manufacturing. The pandemic has also highlighted the relationship between environmental health and human quality of life, spurring the development of green economy, renewable energy and circular economy initiatives. In the long term, the adoption of sustainable practices can not only mitigate the impact of climate change but also improve public health and well-being. COVID-19 pandemic, sustainable environmental practices, climate change, air quality, renewable energy, circular economy, quality of life, green economy.

Keywords: sustainable environmental practices, climate change, air quality, renewable energy, circular economy, quality of life, green economy

I. Introduction

The COVID-19 pandemic triggered extensive global measures aimed at curbing its spread, resulting in unexpected consequences for both the environment and the economy. These unforeseen effects have shed new light on how pandemic control strategies influence environmental health and economic systems, thereby affecting global sustainability efforts. This detailed narrative review thoroughly explores the complex relationship between COVID-19 control measures and environmental well-being (fig.1). Our study examines critical ecological factors such as air and water quality, noise pollution, soil quality, and energy consumption, analyzing how these aspects changed during lockdown periods. We also investigate the pandemic's unexpected economic implications, especially the rapid shift toward digitization and e-commerce. Our research methodology relies on a comprehensive literature review, utilizing meticulous comparisons between conditions during lockdown and those prior to it. Our results indicate a significant improvement in environmental quality indicators during peak lockdown phases, exceeding pre-pandemic levels. This change highlights the possibility of integrating sustainable behaviors into everyday life. The pandemic has acted as both an awakening and a catalyst for sustainable practices. This review emphasizes the unprecedented positive environmental and economic insights revealed by the COVID-19 crisis. As the global community prepares to enhance health and economic resilience for future challenges, the critical lessons learned from the pandemic's benefits should inform the development of future environmental policies and goals. This interplay among health, economy, and environment offers a unique chance to move closer to our collective sustainable development objectives. The COVID-19 outbreak in 2020 prompted the World Health Organization (WHO) to declare a global public health emergency. As of May 2023, COVID-19 had resulted in over 750 million cases and nearly 7 million deaths worldwide. In response to the virus's severity and rapid spread, governments implemented various measures such as lockdowns, restrictions on social interaction, and limitations on movement and economic activities. Among the most affected sectors were transportation, with air travel plummeting by 96%, and the industrial sector, as global oil consumption and prices dropped sharply.

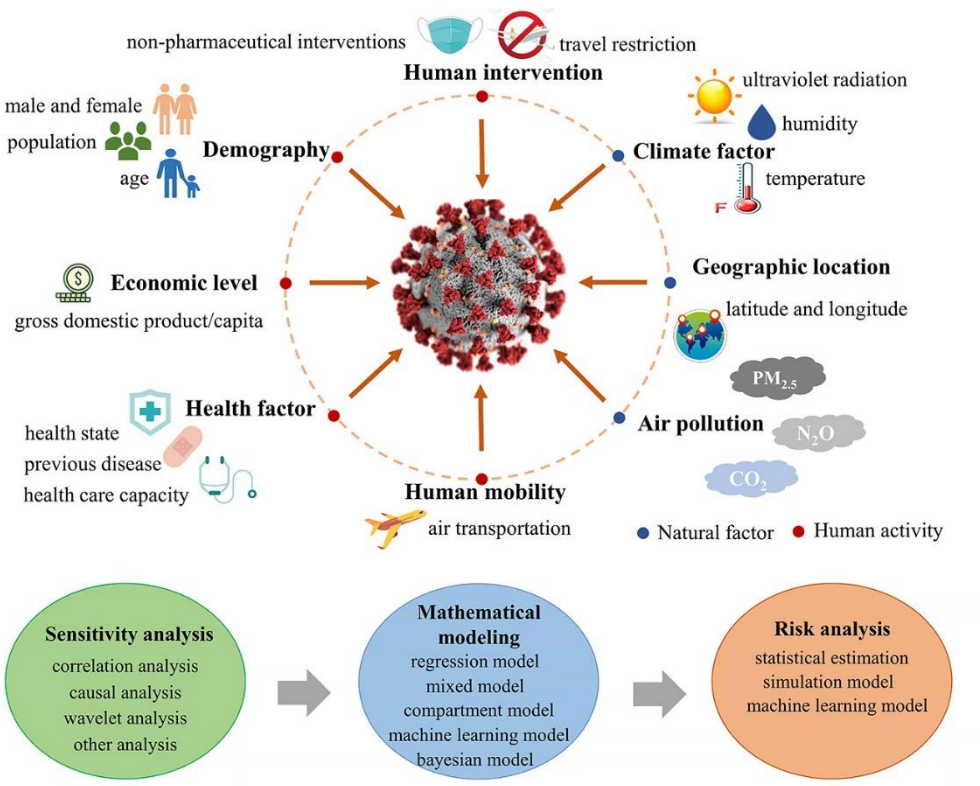

Figure 1: *Impact of main geo-environmental factors on global COVID-19 spread.*

Inger Andersen, Executive Director of the United Nations Environment Program, suggested that post-pandemic leadership in environmental sustainability would be crucial. While the pandemic shifted the global focus toward public health over environmental conservation, it also led to several positive environmental developments. For instance, reduced economic activity lowered pollution and industrial waste emissions, and ecosystems began to recover. Lockdowns helped mitigate environmental issues like climate change, ozone depletion, and air pollution. Silva et al. (2021) noted that COVID-19 indirectly supported several UN Sustainable Development Goals (SDGs) by reducing greenhouse gas emissions, air and noise pollution, and pressures on wildlife.

However, negative environmental impacts also emerged, such as the increased use of single-use plastics and worsening indoor air quality. The pandemic highlighted the intricate relationship between human health, economic stability, and environmental health. Drawing insights from this complex interplay is essential for fostering sustainable practices in the post-pandemic era.

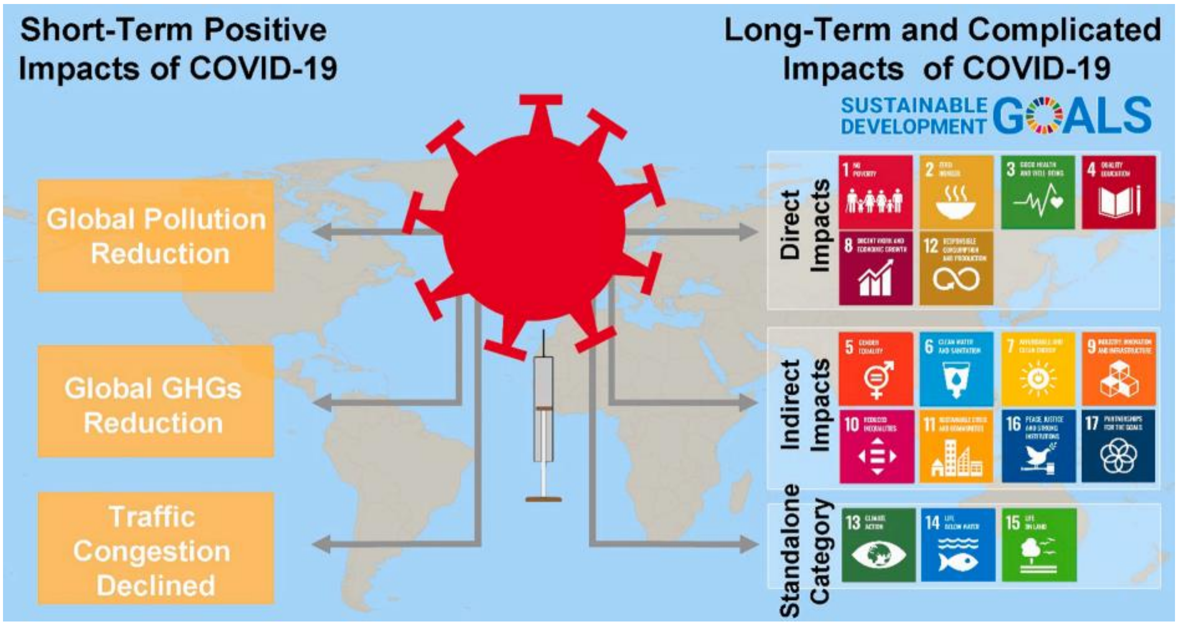

Figure 2: *Conceptualized diagram showing the 17 SDGs as impacted by the COVID-19 in three categories. SDGs-icons are reproduced from UN-website (UN-SDGs)*

This study aims to thoroughly examine both the positive and negative environmental consequences of the pandemic. It will assess immediate impacts, such as improvements in air and water quality, and explore how these changes align with specific SDGs. By linking these environmental shifts to broader global sustainability goals, the study underscores the need for interdisciplinary collaboration in addressing future sustainability challenges. It also calls for further research into the long-term environmental implications of the pandemic, advocating for the continued adoption of eco-friendly practices like digitization and reduced industrial activity. The study's hypotheses propose that COVID-19 lockdowns led to significant improvements in air and water quality, that these improvements contribute to the achievement of certain SDGs, and that the pandemic has revealed sustainable practices that could have lasting positive environmental impacts.

II. Methods

A comprehensive literature review was conducted to gather relevant scientific articles, governmental reports, and research studies examining the impact of COVID-19 on air, water, and soil pollution. Key databases such as PubMed, Google Scholar, and government websites were searched using keywords like "COVID-19," "air pollution," "water pollution," "soil pollution," "lockdown," and "pandemic." The search was restricted to publications from the past five years (2018–2022) to ensure the inclusion of recent and pertinent data.

To ensure rigor, specific inclusion criteria were set, focusing on studies published between 2018 and 2022 that addressed COVID-19's effects on air, water, or soil pollution. These studies needed to provide quantitative data on pollution indicators such as pollutant concentrations, emission levels, or water quality metrics, and compare pre-pandemic levels to those during the lockdown period. Only peer-reviewed articles, governmental reports, and reputable studies were considered. Exclusion criteria eliminated studies published before 2018, those lacking direct relevance to pollution impacts of COVID-19, non-quantitative studies, and non-peer-reviewed materials like opinion pieces and editorials.

The data synthesis and analysis process involved extracting key data from the selected studies, focusing on changes in pollution indicators. This data was categorized by pollution type (air, water, or soil) and geographic region for structured analysis. Summary tables were compiled to compare data across studies, emphasizing significant trends. Descriptive statistical methods were employed to quantify changes in pollution levels during lockdowns relative to pre-pandemic baselines, while comparative analysis helped identify consistent trends across regions and pollution types. The results were also linked to specific United Nations Sustainable Development Goals (SDGs) to assess the broader sustainability implications.

Despite the thorough approach, the study had several limitations. It relied on existing data, which varied in measurement techniques, monitoring locations, and reporting formats, potentially affecting the comparability of findings. Additionally, the study primarily focused on short-term effects of the pandemic, with the acknowledgment that further research is needed to understand long-term impacts. Nevertheless, these methodological details enhance the transparency and reproducibility of the review, offering a solid foundation for evaluating the environmental consequences of COVID-19 lockdowns.

III. Results

The COVID-19 lockdown led to a significant reduction in industrial activities and a subsequent drop in air pollution from sources such as automobiles, power plants, and industrial sites across many urban areas worldwide. This improvement in air quality was confirmed by pollution-monitoring satellites from NASA and the European Space Agency, which reported sharp declines in air pollution, particularly in China and European cities. For example, air pollution in China dropped by 20–30%, and India experienced its lowest airborne particle concentrations in 20 years. Major European cities like Rome, Milan, Madrid, and Paris saw reductions in air pollution by up to 54%, while levels of nitrogen dioxide (NO2) in Eastern and Central China decreased by 10–30%. Similarly, the United States and the UK also recorded notable reductions in NO2 levels.

These findings are consistent with previous research linking industrialization and urbanization to environmental degradation. However, while the improvements in air quality during the lockdown were substantial, they are not enough to achieve the Paris Agreement's goal of limiting global warming to below 1.5°C. Air pollution, exacerbated by industrial and transportation emissions, poses a serious risk to human health, contributing to tens of thousands of premature deaths annually in the UK alone. Long-term exposure to air pollution has been linked to respiratory illnesses, heart disease, lung cancer, and asthma, all of which have been worsened by COVID-19. Yet, during the lockdown, improved air quality likely saved lives by reducing the harmful effects of pollution.

Despite these positive outcomes, scientists caution that the temporary reduction in pollution during the pandemic is not a permanent solution to the broader climate and health challenges posed by air pollution.

IV. Discussion

The COVID-19 pandemic led to the largest annual decline in CO2 emissions ever recorded, exceeding reductions observed during any prior economic crisis or wartime period (Verma and Prakash, 2020). This unprecedented drop in global CO2 emissions was one of the major environmental benefits of the pandemic, primarily driven by a sharp decline in energy consumption, which in turn reduced greenhouse gas (GHG) emissions worldwide (see fig. 3). The decrease is primarily attributed to the ground transportation sector (−18.6%), as well as domestic (−35.8%) and international aviation (−52.4%) (Figs. 3). Figure 3 illustrates the distribution of daily emissions changes across different sectors. The largest contributors to the global emissions reduction in 2020 were ground transportation (−613.3 Mt CO2, 40% of the total decrease; purple in Fig. 3a) and the power sector (−341.4 Mt CO2, 22% of the total decrease; orange in Fig. 3a), with smaller reductions in the industrial sector (−263.5 Mt CO2, 17% of the total decrease; warm orange in Fig. 3a) and the aviation sector (including both domestic and international aviation, −200.8 Mt CO2, 13% of the total decrease; yellow in Fig. 3a). Relatively minor decreases were seen in international shipping (−89.1 Mt CO2, 6% of the total decrease; blue in Fig. 2a) and emissions from the residential sector, which includes residential, public, and commercial buildings (−42.5 Mt CO2, 3% of the total decrease; green in Fig. 2a). The reduction in CO2 emissions during the pandemic was even greater than the combined decreases seen in the five previous economic recessions (IEA, 2020).

However, as economies recover, emissions tend to rise again, potentially masking the progress made during the pandemic unless there is a focused shift towards cleaner, more sustainable energy infrastructures (IEA, 2020). At the same time, some cities saw an increase in pollutants like sulfur dioxide (SO2) and carbon monoxide (CO), which is likely due to a rise in private vehicle use during the pandemic as people avoided public transport and carpooling (Orak and Ozdemir, 2021). These pollutants, which primarily come from the combustion of fossil fuels such as coal and oil, remained prevalent in areas heavily reliant on non-renewable energy sources, such as coal-fired power plants (Filonchyk et al., 2020).

In colder months, the increased demand for heating in residential areas, particularly those dependent on fossil fuels, is expected to further elevate emissions, counteracting some of the temporary reductions achieved during the lockdown. This underscores the need for a transition to cleaner energy sources to sustain the environmental benefits observed during the pandemic. The COVID-19 lockdown brought significant improvements in air quality, primarily due to reduced industrial activities and fewer vehicles on the road. However, maintaining these improvements requires a strategic and gradual shift towards cleaner energy and transportation systems. A key step is increasing the number of electric vehicle (EV) charging stations and encouraging the use of low-emission fuels. Cities need to reorganize by introducing measures like clean air zones or low-emission classifications to restrict polluting vehicles from entering congested urban areas (PHE, 2020).

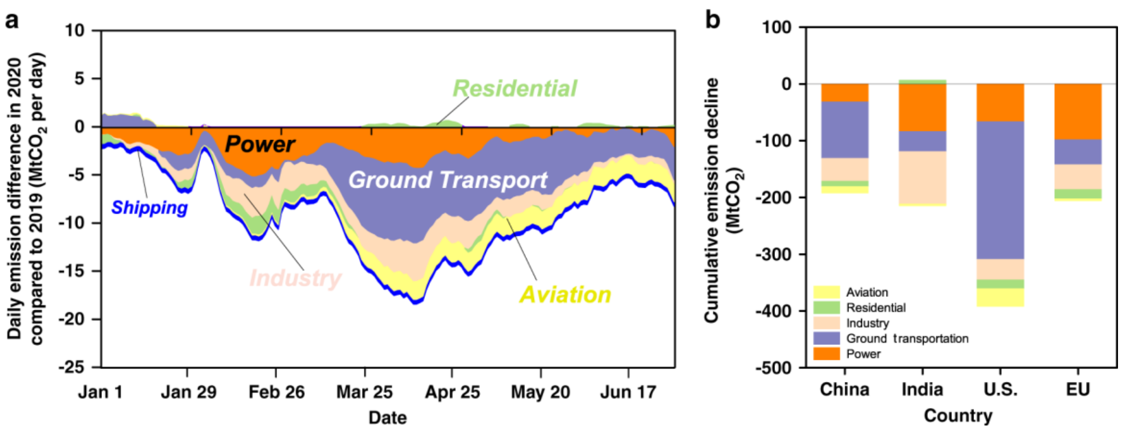

Figure 3: *Sectoral effects of COVID-19 on CO2 emissions*

A critical component of decarbonizing road transport and integrating renewable energy into power grids is the advancement of battery technology (World Economic Forum, 2019).

Overcoming these challenges will require a circular value chain that includes designing products for extended life, implementing Vehicle-to-Grid (V2G) systems, and scaling up shared electric mobility solutions. Integrating the transportation and energy sectors is crucial for building a sustainable battery ecosystem (Masiero et al., 2017; PHE, 2020). Yet, simply replacing all vehicles with electric models won't solve traffic congestion or resource consumption issues. Instead, adopting circular value chains can help minimize these risks, enabling the development of a more sustainable battery industry by reducing emissions during production, ensuring ethical working conditions, and promoting reuse, recycling, and remanufacturing.

The assumption that industrialized economies inherently produce substantial pollution is essential, as air pollutants significantly impact COVID-19 death rates (Fofana et al., 2020). Studies have demonstrated that higher levels of air pollution contribute to increased fatalities. For example, Wu et al. (2020) found that a 1 $\mu g/m^3$ increase in fine particulate matter (PM2.5) correlated with a 15% rise in COVID-19 mortality. These findings highlight the urgent need to prioritize air quality improvements, as poor air quality can exacerbate the spread and severity of airborne diseases like COVID-19. For instance, strong airflow in an air-conditioned restaurant in Guangzhou, China, facilitated viral transmission among diners (Liu et al., 2020).

Road traffic noise, a significant environmental issue in Europe, affects millions of people's health and well-being, contributing to a range of negative outcomes such as sleep disruption, anger, and serious impacts on metabolic and cardiovascular systems (EEA, 2020). The European Environment Agency (EEA) reported that approximately 20% of Europeans live in areas with noise levels that are harmful to their health. This chronic noise pollution leads to around 12,000 premature deaths and 48,000 new cases of ischemic heart disease annually. Additionally, about 22 million people experience chronic high irritability due to noise, and 6.5 million suffer from severe sleep disturbances (EEA, 2020).

Airplane noise has also been shown to impair cognitive abilities, particularly reading, in children. For example, one estimate suggests that airplane noise negatively impacts the reading abilities of 12,500 schoolchildren. While air pollution leads to more premature deaths, noise pollution has a broader impact on people's quality of life and mental health (EEA, 2020).

The COVID-19 pandemic, however, brought a drastic reduction in noise pollution due to a sharp decline in road traffic and industrial operations. Lockdowns reduced noise input into both the troposphere and stratosphere, as noted by Verma and Prakash (2020). Road traffic became rare during this period, contributing to an unprecedented quietness in urban environments (Nazir et al., 2021). This reduction in environmental noise created a conducive environment for outdoor activities, including exercise. A global study found that, during the lockdown, exercise rates increased dramatically. Average individuals experienced an 88% increase in their exercise rates, moderately active individuals saw a 38% rise, and sedentary individuals had a 156% increase (Snider-McGrath, 2020). These statistics reflect the broader positive influence of reduced noise and air pollution on physical well-being.

Marine life also benefited from the reduction in human activity during the lockdown. Noise pollution in the ocean, largely caused by shipping and seismic air cannon experiments for gas and oil exploration, can severely disrupt marine life. Sound travels much farther and faster in water than in air, making noise a significant threat to marine ecosystems (Duarte et al., 2021). One study on humpback whales and other marine animals found that elevated stress hormone levels in these species were linked to increased ocean noise, and prolonged stress can negatively impact reproductive success (Rolland et al., 2012). The temporary reduction in marine traffic during the pandemic likely provided some relief to marine life, although the long-term consequences of decreased ocean noise remain to be fully understood.

In summary, the COVID-19 lockdown led to significant reductions in both terrestrial and marine noise pollution, highlighting the deep connection between human activities and environmental health. The data underscores the importance of addressing noise pollution not only for human well-being but also for the broader ecological health of both land and marine environments.

References

[1] Gakaev, R. Assessing Carbon Dynamics in Diverse Ecosystems: The Role of Carbon Polygons / R. Gakaev , L. Gatsaeva // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03013. – DOI 10.1051/e3sconf/202453703013. – EDN OOIDOS.p.

[2] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[3] Kornienko T.V. Questions of linguistic kinship, 2013. No. 9. P. 155-162.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A.S., Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

[11] Gunya , A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

A NEW DESİGN SOLİD GRAVİTY ENERGY STORAGE SYSTEM FOR RENEWABLE ENERGY

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Abstract

Climate change and global warming necessitate a shift towards renewable energy as the primary source of power. Consequently, environmentally clean renewable energy technologies are rapidly developing. However, the intermittent nature of renewable energy sources has introduced new challenges in grid integration. Addressing these issues is crucial for solving environmental problems on a large scale. To mitigate these emerging challenges, the demand for energy storage systems has increased significantly. These systems play a vital role in maintaining grid stability during the utilization of renewable energy sources and preventing energy crises. By connecting to energy networks, they store excess generated energy and return it to the grid when necessary, ensuring stable system operation. In recent years, solid gravity energy storage technologies have emerged as a promising solution among energy storage systems. This article presents a novel design for a solid gravity energy storage device. The primary objectives of this system are to facilitate large-scale grid integration of renewable energy sources and maintain system stability. Solid gravity energy storage technology offers several advantages over other energy storage technologies, including cost-effectiveness, high security, long lifespan, and increased flexibility. The development and implementation of these systems play a crucial role in advancing the energy sector and supporting the transition to renewable energy sources.

Keywords: mechanical energy storage, renewable energy, solid gravity energy storage, sustainable energy

I. Introduction

The global population growth and rapid industrial development are driving an increasing demand for energy. Both developed and developing countries are prioritizing the energy sector due to its irreplaceable role in economic growth and national development. This escalating energy demand is primarily met through two types of sources: renewable and non-renewable.

Currently, fossil fuels (oil, gas, and coal) account for the majority of global energy consumption [1,2]. Their widespread use is primarily attributed to their relatively low cost and accessibility [3]. However, despite their economic efficiency, fossil fuels are the main contributors to climate change and global warming, posing urgent challenges for all nations [4].

The environmental impact of fossil fuels is severe and long-lasting. Their combustion releases significant amounts of greenhouse gases and carbon dioxide into the atmosphere [1,3]. These emissions are the primary drivers of climate change and global warming, with fossil fuels responsible for over 75% of global greenhouse gas emissions and 90% of all carbon dioxide emissions [5].

Climate change and global warming have far-reaching consequences, affecting human health, water resources, and food security [4]. They contribute to droughts, vegetation destruction, heat waves, and increased water vapor in the atmosphere [4,6].

According to the Intergovernmental Panel on Climate Change (IPCC), the Earth's average temperature has risen by approximately 0.8°C over the past century [7]. Without significant reductions in greenhouse gas and carbon dioxide emissions, global warming is projected to exceed 1.5°C and potentially reach 2°C in the 21st century. The Paris Agreement stipulates that to mitigate these problems, greenhouse gas and carbon dioxide emissions should be reduced by 50% by 2030 and reach "net zero" by 2050 [6,8].

Renewable energy sources offer a clean and sustainable alternative to fossil fuels. Unlike their non-renewable counterparts, renewable energies produce negligible greenhouse gas emissions and have minimal negative impact on the environment and human health. These sources are inexhaustible and have the potential to meet global energy needs many times over [1,8,9,10]. The main types of renewable energy sources include:

- Solar energy
- Wind energy
- Hydroelectric energy
- Geothermal energy
- Wave energy
- Bioenergy

Renewable energies contribute significantly to reducing energy dependence and promoting economic and social development. Their availability in all countries and zero fuel costs make them an attractive option for many nations [1]. As a result, global investment in renewable energy continues to increase annually. According to the International Energy Agency, renewable energy capacity is expected to increase by 50% in 2023 compared to the previous year, reaching 507 GW. Solar, wind, and hydroelectric power are currently the most widely adopted renewable technologies [11].

Despite their numerous advantages, renewable energy sources face several [12]:

1. High initial costs: Development and installation of renewable energy technologies require substantial upfront investments [12].
2. Geographical constraints: Large open areas are often needed for wind and solar energy production, limiting suitable locations [12].
3. Production variability: Solar and wind energy depend on weather conditions, leading to inconsistent energy generation [12].
4. Energy storage: The intermittent nature of many renewable sources necessitates efficient energy storage systems [12].
5. Supply constraints: Equipment, materials, and raw materials for energy production can create bottlenecks [12].

Addressing these challenges is crucial for the widespread adoption of renewable energy and the complete phaseout of fossil fuels. Energy storage technologies play a vital role in overcoming the intermittency of renewable sources, allowing excess energy to be stored and used when needed. The development of these technologies is one of the most effective ways to combat climate change and global warming [13,14].

II. Classification and Advancements in Energy Storage Technologies

Energy storage technologies play a crucial role in the energy sector, facilitating the transition to renewable energy sources as the primary power supply and ensuring grid stability. For renewable energy to become the dominant source, these technologies must address the inherent intermittency of renewables. Energy storage systems are considered the most effective solution for achieving this stability [13,14,15,16].

These systems integrate with renewable energy networks, storing excess generated energy and releasing it back to the grid when renewable sources are unavailable, thus maintaining stable system operation [14,15,16].

Classification of Energy Storage Technologies

Energy storage technologies can be classified based on two main criteria: type and capacity.

1. Type-based classification:

- Chemical energy storage
- Thermal energy storage
- Mechanical energy storage

2. Capacity-based classification:

- Thermal energy storage
- Electrical energy storage

Among these, mechanical energy storage technology is considered more cost-effective than other types. Mechanical energy storage can be further divided into three categories (Figure 1):

1. Gravitational potential energy storage
2. Kinetic energy storage
3. Elastic energy storage

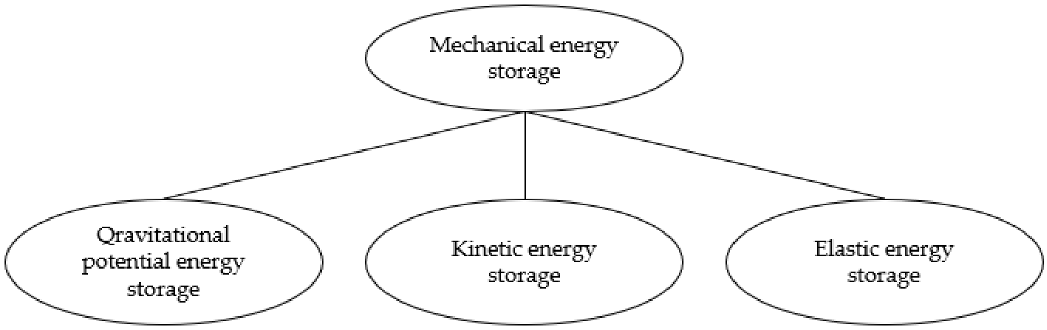

Figure 1. C*lassification of mechanical energy storage technology*

Gravitational Potential Energy Storage

Gravitational potential energy storage technology comprises two main types:

1. Pumped hydroelectric power
2. Solid gravity energy storage

Solid gravity energy storage technology offers advantages over pumped storage and other energy storage technologies due to its economic efficiency and geographical flexibility. Despite being a relatively new technology, it is developing rapidly. The main advantages of solid gravity energy storage are its cost-effectiveness and long operational lifespan [14,15,16].

Solid gravity energy storage technology stores potential energy generated by changing the height of a heavy object in a gravitational field. This process involves converting excess energy from the grid into mechanical energy through an engine-generator system.

Types of Solid Gravity Energy Storage Technologies

There are eight primary types of solid gravity energy storage technologies:

1. Tower Solid Gravity Energy Storage (T-SGES) [17,18,19]
2. Shaft Solid Gravity Energy Storage (S-SGES) [18,19]
3. Rope-hoisting Piston Solid Gravity Energy Storage (RP-SGES) [20,21]
4. Mountain Mine-Car Solid Gravity Energy Storage (MM-SGES) [19,22]
5. Linear Electric Machine-Based Solid Gravity Energy Storage (LEM-SGES) [19,23]
6. Compressed Air Piston Solid Gravity Energy Storage (CAP-SGES) [20,24]
7. Mountain Cable-Car Solid Gravity Energy Storage (MC-SGES) [19,25]

8. Piston Solid Gravity Energy Storage (P-SGES) [24,26]

A critical component of these energy storage technologies is the weight system. The choice of weights significantly influences the technical performance of the storage system. Materials such as sand, concrete, and iron are commonly used due to their efficiency as weights.

Proposed Design: Novel Solid Gravity Energy Storage System

This study presents a new design for a solid gravity energy storage device specifically tailored for use with renewable energy sources, particularly solar and wind energy (Figure 2). The system utilizes excess electricity generated on the grid to lift a massive concrete block, storing energy as gravitational potential energy.

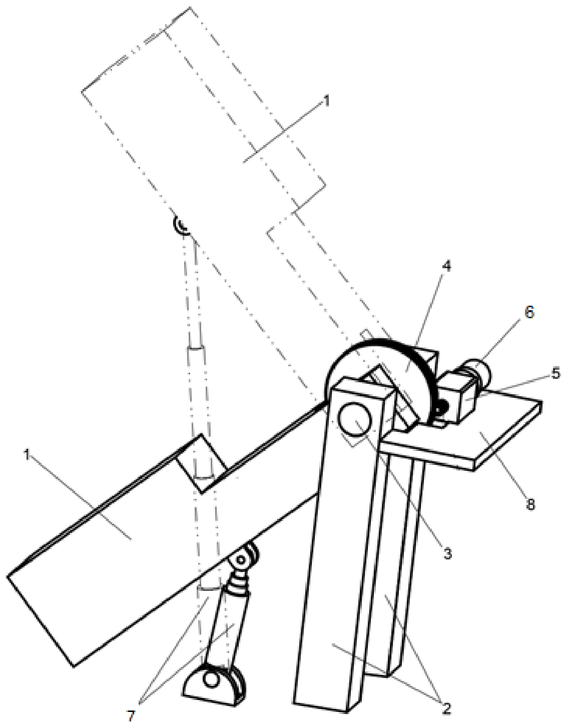

Figure 2: *New design solid gravity energy storage system*

System Components and Operation

The key components of the system include:

1. A concrete block (mass: 1000-3000 tons)
2. Concrete supports
3. A control shaft
4. A gear wheel
5. A reducer with gear wheel
6. An electric motor-generator
7. A hydraulic mechanism for controlled descent
8. A stand to keep the reducer and electric motor at a certain distance

The system operates in two main phases:

Energy Storage Phase

1. Excess energy from the grid powers the electric motor-generator.
2. The motor's rotation is transmitted through the reducer to the gear wheel on the control shaft.
3. As the shaft rotates, it lifts the concrete block.
4. The rising concrete block gains gravitational potential energy.

5. When the block reaches a defined height, the system is fully charged and disconnects from the grid.

Energy Release Phase

1. During a power shortage, the stored mechanical energy is converted back to electrical energy.
2. The concrete block descends, controlled by the hydraulic mechanism.
3. The descending motion drives the electric motor-generator, producing electricity.
4. The generated electricity is fed back into the grid.

System Specifications

- Concrete block mass: 1000 - 3000 tons
- Required construction area: approximately 300 m^2

Mathematical Model

The energy storage capacity of the system is defined by:

$$E = \eta mgh \tag{1}$$

Where: E - is the energy storage capacity; η - is the system's output efficiency; m - is the mass of the concrete block; g - is the acceleration due to gravity; h - is the height change of the concrete block.

The average output power of the system is given by:

$$\bar{P} = \frac{E}{T} \tag{2}$$

Where: $\bar{P}$ - is the average output power; E - is the energy storage capacity; T - is the system's energy discharge time.

According to expression (2), the instantaneous output power is determined by:

$$P = \frac{dE}{dt} \tag{3}$$

For circular motion of the concrete block, the average output power can be expressed as:

$$\bar{P} = M\omega \tag{4}$$

Where: M - is the torque generated during the rotation of the concrete block; ω - is the angular velocity of the concrete block.

This novel solid gravity energy storage technology has been developed to enhance the efficiency of renewable energy sources. The system's energy storage capacity can be adjusted by varying the weight of the concrete block, offering flexibility in design and implementation.

The presented energy storage device represents a promising solution in the fight against climate change and global warming, offering an efficient means of storing and releasing energy from renewable sources.

III. Results

The novel solid gravity energy storage system proposed in this study emerges as a promising solution to the challenges faced in renewable energy storage. Our analysis reveals a multitude of advantages that collectively position this system as a potentially transformative technology in the renewable energy sector.

At the core of the system's appeal lies its structural simplicity. By incorporating straightforward components, the design facilitates easier construction and maintenance processes. This simplicity extends beyond mere ease of assembly; it translates into tangible economic benefits. The minimal maintenance requirements and streamlined construction process result in cost-effective energy storage capabilities, enhancing the system's overall economic efficiency.

One of the most striking features of the proposed system is its compact design. Unlike many traditional energy storage systems that require vast geographical areas, our system's small overall dimensions significantly reduce the space needed for installation. This spatial efficiency opens up a wider range of potential locations for deployment, from urban settings to remote areas with limited available space. Importantly, this compact design does not come at the expense of storage capacity. Our analysis indicates that the system provides substantial energy storage capacity relative to its initial cost, striking an impressive balance between size and performance.

The system's design also prioritizes longevity and safety. Its robust construction and simple mechanics contribute to an extended operational life, a crucial factor in the long-term viability of energy storage solutions. This longevity is further enhanced by the low maintenance requirements of the structural components, which do not necessitate frequent or complex technical inspections. Beyond durability, safety considerations were paramount in the system's design. The proposed configuration incorporates features that effectively reduce potential risks associated with energy storage, an essential aspect for widespread adoption in various settings.

IV. The discussion of the results

To contextualize these advantages, we conducted a comprehensive comparative analysis against existing solid gravity energy storage technologies. This comparison encompassed a range of systems, including Tower (T-SGES), Mountain Cable-Car (MC-SGES), Shaft (S-SGES), Rope-hoisting Piston (RP-SGES), Mountain Mine-Car (MM-SGES), Linear Electric Machine-Based (LEM-SGES), Compressed Air Piston (CAP-SGES), and Piston (P-SGES) systems. Our analysis focused on critical factors such as structural complexity, economic efficiency, required geographical area, energy storage density, and useful lifespan.

The results of this comparison further highlight the potential of our proposed system. Many existing technologies, while innovative, face significant limitations, particularly in terms of geographical requirements and construction challenges. They often necessitate extensive land areas for installation and present considerable hurdles during the construction phase due to their complex structural designs. In contrast, our system's compact dimensions and simpler construction process offer a more versatile solution, adaptable to a diverse range of locations and applications.

Moreover, the scalability of our proposed system emerges as a significant advantage. Its design allows for relatively easy scaling, potentially enabling customization to meet various energy storage capacities. This flexibility could prove invaluable in adapting to different energy demands and grid requirements, a crucial feature in the ever-evolving landscape of renewable energy.

While these theoretical advantages are promising, we acknowledge the need for further research to fully validate the system's benefits. Future investigations should focus on several key areas. Prototype development and testing will be crucial to validate the theoretical performance metrics presented in this study. A comprehensive cost analysis, encompassing construction, operation, and maintenance expenses over the system's entire lifecycle, will provide a holistic view of its economic viability. Environmental impact assessments will ensure the system's alignment with sustainable development goals. Optimization studies could potentially enhance energy storage density and overall system efficiency, while integration studies with various renewable energy sources will assess the system's real-world compatibility and performance.

In conclusion, our novel solid gravity energy storage system shows considerable promise in addressing key challenges associated with renewable energy storage. Its simplicity, potential cost-effectiveness, and space efficiency position it as a valuable addition to the portfolio of energy storage technologies. As the global energy landscape continues to evolve towards sustainability, innovative solutions like the one proposed in this study could play a crucial role in accelerating the transition to a more sustainable energy future. However, it is important to emphasize that while our theoretical analysis suggests significant advantages, the realization of these benefits hinges on the outcomes of the proposed future research directions. The journey from concept to implementation is complex, but the potential rewards in advancing renewable energy storage are substantial.

However, it is important to emphasize that while our theoretical analysis and comparisons suggest significant advantages, the realization of these benefits hinges on the outcomes of the proposed future research directions. The development of prototypes, comprehensive cost and environmental impact analyses, optimization studies, and integration tests with renewable energy sources will be crucial in validating and refining the system's performance.

As the global energy landscape continues to evolve towards sustainability, innovative energy storage solutions like the one proposed in this study will play an increasingly vital role. By addressing the intermittency challenges associated with renewable energy sources, such systems have the potential to accelerate the transition away from fossil fuels and towards a more sustainable energy future. The promising results presented here provide a strong foundation for further research and development in this critical field.

References

[1] Vijay Laxmi Kalyani, Manisha Kumari Dudy, Shikha Pareek. Green energy: the need of the world. Journal of Management Engineering and Information Technology (JMEIT) Volume -2, Issue- 5, Oct. 2015, ISSN: 2394 – 8124.

[2] Adam Mayer. Fossil fuel dependence and energy insecurity. Energy, Sustainability and Society (2022) https://doi.org/10.1186/s13705-022-00353-5

[3] J Cong. Advantages and disadvantages of energy from fossil fuels. Vol. 1 (2), pp. 1-2, August, 2022.

[4] Qi Zhao, Pei Yu, Rahini Mahendran, and e.t.c. Global climate change and human health: Pathways and possible solutions. Eco-Environment and Health. Volume 1, Issue 2, June 2022, Pages 53-62

[5] https://www.un.org/en/climatechange/science/causes-effects-climate-change

[6] Muhammad Kabir, Um E Habiba, Wali Khan. Climate change due to increasing concentration of carbon dioxide and its impacts on environment in 21st century; a mini review. Journal of King Saud University – Science 35 (2023) 102693

[7] https://www.theworldcounts.com/stories/temperature-change-over-the-last-100-years.

[8] Athanasios Valavanidis. The 12 Most Pressing Global Environmental Issues. Environmental problems humanity needs to resolve before 2050.

[9] Robert Ehrlich. Renewable Energy: A First Course 1st Edition. 2013

[10] Dolf Gielen, Francisco Boshell, Deger Saygin and e.t.c. The role of renewable energy in the global enerrgy transformation. Energy Strategy Reviews Volume 24, April 2019, Pages 38-50.

[11] https://www.iea.org/reports/renewables-2023/electricity

[12] https://www.ibm.com/think/insights/renewable-energy-advantages-disadvantages.

[13] Abdul Hai Alami. Mechanical Energy Storage for Renewable and Sustainable Energy Resources. 2020

[14] Ahmad Arabkoohsar. Mechanical Energy Storage Technologies. 2020

[15] Wenxuan Tonga, Zhengang Lub, Jianfeng Sund, and e.t.c. Solid gravity energy storage technology: Classification and comparison. 2022 International Conference on Energy Storage Technology and Power Systems (ESPS 2022), February 25–27, 2022, Guilin, China.

[16] Wenxuan Tong, Zhengang Lu, Weijiang Chen, and e.t.c. Solid gravity energy storage: Journal of Energy Storage 53 (2022) 105226 https://doi.org/10.1016/j.est.2022.105226.

[17] Fyke. The fall and rise of gravity storage technologies. Joule 2019;3(3):625–30.

[18] Moore. The ups and downs of gravity energy storage: Startups are pioneering a radical new alternative to batteries for grid storage. IEEE Spectr 2021;58(1):38–9.

[19] Botha, Kamper, Wang. Design optimisation and cost analysis of linear vernier electric machine-based gravity energy storage systems. J Energy Storage 2021; 44:103397.

[20] Loudiyi Berrada, Zorkani. Toward an improvement of gravity energy storage using compressed air. Energy Procedia 2017; 134:855–64.

[21] Emrani, Berrada, Bakhouya. Modeling and performance evaluation of the dynamic behavior of gravity energy storage with a wire rope hoisting system. J Energy Storage 2021; 33:102154.

[22] Lukic Vazquez, Galvan, et al. Energy storage systems for transport and grid applications. IEEE Trans Ind Electron 2010;57(12):3881–95.

[23] Botha Kamper. Linear electric machine-based gravity energy storage for wind farm integration. In: Proceedings of the 2020 International SAUPEC/RobMech/PRASA Conference, F 29-31 Jan. 2020.

[24] Berrada Loudiyi. Chapter 2 - technical design of gravity energy storage. In: Berrada A, Loudiyi K, editors. Gravity energy storage. Elsevier; 2019, p. 25–49.

[25] Hunt, Zakeri, Falchetta, et al. Mountain gravity energy storage: A new solution for closing the gap between existing short- and long-term storage technologies. Energy 2020; 190:116419.

[26] Gravity power llc. GP. Gravity power. 2021.

INVESTIGATING THE INFLUENCE OF MEDICAL PRACTICES ON HUMAN CAPITAL AND THEIR CONTRIBUTION TO SUSTAINABLE DEVELOPMENT

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Abstract

This study explores the intricate relationship between medical practices and human capital development, highlighting how healthcare systems significantly impact economic growth and sustainability. By examining various medical practices across different regions and historical contexts, the research aims to understand their effects on individual health, productivity, and overall economic performance. The analysis begins with a review of existing literature on the interplay between health outcomes and economic development, emphasizing the role of a healthy population as a cornerstone of human capital. Key indicators of human capital—such as education, workforce participation, and productivity—are assessed to establish how medical practices influence these dimensions. Additionally, the study employs case studies to illustrate successful healthcare models that have effectively enhanced human capital. It examines how investments in preventive care, access to quality medical services, and health education contribute to a healthier workforce, thereby promoting sustainable economic development. Through quantitative and qualitative methodologies, the research identifies barriers to effective medical practice implementation and suggests strategies for integrating healthcare improvements into broader economic policies. Ultimately, the findings aim to provide policymakers, healthcare professionals, and stakeholders with insights on optimizing medical practices to foster human capital development and achieve long-term sustainable economic growth.

Keywords: medical practices, human capital, sustainable development, health influence, economic productivity, access to healthcare, population health, health investments

I. Introduction

The intersection of medical practices and human capital is increasingly recognized as a critical factor in achieving sustainable economic development. As nations strive for economic growth and improved living standards, the health of their populations emerges as a foundational element that drives productivity, innovation, and social well-being. Medical practices encompass a wide range of healthcare services, interventions, and policies designed to promote health, prevent diseases, and manage existing health conditions. These practices not only influence the physical well-being of individuals but also significantly impact their cognitive abilities, educational attainment, and overall economic contributions.

Human capital, defined as the collective skills, knowledge, and experience possessed by individuals, is essential for fostering economic development. Healthier populations tend to exhibit higher levels of productivity, as good health enhances the ability to learn, work, and engage in economic activities. Conversely, poor health outcomes can hinder individuals' capacity to participate in the labor force and can lead to increased healthcare costs, reduced income, and lower economic output.

Moreover, sustainable economic development requires a holistic approach that integrates health into economic planning. Policies that prioritize medical practices not only enhance individual well-being but also contribute to broader economic goals such as poverty reduction, gender equality, and social equity. As such, understanding the influence of medical practices on human capital is vital for policymakers, healthcare professionals, and economists alike.

This investigation aims to explore the various dimensions through which medical practices affect human capital and, consequently, their contribution to sustainable economic development. By examining existing literature and empirical evidence, this study seeks to highlight the importance of investing in healthcare systems, improving access to medical services, and promoting health literacy. Ultimately, this exploration underscores the integral role of health in shaping a resilient and sustainable economy, emphasizing that the well-being of individuals is inextricably linked to the prosperity of societies. The complex of modern vectors of socio-economic development of Russia includes the increase of human capital, which can be achieved through the improvement and development of the healthcare system. Among the problems arising in the modern regional sphere of medical care, there is insufficient resource provision of medical and preventive institutions, an increase in the number of paid services, a shortage of primary care specialists and their low salaries, which leads to reduced motivation of personnel for high-quality work. Taking into account the above problems, in January 2019, the national project (NP) "Healthcare" was launched, which includes 9 federal projects (FP) and was developed by the Ministry of Health of the Russian Federation in order to implement the Decree of the President of the Russian Federation dated May 7, 2018 No. 204. The activities of the national project under consideration are aimed, first of all, at increasing the population and ensuring maximum accessibility of medical and preventive institutions for citizens. In this regard, the study of indicators of medical care in the Republic of North Ossetia-Alania (ROA) in the context of the implementation of the NP "Healthcare" is very relevant.

II. Methods

Open data from the EMISS register of the Federal State Statistics Service, as well as the portal of the budget system of the Russian Federation "Electronic Budget" were taken into account for indicators reflecting the effects of the implementation of federal projects of the NP "Healthcare" in the Republic of North Ossetia-Alania and the Russian Federation for the period from 2020-2023. Relative deviations were calculated for the studied indicators using MS Excel 2016 and SPSS " Statistics " software.

III. Results

A very large federal project is the "Development of the Primary Health Care System" (FP N1), which includes ensuring optimal accessibility of primary care for all segments of the population, including citizens living in remote areas, as well as increasing the coverage of the number of patients who have undergone preventive examinations. Table 1 presents an analysis of the dynamics of changes in the indicators characterizing the development of FP N1. As can be seen from the table, in the Republic of North Ossetia-Alania, starting from 2021 to 2023, the share of citizens undergoing annual medical examinations and professional examinations has been steadily increasing by 11% and 54%, respectively. A similar trend can be seen in the Russian Federation as a whole. In addition, the share of outpatient institutions that took part in the implementation of the "New Model of Organizing Medical Care" has significantly increased in the republic by 26% (2022) and 27% (2023).

Table 1: Dynamics of changes in indicators for the primary health care development system

Name	2021 %	2022		2023	
		%	Relative deviation to 2021, %	%	Relative deviation to 2022, %
(N1) The proportion of citizens who undergo annual preventive medical examination and/or medical check-ups in the total population					
RF	26.3	34.7	132	46.3	133
RSO-A	25.8	28.6	111	44	154
(N1) The share of polyclinics and polyclinic departments participating in the creation and replication of the "New Model for Organizing the Provision of Medical Care"					
RF	61.7	70.8	115	75.1	106
RSO-A	45.9	57.9	126	73.7	127

Analyzing the implementation of Federal Program No. 1, it can be said that in the Republic of North Ossetia-Alania there is a tendency towards the development of primary health care, which is confirmed by a number of transformations according to the data of the Ministry of Health of the Republic of North Ossetia-Alania, including the construction of a medical outpatient clinic in the village of Predgornoye (Mozdok district), the renovation of medical outpatient clinics in the villages of Vinogradnoye, Priterechny (Mozdok district), and Nogir (Prigorodny district); a feldsher-midwife station in the village of Krasnykh Khod (Alagirsky district); polyclinics in the village of Oktyabrskoye (Prigorodny district), and the village of Chikola (Irafsky district).

Another important milestone of the NP "Healthcare" was FP N2 "Combating cardiovascular diseases", which implies equipping cardiology and vascular departments of medical institutions, as well as the formation of conditions for the prevention of cardiovascular diseases in the population. As can be seen from the data in Table 2, starting from 2020, mortality from diseases of the circulatory system in the RNO-A has had positive dynamics. Thus, in 2021, compared to the previous year, mortality decreased by 2%, and in the following years by 7% (2022) and 16% (2023). A similar trend can be seen in the Russian Federation as a whole, with the exception of 2021, when mortality remained virtually unchanged.

Speaking about FP N3 "Combating Cancer", it is important to note that the project is aimed at re-equipping regional oncology centers, organizing outpatient care centers for cancer patients, developing reference centers for effective diagnostics of malignant neoplasms. RUB 983.4 billion was allocated for the implementation of this project, which is half of the financial support for NP "Healthcare". According to statistics, starting from 2020, the share of malignant neoplasms detected at stages I - II has slightly decreased in 2021 (1%), and increased by 3% and 8% in 2022 and 2023, respectively, compared to 2020. Similar positive dynamics are observed throughout the country, which indicates the effective implementation of FP N3.

IV. Discussion

The development of medical care for the population under 18 years of age is also reflected in the directions of the NP "Healthcare". Thus, within the framework of the implementation of FP N4 "Development of children's health care, including the creation of a modern infrastructure for the provision of medical care to children", it is expected to reduce infant mortality to 4.5 cases per 1 thousand newborns; reconstruction and improvement of children's hospitals, clinics, departments; training of health workers in simulation centers of Russia. Analyzing the mortality of children in the Republic of North Ossetia-Alania from 0 to 17 years old, we can say that in 2021, compared to the previous year, this figure increased by 21%, a similar negative trend is observed in subsequent years. Thus, in 2022, mortality increased by 18%, and in 2023 - by 1% compared to 2020. However, comparing the data for 2022, it can be said that child mortality has decreased by 2% compared to 2021, and by 15% in 2023 compared to the previous year. In addition, according to statistics, 100% of children's healthcare institutions are equipped with modern infrastructure for providing medical care to children.

Table 2: *Dynamics of temporary changes in some indicators reflecting the development of federal projects of the NP "Healthcare"*

Name	2020, person	2021		2022		2023	
		person	Relative deviation to 2020, %	person	Relative deviation to 2020, %	person	Relative deviation to 2020, %
(N2) Mortality from diseases of the circulatory system (per 100 thousand population)							
RF	640.8	640.3	100	566.8	88	556.7	87
RSO-A	596.6	586.2	98	553.7	93	499.4	84
(N3) Proportion of malignant neoplasms detected at stages I - II							
RF	56.3	57.9	103	59.3	102	60.5	102
RSO-A	54.6	54	99	55.5	103	59.1	108
(N4) Mortality rate of children 0-17 years (per 10,0000 population of the corresponding age)							
RF	44.6	47.1	106	43.4	97	40.7	91
RSO-A	36.1	43.6	121	42.7	118	36.5	101
Name	**2020, %**	**2021**		**2022**		**2023**	
		%		**%**	**Relative deviation to 2022, %**	**%**	**Relative deviation to 2022, %**
(N4) Number (proportion) of children's clinics and children's clinic departments with a modern infrastructure for providing medical care to children							
RF	-	89.2		98.1	110	98.3	100
RSO-A	-	100		100	100	100	100
(N5) Staffing of medical organizations providing outpatient medical care with doctors							
RF	81.1	81.1	100	82.2	101	89.3	109
RSO-A	90.6	89.7	99	96.9	108	100	103
(N5) Staffing of feldsher stations, feldsher-midwife stations, and medical outpatient clinics with medical workers							
RF	84.6	85.2	101	85.6	101	91.4	107
RSO-A	90.9	95.5	105	96	101	100	104

Note: "-" - the corresponding indicator is not present in the statistical report

The issue of staffing in the problems of organizing medical care has been particularly acute in recent years. In this regard, FP N5 "Provision of medical organizations of the healthcare system with qualified personnel" includes training specialists using distance learning technologies, increasing the number of accredited specialists, and developing interactive educational modules. Assessing the degree of staffing of outpatient organizations and departments with qualified doctors, it can be said that the share of such specialists in the Republic of North Ossetia-Alania in 2021 slightly decreased (1%), and in 2022 and 2023 compared to 2020 increased by 8% and 3%, respectively. Positive dynamics are observed in the change in the staffing of medical workers in feldsher-obstetric stations and medical outpatient clinics. Compared to 2020, the share of such specialists increases significantly up to 2023, which indicates the successful implementation of FP N5.

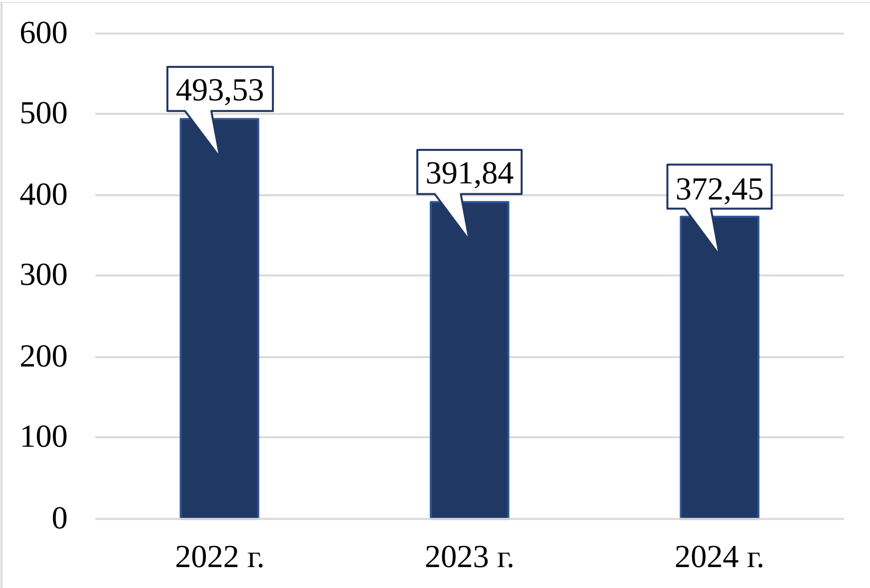

Figure 1: *Financial support for the Federal Program "Modernization of Primary Healthcare in the Russian Federation" (N9) in the Republic of North Ossetia-Alania, million rubles*

In 2022, a new federal project "Modernization of the Primary Healthcare of the Russian Federation" (FP N9) was included in the NP "Healthcare", the implementation of which is expected to increase the availability of medical care for all groups of citizens through the creation of the optimally necessary infrastructure. As can be seen from the histogram (Fig. 1), the volume of financial support for FP N9 from 2022 to 2024 has a negative trend. Thus, in 2023, the volume of funding decreased by almost 21% compared to 2022, and as of October 2024 - by 5% compared to the previous year.

Within the framework of the implementation of federal projects of the NP "Healthcare", such as FP N1, N2, N3, positive dynamics in improving the availability of medical care and reducing mortality from certain diseases are observed. In particular, the share of citizens undergoing medical examinations and preventive examinations annually in the republic is steadily increasing, which indicates a very successful implementation of the corresponding FP. An important aspect is also the fight against cardiovascular and oncological diseases, which has led to a significant decrease in mortality from diseases of the circulatory system, as well as to a decrease in cases of confirmation of malignant neoplasms. However, a number of indicators related to child mortality require closer attention, despite the positive changes in equipping children's institutions with modern infrastructure. Thus, the set of measures implemented within the framework of the NP "Healthcare" has a positive impact on improving the quality and availability of medical care in the Republic of North Ossetia-Alania. To ensure long-term results from the implementation of projects, further integration of digital technologies and modern approaches to healthcare management is necessary, which will ensure the availability of medical services for the population, especially in remote regions. In addition, it is important to develop new training programs and improve the qualifications of medical personnel, with an emphasis on training primary care specialists.

The relationship between medical practices, human capital, and sustainable economic development is multifaceted and critical for understanding how health influences economic outcomes. This discussion delves into several key areas, including the mechanisms by which medical practices enhance human capital, the socio-economic implications of health interventions, and the policy considerations necessary to promote sustainable development.

1. Mechanisms of Influence

Medical practices influence human capital primarily through improving health outcomes and increasing productivity. Effective healthcare services reduce the incidence and severity of diseases, leading to a healthier workforce. This has several direct implications:

- Increased Productivity: Healthier individuals are often more productive at work. They tend to have lower absenteeism rates and higher performance levels, which contributes positively to economic output. Research has shown that every dollar invested in health can yield significant returns in productivity.
- Cognitive Development: Access to quality healthcare, especially during critical developmental periods (such as childhood), significantly affects cognitive abilities. Healthy children are more likely to perform better in school, leading to higher educational attainment and the development of a skilled workforce.
- Life Expectancy and Workforce Participation: Improved medical practices can extend life expectancy, encouraging older individuals to remain in the workforce longer. This can help alleviate labor shortages and ensure the sustainability of social security systems.

2. Socio-Economic Implications

The impact of medical practices on human capital extends beyond individual health outcomes; it also influences broader socio-economic factors:

- Equity and Access: Disparities in access to medical practices can exacerbate social inequalities. Populations with limited access to healthcare services often experience worse health outcomes, which can hinder their economic contributions. Ensuring equitable access to healthcare is essential for maximizing human capital across all segments of society.
- Public Health Investments: Countries that invest in preventive healthcare (e.g., vaccinations, health education) tend to experience lower healthcare costs in the long run. By reducing the prevalence of diseases, these investments not only improve population health but also relieve pressure on healthcare systems and public finances.
- Interconnectedness with Other Sectors: Health intersects with various sectors, including education, employment, and social services. For example, a healthy workforce supports economic growth, which in turn can enhance funding for education and infrastructure, creating a virtuous cycle of development.

3. Policy Considerations

To leverage the influence of medical practices on human capital for sustainable economic development, several policy considerations should be prioritized:

- Strengthening Healthcare Systems: Governments must invest in healthcare infrastructure, ensuring that all individuals have access to quality medical services. This includes funding for hospitals, clinics, and preventive care programs.
- Promoting Health Education: Increasing health literacy is crucial for empowering individuals to make informed health choices. Educational initiatives can foster better health practices, leading to improved individual and community health outcomes.
- Integrating Health into Economic Planning: Policymakers should recognize health as a critical determinant of economic growth. Strategies that promote health in economic development plans can enhance overall productivity and ensure a sustainable future.
- Evaluating Outcomes: Ongoing research and evaluation of health interventions are essential to understand their impact on human capital and economic development. Policymakers should utilize data-driven approaches to assess the effectiveness of healthcare investments and adjust strategies accordingly.

The influence of medical practices on human capital and their contribution to sustainable economic development is profound and far-reaching. By improving health outcomes, enhancing productivity, and addressing socio-economic inequalities, effective medical practices lay the foundation for a resilient and thriving economy. As nations navigate the challenges of economic growth in an increasingly interconnected world, prioritizing health as a cornerstone of development will be crucial for fostering sustainable progress. Policymakers must recognize this relationship and implement strategies that align healthcare initiatives with broader economic goals, ensuring that health and prosperity go hand in hand.

References

[1] Kravtsova, M. V. The role of national projects in solving the socio-economic problems of the state (on the example of the national project "Healthcare")/Economics and Management: scientific and practical journal. - 2023. - No. 2 (170). - P. 8-13

[2] Polukhina , M. G. Prospects for the Development of Rural Health Care in the Context of the Implementation of the National Project "Health Care" /Economics of Agriculture in Russia. - 2020. - No. 10. - P. 93-99

[3] Babaeva Z.Sh., Pogorelova L.A. Differentiation of the standard of living of the population as a reflection of socio-economic development//Journal of Monetary Economics and Management.- 2023.- №2. - P.50-58

[4] Aliyeva M. L., Misirli R. R. Advantages and problems of big data management// Journal of Monetary Economics and Management. - 2023. - No. 1.- P.8-14

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

STRATEGIES FOR MINIMIZING THE RISK OF BANKRUPTCY OF THE ORGANIZATION

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Abstract

In times of economic crises and unstable market conditions, companies face many factors that exacerbate their financial vulnerability. Currency volatility, lower consumer demand and higher cost of credit resources create additional financial burdens on organizations. debt default and inability to maintain normal operations. Moreover, the bankruptcy of one company can cause a chain reaction, affecting its counterparties. Thus, the bankruptcy of even one organization exacerbates crisis phenomena, increases systemic risks and threatens both individual sectors of the economy and the economy as a whole. This necessitates the development of strategies to minimize the risk of bankruptcy of economic entities.

Keywords: bankruptcy of an organization, financial risks, risk minimization strategies, risk management, financial management, organization, microeconomics

I. Introduction

In economic science, bankruptcy is considered as a process during which an enterprise loses its solvency and cannot continue its activities without the intervention of external structures - creditors, insolvency practitioners or third-party investors. Bankruptcy is the final stage of the financial crisis of the enterprise, in which its liabilities significantly exceed assets, which leads to the impossibility of independent restoration of financial stability. As a result of bankruptcy, there is a redistribution of property and resources, which can significantly affect the socio-economic situation of the company's employees. The bankruptcy of large enterprises leads to a sharp reduction in jobs, a decrease in tax revenues to the budget and a deterioration in the socio-economic situation of the regions.

The factors of bankruptcy of an organization can be divided into two large groups: external and internal. External factors of bankruptcy of an organization are a set of macroeconomic, political, legal, social and market conditions that do not depend on the activities of the organization itself, but have a significant impact on its financial stability and ability to fulfill obligations to creditors. The classification of external factors is presented in Fig.1.

Thus, the financial condition of the organization is most influenced by macroeconomic factors - economic cycles, inflationary processes, fluctuations in exchange rates, the state of international trade and the availability of external financing. An economic recession reduces the purchasing power of consumers and slows down capital turnover, which negatively affects the company's earnings. Inflation increases the cost of raw materials and labor, and instability in foreign exchange markets increases the cost of imported goods and services. International sanctions and trade barriers limit the access of economic agents to the necessary resources, technologies and markets, which can lead to their bankruptcy.

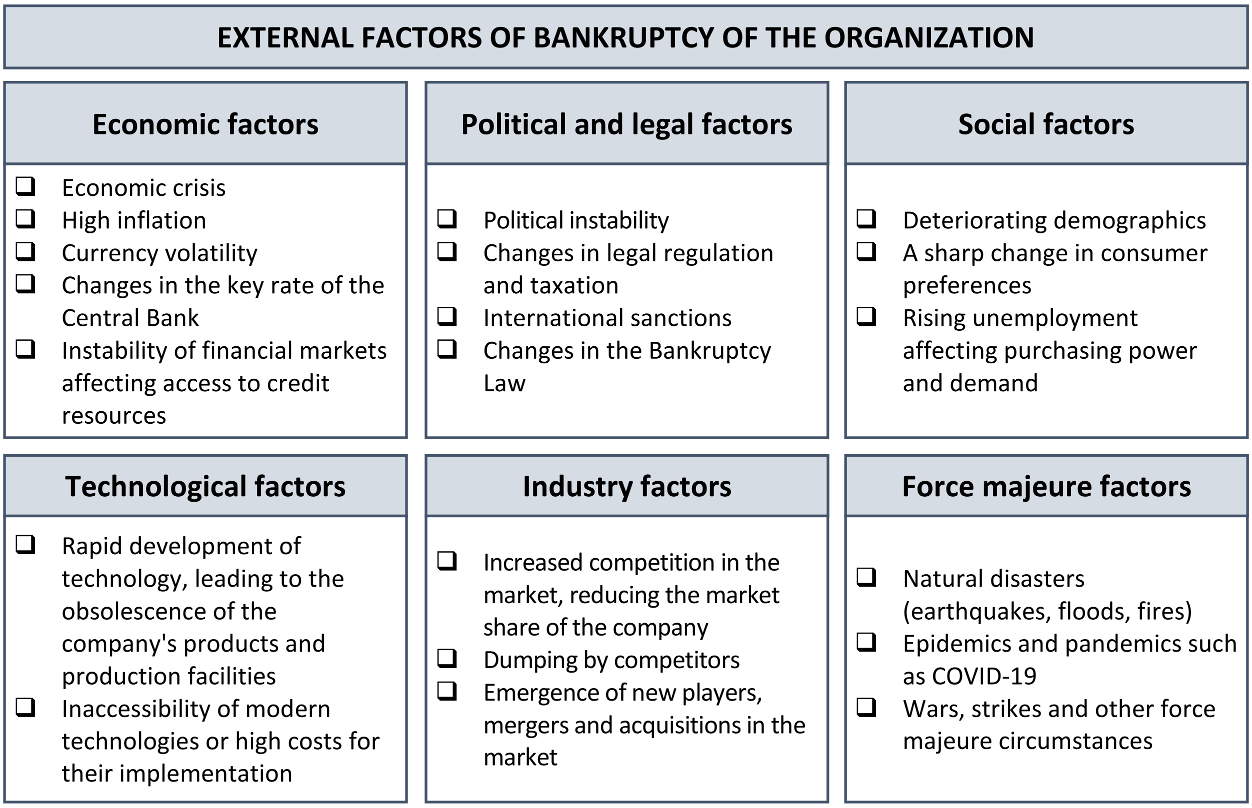

Figure 1: *External factors of bankruptcy of the organization*

II. Methods

Political and legal factors play a key role in shaping the environment in which business operates, and significantly affect the likelihood of bankruptcy risks. Frequent changes of power, political conflicts, social unrest or coups d'état can create an unfavorable environment for doing business, which leads to a reduction in investment, a decrease in confidence from international partners and, as a result, an increase in the risk of bankruptcy. The impact of political instability is particularly strong in countries with irregular legislative processes and poorly developed property rights protections.

Demographic changes (population ageing, migration processes) create imbalances in labor markets, complicating the search for skilled labor and changing consumption patterns. A decrease in demand for specific goods and services, transformations in consumer behavior can lead to a drop in company revenues. Social tensions also lead to lower economic activity and increased risks for businesses, especially in sectors sensitive to fluctuations in demand. The rapid pace of technological change creates risks for companies that do not have time to adapt to new conditions or ignore the implementation of innovations. For example, the development of innovative technologies and products leads to the displacement of traditional products, turning the current business model of the company into outdated and unprofitable. Many companies do not have enough funds to finance R&D and are forced to leave the market. Economic entities investing in innovative technologies may also not receive the expected results, which leads to a shortage of liquidity.

III. Results

Natural disasters, epidemics, man-made accidents, military conflicts, economic sanctions and other force majeure circumstances disrupt normal business processes, causing disruptions in supply chains, destruction of infrastructure and production facilities, as well as a sharp reduction in demand for goods and services. Thus, the COVID-19 pandemic has led to mass bankruptcies of organizations operating in the field of tourism, retail and catering due to the restrictions imposed and changes in consumer habits. Companies that do not have sufficient financial reserves or mechanisms to adapt to such circumstances are on the verge of insolvency and are forced to cease their activities.

The risks of bankruptcy of an organization are also influenced by internal factors related to its production, financial, marketing and other subsystems (Fig. 2).

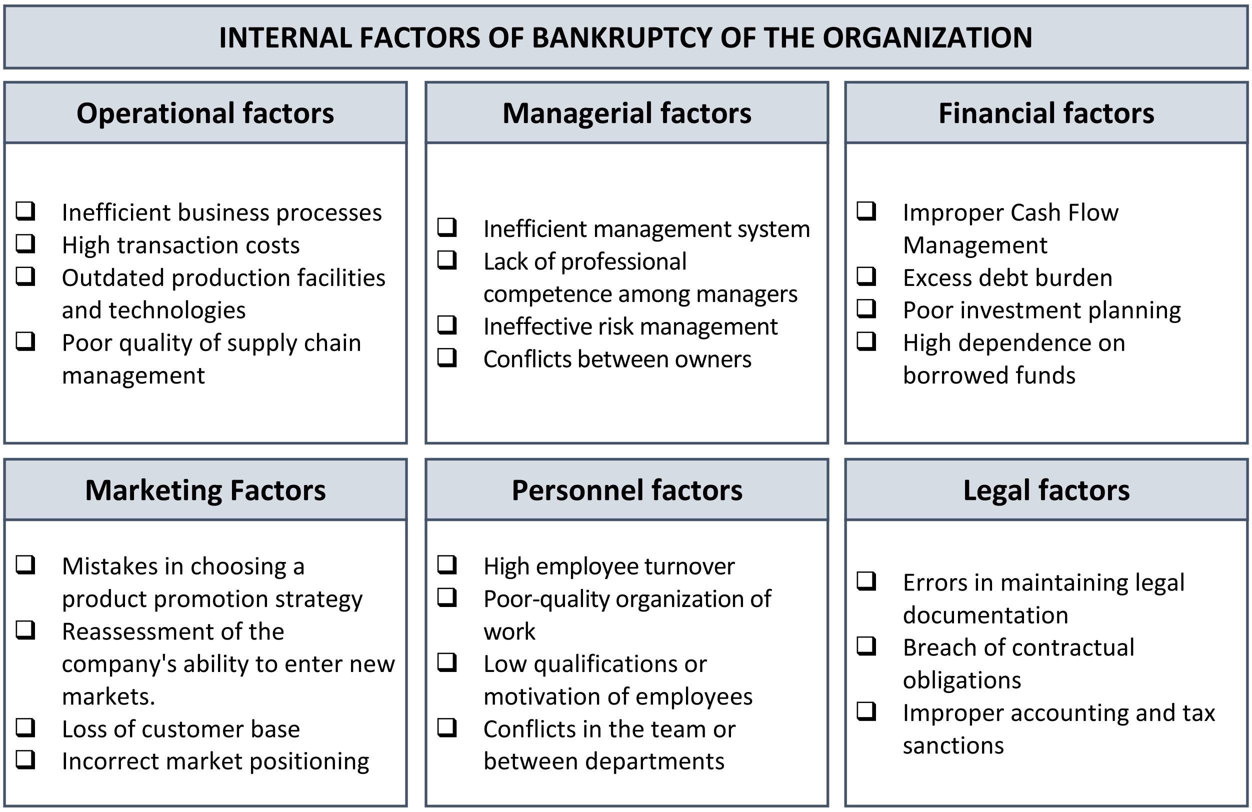

Figure 2: *Internal factors of bankruptcy of the organization*

Thus, the operational factors of bankruptcy are associated with shortcomings in the organization of the company's main business processes.

Managerial factors of bankruptcy are associated, first of all, with incompetent management and lack of strategic vision.

Marketing factors of bankruptcy are associated with the wrong positioning of the company in the market, unsuccessful marketing strategies and the inability to adapt to market transformations.

The legal factors of bankruptcy may be errors in the conduct of contractual work, violation of tax legislation, lack of intellectual property protection or conflict situations with counterparties. In addition, insufficient legal protection of assets, as well as mistakes during reorganization, exacerbate the crisis situation and lead to the bankruptcy of the company. A comprehensive understanding of external and internal factors of bankruptcy allows you to develop effective strategies to minimize their impact on the organization.

IV. Discussion

The first stage in any strategy for preventing the bankruptcy of an organization is the diagnosis of financial risks. The main source of information for assessing the financial condition and risks of the company is the data of accounting (financial) statements. The most common diagnostic method is the study of financial ratios of liquidity, financial stability, profitability and business activity

Strategies for minimizing the risk of bankruptcy are a set of measures aimed at strengthening the financial stability of the company, increasing its competitiveness and adaptability to changing external and internal conditions. The main goal of these strategies is to reduce the likelihood of crisis situations and prevent possible threats of bankruptcy. In today's highly uncertain economic environment, the successful implementation of these strategies can ensure the long-term stability of the company. The avoidance strategy is the organization's deliberate refusal to participate in operations, projects and partnerships that have a high level of uncertainty or potential losses. This approach avoids an unexpected deterioration in the financial situation, especially in conditions of economic uncertainty. A key element of the evasion strategy is a cautious attitude to attracting borrowed funds, investing current assets in forms that are difficult to implement, as well as participating in projects with uncertain profitability. Organizations that adhere to this approach focus on maintaining liquidity, reducing the debt burden and increasing financial stability. They prefer to cooperate with trusted counterparties who have a stable financial position and a positive reputation in the market. Analysis of financial indicators, research of market trends and assessment of possible risks are of key importance in making decisions on the choice of partners and projects.

Thus, the risk avoidance strategy allows them to reduce the likelihood of crisis situations and maintain stable functioning even in the face of adverse external influences. It should be noted that focusing exclusively on the risk avoidance strategy hinders active development and increase in market share, which has a negative impact on the organization in the long term. Therefore, in a market economy, there are mechanisms for transferring certain financial risks to other business entities using factoring, suretyship, insurance and other methods.

To reduce the risk of bankruptcy, companies can use various strategies, including avoidance, transfer, localization, diversification and compensation of risks. As part of a unified crisis management system, companies develop individual approaches to risk management that allow not only to avoid bankruptcy, but also to ensure sustainable growth in the face of uncertainty.

References

[1] Bankruptcy and Financial Recovery of Economic Entities: Monograph / [Ryakhovskaya A. N., Kovan S. E., Alferov V. N. et al.]; edited by A. N. Ryakhovskaya. – Moscow: Yurayt, 2023. – 152 p.

[2] Zhdanov V.Y. Diagnostics of Bankruptcy Risk: Monograph / V.Yu. – Moscow: Prospekt, 2022. – 158 p.

[3] Koraev K.B. Insolvency: a new institution of legal regulation of financial recovery and insolvency (bankruptcy): monograph / K.B. Boraev. – Moscow: Prospekt, 2022. – 317 p.

[4] Tsakaev A.Kh. Anti-Crisis Management in Risk Management: Methodological Aspects / A.Kh. Tsakaev // Risk Management. 2024. № 1 (109). pp. 3-13.

[5] Sharandina A.A. Ways to minimize the risks of bankruptcy of an enterprise / A.A. Sharandina // Modern Science. 2023. № 10-2. pp. 6-10.

RESTORATION OF SOILS THAT HAVE LOST FERTILITY DUE TO UNFAVOURABLE CLIMATIC CONDITIONS

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Abstract

The article is devoted to the search for alternative ways to prevent the negative impact of climate change on precipitation. It is known that as a result of climate change, both on the scale of the Earth and within any country, excessive precipitation falls on one part of the territory, and on the contrary, drought occurs on another. This affects the productivity of agriculture engaged in the cultivation of crops. The physical and mechanical properties of the soil play a key role in crop production. As a result of climate change in arid areas, it is possible to restore soil fertility and increase productivity by improving soil properties - moisture capacity, water evaporation, dehydration and others with the help of various chemicals. For this purpose, the titanium-substituted organic compounds synthesized by us were tested on gray-brown soils. The introduction of various amounts of the proposed preparations into the soil increased the physical and mechanical properties of the soil. As a result, the yield of agricultural crops increased. Accumulation of the introduced compounds as residues in plant products was not observed. Therefore, by safely using them, it is possible to develop agriculture in arid areas and obtain abundant harvests.

Keywords: climate change, drought, thiethane compounds, physical and chemical properties of soil

I. Introduction

Climate change, which affects all countries of the world and every person, has a negative impact on all sectors of the economy. In each country, these changes manifest themselves locally. The impact of climate change on human development depends on the geographical location of the state, the existing climatic conditions in the country and other factors. These changes will be more pronounced in four main areas in each country:

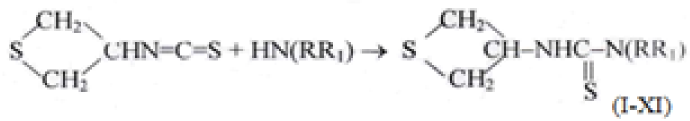
- There is a high probability of reduced agricultural productivity, especially crop production, with the emergence of drought and rainfall patterns in the area. Scientists estimate that by the 2080s, an additional 600 million people will suffer from acute malnutrition as a result of pressures on agriculture and food security caused by climate change [1].
- Shortage of drinking water is a problem. The cause of this problem will be an increase in the number of floods and deluges due to melting glaciers, as well as a decrease in the water level in many rivers during hot weather. This can be observed in the territory of Azerbaijan as well. The current decrease in the level of the Kura River has caused great problems among people living in the surrounding areas. If this problem is not prevented, the number of people suffering from water shortage will increase every year.

- The above problems will lead to the destruction of ecosystems in each area. This will lead to the destruction of biodiversity and the threat of extinction of many plant and animal populations. This will be especially noticeable in coastal areas.
- Climate change will also affect human health. The elderly, those suffering from nervous, cardiovascular, cardiac and respiratory diseases, and children are especially sensitive to these changes. In addition, the risk of infectious diseases is high in areas with floods and droughts.

The above-mentioned climate changes have a negative impact on agriculture. This has a particularly negative impact on the soil, which is the main element of agriculture. Providing the population of each country with food is one of the main directions of the state's economic policy. Work has been carried out in this direction in our republic. "The Food Security Program of the Republic of Azerbaijan" was approved by the Decree of the President of the country, and as a result of the work done within the framework of this Program, the production of agricultural and food products has increased significantly [2]. Reliable food supply is the main condition for economic stability and social stability of each country. In this regard, the Azerbaijani state is implementing comprehensive measures to ensure reliable food supply to its population and is implementing large-scale state programs aimed at developing the agricultural sector, on which food security directly depends. At present, reliable provision of the country's population with food is one of the main directions of the state's economic policy. Therefore, it is very important to constantly implement appropriate measures to fully meet the needs of each member of society for basic food products. In recent years, due to negative trends in the financial market of leading countries as a result of climate change, as well as increased demand for food as a result of population growth, increased floods and droughts, limited water resources and other reasons, prices for basic food products in world markets have begun to rise, and in some countries food shortages have begun to increase, which has become a real threat. Food production in our republic is below the existing potential and capabilities. There are few land plots in our country suitable for cultivation. 1.2 million hectares of land in the country are salinized to varying degrees, have been subjected to various types of erosion, more than 50 thousand hectares of land are polluted. In addition, the fertile layer of more than 1.4 million hectares of agricultural land has been damaged. It is necessary to take step-by-step measures to prevent the process of land degradation. These measures should include the adoption and implementation of land use rules, land management and preparation of relevant maps, as well as the implementation of measures aimed at land rehabilitation and improvement of land quality. One of such measures is the implementation of a set of measures and appropriate mechanisms for the protection and improvement of soil quality [3].

II. Methods

Organic sulfur compounds are used in agriculture for various purposes - pest control, fertilizer production, soil reclamation, etc. For this purpose, we synthesized titanium-substituted compounds. First, 1,2-epithio-3-chloropropane was prepared in an aqueous medium by the reaction of 1,2-epoxy-3-chloropropane with thiourea [4]. Then, 3-thiatanyl isothiocyanate was obtained by the action of ammonium thiocyanate on 1,2-epithio-3-chloropropane in water. The corresponding 3-thiatanyl thioureas were synthesized by the action of various single and binary amines on 3-thiatanyl isothiocyanate [4].



R=R$_1$=H (I); R=H, R$_1$=CH_3- (II), R=H, R$_1$=C_2H_5- (III), R=H, R$_1$=$C(CH_3)_3$- (IV), R=H, R$_1$=$C_{18}H_{37}$- (V), R=H, R$_1$=C_6H_5- (VI), R=H, R$_1$= $C_6H_5CH_2$- (VII), R=H, R$_1$= $C_{10}H_7$- (VIII), R= CH_3- , R$_1$= CH_3- (IX), R= C_2H_5-, R$_1$= C_2H_5-(X), R= C_4H_9-, R$_1$= C_4H_9-(X)

The coupling reactions of aliphatic amines with 3-thiatanyl isothiocyanate are carried out without a solvent, sometimes in benzene, the reaction is isothermal and is completed in 10-30 min. However, the interaction with aryl-substituted amines takes a relatively long time to complete, within 3-4 days. When triethiamine is used as a catalyst to increase the reaction rate, the reaction is completed within 1 day. The synthesized 3-thietanyl-substituted thioureas are white crystalline or oil-like substances. Thiourea can be dissolved in ethyl alcohol and purified by precipitation with benzene. The yield and physicochemical properties of the obtained substances are presented in the table (Table 1).

Table 1: *Physicochemical constants of 3-thiatanyl-substituted thiourea*

№	R	R$_1$	$T_{mel.}$ ^0C	Found, %				Calculated, %				Gross formula
				C	H	N	S	C	H	N	S	
I	H	H		32,57	5,26	18,68	43,48	32,41	5,44	18,89	43,26	$C_4H_8N_2S_2$
II	H	-CH_3		36,92	6,68	15,62	39,27	37,01	6,21	17,26	39,52	$C_5H_{10}N_2S_2$
III	H	-C_2H_5		40,69	6,97	16,68	36,57	40,88	6,85	15,89	36,38	$C_6H_{12}N_2S_2$
IV	H	-$C(CH_3)_3$	120	47,19	7,51	13,82	31,23	47,02	7,89	13,71	31,38	$C_8H_{16}N_2S_2$
V	H	-$C_{18}H_{37}$	125	65,71	11,23	6,78	16,17	65,94	11,07	6,99	16,00	$C_{22}H_{44}N_2S_2$
VI	H	-C_6H_5		53,54	5,52	12,23	28,89	53,54	5,39	12,49	28,54	$C_{10}H_{12}N_2S_2$
VII	H	-$C_6H_5CH_2$	165	55,71	6,18	11,47	27,12	55,43	5,92	11,75	26,90	$C_{11}H_{14}N_2S_2$
VIII	H	-$C_{10}H_7$	166	61,49	5,35	10,04	23,56	61,28	5,14	10,21	23,37	$C_{14}H_{14}N_2S_2$
IX	-CH_3	-CH_3		40,75	6,73	16,64	36,19	40,88	6,85	15,89	36,38	$C_6H_8N_{12}S_2$
X	-C_2H_5	-C_2H_5		47,32	7,59	13,54	31,13	47,02	7,89	13,71	31,38	$C_8H_{16}N_2S_2$
XI	-C_4H_9	-C_4H_9	135	55,41	9,07	10,42	24,71	55,34	9,29	10,75	24,62	$C_{12}H_{24}N_2S_2$

The IR spectrum of the synthesized 3-thiethane-substituted thioureas retains the absorption bands at 670-680, 720-730 and 1420-1445 cm^{-1}, characteristic of the four-membered thiethane cycle. The spectrum also contains an absorption band in the region of 1500-1510 cm^{-1}, corresponding to the stretching vibrations of the NHC(S) fragment. The absorption band corresponding to the isothiocyanate functional group is not observed in the IR spectrum at 2090 cm^{-1}. In the IR spectrum of 3-thiatanyl-substituted thioureas, recorded in a KBr prism, a broad absorption band observed in the region of 3320-3330 cm^{-1} corresponds to the NH bond. When recording the IR spectrum of a 0.005 M solution of these substances in CCl_4, an absorption band is observed at 3380 and 3480 cm^{-1}, corresponding to vibrations of the free valence of the NH bond. In addition, an absorption band at

3040 cm^{-1} is also observed in the spectrum of the dilute solution. This indicates the presence of an internal hydrogen bond NH….S and is consistent with literature data [6]. In the IR spectrum of the compound containing the NH_2 group, unlike other thiatane-substituted ureas, absorption bands are found in the IR spectrum at 3370, 3435 and 3470 cm^{-1}. According to literature data [7]. the absorption bands at 3370 and 3470 cm^{-1} characterize asymmetric and symmetric stretching vibrations of the NH bond.

2.7-3.75 mg.h. in the NMR spectra of 3-titanium-substituted compounds. In the field, signals of protons of two equivalent methylene groups in the four-membered thietane ring are observed as a quintet in the ratio 1.4:6:4:1. The signal of the methine proton, located in the thietane ring, is 4.3-4.7 mg.h. as a quintet. appears in the field. The signal corresponding to the NH group in the thiourea fragment, located in the molecule of all synthesized thioureas, is singlet and is detected in the field of 7.05-7.75 mg.h.

One of the synthesized compounds (VII) was tested as a soil improver for gray-brown soils in greenhouse conditions. The preparation is given in the amount per hectare by dissolving the compounds in water 2.5; 5.0; 7.5; 15.0 kg. As a result of the studies, it was found that after the introduction of the compositions into the soil, the percentage of water-resistant particles >0.25 mm in size, moisture capacity, soil water permeability increases and the under-evaporation capacity decreases, which has a positive effect on soil fertility. Compared with the control, the yield of tomato plants per m^2 in the experimental area increased by 1.2-3.5 kg, and the yield of cucumber plants - by 1.9-4.0 kg.

Table 2: *Effect of 3-thiatanyl-substituted thiourea on the water-physical composition of gray-brown soil*

Scheme of the experiment	Mechanical fraction, volume in mm, %					The volume of waterproof aggregates in mm., %			
	1,0-0,25	0,25-0,01	0,01-0,001	0,001	0,01	>1,0	1,0-0,25	<0,25	>0,25
Option without preparation	37,7	31,5	20,0	10,8	30,8	18,2	34,8	47,0	53,0
Prototype 2,5 kq/hk	34,1	35,6	22,2	9,1	31,3	20,0	35,07	46,3	53,7
Prototip 5,0 kq/hk	31,6	38,0	18,7	11,7	30,4	22,2	32,9	44,9	55,1
Prototype 7,5 kq/hk	27,7	42,6	19,0	10,7	29,7	20,8	34,1	45,1	54,9
Prototype 15 kq/hk	29,6	42,3	18,9	9,2	28,1	18,8	33,0	48,2	51,8
Preparation 2,5 kq/hk	4,8	57,1	19,9	18,4	38,1	10,4	41,2	48,4	51,6
Preparation 5,0 kq/hk	3,9	46,2	30,0	19,7	49,7	8,3	51,7	39,5	60,2
Preparation 7,5 kq/hk	3,2	31,1	36,5	29,7	65,7	6,6	71,2	22,7	77,3
Preparation 15 kq/hk	2,9	27,9	37,1	32,1	69,2	7,0	72,7	28,7	71,3

The quality of the grown products also improved. Currently, processed cumbrin [8], lignosulfonate [9] and acrylic acid [10] are used for this purpose. Lignosulfonate, taken as a prototype and improver of loamy soils by the mechanism of action, is expensive and has a limited raw material base. In addition, the technology for obtaining lignosulfonate is multi-stage and uses expensive metal salts (Fe, Cu, Zn) and polyethyleneamine. The experiments were repeated 4 times on an area of 10 m^2. The results obtained on the effect of the newly synthesized compound and the prototype on the mechanical composition of the soil, water-resistant aggregates and the productivity of vegetable plants are presented in the following experiments.

III. Results

Experiment 1.

The effect of the proposed compound on the water-physical composition of the soil was studied. The mechanical analysis of the soil was determined by treating a pipette with sodium pyrophosphate, and the water-resistant aggregate was determined by the Sabbinova method [11]. The results obtained are presented in the table (table 2). As can be seen, the amount of particles 0.001-0.01 mm in size in the control variant was 9.1-11.7 and 30.4-31.3%, and taking into account the effect of the new combination, this figure was 18.4-32.1 and 38.1-69.2%. If in the control variant the amount of water-resistant aggregate 40.25 mm thick was 51.8-55.1%, then under the influence of the new preparation it was 51.6-77.8%.

Experiment 2.

The effect of the synthesized compound on the moisture capacity, water evaporation and water permeability of the soil was studied and the results obtained are presented in the table (table 3). As can be seen from the table, the new preparation increased the moisture capacity of the soil, reduced water evaporation and increased dehydration, which led to an increase in soil fertility.

Table 3: *The effect of 3-thiatanyl-substituted thiourea on the moisture capacity, water absorption and water evaporation capacity of gray-brown soil*

Scheme of the experiment	Moisture capacity, %	Evaporation,%	Humidity, %	Waterproof	
				ml/ minute	ml / per day
Option without preparation	24,5	9,4	6,1	0,5	17,1
Prototype 2,5 kq/hk	24,4	7,8	6,3	0,8	19,3
Prototype5,0 kq/hk	25,7	8,4	6,7	0,7	20,7
Prototype 7,5 kq/hk	27,3	8,7	7,2	1,3	28,4
Prototype 15 kq/hk	25,0	7,8	7,1	1,0	24,6
Preparation 2,5 kq/hk	24,9	5,4	8,4	0,7	26,4
Preparation 5,0 kq/hk	32,5	4,2	8,6	1,2	30,2
Preparation 7,5 kq/hk	44,6	3,2	9,2	1,8	35,1
Preparation 15 kq/hk	40,3	2,4	8,1	1,5	31,6

Experiment 3.

The effect of the studied compound on the productivity and quality of vegetable plants - tomatoes and cucumbers - was also studied. The results obtained are presented in the table (table 4). As can be seen from the obtained result, the productivity of tomato and cucumber plants increased by 1.2-3.5 and 2.6-4.9 kg/m^2, respectively, compared to the prototype. At the same time, as a result of mathematical calculations using the method of V.V. Pereguov, it was established that the quality of vegetable plants also increased.

Experiment 4.

The effect of the new preparation on the accumulation of residues in vegetable plants was determined colorimetrically using the method of O.A. Drozdova [11]. The results obtained are presented in the table (table 5). The results show that the new compound does not accumulate as a residue in plant organs.

Table 4: *The effect of 3-thietanyl-substituted thiourea on the yield and quality of vegetable plants in gray-brown soil*

Scheme of the experiment	Tomato plant					Cucumber			
	Average yield, kq/m²	The difference kq/m²	Dry mass, %	Acidity, %	Vitamin "C"	Average yield, kq/m²	The difference, kq/m²	Dry mass, %	Vitamin "C"
Option without preparation	7,9	-	4,4	0,32	16,7	9,1	-	3,8	5,2
Prototype e2,5 kq/hk	9,6	-	4,5	0,34	17,0	10,8	-	4,0	5,4
Prototype 5,0 kq/hk	11,3	-	4,7	0,36	17,6	12,1	-	4,2	6,2
Prototype 7,5 kq/hk	12,5	-	5,0	0,38	18,1	13,8	-	4,7	6,5
Prototype 15 kq/hk	10,4	-	4,8	0,37	17,9	11,9	-	4,4	5,7
Preparation 2,5kq/hk	10,8	1,2	4,9	0,39	18,0	12,6	1,9	4,6	5,8
Preparation 5,0kq/hk	13,3	2,0	5,3	0,37	18,5	14,9	2,7	4,8	6,4
Preparation 7,5kq/hk	16,0	3,4	6,4	0,43	19,4	17,9	4,0	5,9	6,7
Preparation 15 kq/hk	13,0	2,6	5,7	0,41	18,9	14,0	2,1	5,6	6,4

Table 5: *Effect of 3-thietanyl-substituted thiourea on the accumulation of residues after plant utilization*

Scheme of the experiment	Tomato plant			Cucumber		
	Past days					
	5	15	30	5	15	30
Option without preparation	-	-	-	-	-	-
Preparation 2,5kq/hk	not observed	not observed	not observed	not observed	not observed	not observed
Preparation 5,0kq/hk		not observed	not observed	not observed	not observed	not observed
Preparation 7,5kq/hk	not observed	not observed	not observed	not observed	not observed	not observed
Preparation 15 kq/hk	not observed	not observed	not observed	not observed	not observed	not observed

Experiment 5.

The toxic effect of the new compound was studied in the field. The results are summarized in a table and it is clear from the results that the new compound does not have a toxic effect (Table 6).

Table 6: *Toxic effect of 3-thiethane-substituted thiourea on vegetable plants, (LD_{50} – kq/hk)*

Prototype	18,7
Preparation	20,5

From the experiments conducted and the results obtained, it can be concluded that the newly synthesized compounds increase the fertility of arid territories and uncultivated soils, making them vulnerable to cultivation and increasing the productivity of crops. We cannot accept the consequences of climate change. In addition to solving this problem with solidarity and joint cooperation of all countries of the world, it is necessary to find ways to solve problems using new achievements of science and technology.

References

[1] Natiq Pasha. Climate changes and global warming - Lecture notes. AzTU 2023.

[2] "The State Program on reliable supply of food products to the population in the Republic of Azerbaijan in 2008-2015" https://azeristilik.safaroff.az/az/fealiyyetimiz/dovlet-proqramlari/2008-2015-ci-illerde-azerbaycan-respublikasinda-ehalinin-erzaq-mehsullari-ile-etibarli-teminatina-dair-dovlet-proqrami.

[3] Qarib Mammadov. Of soil science and soil geography the basics. Textbook for higher schools. Baku, “elm”, 2007.

[4] Akperov N.A., Rakhmatli A.F. Synthesis and study of functional properties of some representatives of 3-(chlorothiophenoxy-substituted) thiethanes. The scientific heritage No 105, 2023,

[5] Shirinova N.A. "Reaction of 1-epithio-3-chloropropane with some nucleophilic reagents and study of reaction products" dissertation, Baku, 2001

[6] Mir C.C., Sheske T.M. Reaktions of Hexafluireactione with Sulfur-Containing Compounds. Inorganic Chemistry Journal. 1980. V.18, №6, P.1510-1514

[7] Siegl W.O., Yonson C.R. 3-Sudstituted Thietane derivaties. Stereochemical Considerations. Tetrahedron, 1971, V.27, №2, P.341-350

[8] Author's certificate of the USSR. №8928, 1950

[9] Author's certificate of the USSR. № 738570, 1978

[10] Author's certificate of the USSR. № 492261, 1975

[11] Samofalova I.A.,. Lobanova E.S. Soil science. Laboratory practical training - Perm: IPC "Prokrost", 2021

MODELING STRUCTURAL-TECTONIC CHARACTERISTICS OF EASTERN FIELDS OF ABSHERON PENINSULA AND THE RISK OF TECTONIC IMPACT ON OIL-GAS BEARING

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Absract

The morphostructural, genetic characteristics and oil-gas potential of local folds of the Buzovna-Mashtaga-Janub-2 anticlinal zone have been studied. These studies made it possible to predict promising oil and gas-bearing objects within individual local structures. This anticlinal zone is situated in the northeastern part of the Absheron Peninsula and consists of en-echelon local folds such as Buzovna–Mashtaga, Gala, Turkan, Zira, Janub and Janub-2. The presence of a regional left-lateral strike-slip fault between the Zira and Janub folds contributed to the displacement of the Janub and Janub-2 folds in the northeast direction and lead to the separation of these structures from studied anticlinal zone. However, they are a tectonic continuation of the anticlinal zone.

The level of dislocation of the studied folds decay in the northeast direction due to a decrease in the intensity of the cross buckle mechanism that forms these structures as they move away from the Greater Caucasus collision.

Due to the complexity of the oil and gas bearing structures under consideration with hemianticlines and taking into account that the latter, as a rule, transform into local folds with stratigraphic depth, they are promising objects for oil and gas prospecting and exploration. The natural reservoirs of the local folds under consideration are saturated with hydrocarbons in accordance with the principle of differential entrapment by S.P. Maksimova - V. Gassou.

Keywords: cross buckle mechanism, natural reservoirs, productive series suites, differential entrapment, Apsheron Peninsula

I. Introduction

The tectonic structure of the Apsheron oil and gas bearing region is characterized by the widespread development of infolded- disjunctive dislocations, injection structures and mud volcanism. There are as well as anticlinal zones, which are characterized by weak developed and buried folds. They are complicated by a small number of relatively low-amplitude faults and are mainly “closed” structures, such as the folds of the Buzovna–Mashtaga–Turkan–Zira–Janub-2 anticlinal zone [1,6].

The studied zone is located in the northeast of the Apsheron Peninsula, extends in a southeastern direction, and includes the local folds of Buzovna–Mashtaga, Gala, Turkan, Zira, Janub and Janub-2.

The Buzovna-Mashtaga fold has a complex structure, while consists by two-dome. The domes are separated from each other by a shallow saddle. In fact, the structure consists of a buried brachyanticlinal Buzovna fold and the Mashtaga structural uplift (Fig. 1) [2, 3].

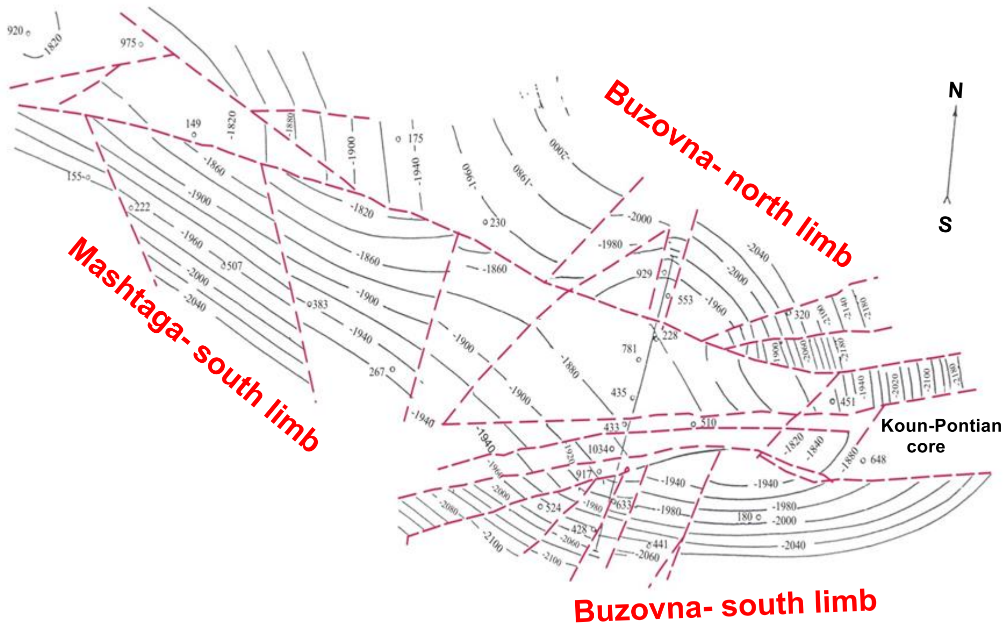

Figure 1:. *Buzovna–Mashtaga field. Structural map constructing by the roof of the PK suite*

II. Method

The goals of the work are to study the morphostructural and genetic characteristics of development, level of complexity, oil and gas saturation of local folds in this anticlinal zone and identifying new promising objects. For this purpose, the study area was analyzed in the direction of Buzovna–Mashtaga–Turkan–Zira–Janub-2 anticlinal zone. The analysis was carried out in the Buzovna–Mashtaga, Gala, Turkan, Zira, Janub and Janub-2 structures. To identifying the

In the study area, models characterizing the problems of anticlinal zone were drawn up. The models are constructed by using of Surfer, Paint programs.

III. Discussion

The Buzovna fold is complicated by longitudinal fault through its axes, along which its northern limb slipped down.

Industrial accumulations of oil in the Buzovna-Mashtaga fold were discovered in the IV, V, VIII horizons of the Sabunchi, X horizon of the Balakhani, as well as in the PKC, PKS, KS and PK suites. Gas was obtained in the near-crest part of the southern limb of the Buzovna fold in horizon II of the Sabunchi suite.

The Gala field, located southeast of the Buzovna-Mashtaga fold, is confined to the same name and sharply asymmetrical brachyanticline. The fold is complicated along the Surakhani suite by 12 transverse faults, as a result of which the tectonic blocks have en-echelon position. In general, the fold is complicated by 13 normal faults (Fig. 2).

It is noteworthy that one normal type fault developed from the upper Miocene to the middle of the Sabunchi suite; its fault plane dips in the direction opposite to the dip of the fault planes that complicate the fold from the Balakhani suite to the top of the Apsheron stage inclusive. The latter mainly complicate the arch of the fold. In turn, 5 faults complicate the near-crest part of the northeastern limb of the fold from the upper half of the Sabunchi suite to the surface. The complexity of the fold crest by a network of faults almost exclusively in the upper part of the section indicates the development of tensile stresses there, not favorable to the preservation of more or less significant accumulations of hydrocarbons (see Fig. 2).

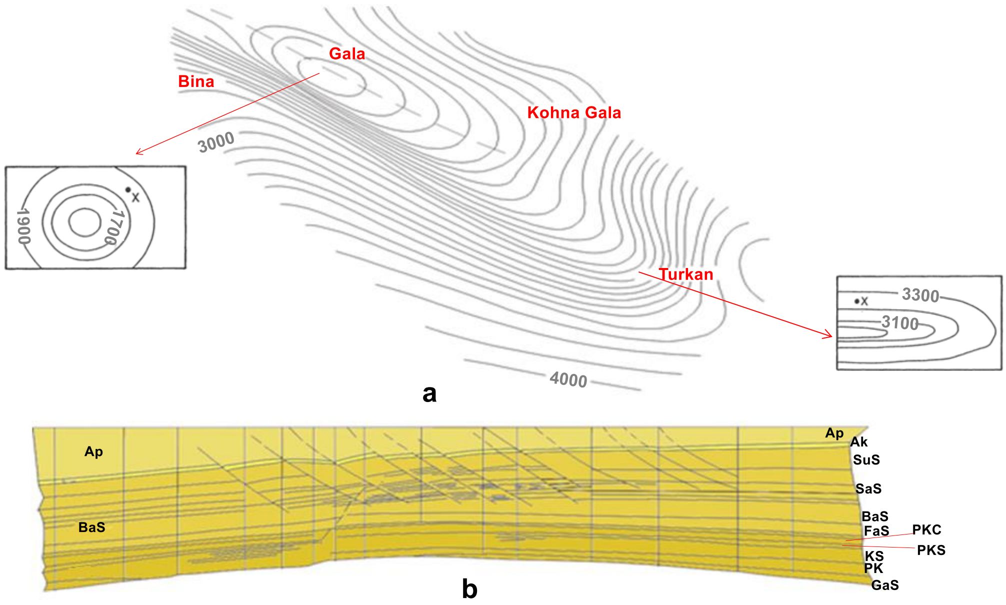

Figure 2: *Gala field: a- structural map along of the roof of the PKC suite; b- geological cross section profile I–I*

In turn, the concentration of hydrocarbon accumulations mainly in the lower section of the Productive series (PS–N $_2{}^1$) is associated with the absence of faults on the crest of the fold, penetrating below the upper half of the Balakhani suite (see Fig. 2). As a result, the lower half of the latter apparently plays the role of a seal for hydrocarbon accumulations in the underlying horizons. The above facts indicate the formation of this fold mainly due to the mechanism of transverse bending [4].

The southeastern periclinal of the fold is strongly elongated along strike due to the development of the Kohna Gala and Turkan structural uplifts in its near-crest zone (see Fig. 2). As a result, the arch of the Gala uplift based on Apsheron deposits is located 3...4 km to the northwest. A characteristic feature of these uplifts is that the dip angles of the layers along the limbs increase with depth. This fact indicates the syndepositional development of the fold. It can be noted that on its southeastern plunge, where the structural uplifts of Kohna Gala and Turkan are located, buried uplifts are developed below the PS, i.e., the fold along the underlying PS deposits is three-arched (see Fig. 2). Structurally, there is a discrepancy between the structure of the upper part of the PS and the structure of its lower section. Another feature of the fold is the complexity of transverse faults, the amplitude of which in the crest of the fold is 50...60 m, closer to the northwestern pericline it decreases to 20...30 m, while on the southeastern plunge to 10...15 m [2]. At the same time, the amplitudes of the faults decrease towards the limbs of the fold and with stratigraphic depth completely attenuate in the upper parts of the Balakhani suite (see Fig. 2, b), which indicates their juvenile age.

The morphology of the Gala uplift changes with depth. Thus, along the roof of the PK suite, the ratio of its width to length is 1:3, while along the Apsheron-Aghjagil deposits it is 1:2. For deposits lying below the PS, the displacement amplitude of faults is 600...700 m, but for the PS it reaches 1200 m [3]. Within the Gala uplift, the main part of the horizons and suites of PS is oil-bearing. In its southeastern pericline there is a structural complication of the Turkan (see Fig. 2), its constituent layers lie at an angle of 5^0. Between the Gala and Turkan areas, the sediments of the Apsheron-Aghjagil stage mainly lie horizontally. Well drilled here

No. 3 (4377 m) showed the presence of oil in the PK suite. Subsequently, wells drilled into this suite No. 1216, 1217 yielded oil only in the second object (GaS_2).

The Zira fold is located southeast of the Turkan structure. Here, the deposits of the upper section of the PS have undergone very weak dislocation, and the lower section manifests itself as a dome-shaped buried uplift. The fold is complicated by two faults with an amplitude of 50 m with a lowered central block (Fig. 3a,b) [2, 3].

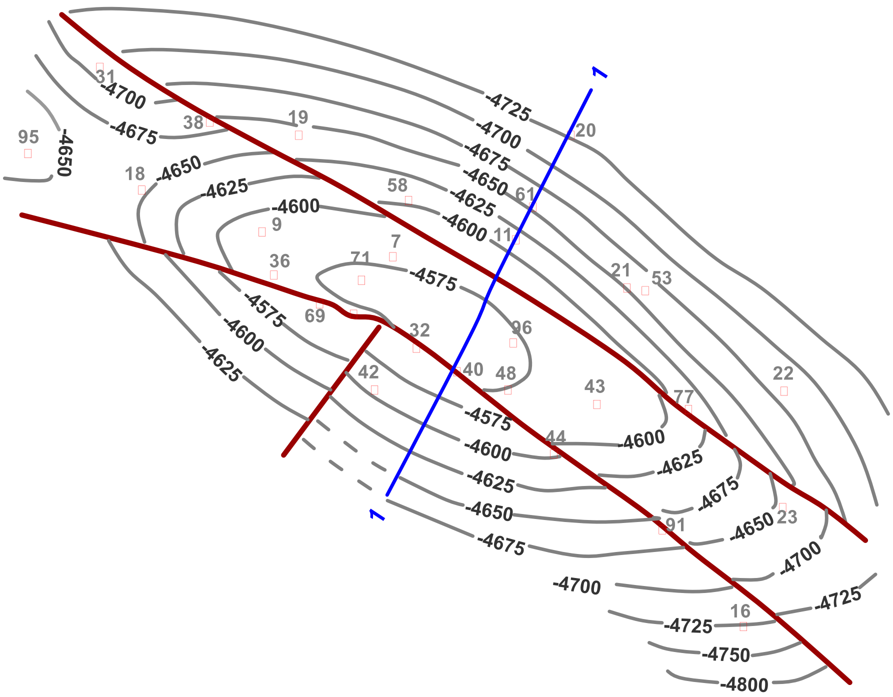

Figure 3a: *Zira field: structural map*

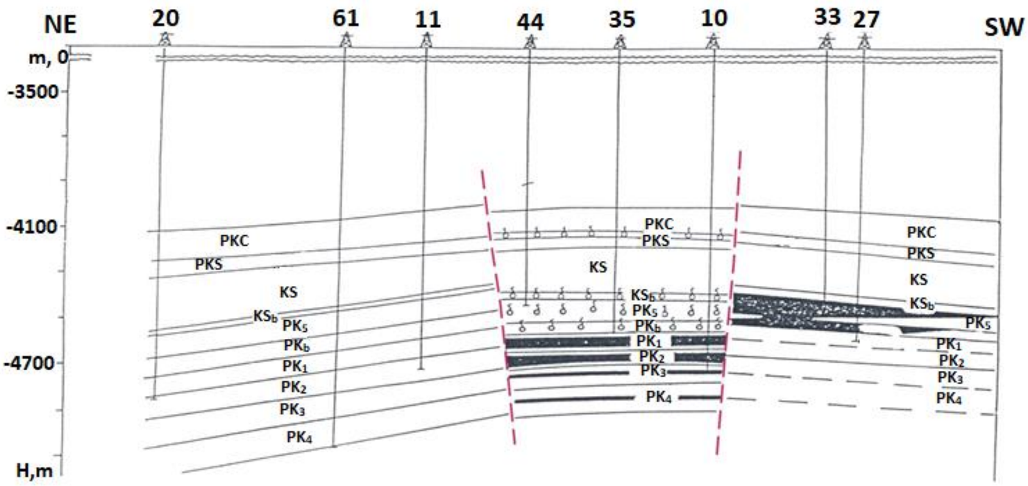

Figure 3b: *Zira field: structural map and geological profile along line I–I*

Based on the profile section, we can say that these fractures played an important role in the distribution of oil and gas over the area and section of the field (see Fig. 3b).

The study of the structures of Zira, Janub, Janub-2 showed that they have a single mode of development and common morphogenetic features. The Zira structure along the top of the PS is also a buried asymmetrical short brachyform fold. Along the roof of the Gala suite, the south limb of the fold lies at an angle of 8...10°, and the north – 3...4°. The Zira field has an oil rim and is gas-condensate-bearing [4].

The Janub structure is a poorly developed buried fold in southeast direction, which flattens upward along the section; as a result, it is very weakly expressed along the top of the Apsheron stage. Along the roof of the Pre-Kirmaki suite, its southwest limb dip at an angle of 6°, and the northeast one – 8° (Fig. 4).

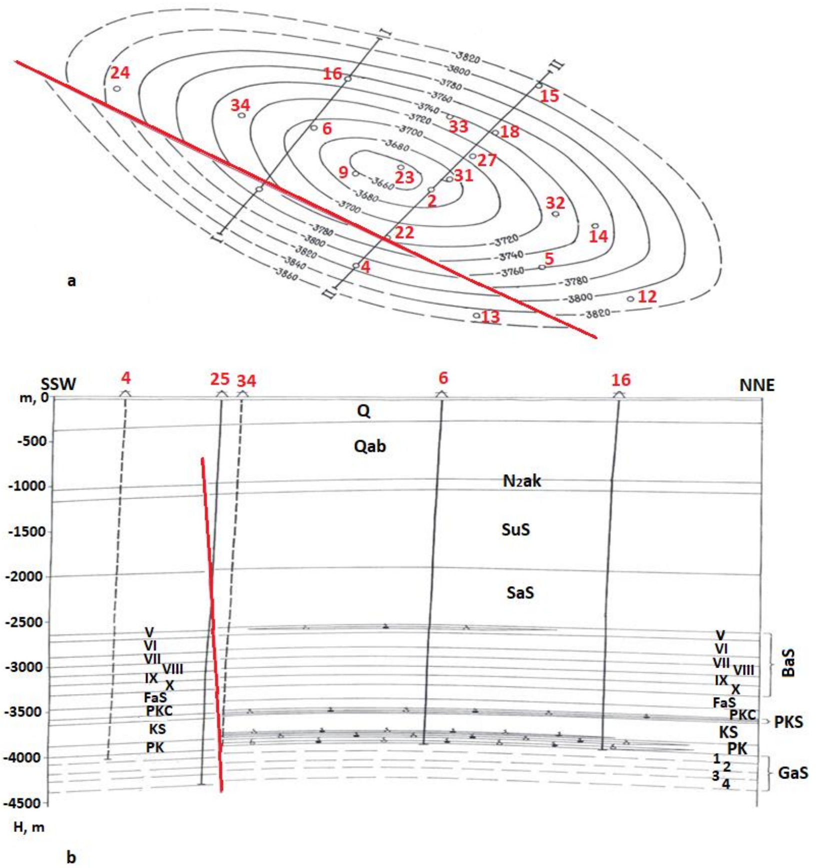

Figure 4: *Janub field: a – structural map by the roof of the PK suite of PS; b –geological cross-section on profile line II–II*

Unlike Zira field, the Janub field in the PS deposits are gas and gas-condensate-bearing.

The Janub-2 fold is located next to southeast of the Janub structure and extends in the same direction. It flattens towards the top of the Aghjagil stage (Fig. 5) and is a gently sloping buried shortened brachyanticline with dimensions of 3.0x1.5 km. With stratigraphic depth, the fold acquires a more distinct form, the dip angles of the limbs increase, and it is more clearly expressed by the bottom of the PS. Based on well data, a transverse fault divides the fold into a downdip northwest and an uplifted southeast blocks. Janub-2 is a gas condensate field, the prospects of which are associated with the lower part of the PS and underlying sediments [4,10].

The Zira, Janub, and Janub-2 uplifts are buried and oil and gas bearing, and are also weakly complicated by disjunctive dislocations, which gives reason to predict the presence of productive objects in the underlying PS strata. The lack complexity with disjunctive dislocations of these folds or its absence also gives reason to predict the likelihood of the formation of gas and gas-condensate accumulations in them.

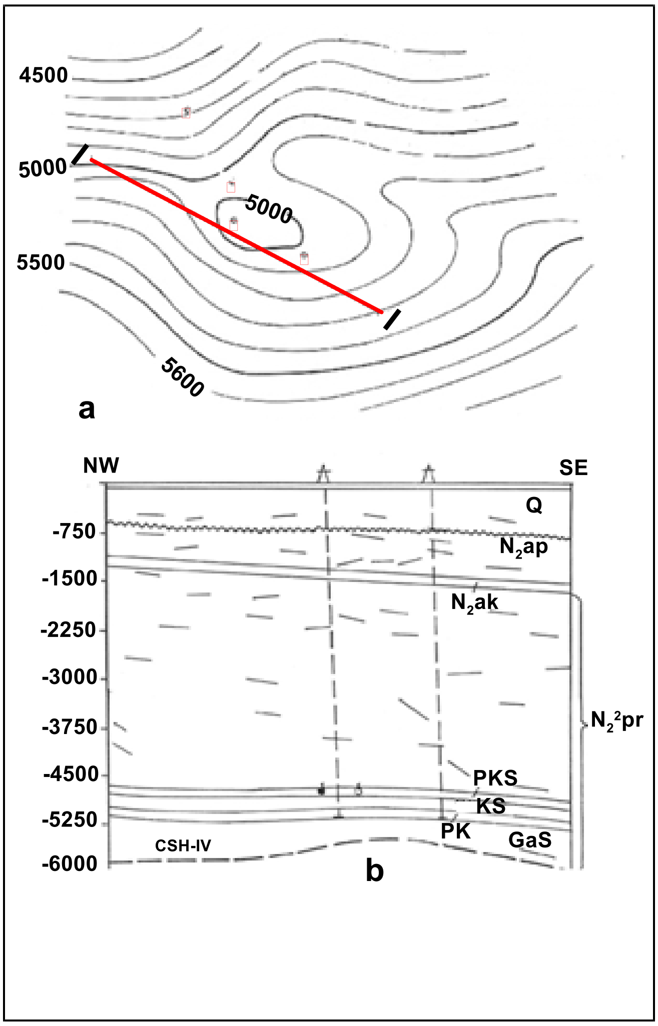

Figure 5: *Janub-2 field: a – structural map by the top of the PK suite of PS; b – seismic geological profile on line I–I*

IV. Results

Thus, it should be noted that along the Buzovna–Mashtaga–Turkan–Janub-2 anticlinal zone, according to the strike of folds from northwest to southeast, as the breakdown of structures by disjunctive dislocations decreases, so phase changes in the accumulation occur. Thus, hydrocarbon accumulations phase changes from oil in the Buzovna-Mashtaga fold to gas condensate and gas phase in the Janub, Janub-2 areas [1].

As can be seen, the degree of complexity of local folds by faults plays a significant role in phase fluid saturation. In this case, regional axis-longitudinal faults can be pathways for the vertical migration of hydrocarbons during the formation of their accumulations or destruction and reformation, and can also serve as a screen on the path of their migration [1].

In other words, any disjunctive can periodically play the role of a screen or conductive. This can also occur in cases where deposits with different hydrodynamic regimes are developed in blocks shielded by a fault. In this case, if a high reservoir pressure gradient occurs between adjacent deposits being developed, it can disrupt the screening role of the fault, which must be taken into account when developing adjacent deposits screened by the same fault.

In the Apsheron oil and gas bearing region, regional axial and transverse disjunctive dislocations play a significant role in the formation, preservation, destruction and reformation of hydrocarbon accumulations. In this area, transverse faults are mostly local and developed mainly in the upper part of the section, and axis-longitudinal faults are mostly regional with deeper penetration and are mostly not components of deep faults. As noted earlier, the Buzovna–Mashtaga field is complicated by 19 transverse and radial faults. Such a large number of them within one fold is obviously associated with upward squeezing of rheologically active clays of the Kovundag-Maykop series (Fig. 6) [2].

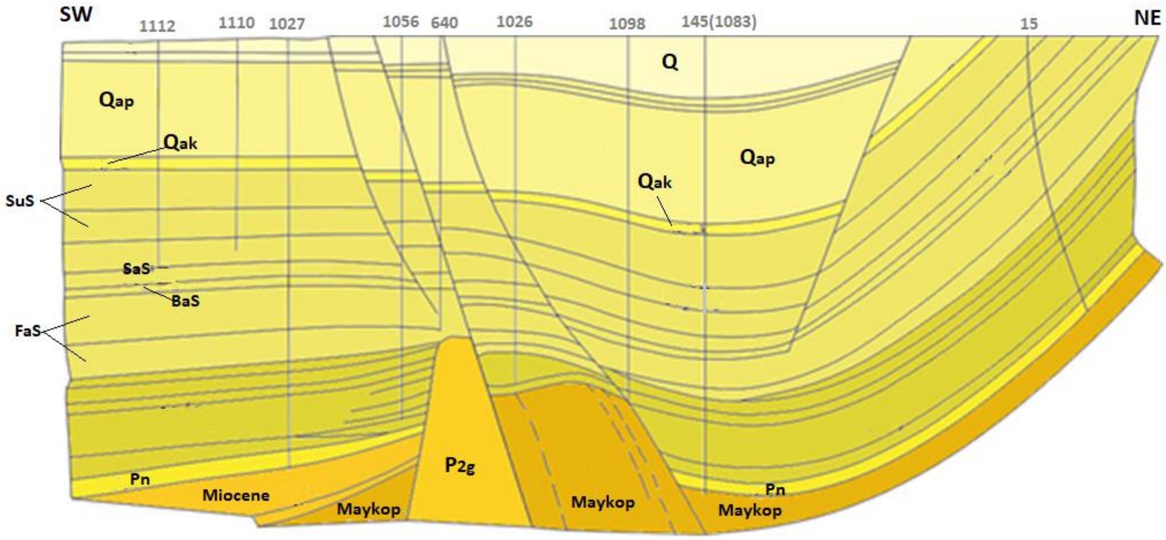

Figure 6: *Geological profile of the Buzovna–Mashtaga field*

As a result, the overlying and more competent rocks of the Pre-Kirmaki, Kirmaki and Post-Kirmaki suites of the lower stage of the PS were subjected to ductile deformations when they were bent and tensile stresses arose in them. The normal faults complicating both limbs of the Buzovna-Mashtaga fold also contributed to the formation of the graben due to the occurrence of tensile stresses. The formation or reformation of hydrocarbon accumulations due to a dense network of normal faults indicates their time-varying role as a conductor and screen, as well as the high probability of the existence of hydrocarbon accumulations in deep-lying rock strata.

From the above, we can conclude that within the territory under consideration, accumulations of hydrocarbons are formed due to stepwise migration. Using the example of the studied anticlinal zone with a chain-like position of local folds and with the main south-southeast–north-northwest direction of fluid migration, i.e., in general along the updip of layers, the differential entrapment of hydrocarbons according to the principle of S.P. Maksimova – V. Gassou is clearly observed [5,7]. Thus, at the southeast end of the zone, in the traps of the Janub, Janub-2 folds, accumulation of gas and gas condensate is found, further along the updip of layers in the Zira fold - gas-gas-condensate-oil, and in the local folds Turkan-Gala-Buzovna-Mashtaga oil deposits were formed (Fig. 7). The presence of gas accumulations in the Aghjagil and Apsheron stages of the Gala and Buzovna-Mashtaga fields may be of a technogenic nature.

The Apsheron oil and gas region is characterized by the destruction and reformation of oil and gas deposits due to the complication of folds by a network of faults and mud volcanism. In the Apsheron, Lower Kura, Shemakhi-Gobustan oil and gas bearing regions, in most cases, mud volcanoes, complicating local uplifts, are located in the zones of intersection of regional axial-longitudinal faults with transverse ones [9]. However, the absence of mud volcanoes in local fold of the Buzovna–Mashtaga–Zira–Janub-2 anticlinal zone is obviously associated with insufficient energy of rheologically active clays of the sedimentary section due to their low mass and absence or very weak development of compressive stresses here. Thus, within the considered anticlinal zone, the Kovundag-Maykop series with a total thickness of about 500...600 m is lithologically represented by clays and shales. An equally important reason for the underdevelopment of local folds in the anticlinal zone under consideration, i.e., their buried nature, is associated with the absence of compressive stresses within this territory [8]. For example, within the Apsheron-Balkan structural megasaddle, complicated mainly by elongated brachy- and linear folds, as well as different-scale and different-type disjunctives, including transverse strike-slip faults, mud volcanism is widely developed. The nature of the latter is associated with the subduction nature of the structural megasaddle.

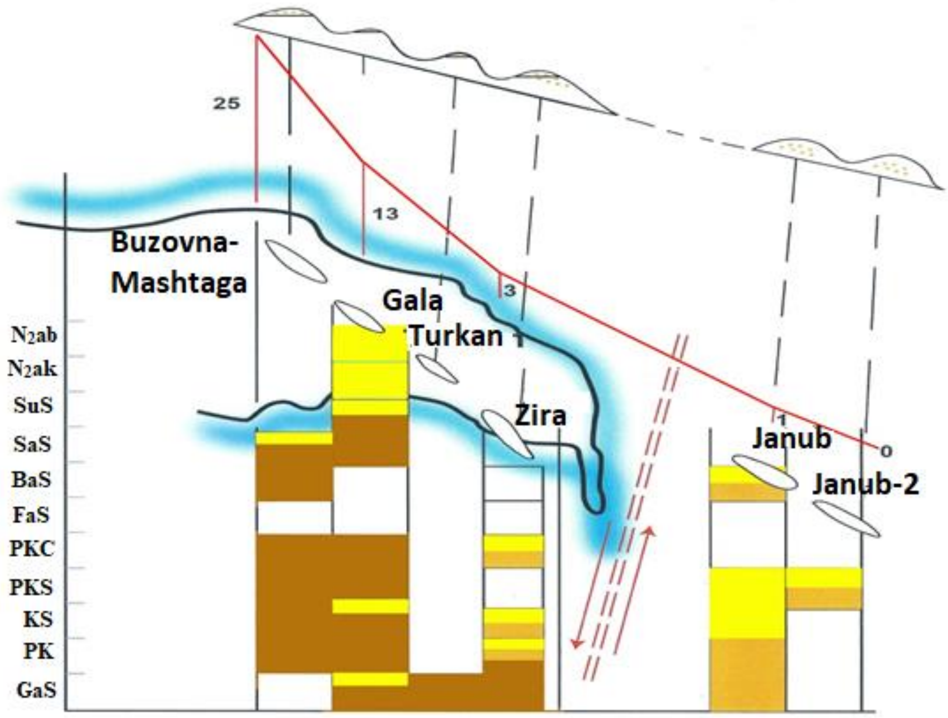

Figure 7: *The nature of oil and gas saturation and the level of dislocation of local folds of the anticlinal zone Buzovna–Mashtaga–Zira–Janub-2*

V. Conclusions

1. Buried folds Janub, Janub-2, according to morphogenetic, structural-tectonic characteristics, spatial orientation and nature of oil and gas saturation, are a structural-tectonic continuation of the Buzovna–Mashtaga–Turkan–Zira anticlinal zone, which developed mainly due to the cross-buckle mechanism.
2. The level of dislocation of local folds of the Buzovna–Mashtaga–Turkan–Janub-2 anticlinal zone weakens in the southeast direction due to distance from the Greater Caucasus collision.
3. Buried local uplifts of the studied anticline zone, expressed as hemianticlines in the overlying rock strata, are promising for oil and gas.
4. Fluid saturation of the reservoirs of natural traps of the studied anticlinal zone occurred according to the principle of differential trapping clearly expressed here by S.P. Maksimova – V. Gassou in the direction of the regional updip of layers and depending on the level of their complexity with disjunctive dislocations.

Reference

[1] Mukhtarova, Kh.Z., Nasibova, G. J., (2022). The role of studying tectonic factors in reducing the risks of ineffective exploration and exploration and determining oil and gas perspectivity southern part of Absheron archipelago. // "Reliability: Theory and Applications" (RT&A), Special Issue № 3 (66) Volume 17, January 133-137 p. DOI : https://doi.org/10.24412/1932-2321-2022-366-133-137 .

[2] Gahramanov, G.N., Mukhtarova, Kh.Z., Shpyrko, S.G., Nasibova, G. J. (2021). Technique of paleotectonic backstripping and assessment of hydrocarbon potential in anticline traps (South Caspian Basin). EAGE, Geoinformatics, 11-14 May, Kiyiv, https://eage.in.ua/?page_id=1526.

[3] Narimanov, N.R., Mukhtarova, Kh.Z., Nasibova, G. J. (2022). The mechanism of formation and prospects of non-structural traps in the South Caspian megadepression. // Journal of Geology, Geography and Geoecology, Ukr., Dnipro, 2022, 31 (3), p. 529-538.

[4] Mukhtarova, Kh.Z., Nasibova, G. J. Prospects of oil and gas potential of the sedimentary strata of the South Caspian Basin based on paleotectonic and geodynamic criteria. // Journal of Geology, Geography and Geoecology, Ukr., Dnipro 2023, 32 (1), p.153-163 DOI https://doi.org/10.15421/112315

[5] Ganbarova, Sh.A. (2024). Course lecture notes of "Prospecting and exploration of oil and gas fields". Baku, 115 p.

[6] Mukhtarova, Kh.Z., Nasibova, G. J. Geodynamic regime and prospects for oil and gas potential South Caspian Basin. // Journal of Geology, Geography and Geoecology, Ukr., Dnipro 2023, 32 (3), p.550-559; DOI https://doi.org/10.15421/112349

[7] Mehtiyev, Sh.F. Selected works. (2010). Baku, 474 p.

[8] Mukhtarova, Kh.Z., Nasibova, G.J., Ganbarova, Sh.A., Zeynalova, S.A., Ismailova, M.M. (2023). The influence of compressive stresses on folding in the Middle Kura depression and the Turkmen shelf. // Journal of Geology, Geography and Geoecology, Dnipro, 32 (2), p. 352-359; doi:10.15421/112332.

[9] Nasibova, G. J., Ismayilzadeh, E. A., Ganbarova, Sh.A., Ismayilova, M. M. (2023). Oil and gas prospects of tectonic crashing zones of the Kura intermountain depression. // "Reliability: Theory and Applications" RT&A, Special Issue No 5 (75) Volume 18, November, DOI: https://doi.org/10.24412/1932-2321-2023-575-313-322.

[10] Xalilova L., Seidov V. Evolution of hydrocarbon deposits in the South Caspian Basin. // Geophysics, 2023, 45(3), p. 126-134. https://doi.org/10.24028/gj.v45i3.282420.

THE ROLE OF DIGITAL PERSONALITY IN PROMOTING SUSTAINABLE BEHAVIOR

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Abstract

In the context of rapid technological advancement and global environmental challenges, digital identity emerges as a crucial tool for promoting sustainable behavior. Digital identity refers to the way individuals express themselves and interact within the online space, influencing their actions and choices in the real world. This paper explores various aspects of digital identity, including its impact on the formation of sustainable habits and practices, the enhancement of environmental awareness, and the development of social responsibility. It analyzes how social media platforms and digital technologies can be utilized to create communities that foster the exchange of sustainable practices and ideas. Additionally, the challenges related to data security and privacy that may affect the use of digital identity in achieving environmental goals are discussed. In conclusion, the necessity of integrating digital identity into strategies for promoting sustainable behavior is emphasized, as it can contribute to a more conscious and responsible relationship with the environment.

Keywords: digital identity, sustainable behavior, environmental awareness, social media, technology, social responsibility, data protection, privacy, sustainable practices

I. Introduction

In an era defined by rapid technological advancement and escalating environmental challenges, the urgency to promote sustainable behavior has become paramount. The world faces a myriad of pressing issues, including climate change, resource depletion, pollution, and biodiversity loss. These challenges necessitate innovative and effective approaches to inspire individuals and communities to adopt more sustainable practices. One promising avenue is the integration of digital identity into sustainability efforts. As societies become increasingly digitized, understanding how digital identity can shape behaviors and attitudes toward the environment is essential.

Digital identity refers to the online persona that individuals cultivate through their interactions on various digital platforms, including social media, forums, and other online communities. This identity encompasses not only personal information but also the values, beliefs, and behaviors individuals express in the digital realm. With the advent of social networks and online communication, people are no longer passive consumers of information; they actively engage, share, and influence one another's behaviors. This engagement provides fertile ground for promoting sustainable practices, as individuals can leverage their digital identities to advocate for environmental issues and inspire change.

Digital identity can significantly impact sustainable behavior in several ways. First, it influences how individuals perceive themselves in relation to sustainability. When people align their digital identity with eco-friendly values—such as reducing waste, conserving energy, and supporting local businesses—they are more likely to adopt these behaviors in real life. For instance, individuals who showcase their sustainable practices online may feel a heightened sense of accountability to continue these actions, as their peers reinforce these behaviors through likes, shares, and comments.

Additionally, digital identity fosters community building around shared sustainability goals. Online platforms enable individuals to connect with like-minded people, forming communities that support and encourage sustainable practices. These communities can facilitate the exchange of ideas, resources, and information about sustainable living, creating a sense of belonging that motivates individuals to engage in environmentally friendly behaviors. As these digital communities grow, they can amplify their collective influence, driving broader societal change.

Another critical aspect of digital identity's role in promoting sustainable behavior is its capacity to raise awareness about environmental issues. Digital platforms serve as powerful channels for disseminating information about sustainability, from climate science to local conservation efforts. Influencers, activists, and organizations can use their digital identities to share compelling narratives, engage followers, and mobilize action. This can include campaigns to reduce plastic use, promote renewable energy, or support wildlife conservation initiatives.

Moreover, digital identity enables the sharing of educational resources, helping individuals understand the impact of their choices on the environment. Online tutorials, webinars, and interactive content can provide valuable insights into sustainable practices, making it easier for individuals to incorporate eco-friendly habits into their daily lives. By harnessing the power of digital identity, individuals can become informed advocates for sustainability, influencing others and contributing to a larger movement toward environmental responsibility.

Despite its potential, the integration of digital identity into sustainability initiatives is not without challenges. Privacy concerns are paramount, as individuals may hesitate to share personal information or engage in online discussions about their eco-friendly choices due to fears of data misuse or surveillance. The need for robust data protection measures is essential to ensure that individuals feel safe in expressing their digital identities.

Furthermore, the phenomenon of "greenwashing" poses a significant challenge. As businesses and organizations increasingly adopt sustainability messaging, discerning authentic commitments from superficial marketing tactics can be difficult for consumers. Digital identity can inadvertently contribute to this issue, as individuals may align their online personas with sustainable practices that do not reflect their real-world behaviors. This disconnect can undermine the credibility of sustainability efforts and diminish trust in digital advocacy.

II. Methods

To explore the role of digital identity in promoting sustainable behavior, three distinct methods were employed: survey analysis, interviews and focus groups, and case study analysis. Each method contributed unique insights into the relationship between digital identity and sustainable practices.

1. Survey Analysis

A comprehensive survey was distributed across various demographic groups to gather quantitative data. The survey included questions on digital identity usage (e.g., social media, digital platforms) and sustainable behaviors (e.g., recycling, energy conservation, ethical consumption). Respondents were asked about:

How often they engaged with digital platforms that focus on sustainability.

Whether their online identity influenced their real-world sustainable actions.

Perceived barriers to adopting eco-friendly behaviors through digital means.

Analysis: The data was statistically analyzed to find correlations between digital engagement and sustainable behavior, using regression models and cross-tabulation to identify trends across different age groups, education levels, and regions.

2. Interviews and Focus Groups

Semi-structured interviews and focus group discussions were conducted with key participants, including sustainability advocates, environmental researchers, and digital platform developers. These qualitative methods provided a deeper understanding of:

Personal experiences with how digital identity influences their commitment to sustainable practices.

Motivations for engaging in online sustainability communities and how digital identities shape those motivations.

Challenges and opportunities faced in promoting eco-consciousness through digital identities.

Analysis: Thematic analysis was employed to identify common themes such as social accountability, digital peer influence, and the impact of digital rewards systems on promoting environmentally responsible behavior.

3. Case Study Analysis

Several case studies of digital platforms that successfully promote sustainability (e.g., apps or websites dedicated to green living, carbon footprint tracking, or ethical shopping) were analyzed. The focus was on:

How these platforms construct and maintain user digital identities that align with environmental values.

The mechanisms used to encourage sustainable actions, such as gamification, social sharing, or incentives.

The long-term impact of these platforms on user behavior and environmental outcomes.

Analysis: Comparative analysis was conducted across case studies to evaluate which strategies most effectively integrate digital identity with sustainable behavior. Specific factors such as user engagement levels and measurable environmental impact were compared.

By combining these three methods, the study offers a comprehensive understanding of how digital identity can drive sustainable behavior and what strategies can further enhance this connection.

III. Results

Although discussions on sustainability and its relevance began to surface prominently towards the end of the last century, particularly with the 1972 Stockholm Conference organized by the United Nations (UN) (Rodrigues, 2009), concerns regarding this issue actually date back to the first (1760-1840) and second (1850-1945) industrial revolutions. The industrial revolution led to a dramatic increase in the production of goods and wealth, raising people's purchasing power. However, it also resulted in negative outcomes, including increased economic inequalities and significant environmental impacts due to heightened production. During this time, economists like John Stuart Mill (1848) and Thomas Malthus (1878) warned of the adverse effects that unchecked economic and population growth could have on both the environment and human well-being. Furthermore, the industrial revolution introduced a surge in consumption, making it a central aspect of economic development and shaping human relations. Mass production created an environment where consumerism—driven by the need to quickly dispose of goods—became normalized and encouraged. Over time, the satisfaction of personal desires began to take precedence over the fulfillment of genuine needs. This "consumerism," the ever-increasing production and acquisition of non-essential goods in pursuit of well-being, has since become a critical consideration within the sustainability discourse, as it places tremendous pressure on natural resources and the environment. Growing concerns over long-term environmental degradation sparked global events and environmental movements in the late 1960s and 1970s, which initiated widespread debates on the limits of growth and how environmental issues could be integrated into mainstream development goals. One significant milestone in this sustainability debate was the UN World Commission on Environment and Development's (WCED) 1987 "Our Common Future" report. It was one of the first comprehensive efforts to establish a global agenda for rethinking the human development model. The report defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". It highlighted poverty in developing nations and rampant consumerism in developed countries as key factors preventing equitable development and causing serious environmental crises, which in turn sparked extensive academic and political discussions worldwide. This evolving sustainability discourse eventually found its way into business practices, with the introduction of the "Triple Bottom Line" concept. This framework expanded corporate objectives beyond just economic factors, proposing that sustainability involves the pursuit of economic prosperity, environmental protection, and social equity in an interconnected manner. In environmental terms, this approach urged businesses to preserve natural capital and maintain the planet's life support systems by balancing resource generation, consumption, and waste management.

IV. Discussion

Scientific and academic advancements in sustainability, alongside technological innovations and the rise of an eco-friendly culture, have fostered an environment where brands are increasingly motivated to address environmental issues and contribute to their resolution. Consequently, numerous online brand campaigns have emerged, wherein companies raise awareness about environmental challenges and strive to encourage sustainable behaviors among consumers. Many brands are now implementing pro-environmental initiatives, such as creating digital re-commerce platforms that promote conscious consumption.

However, while some brands successfully influence consumers' pro-sustainability behaviors through these actions, others fall into the trap of greenwashing, which can have detrimental effects not only on the brands themselves but also on consumers’ willingness to engage in environmentally friendly practices. To ensure the success of their online environmental campaigns and effectively inspire pro-sustainability in their consumers, brands must establish a well-defined and authentic environmental purpose. This means aligning their communications with their actual practices to avoid inconsistencies. Specifically, brands must ensure that their environmental stance is congruent with their corporate identity, values, business operations, and overall mission. Additionally, brands must engage authentically and actively with the causes they advocate.

Lin emphasizes that companies should invest their resources and expertise in areas where they possess knowledge and a competitive advantage. They should also ensure that their internal policies align with the environmental purpose they wish to project in their campaigns. Collaborating with activists is crucial for understanding and fulfilling their collective moral responsibilities toward communities and the environment.

For brands to effect meaningful changes in consumers' pro-sustainable behavior, their environmental positions must be perceived as genuine and sincere. Authentic environmental activism requires maintaining a continuous alignment between a brand's stated intentions—reflected in its communication messages—and the actions it takes, such as implementing pro-environmental corporate practices, forming partnerships with environmental organizations, and supporting environmental initiatives.

Beyond establishing a coherent environmental purpose and maintaining authenticity, companies must communicate their environmental stances and actions effectively to ensure they resonate with the target audience and catalyze positive environmental changes. According to Key et al. (2021) and Taylor et al. (2001), brand activist communications should prioritize dialogic communication, facilitating ongoing interactions and providing relevant information to the target audience. Companies must understand how their audience receives and interprets their messaging, creating campaigns that align with consumers' expectations, experiences, and comprehension of the environmental issues at hand.

To encourage consumers to adopt pro-sustainable behaviors and commit to conscious consumption, brands should not only inform consumers about their environmental policies and the importance of the advocated environmental issues but also educate them on how to act and consume more sustainably. This could involve providing guidance on the responsible use and disposal of products. Additionally, brands must consistently convey their perspective across all online and offline communications, capturing and reinforcing the essence of their environmental stance with transparency and credibility. This includes highlighting their environmental strengths while also acknowledging areas for improvement.

In summary, companies need to be intentional in communicating their environmental positions and causes, grounding their messages in tangible evidence of their environmental performance. This could include third-party audits or ecolabels to reduce the risk of consumer alienation and enhance their capacity to drive pro-environmental behaviors. Given the significance of environmental communication within the realm of new digital platforms, particularly in market contexts, further investigation into how these platforms can facilitate or hinder pro-environmental change is essential. Future research could explore how brands' online environmental communication strategies impact various stakeholders, including employees and shareholders, analyze consumer reactions to greenwashing on social media, and examine whether such campaigns hinder conscious consumption by fostering skepticism. Additionally, studying how brands can make environmental issues more appealing to consumers through immersive technologies like augmented and virtual reality could prove valuable. Internally, it would be insightful to investigate how brands leverage digital technologies to reduce their ecological footprints, for instance, by enhancing internal communication regarding sustainability, improving supplier product breakage management, or optimizing distribution routes.

References

[1] Podkolzina I.M., Taranova I.V., Paytaeva K.T., Revunov S.V., Abrosimova T.F. Innovative approaches in financial support for regional economic security// The Challenge of Sustainability in Agricultural Systems. Heidelberg, 2021. C. 549-558.

[2] Faka A. Assessing Quality of Life Inequalities. A Geographical Approach // International Journal of Geo-Information. 2020. Vol. 9. 600 p.

[3] Caeiro, S., Sandoval Hamón, L.A., Martins, R., Bayas Aldaz, C.E. (2020). Sustainability Assessment and Benchmarking in Higher Education Institutions: A Critical Reflection. Sustainability 2020, 12, 543.

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. C. 239-245.

[7] Rao M, Vasa L, Xu Y, Chen P (2023) Spatial and heterogeneity analysis of environmental taxes' impact on China's green economy development: a sustainable development perspective. Sustainability 15(12):9332

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

IMPROVING THE EFFICIENCY OF DISTRIBUTIVE NETWORKS WITH THE APPLICATION OF GREEN TECHNOLOGIES

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Abstract

Based on an analysis of the capabilities of various software systems for analyzing the modes of distribution power networks using simulation models, it was determined that the most effective module that allows for visual and operational research is the use of the DIgSILENT PowerFactory program. Using this complex, a study of the load conditions of the Sarygaya distribution network of Azerishik OJSC was carried out. The results obtained showed that the loads of most 6 kV feeders exceed the permissible values, the voltage drops are high, and these conditions confirm the high probability of emergency outages in the network. Accordingly, proposals were made to redesign and design the network topology. The calculated experiments conducted with the application of the software complex require the implementation of the necessary scheme-mode measures for the improvement of the reliability of the distribution network and the implementation of uninterrupted electric power supply. As one of such measures, it was proposed to connect green energy sources to two points of the studied distribution network. Studies have confirmed that the obtained new circuit topology is convenient and effective.

Keywords: distribution network, DIgSILENT PowerFactory complex, line overloads, voltage drop, voltage profile

I. Introduction

The application of green energy technologies through renewable sources is a priority for modern energy systems. These sources are primarily integrated into distributive electric systems (DES) at lower voltage levels [1-4]. However, addressing the challenges of modern demands involves improving or reconstructing existing distributive networks and employing various approaches to solve emerging issues. Primarily, adopting effective decisions among existing and proposed alternatives requires rigorous regime investigations. Conducting regime investigations through simulation models is advantageous [5]. These models simulate the processes of electricity generation, transmission, and distribution in the power system, enabling the analysis of system performance mechanisms. Such analyses typically aim to identify important regime parameters such as voltage drops, active and reactive power losses, non-sinusoidal and non-symmetrical regimes, and power distribution to assess the overall state of the energy system.

One of the main issues addressed by DES is assisting in optimizing system design. Simulations are conducted to improve the system's performance mechanism and increase efficiency by altering different components and parameters. This is crucial for reducing investment costs, minimizing power losses, and ensuring security. Furthermore, simulation models in DES allow for the optimization of exploitation processes, such as energy production and transmission, in the most effective and secure manner, empowering system and network operators to manage them in real time through simulations.

Moreover, in complexly configured DES, simulations can be used to determine the type of fault and implement necessary corrections, analyze and resolve issues such as energy imbalance, regime oscillations, non-sinusoidal voltage problems, voltage drops, and other problems. Simulations can also be employed for the analysis and resolution of these issues[6,7]. The article focuses on the analysis of regimes and the enhancement of efficiency based on real DES using DIgSILENT PowerFactory complex models, in conjunction with the application of green energy technologies.

II. Mathematical Model for the Regime Calculation of the Distributive Network

Generally, the following non-linear equations system is used in the investigation of regimes in electric power systems: [8]:

$$\left.\begin{aligned}\Delta P\left(\delta,\ P_s,\left|U_{наг}\right|,\ Q_g\right)=P_i^{sp}-\left|U_i\right|\cdot\sum_{j=1}^{N}\left|U_j\right|\cdot\left(G_{ij}\cos\delta_{ij}+B_{ij}\sin\delta_{ij}\right)=0,\ \ \forall i\in N\\ \Delta Q\left(\delta,\ P_s,\left|U_{наг}\right|,\ Q_g\right)=Q_i^{sp}-\left|U_i\right|\cdot\sum_{j=1}^{N}\left|U_j\right|\cdot\left(G_{ij}\sin\delta_{ij}-B_{ij}\cos\delta_{ij}\right)=0,\ \forall i\in n_{pa}\end{aligned}\right\}\qquad(1)$$

in here $\Delta P, \Delta Q$ - the non-linear difference functions of active and reactive power injections in the $i -$ node; P_i^{sp}, Q_i^{sp} the given values of active and reactive power injections at the $i -$ node; $\delta -$ the angle of the voltage vector at the node; $P_s -$ the generation active power of the base node; $Q_g - PU$ the generation reactive power; $|U_{наг}| - PQ$ the voltage at the nodes; $|U_i| -$ the voltage at the
$i -$ node; $\delta_{ij} -$ The angle between the voltage vectors of busbars i and j ; $G_{ij}, B_{ij} -$ the real and imaginary parts of the admittance matrix elements; $N -$ the number of nodes.

Equations (1) and (2) can be written in vector form as follows:

$$f(x)=\begin{bmatrix}\Delta P\left(\delta,P_s U_{PQ},Q_g\right)\\ \Delta Q\left(\delta,P_s,U_{PQ},Q_g\right)\end{bmatrix}=0\qquad(2)$$

Since it is directly impossible to obtain several solutions simultaneously based on equation (3), the problem is solved iteratively with the help of known methods. For example, by using the Newton-Raphson method, the problem posed by the linearization of equations (1) and (2) can be solved:

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}=\left[J\right]\begin{bmatrix}\Delta\delta\\ \Delta P_s\\ \Delta U_{PQ}\\ \Delta Q_g\end{bmatrix}\qquad(3)$$

here $[J]-$ As known, the Jacobian matrix is written as follows [10,11]:

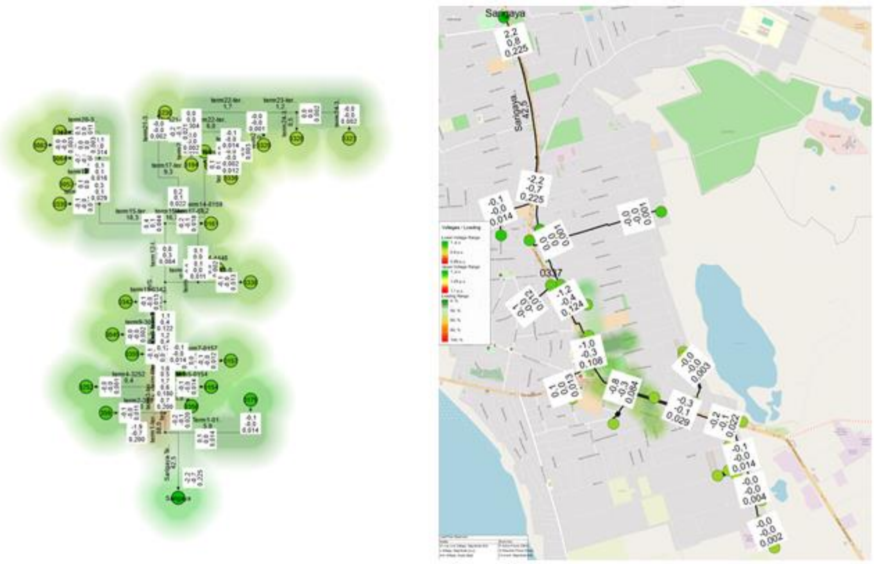
$$[J] = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial P_s} & \frac{\partial P}{\partial U_{PQ}} & \frac{\partial P}{\partial Q_g} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial P_s} & \frac{\partial Q}{\partial U_{PQ}} & \frac{\partial Q}{\partial Q_g} \end{bmatrix} \quad (4)$$

III. Investigation of the Determined Regimes of the Distributive Network

III.1. Research on the current determined regime of the power grid

Currently, the problems identified in the network of the transmission system operator of the electricity system in Azerbaijan have not yet been fully resolved. These problems include inadequate planning for the construction of new substations and half-stations, excessive voltage drop, continued use of outdated electrical equipment, etc. To address these issues, it is crucial to simulate replacement equipment and establish a mathematical model during the refurbishment process. For instance, analyses of load and voltage profiles have been conducted using the "DIgSILENT Powerfactory" program for the 6 kV feeder "Novxanı - 1 H/X," which is 11.2 km long and supplied from the 35/6 kV "Sarıqaya" substation. Active and reactive power losses have been calculated, and simulations have been performed for refurbishment works on the feeder. Several loading regimes have been examined in the simulation program: normal regime, 50%, and 70% overload regimes.

In Figure 1, the simulation model (a) of the load analysis of the Novxanı-1 6 kV feeder and the integration scheme (b) of the feeder into the GIS are presented. As shown in Figure 1a, there are several branches along the length of the distribution network, and the 6/0.4 kV voltage transformer stations are capable of handling underloading conditions (up to 10%). Even in normal loading conditions, some elements may experience overload (Figure 1b), highlighting the necessity of appropriate exploitation, refurbishment, and improvement measures to enhance the efficiency of the network operation. Research investigations on the aforementioned issues were conducted based on the simulation model of the Distribution Management System (DMS). Initially, the loading of the 17-branch 6 kV feeder was examined under the current normal operating conditions. Table 1 illustrates the voltage profile on the "Novxanı-1 6 kV feeder line" within the network area connected to "Sarıqaya" in the normal regime.



a) b)

Figure 1: *Simulation model of the 6 kV "Novxanı-1" feeder: a - model of the load analysis in the determined regime of the feeder; b - integration of the load analysis mathematical model into the Geographic Information System (GIS) in the determined regime of the feeder.*

. In the current determined operating regime, there has been a voltage drop of ΔU=7% at the final transformer station of the feeder.

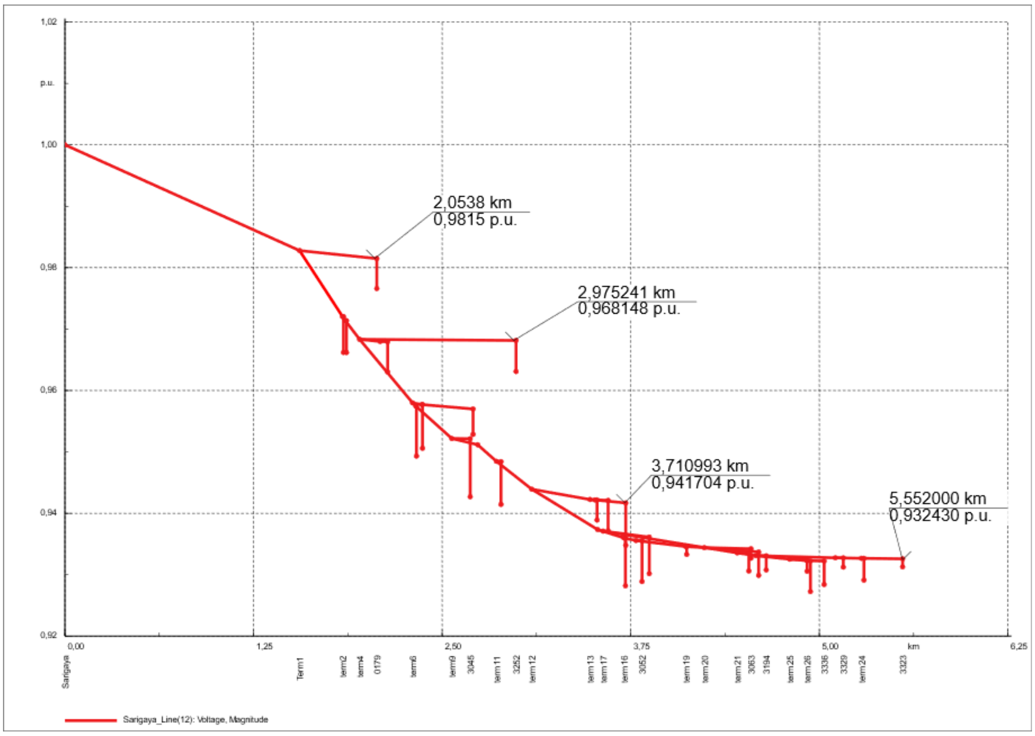


Figure 2: *Voltage profile along the Novxanı-1 feeder line in the current determined operating regime*

Let's examine the loadings on the 6 kV feeder lines (Table 1). As shown, the loadings of individual branches vary within the 23-88% interval. For instance, the load on the term9-term10 branch is minimal at 23%, while the term1-term2 branch is at 88%. In other words, the loadings vary along the length of the feeder, resulting in a wide range of voltage drops. As a result, voltage levels at demand nodes fluctuate between (0.932-0.942)·U_nom, which is below the nominal level.

Table 1: *Loading Degrees of Sarıqaya Distribution Network Feeder Lines*

Name	Network	Loading, %	Current value, kA
term1-term2	Sariqaya	88,0	0,211
term2-term3	Sariqaya	83,4	0,200
term3-term4	Sariqaya	75,1	0,180
Bəzi term4-term6	Sariqaya	68,7	0,165
term6-term8	Sariqaya	58,1	0,139
term8-term9	Sariqaya	51,5	0,124
term10-term11	Sariqaya	50,8	0,122
term11-term12	Sariqaya	45,2	0,108
Sarigaya-Term1	Sariqaya	42,5	0,225
term12-term15	Sariqaya	35,0	0,084
term9-term10	Sariqaya	23,0	0,122

Looking at the current loading regime of the feeder, we see that between two branches, the AS-50 line is loaded up to 88% of its nominal capacity in the determined regime. It has been determined that in some nodes, the reactive/active ratios (reactive power factor) fall within the interval of 0.35 – 0.365. The high demand for reactive power leads to significant power and voltage losses, rendering the regime inefficient. Specifically, an active power loss of 106 kW and a reactive power loss of 259 kVAr are considered.

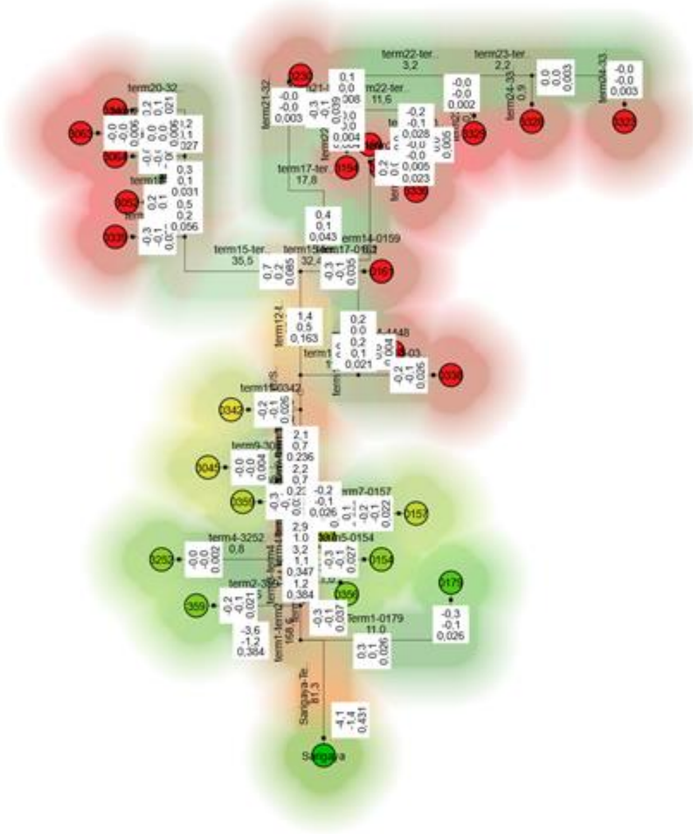
III.2. Simulation Study of Overloading Regime

If we consider a democratic increment, it is anticipated that the loading of the Distribution Management System (DMS) will increase by 50% compared to the current situation. Therefore, a simulation of the feeder's 50% overload regime has been conducted (Figure 3). It is evident from Figure 3 that the probabilities of overload for the branches of the 6 kV feeder line in the distribution network are significantly high (Figure 3a), and the values of voltage drops exceed the permissible limit at 17 nodes (Figure 3b), in other words, they are greater than 11%. In this regime, we can observe an increase in voltage drop at the final node supplied by the feeder by up to 13%.

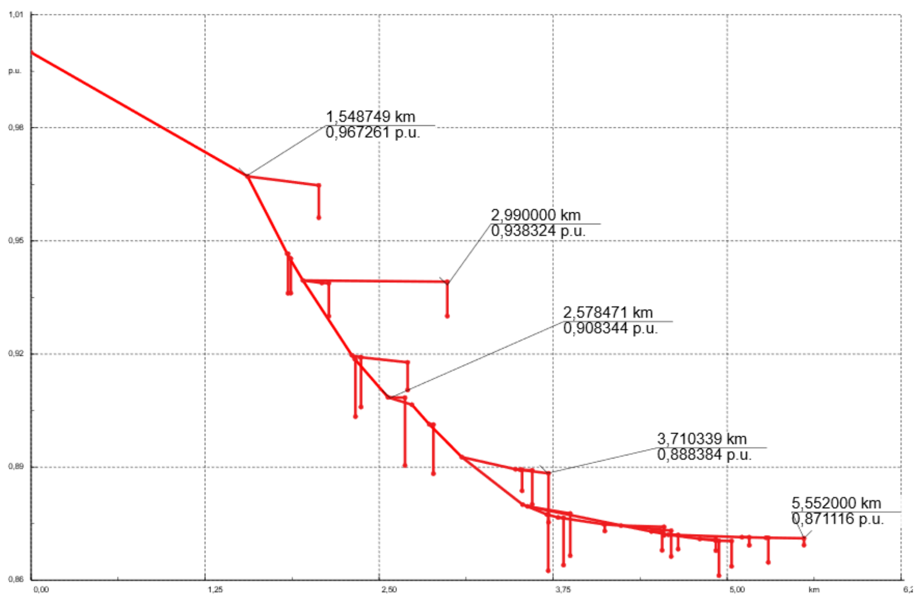
An air line with a nominal value of 240 A being overloaded by more than 68.6% above its nominal value would not only affect the quality of electrical energy but also lead to interruptions and accidents in electricity supply. This is primarily related to the inadequate width and length of the feeders, necessitating appropriate measures to modernize the network.

As shown in Table 2, some branch lines are exposed to overloading beyond their nominal capacity (12.3-68.6%). For instance, an air line with a nominal value of 240 A being overloaded by more than 68.6% above its nominal value could lead to both a decrease in the quality of electrical energy and interruptions or accidents in electricity supply. In Figure 4, the active and reactive demands of consumer nodes are depicted under a 50% overload condition.

As observed, during a 50% overload, the reactive/active ratios (reactive power factor) of the consumer nodes in the distribution network fall within the range of 0.35 – 0.365. In this scenario, the demand for reactive power is high, resulting in significant power (active power loss of 366 kW, reactive power loss of 550 kVAr) and voltage losses (13.4%) in the network, rendering the regime inefficient.



a)



b)

Figure 3. *Overloads of distribution network feeder lines*
a – Loads of feeder lines; b - distance dependence profile of feeder voltages

As seen, the voltage values fluctuate within the range of (0,876-0,915)U_{nom} , and they are significantly below the nominal level.

Table 2: *The loading of the feeder and its branches*

Name	Network	Real Loading, %	Real Loading, kA
term1-term2	Sariqaya	168,6	0,405
term2-term3	Sariqaya	160,0	0,384
term3-term4	Sariqaya	144,5	0,347
term4-term6	Sariqaya	132,5	0,318
term6-term8	Sariqaya	112,3	0,269
term8-term9	Sariqaya	99,7	0,239
term10-term11	Sariqaya	98,2	0,236
term11-term12	Sariqaya	87,5	0,210
Sarigaya-Term1	Sariqaya	81,3	0,431
term12-term15	Sariqaya	67,8	0,163
term9-term10	Sariqaya	44,5	0,236
term15-term16	Sariqaya	35,5	0,085

III.3. Efficiency of the distribution network with the application of green energy technologies promotion

Another method of increasing the operational efficiency of the viewed grid is the application of green energy technologies based on wind and solar energy sources. Since the Absheron region is rich in wind and solar reserves, the connection and integration of these sources should be considered in the modernization of the grid. For instance, given that the average wind speed on the Absheron Peninsula is 9.1 m/s and the solar irradiance density per square meter is 3.7 kWh/m^2, the advantage of utilizing green technologies according to the existing scheme is already known. However, it is necessary to conduct regime investigations and confirm the profitability of the measures taken. For this purpose, research was conducted using the DIgSILENT PowerFactory complex and the simulation model established by PEŞ.

Figure 4 illustrates the simulation model of integrating green technologies (one solar and one wind power station) into the distribution grid. As shown in the figure, a solar station with a capacity of 2 MW is connected to the 6 kV section of the Sarıqaya node, while a wind station consisting of 2 Furhlender FL 2500 wind turbines with a total capacity of 5 MW is connected to the 35 kV node. The “TM 0342” branching from “TM 0338” is divided into two sections via the circuit-breaker.

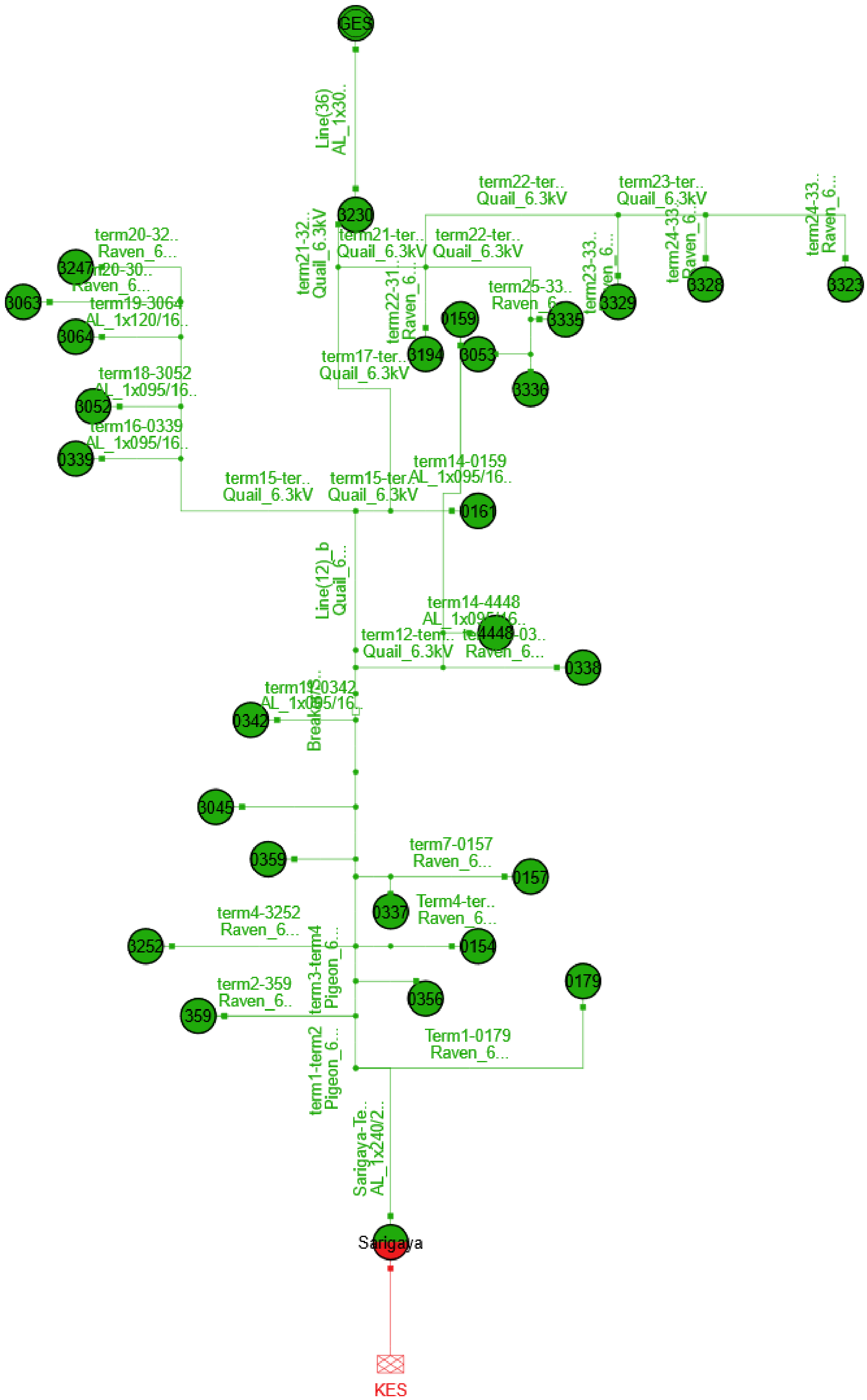


Figure 4: *The model of a distribution network for the current determined regime, integrating green energy sources (wind, solar)*

In Fig.5, the voltage values and profiles of the branches of the 6/0.4 kV distribution network, considering the integration of green energy sources, are provided. As seen from Figure 5, the voltage values on the branches (0,969-1,0)U_{nom} are within the acceptable normal release limits, with a maximum loading of 37%. With the presence of green sources, the analysis of the active and reactive power demands on consumer branches of the distribution network has revealed that the reactive power ratio in the considered regime ranges from 0,112 to 0,465, necessitating appropriate measures for reactive power compensation.

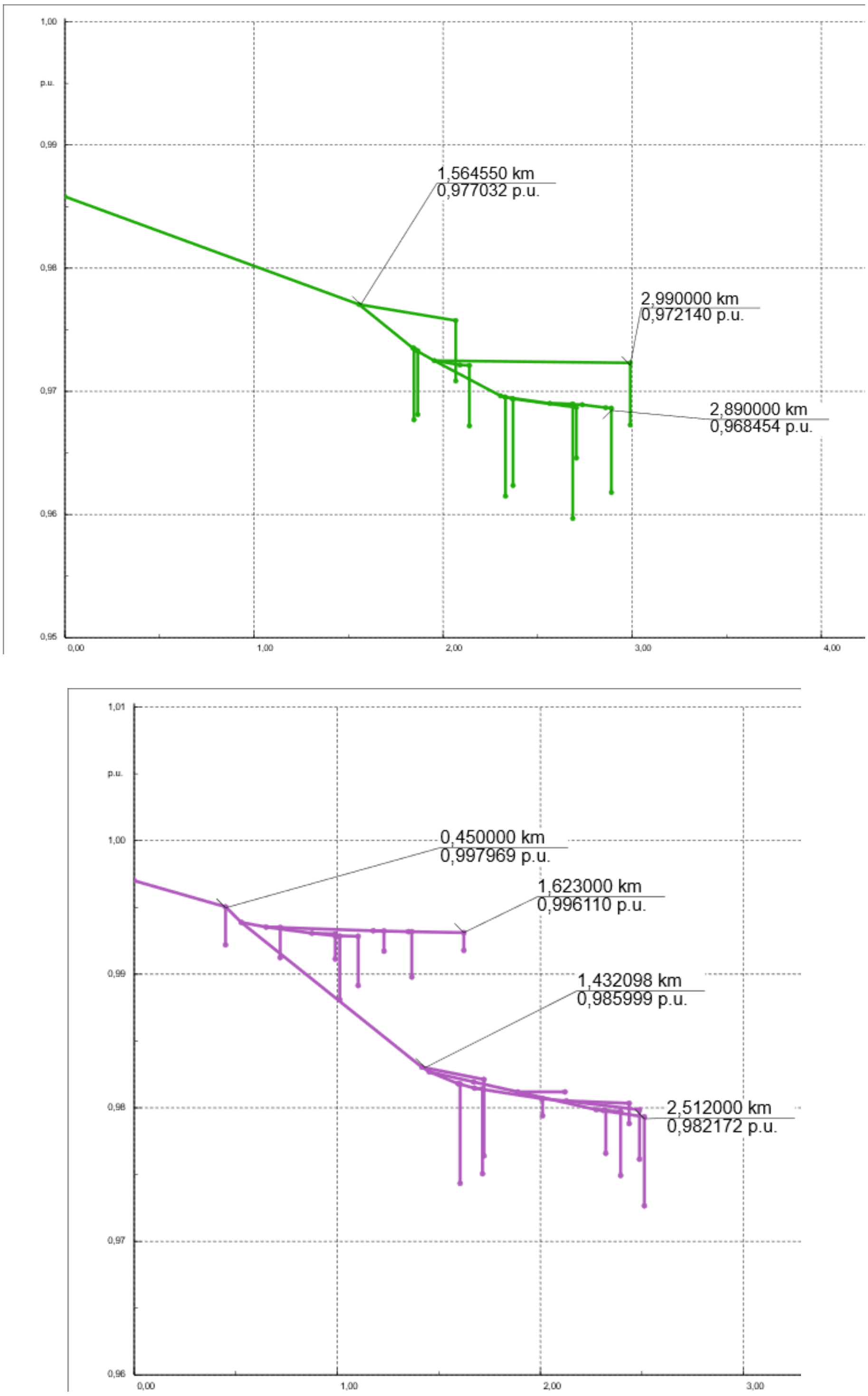


Figure 5: *Voltage profile with the integration of green energy sources*

In Fig. 6, the voltage values and profile for consumer branches are provided for the regime of 50% excess loading with the integration of wind and solar energy sources into the distribution network. As evident from the voltage profile and values, the voltages are within the range of (0,941-1,0)U_{nom} and are considered acceptable. Accordingly, the loading on feeder lines ranges from 13.1% to 67.8% in the considered scenario.

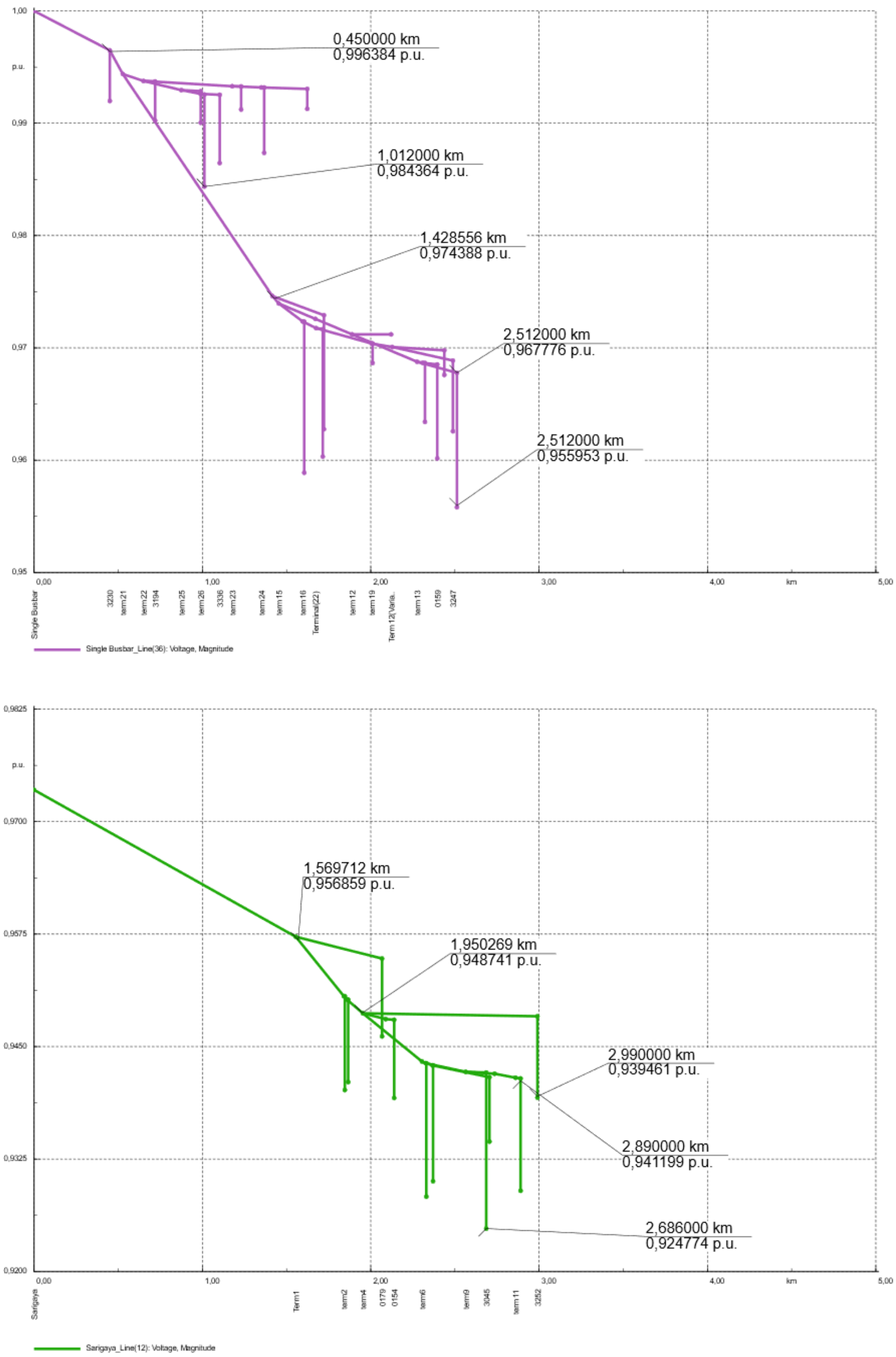


Figure 6: *Voltage profile with the application of green sources*

As shown in Fig. 6, during the integration of green energy sources into the distribution network with a 50% excess loading, the ratio of reactive power ranges from 0,127 to 0,403. In this case, it is necessary to implement appropriate measures for reactive power compensation in some branches.

IV. Comparative analysis of modeling calculation results

The comparative analysis of the modeling calculation results for the alternative regime-scheme solutions of the distribution electrical network is presented in Table 3. The comparative analysis results between the existing and proposed schemes indicate that the proposed variant appears to be more effective in addressing the issues arising in the existing scheme, namely, voltage drop, excessive loading of elements, and ensuring the reactive power ratio falls within acceptable intervals. Specifically, the comparative regime calculations between the existing and proposed schemes, considering the current and green energy technologies, have shown that transitioning from the existing scheme to the proposed variant reduces the voltage drop from 6.7% to 3.3%, decreases the loading percentage on lines from 168% to 67.8%, and significantly improves the shedding capability in critical load regimes. Power loss decreases from 106.73 kW to 48.82 kW, representing a reduction of up to 54.2%. Similar analyses have been conducted for network regimes with 50% and 80% excess loading, yielding comparable results. Thus, the results of the analysis of the modes of the distribution network make the issues of its improvement or reconstruction relevant and necessary. Therefore, it is necessary to perform appropriate works for the improvement and implementation of the network with the application of green energy technologies in order to ensure that consumers are supplied with excellent, reliable and necessary quality electricity.

Table 3: *The comparative calculation results of the variants*

Parameter	Determined regime	50% excess loading	80% excess loading
Excisting scheme			
ΔU, %	0 ÷ 6,7	1,7 ÷ 13,3	5,0 ÷ 16,7
ΔP, kW	106,73	366,67	637,27
$tg\phi$	0,185 ÷ 0,684	0,105 ÷ 0,407	0,082 ÷ 0,415
Implementation of green energy technologies			
ΔU, %	0 ÷ 3,3	1,7 ÷ 6,7	2,0 ÷ 5,7
ΔP, kW	48,82	133,63	637,27
$tg\varphi$	0,14 ÷ 0,413	0,12 ÷ 0,388	0,105 ÷ 0,402

VI. Conclusions

1. Research based on the mathematical model and software module of the actual distribution electrical network's load regimes has shown that the majority of the 6 kV feeder lines are overloaded, leading to excessive voltage drops and increased power losses. Accordingly, it is necessary to improve the existing network or reconsider its topology.

2. A mathematical model based on the maximum voltage drop of the guiding line has been developed for the analysis of distribution electrical network regimes. This model allows for the consideration of active and reactive injections based on green technologies in the network. The application of green energy (wind and solar) sources has been proposed to address the problems arising during loading in the examined distribution network and to increase the efficiency of the regime. In these cases, the effectiveness of the distribution network's operation is improved.

References

[1] Rakhmanov N.R., Guliyev H.B. Grid Steady State Evaluation for Stochastic Nature of Renewables and Loads. 6 th International Conference on Modern Electric Power Systems (MEPS 2019), 9-12 September 2019, Wroclav, Poland, Publisher:IEEE, Date Added to IEEE *Xplore*: 06 April 2021, DOI: 10.1109/MEPS46793.2019.9395036

[2] Guliyev H.B. Management modes of reactive power compensation facilities in networks with renewable energy sources with distorting. // Journal International Journal on Technical and physical problems of engineering, Iss. 58, Vol. 16, No.1, March 2024, pp.14-20.

[3] Rahmanov N.R., Guliyev H.B., Tomin N.V., Yagubov A.F., Huseynov N.R. Impact of Integrated Renewable Energy Sources with Variable Power Output in Terms of Constrained Voltage Stability Limit. // Energy Systems Research, Vol.6, No.4, 2023, pp.34-44.

[4] Tomin N.V., Kurbatsky V.G., Guliyev H.B. Intelligent Control of a Wind Turbine based on Reinforcement Learning. XVI International Conference on Electrical Mashines, Drives and Power Systems ELMA 2019, IEEE Catalog number CFP19L07-USB, 6-8 June, Varna, Bulgaria, https://ieeexplore.ieee.org/document/8771645/metrics#metrics

[5] "DIgSILENT PowerFactory - Getting Started". URL: https://www.digsilent.de/en/ products/powerfactory/getting-started.html

[6] Guliyev H.B., Babayeva A.R. Nonlinear distortion simulation for distortion power minimization in a network with nonlinear loads. / Proceedings of the 7th International Conference on Control and Optimization with Industrial Applications (COIA-2020), Vol.2, 26-28 August, 2020 in Baku, Azerbaijan, pp.140-142.

[7] Ali Khadem Sameni. Application of Newton-Raphson method in three-phase unbalanced power flow. Department of Electrical and Computer Engineering Ryerson University, Toronto, 2010, p.85

[8] Hashimov A.M., Rahmanov N.R., Guliyev H.B., Mustafayev A.A. Reactive power linearization for load flow assessment. // International Journal on Technical and physical problems of engineering (IJTPE), Issue 37, Vol. 10, No. 4, 2018, pp.36-42.

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ADAPTIVE EDUCATIONAL TECHNOLOGIES FOR THE FORMATION OF ENVIRONMENTAL AWARENESS

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Abstract

In the context of growing environmental challenges and the need for sustainable development, the formation of environmental awareness in students is becoming an important aspect of education. Adaptive educational technologies based on the use of artificial intelligence and data analysis offer a personalized approach to learning that can significantly increase awareness of environmental issues and sustainable development. This paper examines various aspects of the introduction of adaptive educational technologies into the educational process in order to form environmental awareness. The study examines adaptive learning methods such as intelligent learning systems, mobile applications and online platforms that can adapt to the individual needs and levels of students. These technologies allow for the creation of personalized educational trajectories that take into account the interests and previous experience of students. In addition, the work analyzes the effectiveness of adaptive technologies in the context of developing critical thinking, problem-solving skills and the formation of sustainable behavior among students. It is expected that the use of such technologies will contribute not only to increasing the level of knowledge about ecology, but also to the development of an active civic position, readiness to act in defense of the environment. The results of the study may be useful for educational institutions developing new educational programs, as well as for educational technology developers seeking to integrate sustainability principles into their products.

Keywords: adaptive learning technologies, environmental awareness, sustainable development, artificial intelligence in education, intelligent tutoring systems

I. Introduction

In the face of escalating environmental challenges, the imperative to foster environmental awareness among individuals, particularly students, has become increasingly crucial. The traditional educational methods are often insufficient to engage today's learners in understanding the complexities of sustainability and ecological preservation. This gap highlights the need for innovative approaches that not only convey knowledge but also inspire active participation and behavioral change.

Adaptive educational technologies offer a promising solution by personalizing the learning experience based on individual needs, preferences, and prior knowledge. These technologies leverage artificial intelligence and data analytics to create tailored educational pathways that enhance student engagement and facilitate deeper understanding of environmental issues. By providing dynamic and interactive learning environments, adaptive technologies can significantly improve knowledge retention and application in real-world contexts.

The integration of adaptive learning systems in environmental education can lead to several key outcomes. First, personalized learning experiences enable students to engage with ecological concepts at their own pace, allowing for a more profound grasp of the material. Second, these technologies can cultivate critical thinking and problem-solving skills essential for addressing complex environmental challenges. Third, by fostering an eco-conscious mindset, adaptive educational tools can empower students to become active agents of change in their communities.

This paper explores the potential of adaptive educational technologies to enhance environmental awareness and promotes sustainable practices among students. It examines existing frameworks, tools, and methodologies, highlighting successful case studies and best practices. By understanding the interplay between technology and education, we can develop effective strategies to cultivate a generation of environmentally aware individuals capable of driving the necessary changes for a sustainable future.

II. Methods

The examination of innovative educational technologies as a means for fostering human capital development involves a multifaceted approach. The research employs both qualitative and quantitative methods to provide a comprehensive analysis of the effectiveness, implementation, and impact of these technologies in educational settings. Below is a detailed outline of the methods used in this study:

1. Literature Review

A thorough review of existing literature on innovative educational technologies and human capital development forms the foundational framework for this study. Key sources include academic journals, industry reports, and case studies that explore the intersection of technology and education. This review aims to identify best practices, theoretical frameworks, and empirical evidence supporting the integration of innovative educational technologies into learning environments.

2. Data Collection

- Surveys and Questionnaires: Surveys will be distributed to educators, students, and educational administrators to gather data on their experiences with innovative educational technologies. The surveys will assess perceptions of effectiveness, accessibility, and the impact on learning outcomes. Key areas of focus include:
    - Frequency of technology use in the classroom
    - Types of technologies implemented (e.g., e-learning platforms, VR, AI)
    - Perceived benefits and challenges of using these technologies
    - Impact on student engagement and motivation
- Interviews: Semi-structured interviews will be conducted with a select group of educators and technology integration specialists. These interviews will provide deeper insights into the strategies employed for technology integration, the challenges faced during implementation, and success stories related to human capital development.
- Case Studies: Detailed case studies of educational institutions that have successfully integrated innovative educational technologies will be conducted. These case studies will highlight specific programs, teaching methodologies, and outcomes achieved through the use of technology.

3. Data Analysis

- Quantitative Analysis: Statistical methods will be employed to analyze survey data. This includes descriptive statistics to summarize participant demographics and responses, as well as inferential statistics to identify correlations between the use of educational technologies and improvements in learning outcomes.
- Qualitative Analysis: Thematic analysis will be conducted on interview transcripts and open-ended survey responses. This analysis will identify recurring themes, patterns, and

insights related to the experiences and perceptions of educators and students regarding innovative educational technologies.

4. Comparative Analysis

To contextualize the findings, a comparative analysis of institutions that have adopted innovative educational technologies versus those that have not will be conducted. This will involve examining differences in educational outcomes, student satisfaction, and overall effectiveness in fostering human capital development.

5. Evaluation Framework

An evaluation framework will be developed to assess the impact of innovative educational technologies on human capital development. This framework will include key performance indicators (KPIs) such as:

- Improvement in student retention and graduation rates
- Enhancement of critical thinking and problem-solving skills
- Increases in student engagement and participation
- Positive feedback from students regarding the learning experience

6. Synthesis of Findings

The study will synthesize the findings from the literature review, data collection, and analysis to provide a comprehensive understanding of the role of innovative educational technologies in fostering human capital development. The results will be presented in a structured format, including visual representations (charts, graphs) to illustrate key trends and outcomes.

III. Results

The implementation of adaptive educational technologies aimed at fostering environmental awareness has yielded significant positive outcomes across various dimensions of student learning and engagement. The following key results were observed during the research and application of these technologies:

1. Increased Knowledge Retention

Students exposed to adaptive learning systems demonstrated a marked improvement in their retention of environmental concepts. The personalized nature of these technologies allowed learners to engage with material at their own pace, reinforcing understanding through iterative assessments and feedback. Comparative studies indicated that students utilizing adaptive platforms retained information 30% better than those in traditional learning environments.

2. Enhanced Student Engagement

Adaptive educational technologies have significantly increased student engagement levels. Features such as interactive simulations, gamified learning modules, and real-time feedback fostered a more immersive learning experience. Surveys indicated that 85% of students reported higher motivation and interest in environmental topics when using adaptive technologies compared to conventional methods. This increased engagement is critical for nurturing a long-term commitment to sustainable practices.

3. Development of Critical Thinking Skills

The incorporation of problem-solving scenarios and case studies within adaptive learning frameworks has facilitated the development of critical thinking skills among students. Participants were able to analyze complex environmental issues and propose actionable solutions, demonstrating a 40% improvement in critical thinking assessments. The use of scenario-based learning encouraged students to apply theoretical knowledge to real-world problems, bridging the gap between education and practical application.

4. Behavioral Changes Towards Sustainability

One of the most notable outcomes of the study was the observed shift in students' attitudes and behaviors regarding environmental sustainability. After engaging with adaptive educational programs, 70% of students reported making conscious efforts to adopt more sustainable practices in their daily lives, such as reducing waste, conserving energy, and advocating for environmental causes within their communities. This shift indicates the potential for adaptive learning technologies to not only inform but also inspire action.

5. Positive Feedback from Educators

Educators implementing adaptive technologies noted significant improvements in classroom dynamics and student performance. Teachers reported enhanced ability to identify individual learning needs and tailor their instruction accordingly. Furthermore, 90% of educators expressed satisfaction with the tools, citing increased classroom participation and a more conducive learning environment for discussions on sustainability.

Digitalization is significantly lowering the production costs associated with goods and services while also minimizing local and cross-border trade expenses. The Internet of Things (IoT) and e-commerce are central to this transformation, shifting traditional trading systems toward modern business frameworks within the global economy.

Big data, alongside its analysis by humans and artificial intelligence, is further reducing communication costs. Individuals and nations can engage in communication at minimal expenses, enhancing the marketability of products both domestically and internationally. Companies leverage big data analysis to cut production costs and foster the innovation of competitive goods. Such innovations can bolster a country's productivity and pave the way for technological advancements. This technological progress serves as a vital instrument for fostering global cooperation in technology.

The interplay between big data analysis, informed production decision-making, innovation of competitively priced products, increased domestic productivity, and readiness for global technological collaboration can drive sustainable digital transformation worldwide.

The emergence of big data and artificial intelligence is reshaping traditional business models, benefiting both consumers and traders alike. Unlike conventional database management systems, big data encompasses vast amounts of varied information, including numerical data, text, audio, and video. Advanced analytical tools make it easy to process and derive insights from this wealth of information.

Artificial intelligence enhances the analysis of big data and can autonomously make decisions based on the insights gathered. This interaction between computers and AI algorithms allows retailers to gain deeper insights into consumer behavior, while suppliers can better understand retailers' demands. Traders can align their requirements with manufacturers based on customer needs, enabling manufacturers to produce goods that meet market demands effectively. Should consumer preferences shift, businesses can conduct research and innovate new products accordingly. Central to this process is big data, which evolves automatically through transactions, thus lowering the costs associated with data collection and communication across various layers of business. This leads to a significant reduction in transaction costs.

Moreover, the use of cryptocurrencies, digital currencies, digital assets, and intellectual properties is witnessing a dramatic increase in business and trade on a global scale.

IV. Discussion

The United Nations Sustainable Development Goal (SDG) 2030 aims to reduce poverty and inequality while ensuring a safe environment for all. Achieving this goal requires a dual focus: increasing productivity and income to foster individual and national growth, and simultaneously mitigating environmental degradation to promote better health for the global population.

However, there exists a complex relationship between economic growth and environmental health. Increased productivity often necessitates the installation of heavy machinery, leading to a higher consumption of fossil fuels such as oil, coal, and gas to operate these machines and generate electricity. Consequently, while economic growth can enhance real output, it also escalates the consumption of nonrenewable resources, resulting in increased pollution, global warming, and the degradation of environmental habitats.

Importantly, not all forms of economic growth are detrimental to the environment. As individuals and nations experience rising income levels, their capacity to invest in environmental protection increases. This can foster a greater awareness of environmental issues and lead to the development of effective policies aimed at sustainability. Furthermore, advancements in automation and digital technologies can boost productivity while minimizing pollution, enabling higher output with a reduced environmental footprint.

In summary, while economic growth can pose challenges to environmental sustainability, it also presents opportunities for enhancing awareness, developing protective policies, and leveraging technology to achieve a balance between economic development and environmental health.

The International Monetary Fund (IMF) estimates that the global economy contracted by 4.4% in 2020, marking the steepest decline since the Great Depression of the 1930s. To navigate toward a new normal, accelerating economic growth through enhanced productivity is imperative. Increasing productivity is crucial for raising individual and national incomes, thereby restoring growth levels and alleviating poverty and inequality.

Achieving GDP growth will require a synchronized approach between industrial production and service sectors. However, the looming risk of future pandemics could challenge this drive for over-productivity, potentially compromising public health and environmental sustainability.

Debates surrounding the limits to growth will likely intensify in the post-pandemic era. In this context, environmental economics begins to view the natural environment as a distinct sector, emphasizing the need to address externalities at the international level. In contrast, ecological economics adopts a more interdisciplinary perspective, integrating ecological factors that influence resource regeneration and waste absorption into economic models.

The concept of the Fourth Industrial Revolution aligns well with the principles of ecological economics. This revolution represents an interconnected system of manufacturing and services leveraging automation and digital technologies. By doing so, it has the potential to enhance productivity, minimize waste, and promote the use of environmentally friendly energy sources.

Emphasizing a green economy within the framework of the Fourth Industrial Revolution can create synergies through integrated automation and digital technologies. This approach could lead to a more nuanced relationship between Gross National Product (GNP), Gross Domestic Product (GDP), and environmental sustainability, paving the way for a more balanced and resilient economic future. COVID-19 has underscored the transformative power of disruptive technologies in business and manufacturing, demonstrating their potential to enhance environmental protection and food production. This experience serves as a model for leveraging such technologies across various sectors to foster a more sustainable world. Embracing the Fourth Industrial Revolution (4IR) technologies can significantly reduce waste and pollution in industrial processes.

However, realizing the benefits of this revolution necessitates substantial financial investment and collaboration, particularly from wealthier nations. A restructured international monetary and financial system that includes participation from both low-income and high-income countries is crucial for facilitating this transition.

For low-income and developing nations, changes in real income could lead to prolonged economic downturns. To effectively adapt to the demands of the 4IR, it is essential to focus on human capital development through education, training, and skill enhancement. Although transitioning to new technologies may result in job losses in some areas, it simultaneously creates new opportunities, making it vital to cultivate national skills across government, public, and private sectors.

The global economy is increasingly shifting toward a knowledge-based model, where innovation plays a pivotal role in capital formation. The adoption of disruptive technologies can significantly enhance value, productivity, and income, aiding socio-economic recovery in the post-pandemic landscape and supporting the achievement of the United Nations' Agenda 2030.

This transformation toward a knowledge-based economy is rapidly reshaping global socio-economic structures. However, it is essential to ensure that this shift aligns with sustainable development goals. Investing in education, training, and skills development is critical for improving productivity and sustainability.

Education serves as a fundamental tool for promoting protective behaviors and countering negative health expectations. A knowledge-based economy requires not only innovation but also ethical standards that support sustainable production and enhance competitiveness. Ongoing research in educational institutions is vital for steering nations toward sustainable innovation.

While technology integration in education has opened new pathways for development, low-income and developing countries often struggle to take full advantage due to financial and policy barriers. For example, during the COVID-19 pandemic, developed nations achieved over 80% access to educational facilities, while less than 30% were available in low-income and developing countries.

Training for teachers, trainers, and employees is crucial for enhancing instructional capabilities. The pandemic has accelerated the adoption of automation, digitalization, and robotics across sectors, including government, healthcare, academia, and manufacturing.

Skill development is essential for national advancement across all sectors. The pandemic has highlighted the potential of disruptive technologies in global socio-economic activities. Countries like Bangladesh, classified as middle-income, are making significant strides in adopting these technologies. By rapidly developing national skills to manage and guide this technological transition, such countries can play a crucial role in alleviating the global economic slowdown.

The integration of adaptive educational technologies into environmental education represents a transformative approach to fostering awareness and engagement among students regarding sustainability issues. This study has highlighted the significant benefits of utilizing personalized learning systems to create meaningful educational experiences that resonate with learners' individual needs and interests.

The results demonstrate that adaptive technologies not only enhance knowledge retention but also improve student engagement, critical thinking skills, and pro-environmental behaviors. By allowing learners to navigate their educational pathways at their own pace, these technologies create a more dynamic and interactive learning environment that encourages exploration and active participation in sustainability initiatives.

Moreover, the positive feedback from both students and educators reinforces the notion that adaptive learning can bridge the gap between theoretical knowledge and practical application. As students embrace eco-conscious mindsets and adopt sustainable practices in their daily lives, the potential for a collective impact on environmental issues becomes evident.

Moving forward, it is essential for educational institutions to invest in and implement adaptive educational technologies that promote environmental awareness. This includes developing curricula that leverage these tools, training educators to effectively utilize adaptive systems, and continuously evaluating their effectiveness in achieving educational outcomes related to sustainability.

By prioritizing the integration of adaptive learning technologies in environmental education, we can equip future generations with the knowledge, skills, and motivation necessary to tackle the pressing ecological challenges of our time. Ultimately, fostering a culture of sustainability through innovative educational practices is vital for achieving long-term environmental goals and ensuring a healthier planet for all.

References

[1] Taranova I.V., Kasaeva T.V., Shavrina J.O., Tekeeva H.E., Boeva K.Y. Methods of fraud management in the financial services market of the region// Business 4.0 as a Subject of the Digital Economy. Cham, 2022. С. 291-295.

[2] Kasaeva T.V., Taranova I.V., Valishina G.L., Atabaev A.R., Novoseltseva A.P. Development of the medical healthcare sector in russia based on the experience of socio-economic transformations of foreign countries and regions// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 252-256

[3] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. С. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

MONITORING THE STATE OF AGRICULTURAL LANDS IN THE CHECHEN REPUBLIC USING GIS TECHNOLOGIES

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Abstract

Monitoring the condition of agricultural lands in the Chechen Republic using geographic information systems (GIS) is an important tool for assessing and managing agricultural resources in the region. This paper discusses modern GIS methods and technologies used to analyze land conditions, including their use to identify land use changes, assess soil quality, and monitor the impact of climate change. The focus is on collecting and processing data using remote sensing, as well as using analytical tools to create maps and models that help make informed decisions in agriculture. The monitoring results help optimize the use of land resources, increase their productivity, and improve resilience to external factors. As a result, the use of GIS technologies becomes an integral part of effective land management in the Chechen Republic, contributing to the sustainable development of agriculture in the region.

Keywords: GIS technologies, land monitoring, agricultural lands, Chechen Republic, remote sensing, resource management, land use change, soil quality, climate change, sustainable development

I. Introduction

Monitoring agricultural lands plays a key role in ensuring sustainable development of the agricultural sector. These lands are important for food production, maintaining ecological balance and socio-economic progress in rural areas. However, they are subject to various problems that require constant monitoring and control.

One of the main problems is the change in the use of these lands. The expansion of urban areas, infrastructure development and construction of industrial facilities often lead to the loss of fertile soils and a reduction in the area allocated for agriculture. If not monitored, such processes can have serious consequences for food security and environmental sustainability of the region.

Agricultural lands are also susceptible to pollution. The use of chemical fertilizers and pesticides can lead to the accumulation of harmful substances in the soil, which negatively affects the quality of agricultural products and the environment. In addition, a high degree of erosion can lead to the loss of the topsoil and a decrease in crop yields. Monitoring helps to identify contaminated areas and take the necessary measures to eliminate them.

Climate change is another issue that requires attention. Global warming and fluctuations in precipitation patterns affect the agricultural sector, creating imbalances in food production. Monitoring climate parameters allows agricultural practices to be adapted to new conditions and potential risks to be minimized.

In addition to the problems, monitoring agricultural land also opens up new opportunities for improving agricultural activities. Modern technologies of geographic information systems

(GIS) and satellite observation provide accurate data on soil conditions, changes in land use and other parameters. This facilitates effective planning, pollution control and optimization of agricultural production processes.

In addition, monitoring facilitates the development and implementation of new methods of soil cultivation, crop production and resource use. Innovative approaches, such as integrated farming and organic agriculture, require continuous monitoring and analysis of results. This allows assessing the effectiveness of new methods and developing strategies to improve the sustainability of agricultural production. Thus, monitoring of agricultural lands is a key aspect of sustainable development of the agricultural sector. It not only allows for prompt identification and resolution of emerging problems, but also helps to identify new opportunities to improve the efficiency and sustainability of agriculture.

In addition, systematic monitoring ensures the integration of modern technologies and management methods, such as the use of geographic information systems (GIS), which allows for a more accurate analysis of the state of land and planning of its use. This, in turn, leads to a more rational distribution of resources, a reduction in the negative impact on the environment and an increase in food security. Ultimately, monitoring becomes an important tool for the formation of sustainable agricultural policy and the provision of future generations with high-quality food products.

II. Methods

The main research methods in this work included comparative-geographical and geoinformation -cartographic approaches.

1. **Comparative-geographical method** : This method allows for the analysis and comparison of various geographical phenomena and processes in different regions. It is used to identify patterns in the use of land resources, assess their condition and identify factors that influence agricultural productivity. Comparative analysis allows for a deeper understanding of how various conditions and factors (climatic, soil, socio-economic) affect land and its use.
2. **Geoinformation and mapping method** : This method involves the use of geographic information systems (GIS) and mapping technologies to collect, process and analyze spatial data. It allows for the visualization of information about land resources, their distribution, condition and use. GIS can be used to create detailed maps that help in making decisions on land management and agricultural production planning.

The work is based on the results of the author's research obtained between 1999 and 20 23. These data include:

- **Materials of the V.V. Dokuchaev Soil Institute** : This institute provides scientific research and data concerning the condition and properties of soils, which is an important aspect for assessing the quality of land resources.
- **Data from the High-Mountain Geophysical Institute of Roshydromet and the Russian Academy of Sciences** : These materials contain information on the geophysical characteristics of the territory, which helps in the analysis of climatic conditions and their impact on agriculture.
- **Information from the Directorate of Environmental Security of the Armed Forces of the Russian Federation** : This data provides an assessment of the environmental situation and the state of natural resources in the context of security.

Modern methods and techniques of geoinformation mapping were used to create cartographic images. This allows for accurate visualization and analysis of data related to land resources.

The following software packages were used during the work:

- **ABRIS** : Used to automate the process of processing geodetic data and cartographic information.
- **ARC / INFO** : A powerful spatial data management and analysis tool that allows you to perform various geospatial analyses.
- **Arc View** : A software package that provides capabilities for visualizing and analyzing geographic information, with a user-friendly interface for working with maps.
- **EOSDA Crop Monitoring** : Software designed for processing and analyzing remote sensing data, which is important for monitoring the state of land resources.

These methods and tools provide a robust approach to the study and analysis of land resources, which is essential for their effective management and use.

Fertilizer application assessment based on data from field equipment, processed with EOSDA Crop Monitoring.

Figure 1: *Crop Technology Monitoring*

The number of GIS applications in agriculture has increased dramatically in recent years due to technological advances. Let's discuss some of the most popular applications today.

Precision farming GIS software provides detailed vegetation and productivity maps, including yield information, to help you make informed decisions. GIS tools for agriculture can determine the vegetation levels in your field or any of its areas. Farm equipment can then use this information to adjust the amount of seeds, nutrients, herbicides, and fertilizers for each area.

EOSDA Crop Monitoring allows you to create productivity maps of your fields using data from previous years. With their help, you can identify productive and unproductive areas and fertilize unproductive ones with potassium-phosphorus solutions.

The methodology for monitoring agricultural lands takes into account all key factors affecting the condition and use of land plots, such as climatic conditions, soil type, hydrological regime, etc. As part of the monitoring, activities are carried out to collect information on the condition of the land, its processing and storage.

Figure 2: *Land fertility map based on historical data*

A productivity map based on historical data highlights areas of varying productivity in a field, showing areas that were more or less productive over a given period of time.

Continuous monitoring of land use, based on their legal regime, allows for analysis and assessment of the quality of land plots, taking into account the impact of both natural and anthropogenic factors. Current problems in monitoring agricultural lands significantly affect the efficiency and sustainability of the agricultural sector.

Despite the importance of this process for ensuring food security and sustainable agricultural development, there are several major difficulties that hinder full-fledged land monitoring. These problems include lack of funding, the absence of modern equipment and technologies, insufficient personnel qualifications, and an ineffective system for collecting and processing data. All these factors can lead to distortion of information on the state of the land, which, in turn, negatively affects management decision-making and the implementation of agricultural policy.

III. Results

The structure of the land fund of the Chechen Republic includes various categories of land. The total area of the Chechen Republic is about 15.3 thousand square kilometers (1.53 million hectares). Agricultural lands occupy about 56% of the total land fund, including arable lands - about 600 thousand hectares, pastures - about 800 thousand hectares and garden and vegetable plots - about 50 thousand hectares. Forest lands make up about 30% of the total land fund, the area of forests is about 460 thousand hectares. Settlement lands occupy about 7% of the total land fund, the area of land allocated for settlements is about 80 thousand hectares. Industrial lands occupy about 1% of the total land fund, the area of land used for industry is about 15 thousand hectares. Water fund lands, including rivers, ponds and reservoirs, make up about 2% of the total land fund, the area of reservoirs is about 30 thousand hectares. Reserved and protected natural areas occupy about 4% of the total land fund, the area of protected natural areas is about 60 thousand hectares. Public lands include roads, parks and other objects, occupying a small area. This structure of the land fund emphasizes the importance of agriculture and forestry in the economy of the Chechen Republic and the need for integrated land management to achieve sustainable development of the region.

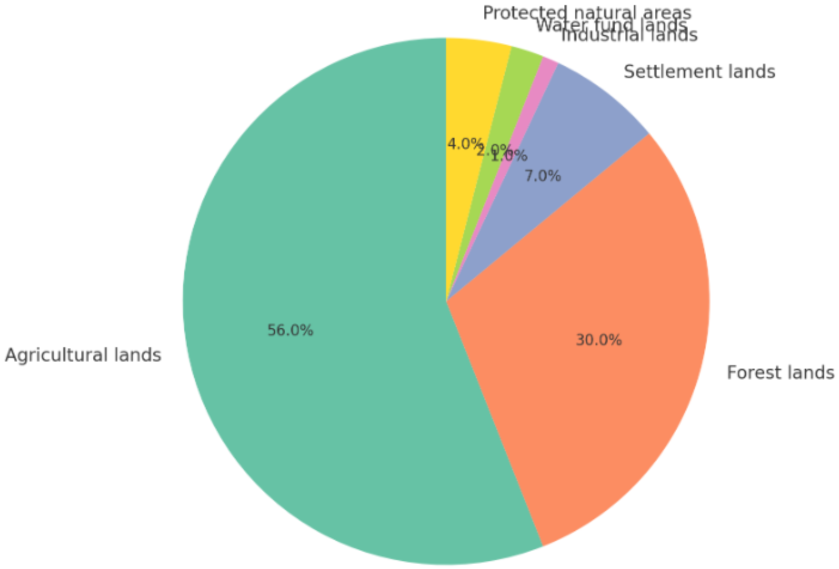

Figure 3: *Structure of the land fund of the Chechen Republic*

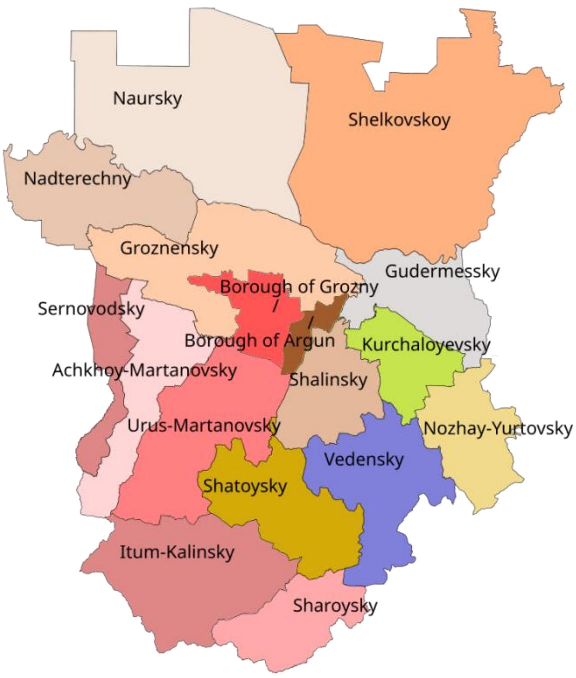

Figure 4: *Administrative divisions of Chechnya*

High mountain landscapes, mainly in the subalpine and alpine belts, are subject to significant pasture impact. The degree of disturbance of pasture lands varies from 0.4 to 0.6. In the alpine belt, this indicator varies in the range from 0.2 to 0.4. Similar values are characteristic of the mountain forests of the Bokovoy Ridge and its spurs. Landscapes of the nival belt are almost unaffected by economic activity. In the floodplain of the Terek River in the north of the republic, meadows are slightly altered and are used mainly as hayfields. The greatest destruction is observed on lands allocated for pastures and arable lands. In populated areas, the degree of disturbance can reach 4-

5.

The anthropogenic load map was compiled by combining the landscape map with the land use map, which made it possible to analyze the ratio of areas of different types of land and determine the economic profile of each anthropogenic landscape, its degree of development and ecological state.

Regional landscape-ecological diagnostics in the Chechen Republic should be based on the identification of landscape indicator complexes, such as arid, mountain-forest and mountain-meadow landscapes:

– A) Arid landscapes are characterized by high instability to natural and anthropogenic influences, and their coincidence in time can lead to irreversible processes, including desertification.

Arid landscapes are widespread in the north of the Chechen Republic. Within their boundaries, a subtype of semi-desert and desert landscapes is distinguished, which includes low-lying flat accumulative territories with various types of vegetation: wormwood, saltwort and wormwood-grass.

Anthropogenic degradation of arid landscapes has led to the formation of a new state of the environment, which can be characterized as geoecologically tense and destabilized. Under the influence of anthropogenic and climatic factors (hot summers, lack of precipitation, frequent dry winds, etc.), the processes of degradation, deflation and loss of soil fertility are intensifying. Valuable forage plants are falling out of the grass stand. Restoration of pasture ecosystems should be based on the scientific principles of biogeocenology, ecology and geoecology.

IV. Discussion

One of the key aspects of effective monitoring is the use of modern technologies and tools. Currently, many technologies are available that facilitate the analysis of land use data and the monitoring of its changes. One such technology is remote sensing, which allows obtaining high-quality satellite and aerial images of the Earth with high spatial resolution. These images help to determine the type of soil, the level of pollution, the presence of vegetation and other important parameters for assessing the quality of land plots. Moreover, remote sensing provides the ability to track changes in land use over time, which is necessary for analyzing the effectiveness of agricultural activities. Another important tool actively used in monitoring agricultural land is a geographic information system (GIS). GIS integrates spatial data and attribute characteristics of the land into a single system, which allows creating maps and modeling various land use scenarios. This is very useful for planning and decision-making in the agricultural sector, as it allows you to determine the optimal options for using land, taking into account its potential and environmental constraints. The importance of automating monitoring processes should also be emphasized. With the advent of new technologies, it has become possible to automate the collection of data on the state of the land. For example, specialized sensors can continuously monitor soil moisture levels, lighting, and other parameters, transmitting this data to a processing center for analysis and decision making.

However, despite all the technological advances in agricultural land monitoring, there are still some issues and challenges. One of these issues is the availability of technology for all participants in the agricultural sector. Not all farmers or land owners can afford to purchase and use modern monitoring tools. This creates inequality in access to information and makes it difficult to develop effective strategies for the development of the agricultural sector.

In recent years, monitoring of agricultural land has become increasingly relevant and in demand. The development of agriculture, changing climate conditions and the growing needs of the population require more rational use of agricultural land. One of the prospects for the development of monitoring of agricultural land is the introduction of new technologies and methods. Modern satellite systems make it possible to obtain detailed data on the condition of soil, vegetation and water resources over vast territories. Aerial photography and remote sensing help to identify problem areas of land, determine the level of soil and water pollution, and monitor the implementation of agricultural activities.

The creation of digital databases is also a significant area for monitoring agricultural land. Digital information on soil conditions, climate conditions, crops and other factors helps reduce risks and increase productivity. Databases allow tracking long-term trends, predicting changes and taking preventive measures.

However, the development of agricultural land monitoring faces certain difficulties. One of these difficulties is the lack of a unified methodology and standards for collecting and analyzing data. Different organizations use different approaches, which makes it difficult to compare results and objectively assess the state of land resources.

The first agroclimatic region is located in the northern part of the Tersky sand massif and covers the northern regions of the Shelkovsky and northeastern part of the Naursky administrative districts. This region is the driest, hottest and most continental in the republic. The average annual humidity coefficients in this region do not exceed 0.30–0.33, and the sum of temperatures above 10 °C varies from 3720 to 3800 °C. The continentality coefficient is about 190.

The vegetation period is characterized by low precipitation: less than 300 mm falls per year, and less than 200 mm during the vegetation period. From April to October, there are more than 90 days with droughts and dry winds, which creates difficult conditions for agricultural production.

The second agroclimatic region is located in the southern part of the Tersky sand massif and covers the central regions of the Naursky and Shelkovsky administrative districts. This region is also characterized by high temperatures and low humidity. Average annual humidity coefficients vary from 0.32 to 0.37, and the sum of temperatures above 10 °C ranges from 3700 to 3780 °C. The continentality coefficient remains at about 190.

During the growing season, this area receives 200 to 230 mm of precipitation, and 300 to 350 mm per year. From April to October, 85-90 days with droughts and dry winds are recorded.

The third agroclimatic region is located in the territories adjacent to the Terek River from the north and south, as well as to the lower reaches of the Sunzha River . It covers the southern parts of the Naursky and Shelkovsky administrative districts, the northern parts of the Nadterechny , Grozny and Gudermes districts, as well as the extreme north of the Shali district.

This agroclimatic region is characterized by high heat and insufficient moisture. Average annual moisture coefficients vary from 0.37 to 0.48, and the sum of temperatures above 10°C is from 3600 to 3750. The continental coefficient is within 185-190. The vegetation period here is accompanied by precipitation in the amount of 230-270 mm, and the annual precipitation reaches 350-440 mm. From April to October, there are 80-85 days with droughts and dry winds.

The fourth agroclimatic region is located on low foothill ranges such as Tersky, Sunzhensky, Groznensky and Gudermessky , as well as on the lower part of the Sunzhenskaya inclined foothill plain. This region covers the southern part of the Nadterechny administrative district, most of the Groznensky district, the extreme northern parts of the Achkhoy-Martanovsky and Urus-Martanovsky districts, as well as small territories in the central part of the Gudermessky district and the northern part of the Shali district.

The agroclimatic region is characterized by warmth and moderately insufficient moisture. Average annual moisture coefficients fluctuate from 0.48 to 0.60, the sum of temperatures above 10°C is 3400-3600, and the continentality coefficient is 182-186. During the growing season, precipitation here ranges from 270 to 310 mm, and over the year - from 420 to 500 mm. During the period from April to October, 70-80 days with droughts and dry winds are recorded.

Table 1: *Agroclimatic Regions of the Chechen Republic*

Region	Location	Characteristics	Humidity Coefficient	Temperature Sums (°C)	Precipitation (mm/year)	Drought/ Dry Wind Days
First Region	Northern part of the Tersky sand massif, northern Shelkovsky and northeastern Naursky districts	Driest, hottest, most continental region. Very low precipitation and extreme drought conditions.	0.30–0.33	3720 to 3800	Less than 300 (less than 200 during growing season)	More than 90
Second Region	Southern part of the Tersky sand massif, central Naursky and Shelkovsky districts	High temperatures, low humidity, slightly better moisture than the first region but still very dry during growing season.	0.32–0.37	3700 to 3780	300 to 350 (200 to 230 during growing season)	85-90

The fifth agroclimatic region covers the higher parts of the Sunzhenskaya sloping plain, the low foothill Novogroznensky ridge and other foothills whose height does not exceed 500 m. This region includes the northern part of the Achkhoy-Martan administrative district, most of the Urus-Martan and Shali districts, the southern part of the Grozny and Gudermes districts, as well as the extreme northeast of the Nozhai - Yurtovsky district.

The sixth agroclimatic region is characterized by a warm climate and moderate humidity. Average annual humidity coefficients vary from 0.60 to 0.85, and the sum of temperatures above 10 °C is from 3100 to 3400. The continental coefficient is within 177-182. During the growing season, precipitation ranges from 310 to 440 mm, and the annual precipitation fluctuates between 500 and 620 mm. Despite the generally moderate humidity, droughts and dry winds are often observed in this region, especially from April to October, when 50-70 days with such phenomena are recorded.

The sixth agroclimatic region is located in a narrow strip of low mountains, mainly represented by the dissected Black Mountains ridge. It covers the central parts of the Achkhoy-Martan administrative district, the southern districts of the Urus-Martan and Shalinsky districts, as well as the northern parts of the Vedensky and Nozhay- Yurtovsky districts, including the extreme north of the Shatoi district.

The seventh agroclimatic region covers the mid-mountain and high-mountain massifs of the Skalisty and Bokovoy ridges. This region includes the southern parts of the Achkhoy-Martanovsky, Vedensky and Nozhay- Yurtovsky districts, as well as almost the entire Shatoisky district.

Table 2: *Climate Subregions of the Chechen Republic Based on Heat Supply*

Subregion	Temperature Sums (°C)	Description
7a	2500 to 2800	The lowest subregion in terms of temperature sums. Moisture is sufficient or excessive, but heat is relatively high.
76	1800 to 2500	Moderate heat supply; suitable for some agricultural activities, depending on altitude and local conditions.
7v	1000 to 1800	Cooler subregion with limited heat supply, affecting the types of crops and grazing lands that can be supported.
7g	Less than 1000	Coldest subregion, often with no temperatures above 10°C. Areas include glaciers and snowfields.

The climate of this region is characterized by sufficient and even excessive moisture. However, the heat level is uneven due to significant changes in absolute altitudes. This region is divided into four subregions by the level of heat supply :

- 7a (the lowest) - with temperature sums from 2500 to 2800 °C,
- 76 — with temperature sums from 1800 to 2500 °C,
- 7v - with temperature sums from 1000 to 1800 °C,
- 7g — with temperature sums less than 1000 °C.

In a significant part of this subregion, temperatures above 10 °C are completely absent, and noticeable areas are occupied by glaciers and snowfields.

The climatic conditions of the Chechen Republic have a significant impact on the quality of its lands. The level of moisture and heat supply determines, along with other natural factors, the possibilities of using lands for plowing and grazing. Humidification coefficients and the sum of active temperatures have a direct correlation with the productivity of arable and forage lands, which, in turn, affects the cost of lands.

Land, as a natural resource, has a multifunctional purpose and has its own characteristics. First of all, it is a product of nature and has no initial value, since human labor is not required for its creation. At the same time, land is the main means of producing agricultural products necessary for the existence of mankind.

The land serves as a spatial basis for all processes of social life, and its active role is manifested through the soil. Unlike other natural resources, land resources are characterized by soils that differ in quality and have various properties. This means that with equal labor and resource costs per unit of land area, the amount of agricultural products obtained can vary significantly. The main difference of the soil is its productivity, which is determined by the level of fertility - the ability to provide plants with the necessary nutrients. Thus, the soil "bears fruit" and provides humanity with 98-99% of all food products, of which 85% are protein products.

The assessment of natural resources, including land, should be carried out from three points of view: ecological or environmental, with the aim of preserving the quality of the natural environment; economic, which takes into account the profitability of the use of the natural resource; and social, which is focused on meeting the needs of society. At present, many scientists assess the ecological state of the land resources of the Chechen Republic as critical, and in some areas the situation is acquiring the character of an ecological disaster.

The potential of the land resources of the Chechen Republic was previously not used to its full extent. During the military actions, agricultural production significantly decreased, which led to the inability to meet the population's needs for food products. At present, when the economy of the republic is destroyed, land remains practically the only means of production. Therefore, the transition to economic methods of management in the republic is impossible without the presence of complete and reliable information on the quality of land plots.

Another problem is limited access to information. A lot of data on the state of the soil, water resources and other important parameters is stored in various government agencies and commercial companies, which are not always ready to share this information with specialists, which makes it difficult to conduct full-fledged monitoring.

It is also worth noting the high costs of monitoring agricultural land. The acquisition of the necessary equipment, training of specialists and processing of the collected data require significant financial resources.

However, the development of agricultural land monitoring has great potential. The use of modern technologies such as geographic information systems (GIS), as well as the assessment of the sustainability of agroecosystems and the creation of digital databases can significantly improve the efficiency of production activities and contribute to the conservation of natural resources.

To successfully implement these prospects, it is important to develop uniform monitoring methods and standards, as well as to ensure access to information and attract sufficient financial resources.

As a result, monitoring of agricultural lands plays a key role in sustainable agricultural development. It provides the necessary information to optimize land use, improve production efficiency, and ensure environmental safety. The prospects for monitoring development are closely linked to the use of new technologies that allow for more accurate and timely analysis of the state of the land fund.

Soil moisture and temperature are variable characteristics that change depending on various factors such as meteorological conditions, soil texture, vegetation type and groundwater level.

Humus content is one of the key factors determining soil quality. Humus is the most important part of the soil, directly related to its fertility. The humus layer accumulates the main elements necessary for plant nutrition. In addition, humus affects such soil characteristics as its absorption capacity, moisture, aeration, color and structure.

The main characteristics of the soil also include acidity. The degree of soil acidity is an important indicator for the economic assessment of land, since it determines what types of plants can grow in a given area. When assessing the lands of the Chechen Republic, negative soil parameters are also taken into account, such as erosion, deflated, solonetzic, salinity, as well as the content of rubble and stones.

It is important to assess soils taking into account all of these characteristics, as well as their toxicity and potential hazard to humans and plants caused by pollution.

The influence of climatic conditions on the assessment indicators of land plots is complex. However, for each physical-geographical region of the republic, the accounting and registration of this influence must take into account specific features, such as agricultural methods, types of vegetation, characteristics of soils and grounds, as well as relief forms.

Climate also significantly affects the relief and causes exogenous processes. The assessment of the degree of this impact is based on the registration of the amount and types of precipitation for a given territory, the intensity of their seasonal fallout, as well as wind characteristics and temperature fluctuations.

Soils and grounds can undergo significant changes under the influence of climatic factors. For example, strong winds in the steppe zone can destroy the fertile humus layer, and intense precipitation, especially heavy rainfall, in the foothill and mountain zones can lead to its erosion, which reduces fertility and, accordingly, worsens the assessment indicators.

The influence of climate on vegetation is most noticeable, since it is climate that determines the types and forms of plants that can adapt to specific conditions. Even small changes in precipitation or average annual temperature can significantly affect crop yields. Thus, climatic factors have a constant, although changing, effect on land quality. The main climatic factors affecting land quality are temperature and moisture conditions.

Temperature is one of the most significant and constant natural factors affecting all categories of land. The impact of temperature on agricultural land is most noticeable compared to other categories. For example, a decrease in temperature in the foothill and mountainous regions of the republic can negatively affect the quality of these lands.

The amount of precipitation, like the temperature regime, plays a decisive role in the qualitative characteristics of agricultural territories. An increase in the amount of precipitation usually leads to an improvement in the quality of the land. However, when assessing precipitation, it is necessary to take into account the climatic zone in which this assessment is carried out.

The degree of moisture and heat supply has a direct correlation with the productivity of arable and forage lands, which in turn affects the cost of land. Therefore, when calculating soil-ecological indices for the conditions of the Chechen Republic, the main attention is paid to climatic indicators, such as the average annual sum of temperatures above 10 °C (Pg 10), the moisture coefficient (MC) and the continentality coefficient (CC).

The average annual sum of positive (active) temperatures above 10°C is an important indicator of the thermal regime during the vegetation period, which covers the period of plant growth and reproduction. The moisture coefficient reflects the ratio of the annual precipitation to the potential annual evaporation. This coefficient allows us to estimate how much precipitation in a given region compensates for evaporation, which is critical for agronomic and environmental calculations.

The diversity of climatic conditions in the Chechen Republic significantly affects the cadastral valuation of agricultural land. Price indices reach their highest values in areas with an optimal combination of heat and moisture reserves. However, in the northern parts of the republic, despite the high heat, price indices remain low due to a lack of moisture. A similar situation is observed in high-mountain areas, where, although moisture is generally sufficient, heat supply indicators remain very low.

Within the Chechen Republic, the following natural and economic zones are distinguished: foothill-plain, mountainous, and priterechno-lowland. The foothill-plain zone includes the Gudermes , Grozny, Shali, Achkhoy-Martanovsky, and Urus-Martanovsky districts, with the exception of their southern parts, which belong to the mountainous zone. The mountainous zone also covers the Nozhai - Yurtovsky, Vedensky, Shatoisky, and Itum-Kalinsky districts. The boundary between the foothill-plain and mountainous zones can be conditionally drawn along an isohypse at an altitude of 500 meters above sea level, since it is from these heights that noticeable dissection of the relief begins, which significantly affects the territorial organization. The priterechno -lowland zone includes the Shelkovsky, Naursky, and Nadterechny districts.

The use of geographic information systems (GIS) for monitoring agricultural lands in the Chechen Republic has demonstrated high efficiency and relevance in the context of modern land use. The use of these technologies has made it possible to comprehensively assess the current state of agricultural lands, identify key problems such as soil degradation, erosion processes, salinization, and changes in the structure of the land fund.

Table 3: *Natural and economic zones of the Chechen Republic and their distribution by provinces*

Zone	Districts	Notes
Foothill-Plain Zone	Gudermes, Grozny, Shali, Achkhoy-Martanovsky, Urus-Martanovsky (excluding southern parts)	Includes most of these districts, except for southern parts belonging to the mountainous zone.
Mountainous Zone	Nozhai-Yurtovsky, Vedensky, Shatoisky, Itum-Kalinsky, southern parts of Achkhoy-Martanovsky and Urus-Martanovsky	Covers districts in the highlands, starting from approximately 500 meters above sea level.
Priterechno-Lowland Zone	Shelkovsky, Naursky, Nadterechny	Includes lowland districts near the Terek River.

Monitoring using GIS technologies ensures regular and accurate collection of data on the state of land, which allows for prompt action to improve soil fertility, optimize the use of land resources, prevent degradation and reduce negative anthropogenic impacts. Data obtained through remote sensing and processing of satellite images allows for the identification of both short-term changes associated with natural phenomena (drought, floods) and long-term trends affecting the agroecological situation in the region.

The introduction of GIS technologies creates preconditions for more rational land use and sustainable agriculture, which is especially important for the Chechen Republic, where a significant portion of the population is employed in the agricultural sector. The monitoring results can become the basis for developing and adjusting agricultural policy, effective planning and implementation of environmental protection measures aimed at restoring and preserving soil fertility.

In the long term, continued use of GIS and integration of these data with other information sources such as meteorological data and indicators of agricultural practices will help improve land management, thereby ensuring sustainable agricultural development in the region.

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References

[1] Razumova N.V. Assessment of the current state of land resources of the Chechen Republic using GIS technologies: dissertation ... candidate of geographical sciences: 25.00.23. - Moscow, 2002. - 217 p.: ill. RSL OD, 61 03-11 / 62-2

[2] Bratkov V.V., Bekmurzaeva R.Kh., Bekmurzaeva L.R. Potential of GIS technologies for assessing and monitoring climatic conditions of the Makazhoy basin (Chechen Republic). South Russia : ecology , development . 2024;19(2):160-169. https://doi.org/10.18470/1992-1098-2024-2-14

[3] Kornienko T.V. Questions of linguistic kinship, 2013. No. 9. P. 155-162.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House, 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L. : Gidrometeoizdat , 1979. 408 p.

[8] Salamova AS, Socio-economic factors in the fight against poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] Khotinsky N.A., Savina SS Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin V.I., Deniz DS Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11.No. 4. P. 1893-1904.

[11] Gunya, A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

DIGITAL TECHNOLOGIES AS A TOOL FOR ECONOMIC STIMULATION OF SUSTAINABLE CONSUMPTION AND PRODUCTION

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Abstract

The article "The Impact of Digital Technologies on Sustainable Consumption and Production" explores the transformative role of digital innovations in advancing sustainability across industries. It focuses on how technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics are reshaping the way businesses and consumers interact with resources, leading to more sustainable consumption and production models. These technologies help optimize resource use by improving the efficiency of supply chains, enhancing waste management systems, and enabling real-time monitoring of environmental impacts. For instance, AI and machine learning algorithms allow companies to forecast demand more accurately, reducing overproduction and minimizing waste. IoT devices provide valuable data on energy and resource consumption, enabling more efficient production processes, while blockchain ensures transparency and traceability in supply chains, helping consumers make informed, sustainable choices. The article also examines the growing influence of digital platforms that promote sustainable consumption, such as apps encouraging eco-friendly purchasing decisions or online marketplaces for sharing and reusing goods. By leveraging data-driven insights, these platforms encourage consumers to adopt sustainable lifestyles, while businesses can better align their operations with sustainability goals. Additionally, the article delves into the potential for digital technologies to accelerate the transition to a circular economy, where products and materials are reused, repaired, and recycled instead of following a linear lifecycle. However, the article also addresses the challenges and limitations of adopting digital technologies for sustainability. These include concerns over data privacy, the energy consumption of digital infrastructures, the need for standardized regulations, and the widening digital divide that could limit the accessibility of these technologies in certain regions. Despite these hurdles, the potential of digital technologies to revolutionize sustainable consumption and production is immense, offering new pathways to achieve global sustainability targets and reduce environmental degradation.

Keywords: circular economy, resource optimization, waste management, real-time monitoring, supply chain transparency, eco-friendly platforms, sustainability goals

I. Introduction

In the modern era, digital technologies are playing an increasingly pivotal role in transforming industries and reshaping how societies consume and produce goods. As the global community faces growing environmental challenges—such as climate change, resource depletion, and waste accumulation—there is an urgent need to shift towards more sustainable models of consumption and production. Sustainable Development Goal 12 (SDG 12), established by the United Nations, emphasizes the importance of responsible consumption and production patterns to ensure the long-term well-being of both people and the planet.

In this context, digital technologies like artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics are emerging as powerful tools for fostering sustainable practices. These technologies offer unprecedented opportunities to enhance efficiency, reduce waste, and create transparency across supply chains, which are critical in promoting sustainability across various sectors.

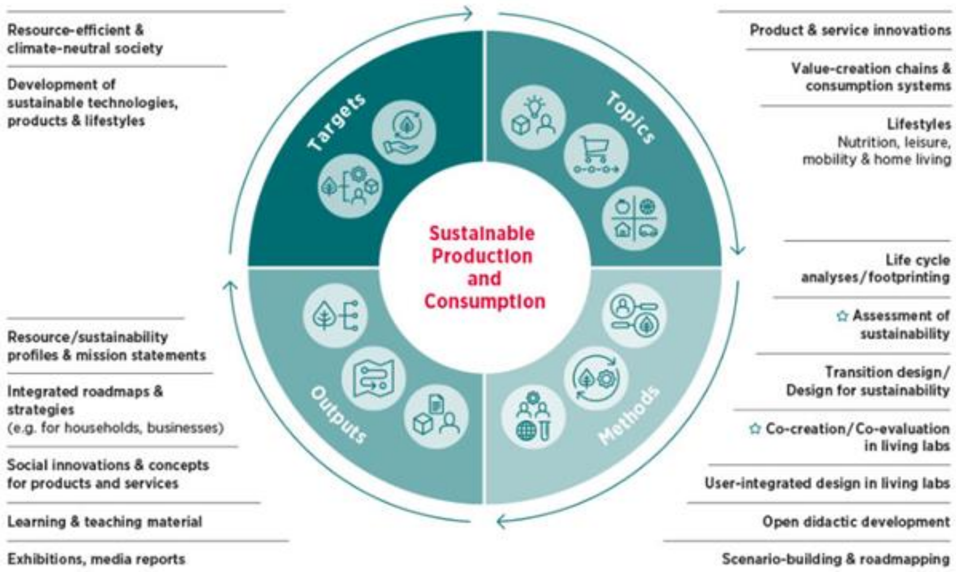

Figure 1: *Sustainable Production and Consumption Division analyses*

To create a climate-neutral and resource-efficient society in the medium to long term, it is essential to undertake a fundamental "dematerialization" of production and consumption. This involves implementing strategies focused on efficiency, consistency, and sufficiency, which ensure that products are designed to be "lighter on resources" and can be utilized for longer periods and in more effective ways. The process of achieving this is inherently tied to thoughtful design.

The Sustainable Production and Consumption Division is dedicated to analyzing, evaluating, and developing technological and social innovations through the use of real-world laboratories and living labs. These environments actively involve users in the development process, both before and during innovation implementation. Researchers assess the resource efficiency and social impacts of production and consumption along value chains, creating transformative approaches and scenarios that aim for climate neutrality, resource efficiency, and sustainability. Their focus areas include nutrition, leisure, mobility, and housing.

For meaningful changes in production and consumption patterns to take place, it is crucial to have companies that create and provide these innovative products and services. Additionally, empowered consumers who actively utilize these offerings are necessary, along with a supportive political framework that facilitates the transformation process.

The research undertaken by the Sustainable Production and Consumption Division encompasses several key areas:

- Sustainability and Resource Assessment: Evaluating the sustainability of materials and processes.
- Product and Service Innovations: Developing new offerings in real-world laboratories and living labs that prioritize sustainability.

- Education: Fostering knowledge and awareness around sustainable practices among consumers and businesses.
- Science-Based Innovation, Enterprise, and Consumer Policy Approaches: Informing policies that support sustainable production and consumption.

This research is characterized by its inter- and transdisciplinary nature, leveraging collaborations across numerous national and international networks. The Division draws upon extensive experience from various third-party funded projects, enhancing its ability to drive forward the agenda of sustainable production and consumption.

The integration of these digital innovations is not just limited to businesses optimizing their production processes but also extends to consumers who are becoming more empowered to make eco-friendly choices. Digital platforms are facilitating access to information, enabling consumers to adopt sustainable lifestyles, while businesses are using real-time data to reduce their environmental footprint.

However, while digital technologies present immense potential for advancing sustainability, their implementation comes with challenges. Issues such as the energy consumption of digital infrastructures, data security, and the need for comprehensive regulations to govern digital ecosystems must be addressed to ensure that these technologies contribute meaningfully to sustainable development.

This paper aims to explore how digital technologies are impacting sustainable consumption and production, highlighting both the opportunities they offer and the obstacles that must be overcome to harness their full potential.

Demographic shifts, including population growth and rapid urbanization, are intensifying pressure on existing food systems and agricultural resources. As global food demand rises, there is an urgent need for sustainable practices to ensure food security while safeguarding the environment. Additionally, the ongoing effects of climate change further strain the availability and quality of essential resources for agriculture, underscoring the importance of adaptation and innovation in food production. These complex challenges demand integrated, forward-thinking approaches to achieve sustainability in food systems, requiring transformative changes across agricultural practices.

A key aspect of this transformation involves the evaluation and adoption of advanced production technologies, which can help drive sustainable productivity growth. These technologies also hold potential for influencing broader trends, such as sustainable consumption patterns and reductions in greenhouse gas (GHG) emissions.

Digital technologies, including artificial intelligence (AI), big data (BD), the Internet of Things (IoT), and cloud computing (CC), are increasingly recognized as vital tools for addressing sustainability challenges in food systems. These technologies can enhance supply chain transparency and efficiency, reduce food loss and waste, and optimize resource use. For example, automation can streamline production processes, while biotechnologies can improve crop resilience and quality, essential for maintaining sustainable production in the face of climate change. Furthermore, digital innovations can optimize transportation and logistics, lowering carbon footprints and minimizing environmental impacts across the food supply chain.

Investment in research and development of digital technologies could yield significant benefits, particularly in promoting sustainable food systems globally. However, fully realizing the potential of these technologies requires not only technical innovation but also increased awareness, understanding, and adoption by all stakeholders in the food supply chain.

This paper seeks to explore the broader impact of digital technologies on sustainable food production and consumption. Specifically, it aims to assess how these innovations affect municipal waste, primarily stemming from food consumption, and agricultural emissions of nitrogen and methane, which are key contributors to GHG emissions. Additionally, the study aligns with the objectives of Sustainable Development Goal 12 (SDG12), which focuses on promoting responsible consumption and production patterns.

Despite the growing importance of digital solutions in agriculture, research gaps remain, particularly in the form of detailed longitudinal analyses that track the long-term impact of digital technologies on food sustainability. There is also a need for a more comprehensive understanding of the intricate relationships between food production, consumption, and critical variables tied to sustainability.

The originality of this study lies in its application of Structural Equation Modeling (SEM) to assess correlations between the adoption of digital technologies and key sustainability metrics, particularly in relation to food production and consumption. By offering valuable insights into how these technologies can mitigate food waste and agricultural emissions, this research aims to contribute to the development of policies and practices that foster long-term food sustainability.

The structure of this paper includes six sections: an introduction outlining the research purpose and objectives, a literature review and hypothesis development, a description of the research methodology, presentation of the findings, discussion of the results, and conclusions summarizing the key contributions of the study.

II. Methods

This section outlines the research design, data collection, and analysis methods used to assess the impact of digital technologies on sustainable food production, consumption, and related sustainability metrics. The study primarily focuses on exploring the correlations between digital technology adoption and key variables such as municipal waste, greenhouse gas (GHG) emissions from food production (specifically nitrogen and methane emissions), and overall progress towards Sustainable Development Goal 12 (SDG12), which promotes responsible consumption and production.

1. **Research Design**

This study employs a mixed-methods approach, combining quantitative data analysis with qualitative insights to understand the multifaceted impact of digital technologies on food sustainability. The research was designed to capture both the breadth and depth of technological influences across the food supply chain, from production to consumption.

Structural Equation Modeling (SEM) was chosen as the primary analytical tool to assess the relationships between digital technology adoption and sustainability outcomes. SEM allows for the testing of complex relationships between observed and latent variables, making it well-suited for evaluating the multi-dimensional effects of digital technologies on food systems.

2. **Data Collection**

The study utilized secondary data sources for quantitative analysis, including data from international organizations, government reports, and industry publications. These data sources provided information on the following variables:

- Adoption of digital technologies: Data on the implementation of AI, Big Data, IoT, and cloud computing in agricultural and food supply chain processes were gathered from industry reports and technology adoption studies.
- Municipal waste: Data on food waste at the municipal level, particularly in urban areas, were sourced from reports by the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization (FAO).
- Agricultural GHG emissions: Data on nitrogen and methane emissions from agriculture were obtained from reports by the Intergovernmental Panel on Climate Change (IPCC) and national greenhouse gas inventories.

- Sustainable Development Goal 12: Indicators related to SDG12 were collected from the United Nations' Sustainable Development Goals (SDG) database, focusing on responsible consumption and production patterns, particularly those tied to food systems.

In addition, qualitative data were collected through interviews with industry experts, technology providers, and stakeholders in the food supply chain, including farmers, food processors, retailers, and policymakers. These interviews provided insights into the practical challenges and opportunities of implementing digital technologies in real-world settings.

3. **Data Analysis**

The analysis followed a two-step process:

A. Quantitative Analysis using Structural Equation Modeling (SEM)

SEM was used to test the hypotheses on the impact of digital technologies on sustainable food production, consumption, and waste reduction. This method allowed for the examination of both direct and indirect effects of technology adoption on food sustainability metrics. Key steps in the SEM analysis included:

1. Model Specification: A conceptual model was developed to represent the hypothesized relationships between digital technology adoption, food waste reduction, GHG emissions, and SDG12 indicators.
2. Model Estimation: Maximum likelihood estimation (MLE) was used to estimate the parameters of the SEM model.
3. Model Fit Assessment: Goodness-of-fit indices, such as the Chi-square test, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA), were used to evaluate the model fit.
4. Hypothesis Testing: The relationships between variables were tested for significance using standard error estimates and p-values.

B. Qualitative Analysis

A thematic analysis of interview data was conducted to complement the quantitative findings. Key themes included:

- Barriers to technology adoption: Challenges faced by stakeholders in integrating digital solutions into their operations.
- Opportunities for sustainability: Insights into how digital technologies can contribute to improved resource efficiency, waste reduction, and sustainable practices.
- Policy and regulatory support: The role of governments and international organizations in facilitating or hindering the adoption of sustainable technologies.

5. Hypotheses Development

Based on the literature review and theoretical foundations, several hypotheses were developed to guide the research. These hypotheses included:

- H1: The adoption of digital technologies (AI, Big Data, IoT, CC) in the food supply chain positively correlates with a reduction in municipal food waste.
- H2: Digital technologies in agriculture contribute to the reduction of nitrogen and methane emissions, improving agricultural sustainability.
- H3: Digital technologies in food systems positively impact the achievement of Sustainable Development Goal 12 by enhancing sustainable consumption and production patterns.
- H4: The effect of digital technologies on food sustainability is mediated by improved supply chain transparency and collaboration among stakeholders.

5. Limitations

Several limitations should be acknowledged in this study. First, reliance on secondary data may present challenges regarding the consistency and accuracy of the data, as reporting practices vary across sources. Second, the cross-sectional nature of the quantitative data limits the ability to draw conclusions about long-term trends. Future research could benefit from longitudinal studies that track the impact of digital technologies over time.

In summary, the methods employed in this study, including SEM and qualitative interviews, provide a comprehensive framework for assessing the impact of digital technologies on food sustainability, focusing on critical variables such as municipal waste, GHG emissions, and progress towards SDG12. The combination of quantitative and qualitative data ensures a robust understanding of the challenges and opportunities presented by digital innovations in the food sector.

III. Results

The use of digital technologies in agriculture can have a significant impact on the efficiency and sustainability of food systems. However, for these technologies to achieve a truly transformative effect, their implementation must consider the social, economic, and cultural contexts of the communities in which they are used. Improving access to food and reducing the carbon footprint of global agri-food systems are critical priorities for achieving Sustainable Development Goals (SDGs) and ensuring global food security.

The primary objective of this study was to explore the impact of digital technologies on food production and consumption, with a particular focus on their influence on municipal waste, largely originating from food consumption, nitrogen and methane emissions from agriculture, and sustainable consumption and production in alignment with SDG12. The study utilized longitudinal data to track trends over time, offering insights into how these technologies affect sustainability in the food sector. Additionally, it examined the relationships between agricultural production, waste generation, and greenhouse gas (GHG) emissions to better understand the complex interactions in the food supply chain.

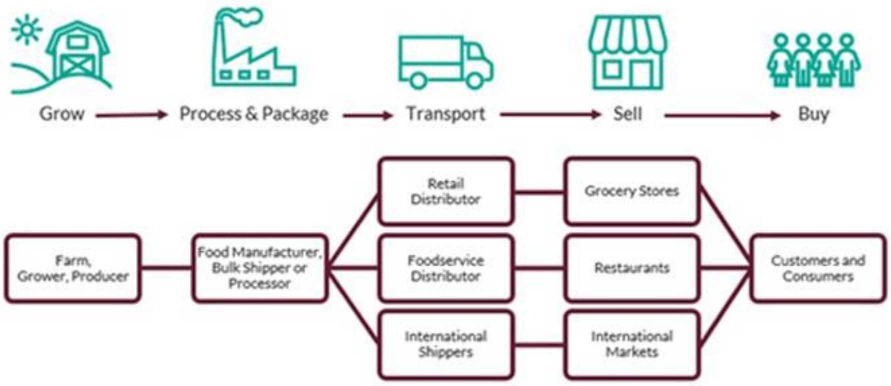

Figure 2: *The Global food supply chain*

Food supply chains represent one of the most significant yet underappreciated areas for investment and business innovation. This industry impacts every individual globally and stands at the precipice of disruption.

In the medium term, the future of food supply chains will revolve around assembling a network of resilient suppliers capable of providing year-round harvests, with inputs sourced from around the globe. The long-term outlook is even more promising, especially with emerging technologies guiding us toward a post-carbon future. For instance, "touchless agriculture" is one of the transformative technologies on the horizon, utilizing extensive data analytics to help farmers select optimal seeds without the need for physical planting, potentially revolutionizing agricultural practices.

The global food supply chain plays a critical role in transporting, processing, and marketing food worldwide. Globalization has facilitated this process, enabling food chains to deliver substantial quantities of quality products to nourish approximately one in nine people on Earth.

However, globalization should not be viewed solely from an economic standpoint; its social and environmental implications are equally important.

While globalization enhances the availability of quality foods and fosters advancements in agricultural techniques and transportation, it also poses sustainability challenges. The environmental and cultural impacts of global food chains cannot be overlooked. For example, the globalization of food production can lead to job losses in specific regions due to outsourcing and shifts in transportation practices. It has contributed to enhanced food security but simultaneously raised concerns regarding food safety.

Moreover, global food chains have induced considerable ecological disturbances at local, regional, and even international levels. Although globalization brings numerous advantages, it also carries side effects that often go unnoticed or unaddressed.

Given that globalization is a persistent reality, food supply chains must take proactive measures to ensure their long-term sustainability. This requires a holistic approach that balances economic growth with environmental stewardship and social responsibility, ensuring that food systems remain resilient and equitable for future generations. Embracing sustainable practices within global food chains will be essential for mitigating adverse effects while maximizing the benefits of globalization.

The key findings of the study revealed several important points. First, there is a negative relationship between digital technologies and SDG12, indicating that while these technologies can have a positive effect on sustainability, their overall impact on consumption and production is moderate but significant. This supports the H2 hypothesis, suggesting that the application of digital technologies may have unintended consequences for sustainable development. The study also found that increasing efficiency through digital tools can paradoxically lead to higher resource consumption.

The study also highlighted the challenges posed by digitalization in agriculture. As Kamble et al. pointed out, these include ensuring equal access to technology and data for all stakeholders, particularly smaller producers, as well as addressing concerns around data protection and cybersecurity in increasingly complex and interconnected food supply chains. Despite these challenges, the research confirmed a positive relationship between agricultural production and both sustainable consumption and the generation of municipal solid waste, validating the H1 and H3 hypotheses. This finding emphasizes the close connection between agricultural productivity and sustainability, as increased production brings both benefits and challenges for waste management.

Moreover, the study demonstrated that digital technologies can play a crucial role in reducing municipal solid waste by optimizing various processes such as production, distribution, and inventory management. This finding, which aligns with the research of Bahn et al., validates the H4 hypothesis, showing that digital tools can contribute to more effective waste management and, in turn, support the sustainability of food systems. However, the study also stressed the importance of considering the indirect environmental impacts of digital technologies, such as increased energy consumption and the generation of electronic waste. These factors must be managed carefully to ensure that the sustainability benefits of digitalization in agriculture are not undermined.

In conclusion, the study highlights the dual nature of digital technologies in the agricultural sector. While they offer significant potential to reduce waste, improve supply chain efficiency, and contribute to sustainable food production, they also present risks related to increased energy consumption and unequal access. As a result, a balanced and cautious approach to the implementation of these technologies is essential to ensure they contribute positively to the long-term sustainability of food systems.

IV. Discussion

The findings of this study indicate that sustainable consumption and production practices, in alignment with Sustainable Development Goal 12 (SDG12), have a negative influence on greenhouse gas (GHG) emissions from agriculture, supporting the H5 hypothesis (fig.3). This result highlights the critical role that sustainable practices can play in reducing agricultural emissions and mitigating environmental impact. These findings are consistent with the research of Dong et al., Agrawal et al., and Sharma et al., who emphasize that companies can enhance their operational efficiency using digital technologies while contributing to sustainability efforts, particularly in achieving SDG12. By improving efficiency and reducing GHG emissions, digital technologies can strengthen the sustainability of supply chains, making them more transparent and accountable. Furthermore, these technologies facilitate the monitoring and reporting of sustainable practices, thereby reinforcing sustainability goals across industries.

The study also confirmed the H6 hypothesis, revealing a positive relationship between agricultural production levels and GHG emissions. This suggests that as agricultural production increases, so too do emissions, underscoring the urgent need for more sustainable agricultural practices to reduce environmental degradation. Research by Kabange, Xu, Wang, and Ouyang supports these findings, showing that agriculture is a significant source of global GHG emissions due to activities like livestock fermentation and fertilizer use. However, modern agricultural practices, coupled with the adoption of digital technologies, can help mitigate these emissions by enhancing efficiency and sustainability.

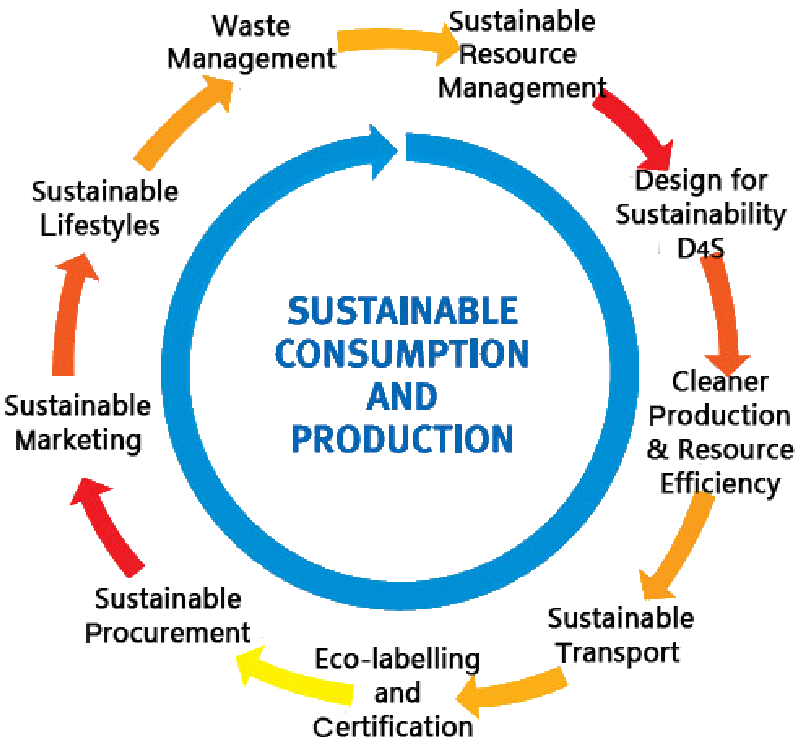

Figure 3: *Sustainable consumption & production*

Digital technologies, when implemented in agriculture, can provide significant advantages, including better resource management, real-time decision-making tools, and more sustainable farming practices. The results highlight the importance of promoting the adoption of these technologies across the food supply chain to meet sustainability goals. However, challenges remain, particularly regarding the equitable access to these technologies, especially for small- and medium-sized primary producers. Investments in digital infrastructure and education are necessary to support the transition to more efficient and sustainable agri-food systems.

The European Union (EU) is taking a proactive stance in promoting the digitalization of agriculture as part of its efforts to transition to more sustainable farming practices. The concept of the "fourth agricultural revolution" emphasizes the potential for digital technologies to transform agriculture radically. By integrating these technologies, production processes and resource management can be optimized, enhancing sustainability and resilience in the face of current and future challenges.

Digital technologies offer numerous benefits to agriculture, such as increased efficiency, reduced environmental impact, improved food quality, and higher incomes for producers. These tools also support more sustainable farming practices by reducing reliance on external inputs like pesticides and chemical fertilizers, while promoting the efficient use of natural resources. Additionally, they enhance access to agricultural information and services, particularly for rural producers, fostering greater transparency and efficiency across the entire food supply chain.

However, despite the advantages of digitalization, there are significant barriers to its widespread adoption. The high cost of advanced agricultural technologies can be prohibitive for primary producers, particularly in developing countries. Furthermore, a lack of training and resources to support the adoption of these technologies may exacerbate existing inequalities, creating a digital divide within the agricultural sector. Therefore, efforts to promote digitalization must address these challenges to ensure that the benefits of technology reach all stakeholders and contribute to the broader goal of sustainable development.

The challenges facing food systems are multifaceted and interconnected, reflecting the complexity and fragility of the global food chain. Issues such as population growth, competition for resources, climate change, dietary shifts, limited food access, unsustainable agricultural practices, and significant food waste contribute to the precariousness of food security. Rapid urbanization and population expansion place immense pressure on natural and agricultural resources, increasing the risks of food insecurity and environmental degradation. Climate change exacerbates these problems by directly impacting agricultural productivity and food accessibility for millions worldwide. Unsustainable farming methods further highlight the urgent need for reforms in agricultural and food supply chains to promote more equitable and sustainable production and consumption practices.

Reducing food waste and improving access to nutritious, sustainable food are essential to achieving future food security and sustainability. A sustainable food system benefits not only human health by ensuring access to safe, healthy food but also the environment and economies by protecting natural resources and supporting agricultural communities. As agriculture is a fundamental part of global economies and livelihoods, efficient and sustainable agricultural practices are critical to minimizing the sector’s environmental footprint. The current production and consumption patterns exacerbate climate change through increased greenhouse gas (GHG) emissions, highlighting the need for more environmentally friendly agricultural practices that protect future generations.

This paper emphasizes the role of digital technologies in optimizing resource use and reducing environmental impacts, fostering more sustainable consumption and production patterns. Additionally, these technologies can mitigate municipal waste by improving resource management. However, without appropriate regulations and sustainable resource management strategies, the use of these technologies could lead to resource overuse, necessitating a balanced approach to their implementation. To fully harness the benefits of digital technologies, legislative and policy frameworks must evolve in tandem with technological advancements, facilitating widespread adoption in agriculture beyond the food industry.

Understanding the needs and perspectives of primary producers is also essential to developing digital solutions that support a more efficient and inclusive transformation in agriculture. Despite the paper's efforts to explore the relationships between digital technologies, sustainable food production, GHG emissions, and municipal waste, certain limitations exist. The longitudinal nature of the study, while tracking trends over time, may have been influenced by contextual factors or unforeseen events. Additionally, the study focused primarily on the relationship between digital technologies and key aspects of food sustainability, such as crop and animal output, municipal waste, nitrogen and methane emissions, and Sustainable Development Goal 12 (SDG12). Future studies should consider broader aspects of food sustainability, including the social and economic impacts of technological shifts, such as employment in agricultural labor, market access for small producers, or the equitable distribution of technological benefits.

Another important area for future research is the unintended consequences of digitalization in agriculture. While the benefits of digital technologies are substantial, their potential negative impacts, such as the risk of digital exclusion or the concentration of economic power among large corporations, must also be examined. Future studies could investigate the specific effects of emerging digital technologies, including the Internet of Things (IoT), data analytics, and artificial intelligence (AI), on the sustainability of food systems. Such research would provide a more comprehensive understanding of how these technologies can be leveraged to enhance food system resilience while avoiding potential drawbacks.

References

[1] Dobrynina M.V., Kovalenko D.G. Youth social entrepreneurship: problems and prospects//Economic and social-humanitarian research. 2023. No. 3 (39). P. 53-61.

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] Zheng, Q., Wang, M., & Yang, F. (2021). Optimal channel strategy for a fresh produce e-commerce supply chain. Sustainability, 13, 6057. Retrieved July 2022, from https://www.mdpi.com/2071- 1050/13/11/6057

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] European Commission (2022a) Communication from the Commission. Guidelines on the application of the Regulation (EU, EURATOM) 2020/2092 on a general regime of conditionality for the protection of the Union budget. Brussels, 2.3.2022 C (2022) 1382 final.

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 2137-2144.

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

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ENVIRONMENTAL AND NATURAL CHALLENGES FACED BY DEPORTED PEOPLES IN THEIR NEW PLACES OF RESIDENCE

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Abstract

Deported populations often confront a wide array of environmental and natural challenges in their new places of residence, which can exacerbate the difficulties of displacement and resettlement. These challenges arise from being relocated to unfamiliar and often marginal areas with limited resources. Many of these regions may have poor soil quality, unreliable or limited access to clean water, and scarce arable land, making agricultural activities and food production difficult. Deported peoples may also face extreme climatic conditions such as heatwaves, cold spells, or heavy rainfall, depending on the region. Additionally, they often lack knowledge about the local ecosystems, which hinders their ability to utilize available resources effectively or protect themselves from environmental risks. Natural hazards, including droughts, floods, landslides, or even proximity to dangerous industrial sites, further threaten the deported populations' well-being. These groups often live in underdeveloped or impoverished regions that are vulnerable to environmental degradation, climate change impacts, and pollution. Combined with the socio-economic challenges they face, such as limited access to healthcare, education, and employment, these environmental and natural stressors significantly affect their capacity to adapt and rebuild their lives in new locations. The intersection of these environmental difficulties with social, economic, and political marginalization often leads to severe living conditions for deported peoples, undermining their long-term resilience and sustainability. Addressing these issues requires a holistic approach, including humanitarian aid, sustainable development practices, and policies that ensure deported communities have access to resources and the knowledge needed to thrive in their new environments.

Keywords: deportation, environmental challenges, climate adaptation, resource scarcity, natural hazards, livelihood vulnerability, ecosystem unfamiliarity, forced relocation

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I. Introduction

Deportation is a complex and multifaceted issue that affects millions of people worldwide, often as a consequence of political, social, or economic instability. Individuals and families forced to leave their homes encounter not only the emotional and psychological toll of separation from their communities but also face numerous practical challenges in their new environments. The experience of being deported is compounded by the environmental and natural challenges they encounter, which can hinder their ability to adapt, integrate, and rebuild their lives.

When deported individuals arrive in their new places of residence, they frequently find themselves in regions that are unfamiliar, often marked by different climatic conditions, ecosystems, and resource availability. For many, this transition involves significant adaptation challenges, as they must navigate new agricultural practices, local flora and fauna, and different weather patterns. In many cases, they are relocated to marginal lands that suffer from environmental degradation, including poor soil quality, limited access to clean water, and inadequate infrastructure. These conditions make it difficult to secure reliable livelihoods, leading to food insecurity and heightened vulnerability.

Moreover, the environmental challenges faced by deported peoples are often exacerbated by natural hazards. Many are resettled in areas prone to floods, droughts, landslides, or other environmental risks, which can lead to loss of property and livelihoods. Such hazards not only threaten their immediate survival but also undermine their long-term prospects for stability and self-sufficiency. The lack of familiarity with the local environment can prevent deported individuals from effectively utilizing available resources or mitigating risks associated with their new surroundings.

The socio-economic challenges that deported peoples face further complicate their situation. Limited access to healthcare, education, and employment opportunities makes it difficult for them to achieve financial independence and social integration. In many instances, they may encounter discrimination or hostility from local populations, which can isolate them and hinder their efforts to adapt. The intersection of these social and environmental stressors creates a cycle of vulnerability that is hard to escape, as deported individuals struggle to secure a stable and sustainable future.

Understanding the environmental and natural challenges faced by deported populations is critical for informing policies and practices that promote their resilience and integration. This understanding must encompass not only the immediate needs of deported individuals but also the long-term sustainability of their new communities. Strategies must focus on providing humanitarian assistance, enhancing access to resources, and implementing sustainable development practices that take into account the unique environmental contexts of resettlement areas.

As the world grapples with increasing displacement due to conflict, climate change, and globalization, it is essential to prioritize the experiences of deported peoples and their interactions with the environments they inhabit. By addressing both the environmental and socio-economic dimensions of their challenges, we can work towards creating a more inclusive and supportive framework for the integration of deported communities. This introduction serves as a foundation for a deeper exploration of the various environmental and natural challenges faced by deported populations, as well as the policy implications and strategies needed to support their adaptation and well-being.

II. Methods

This study employs a multidisciplinary approach to analyze the influence of natural and climatic conditions on the integration process of deported peoples in special settlements. The methods used include a combination of historical analysis, geographical assessment, and qualitative case studies, drawing on both primary and secondary sources. The research is designed to provide a comprehensive understanding of how environmental factors shaped the experiences of these deported populations during their resettlement and adaptation.

1. Historical Document Analysis**:**

The primary method involves the analysis of archival records, government reports, and personal testimonies from deported individuals. Soviet-era documents, including official resettlement plans, labor assignments, and population censuses, provide crucial insights into the logistical and administrative aspects of the deportations. These records are cross-referenced with memoirs, letters, and oral histories of deportees to capture the lived experiences of those affected. By comparing official Soviet reports with personal narratives, the research aims to uncover the discrepancies between state policies and the realities faced by the deported peoples.

2. Geographical and Climatic Data Assessment**:**

A significant aspect of the research focuses on the geographical and climatic conditions of the regions where deportees were sent. This involves the use of historical climate data and geographic mapping to analyze the specific environmental challenges faced in different regions, such as Siberia, Kazakhstan, and the Russian Far East. Factors such as average temperatures, precipitation levels, and soil quality are examined to assess how they impacted agricultural productivity, labor requirements, and living conditions in the special settlements.

By mapping deportation locations and overlaying climatic data, the study seeks to correlate environmental conditions with integration outcomes. For example, settlements in extremely cold regions are compared with those in arid or semi-arid areas to identify patterns in survival rates, labor output, and community development.

3. Case Study Analysis**:**

The research also employs a case study approach to provide detailed accounts of specific deported communities and their adaptation processes. These case studies focus on deported groups such as Chechens, Crimean Tatars, and ethnic Germans, who were relocated to different regions under varying climatic conditions. Each case study looks at factors such as employment in local industries, agricultural success, mortality rates, and social cohesion to understand how natural environments influenced integration.

By using a comparative case study method, the research highlights how some groups managed to adapt more successfully than others, depending on the environmental conditions they encountered. These case studies are drawn from a variety of sources, including regional archives, local histories, and ethnographic studies.

4. Qualitative Interviews and Oral Histories**:**

In addition to archival research, the study incorporates qualitative interviews and oral histories where available. Interviews with descendants of deportees, as well as existing oral history projects, provide personal insights into the challenges faced by these populations and how they perceived the impact of climate on their daily lives. This qualitative data helps to capture the emotional and psychological aspects of integration that are not always reflected in official documents.

5. Thematic Analysis**:**

The data collected from archival research, climate analysis, case studies, and interviews are subjected to thematic analysis. Key themes such as "adaptation to harsh climates," "resource scarcity," "labor struggles," and "social cohesion under environmental stress" are identified and analyzed to explore the broader patterns of integration. This thematic approach helps to link the specific experiences of different deported groups with the overarching influence of environmental conditions.

6. Comparative Analysis**:**

Finally, a comparative analysis is conducted between different groups of deported peoples and the various regions to which they were relocated. This allows for the identification of factors that either facilitated or hindered the integration process across different natural and climatic contexts. Variables such as the type of labor, proximity to local populations, government support, and climatic severity are considered in comparing the experiences of deported communities.

Through this combination of methods, the study aims to offer a comprehensive and nuanced understanding of the role that natural and climatic conditions played in shaping the integration of deported peoples in special settlements.

III. Results

The deportation of Chechens, particularly during the tumultuous events of the 1940s, was marked by a profound and multifaceted influence of nature in their new environments. Forced to leave their ancestral lands, the deported Chechens were relocated to unfamiliar regions that posed significant challenges in terms of climate, landscape, vegetation, and access to natural resources. This drastic change impacted their traditional ways of life, especially in agriculture and animal husbandry, which had been central to their cultural identity and survival.

In their new areas of settlement across Russia, the Chechens encountered varying climates that dramatically affected their health and adaptability. The transition from one climatic zone to another introduced difficulties in acclimatizing to new temperatures and weather conditions. These changes in climate were not merely physical; they also had psychological and social implications, as the deported individuals struggled to navigate their new realities while mourning the loss of their homeland.

The new natural environments presented distinct challenges. For instance, the vegetation, soil fertility, and availability of pasture differed significantly from what the Chechens were accustomed to. Traditional Chechen agricultural practices, honed over generations, were often incompatible with the new conditions. The lack of familiar crops and suitable land for livestock exacerbated food insecurity and limited their ability to sustain their families. As a result, the relationship between the deported Chechens and their environment became strained, leading to a struggle for survival amid changing ecological contexts.

The interaction between people, development, and the environment is pivotal in understanding the broader implications of deportation. In the case of the Chechens, their development and growth were inextricably linked to the natural resources available in their new surroundings. The degradation of these resources, often compounded by environmental neglect and lack of support from the authorities, hindered their ability to thrive and integrate into their new communities.

This moment in history serves as a crucial reminder of the need for greater awareness and regulation of human activities concerning their environmental impacts. As we navigate the complexities of modernization and development, it is imperative to consider the long-term consequences of our actions on the natural world. The potential for irreparable damage to the environment is a pressing concern that demands urgent attention, particularly in light of the needs of vulnerable populations like the deported Chechens.

Protecting and improving the environment is essential for creating sustainable living conditions. Initiatives that focus on enhancing the natural landscape and promoting biodiversity can foster more favorable conditions for human habitation and recreation. In the context of the deported Chechens, addressing these environmental challenges is not only an ecological imperative but also a humanitarian one. By providing support and resources to help them adapt to their new environments, we can assist in their integration and promote their resilience.

Ultimately, the case of the deported Chechens illustrates the intricate relationship between people and their environment. Ensuring that future generations inherit a healthy and sustainable world is a responsibility we all share. As we reflect on the lessons from the past, it becomes clear that our collective actions today must prioritize environmental stewardship, especially for communities that have already endured significant hardships. The legacy of the deported Chechens reminds us that the health of our planet is intimately tied to the well-being of its inhabitants.

IV. Discussion

The deportation of Chechens during the 1940s serves as a poignant example of the complex interplay between human displacement and environmental challenges. The significant and multifaceted influence of the natural environment on deported Chechens highlights the broader implications of forced migration, particularly in relation to climate adaptation, resource management, and cultural identity.

Upon their relocation, deported Chechens faced a variety of environmental challenges that deeply affected their lives. The unfamiliar climates, often with extreme temperatures, posed immediate difficulties for adaptation. This climatic shift impacted their health, food security, and overall well-being. The Chechens were accustomed to specific agricultural practices and livestock management, which were not necessarily suited to the new areas they inhabited. This lack of compatibility forced them to abandon or radically alter their traditional ways of life, leading to food shortages and economic instability.

Moreover, the landscapes they were forced to navigate often presented additional barriers. The soil fertility varied significantly, which directly impacted their agricultural productivity. In many cases, the deported populations were settled in less fertile regions, which hindered their ability to cultivate crops that were staples in their traditional diet. This disconnect between their cultural practices and their new environmental realities illustrates how displacement can sever the bonds between communities and their land, leading to a loss of cultural identity and continuity.

Access to natural resources is another critical factor that shaped the experiences of deported Chechens. The abrupt transition to new environments not only affected the availability of resources but also introduced competition and conflict over these resources. In their original homeland, Chechens had established relationships with the land that facilitated sustainable use of resources. In contrast, the new regions often lacked the necessary support systems for resource management, exacerbating challenges related to water scarcity, land use, and food production.

Additionally, the socio-political dynamics of the regions where the Chechens were resettled often further complicated their access to resources. Discrimination and marginalization in these new communities could hinder their ability to integrate and secure necessary resources. The lack of supportive infrastructure and policies to assist deported individuals in their transition created an environment of vulnerability and instability, perpetuating cycles of poverty and displacement.

The cultural identity of the deported Chechens was significantly impacted by their environmental circumstances. The disconnection from their ancestral land and the subsequent changes in lifestyle challenged their sense of belonging and cultural practices. Traditional occupations such as agriculture and animal husbandry were not merely economic activities; they were integral to their cultural identity and community cohesion. The loss of these practices led to feelings of alienation and a diminished sense of community among deported populations.

However, resilience emerged as a key theme in the experiences of the deported Chechens. Despite the numerous challenges they faced, many individuals and families demonstrated remarkable adaptability and resourcefulness. Community networks formed to share knowledge, resources, and support, helping to create a sense of solidarity amidst adversity. This resilience underscores the importance of community and cultural continuity in navigating the complexities of forced displacement.

The discussion surrounding the experiences of deported Chechens highlights the need for policies that recognize the interplay between environmental factors and human displacement. Addressing these challenges requires a comprehensive approach that integrates humanitarian aid, sustainable development practices, and community support systems.

Policymakers should prioritize the following strategies:

1. Environmental Education and Adaptation: Providing deported populations with education about their new environments and training in sustainable agricultural practices can enhance their adaptability and resilience.
2. Resource Management and Accessibility: Ensuring equitable access to resources, including land and water, is crucial for the well-being of deported communities. Policies

should be implemented to support resource management initiatives that include the voices and needs of displaced populations.

3. Cultural Preservation: Recognizing the importance of cultural identity in the adaptation process, initiatives should be developed to help deported populations maintain their cultural practices and strengthen community ties. This could involve supporting traditional occupations and creating platforms for cultural expression.
4. Integrated Support Systems: Holistic approaches that integrate health, education, and economic support can help deported communities navigate the complexities of their new environments more effectively.

In conclusion, the experiences of deported Chechens illustrate the profound impact of environmental factors on the lives of displaced populations. By understanding these challenges and implementing supportive policies, we can foster resilience and help displaced communities adapt to their new realities while preserving their cultural identities. Addressing the environmental challenges associated with displacement is not only a matter of humanitarian concern but also a crucial step toward ensuring a more sustainable and equitable future for all.

The development of new lands by exiled Chechens in Kazakhstan and Central Asia was a complex and multifaceted process marked by a series of challenges and adaptations. Forced to leave their ancestral homes, the Chechens faced numerous obstacles as they sought to establish themselves in unfamiliar territories, where they needed to navigate new natural conditions and build sustainable livelihoods. This section explores the various aspects involved in this process, shedding light on the resilience and adaptability of the deported Chechen community.

Upon arriving in Kazakhstan and Central Asia, exiled Chechens were confronted with the necessity of adapting to new climatic and natural conditions. The state provided them with land plots to facilitate their settlement, which were essential for their agricultural and livestock-raising activities. However, adapting to the local environment involved more than just occupying new land. It required understanding the regional climate, seasonal variations, and the specific characteristics of local soils and pastures.

Chechens needed to familiarize themselves with the vegetation, local flora, and the agricultural practices suitable for their new environment. This adaptation was crucial for their survival and success as farmers and livestock herders. Given their traditional reliance on farming and animal husbandry, they required assistance and training to implement effective farming methods tailored to the climatic conditions of their new homes. This educational support was vital in ensuring that they could produce food and sustain their families in a new and often challenging environment.

In addition to environmental adaptation, the deported Chechens encountered significant infrastructure challenges in their new settlements. Many areas lacked essential services, including roads, schools, and medical facilities, which were necessary for the community's integration and development. The rebuilding and rehabilitation of infrastructure were critical to ensuring that the Chechens could access education, healthcare, and economic opportunities.

The state played a vital role in addressing these infrastructural deficits, and efforts were required to restore and improve the facilities needed for a functional community. The successful rehabilitation of infrastructure would not only support the immediate needs of the deported population but also contribute to their long-term development and integration into the broader societal fabric of Kazakhstan and Central Asia.

While developing new lands, it was equally important for the exiled Chechens to preserve their cultural traditions. The maintenance of cultural identity, including language, religion, rituals, and crafts, was essential for fostering a sense of community and belonging among the deported population. In the face of displacement, these cultural practices provided a vital connection to their heritage and history.

The integration of Chechen cultural traditions into the new social landscape was not only a matter of personal identity but also contributed to the cultural diversity of the regions where they settled. The mutual respect and brotherhood between Chechens, Ingush, and Kazakhs helped facilitate cultural exchanges and promote social cohesion, which was beneficial for all communities involved. The shared Islamic faith among these groups also fostered a sense of solidarity, as they navigated the challenges of their new environments together

The psychological impact of deportation and the challenges of adapting to new lands cannot be overlooked. Many deported Chechens experienced significant psychological distress due to the abrupt changes in their lives and the trauma of displacement. To cope with these changes, they needed psychological support and counseling to help them navigate their new reality.

The harsh conditions faced by all residents of Kazakhstan, combined with the trauma of displacement, created a complex environment where psychological support was crucial. Local communities, including Kazakhs, played an essential role in providing support to the deported Chechens, offering assistance and understanding during their difficult transition. The historical bonds between these groups, rooted in shared experiences and mutual respect, were vital for fostering resilience among the deported population.

The deportation of Chechens and their subsequent resettlement in Kazakhstan and Central Asia represents a significant chapter in the history of the region, yet it remains underexplored in Russian historiography. The ideological constraints and historical narratives surrounding the deportation have led to a lack of comprehensive research on this topic, creating what some scholars refer to as "blank spots" in the historical record.

Contemporary historiography faces the challenge of addressing these gaps and providing a nuanced understanding of the deportation experience. Scholars from various fields, including sociology, political science, and history, have begun to examine the complexities of Chechen deportation, shedding light on the social, political, and cultural dimensions of this historical event. The ongoing discourse surrounding the history of the Chechen people and their experiences during deportation is essential for recognizing the profound impact of these events on their identity and cultural heritage.

The development of new lands by exiled Chechens in Kazakhstan and Central Asia was marked by a multitude of challenges, including adaptation to new environmental conditions, infrastructural rehabilitation, cultural preservation, and psychological adjustment. Despite the difficulties they faced, the deported Chechens exhibited remarkable resilience and adaptability as they sought to rebuild their lives. The historical context of their deportation and settlement underscores the importance of continued research and recognition of their experiences, paving the way for a deeper understanding of their cultural identity and the impact of displacement on communities.

References

[1] Isakieva Z.S. Labor contribution of deported Chechens and Ingush to the mining industry of Central Kazakhstan in the 40-50s of the XX century / Z. S. Isakieva: abstract of dis. ... candidate of historical sciences: 07.00.02. - Vladikavkaz, 2016.- 31 p.

[2] Tsutsulaeva S.S., Mamsurova M.Sh., Daudov A.Z., Shamsadov S.S. Rehabilitation and restoration of national autonomy of the chechen people: historiographic problems, 2020. C. 3457-3463.

[3] Bugaev A.M. National-state construction in Chechnya: historical experience and modernity, 2001. P.21-22.

[4] Tsutsulaeva S.S. Issues of deportation of the Chechen people in historical literature, 2019. P. 30-35.

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V.

Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Gladkov I.S. World economic evolution: trends at the present stage. 2023. No. 4 (40). P. 6-15

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., . . . Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

INSTRUMENTS FOR FINANCING ENVIRONMENTAL PROJECTS DURING THE GLOBAL ENERGY TRANSITION

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Abstract

This article examines the financing tools for environmental projects that ensure an effective flow and transfer of capital between global investors. All this is aimed at expanding the use of "green" technologies, strengthening "green" culture and environmental sustainability, as well as solving the problem of climate change during the global energy transition. The study noted that improving the energy efficiency of countries and economies will be crucial in order to meet climate ambitions, ensure growth and improve well-being, especially to achieve the goal in terms of carbon emissions in the long term. Energy efficiency in the financial industry is considered an attractive investment, as it generates new dynamics to accelerate and expand private financing of investments and make these investments more effective for investors. The publication lists various instruments for financing environmental projects. The distribution of funds distributed among various programs within the framework of the EU's next-generation economic recovery program for the period from 2020 to 2027 and the Use of green bond programs in Europe in 2014-2021 by industry are also presented in the form of graphs. Financing instruments for environmental projects play a key role in promoting sustainable development and reducing negative environmental impacts. In recent years, there has been a growing interest in "green" financing, which includes various financial instruments aimed at supporting environmentally friendly technologies and projects. Crowdfunding as an alternative source of financing: Crowdfunding allows you to attract an unlimited number of investors with different levels of financial literacy and accessibility, which makes it attractive for environmental projects. Green bonds and loans are important tools for financing the transition to a green economy by providing extra-budgetary sources of financing.

Keywords: capital movement, the "green" transition, energy efficiency, safe and reliable economic justification, Innovative tools, financing of environmental projects, global energy

I. Introduction

Investments in energy efficiency often lead to high transaction costs because projects are small and not aggregated enough to attract investors. These types of investments, such as building overhauls, have a long payback period, and investors fear that the savings achieved will not justify the cost of energy upgrades. However, it is becoming increasingly clear that the risks associated with them are lower than the level perceived by the market.

To convince investors that energy efficiency projects in general have a safe and reliable economic justification, and to help banks and other financial institutions easily understand and assess all the risks and opportunities associated with a particular project. There is an urgent need for technical and legal standardization at all stages of the investment value chain in order to simplify transactions and increase the trust of financial institutions.

The lack of standardization of projects hinders the securitization of energy-efficient assets in the capital markets. It is usually expected that the cost of energy efficiency investments will be offset solely by reducing energy bills, but it is becoming increasingly clear that the benefits are non-energy in nature, including improving comfort and health parameters in buildings, increasing the cost of the building itself, increasing the cost. A lower probability of default on mortgages and lower rates for attracting tenants or vacant property play a key role in deciding whether to invest in this area. Therefore, there are tangible financial and economic incentives to encourage financial institutions to invest more in energy efficiency. In Italy, innovative tools proven by industry are aimed at encouraging additional investments in energy efficiency initiatives, especially those conducted by small and medium-sized businesses.

II. Methods and materials

The research uses information data, as well as methods of theoretical research, namely: monographic.

Financing environmental projects in the energy sector is an important aspect for achieving sustainable development and reducing negative environmental impacts. In recent years, there has been an increase in interest in various financial instruments that can support the implementation of such projects.

III. Results and discussion

Green bonds and other debt instruments. The use of green bonds and other debt instruments such as corporate bonds, project bonds and financial green bonds to mobilize private capital. The use of project financing for large investment projects in the field of renewable energy allows for better risk management and reduction of agency conflicts. Guarantee schemes and tax benefits. Development of green loan guarantee schemes to reduce credit risks and the use of tax incentives to increase the profitability of green projects.

Funds and subsidies. Creation of funds, such as the Environmental Protection and Energy Efficiency Fund (EPEEF) in Croatia, to finance environmental and energy projects through soft loans, subsidies and grants. Legal mechanisms and digital green industrial mortgages. Development of legal mechanisms, such as digital green industrial mortgages, to attract investments in environmental projects in the fuel and energy sector.

Risk and profitability management. An effective policy should simultaneously take into account the risks and returns on investment in order to attract private capital to renewable energy projects. Financing environmental projects in the energy sector requires an integrated approach, including the use of various financial instruments such as green bonds, project financing, tax incentives and guarantee schemes. Both state and non-state financial institutions play an important role. Effective legal and policy mechanisms aimed at managing risks and profitability are also key to successfully attracting investments in this area.

Green bonds: the energy sector benefits the most. Use of procceds from green bonds in Europe 2014-2021, by industry (in billion U.S. dollars) (Fig. 1).

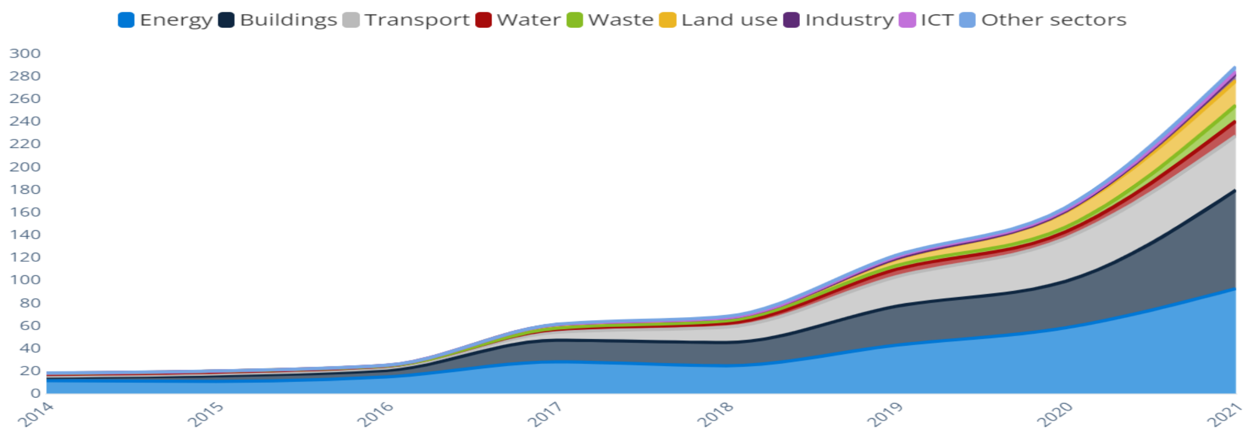

Figure 1: *Green bonds: the energy sector benefits the most. Use of procceds from green bonds in Europe 2014-2021, by industry (in billion U.S. dollars)*
Source: https://www.statista.com/topics/6233/green-bonds-in-europe/#topicOverview [103]

Green bonds, also called climate bonds, indicate that investors are interested in sustainable development. Environmental degradation and climate change pose serious physical and transitional risks to financial stability, such as business disruptions, asset destruction, reduced value of unused assets and increased insurance costs. Investors recognize the potential of sustainable financing and launch new and restructure old financial products to identify opportunities, mitigate risks, or align values. In Europe, the most common type of green bond issuers were financial corporations, which accounted for a third of all green bonds issued in Europe in 2022 [1-11].

The role of financing is extremely important to fill the deficit in order to develop Indonesia's green economy. The government has released an innovative financial instrument for financing the state budget (APBN) with the help of "green" sukuk. In 2019, the government also established the Environmental Fund Management Agency (BPDLH) to improve the quality of green financing.

Singapore has allocated 2.1 billion Singapore dollars from proceeds from the sale of bonds maturing in 50 years to cover the cost of building two subway lines. This bon was presented as part of the Singapore Green Bon program and is part of a larger government strategy to finance environmental projects. The construction costs of MRT Jurong and MRT Pulau include 1.7 billion Singapore dollars due to green bonds issued in 2022 and 0.4 billion Singapore dollars due to green bonds issued in September 2023, where trade turnover increased 1.4 times to 2.8 billion Singapore dollars.

Since 2027, the construction of the MRT in the Jurong area and on Penang Island has been carried out in stages. The opening of two metro lines will help reduce carbon dioxide emissions by more than 100,000 tons per year, which is equivalent to eliminating the use of 22,000 trains on motorways. He notes an 81 percent reduction in CO2 emissions. A $2.1 billion green bond fund has been allocated for the construction of a highway across Jurong Island [12].

A total of $ 2.1 billion raised through green bonds issued by the Government has been allocated for the construction of the Jurong Area Line (JRL) and the Inter-Island Line (CRL), which are currently under construction. Both routes support the basic principles of the "sustainable lifestyle" of the Singapore Green Plan 2030. According to the September 25 report of the Ministry of Finance (MOF), the funds were distributed in 2023. As part of this phase, it is planned that by 2030, 75 % of passengers will use public transport during peak hours compared to private transport. According to the latest data, this figure is about 64 %.

This is a serious effort to achieve the ambitious goal of significantly reducing carbon dioxide emissions by land transport in absolute terms, in line with Singapore's goal of zero carbon dioxide emissions by 2050. Experts estimate that routes in the Jurong area and between the islands will provide total carbon dioxide emissions savings equivalent to the use of at least 22,000 vehicles. It is expected that the remaining funds from the newly opened part of the program will be fully allocated by the end of the 2025 fiscal year. Today, Singapore's green bond system remains a key element of Singapore's efforts to channel investments into projects that will contribute to sustainable development efforts.

By 2030, the Singapore government will issue green bonds worth up to $35 billion to finance public sector green infrastructure projects. The relevant categories included renewable energy sources, energy efficiency, green construction, environmentally friendly transport and sustainable management of water supply and wastewater. These projects are expected to help Singapore transition to a low-carbon economy, contributing to the achievement of the climate and environmental goals set by the Government. As a leading energy transition company, Pertamina is committed to achieving zero emissions by 2060 by continuing to support programs that directly impact the achievement of the Sustainable Development Goals (SDGs). All these efforts are consistent with the principles of environmental, social and managerial responsibility (ESG) in all business lines and operations of Pertamina.

The Government has put into effect the tools of the Federal Communications Commission to finance environmental protection measures in forests. A non—market financial instrument, the Forest Conservation Certificate (FCC), is used to finance forest conservation and environmental protection activities. The FCC is one of the mechanisms developed by the Malaysian Forest Fund (MFF) since 2022 as part of the Financial REDD Plus (RFF) program.

The Forest Conservation Certificate (FCC) issued by the Malaysian Forest Fund (MFF) is a financial instrument that is not used in the market to finance environmental protection measures and initiatives for sustainable forest management, as well as to protect the environment.

Since 2022, Malaysia has begun work on the creation of innovative financial instruments based on RFF. Thus, the RFF mechanism is a one—step transformation that provides a new paradigm in financing environmental activities and nature-based solutions, recognizing the important role of the public-private partnership structure.

Breakdown of funds allocated among different programs in the NextGenerationEU economic recovery package from 2020 to 2027(in billion Euros) (Fig. 2).

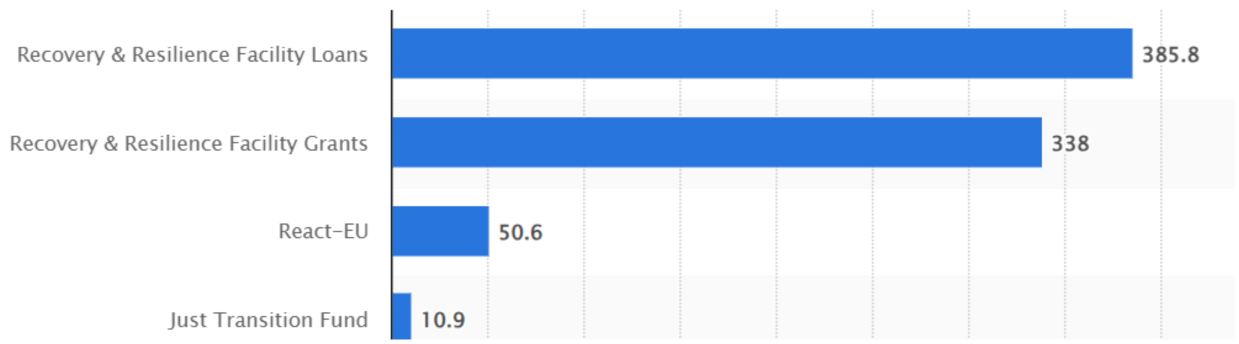

Figure 2: *Breakdown of funds allocated among different programs in the NextGenerationEU economic recovery package from 2020 to 2027(in billion Euros)*
Source: https://www.statista.com/statistics/1366824/next-generation-eu-funds-allocation/

From Fig. 2 it can be seen, the largest share in the package is occupied by the Recovery and Sustainability Fund, which provides loans and grants to participating countries to invest in projects that promote the growth of "green" industries, stimulate the digitalization of the economies of participating countries, as well as to invest in social, economic and institutional development. Other programs included in the NextGenEU package range from the Fair Transition

Fund, which aims to support regions most affected by the transition to a green economy, to rescEU, which invests in supplies to respond to humanitarian crises.

About 45 percent of the total funds of the Recovery and Sustainability Fund (RRF) were allocated to green transition projects (not including projects in which the element of green transition is combined with one of the other categories). Member States such as Denmark, Poland, Belgium and Ireland have allocated most of their funds to this category. On the other hand, Greece, Slovakia, Latvia and Cyprus have allocated more funds to projects focused on social, economic and institutional development. Germany has allocated the largest share of RRF funds to digital transformation — about 37 percent of the total.

IV. Conclusion

Financing instruments for environmental projects play a key role in promoting sustainable development and reducing negative environmental impacts. In recent years, there has been a growing interest in "green" financing, which includes various financial instruments aimed at supporting environmentally friendly technologies and projects.

Crowdfunding as an alternative source of financing: Crowdfunding allows you to attract an unlimited number of investors with different levels of financial literacy and accessibility, which makes it attractive for environmental projects.

Green bonds and loans are important tools for financing the transition to a green economy by providing extra-budgetary sources of financing.

References

[1] Abramova M. Features of the mechanism for implementing sustainable development through the green economy. E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

[2] Berstembayeva, R., et al. (2024). The impact of the green economy on the sustainable development of Kazakhstan. In *BIO Web of Conferences* (Vol. 116, p. 07040). EDP Sciences

[3] Yessymkhanova, Z. et al. The potential of the water industry in the context of sustainable development. IOP Conference Series: Earth and Environmental Science, 2021, 937(3), 032027 DOI: 10.1088/1755-1315/937/3/032027

[4] Yerzhanova, S., et al. (2017). Perfection of the administrative mechanism of stimulation of tourist business. *Journal of Environmental Management and Tourism*, *8*(8), 1494-1503.

[5] Yerzhanova, S., et al. (2023). Development Prospects Labor Income of the Population of the Republic of Kazakhstan: Economic Efficiency and Priorities of Regulation. *Montenegrin Journal of Economics*, *19*(2), 21-32.

[6] Dauletkhanova, Z. et al. Water resources management in Kazakhstan in conditions of their shortage. IOP Conference Series: Earth and Environmental Science, 2021, 937(3), 032012 DOI: 10.1088/1755-1315/937/3/032012

[7] Burkaltseva, D. et al.Assessment of the Development of the Stock Market in the Russian Federation in a Crisis. Journal of Risk and Financial Management, 2022, 15(1), 4 DOI: 10.3390/jrfm15010004

[8] Burkaltseva, D.et al. Methodological Foundations of the Risk of the Stock Markets of Developed and Developing Countries in the Conditions of the Crisis.., Journal of Risk and Financial Management, 2022, 15(1), 3 DOI: 10.3390/jrfm15010003

[9] Ruzieva, E. et al. Optimization and management of the lecture training strategy for students. Entrepreneurship and Sustainability Issues, 2020. –№7(3)– PP. 2407–2418 https://doi.org/10.55908/sdgs.v11i2.318

[10] Evmenchik, O.S. The Role of Gross Profit and Margin Contribution in Decision Making. Studies in Systems, Decision and Control, 2021, 314, pp. 1393–1404 DOI:10.1007/978-3-030-56433-9_145

[11] Malbekova, D., et al. (2023). Social support of young medical personnel in the conditions of sustainable development of rural areas of Kazakhstan. In *BIO Web of Conferences* (Vol. 65, p. 05012). EDP Sciences.

[12] Bondarenko I.S. Analysis of the digital economy of the russian federation according to the methods of international organizations // Economics and Management. – 2024. – № 2 (49). – P. 29-35. doi: 10.21777/2587-554X-2024-2-29-35

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THE RISK OF CHANGE IN THE THICKNESS, SAND AND OIL-GAS CONTENT OF THE PRODUCTIVE SERİES SEDIMENTS ON THE NORTHERN SLOPE OF THE SOUTH CASPIAN DEPRESSİON

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Absract

Studies were carried out on Pirallahi, Gurgan-deniz, Khali, Chilov, Janub, Janub-2, Azi Aslanov, Palchig-Pilpilesi, Neft Dashlari, Gunashli, Chirag, Azeri and Kapaz structures in the Absheron-Balkan oil and gas-bearing zone. Paleogene-Quaternary sediments are represented in the section of the sedimentary cover of the Absheron-Balkan zone. The industrially productive oil and gas deposits discovered in this zone are related to the suites of the lower and upper stages of the Productive series (Pliocene).

The changes risk of the total thicknesses and sand content of the suites of Productive series in the structures of the study area were analyzed in the direction of four anticlinal zones.

To determine the change risk of thickness and sand content of individual suites of the PS and the phase zonation of hydrocarbons corresponding graphs were constructed and analyzed. The graphs are constructed based on average values of thickness and sand content.

According to the conducted analyses, the thickness and sand content of the suites of the lower and upper stages of the PS on the Pirallahi-Janub-2, Khali-Neft Dashlari, Gunashli-Kapaz anticlinal zones are increas from the northwest to the southeast along the northeast and southwest limbs. The characteristics of the thickness changes risk of the PS suites show that the tectonic movements and the relief of the basin bottom play a key role in the thickness distribution. Based on the change of sand content in the study area, it can be noted that the paleogeographical conditions in the basin during the formation of PS sediments were quite favorable.

The Kapaz structure, located at the southeastern end of the Gunashli-Kapaz anticlinal zone, is similar in geological structure with other folds of the anticlinal zone where it is located. It can be noted that the GaS, PK, PKS, Balakhani suites with gas-condensate-oil bearing in the adjacent fields are also highly promising here. In the Azeri field, which is located in this anticlinal zone, the PKS suite of the Productive series is gas-condensate bearing. The PK and GaS are oil-gas-condensate-bearing in the neighboring Chirag and Gunashli fields, so, they are also can be promising here.

The complexity level of the folds noted here is different. İt is play a fundamental role in the distribution of oil and gas fields. İt should be noted that longitudinal faults play a key role in the distribution of hydrocarbon accumulations in the fields of Absheron oil and gas region. Due to influence of the transverse faults folds are placed in a stepped form. İt is lead to reshape the oil fields in Pliocene sediments. Regarding the formation of oil and gas deposits, it should be noted that this process is formed as a result of the alternating activity of vertical and lateral migrations. Therefore, in the chain-arranged ascents within the mentioned zone, in the southeast-northwest direction, so, the differential entrapment of oil and gas along up dip is justified. That is, along the Pirallahi-Janub-2 anticlinal zone, gas-condensate deposits are replaced by oil-gas, in turn, the oil-gas deposits are replaced by oil deposits in the southeast-northwest direction. The lower suites of the PS on the Gunashli-Kapaz anticlinal zone are mainly characterized by gas-condensate, and the upper suites are mainly characterized by the presence of oil-gas accumulations.

Keywords: deposits, gas-condensate, suites, anticlinal zone, fault, vertical and lateral migrations, subduction zone, differential entrapment

I. İntroduction

The Absheron-Balkan structural megasaddle, which is a structural element of the South Caspian depression, geodynamically is a structural-tectonic expression of a non-classical subduction zone, as well as at the same time forms the north-northeast slope of the South Caspian depression [9, 10]. The Absheron-Balkan oil and gas-bearing zone includes Pirallahi, Gurgan-deniz, Janub, Janub-2, Khali, Chilov Island, A. Aslanov, Palchig Pilpilesi, Neft Dashlari, Oguz, Gunashli, Chirag, Azeri and Kapaz fields (Fig. 1) [3].

12 of the 14 structures located in the Absheron-Balkan folding zone are considered deposits that they are being developed. Oil, gas and gas-condensate system deposits here belong to both the upper (Surakhani-Fasila suites) and lower (PKC, PKS, KS, PK, GaS) stages of the Productive series (PS) sediments.

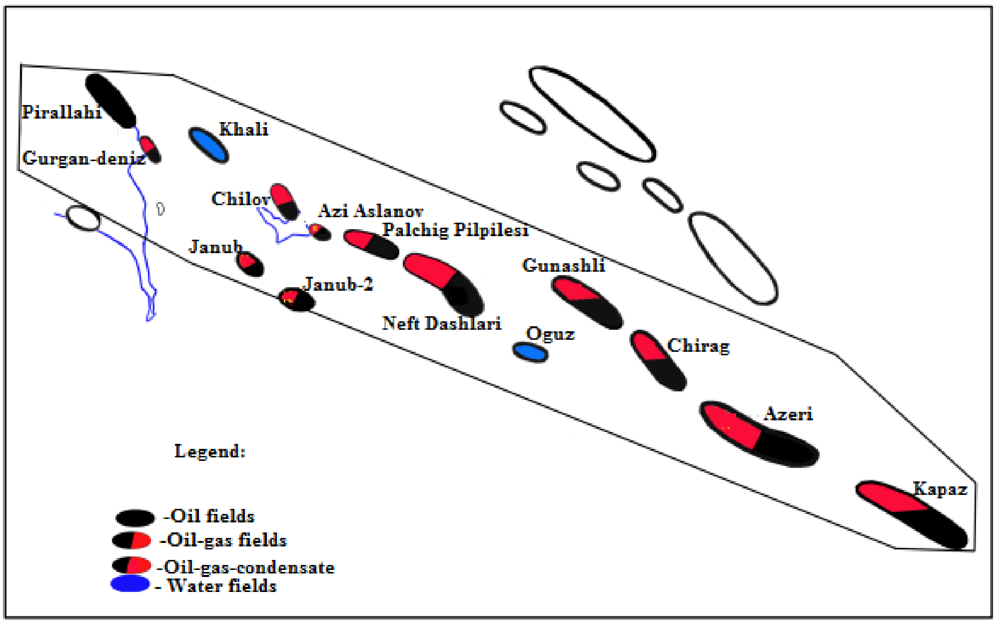


Figure 1: *Overview map of the structures*

Since the 80s of the last century, complex geological (drilling, seismoacoustic profiling, engineering-geological studies) work has been started in the abyssal exploration areas of the Caspian Sea, including the Gunashli, Chirag, Azeri, and Kapaz areas. As a result of structural-prospecting and prospecting-reconnaissance drilling, the Pirallahi Island, Gurgan, Palchiğ Pilpilesi and Neft dashlari fields were discovered.

The sediments involved in the geological structure of the areas belonging to the Absheron-Balkan zone cover a wide stratigraphic interval (from the Paleogene (₽) to the Quaternary (Q)).

Rich oil and gas deposits discovered in the Apsheron zone are associated with Pliocene sediments. In the Apsheron-Balkan oil-gas-bearing zone, studies were carried out on the Pirallahi, Gurgan-deniz, Khali, Chilov, Janub, Janub-2, Azi Aslanov, Palchig-Pilpilesi, Oguz, Neft Dashlari, Gunashli, Chirag, Azeri and Kapaz structures [12-14].

In general, in certain periods in the study area, mainly at the end of the Lower Pliocene, the occurrence of uplift affected either partial or complete washing out of the upper PS sediments, as well as the change of their lithological composition, leading to pinching out of a number of layers and, therefore, restrictions in terms of oil and gas prospects.

II. Method

The changes of total thickness and sand content of PS sediments in the structures of the study 244 wells were included in the interpretation project. 5 in Pirallahi, 7 in Gurgan-deniz, 5 in Khali, 6 in Chilov, 9 in Janub and 3 in Janub-2 fields, 5 in A. Aslanov, 4 in Palchig-Pilpilesi, 19 in Neft Dashlari, 2 in Oguz areas, 17 wells in the Gunashli, 4 in the Chirag, 3 in the Azeri, as well as 5 in the Kapaz field were studies. The results of the geophysical studies conducted in the wells were investigated [13].

In the study area, models characterizing the thickness and sand content of individual anticlinal zones were drawn up. The models are constructed by using of Surfer program.

III. Discussion

The thickness and sand content of the horizons and suites of the PS sediments in separate anticlinal zones are traced in the study area. As is known, the analysis of changes in the petrophysical properties of rocks along the area and depth allows to determine their reservoir properties change in that direction and to relatively objectively assess both the fluid capacity and oil-gas prospects of natural reservoirs [8]. For this purpose, in order to determine the thickness and sand content of the individual suites of the PS in the Pirallahi, Gurgan-deniz, Janub, Janub-2, Chilov, Palchig Pilpilesi, Neft Dashlari, Gunashli, Azeri, Chirag, Kapaz fields and to determine the phase zonation of hydrocarbons, the corresponding graphs were constructed and analyzed. The graphs are constructed based on average values of thickness and sand content values (Fig.2).

According to the graph the thickness of the Pre-Kirmaki sandy (PKS) suite is fluctate between 41-54 m in the Pirallahi, 34-54 m in the Gurgan-deniz, while 57-60 m in the Janub fields. It varies up to 52 m in the Janub-2 field located along the Pirallahi-Gurgan-deniz-Janub-Janub-2 anticlinal zone. The sand content of PKS varies between 27-58% in the Pirallahi, 25-78% in the Gurgan-deniz, 33-35% in the Janub and up to 31% in the Janub-2 fields.

The thickness of the Kirmaki suite (KS) varies between 234-292 m in the Pirallahi, 285-566 m in the Gurgan-deniz, 226-243 m in the Janub fields, while up to 230 m in the Janub-2 area. The sand content of the KS varies between 14-32% in the Pirallahi, 16-31% in the Gurgan-deniz, 9-15% in the Janub areas, and up to 38% in the Janub-2 area.

The thickness of the Pre-Kirmaki (PK) suite ranges from 22 to 90 m in the Pirallahi, from 130 to 173 m in the Gurgan-deniz, from 127 to 133 m in the Janub areas, while up to 128 m in the Janub-2 area. The sand content of the PK suite varies between 36-62% in the Pirallahi, 27-65% in the Gurgan-deniz, 60-92% in the Janub areas, and up to 94% in the Janub-2 area. The uncovered thickness of the Gala suite (GaS) varies between 135-333 m in the Gurgan-deniz, 143-379 m in the Janub areas, while up to 120 m in the Janub-2 area. The sand content of GaS varies between 8-19% in the Gurgan-deniz, 8-10% in the Janub, and up to 75% in the Janub-2 areas.

According to the graph constructed along the Chilov-A.Aslanov-Palchig Pilpilesi-Neft Dashlari anticlinal zone [12], the thickness of the PKS suite in the southwest limb of the structures is noted as following: 26-45 m in the Chilov area, up to 38 m in the A.Aslanov area, and between 28-38 m in the Palchig Pilpilesi, it varies between 26-30 m in the Neft Dashlari, and up to 49 m in the Oguz areas. The sand content of the suite is consists 16-50% in the Chilov, 24% in the A. Aslanov areas, between 16-29% in the Palchiq Pilpilesi, 23-75% in the Neft Dashlari, and 55% in the Oguz areas is observed (Fig. 3).

The thickness of the KS varies between 223-504 m in the Chilov, up to 364 m in the H. Aslanov, 276-372 m in the Palchig Pilpilesi, 280-379 m in the Neft Dashlari, and up to 258 m in the Oguz areas. The sand content of KS varies between 4-20% in the Chilov, 3% in the A.Aslanov areas. İt is fluctate between 3-8% in the Palchig Pilpilasi, 2-3% in the Neft Dashlari areas, while up to 2% in the Oguz area.

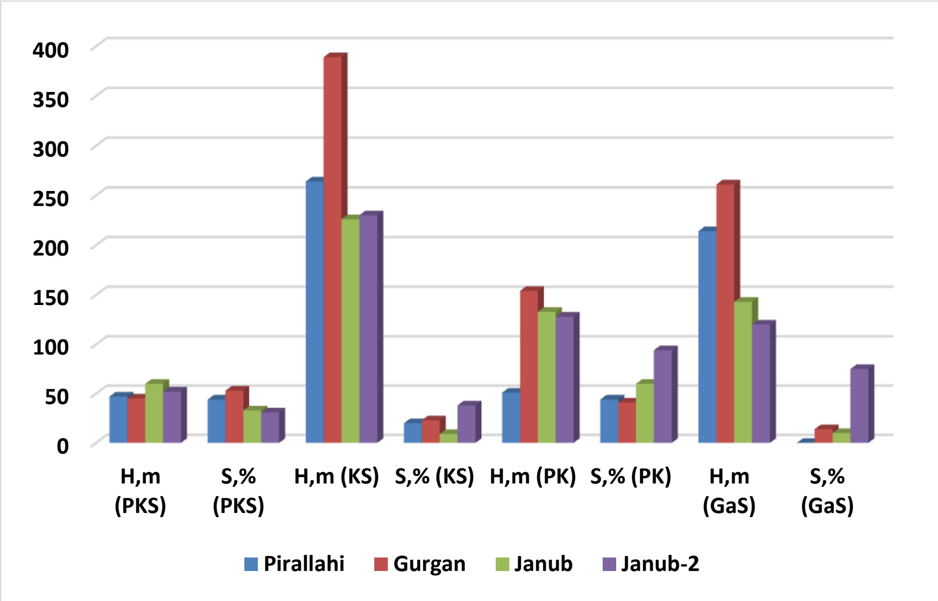


Figure 2: *The thickness and sand content of suites of the PS sediments along the Pirallahi-Gurgan-deniz-Janub-Janub-2 anticlinal zone*

The thickness of PK suite varies between 93-114 m in the Cilov area, while up to 92 m in the A.Aslanov area. It represented by 80-117 m section in the Palchig Pilpilesi area, while 35-89 m in the Neft Dashlari field, and up to 116 m in the Oguz area. Sand content of PK 24-27% along the Chilov area is observed, while 35% along the A.Aslanov area. İt is consists of 25-39% in the Palchig Pilpilesi, 34-53% in the Neft Dashlari areas, and 94% along the Oguz area is noted.

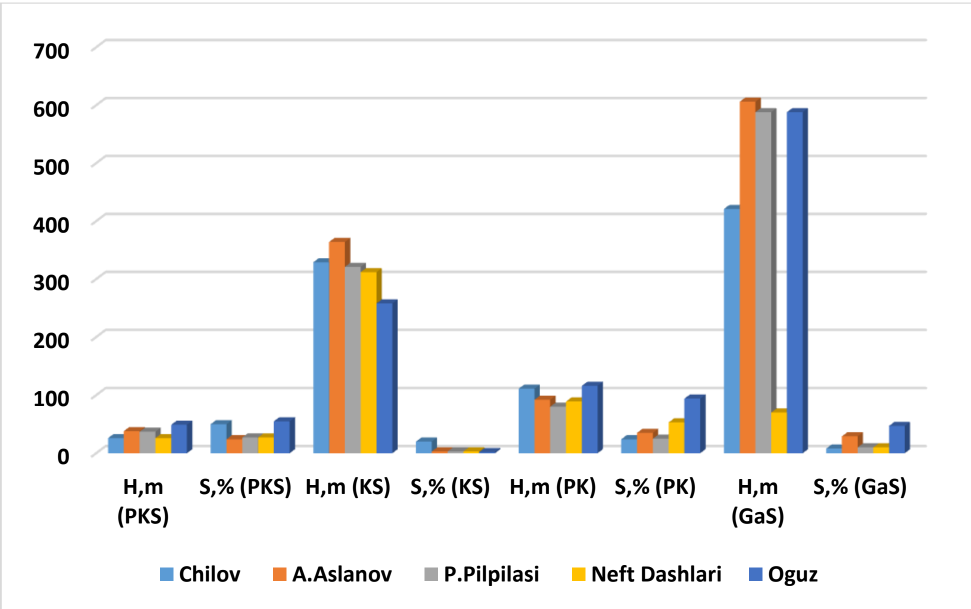


Figure 3: *The thickness and sand content of suites of the PS sediments along the Chilov-A.Aslanov-Palchig Pilpilesi-Neft Dashlari*

The exposed thickness of GaS ranges from 187-498 m in the Chilov area, while up to 606 m in the A.Aslanov field. İt is 394-588 m in the Palchiq Pilpilesi area, and up to 70 m in the Neft Dashlari area. The Oguz area is represented up to 588 m by the GaS sediments. The sand content of GaS ranges from 8-16% in the Chilov area, it is 29% in the A.Aslanov field. The Palchiq Pilpilesi and Neft Dashlari field sections are represented by 10-27% and 10% respectivly. İt is up to 47% in the Oguz area.

According to the longitudinal correlation scheme in the northwest limb direction, the thickness of the PKS is up to 38 m in the Khali area, while 26-38 m in the Chilov area. İt is up to 29 m in the A. Aslanov area. The Palchiq Pilpilesi and the Neft Dashlari areas are represented by the PKS sediments of 27-39 m and 25-46 m correspondingly. The sand content of PKS suite is 42% in the Khali area, 27-42% in the Chilov area, 83% in the A. Aslanov area, 12-22% in the Palchig Pilpilesi area, while 88-100% in the Neft Darshali [11, 12].

The thickness of KS ranges up to 274 m in the Khali area, between 325-351 m in the Chilov, while up to 329 m in the A. Aslanov area. İt is 271-357 m in the Palchig Pilpilesi and 250-372 m in the Neft Dashlari areas. Sand content of PK suite is 24% alomg the Khali, between 2-8% in the Chilov, 22% in the A. Aslanov areas is observed. 2-13% and 2-3% along the P. Pilpilesi and the Neft Dashlari areas is noted, respectivly.

The thickness of PK suite varies up to 72 m in the Khali area, between 112-131 m in the Chilov area, while up to 72 m in the A. Aslanov area is observed. Between 78-133 m and 69-99 m in the Palchig Pilpilesi and the Neft Dashlari areas is noted, correspondingly. The sand content of the PK suite is noted as following: 69% in the Khali, 19-55% in the Chilov, 50% in the A. Aslanov, 7-13% on the P. Pilpilesi area, 33-56% along the Neft Dashlari (Fig.4).

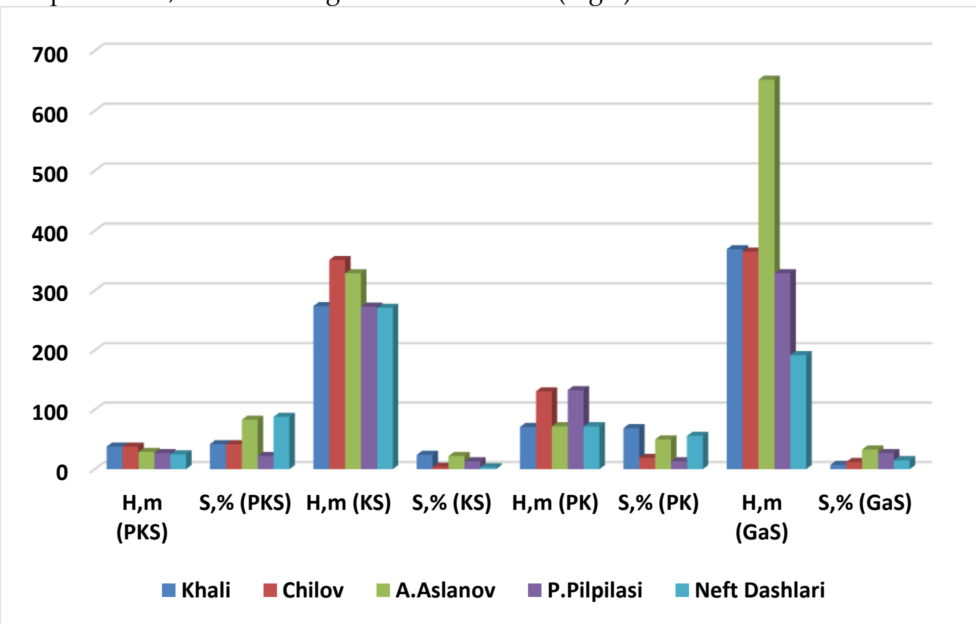


Figure 4: *The thickness and sand content of suites of the PS sediments along fields*

The uncovered thickness of GaS varies up to 369 m in the Khali, between 282-445 m in the Chilov, up to 652 m in the A. Aslanov, between 329-470 m in the Palchig Pilpilesi areas, and between 134-192 m in the Neft Dashlari field. The sand content of GaS suite is 7% in the Khali, 12-15% in the Chilov, 33% in the A. Aslanov, 13-29% in the P. Pilpilesi areas, while 15-28% in the Neft Dashlari area.

According to the longitudinal correlation scheme (Fig. 5) in the direction of the northeast limbs of the Guneshli, Chirag, Azeri, Kapaz structures according to the top of PKC suite the thickness of SuS varies between 1105-1385 m in the Gunashli, 888-968 m in the Chirag, 920-1028 m in the Azeri, and up to 1430 m in the Kapaz areas. The sand content of SuS varies up to 1-2% along the Gunashli, 3% - Chirag, 2-4% - Azeri, and up to 2% in the Kapaz areas is noted.

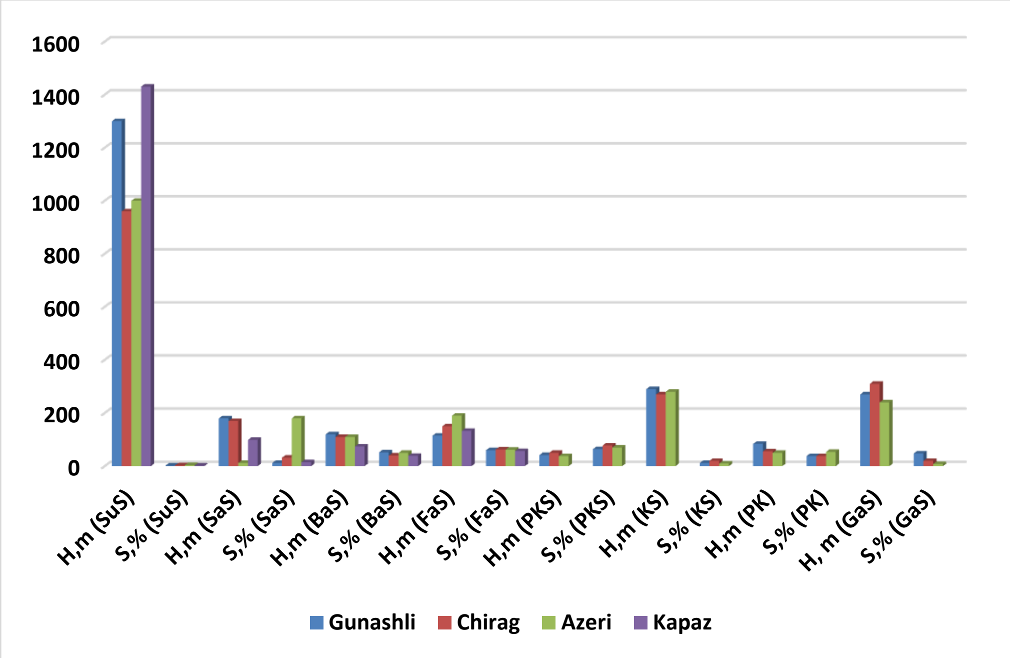


Figure 5: *The thickness and sand content of suites of the PS sediments along the northeast limbs of the structures*

The thickness of the horizon IV of SaS varies between 143-181 m in the Gunashli area. İt is 118-174 m in the Chirag, 98-99 m in the Azeri, and up to 99 m in the Kapaz areas. The sand content of the horizon IV of SuS varies as following: between 7-13% in the Guneshli area, 19-33% -in the Chirag, 8-13%- in the Azeri, and up to 15% in the Kapaz areas.

The thickness of the horizon V of the BaS ranges 74-148 m in the Gunashli, up to 100 m in the Chirag, 180-185 m in the Azeri, and up to 92 m in the Kapaz areas. The sand content ranges as following: 16% -in the Guneshli, 17-18% -in the Chirag, 21-23% -in the Azeri, and up to 17% in the Kapaz areas is abserved.

The thickness of the BaS (VI horizon) varies between 101-141 m in the Gunashli, 101-125 m in the Chirag, 109-117 m in the Azeri areas, and up to 137 m in the Kapaz field. The sand content of the BaS horizon VI is 24% in the Gunashli, 22% in the Chirag, 18-20% in the Azeri, and up to 17% in the Kepaz areas.

The thickness of the horizon VII BaS varies along following: 109-123 m, 99-117 m, 103-112 m and up to 74 m in the Gunashli area, Chirag Azeri and Kapaz areas, correspodingly. The sand content between 52-53%, 30-40%, 31-50% and up to 39% in the Gunashli, Chirag, Azeri, Kapaz areas is observed.

The thickness of the BaS (horizon VIII) varies between 109-119 m in the Gunashli area. İs 146-165 m in the Chirag, 118-127 m in the Azeri, and up to 73 m in the Kapaz areas. The sand content of horizon VIII varies between 18-30%, 18-35%, 26-43% and up to 28% in the Gunashli, Chirag, Azeri and Kapaz area, respectively.

The thickness of the BaS IX horizon section ranges from 120-148 m in the Gunashli field. 112-113 m in the Chirag, 111-130 m in the Azeri, and up to 90 m in the Kapaz areas. The sand content of the horizon IX consists 16-50%,14-34%, 18-22%, and up to 18% along the Guneshli, Chirag, Azeri, and Kapaz areas, respectively.

The thickness of the X horizon of BaS is identifid of 46-104 m in the Guneshli area, 92-95 m in the Chira, 97-105 m in the Azeri, and up to 68 m in the Kapaz areas. The amount of sand along the section of horizon X varies between 18-34% in the Guneshli, 27-48% -in the Chirag, 30-44% -in the Azeri, and up to 33% in the Kapaz areas is identified.

The thickness of Fasila suite is concidered as following sequentially: in Gunashli area -110-115 m, in Chirag- 132-153 m, in Azeri area- 135-196 m, up to 133m in Kepaz. The sand content of suite varies between 53-63%, 63%, 61-63% and up to 57% in the Gunashli, in the Chirag, in the Azeri, in the Kapaz areas, respectively.

The thickness of the sediment of PKS suite varies from 34 to 43 m in the Gunashli area. İt is consists 45-50 m in the Chirag, and varies from 37 to 38 m in the Azeri field. The sand content of the suite varies 62-65%- in the Guneshli, 68-78% -in the Chirag, while between 46-71% in the Azeri areas.

The thickness of KS varies between 268-293 m in the Guneshli area, between 242-271 m in the Chirag area, and between 263-283 m in the Azeri area. The sand content of the suite varies from 12% in the Gunashli, 16-20% in the Chirag, and 9-12% in the Azeri areas.

The thickness of PK suite ranges from 69 to 85 m in the Guneshli area. İn the Chirag and in the Azeri areas is represented by 45-57 m and 36-53 m thick section. The sand content of the suite is 33-38%, 35-39%, 40-54% in Guneshli, in Chirag, and in Azeri areas, correspondingly.

The thickness of the GaS varies between 252-279 m in the Gunashli, 291-316 m in the Chirag, and 240-318 m (opened) in the Azeri fields. The sand content of GaS about 28-49% in the Gunashli area is noted. İt is 4-23% in the Chirag, and 5-8% in the Azeri areas.

According to the longitudinal correlation scheme (Fig.6) in the SW limb direction in the Gunashli, Chirag, Azeri, Kapaz areas according to the top of FaS the thickness of SuS 950-1158 m in the Gunashli, 1074-1108 m in the Chirag, up to 951 m in the Azeri, and up to 1397 m in the Kapaz areas is found. Sand content of section 1-4%, 2-3%, 3% and 2% in Guneshli, in Chirag, in Azeri, in Kapaz areas is noted, relatively.

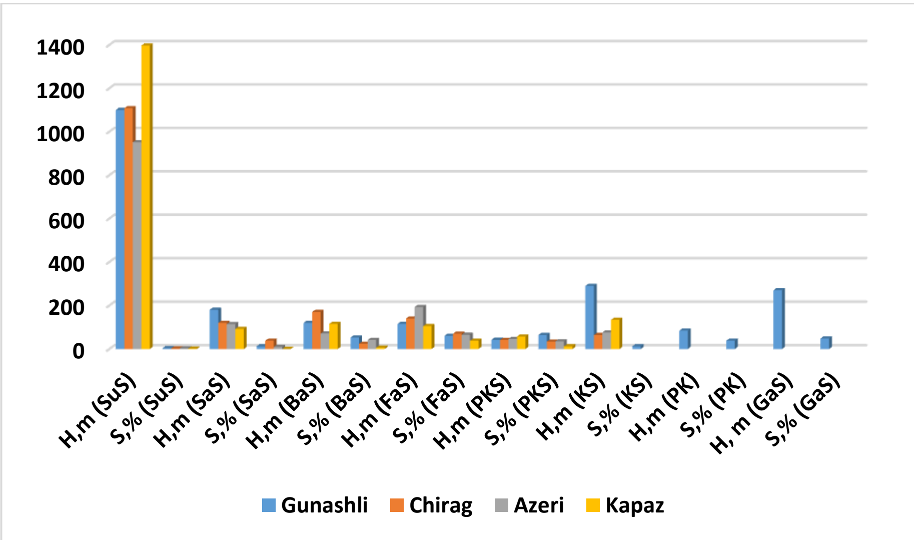


Figure 6: *The thickness and sand content of suites of the PS sediments along the southwest limbs of the structures*

The thickness of the IV horizon of SaS varies as following: in the Gunashli area- 155-173 m, in the Chirag area -between 90-122 m, in the Azeri area- up to 114 m, while up to 92 m in the Kepaz area. The sand content of the this horizon of 6-9% in the Gunashli, 14-39% in the Chirag, and up to 9% in the Azeri areas is found.

The thickness of the V horizon of BaS varies between 69-79 m in the Gunashli, 131-140 m in the Chirag, up to 148 m in the Azeri, and up to 83 m in the Kepaz areas. Amount of the sand along horizon ranges 14% in the Gunashli area. 13-20% in the Chirag, 12% in the Azeri, and up to 12% in the Kapaz areas is identified.

The thickness of the horizon VI of BaS 104-145 m, 100-175 m, up to 71 m and 115 m in the Gunashli, Chirag, Azeri, Kapaz areas is observed. The sand content 10-29% -in the Gunashli, 24% -in the Chirag, 41% -in the Azeri, and up to 6% -in the Kapaz area is noted.

The thickness of the BaS (VII horizon) varies as following: in the Guneshli area- 126-136 m, in the Chirag area- 110-118 m, in the Azeri field- up to 107 m, while up to 86 m in the Kapaz. The sand content of the horizon 27% in the Guneshli, 1-32% in the Chirag, 13% in the Azeri, and 17% in the Kapaz areas is considered.

The thickness of the horizon VIII section 114-131 m in the Gunashli, 145-166 m in the Chirag, up to 140 m in the Azeri, and up to 98 m in the Kapaz fields is found. The sandiness its up to 12% in the Chirag, 74% in the Azeri, and 8% in the Kapaz areas is observed.

The thickness of the BaS horizon IX varies between 125-147 m in the Gunashli field, between 86-133 m in the Chirag field, up to 150 m in the Azeri field, and up to 100 m in the Kapaz field. The sand content of the BaS IX horizon is between 11-23% in the Gunashli area, 24% in the Chirag area, 28% in the Azeri area, and 18% in the Kapaz area.

The thickness of the X horizon is 64-111 m thick in the Gunashli area. İn the Chirag area it is 105-110 m, up to 110 m in the Azeri, and up to 84 m in the Kapaz area. The sand content its changes 25-40% -in the Gunashli, 28-31% -in the Chirag, 39% in the Azeri, and up to 20% in the Kapaz areas.

FaS thickness fluctate in 107-119 m in the Gunashli field section, however, 110-149 m in the Chirag, up to 193 m in the Azeri, and up to 105 m in the Kapaz areas sections. Amount of sand 48-55%, 65-72%, 65%, and up to 39% along the section of the fields.

The thickness of the PKS suite rocks varies up to 44 m, 41m, 46m and up to 57m in the Gunashli, Chirag, Azeri, and in the Kapaz fields, respectively. The sand content of the suite reches up to 30% in the Guneshli, 34% in the Chirag, 35% in the Azeri, and 12% in the Kapaz areas.

The thickness of KS varies up to 371 m in the Gunashli area, up to 64 m (uncovered) in the Chirag area, up to 76 m (uncovered) in the Azeri area, up to 134 m (uncovered) in the Kapaz area. The sand content up to 8% in the Gunashli area is found.

The thickness of PK suite is 78 m, and the sand content up to 49% in the Gunashli area is abserved.

The thickness of GaS is 315 m in the Gunashli area, and the sand content varies up to 23%.

Based on the thickness correlation scheme along the Pirallahi-Janub-2 anticline line the thickness of individual layers increases from northwest to southeast (see, fig.2).

The thickness of the PS suites of the Chilov-Neft Dashlari anticlinal zone is greater in the southwestern limb than in the northeastern one. This shows that there is no influence of tectonic movements in the accumulation of those sediments in the southwestern limb.

In the Gunashli-Kapaz anticlinal zone, the thickness of the sediments increases in the direction of the Azeri field, and relatively decreases towards the Kapaz area. A sharp increase in thickness (1430 m) in the Kapaz area is observed in the VI horizon (137 m) of the Surakhani and the Balakhani suites. Accordingly, it can be noted that the rate of descent of the basin floor increased from the Azeri area to Kapaz during the deposition of Surakhani suite sediments. During the accumulation of the remaining suites of the PS, the regime of tectonic movements in the basin was the same.

The characteristics of the thickness changes of the PS suites show that the tectonic movements and the relief of the basin bottom play a key role in the thickness distribution.

The obtained results indicate that along the Pirallahi-Janub-2 anticline, the sand content increases from the Pirallahi area to the NE, from the Khali area to the NE in the Khali-Kapaz anticline line, reaches its maximum in the Gunashli-Chirag-Azeri areas, and decreases relatively towards the Kapaz area.

In many cases, the occurrence and distribution of hydrocarbons in sediments of the same stratigraphic age do not follow a clearly explained pattern. Therefore, in order to clarify the presence of any regularity sought in different structures, the obtained complex geological-geophysical data must first be analyzed within a specific structure. The increase in hypsometric depth in the western part of the South Caspian basin and the high gas saturation of the PS prove that the productive areas in this region have spread over a large area.

Except of the A.Aslanov and the Janub anticlinal structures, the arch parts of all deposits are of brachyanticlinal type, subjected to disjunctive dislocation to varying degrees.

Depending on the depth, while the Balakhani and Fasila suites in the Neft Dashlari (260-1300 m depth range) and Gunashli structures (2460-2710 m depth range) are oil fields, the continuation of these suites to the Janub-1,2 fields (2575-4690 m depth range)) are gas condensate.

The KS is oil-bearing in all known fields of the archipelago (depth intervals 480-1800 m), except of Janub-1 gas condensate field. The PK suite is oil-bearing in the Pirallahi, Gurgan-deniz, Chilov Island, A.Aslanov, Palchig Pilpilesi, Neft Dashlari fields (depth interval 650-2600 m), while is gas-condensate-bearing in the Janub-1, Gunashli fields (at a depth of 3260-5200 m) [7]. Variations are also observed due to stratigraphic distribution in individual deposits. So, if all the intermediate layers, from the Sabunchi suite to the PK suite including, layer in the structures of Neft Dashlari, Chilov Island are characterized by oil deposits, then oil and gas deposits are known in the Gala suite (GaS), which is involved in the geological structure of these areas.

The Western Absheron field, including Chilov Island (Western Absheron, Absheron bank, Darwin bank, Pirallahi Island, Gurgan-deniz, and Chilov Island), oil deposits are assossated with PKS, KS and PK suite sediments [14].

The oil-gas-bearing deposits are found in the GaS sediments which lie deeper than these formations in the Garbi Apsheron, Chilov Island and Neft Dashlari structures of the area. It is a special case that the "Fasila" suite in the Kapaz structure, which is located in the continuation of this zone, is oil and gas-bearing. So, in known fields (Neft Dashlari, Gunashli, Chirag, Azeri) "Fasila" suite is oil saturated.

During the test of well 1 drilled in the north-east limb of the Kapaz field (3527-3491 m), 286 t of oil and 20 thousand m^3 of gas per day were obtained from the FaS by the open flow method. 375 t of oil and 35 m^3 of gas per day were obtained from the 3725-3682 m interval of well 3 in the southwest limb. During the test of well 5 dug in the southwest limb, a gas flow with a daily output of 100,000 m^3 was obtained from a depth of 3684-3640 m. If we take into acount that the KS (Gunashli), PK (Gunashli, Chirag), PKC (Gunashli, Chirag, Azeri), Balakhani (Gunashli X horizon) suites are gas-condensate-oil-bearing in the neighboring fields, and the similarity of the geological structure and geological development history, hydrogeological conditions, etc. of the Kapaz field with these fields , it can be assumed here the high prospectivity of the suites of the same name of the PS (Fig.7).

If you follow the productive horizon of the same name along a certain area, it is observed that there are different products in them. For example, the PKS suite is oil-bearing in the Chilov Island, the Janub, the Palchig Pilpilesi, and the Neft Dashlari fields, while it is gas-condensate-bearing in the Gunashli, Chirag, Azeri fields. There can be two explanations for the observation of such a situation in this structure. First of all, it can be explained by the free diffusion of gas dissolved in oil through geotectonic dislocations that occurred in the long geological period as a result of low formation pressure and temperature in shallow deposits. On the other hand, oil-gas, oil, gas condensate deposits form a strip of independent deposits located in different zones in the same region.

If the latest actual data is taken as the basis, in the direction of the Gum-deniz, Janub-1, Janub-2, Gunashli and Bahar-Azeri-Kapaz fields, there are rich underground (buried) intermediate structures, where productivity of Fasila, PKS, KS, PK and GaS are possible. In addition, based on new seismological and geophysical studies of wells, it is shown that the continuation of the oil-gas-bearing deposit of the Fasila suite in the Kapaz structure corresponds to the top of the VII oil-gas-bearing horizon of the Red series in the Turkmenistan sector [1, 2].

In this regard, the study of the regularity of the location and distribution of hydrocarbon deposits in the Absheron-Balkan archipelago plays a key role.

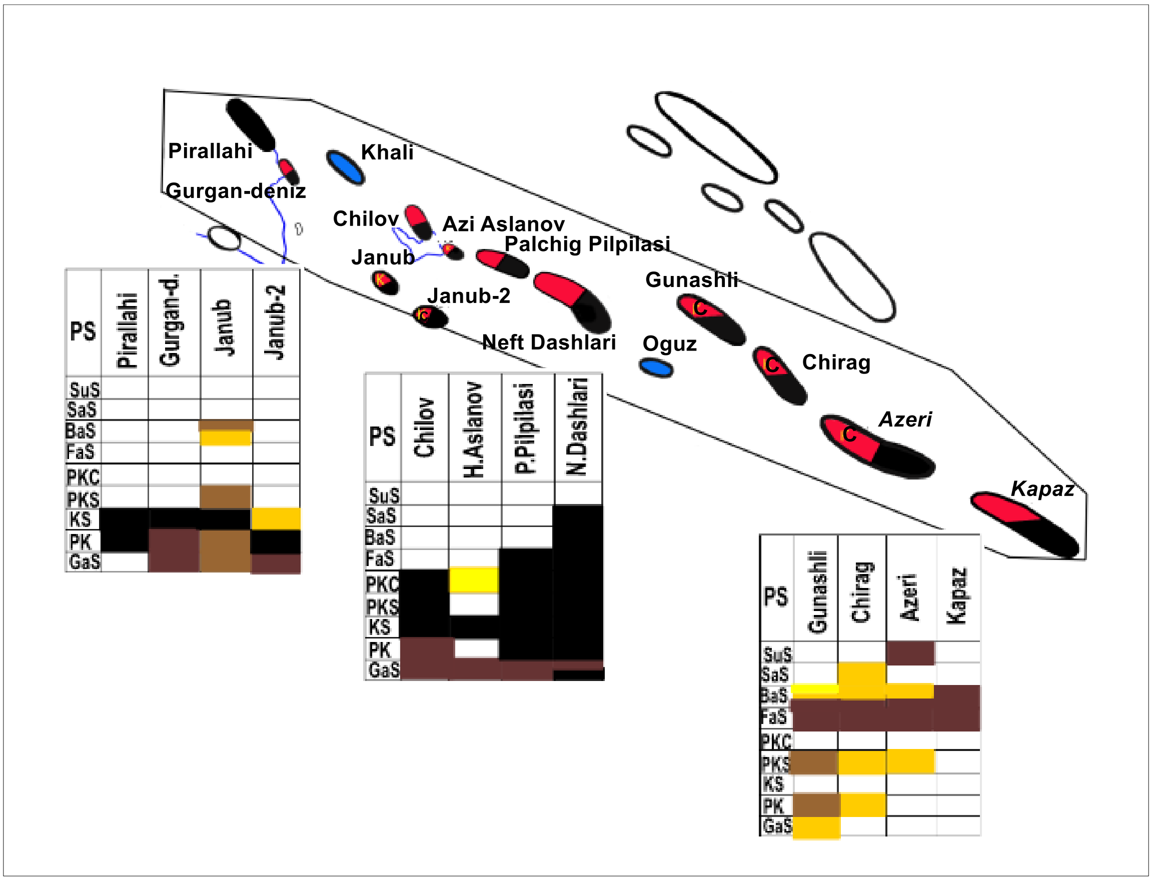
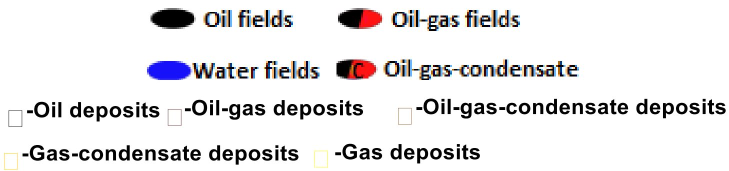


Figure 7: *Oil and gas deposits distrubution within fields*

Legend:



The level of complexity of the folds with faults mentioned here is different and play a fundamental role in the distribution of oil and gas fields [4]. It is known that, in one case, longitudinal faults play a role as oil and gas migration paths, both in their formation and in the destruction of deposits in Pliocene, Miocene-Paleogene, Upper Cretaceous and older sediments, and in the other case, as a screen in separate tectonic blocks and near-faulted zones prevents the displacement of oil and gas and form conditions to the accumulation of hydrocarbons. In the process of development of regional faults, transverse faults formed at separate stages create conditions for the formation of tectonic screened microblocks and its prevent the destruction of deposits in these microblocks [6]. Longitudinal faults play a key role in the distribution of hydrocarbon accumulations in the fields of Absheron oil and gas-bearing region. Transverse faults reshape the oil fields in Pliocene sediments by giving a stepped shape to the folds. It should be noted that here longitudinal faults are developed in the lower stage of the PS, and transverse faults often developed in the upper stage. The Janub, Janub-2 folds are complicated by normal faults. The formation of deposits through vertical migration along faults caused by tensile stress leads to the formation of a zone of deep oil and gas accumulation in the basin. This zone can be distinguished as the main oil and gas zone of the basin, which is located above the oil and gas formation sourses. Within it, the deposits are grouped along the main tensile zones and the faults branching from them. Regarding the formation of oil and gas deposits, it should be noted that this process is usually stepwise, that is, they are formed as a result of the alternating activity of vertical and lateral migrations. Therefore, in the chain-arranged ascents within the mentioned zone, in the southeast-northwest direction, so, in the direction of ascent of the layers, the differential entrapment of oil and gas is justified [5]. That is, along the Pirallahi-Janub-2 anticlinal zone, gas-condensate deposits are replaced by oil-gas and oil deposits in the southeast-northwest direction. The suites of the lower stage of the PS in the Gunashli-Kapaz anticlinal zone are mainly characterized by gas-condensate deposits, and the suites of the upper stage are mainly characterized by the presence of oil-gas accumulations.

IV. Conclusion

1. According to the results of the analyzes conducted in the Pirallahi-Janub-2, Khali-Neft Dashlari, Gunashli-Kapaz anticlinal zones, the thickness and sand content of the suites of the lower and upper stages of the PS are increas from northwest to southeast along of the northeast and southwest limbs of the structures.
2. The characteristics of the thickness changes in the PS suites show that the tectonic movements and the relief of the basin bottom play a key role in the distribution of thicknesses.
3. The GaS, PK, PKS, Balakhani suites are gas-condensate-oil-bearing in the adjacent fields. Taking into account this factor it is possible to note the high prospects of the suites of the same name of PS in the Kapaz field, due to the similarity of geological structure with these fields.
4. Faults that complicate structures play a key role in the formation of hydrocarbon deposits.

References

[1] Ali-zadeh, A.A. (2011). Selected works. Nafta-Press, 530 p.

[2] Aliyev, G.I., Aliyev, E.A. (2011). Oil and gas potential of great depths. Baku, 419 p.

[3] Bagir-zadeh, F.M., Karimov, K.M., Salayev, S.G. (1987). Deep structure and oil and gas potential of the South Caspian megadepression. AN Publishing House, 302 p.

[4] Narimanov, N.R., Rzayeva, S.M., Nasibova, G.J., Mansurova, S.I. (2014). Influence of the geodynamic regime on folding in the Absheron and Baku archipelagos of the South Caspian depression and on the Turkmen shelf. Geophysics innovations in Azerbaijan, 3-4, 26-33.

[5] Narimanov, N.R. (2005). Geodynamic aspects of formation structures in the South Caspian depression. Baku, ANE, 9, 14-21.

[6] Nasibova, G.J., Mukhtarova, Kh.Z., Ganbarova, Sh.A., . Ismayilova, M.M., Zeynalova, S.A. (2023). The influence of compressive stresses on folding in the Middle Kura depression and the Turkmen shelf. // Journal of Geology, Geography and Geoecology, 32(2), 352-359.

[7] Mukhtarova, Kh.Z., Nasibova, G.J. Estimation of oil and gas carrying capacity of local uplifts of the North-Absheron zone based on petrophysical parameters (on the basis of local uplifts of Goshadash-Agburun-deniz-Darwin bank-Gurgan-deniz). // Engineering of georesources. 2021, V. 332, 7, 7-19; DOI https://doi.org/10.18799/24131830/2021/7/3259.

[8] Nasibova, G.J.Oil and gas perspectives of the Umid structure in connection with its history of geological development . // "Reliability: Theory and Applications" (RT&A), Special Issue № 3 (66) Volume 17, January 2022c. 133-137. DOI: **https://doi.org/10.24412/1932-2321-2022-366-186-192**

[9] Senin, B.V., Kerimov, V.Yu., Mustaev, R.N.,Алиева, С.А. Lithological and paleo-geographic conditions for the formation and location of sedimentary basins of the Caspian region. // ANAS Transactions Earth Sciences. 1 / 2021. Geology and geophysics. p.16-27. 10.33677/ggianas20210100051

[10] Kerimov V. Yu., Mustayev R. N., Senin B. V., Aliyeva S.A. Modern structural and tectonic model of the Caspian region. // International Journal of the Federal Educational and Methodical Association on Applied Geology, Mining, Oil and Gas Activities and Geodesy EURASIAN MINING, 1 (37). 2022. p.27-33. https://www.rudmet.ru/catalog/journals/details/8/

[11] Gurbanov V.Sh., Galkin S.V., Narimanov N.R., Sultanov L.A., Abbasova G.G.. Petrophysical characteristics of Meso-Cenozoic sediments of the southeastern subsidence of the Greater Caucasus in connection with their oil and gas potential. SOCAR Proceedings, Bakı.2021. DOI:10.5510/OGP20210300524

[12] Mukhtarova, Kh.Z., Nasibova, G.J. Prospects for the oil and gas potential of the Khali-Neft Dashlar anticlinal zone in connection with its paleotectonic conditions. // News of Tomsk Polytechnic University. Georesources Engineering. V. 331, № 7 (2020) 176-185 p. 2020.

[13] Huseyinova A.N., Khuduyeva G.M. Comparative characteristics of the lithological composition and reservoir properties of rocks from the Gunashli and Kapaz fields. // Azerbaijan Oil Economy. 07-08.2016, p.11-14.

[14] Khuduzade A.I. Formation of uplift structures and oil-gas content in the northwestern part of the Apsheron archipelago. // Azerbaijan Oil Economy. 04.2016, p.13-18.

TAX POLICY AS A TOOL FOR STIMULATING SUSTAINABLE DEVELOPMENT: INTERNATIONAL AND RUSSIAN EXPERIENCE

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Abstract

This paper delves into the utilization of tax policy as a strategic tool for promoting sustainable development, comparing international practices with the Russian experience. Tax policy, when aligned with sustainability objectives, can drive economic growth, foster social equity, and protect the environment. The paper reviews various tax instruments such as carbon pricing, eco-taxes, incentives for renewable energy investments, and tax benefits for sustainable business practices, focusing on how they have been implemented globally and in Russia. Special attention is given to policies that address environmental externalities and encourage the transition to a low-carbon economy. In the case of Russia, the paper assesses the effectiveness of recent tax reforms aimed at fostering sustainable development, including energy efficiency incentives and efforts to diversify government revenues beyond fossil fuels. By examining successes, limitations, and lessons learned from both international and Russian contexts, the paper provides actionable recommendations to strengthen the role of tax policy in advancing sustainable development.

Keywords: tax policy, sustainable development, carbon pricing, environmental levies, renewable energy incentives, green fiscal reform, climate change mitigation, sustainable economic growth, eco-taxes, low-carbon economy

I. Introduction

The modern world faces a number of global challenges related to the need to ensure sustainable development (Fig.1). The concept of sustainable development includes three interrelated aspects: economic growth, social well-being and environmental safety. In the context of these tasks, tax policy becomes an important tool for achieving sustainable development goals. Properly designed tax mechanisms can not only promote economic growth, but also stimulate responsible use of natural resources and reduce negative impacts on the environment.

Many countries are already actively using tax instruments to promote environmental initiatives and support the transition to a low-carbon economy. Carbon taxes, environmental charges and tax incentives for "green" technologies are just a few examples of successful measures applied at the international level. Russia is also taking steps in this direction, introducing tax reforms aimed at reducing dependence on hydrocarbons and supporting innovative environmentally friendly technologies.

Introducing elements of sustainable development into tax policy is a complex process that requires taking into account the specifics of national economies and adapting to international trends. This article analyses international experience in using tax policy to stimulate sustainable development and examines how Russia is adapting these approaches to address its own environmental and economic challenges.

Figure 1: *Sustainable Development Solutions Network*

The International Spillover Index is a metric designed to evaluate how a country's actions affect the ability of other nations to achieve the Sustainable Development Goals (SDGs). This index quantifies the international ripple effects resulting from a country's policies and practices, providing valuable insights into their broader implications.

The index considers three main dimensions of these spillover effects:

1. Environmental and Social Impacts: This dimension examines the environmental and social repercussions associated with trade practices, such as pollution resulting from production activities intended for export. It highlights how a country’s production methods can affect ecological sustainability and social well-being in other regions.

2. Economic and Financial Spillovers: This aspect assesses how economic policies and financial events in one country can lead to spillover effects that impact neighboring or distant nations. For instance, financial crises can spread across borders, leading to economic instability and adverse effects on development efforts elsewhere.

3. Security Spillovers: This dimension analyzes how instability or conflict in one country can affect the security and stability of other nations. It underscores the interconnectedness of global security, where challenges in one region can lead to increased risks and challenges in another.

By measuring these dimensions, the International Spillover Index provides a comprehensive overview of the ways in which countries' actions can support or hinder the achievement of global sustainable development objectives.

II. Methods

A comprehensive methodological approach, including qualitative and quantitative research methods, was used to analyze the role of tax policy in stimulating sustainable development.

1. Comparative analysis: The main method used was a comparative analysis of tax practices in various countries aimed at supporting sustainable development. The study covers the experience of both developed and developing countries, including Russia, the European Union, the United States, China and a number of other countries. The comparison includes a study of carbon taxes, environmental charges and incentives for the introduction of renewable energy sources.

2. Analysis of the regulatory framework: A study of existing laws and regulations in Russia and abroad related to environmental and tax policy was conducted. This allowed us to identify the key tax instruments used to stimulate environmentally friendly technologies, energy efficiency and reduce the carbon footprint.

3. Econometric analysis: Econometric modeling methods were used to quantitatively assess the impact of tax instruments on sustainable development. The study examined GDP, carbon emissions, energy efficiency and green investment indicators in countries with different tax regimes. This made it possible to identify correlations between tax measures and improvements in environmental and economic indicators.

4. Case studies: Specific examples of successful application of tax policy to promote sustainable development were analyzed. Cases from Russia and other countries were considered to identify key success factors and obstacles in the implementation of "green" tax reforms.

5. Expert interviews: To obtain practical data on the application of tax policy in the context of sustainable development, interviews were conducted with Russian and international experts in the field of ecology, tax law and economic development. This helped to complement the theoretical analysis with real examples and forecasts for the further development of tax policy.

Thus, the use of several research methods provides a comprehensive analysis of the role of tax policy in achieving sustainable development goals, taking into account both international and Russian experience.

III. Results

Environmental sustainability is another key area where taxation can have a significant impact. Environmental taxes, such as carbon taxes, aim to incorporate external environmental costs associated with environmental degradation into the price of goods and services. By imposing taxes on environmentally damaging activities, such as fossil fuel use or industrial pollution, governments can discourage environmentally harmful practices and encourage the use of cleaner technologies. For example, carbon taxes create an economic incentive for companies and individuals to reduce their carbon emissions, thereby helping to mitigate climate change. Revenues from environmental taxes can be used to support sustainable projects, such as renewable energy, energy efficiency, and environmental programs, thereby amplifying the impact of environmental initiatives. In addition, tax policy can play an important role in shaping corporate behavior and encouraging sustainable business practices. Through tax incentives and subsidies, governments can encourage companies to invest in sustainable technologies, adopt clean production methods, and stimulate innovation for sustainable development. For example, tax incentives for research and development in renewable energy can encourage innovation in this sector by making clean energy more affordable. Similarly, tax incentives for companies that meet environmental or social standards can motivate greater corporate responsibility and sustainability.

International tax cooperation also plays a critical role in promoting sustainable development, particularly in combating tax evasion. The globalization of the economy has made it easier for multinational corporations and wealthy individuals to shift profits and assets to countries with low tax rates, eroding the tax bases of countries, especially developing countries. International initiatives such as the OECD-led BEPS (Base Erosion and Profit Shifting) project aim to address these problems by increasing transparency and ensuring that taxes are paid in the countries where the real economic activity takes place. Combating tax evasion helps protect the revenue needed to achieve sustainable development goals.

IV. Discussion

The underlying cause of many development issues in the Far East, and in Russia more broadly, is the lag in research and development (R&D) progress. This problem is well-known, and a widely adopted solution in numerous countries is the introduction of specific tax incentives to stimulate growth. In this context, a key strategy would be to enhance tax benefits for residents of special economic zones (SEZs), which act as small but dynamic "growth hubs" in the Far East. These hubs can foster the creation of new technologies that, once disseminated throughout the region, could significantly improve overall development metrics.

Studies by Zhang et al. [8], Gasmi et al. [9], and Yuan et al. indicate that well-targeted tax incentives lead to a more efficient use of existing infrastructure, human resources, and other critical assets.

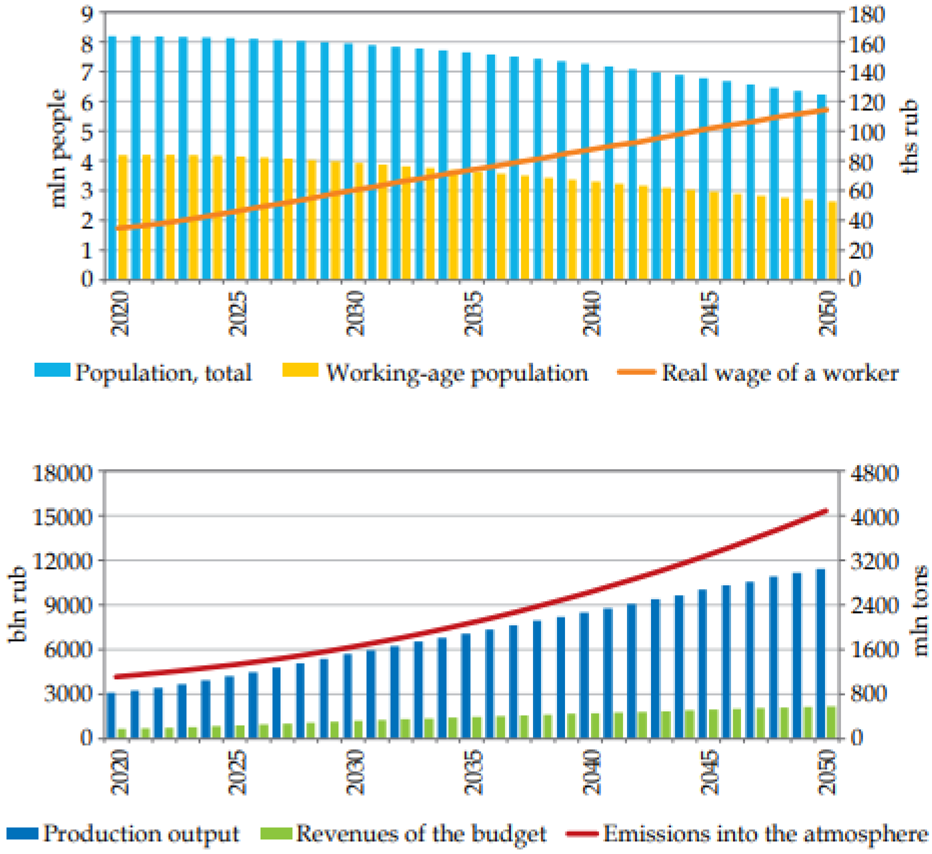

Figure 2: *Inertial scenario. Indicators characterizing the dynamics of the region's economic-technological and socio-ecological subsystems*

Currently, the SEZs operating in the region offer a variety of tax benefits and incentives aimed at attracting businesses. These include reduced corporate income tax rates, lower social insurance contributions, and reduced land tax rates. Such measures help improve business profitability, often measured by return on equity (ROE), which is undoubtedly a crucial factor for enterprises. However, profitability alone is not sufficient, especially given the region's prolonged economic challenges and the relatively weak innovation drive within the private sector. To address these issues, it would be prudent to introduce tax incentives that are tied to reciprocal commitments from businesses, particularly in the areas of innovation and capital investment.

This approach would involve structuring tax incentives around contractual obligations. A prime example could be the implementation of an Investment Tax Credit (ITC), allowing businesses to offset their tax liabilities. A similar mechanism is successfully employed in Italy, where companies are offered a generous 12% tax credit on qualified R&D expenditures, which can be used to reduce any type of tax obligations. Such a policy could serve as a model for fostering innovation and investment in the Far East's SEZs.

The effectiveness of taxation in promoting sustainable development is closely tied to the efficiency and fairness of tax administration. A fair and transparent tax system that minimizes evasion and ensures compliance is crucial for building public trust and making tax revenues available for development purposes. Efficient tax administration reduces the costs of tax collection and increases the revenues available for public investment. Fairness in tax administration ensures an equitable distribution of the tax burden, preventing undue hardship for low-income individuals and avoiding the concentration of wealth.

In conclusion, taxation serves as a fundamental tool for achieving sustainable development. It provides the necessary revenues for public investments in critical sectors, facilitates income redistribution to reduce inequality, and encourages environmentally sustainable practices. An effective tax policy can stimulate economic growth, promote social integration, and protect the environment by aligning national development strategies with global sustainable development goals. The role of taxation extends beyond revenue generation; it encompasses the facilitation of equitable economic growth, environmental protection, and social welfare. Therefore, the development and implementation of tax policies must continuously adapt to the evolving challenges and opportunities of sustainable development. Through progressive, efficient, and fair tax systems, governments can harness the power of taxation to build a more sustainable and equitable future for all.

Tax incentives encompass various aspects related to green technologies, and their analysis can be instrumental in defining the trajectory for transforming tax instruments that stimulate investment in these technologies. Many countries have established tax incentives to encourage investors. In the United States, such incentives are provided through tax exemptions and accelerated depreciation for corporate profits. Tax benefits are also available for specific business activities, including green investments, based on the Opportunity Zones legislation, which has been in effect since 2017. The aim of reducing the tax burden is to motivate ESG investing across various sectors, emphasizing the importance of capital allocation that considers environmental protection, social development, and corporate governance.

To control environmental pollution and ensure the safe handling of solid waste and the recycling of valuable materials, the Pollution Control Tax-Exempt Bond Financing Program has been established. This program allows borrowers to lower the cost of financing clean technologies through reduced interest rates compared to conventional loans. Green bonds for environmental projects that meet climate investment standards are actively issued by the California Pollution Control Financing Authority (CPCFA). Eligible projects for tax-exempt bond financing include the creation and reconstruction of wastewater treatment facilities, waste-to-energy conversions, waste disposal, and landfill reclamation. The effectiveness of tax incentives in the U.S. is evidenced by the increase in reported and supported projects. For instance, the list of projects receiving financial assistance and tax benefits includes initiatives for purchasing clean vehicles for waste management companies and recycling used oil, as well as construction debris disposal projects. Some of these incentivized projects can be implemented by small businesses and supported at the municipal level, thus stimulating local economic development. Overall, U.S. tax incentives have resulted in investments in green projects averaging up to $15 billion per year, positioning the country as a leader in green technology.

In Malaysia, a comprehensive set of green tax incentives is available for industrial enterprises and investors. Funding for clean technologies is facilitated through the Green Technology Financing Scheme (GTFS 3.0), which was launched as part of the Sustainable and Responsible

Investment (SRI) support program aimed at promoting the adoption of green technologies. This scheme enables the incorporation of green technology elements into investment projects while reducing the tax burden. It includes tax incentives for electric vehicles, profit tax exemptions, and the Green Income Tax Exemption (GITE), as well as the Green Investment Tax Allowance (GITA).

Conversely, the current taxation framework in Russia does not include specific provisions for modifying elements related to green technology, such as tax bases, exemptions, or rates. The concept of green technologies is not explicitly defined in Russian regulatory documents. Traditionally, green technologies are associated with those that do not harm the environment or, when utilized, cause minimal ecological damage.

References

[1] Podkolzina, I.M., Gladilin, A.V., Reshetov, K.Y., Taranova, I.V., Gladilin, V.A. Building a Financial Security System to Ensure Russia's Food Security // Lecture Notes in Networks and Systems, 2021, 205, pp. 539–548

[2] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev, L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[3] Shmatko S.G., Agarkova L.V., Gurnovich T.G., Podkolzina I.M. Problems of increasing the quality of raw material for wine in the stavropol region // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2016. T. 7. № 2. C. 725-730.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House, 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development // Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

MAIN DIRECTIONS OF DEVELOPMENT OF MARGINAL OIL FIELDS OF THE CASPIAN SECTOR OF AZERBAIJAN

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Abstract

The article discusses the problems of developing and justifying a strategy for the geological study and preparation of oil reserves from marginal oil and gas fields in the Caspian sector of Azerbaijan. The scientific works of domestic and foreign scientists studying issues related to the use of subsoil containing volumes of recoverable reserves, located in difficult geological and field conditions and located in remote, inaccessible areas with poorly developed infrastructure, are presented in detail. In addition, unclaimed oil reserves have been scientifically analyzed to determine the industrial significance of the objects and to determine the conditions for the profitable development of marginal offshore fields.

Keywords: fields, marginal, development, strategy, model, oil reserves, category

I. Introduction

The energy strategy of Azerbaijan for the period until 2035 determines that the Caspian sector of the republic will remain the main subsoil use areas that ensure an increase in oil and gas reserves. Solving the assigned tasks will require SOCAR (Azerbaijan Republican State Oil Company) to develop and justify a strategy for geological study and preparation of subsoil reserves. At the same time, the modern oil industry of Azerbaijan is characterized by a decrease in the quality of the natural characteristics of explored offshore fields. In these conditions, SOCAR faces the question of the need to prepare low-profit oil reserves that fall into the category of so-called marginal fields [1].

The calculation results show that the share of proven reserves in the offshore structure of the oil and gas sector is extremely high and comparable to the oil resources currently under development. Maintaining advantageous positions and dynamic development of the extractive sector based on marginal oil fields (MOR) will obviously require oil companies to introduce fundamentally new technological solutions and financial schemes for their development. In addition, at the level of government management of the industry, it is necessary to provide for the creation of a favorable taxation regime and measures to increase the investment attractiveness of MMN projects.

Solving these problems requires the formation of strategic priorities for the involvement in the development of a new cluster of low-profit offshore oil fields and the substantiation of an organizational and economic mechanism (OEM), which provides for a system for stimulating the processes of development of the international oil production complex based on interaction with SOCAR with the participation of scientific, technical and educational centers.

Providing the needs of the republican economy with hydrocarbon raw materials in the long term and maintaining the country's position in the global hydrocarbon raw materials market is state policy.

As world experience shows, consumption of fuel and energy raw materials in individual countries depends on the level of economic development of the countries [2]. As economic potential grows, scientific and technological progress increases, and the needs of the population increase, the volumes of mineral resources used expand. According to foreign experts, over the past 40-50 years, 70-80% of the oil, about 40% of the coal and iron ores mined by mankind throughout history have been sold. According to many scientists and experts, by 2050 the demand for energy and its production will more than double.

The above necessitates the consolidation of all energy sources to meet the expected growth in its demand; competition between various energy sources (natural gas, oil, coal, hydropower, nuclear energy, and in the future – solar, wind, geothermal, etc.) is especially inevitable.

It should be noted that the existing mechanisms for regulating the global energy market do not work in the global energy sector. It is increasingly obvious that competition between consumers is becoming more intense due to the emergence of such powerful players as China and India in the market. While the main consumers of oil are highly developed countries, the bulk of the world's hydrocarbon reserves are concentrated in a relatively small group of developing countries and countries with economies in transition. Large consumers such as the United States and the European Union are concentrating economic and political resources to expand into markets, which leads to increased competition.

II. Methods

In the specialized scientific literature of both domestic and foreign scientists studying subsoil issues, the terms "marginal deposit" or "marginal object" lack a unified interpretation. It is often used to classify groups of fields containing small volumes of recoverable reserves, located in difficult geological and field conditions and located in remote, inaccessible areas with poorly developed infrastructure. In contrast to our approach, foreign countries extensively study and develop marginal oil fields. This is due to the fact that in countries with a developed mining industry, but with limited hydrocarbon reserves, some types of marginal oil deposits have been developed quite successfully for a long time. This includes the positive experience of Canadian companies that have ensured the cost-effective development of high-viscosity oils and oil sands [3,4,5]. A classic example of the development of marginal deposits is the emergence of a new sub-industry of the US oil industry, focused on the integrated development of so-called shale oil deposits [6,7]. The term "marginal oil reserves" is spelled out in regulatory documents and laws, which indicates that the issues of studying and developing these fields have been addressed at the state level. For example, in the countries of North America (USA, Canada), a special preferential tax regime has been developed for companies developing such deposits [6].

From our perspective, the category of 'marginal development object' primarily pertains to the economic aspect and combines objects that have a marginal degree of profitable development. For marginal oil reserves, the most important criteria for their development by oil producing enterprises are net present value (NPV), internal rate of return (IRR), and increase in reserves for each manat of invested funds. The main task of this stage is to determine the best available technologies for studying and developing a marginal object, as well as the investments required for its implementation.

At the same time, projects for the development of marginal reserves of offshore oil fields, such as Oil Rocks, Divanny, Khara-Zira, Peschanny and others, which are at the stage of geological study or industrial development, are presented with a high degree of detail. In order to develop deposits for investing in such projects, the company has a complete understanding of the technological scheme of their development, which can be obtained during their implementation [8].

The organizational model for the study and development of marginal oil fields can be implemented by creating a sustainable oil industry complex that can ensure cost-effective exploration, production, and transportation of raw materials by integrating innovative technologies into production.

It should be noted that the development and implementation of optimal projects will allow obtaining the following economic effects:

- increase in oil production volumes due to the exploitation of previously unclaimed resources;
- attracting additional volumes of domestic and foreign investments;
- stimulating the introduction of innovative technologies;
- reducing the payback period of investments;
- increase in oil recovery factor.

Based on the study and generalization of the works of Academician A.Kh. Mirzajanzadeh, B.A. Sudeimanova, A. A. Gerta, V. I. Nazarova, Yu. P. Ampilova, A. G. Zdotnikova, R. S. Khirsanova and others in the field of geological and economic assessment of oil and gas reserves and resources, we have introduced three criteria (marginally profitable, conditionally profitable, unprofitable) marginal reserves according to the economic efficiency of their development.

We believe that the development and commissioning of marginal offshore oil fields can contribute to the rational use of subsoil in Azerbaijan. At the same time, the creation of a flexible system by SOCAR will have a positive effect on oil production. However, there is little to no action in this direction from both the state and SOCAR's subsoil management.

Based on well-known domestic and foreign definitions of MOR, these include the following categories of promising hydrocarbon objects: unclaimed, unconventional and hard-to-recover. Unclaimed reserves may include hard-to-recover and unconventional reserves, and hard-to-recover reserves may include unclaimed and unconventional reserves (Fig. 1).

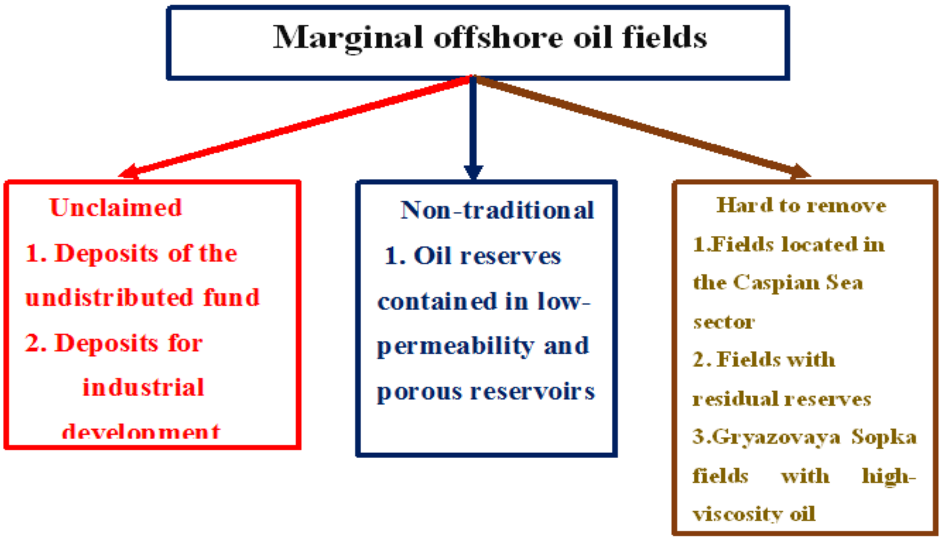

Figure 1: *Classification of marginal offshore oil fields of SOCAR*

III. Results

As can be seen from the figure, unclaimed oil reserves include those resources whose development from a technical and economic point of view is not feasible given the current situation in the global oil market. These reserves belong to the distributed and undistributed subsoil fund and are located in undeveloped layers. In addition, it is proposed to classify unappraised deposits within local objects as unclaimed. Unconventional oil reserves include those located in low-permeability and low-pore reservoirs. When developing unclaimed oil reserves, the following factors determine the industrial significance of the objects:

- complexity of the geological structure;
- lack of modern equipment and production technologies;
- remoteness from industrial infrastructure deposits;
- low prices for crude oil in the domestic markets.

Hard-to-recover oil reserves are characterized by unfavorable geological conditions and are highly viscous.

The main difference between traditional and unconventional reserves and resources from an economic point of view is that the development of the latter requires the use of significantly more investment-intensive technologies.

When studying the category of marginal development objects, the fundamental question is to determine their role in ensuring the sustainability of the development of the country's oil and gas complex. The basis for such development is the processes of reproduction of the mineral resource base of the country's oil and gas resources as the reserves of the developed fields are depleted [9,10].

We have defined the role of marginal deposits as follows: when highly profitable reserves are reduced, the process of industrial development and development involves deposits and extraction of reserves, which are characterized by a lower degree of profitability. At the final stage of development of offshore fields, low-profit fields are introduced into the process of industrial development.

Assessing the industrial significance of marginal deposits requires evaluating various factors such as geological, mining, and economic conditions. These factors, which vary among enterprises and change over time, collectively determine the effectiveness of marginal oil facilities.

The problem of assessing the limiting parameters of marginal objects is associated with the lack of sufficient methodological and practical experience in their development. In addition, promising objects containing marginal oil reserves have been little studied and do not have approved project documents by SOCAR. But for oil producing enterprises, it is important to have projects at the initial stage of geological exploration or industrial development of objects.

Currently, one of the few methods for conducting economic assessment is the construction of an economic-mathematical model for assessing acceptable parameters for the development of marginal objects. At the same time, in order to assess the economic efficiency of developing marginal oil reserves, it is necessary to justify prices for crude oil on the domestic market, and calculate the volume of capital and operating costs.

A change in the direction of decreasing or increasing the volume of recoverable marginal oil reserves, subject to changes in their depth and oil production rate of wells, is calculated based on an assessment of the capital and operating costs required for field development. With the definition, it is possible to calculate the minimum technological and economic initial data acceptable for development. The amount of capital costs associated with the construction of production and injection wells, and, accordingly, the costs of their operation, depends on the depth of the formations.

With an increase in the price of oil on the world market, revenues from the implementation of a project for the development of marginal oil reserves increase. At the same time, the volume of tax revenues to the State Budget increases. If world oil prices decline, the opposite situation occurs.

Conclusion

1. Sustainable development of the oil production complex of marginal offshore oil fields directly depends on SOCAR's technological capabilities to ensure cost-effective development and development of low-profit deposits.

2. In all the leading oil companies of foreign countries, there are many solutions that differ from each other in the methods and technologies used for the development of marginal oil fields. However, SOCAR has few methods for increasing oil recovery are used mainly in depleted oil fields for the purpose of conducting pilot tests.

3. Currently, the main strategic directions of development of SOCAR-BP cooperation in the field of studying and developing marginal oil reserves of the Caspian sector of Azerbaijan are the development of joint projects in the field of creating highly effective technological solutions aimed at increasing oil recovery, since their implementation in the oil and gas producing enterprises of the republic will lead to to reduce costs and will allow such facilities to be brought to a profitable level.

References

[1] Masteranov A. M. Reality and prospects for sustainable development of energy supply in Russia // Economics of the fuel and energy complex of Russia. M., 1994. No. 2.

[2] Belenkiy V., Lukatsky A. Methods for studying the mutual influence of economics and energy // Izvestiya RAS. Series: Energy. 1995. No. 6. pp. 45–52. 19.

[3] Danilova E. Heavy oils of Russia // The Chemical Journal. 2008. December. pp. 36–37.

[4] Johnston J. Economic methods. M.: Statistics, 1990. 344 p.

[5] Fan Tingting. Development of Russian-Chinese energy cooperation // Ethnosocium. 2011. No. 7.

[6] New aspects in the taxation system of capitalist countries. M., 1990

[7] Tutoshkin A. Americans looked into every well // Kommersant-DAILY. 1996. March 26. No. 49.

[8] Development and operation of Caspian offshore fields. M., Nedra, 2016. 123-126p.

[9] Dolan E. Lzh., Lindsay D. Market: microeconomic model. St. Petersburg, 1992. 235 p.

[10] Methodological recommendations for the application of the Classification of reserves and forecast resources, approved by order of the Ministry of Natural Resources and Ecology of the Russian Federation, dated November 1, 2005 No. 298.

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THE ROLE OF ENVIRONMENTALLY ORIENTED START-UPS IN THE TRANSFORMATION OF TRADITIONAL SECTORS OF THE ECONOMY

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Abstract

This paper delves into the significant role that environmentally oriented start-ups play in transforming traditional sectors of the economy. As the world grapples with pressing environmental challenges such as climate change, resource depletion, and biodiversity loss, these innovative enterprises are emerging as vital agents of change. The study investigates how these start-ups disrupt conventional business models by implementing sustainable practices, enhancing resource efficiency, and promoting the principles of the circular economy. By harnessing cutting-edge technologies and innovative approaches, environmentally focused start-ups contribute to a range of economic activities that prioritize sustainability. They challenge traditional industry norms by offering greener alternatives, optimizing supply chains, and minimizing waste. This paper also explores case studies that exemplify the successful integration of sustainable practices into sectors such as agriculture, manufacturing, and energy, showcasing how these start-ups not only address environmental issues but also create economic opportunities and stimulate job growth. Furthermore, the findings emphasize the importance of supportive policies, regulatory frameworks, and collaborative ecosystems in nurturing the growth of these start-ups. The paper advocates for the establishment of partnerships between governments, established businesses, and start-ups to create an environment conducive to innovation and sustainability. By fostering collaboration, these stakeholders can ensure that environmentally oriented start-ups are equipped to make a meaningful contribution to the transition towards a green economy.

Keywords: environmentally oriented startups, transformation of traditional sectors, sustainable development, circular economy, innovation, sustainable practices

I. Introduction

The transformation of traditional sectors through the emergence of environmentally oriented startups marks a significant shift in the global economic landscape (fig.1). With growing awareness of climate change, resource depletion, and environmental degradation, these startups are stepping in to challenge established norms and drive innovation toward sustainability. They often operate at the intersection of technology, sustainability, and business, offering novel solutions that traditional industries can adopt to reduce their ecological footprints.

Role in Traditional Sectors.

In sectors such as agriculture, manufacturing, and energy, environmentally oriented startups are innovating processes and products that minimize environmental harm. For instance, in agriculture, these startups are developing precision farming techniques that optimize resource use and reduce chemical inputs, promoting sustainable food production. In manufacturing, companies are adopting circular economy principles, where waste is minimized, and materials are reused or recycled, significantly lowering production costs and environmental impact.

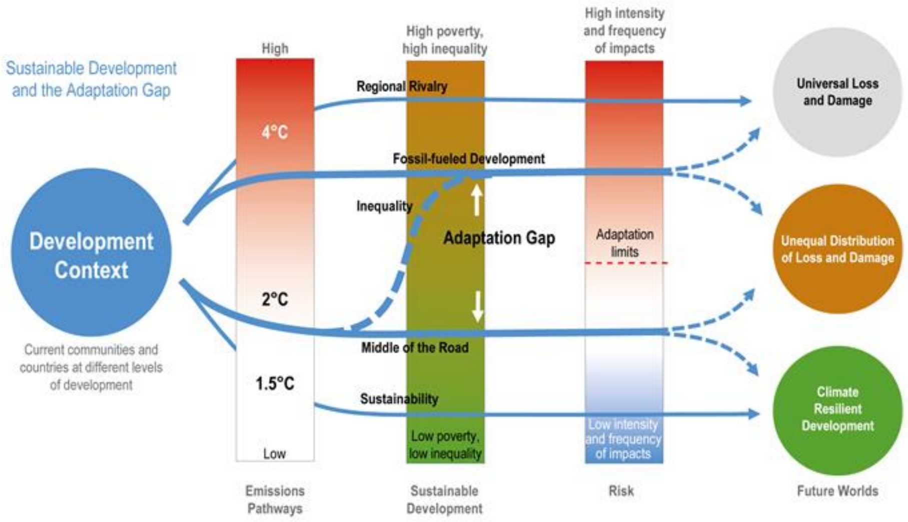

Figure 1: *Sustainable Development and the adaption gap*

In the energy sector, startups are spearheading the development of renewable energy technologies, such as solar, wind, and bioenergy. By providing affordable and accessible alternatives to fossil fuels, these startups not only reduce greenhouse gas emissions but also empower local communities and stimulate economic growth through job creation in green technologies.

Innovation and Collaboration.

Collaboration is another vital aspect of the role played by environmentally oriented startups. By partnering with traditional companies, these startups facilitate knowledge transfer and innovation diffusion. Established businesses often benefit from the agility and creativity of startups, allowing them to adopt sustainable practices more rapidly. This partnership can take many forms, including joint ventures, research collaborations, and supply chain integration, which ultimately foster a culture of sustainability within traditional sectors.

Moreover, startups often emphasize a stakeholder-centric approach, recognizing that environmental and social responsibilities go hand in hand. By engaging consumers and local communities in their initiatives, these businesses create a sense of ownership and accountability, driving broader societal change toward sustainability.

Policy and Regulatory Frameworks.

The role of government policy and regulatory frameworks cannot be understated in this transformation. Supportive policies, such as incentives for green innovation, subsidies for renewable energy, and stringent environmental regulations, create an enabling environment for environmentally oriented startups to thrive. Policymakers play a crucial role in fostering innovation ecosystems that facilitate startup growth by providing funding opportunities, incubators, and networks that connect startups with investors and industry leaders.

Furthermore, regulatory frameworks that encourage sustainable practices can significantly influence the behavior of traditional sectors. By mandating transparency in environmental reporting and promoting sustainability standards, governments can drive systemic change across industries, leading to a more sustainable economy.

Challenges and Future Directions.

Despite their potential, environmentally oriented startups face several challenges, including access to financing, market competition, and regulatory barriers. Many startups struggle to secure funding, particularly in the early stages, which can hinder their growth and scalability.

Additionally, competition from established companies with significant resources and market power can make it difficult for startups to penetrate traditional markets.

To overcome these challenges, it is essential to create a robust support system for environmentally oriented startups that includes financial backing, mentorship, and networking opportunities. Encouraging public-private partnerships can also help facilitate innovation and accelerate the adoption of sustainable practices in traditional sectors.

II. Methods

In exploring the role of environmentally oriented startups in transforming traditional sectors of the economy, a comprehensive methodological approach is essential. This section outlines three key methods that will be employed in the study:

1. **Case Study Analysis**
   - Description: This method involves an in-depth examination of specific environmentally oriented startups that have successfully transformed traditional sectors. Case studies will provide detailed insights into the strategies, innovations, and impacts of these startups on their respective industries.
   - Implementation: Selected startups from various sectors (e.g., agriculture, energy, manufacturing) will be analyzed. Data will be collected through interviews with founders, employees, and stakeholders, as well as through document analysis (e.g., business reports, press releases).
   - Expected Outcome: This method aims to identify best practices, challenges faced, and lessons learned that can inform other startups and traditional businesses seeking to embrace sustainability.
2. **Surveys and Questionnaires**
   - Description: Surveys will be used to gather quantitative data from a broader range of environmentally oriented startups and traditional businesses. This method will help assess perceptions, strategies, and the impact of startups on traditional sectors.
   - Implementation: A structured questionnaire will be developed, covering areas such as sustainability practices, collaborations with startups, and perceived barriers to adopting green innovations. The survey will be distributed to a sample of businesses in relevant sectors to collect data.
   - Expected Outcome: This method will provide statistical insights into trends, challenges, and opportunities related to the integration of environmentally oriented startups into traditional sectors.
3. Interviews with Key Stakeholders
   - Description: Semi-structured interviews will be conducted with key stakeholders, including entrepreneurs, industry experts, policymakers, and representatives from traditional sectors. This qualitative method will yield rich, nuanced perspectives on the role of startups in promoting sustainability.
   - Implementation: Interview questions will focus on experiences, opinions on the impact of startups, and recommendations for enhancing collaboration between startups and traditional businesses. The interviews will be recorded, transcribed, and analyzed for common themes and insights.
   - Expected Outcome: This method aims to capture diverse viewpoints and deepen understanding of the systemic changes driven by environmentally oriented startups in traditional sectors.

III. Results

A start-up is typically defined as a temporary organization or institution focused on finding a profitable, measurable, and scalable business model. The key differentiating factor is the high level of uncertainty faced by start-up ventures. As long as a product or service is entirely novel and untested, it remains uncertain how the market will respond. Generally, start-ups progress through two developmental phases: the experimental phase and the production phase. Currently, approximately 90 percent of start-ups worldwide fail to advance beyond the experimental stage. Global experience indicates that start-ups require support during this initial phase, often referred to as the "start-up ecosystem." This experimental phase typically lasts about five years, although some start-ups may experience longer or shorter durations, necessitating ongoing support from the ecosystem. Such ecosystems globally are characterized by clear legal and regulatory frameworks, diverse partnerships and collaborations, engagement from public and private stakeholders, and incentives that create a conducive environment for the establishment and growth of start-up ventures. The concept of an ecosystem in business, borrowed from ecology, was first defined by Start-ups play a crucial role in the development, growth, and long-term sustainability of economy, as they represent the future evolutionary path of the nation. Consequently, it is essential to encourage and support these ventures. Their significance is emphasized in Business and Investment Development Strategy 2021-2027, which outlines steps to promote innovation initiatives, allocate more funds for research and development, and create a more favorable environment for start-up growth.

IV. Discussion

The start-up revolution has been fueled by significant infusions of public and private capital, which provide the necessary resources for these ventures to scale quickly and transform their innovative ideas into reality. As start-ups expand, they garner attention from industry veterans, paving the way for collaborations that blend traditional expertise with fresh perspectives. Rather than competing for dominance, start-ups and established industries are increasingly discovering avenues for coexistence and collaboration. Start-ups bring new ideas and energy, while established players contribute industry knowledge and resources. This synergy fosters a harmonious ecosystem in which innovation can flourish, all while honoring the rich traditions of established practices.

This new developmental trajectory is made possible by substantial investments, which ultimately benefit the economy as a whole. In the last five years leading up to 2023, the European Union alone has invested over $300 billion to create a more favorable environment for start-up development. This massive injection of public funds is complemented by private investments, and these considerable financial resources have undeniably brought about economic benefits.

Innovative products and services introduced by start-ups significantly contribute to market growth and expand consumer choices. Start-ups are recognized as key drivers of innovation, which can lead to economic growth and diversification. According to Germany’s Federal Ministry for Economic Affairs and Climate Action, start-ups are critical to market growth and increasing competition through their introduction of new products and services (BMWK, 2017). By presenting ideas that challenge established industries, start-ups create new investment opportunities and facilitate industry development.

This cycle of innovation yields positive economic effects, including increased job opportunities and heightened competitiveness within various sectors. The emergence of new concepts and technologies from start-ups can invigorate markets, fostering healthy competition and improving consumer offerings. Through their inventive approaches, start-ups can profoundly influence economic expansion and prosperity, reshaping the landscape of future industries.

The market becomes more competitive with the entry of new players offering innovative products and services. Start-ups play a crucial role in driving economic dynamism through their creative strategies. By disrupting traditional market dynamics, they stimulate economic growth and foster innovation. This competition compels established companies to enhance their offerings, leading to a diverse array of consumer choices and improved quality.

Consumers benefit from a broader selection of products and services, as well as competitive pricing options. The presence of start-ups creates a more competitive market environment, resulting in greater overall value and quality for consumers. The competition instigated by start-ups not only benefits consumers but also contributes to economic advancement by promoting innovation and revitalizing the market.

According to Henry et al. (2020), circular start-ups can be classified into five distinct archetypes:

1. Design-based: These start-ups focus on product designs that require less material during production.
2. Waste-based: These ventures utilize waste as an input material for new products.
3. Platform-based: These include consumer-to-consumer marketplaces that facilitate the sharing or selling of pre-owned products.
4. Service-based: These start-ups replace ownership with access, allowing consumers to utilize services without needing to own the product.
5. Nature-based: These ventures leverage natural ecosystems for production without causing harm.

These categories cut across various industries, and it is possible for start-ups to incorporate multiple archetypes within a single venture.

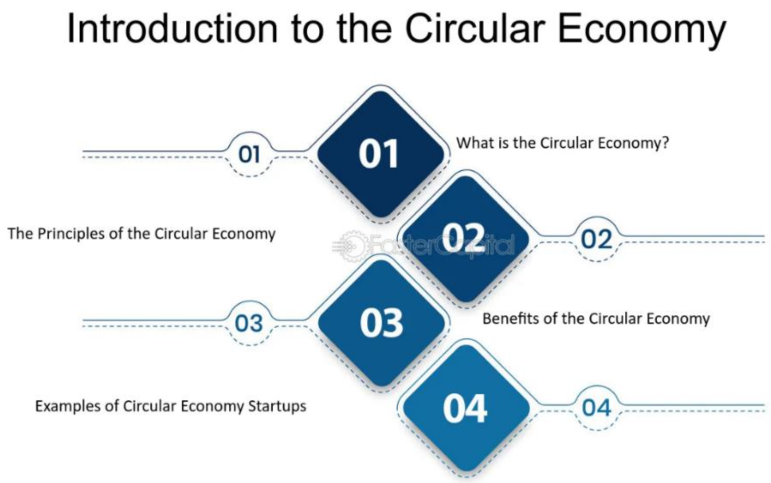

Figure 2: *Circular economy principles*

The idea of a circular economy is receiving considerable attention as a viable solution to the environmental issues we currently face. In contrast to the traditional linear economy, which operates on a "take, make, and dispose" model, the circular economy seeks to maximize the use of products and materials for as long as possible. This approach aims to minimize waste and enhance resource efficiency.

Principles of the Circular Economy.

To grasp the concept of the circular economy, it is crucial to understand its fundamental principles:

A. Eliminating Waste: The circular economy highlights the necessity of designing products and systems that reduce waste and pollution. This can be achieved by utilizing eco-friendly materials, adopting efficient manufacturing techniques, and creating products that are easy to repair, reuse, and recycle.

B. Keeping Products and Materials in Circulation: Rather than discarding items after their initial use, the circular economy promotes their refurbishment and reuse. By prolonging the lifespan of products, we can maximize their value and lessen the demand for new resources.

C. Restoring Natural Systems: The circular economy encourages the restoration and regeneration of natural resources. This encompasses sustainable practices like reforestation, water conservation, and the utilization of renewable energy sources.

Benefits of the Circular Economy.

Adopting the circular economy offers a variety of environmental and economic benefits, including:

A. Waste Minimization: By concentrating on waste prevention and recycling, the circular economy diminishes the volume of waste that ends up in landfills, thereby reducing environmental pollution and conserving natural resources.

B. Financial Savings: Implementing circular economy strategies can lead to significant cost reductions for businesses. For example, reusing materials and components can lower production expenses and decrease reliance on costly raw materials.

C. Job Creation: The circular economy has the potential to create new employment opportunities across various sectors, such as recycling, repair, and remanufacturing. This can foster economic growth and social advancement.

Examples of Circular Economy Startups

Many startups are emerging to facilitate the shift toward a circular economy. Here are a few noteworthy examples:

A. TerraCycle: This company specializes in recycling materials that are difficult to process. TerraCycle collaborates with major brands to collect and recycle items like cigarette butts, coffee capsules, and even chewing gum, transforming them into new products.

B. Grover: Grover offers a subscription-based rental service for electronics, allowing users to rent devices instead of buying new ones. This model promotes product reuse and helps reduce electronic waste.

C. ResQ Club: This app connects consumers with restaurants, cafes, and other food establishments to sell surplus food at discounted prices. By reducing food waste, ResQ Club supports the circular economy while providing affordable meals to customers.

In summary, the circular economy signifies a transformative shift toward a more sustainable and efficient economic model. By embracing the principles of the circular economy, businesses and individuals can aid in reducing waste, achieving cost savings, and restoring natural resources. Innovative startups are playing a pivotal role in advancing this transition and demonstrating the circular economy's potential to foster a more sustainable future.

Figure 3: *Circular start-ups*

Circular start-ups are poised to play a critical role in advancing the transition to a circular economy and achieving sustainability objectives. Their adaptability to shifting market dynamics and their inclination to adopt radical circular business models (CBMs) distinguish them from traditional firms. As a result, circular start-ups are expected to gain competitive advantages and excel in development and growth. However, similar to conventional start-ups, they may face significant barriers to scaling up.

Startups that are spearheading innovation in the circular economy frequently attract investment and support from a diverse range of stakeholders, including venture capitalists, impact investors, and government agencies. This financial backing is crucial as it empowers startups to scale their operations and bring their innovative solutions to market.

In conclusion, startups are pivotal in fostering innovation within the circular economy. Their fresh perspectives, agility, technology-driven approaches, and disruptive nature, combined with their capacity to attract investment, position them as key players in the quest for a more sustainable and circular economy. By investing in and supporting these startups, we can expedite the transition to a circular economy and pave the way for a more sustainable future.

1. Startups Offer Innovative Perspectives

Startups play a vital role in fostering innovation within the circular economy by providing fresh perspectives that challenge conventional thinking. Unlike established companies that often adhere to traditional practices, startups are unencumbered by these norms, allowing them to explore creative solutions. For instance, Circularity Capital, an investment firm based in London, actively supports startups focused on developing circular economy solutions. By channeling investment into these ventures, Circularity Capital contributes to advancing innovation and facilitating the transition toward a more sustainable circular economy.

2. Startups Are Agile and Adaptive

The agility and adaptability of startups are critical attributes that drive innovation in the circular economy. These companies are willing to take risks and experiment with new concepts, allowing them to pivot quickly when circumstances change. A prime example is RePack, a Finnish startup that has created a reusable packaging solution tailored for the e-commerce sector. By providing a sustainable alternative to conventional single-use packaging, RePack not only reduces waste but also promotes a more circular delivery system for goods.

3. Startups Utilize Technology for Innovation

Many startups harness advanced technology to propel circular economy innovations. They are designing cutting-edge solutions that employ data analytics, artificial intelligence, and automation to optimize resource utilization and minimize waste. For example, Optoro, a US-based startup, has created a software platform that assists retailers in managing and optimizing their product returns. By decreasing the volume of returned items that end up in landfills, Optoro plays a significant role in advancing the principles of a circular economy.

4. Startups Disrupt Traditional Industries

Startups have the potential to disrupt traditional industries and challenge established norms. Free from the constraints of legacy systems, they can introduce new business models that prioritize sustainability and circularity. A notable case is Too Good To Go, a Danish startup that has developed a mobile application connecting consumers with restaurants and grocery stores to rescue surplus food. By preventing food waste and establishing a market for surplus items, Too Good To Go disrupts the food industry and encourages a more circular approach to food consumption.

References

[1] Dobrynina M.V., Kovalenko D.G. Youth social entrepreneurship: problems and prospects//Economic and social-humanitarian research. 2023. No. 3 (39). P. 53-61.

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Garrido MAB, Villar IM (2023) Teaching transversal competences in civil and procedural

law through the sustainable development goals (SDGs). In: Gstrein OJ, et al (eds) Modernising European legal education (MELE). Springer, Cham

[4] N. Dobbeling-Hildebrandt, ¨ K. Miersch, T.M. Khanna, M. Bachelet, S.B. Bruns, M. Callaghan, O. Edenhofer, C. Flachsland, P.M. Forster, M. Kalkuhl, et al., Systematic review and meta-analysis of ex-post evaluations on the effectiveness of carbon pricing, Nat. Commun. 15 (1) (2024) 4147, https://doi.org/10.1038/ s41467-024-48512-w.

[5] Santikarn M; Churie Kallhauge AN; Bozcaga MO; Sattler L; Mccormick MS; Ferran Torres A; Conway D; Mongendre L; Inclan C; Mikolajczyk S; et al.; Washington, D. C.: World Bank Group, 2021.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] European Commission (2022a) Communication from the Commission. Guidelines on the application of the Regulation (EU, EURATOM) 2020/2092 on a general regime of conditionality for the protection of the Union budget. Brussels, 2.3.2022 C (2022) 1382 final.

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. С. 239.

[9] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 2137-2144.

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

SUSTAINABLE TOOLS FOR BUSINESS PROCESSES IMPROVEMENT

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Abstract

The article studies the tools for improving the business processes of an enterprise. There are primary and auxiliary business processes at a manufacturing enterprise. The primary processes are those that result in the production of the main product (value), while all other processes are auxiliary. Thus, auxiliary processes include: service, management, and enterprise development processes. Attention is paid to the main areas of business process optimization, among which the following are highlighted: the minimum number of performers, the minimum involvement of managers, and the minimum number of control operations, and, in contrast to them, the maximum typing of processes, the maximum simplification of operations, and the maximum possible parallelism of business processes. The result of optimization of business processes at an enterprise is the elimination of unnecessary losses in the execution of processes that do not bring value to consumers, thereby achieving maximum satisfaction of needs, strengthening the position of the enterprise in the market, and ensuring the maximum inflow of profits to the enterprise.

Keywords: business model, business process, optimization, reengineering, benchmarking

I. Introduction

Establishing a profitable or at least break-even production process in the short term is an important issue. Given the aggravation of the economic crisis, which is now hindering the activities of manufacturing enterprises and leading to bankruptcy or forced cessation of business activities, the issue of optimizing the main and auxiliary production processes in order to exclude unproductive and unnecessary elements from the value chain, which would ensure the effectiveness of the business model, is becoming relevant.

The works of a large number of scientists are devoted to the study of issues of optimization of business processes of manufacturing enterprises [1-5, etc.]. The works pay attention to the problems of managing business processes of modern enterprises, forming strategies for overcoming crisis phenomena, consider resource management technologies based on the use of ERP systems, describe errors that occur in the process of optimizing the value chain of an enterprise. However, despite the sufficient elaboration of the issue, the problems of optimizing the main and auxiliary processes of manufacturing enterprises remain poorly studied, with the aim of eliminating unnecessary processes from the value chain and acquiring competitive advantages of the enterprise in the market.

The aim of the article is to study the directions of optimization of the main and auxiliary business processes of a manufacturing enterprise to improve the product value chain in the business model of a modern enterprise.

Business processes are understood as a set of interrelated actions, using appropriate technologies, making it possible to transform inputs (resources) into outputs (results) that are valuable to consumers and contribute to the growth of the enterprise value. A business process that ensures the achievement of the enterprise's business goals, expressed in quantitative and qualitative indicators used as optimization criteria, is considered optimal.

In general, the following set of business processes takes place at a manufacturing enterprise: main business processes, supporting (auxiliary), management and development processes.

II. Methods

The main business processes include processes during the implementation of which a product or service is created, in other words, added value that is valuable to the consumer. These processes are of great importance to the enterprise.

Supporting or auxiliary processes do not have strategic importance for the enterprise, they are engaged in maintaining the infrastructure, and their main consumers are the main processes. These processes can, if necessary, turn into main business processes, or, if competitive alternatives appear, can be outsourced.

Management and development processes represent the processes of managing the enterprise's activities, implementing the functions of planning, organizing, accounting, monitoring and regulating the main and auxiliary business processes. From the point of view of creating added value, such processes should be classified as auxiliary, since they also ensure the effective flow of the main processes.

Development processes are separate and are also considered auxiliary, since their task is to ensure the development of the enterprise and its product in the long term.

The given classification, in the author's opinion, is quite convenient, because it helps to understand the entire set of business processes occurring at the enterprise and optimize them by implementing effective management.

In 1985, M. Porter described a model of the enterprise value chain, which considers the entire enterprise as a set of interconnected business processes and allows for their optimization in order to reduce costs (business processes that do not represent value for the consumer) and generate profit.

III. Results

The value chain combines the primary and secondary processes of an enterprise in one circuit. The primary processes are represented by the production and distribution of the main product, and the secondary processes ensure the effective flow of the primary business processes.

Thus, within the framework of the value chain model with this approach, the following main business processes are distinguished: internal and external logistics, production, marketing and sales, as well as after-sales service.

Auxiliary business processes include: material and technical support, maintenance of enterprise infrastructure, human resource management, and development of the enterprise's technical and technological base.

The main characteristics of the enterprise business processes are:

– focus on the end consumer and "influence groups", thanks to which the process of realizing the produced value will take place;

– "process entry parameters" are the requirements that the consumer puts forward for the final product, namely the value for which the consumer is willing to pay;

– unsatisfied consumer demand at a certain point in time is the catalyst for the business process, and the satisfaction received from the product or service is its final stage;

– a business process consists of a set of interconnected processes and tasks, where the final result of one task is the beginning for the next, that is, a certain chain is created;

– each process executor unit acts as the executor of a certain range of work, however, sometimes they can be the executors of several types of processes;

– business processes are repetitive in time and space.

Optimization of business processes is extremely important for enterprises that provide services to consumers and have an extensive network of branches. These are, first of all, distributors, service enterprises, retail chains, etc. [4].

In general, optimization makes it possible to describe and link all business processes that are present at the enterprise for the purpose of regulating them, that is, defining the areas of responsibility of each employee or department to eliminate conflicts within the company, which will ensure their effectiveness. Only those processes that are often repeated should be optimized.

Optimization is relevant in the case of:

– the need to increase the company's transparency;

– change of the enterprise manager;

- sales of the enterprise;

- associations of enterprises.

The description of business processes becomes effective under the following conditions:

– if the company in which optimization is planned is small, since it is constantly changing its strategy, and therefore optimization may no longer be relevant and costly;

– if, on the contrary, the enterprise is quite large and has more than 5 thousand employees, in this case, optimization will be quite costly in terms of finances and time, since it requires the use of special technologies for describing business processes;

– in the absence of managers at the enterprise who would be responsible for organizing and adjusting business processes.

The main areas of business process optimization include:

1. Optimization of resource provision of the business process along the entire value chain of the enterprise, which is achieved through vertical and horizontal compaction of processes. Vertical compaction is possible due to the provision of independence to employees in decision-making (delegation of authority from the manager's area of activity) and leads to a reduction in the time for the process execution. Horizontal compaction is based on the use of labor of semi-skilled and broadly specialized workers who will specialize in the execution of a number of similar processes. This direction, on the one hand, allows avoiding a number of errors in the execution of business processes due to the minimization of performers, and on the other hand, helps to minimize information gaps, which, as a rule, slow down the flow of processes.

2. Minimal involvement of managers in the implementation of the business process – as practice shows, the involvement of a manager slows down the implementation of the business process, employees begin to lose independence, and affects the time and quality of the results obtained.

3. Elimination of unnecessary stages of conducting control operations of the business process. It is worth eliminating, if possible, intermediate control, which is carried out by the functional divisions of the enterprise during the implementation of the business process, but strengthening control over its results, which significantly optimizes the time of its implementation.

4. Application of such an important principle of production organization as parallelism. Currently, reducing the cycle of business process execution is a competitive advantage in the market, therefore, there is a need to execute most processes in parallel, which of course will complicate the business process itself, but will provide savings in time for its execution.

5. Implementation of typification of most processes. A high degree of typification of partial processes makes it possible to automate them and allows, having several algorithms for implementing the process, to determine typified scenarios for its flow.

6. Maximum simplification of processes to increase the ease of their execution, which will minimize the number of errors during the process and speed up the time of their execution.

7. Using benchmarking procedures to study best practices in organizing business processes. The essence of this method is to study the best experience in implementing business processes in order to transfer the main procedures, technologies, standards, and methods for implementing these processes to the activities of your own enterprise. The best representative of the industry is selected for the study and it is determined how this business process ensures profit generation, how costs are saved, the quality and competitiveness of products are ensured, etc.

As practice shows, when implementing benchmarking, the organization's managers may encounter various problems that create obstacles to effective benchmarking activities. Some problems are associated with improperly conducted research, and some - with insufficient motivation to adapt best practices. In addition to these, other problems may arise, for example, lack of resources, limited time, lack of necessary information about competitors, imperfect planning, insufficient skill level of employees, etc. However, despite the problems that may arise when conducting benchmarking, the successful results of its application by many leading organizations are evidence of its value and effectiveness.

Benchmarking is a specific technology that involves the implementation of five consecutive stages:

1. Planning. At this stage, the scope and objectives of benchmarking are determined to improve the organization's activities.

2. Data collection. This stage involves collecting the data needed for comparison, as well as determining the methodology for conducting the analysis.

3. Analysis. At this stage, the level of efficiency of two organizations is assessed: your own organization and the one selected for comparison.

4. Implementation. At this stage, a strategy and tactics for combating the organization's weaknesses that were identified during the comparison are formed.

5. Monitoring and evaluation. This stage involves calculating the relevant performance indicators in order to determine the impact of the implemented benchmarking activities on the main processes of the organization.

One of the important advantages of using benchmarking is that it has a positive impact on the innovative development of the organization, in particular [1]:

– promotes the generation of innovative ideas and their implementation;

– ensures increased efficiency and productivity of business processes;

– improves the quality of products and services provided by the organization;

– increases the motivation of employees to achieve new goals and organizational development. "As a result, the lack of effective change management can lead to the collapse of the organization" [3];

– contributes to the growth of the organization's competitive advantages in the market.

8. Business process reengineering. This approach is used to redesign existing processes that are likely to be poorly performing or are outdated and not generating profit. Reengineering requires the involvement of a team that will create a new business process without paying attention to the existing one.

9. Continuous improvement of business processes based on systematic analysis with the development of procedures for their improvement.

Partial methods of business process optimization include the following:

– optimization of the product portfolio, which is based on conducting marketing research and identifying products that provide the greatest inflow of profit to the enterprise;

– optimization of cash flows that do not contribute to obtaining profit in the planned amount and require changing the schedule of investments in low-income projects in order to eliminate gaps in cash flows between the receipt and expenditure of monetary resources;

– optimization of work with debtors, which includes revision of the terms of commercial credit in terms of payment terms and amounts;

– optimization of accounts payable, which can be carried out by methods of transferring part of the rights to ownership of assets in repayment of debt to creditors or transferring shares or a stake in the capital of an enterprise in exchange for receiving better conditions for attracting credit resources [5].

IV. Discussion

Let's look at a number of the main mistakes that business process managers and executives make during their optimization in an unfavorable economic situation:

– refusal or "freezing" of some projects that are aimed at the development of the enterprise, because the situation on the market will change, and development will have to be accelerated, which will lead to additional costs and possible losses of consumers, market share, etc.;

– lack of foresight and the closure of some areas of activity that are currently unprofitable, without waiting for the return on investment;

– savings on wages of key employees, reduction of bonuses and other additional payments;

– reduction of the number of employees through dismissal or transfer and a shorter working day [2].

The expected results of optimizing the enterprise's business processes include:

- reduction of the time for the execution of the entire business process, which is ensured by the reduction of the time for the execution of each partial process, due to the implementation of the principle of parallel execution and typification, because, as the practice of leading companies shows, the implementation of these measures helps to reduce the time for the execution of business processes by 20 - 200 times;

– reduction of downtime between operations of the main business process;

– reducing the duration of the business process leads to increased labor productivity of workers, acceleration of the turnover of the enterprise's capital and improvement of the enterprise's business activity, growth of the enterprise's market share and increase in profits;

– optimization of business processes ensures a reduction in their cost;

– maximum satisfaction of existing consumer needs is achieved;

– interaction between the functional divisions of the enterprise is improved by eliminating duplication of their responsibilities and reducing the time required for decision-making, etc.

Thus, modern trends in economic development put forward new requirements for the functioning of business models of manufacturing enterprises, which, in an attempt to maintain competitive positions in the market, must implement a number of measures to optimize their own business processes throughout the entire value chain for the end consumer.

It has been established that a business model consists of a number of business processes (partial elements), which in turn are divided into primary, auxiliary, management business processes and enterprise development processes. It has been proven that optimization of business processes is a necessary condition for enterprise survival in the market. The main directions of optimization of business processes of a business model of a manufacturing enterprise are presented, among which the most important are those that make it possible to reduce the costs of time and resources when performing each element of a business process, which ultimately leads to increased labor productivity, acceleration of the enterprise's capital turnover, reduction of production and commercial cycles, ensuring the generation of profit in the planned volume, maximum satisfaction of existing and potential consumer needs and an increase in the presence of the enterprise in a certain market niche.

References

[1] Benchmarking of the personnel management system: training. practical. manual / A. V. Cherepanov. - Novosibirsk: Zolotoy Kolos, 2019. - 121 p.

[2] Kotovskaya S.V. Management potential: problems of personal and organizational effectiveness: a tutorial / S.V. Kotovskaya, E.V. Maklakova, S.Yu. Nartsissova. - M .: MNEPU

Academy. - 2020 .-- 250 p.

[3] Parakhina L.V., Shichiyakh R.A., Musostova D.Sh. Modern approaches to managing changes in economic systems // Bulletin of the Academy of Knowledge. - 2024. - No. 2 (61). - P. 698-703.

[4] Spivak V.A. Change management: a textbook for universities / V.A. Spivak. - M .: Yurait, 2022 .-- 357 p.

[5] Shapovalov A.A., Suvorova A.V. Improving the company's business processes under the influence of external factors // Business development: strategies, projects, finances and communications. - 2022. - No. 4. - P. 825-829.

ON FINANCING GREEN PROJECTS CONTRIBUTING TO THE ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT GOALS

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Abstract

In recent years, commercial banks have been actively involved in financing projects related to the green economy, reflecting the global trend of transition to sustainable development.
Many banks are switching to electronic document management and using alternative energy sources for their operations. Despite the positive changes, banks face certain challenges. There is a risk that financing green technologies may negatively affect the performance of traditional companies. The State provides support commercial banks in the implementation of green economy projects.
The Bank of Russia and other government organizations are developing concessional lending programs that allow banks to provide loans on more favorable terms for projects aimed at sustainable development. This may include reducing capital reserve requirements for "green" projects, which makes them more attractive to banks. Commercial banks can receive subsidies to cover part of the interest rates on loans issued to finance environmentally friendly projects. This reduces the financial burden on borrowers and encourages them to implement sustainable initiatives. In some cases, Russian banks may cooperate with international financial institutions.
The implementation of green economy projects by commercial banks is not widespread enough. The successful development of green banking requires an integrated approach, including the adaptation of products, internal processes and corporate culture to new environmental standards. This study is devoted to an overview of the mechanisms and methods of stimulating and implementing green banking.

Keywords: green loans, green finance bonds, certification of green financial products, commercial banks, taxonomy of green projects

I. Introduction

Such instruments as green loans, green finance bonds and certification of green financial products serve the goals of widespread introduction of green banking financing. Green loans are becoming an important tool to support businesses striving for sustainable development and reducing their environmental footprint. Commercial banks are actively developing this area, offering a variety of products that can help both individual entrepreneurs and large companies. The objectives of financing green economy projects are green construction, environmentally friendly transport, waste management and much more.

Banks can act as organizers of the issue of green bonds by other companies, providing consulting services and helping with the placement of securities. In order to ensure transparency and investor confidence in green financial products of banks, their certification for compliance with the principles and standards of green finance.

Non–financial reporting of clients helps banks reduce the risks of implementing green financing projects and confirm a responsible approach to the implementation of green projects.

Non–financial reporting of banks helps to: establish trust from investors and customers, assess and manage risks; comply with international standards and expectations, which helps to increase their competitiveness in the market. Large Russian banks are already actively implementing non–financial disclosure practices. They publish reports containing not only statistical data, but also information about projects, initiatives and interactions with key stakeholders. This allows them not only to meet the requirements, but also to stand out from the competition. However, a large number of commercial banks have not yet introduced the usual practice of disclosing non–financial information.

Thus, it is relevant to research and develop mechanisms and methods to stimulate and implement green banking for implementation by commercial banks, including creating incentives for private investors and financial organizations.

The purpose of this study is to study the best practices of commercial banking financing of green economy projects and to develop mechanisms and methods for stimulating and implementing green banking for implementation by commercial banks.

The objectives of this study:

– conduct benchmarking of leading countries in the field of green banking, such as Germany, Sweden and The Netherlands, in order to identify the best practices for financing environmentally sustainable projects by commercial banks;

– to investigate the impact of government support on the activity of commercial banks in the field of green banking by analyzing the effectiveness of various subsidy mechanisms and tax incentives;

– compare the volumes and dynamics of green lending in the leading countries of Russia, identifying the key factors contributing to or hindering the growth of this segment;

– to assess the degree of involvement of commercial banks in sustainable development projects through a quantitative analysis of the structure of their loan portfolio and participation in green bonds.

II. Methods and materials

The research uses information data, as well as methods of theoretical research, namely: monographic.

III. Literature review

A lot of research has been devoted to green banking in a wide range of areas, including those that are the focus of this study. Thus, many authors emphasize that a significant amount of financial resources is needed to promote green projects, in which banks play a key role, acting as active participants in financing projects.

This includes the creation of a "green" banking system that unites various financial institutions, such as "green" banks and development banks. An important aspect is the need to regulate banking activities, including "green" financing, which should be supported by government politicians and banking regulators. This allows you to direct financial flows to sustainable projects and minimize environmental risks.

Some researchers notes that Russia, as a participant in the international environmental agenda, should actively develop the green finance market, taking into account international standards and practices. The paper points to the underdevelopment of the Russian financial market and the lack of active participation in international organizations, which may hinder this process. Success in the field of green finance can lead to attracting foreign investment and improving the country's reputation in the international arena.

Karpukhina (2020), Artemyev (2024) emphasize that banks, being financial intermediaries, cannot stay away from the implementation of ESG projects [1, 2]. However, a full understanding of the importance of the ESG agenda in the banking sector has not yet been achieved. The main factors slowing down development include the poor quality of information for analyzing borrowers.

IV. Results and discussion

The study showed that benchmarking of leading countries in the field of green banking, such as Germany, Sweden and the Netherlands represent a valuable area of research that can enrich Russian banking practice with the best global approaches.

However, despite their successes, the adaptation of this experience to the Russian economy it is associated with a number of challenges due to the peculiarities of the national context.

Germany, one of the largest economies in Europe, has demonstrated outstanding results in the field of green banking, especially in the framework of energy efficiency and renewable energy development programs. The main driver here is government support, expressed in large–scale subsidy programs, guarantees and benefits that make financing green projects more attractive to commercial banks. An important aspect is the participation of such large institutions as KfW Bankengruppe, which not only provides financial support, but also actively participates in the development of sustainable development strategies. This approach minimizes risks for banks and entrepreneurs, providing a high degree of confidence in the return on investment.

At the same time, the adaptation of the German green banking model presents certain difficulties for Russia. One of the key obstacles is the insufficient level of government support and subsidies for green projects, as well as the relatively weak development of renewable energy infrastructure. Unlike Germany, where a significant part of electricity is produced by wind and solar, in Russia the energy sector is still dominated by traditional hydrocarbons.

However, on the other hand, there is potential for growth in this segment, given Russia's rich natural resources, which can be used to transition to more sustainable energy supply models.

Sweden, being one of the most environmentally oriented countries, is actively developing green banking practices. Sweden is a leader in green bond issuance, which helps to raise significant funds to finance sustainable projects. Adapting the Swedish experience in Russia may also face certain difficulties. Firstly, the Russian green bond market is at the stage of formation, and the volume of issues is still significantly behind its Western counterparts. Secondly, the level of awareness and acceptance of ESG principles among Russian companies and banks remains low. Although interest in sustainability is growing, many companies still view ESG as an additional burden rather than an opportunity to create long–term value. Nevertheless, taking into account global trends and the growing interest of investors in sustainable financing, the introduction of ESG factors into Russian banking may become a strategically important area.

The Netherlands, in turn, demonstrates an innovative approach to green banking, actively developing new financial instruments and mechanisms, such as public–private partnerships. Dutch banks cooperate extensively with international financial institutions, which allows them to borrow best practices and integrate them into the national banking system. An important area is the financing of sustainable agriculture and water resources management, which corresponds to the natural and economic conditions of the country.

For Russia, where agriculture and water resources also play an important role, the experience of the Netherlands is of particular value. However, it should be borne in mind that the adaptation of these practices requires significant institutional changes and the development of new mechanisms for interaction between the state, banks and the private sector. Moreover, unlike the Netherlands, Russia faces problems of regional inequality, which can make it difficult to scale successful projects throughout the country. For example, successful green finance models in Central Russia may not be as effective in Siberia or the Far East. In the East, where the infrastructure is much less developed.

It is important to take into account that the successful adaptation of international practices requires an integrated approach, including not only the borrowing of specific financial instruments, but also the creation of an appropriate institutional environment, raising awareness and adoption of ESG principles, as well as the development of public partnerships with the private sector. In this context, the role of the state becomes key, since it is it that is able to set the vector of development and provide the necessary conditions for the growth of green banking in Russia. Fig.1 schematically shows the role of a commercial bank in the field of sustainable development.

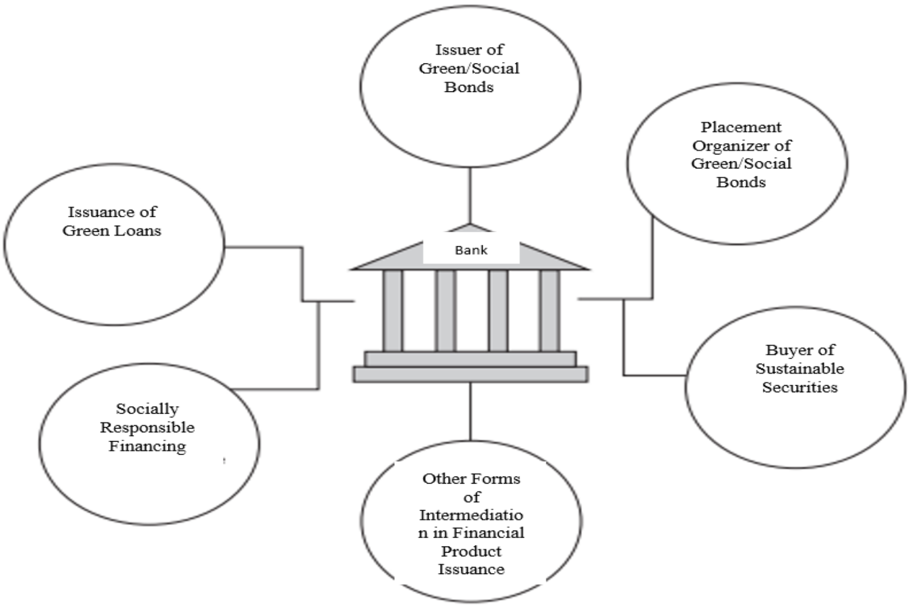

Figure 1: *The role of a commercial bank in the field of sustainable development*.
Source: according to the materials [3-15]

To quantify the impact of green finance on the financial results of commercial banks, a model based on regression analysis is proposed, which takes into account the volumes of green loans issued and green bonds issued in different countries.

The main estimation method is multiple linear regression, where dependent variables (ROA, ROE, profit) will be modeled depending on independent variables.

The obtained regression coefficients will allow us to assess how changes in the volume of green financing affect the financial results of banks. For example, a positive and significant value of the β1 coefficient will mean that an increase in the volume of green loans contributes to an increase in the profitability of the bank's assets. Control variables can be added to the model, such as the total assets of the bank, interest rates, and the economic situation in the country, in order to take into account external factors that can also affect financial results. After evaluating the model, hypotheses about the importance of green finance for banks' financial performance can be tested.

Also, based on the model, it is possible to make forecasts and assess how an increase in green financing may affect the bank's future results. It is important to keep in mind that the volume of green loans and bonds in Russia is still small compared to other countries, which may reduce the importance of regression coefficients. However, as the green banking sector grows, the model may become an important tool for evaluating the effectiveness of such investments and developing strategies for Russian commercial banks. In order to ensure the rapid growth of the green banking sector, state support for the activity of commercial banks in the field of green banking is necessary, including various mechanisms of subsidies and tax incentives.

Financial institutions are facing new challenges and requirements, and the effectiveness of various subsidy mechanisms and tax incentives is becoming a determining factor for the successful integration of green finance principles into the banking sector. One of the main instruments of government support is subsidizing interest rates on green loans. In a number of countries, such as Germany and France, this mechanism has proven to be highly effective.

In turn, this makes such projects more attractive to commercial banks, reducing their risks and increasing their potential profitability. An example of the successful implementation of this approach is the program implemented in Germany through KfW Bankengruppe, which provides subsidies and guarantees to green projects.

Tax incentives are another important mechanism of state support that can stimulate the development of green banking. In countries such as Sweden and the Netherlands, tax incentives are provided not only to enterprises implementing green projects, but also to banks actively involved in financing such initiatives.

However, at the moment their use remains limited, which reduces the motivation of banks to participate in green projects. The introduction of systemic tax incentives for banks supporting sustainable development could It would significantly increase their interest in expanding green lending and issuing green bonds. This, in turn, would create conditions for increasing investments in projects aimed at environmental modernization and reducing the carbon footprint.

Despite the obvious advantages of government support, it must be borne in mind that its effectiveness depends not only on the scale of subsidies and benefits, but also on the quality of program implementation.

It is important to ensure transparency and accessibility of support mechanisms so that they really contribute to the growth of green banking, and do not create additional barriers for commercial banks.

The development of green lending in the world today is determined by many factors that differ in their importance and impact on the financial results of banks and the economy as a whole.

Comparing the volumes and dynamics of green lending in leading countries such as Germany, Sweden and the Netherlands with the situation in Russia allows not only to assess the current state of affairs. Such criteria include institutional support, the development of a regulatory framework, the level of awareness of the importance of ESG principles.

Over the past decades, Germany, Sweden and The Netherlands has consistently strengthened its position in the field of green lending, which has led to significant successes in this area. In Germany, the volume of green loans annually shows steady growth exceeding 15–20 %.

Which, through state–owned banks such as KfW, provides subsidies and guarantees for green projects, the development of renewable energy sources and sustainable construction. This allows banks to reduce their risks and attract more customers interested in sustainable development. In Sweden, the dynamics of green lending is also impressive, with an annual increase of 12–18 %, and the share of green loans in the total loan portfolio of Swedish banks is 10–12 %.

This was achieved through the active integration of ESG principles into banking practice and government support in the form of tax incentives and special financing programs. The Netherlands shows similar results, with green lending growing at 10–15% per year and significant investment in projects related to sustainable agriculture and water management. At the same time, the Russian green lending market lags far behind its Western counterparts. The volume of green loans in Russia is less than 1% of the total loan portfolio of banks, and the growth rate remains modest, ranging from 5–7 % per year.

These indicators indicate a significant lag, which requires an analysis of the factors hindering the growth of green lending in the country. One of the key barriers is insufficient institutional support. While in In Germany and Sweden, state–owned banks play an active role in stimulating green lending, while such mechanisms have not yet become widespread in Russia. The availability of subsidy programs is limited and access to them is difficult, which constrains banks' interest in this segment. Another important factor is the regulatory framework. Leading countries have long developed and implemented clear standards and taxonomies for green projects, which ensures transparency and reduces risks for market participants.

In Russia, such a regulatory framework is still being formed, and the lack of clear criteria creates uncertainty for both banks and investors. This leads to the fact that banks are afraid to participate in green lending due to high risks and uncertain prospects for return on investment. In addition, the level of awareness about the importance of ESG principles in Russia remains low. In Germany and Sweden, environmental responsibility and sustainable development have long been an integral part of banks' corporate culture and strategy. In these countries, customers and investors are aware of the importance of sustainable development and require banks to meet high standards. In Russia ESG principles are still perceived as additional requirements rather than an opportunity to create long–term value. This hinders the development of green lending, as demand for such products remains limited.

In Sweden and the Netherlands, tax incentives and other financial instruments create additional incentives for banks interested in developing green finance. There are practically no such benefits in Russia, which reduces the motivation of banks to participate in green projects.

Global trends in sustainable development, international commitments to reduce carbon emissions and growing investor interest in sustainable projects create prerequisites for the activation of this segment. The introduction of successful practices from other countries, the adaptation of the regulatory framework, increased government support and increased awareness of the importance of ESG principles can be key factors contributing to the growth of green lending in Russia.

Thus, a comparative analysis of the volumes and dynamics of green lending in leading countries and Russia shows that the successes of most countries in this area are achieved thanks to a well–structured system of institutional support, a developed regulatory framework, a high level of awareness of the importance of ESG principles and the availability of economic incentives. In Russia, on the contrary, insufficient government support, a weak regulatory framework, a low level of acceptance of ESG principles and a lack of significant economic incentives are the main barriers.

The growth rate of green loans – an analysis of changes in the volume of green loans in dynamics allows us to assess how actively the bank is expanding its sustainable financing programs. Sustained growth indicates a strategic focus on sustainable development.

The analysis requires collecting the following data: the total volume of the bank's loan portfolio, the volume of green loans issued, the volume and number of green bond issues.

The methodology for analyzing green finance should include both retrospective and forward–looking approaches.

The forward–looking approach includes modeling the future growth of green lending based on current trends and evaluating possible market development scenarios. This approach will make it possible to determine which measures can stimulate an increase in the share of "green" loans in the loan portfolio and how actively banks are ready to support the transition to sustainable development. An equally important aspect of the engagement assessment is the analysis of the participation of Russian banks in the issuance of "green" bonds. Green bonds are debt instruments designed to finance environmentally sustainable projects. Participation in the issuance of such bonds indicates that the bank not only supports sustainable development at the lending level, but also actively participates in raising capital for the implementation of environmental initiatives through the capital market.

It is important to note that participation in the issue of green bonds can be either direct, when the bank itself acts as an issuer, or indirect, when the bank supports the issue of third parties by providing guarantees or acting as an organizer of the issue. To quantify the involvement of

Russian banks in green bonds, it is necessary to analyze the structure of their investment portfolio and determine what share green bonds occupy in it.

Thus, for a comprehensive assessment, it is necessary to analyze not only the volume of bond issuance, but also the structure of the use of borrowed funds. It is also interesting to consider the degree of involvement of Russian banks in international partnerships and projects related to sustainable development. Within the framework of such projects, banks can not only improve their skills in the field of green finance, but also gain access to best practices and technologies that can be adapted for use in the Russian market. This is especially important in the context of the growing global trend towards increased regulation and accountability in the field of sustainable development.

Banks that actively implement ESG principles in their activities have a higher ability to adapt to changing market conditions. Therefore, in order to increase the involvement of Russian banks in sustainable development projects, it is necessary not only to expand credit programs and issue green bonds, but also to invest in the development of internal competencies and corporate culture focused on the principles of sustainable development.

Thus, a quantitative analysis of the loan portfolio structure and participation in green bonds allows a deeper understanding of the degree of involvement of Russian commercial banks in sustainable development projects. This, in turn, opens up opportunities for further development of this segment and integration of the principles of sustainable development into banking activities on a long–term basis.

This will not only attract capital to finance environmentally significant projects, but also strengthen the bank's reputation as a sustainable financial institution. The implementation of a monitoring and reporting system for green projects will ensure transparency of the bank's activities and strengthen the trust of investors and customers. In addition, providing technical assistance and advice to clients on sustainable development issues will help them better understand the requirements of green finance and increase their willingness to participate in such projects.

It is necessary to adapt international standards of green finance to Russian conditions, taking into account the specifics of the national market. At the same time, it is necessary to actively raise awareness and train the bank's staff on sustainable development issues, which will allow banks to work more effectively with environmentally significant projects. An important aspect is also the introduction of tax incentives for clients implementing projects in the field of sustainable development. This may include benefits and subsidies that will help make green finance more affordable. The active involvement of private investors and the expansion of cooperation with government support programs are also important elements of the strategy for adapting international best practices.

V. Conclusion

Supporting the development of infrastructure for green finance, including project verification and certification systems, will also be an important step towards strengthening the position of Russian banks in this area. Participation in educational and information campaigns on sustainable development issues will help banks not only strengthen their reputation, but also raise public awareness of the benefits of green financing. It is also important to develop non–financial disclosure practices, including sustainability indicators, which will allow banks to meet international standards and investor expectations.

Thus, green projects and Green Banking in Russia are at the stage of formation, which is manifested in the relatively low share of green loans and bonds in the total portfolio of commercial banks. Nevertheless, global trends and international commitments stimulate the growth of interest in sustainable financing, which creates prerequisites for the accelerated development of this segment.

References

[1] Karpukhina O. Development of foreign trade activities and ensuring economic security of the Russian Federation // Economics and Management. – 2020. – № 3 (34). – P. 13–19. doi: 10.21777/2587–554X–2020–3–13–19

[2] Artemyev N.V., et al. The impact of migration processes on the economic security of the Russian Federation // Economics and Management. – 2024. – № 2 (49). – P. 17–28. doi: 10.21777/2587–554X–2024–2–17–28

[3] Zakiryanov, B.K., et al. Development of Rural Green Tourism of Regions of Kazakhstan. Environmental Footprints and Eco–Design of Products and Processes, 2022, pp. 33–38 DOI:10.1007/978–981–19–1125–5_2

[4] Moldashbayeva, L., et al. Green bonds – A tool for financing green projects in countries. E3S Web of Conferences, 2021, 244, 10060 DOI:10.1051/e3sconf/202124410060

[5] Troyanskaya, M., et al. Instruments for financing and investing the green economy in the country's environmental projects. E3S Web of Conferences, 2021, 244, 10054 DOI:10.1051/e3sconf/202124410054

[6] Jazykbayeva, B., et al. The Growth of green finance at the global level in the context of sustainable economic development. E3S Web of Conferences, 2021, 244, 10058 DOI:10.1051/e3sconf/202124410058

[7] Abramova M., Varzin V. et al. Features of the mechanism for implementing sustainable development through the green economy. E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

[8] Zverkova A., et al. Features of the "Green" strategies for the development of banks. E3S Web of Conf., 402 (2023) 08029 DOI: 10.1051/e3sconf/202340208029

[9] Antonenko A.P. Ideological foundations of a new stage in the development of civilization // Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences. – 2021. – № 3 (29). – Pp. 5–8. doi: 10.21777/2587–9472–2021–3–5–8

[10] Archimandritova A.V., Suptelo N.P. Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – 1 (40). 85–94. doi: 10.21777/2587– 554X–2022–1–85–94

[11] Baburin S.N. Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences.– 2019. – 4 (22). – 6–12. doi: 10.21777/2587–9472–2019–4–6–12

[12] Berstembayeva, R., et al. (2024). The impact of the green economy on the sustainable development of Kazakhstan. In *BIO Web of Conferences* (Vol. 116, p. 07040). EDP Sciences.

[13] Bunevich K.G., Gorbacheva T.A. «Green» trends in the development of the world financial system // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – № 1 (40). – Pp. 52–60. doi: 10.21777/2587–554X–2022–1–52–60

[14] Burykin, E.S.: Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. 4(35), 81–86 (2020). https://doi.org/10.21777/2587–554X2020–4–81–86

[15] Gavrilova E.N. «Green» financing in Russia: specifics, basic tools, problems of development // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2020. – № 2 (33). – Pp. 48–54. doi: 10.21777/2587–554X–2020–2–48–54

SOCIOECONOMIC BENEFITS OF THE TRANSITION TO A LOW-CARBON ECONOMY

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Abstract

The transition to a low-carbon economy is a crucial strategy in combating climate change and promoting sustainable development. This shift not only aims to reduce greenhouse gas emissions but also offers substantial socioeconomic benefits. Firstly, the move towards a low-carbon economy generates new job opportunities in renewable energy sectors, energy efficiency initiatives, and sustainable transportation systems, thereby driving economic growth. For instance, investments in green technologies can create a diverse range of employment options, from research and development to manufacturing and installation. Secondly, transitioning to clean energy sources decreases dependence on fossil fuels, which enhances energy security for nations and regions. By diversifying energy supply and investing in local renewable resources, countries can mitigate the risks associated with fluctuating fossil fuel prices and geopolitical tensions. Moreover, the reduction of environmental pollution resulting from a low-carbon economy leads to significant public health improvements. Cleaner air and water translate into lower healthcare costs and increased productivity among workers, as health-related absences decrease. Additionally, investing in low-carbon technologies promotes the development of sustainable cities and communities, which improves residents' quality of life through better public transport, green spaces, and healthier living conditions. Furthermore, transitioning to a low-carbon economy supports innovation and technological advancements. By fostering research and development in sustainable technologies, countries can position themselves as leaders in the emerging green economy, creating further economic opportunities. This transition also aligns with global climate agreements and sustainability goals, enhancing a nation's reputation and attracting investment.

Keywords: energy security, public health, quality of life, environmental sustainability, innovation, green economy, climate change, sustainable development, economic growth

I. Introduction

The transition to a low-carbon economy is becoming increasingly critical in the face of escalating climate change and environmental degradation. This paradigm shift aims to reduce greenhouse gas emissions by transforming traditional energy systems and adopting sustainable practices across various sectors, including industry, transportation, and agriculture. The urgency for action has been underscored by international agreements, such as the Paris Agreement, which seek to limit global warming to well below 2 degrees Celsius.

Transitioning to a low-carbon economy presents a unique opportunity not only to address environmental challenges but also to foster significant socioeconomic benefits. As governments, businesses, and communities strive to implement cleaner technologies and sustainable practices, they open avenues for job creation, economic diversification, and improved public health outcomes. This transformation aligns with broader objectives of sustainable development, promoting a balanced approach that integrates economic growth with environmental stewardship.

The potential for job creation is particularly noteworthy. Investments in renewable energy sources, energy-efficient technologies, and sustainable transportation infrastructure are expected to generate millions of jobs globally. These sectors are labor-intensive and can provide employment opportunities in both urban and rural areas, enhancing economic resilience and reducing inequality.

Moreover, a low-carbon economy contributes to energy security by reducing reliance on fossil fuels, which are subject to price volatility and geopolitical tensions. By investing in renewable energy and local resources, countries can enhance their energy independence, stabilize energy prices, and promote local economic growth.

The environmental benefits of this transition are equally compelling. Reducing greenhouse gas emissions leads to improved air and water quality, resulting in better public health outcomes and reduced healthcare costs. Healthier populations contribute to increased productivity, benefiting economies at large. In light of these considerations, this paper explores the socioeconomic benefits of transitioning to a low-carbon economy. It highlights the interconnectedness of environmental sustainability and economic development, emphasizing the need for integrated policy approaches that promote innovation, job creation, and improved quality of life. By examining these benefits, the paper aims to provide insights into the critical role that a low-carbon economy can play in fostering a sustainable future for individuals and communities worldwide.

II. Methods

This study employs three primary methods to analyze the socioeconomic benefits of transitioning to a low-carbon economy:

1. **Literature Review:** A comprehensive literature review was conducted to gather and analyze existing research on the socioeconomic impacts of low-carbon initiatives. This review included academic journals, government reports, and case studies from various countries. By synthesizing findings from these sources, the study identifies key themes, trends, and potential gaps in the understanding of how transitioning to a low-carbon economy affects job creation, public health, and economic growth.
2. **Case Studies:** In-depth case studies were performed on specific countries or regions that have successfully implemented low-carbon strategies. These case studies highlight real-world examples of the socioeconomic benefits associated with the transition, focusing on metrics such as job creation in renewable energy sectors, improvements in public health outcomes, and overall economic growth. Analyzing these case studies provides valuable insights into effective practices and policies that can be replicated in other contexts.
3. **Surveys and Interviews:** Surveys were conducted with stakeholders, including policymakers, business leaders, and community members, to gather qualitative and quantitative data on perceptions and experiences related to the low-carbon transition. In addition, semi-structured interviews with experts in renewable energy and environmental economics were carried out to provide deeper insights into the challenges and opportunities associated with low-carbon initiatives. This method helps to capture diverse perspectives and enriches the analysis of socioeconomic impacts.

By utilizing these three methods, the study aims to provide a well-rounded understanding of the socioeconomic benefits of transitioning to a low-carbon economy.

III. Results

The digital economy is crucial in facilitating unprecedented access to information. With the rise of digital technologies and the widespread availability of the internet, individuals, organizations, and communities can now easily and efficiently tap into a vast range of information. The significance of the digital economy in information access can be illustrated through several key points:

1. **Democratization of Information:** The digital economy has democratized information access, dismantling traditional barriers and enabling people from various backgrounds to gain knowledge. Previously, access was often restricted to those in privileged positions. Today, the digital economy has leveled the playing field, empowering individuals regardless of their location, socioeconomic status, or educational background.
2. **Connectivity and Global Reach:** The digital economy allows for global access and sharing of information. The internet has interconnected individuals from around the world, enabling rapid information dissemination and exchange across borders. This interconnectedness fosters cross-cultural understanding, collaboration, and the sharing of diverse viewpoints.
3. **Abundance and Variety of Information:** The digital economy has generated a wealth of information in multiple formats, including text, images, audio, and video. Online platforms, search engines, and digital libraries provide extensive repositories of knowledge on a wide array of topics. This information wealth allows individuals to explore, learn, and remain informed about subjects that interest them, encouraging personal growth and lifelong learning.
4. **Timeliness and Real-time Updates:** The digital economy ensures that information is accessible in real time. News websites, social media platforms, and online publications deliver immediate updates on current events, allowing individuals to stay informed about the latest developments globally. Real-time access to information is essential in various fields, such as emergency response, financial markets, and scientific research.
5. **Customization and Personalization:** The digital economy offers personalized access to information tailored to individual preferences and needs. Recommendation algorithms and personalized content delivery systems adjust information to align with users' interests, providing a more relevant and engaging experience. This customization enhances individuals' ability to acquire knowledge in a focused manner.
6. **Open Educational Resources:** The digital economy has facilitated the development and distribution of open educational resources (OERs). OERs are freely available educational materials accessible online, including textbooks, lecture notes, multimedia resources, and interactive learning platforms. These resources broaden access to education and lifelong learning, making high-quality educational content available to a wider audience.

In summary, the digital economy has transformed access to information by democratizing knowledge, providing global connectivity, offering a wealth of information, delivering real-time updates, enabling personalization, and promoting open educational resources. Its role in information access is vital for empowering individuals, fostering continuous learning, and creating a more informed and connected global society.

IV. Discussion

While the digital economy holds significant promise for sustainable development, it also poses several challenges that must be addressed. One major issue is the digital divide, which refers to the disparity between those who have access to digital technologies and the internet and those who do not. In many areas, especially low-income regions and marginalized communities, access to digital infrastructure and internet connectivity is limited or nonexistent. This gap restricts equal participation in the digital economy, exacerbates existing inequalities, and limits access to information, education, and economic opportunities.

Another concern is the environmental impact of the digital economy. The rising demand for digital devices, data centers, and cloud computing infrastructure contributes to significant energy consumption and the generation of electronic waste. The production, use, and disposal of electronic devices lead to resource depletion, carbon emissions, and hazardous waste. It is essential to balance the advantages of the digital economy with its environmental impacts to ensure sustainable development.

Additionally, the rapid pace of technological advancement and the shorter lifecycle of digital devices contribute to the escalating issue of electronic waste (e-waste). E-waste contains hazardous materials that can harm both the environment and human health if not properly managed. Effective e-waste management systems, including recycling and responsible disposal practices, are vital to mitigate the negative environmental and health impacts associated with electronic waste.

Moreover, the digital economy heavily relies on the collection, storage, and utilization of personal data, raising privacy and security concerns. This reliance poses risks related to the potential misuse or unauthorized access to sensitive information. Furthermore, the increasing interconnectedness of digital systems makes them susceptible to cyber-attacks and security breaches.

The digital economy also introduces ethical considerations regarding the responsible use of technology and data. Issues such as algorithmic bias, digital surveillance, and the implications of automation for jobs and labor markets require careful attention. Striking a balance between technological advancement and ethical considerations is crucial to prevent unintended negative consequences and promote fairness and social inclusion.

Effective participation in the digital economy necessitates individuals possessing the requisite skills and digital literacy. However, many individuals, particularly those from disadvantaged backgrounds or older generations, may lack the necessary skills and knowledge. Bridging the digital skills gap and promoting digital literacy programs are essential for ensuring inclusive access and equal opportunities for all.

Addressing these challenges demands a collaborative approach involving multiple stakeholders, including governments, businesses, civil society organizations, and international bodies. Policies and regulations should be established to bridge the digital divide, promote sustainable practices within the digital economy, safeguard privacy and security, and uphold ethical considerations. Additionally, investing in digital infrastructure, education, and capacity-building programs can empower individuals and communities to leverage the benefits of the digital economy for sustainable development.

Several obstacles hinder the digital economy's role in achieving sustainable development. Poor infrastructure in many regions and countries can impede effective communication and IT development. Slow internet speeds and a lack of network coverage significantly hinder the growth of the digital economy and sustainable development efforts. Furthermore, many individuals and organizations struggle to acquire the digital skills necessary to engage fully in the digital economy. Providing training and continuing education opportunities is essential to enhance digital skills and empower people to utilize digital technology effectively.

Existing legislation and policies can also obstruct the development of a sustainable digital economy. Legal and regulatory constraints may hinder innovation and investment in the digital sector, necessitating the creation of policies that encourage technological development while promoting resilience and innovation. Cultural and social challenges further complicate this issue, as some communities may resist adopting digital technology due to mistrust or lack of awareness of its benefits. Promoting awareness and education about the digital economy can help foster acceptance and usage in these communities.

To realize the digital economy's potential in achieving sustainable development, it is crucial to promote innovation and entrepreneurship. Technological innovation can drive sustainable development by developing new digital technologies and solutions that enhance resource efficiency and improve economic and environmental outcomes. Supporting digital entrepreneurship stimulates innovation and sustainable development. Creating a favorable environment for startups and innovators in the digital sector can lead to job creation, improved productivity, and enhanced innovation.

Financial assistance and resources are necessary for startups and innovators in the digital sector. This includes investment funding, government programs aimed at promoting entrepreneurship, and training and technical assistance to nurture innovation and growth among startups contributing to sustainable development. Finally, strengthening collaboration between the public sector, private sector, and civil society is vital to achieving sustainable development through the digital economy. Sharing knowledge and experiences can enhance integration and collective efforts toward sustainability.

By addressing these challenges and promoting innovation, the digital economy can play a transformative role in achieving sustainable development goals.

The transition to a digital economy presents both opportunities and challenges in the pursuit of sustainable development. The interplay between digital technologies and sustainability underscores the need for a nuanced understanding of how these tools can be leveraged to foster economic growth while minimizing environmental impact and enhancing social equity.

One of the most promising aspects of the digital economy is its capacity to democratize access to information. By breaking down traditional barriers, individuals from various backgrounds can gain access to knowledge and resources that were previously out of reach. This democratization fosters greater participation in the economy and society, potentially leading to a more equitable distribution of opportunities. However, it is crucial to recognize that not everyone benefits equally from this access. The digital divide remains a significant obstacle, particularly in low-income regions and marginalized communities where internet connectivity is limited. Bridging this divide requires targeted interventions, such as investment in infrastructure and digital literacy programs, to ensure that all individuals can participate fully in the digital economy.

The environmental impact of the digital economy is another critical issue that requires careful consideration. While digital technologies can enhance efficiency and reduce resource consumption in some sectors, they also contribute to energy consumption and electronic waste. For instance, the proliferation of data centers and the demand for electronic devices can lead to significant carbon emissions and resource depletion. As a result, it is imperative to adopt sustainable practices within the digital economy, including promoting energy-efficient technologies and effective e-waste management systems. Policymakers must find ways to balance the benefits of digital innovation with its environmental consequences, ensuring that sustainable development goals are met without compromising ecological integrity.

Privacy and security concerns are also paramount in the digital economy. The reliance on personal data collection and storage raises questions about data protection and the potential for misuse. Ensuring robust privacy regulations and enhancing cybersecurity measures are essential to build trust among users. Without addressing these concerns, the potential benefits of the digital economy may be overshadowed by public apprehension and resistance to adopting new technologies.

From an ethical standpoint, the digital economy raises important questions about fairness and inclusion. Issues such as algorithmic bias and the implications of automation on employment necessitate careful scrutiny. Policymakers and stakeholders must engage in ongoing dialogues about the ethical implications of digital technologies, fostering practices that promote equity and social inclusion. This is particularly important in light of the potential for automation to displace workers, which could exacerbate existing inequalities if not addressed proactively through retraining and upskilling initiatives.

Skills and digital literacy are fundamental to maximizing the benefits of the digital economy. Individuals who lack the necessary skills to navigate digital platforms may find themselves at a disadvantage, unable to participate fully in the opportunities presented by digital technologies. Addressing this skills gap requires a concerted effort from educational institutions, governments, and private sectors to develop training programs that equip individuals with the tools they need to thrive in a digital world.

Collaboration among various stakeholders is critical to overcoming the challenges posed by the digital economy. Governments, businesses, civil society, and international organizations must work together to create an inclusive digital landscape that fosters innovation and entrepreneurship. By promoting partnerships and knowledge sharing, stakeholders can better address the complexities of the digital economy and drive sustainable development efforts.

Finally, promoting innovation and entrepreneurship in the digital sector is essential for unlocking the potential of the digital economy. Encouraging the development of new technologies and solutions can lead to improved resource efficiency and economic growth. Providing financial support and resources for startups can stimulate innovation and create jobs, further enhancing the positive impact of the digital economy on sustainable development.

In summary, the digital economy offers significant potential for sustainable development, but it also presents a set of challenges that require careful consideration and proactive measures. By addressing the digital divide, mitigating environmental impacts, safeguarding privacy, promoting ethical practices, and enhancing skills and collaboration, we can harness the transformative power of the digital economy to create a more sustainable and equitable future.

References

[1] Nazarova I. T., Gurezov Z.Ways of managing innovative organizations in Russia.//Journal of Monetary Economics and Management. -2022-№1-C.18.

[2] Altsybeeva I. G., Andreeva L. O.Financial strategy in the management of the enterprise.//Journal of Monetary Economics and Management. -2022-№1-C.6.

[3] Shmatko S.G., Agarkova L.V., Gurnovich T.G., Podkolzina I.M. Problems of increasing the quality of raw material for wine in the stavropol region // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2016. T. 7. № 2. C. 725-730.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Aliyeva M. L., Misirli R. R. Advantages and problems of big data management// Journal of Monetary Economics and Management. - 2023. - No. 1.- P.8-14

[6] Mezentsev D.A. Methods of increasing sales in the context of modern business development//Journal of Monetary Economics and Management.- 2023.- No. 4. - P.15-23

[7] Babaeva Z.Sh., Pogorelova L.A. Differentiation of the standard of living of the population as a reflection of socio-economic development//Journal of Monetary Economics and Management.-2023.-№2. - P.50-58

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of

the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

SYSTEMATIC AND BIOMORPHOLOGICAL ANALYSIS OF AQUATIC PLANTS OF THE CHECHEN REPUBLIC

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Abstract

Compiling a list of aquatic plants of the Chechen Republic is very important from an ecological point of view. The main goal of this study was to provide a detailed list of aquatic plants growing on the territory of the republic. Aquatic plants play an important role in water systems. This work presents a systematic and biomorphological analysis, as well as the occurrence of aquatic plants of the Chechen Republic. This study is an inventory and analysis of the aquatic flora of the republic. These studies were conducted based on the processing of herbarium materials and the authors' own observations. Aquatic vegetation forms the basis of aquatic ecosystems, providing habitats, food, and oxygen for a wide range of aquatic organisms, from invertebrates and fish to larger predators. Moreover, aquatic plants contribute to water purification by filtering pollutants and stabilizing sediments, thus playing a key role in maintaining water quality. The primary objective of this study was to compile a comprehensive list of aquatic plants growing in the various water bodies across the Chechen Republic and to analyze their occurrence, distribution, and ecological roles. This work involved both a systematic and biomorphological analysis of the region's aquatic flora, along with an assessment of how these plants are distributed across different habitats.

Keywords: Chechen Republic, water, aquatic plants, species, genus, family, biomorph, hemicryptophytes, cryptophytes, therophytes, occurrence

I. Introduction

Chechen Republic is located V moderate climate belt, what provides big diversity And wealth flora. In the northern part of the Chechen Republic, the semi-desert turns into steppe, the territories close to the central part change from forest-steppe to forest. Between the belt of forests and snowy peaks there are subalpine and alpine meadows. Thus, the territory of our republic is very diverse in climatic terms, due to which plant forms have great geographic plasticity [5].

Water, the most important resource for sustaining life on our planet, is of critical importance to both humans and the ecosystem as a whole. A number of factors, including population growth, rapid industrialization, urbanization, and unsustainable use of natural resources, have significantly affected water quality in recent decades.

Aquatic plants play an important role in aquatic systems. A comprehensive understanding of their spatial distribution can help in developing biodiversity conservation plans.

II. Methods

Aquatic plants are perennial (less often annual) plants, the necessary condition of life of which is full or partial stay in fresh (mostly), salt or brackish water. Aquatic plants are mostly represented by herbs.

The purpose and objectives of the study. The purpose of the work is to conduct a systematic, biomorphological, and also an analysis of the occurrence of aquatic plants in the Chechen Republic.

III. Results

In the study of the flora, the material obtained during the field research and observations of the authors, as well as information obtained during the study of the herbarium collections of "Botany, Zoology and Bioecology" was used. Chechen State University named after A.A. Kadyrov.

This study presents aquatic plants of the Chechen Republic that have economic significance. As a result of the study, a total of 78 plant species were registered, united into 28 different families. It was established that the dominant families are Cyperaceae, Poacea, and Buckwheat [7] .

The complete list is presented in Table 1. Their numerical ratio is shown in Fig.1.

Table 1: *Systematic analysis of aquatic plants of the Chechen Republic*

No.	Family	Genus	View
1.	*Equisetaceae* Rich. ex DC. – Horsetail	*Equisrtum*	*Equisrtum arvense* L. – Field Horsetail
			Equisrtum fluviatile L. (*E. heleocharis* Ehrh.) – Marsh horsetail
2.	*Marsileaceae* Mirb. – Marsileaceae	*Marsilea*	*Marsilea quadrifolia* L. – Marsilea quadrifolia
3.	*Salviniaceae* Lest. – Salviniaceae	*Salvinia*	*Salvinia natans* (L.) All.– Floating salvinia
4.	*Iridaceae* Juss. –Iridaceae (Iridaceae)	*Iris*	*Iris pseudacorus* L. – Iris (Iris) yellow
5.	*Droseraceae* Salisb. – Sundews	*Drosera*	*Drosera rotundifolia L.* – Round-leaved sundew
6.	*Trapaceae* Dumort. – Chilimaceae (Cornworts)	*Trapa*	*Trapa hyrcana* Woronow – Chilim Hyrcana
7.	*Ranunculaceae* Juss. – Buttercups	*Ranunculus*	*Ranunculus sceleratus* L. – Poisonous Buttercup
			Ranunculus repens L. – Creeping Buttercup
		Aquilegia	*Aquilegia caucasian* Bieb . (*A. olympica* Boiss .) – Caucasian columbine
8.	*Butamaceae* Rich. – Susakovyh	*Butomus*	*Butomus umbellatus* L. – Umbrella susak
9.	*Brassicaceae* Burnett *(Cruciferae)* – Cabbage (Cruciferae)	*Rorippa*	*Rorippa barbareifolia* (DC.) Kitag. *(R. islandica* (Oed.) Schinz et Thell; *R. palustris* (Leyss.) Bess. *)* – Icelandic watercress
			Rorippa austriaca (Crantz) Bess. – Austrian watercress

10.	*Rosaceae* Juss. – Pink	*Potentilla*	*Potentilla supina* L. – Low cinquefoil
			Potentilla reptans L. – Creeping cinquefoil
11.	*Lythraceae* J.St.- Hil. – Lythraceae	*Lythrum*	*Lythrum salicaria* L. – Willow-leaved loosestrife
12.	*Hypericaceae* Juss. - St. John's wort	*Hypericum*	*Hypericum quadrangulum* L. (*N. tetrapterum* Fries; *N. acutum* Moench. now. illegit.) - 3 willow four-winged
13.	*Onagraceae* Juss. – Willowherb (Nickweed)	*Epilobium*	*Epilobium palustre* L. – Fireweed
14.	*Apiaceae* Lindl. – DonkeyCelery (Umbelliferae)	*Berula*	*Berula erecta* (Huds.) Cov. *(Sium erectum Huds.)* – Berula straight
15.	*Polygonaceae* Juss. – Buckwheat	*Rumex*	*Rumex patientia* L. – Spinach sorrel
		Polygonum	*Polygonum amphibium* L – Amphibian knotweed
			Polygonum hydropipe L - Water pepper, water pepper
			Polygonum lapathifolium L. – Buckwheat (Polygonum) sorrel-leaved
			Polygonum persicaria L – Buckwheat
16.	*Primulaceae* Vent. – Primroses	*Samolus*	*Samolus valerandi* L. – Northerner Valeranda
		Lysimachia	*Lysimachia vulgaris* L. – Common loosestrife
17.	*Apocynaceae* Juss . – Apocynaceae	*Trachomitum*	*Trachomitum sarmatiense* Woodson – Sarmatian kendyr
18.	*Laimiaceae* Until. – Lamiaceae (Labiatae)	*Scutellaria*	*Scutellaria galericulata* L. – Skullcap
		Lycopus	*Lycopus europaeus* L. – European watercress
		Menta	*Mentha caucasica* Yand. – Caucasian mint (long-leaved)
			Mentha aquatica L. – Water mint
19.	*Scrophulariaceae* Juss. – Norichnikovye	*Veronica*	*Veronica anagallis-aquatica* L. – Spring Veronica
			Veronica beccabunga L . – Veronica potochnaya
20.	*Asteraceae* Dumort . (*Comnositae*) – Asteraceae (Compositae)	*Eupatorium*	*Eupatorium cannabinum* L. – Eupatorium hemp-like
		Bidens	*Bidens tripartite* L. – Three-part succession
		Sonchus	*Sonchus palustris* L. – Marsh sow thistle
21.	Typhaceae Juss . – Cattails	*Typha*	*Typha latifolia* L. (*T. shulttleworthii* C. Koch et Sond .) – Broadleaf cattail
			Typha angustifolia L. – P ogoz angustifolia
22.	*Sparganiaceae* Rudolnhi – Sparganiaceae	*Sparganium*	*Sparganium erectum L.* (*S. polyedrum* (Ackers, et Graebn.) Juz .; *S. ramosum* Huds .) – Straight burdock
23.	*Potamogetonaceae* Dumort.	*Potamogeton*	*Potamogeton filiformis* Pers. – Filiform

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	– Pondweeds		Potamogeton
			Potamogeton crispus L. – Curly garden plant
			Potamogeton natans L. – Floating Potamogeton
24.	*Alismataceae* Vent. – Chasmataceae	*Alisma*	*Alisma plantago aquatica* L.– Chastuha plantain
25.	*Poaceae* Barnhart – Poaceae (Grasses)	*Polypogon*	*Polypogon monspeliensis* (L.) Desf . – Monspelien's polybeard
		Phragmites	*Phragmites australis* (Cav.) Trin. ex Steud. (*Ph. communis* Trin.) – Reed southern
		Calamagrostis	*Calamagrostis pseudophragmites* (Hall fil.) Koel.– False reed grass
		Catabrosa	*Catabrosa aquatic* (L .) Beauv . – Water lily
		Poa	*Poa palustris* L – Marsh bluegrass
		Glycera	*Glycera fluitans* (L .) R . Br . – Mannik floating
			Glycera notata Chevall. (*G. Plicata* (Fries) Fries , *G. acutiuscula* H.Scholz) – Mannik folded
26.	*Cyperaceae* Juss. – Sedges	*Cyperus*	*Cyperus longus* L. – Long sedge
			Cyperus Glaber L. – Smooth cyperus
			Cyperus glomeratus L. – Syt crowded
		Juncellus	*Juncellus serotinus* (Rottb.) Clarke (*Cyperus serotinus* Rottb.) – Sitnichek late
		Scirpus	*Scirpus sylvaticus* L. – Common reed
		Schoenoptectus	*Schoenoplectus lacustris* (L.) Palla (*Scyrpus lacustris* L.)
			Schoenoptectus tabernaemontanii (CC Gmel .) Palla (S. tabernemontanii CCGmel.)
			Schoenoptectus triqueter (L.) Palla (S. triqueter L.) – Three-sided Schenoptectus
		Bolboschoenus	*Bolboschoenus maritimus* (L.) Palla (*B. compactus* (Hoffm.) Drob.) – Sea bulrush
		Eleocharis	*Eleocharis acicularis* (L.) Roem.etSchult. – Needle moth
			Eleocharis quinqueflora (FX Hartm.) O.Schwarz (*E. pauciflora* (Lightf) Link) – Five-flowered marsh grass
			Eleocharis uniglumis (Link) Schult. (*E. multiseta Zinserl.*) – Marsh grass single-scaled
			Eleocharis palustris (L.) Roem.et Schult. (*E. eupalustris* Linld.fil., *E. crassa* Fisch. et CA Mey. ex Zinserl.; *E. intersita* Zinserl.) – Swamp swamp
		Carex	*Carex remote* L.– Sedge spread

			Carex pseudocyperus L.– Sedge false
			Carex dilute Bieb .– Light sedge
			Carex hirta L.– Short-haired sedge
			Carex hordeistichos Vill .– Barley sedge
			Carex acutiformis Ehrh .– Sedge false-acute
			Carex riparia Curt.– Coastal sedge
		Cladium	*Cladium mariscus* (L.) Pohl – Common sword grass
27.	*Lemnaceae* SFCrav – Duckweed	*Lemna*	*Lemna minor* L. – Duckweed
			Lemna trisulca L . – P ternate clover
28.	*Juncaceae* Juss. – Sitnikovye	*Juncus*	*Juncus articulatus* L.– Sitnik articulate
			Juncus bufonius L.– Sitnik froglike
			Juncus Gerardii Loisel.– Sitnik Gerard
			Juncus effusus L. – Divergent rush
			Juncus inflexus L. – Inflexible rush
Total:		47	78

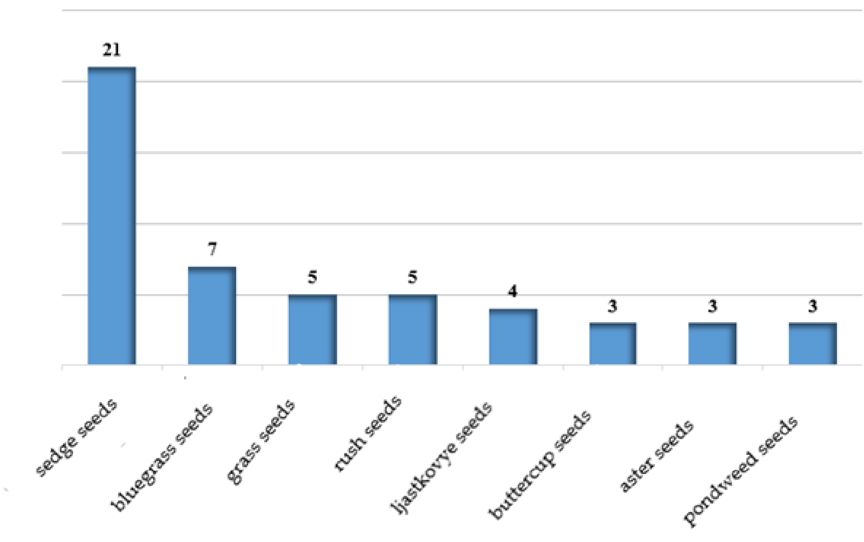

Figure 1: *The numerical ratio of aquatic plants in the Chechen Republic*

According to the classification of K. Raunkier, among 78 species there are 3 biomorphs – hemicryptophytes, cryptophytes and therophytes.

Hemicryptophytes 34 species: *Aquilegia caucasica* – Caucasian columbine , *Potentilla reptans* – Creeping cinquefoil, *Lythrum salicaria* – Willow-leaved loosestrife, *Epilobium palustre* – fireweed, *Rumex patientia* – Spinach sorrel, *Samolus valerandi* – Northern sorrel Valeranda, *Lysimachia vulgaris* – Loosestrife common, *Juncus inflexus* – Sickweed, *Schoenoptectus triquette* – Schenoplektus triangularis, *Scirpus sylvaticus* – Forest reed, *Cyperus longus* – Long-leaved sedge, *Catabrosa aquatic* - Water Adjutant, *Veronica beccabunga* - Veronica Potochnaya and others.

Cryptophytes 30 species: *Equisrtum arvense* – Horsetail, *Equisrtum fluviatile* – X Marsh wax, *Marsilea quadrifolia* – Marsilea quadrifolia, *Iris pseudacorus* – Yellow Iris, *Ranunculus repens* – Creeping Buttercup , *Butomus umbellatus* – Umbrella rush, *Rorippa austriaca* – Austrian watercress, *Berula erecta* – Berula erecta, *Polygonum amphibium* – Amphibian knotweed, *Veronica anagallus - aquatica* – Spring Speedwell, *Typha latifolia* – Broadleaf cattail, *T. angustifolia* – Narrow-leaved cattail , *Sparganium erectum* – Straight bur-reed, *Alisma plantago - aquatica* – Plantago alimentosa, *Potamogeton biliformis* – thread-leaved pondweed, *P. natans – floating pondweed* , etc.

Therophytes 14 species: *Salvinia natans* – Salvinia natans, *Trapa hyrcana* – Hyrcana Chilim, *Ranunculus sceleratus* - Poison buttercup, *Potentilla supine* – Cinquefoil low, *Polygonum amphibia* – Buckwheat (Polygonum) amphibian , *P. lapathifolium* – G. (buckwheat) sorrel-leaved, *P. persicaria* – G. (buckwheat) bird-leaved, *Bidens tripartite* – Three-part Bidens, *Polipogon monspeliensis* – Hemp-beard, *Cyperus Glaber* - Naked sedge, *Lemna minor* – Duckweed, *Cyperus glomeratus* – *Lemna trisulca* – P. trifoliate and *Juncus bufonius* – frog rush [7] .

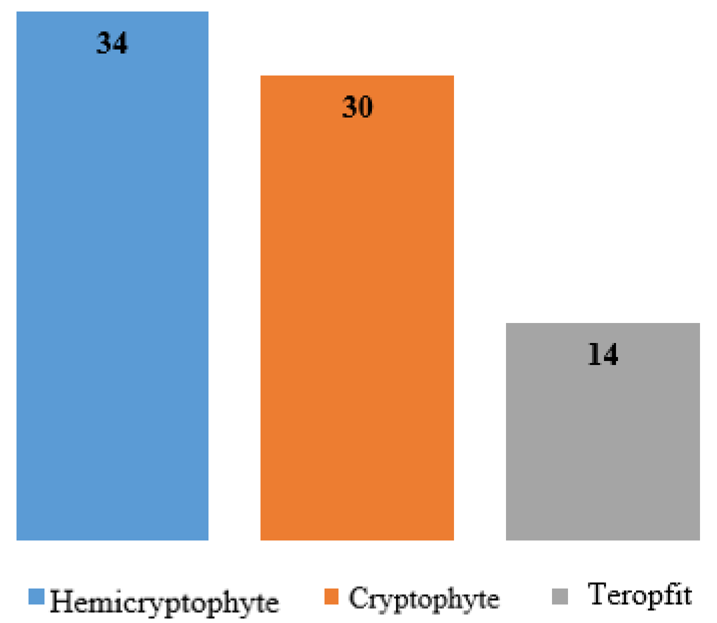

Figure 2: *Biomorphological analysis of aquatic species of the Chechen Republic*

In the process of human anthropogenic impact on nature, species that are small in number or are found scattered, rare, or very rare are at risk.

The largest number of species (32) are **scattered** , which is 41.02%: *Carex hordeistichos* Vill . – Barley-growing sedge, *Eleocharis palustris* (L.) Roem . et Schult – Marsh moth, *Schoenoptectus triqueter* (L.) Palla . – Chenoplectus triquetrum, *Scirpus sylvaticus* L. – Forest reed, *Juncellus serotinus* (Rottb .) Clarke – *Glycera notes* Chevall . (*G. Plicata* (Fries) Fries , *G. acutiuscula* H. Scholz) – Mannik plicata, *Potamogeton natans* L. – Floating pondweed, *Sparganium erectum* L. (*S. polyedrum* (Ackers , et Graebn .) Juz.; *S. ramosum* Huds .) – Straight burdock, *Sonchus palustris* L. – Marsh sow thistle, *Eupatorium cannobinum* L. – Hemp agrimony, etc.

Typically 28 species (35.89%) are found: *Ranunculus repens* L. – Creeping buttercup, *Potentilla reptans* L. – Creeping cinquefoil, *Typha angustifolia* L. – Narrow-leaved cattail, *Catabrosa aquatica* (L.) Beaur . – Water lily, *Schoenoptectus lacustris* (L.) Palla . – Lake Schenoplektus, *Bolboschoenus maritimus* (L.) Palla – Sea club-rush, *Carex riparia* Curt . – Coastal sedge, *Juncus gerardii* Loisel . – Sitnik Gerard et al.

Rarely found 17 species (21.79%): *Lemna trisulca* L. – *Carex* trifoliate*pseudocyperus* L. – False sedge, *Eleocharis uniglumis* (Link) Schult – Cyperus *glomeratus* L. – Crowded cyperus, *Polipogon monspeliensis* (L.) Desf . – *Polygonum amphibia* L. – Knotweed (buckwheat) amphibious, *Potamogeton biliformis* Pers . – Thread-leaved pondweed, etc.

Very rare 1 species is found, which makes up 1.28%: *Cladium mariscus* (L.) R. Br . – Common sword grass [7] .

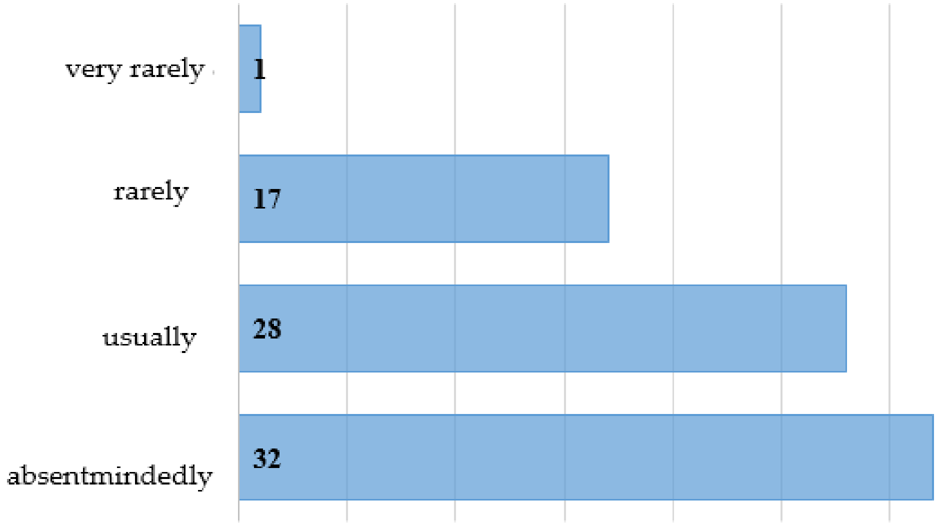

Figure 3: *Analysis of the occurrence of aquatic plant species in the Chechen Republic*

IV. Discussion

The systematic and biomorphological analysis is a scientific study focused on the flora of aquatic and riparian ecosystems in this region. The primary goal of this analysis is to examine the species diversity, taxonomic classification, biomorphological features, and ecological adaptations of aquatic plants in the specific environmental conditions of the Chechen Republic. This analysis can be broken down into several key components.

First, the **systematic analysis** involves the classification and identification of plant species present in the water bodies, such as rivers, lakes, ponds, and wetlands, as well as in adjacent shoreline areas. This process includes determining the species composition of aquatic plants, grouping them into families, genera, and species based on traditional morphological and molecular data, and analyzing their geographical distribution. It also involves comparing the local flora with that of other regions to understand regional uniqueness and shared characteristics. For example, a taxonomic breakdown may include species like Potamogeton natans (floating-leaved pondweed) from the family Potamogetonaceae, part of the class Monocotyledonae.

Second, the biomorphological analysis focuses on the morphological characteristics and life forms of aquatic plants, as well as their adaptations to the aquatic environment. This includes studying the anatomical and morphological features of the plants, such as leaf shapes, stem structures, root systems, and reproductive organs. Moreover, plants are classified according to their life forms and survival strategies in aquatic habitats, such as hydrophytes (fully submerged plants) and hygrophytes (plants growing in wet soils). These adaptations include specialized structures like aerenchyma (air-filled spaces in tissues for gas exchange), hydrophilic leaf structures optimized for water absorption, and reproductive strategies such as floating seeds or vegetative propagation. Examples include fully submerged species like *Elodea* and amphibious plants like reeds and rushes that thrive in wetland areas.

In addition to biomorphological characteristics, this analysis also examines ecological factors influencing plant growth and distribution, such as hydrological conditions (water levels, flow rates) and the impact of anthropogenic activities like agriculture, pollution, and water regulation.

Understanding these factors helps in assessing the overall health of aquatic ecosystems and the adaptability of plant species to changing environmental conditions.

The significance of this research lies in its contribution to the conservation of biodiversity. By identifying rare or endemic species and evaluating the threats to their survival, such studies play a crucial role in the development of conservation strategies. Additionally, the findings from this analysis support better management and restoration of aquatic ecosystems, particularly in the face of climate change and human impact. This type of systematic and biomorphological analysis is essential for understanding the structure, function, and preservation of aquatic plant communities in the Chechen Republic's water bodies.

Among the aquatic plants of the study area, the most numerous in terms of species content are the family *Cyperaceae* Juss . – Sedge (21 view). Family *Poaceae* Barnhart – Poaceae (7 species), *Polygonaceae* Juss . – Buckwheat and *Juncaceae* Juss . – Rush (5 species), 4 species belong to the *Laimiaceae family* Until . – Lamiaceae, the families Ranunculaceae, Asteraceae and Podestaceae have 3 species each, 7 families have 2 species, 13 families contain only 1 species each.

According to the classification of K. Raunkier, among 78 species there are 3 biomorphs. There are 34 species of hemicryptophytes, 30 species of cryptophytes, and 14 species of therophytes.

According to the occurrence analysis, 32 species are scattered, 28 are commonly found, 17 are rare, and 1 species is very rare.

The results of this study show that aquatic plants of the republic contribute to the richness of plant diversity, indicating the need for conservation and protection of the study area.

References

[1] Bobrov E. G., Borisova A. G., Vasiliev V. N., et al. Flora of the USSR volume 14. M-L: Publishing House of the USSR Academy of Sciences, 1949. - 317-349 p.

[2] Borisova A. G., Vasilchenko AND. T., Flora of the USSR volume 22. M-L: Publishing House of the USSR Academy of Sciences, 1953. - 18-98 p.

[3] Galushko A.I. Analysis of the flora of the western part of the Central Caucasus // Flora of the North Caucasus and questions of its history, issue 1. Stavropol, 1976. - 5-130 p.

[4] Galushko A. I. Flora of the North Caucasus (key). 1-3 volumes. Rostov, 1978-1980: 1978 – V.1. – 317 p.; 1980. – V.2. – 350 p.; 1980. – V.3. – 327 p.

[5] Gvozdetsky N.A. Physical Geography of the Caucasus. Moscow: Moscow State University Publishing House, 1954. -208 p.

[6] Gubanov I. A. Illustrated guide to plants of central Russia. Moscow: Institute of Technological Research. 2004. - 51, 165-170 p.

[7] Umarov M.U., Taisumov M.A.. Abstract of the flora of the Chechen Republic. Grozny. 2011

INNOVATIVE TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE IN REPRODUCTIVE MEDICINE

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Abstract

Innovative technologies in reproductive medicine are radically changing approaches to the treatment of infertility, genetic diseases and reproductive health problems. Modern methods such as assisted reproductive technologies (ART), including in vitro fertilization (IVF) and embryo cryopreservation, have significantly increased the chances of successful conception. Key achievements have also included preimplantation genetic testing (PGT), which allows identifying genetic abnormalities in embryos before they are transferred to the uterus, and genome editing technologies (such as CRISPR), which offer the prospect of correcting genetic defects at an early stage of development. In addition, stem cell research is actively developing, which in the future may make it possible to create artificial gametes, which will be a solution for people who lack functional germ cells. Another significant breakthrough is uterine transplantation, which gives a chance to bear a child to women who do not have their own functional uterus. These advances not only increase the success of reproductive procedures, but also open up new horizons in the field of personalized medicine and raise important ethical questions related to reproductive technologies. Innovative developments in reproductive medicine are aimed at improving the quality of life of people and expanding opportunities to overcome barriers to parenthood, making them an important component of modern healthcare.

Keywords: innovative technologies, reproductive medicine, ART, IVF, cryopreservation, preimplantation genetic testing

I. Introduction

Innovative technologies in reproductive medicine are revolutionizing the way we approach fertility, genetic disorders, and overall reproductive health. Over the past few decades, significant advancements have emerged, offering new hope to individuals and couples struggling with infertility and hereditary diseases. These developments are particularly evident in the realm of assisted reproductive technologies (ART), such as in vitro fertilization (IVF), which has dramatically improved success rates for conception. The ability to freeze embryos and eggs through cryopreservation has further expanded reproductive options, allowing patients to preserve their fertility for future use.

In parallel, preimplantation genetic testing (PGT) now enables the screening of embryos for genetic abnormalities before implantation, reducing the risk of passing on hereditary diseases and improving the overall chances of a healthy pregnancy. Additionally, cutting-edge gene-editing technologies like CRISPR are opening new doors by offering the potential to correct genetic defects at the embryonic stage, presenting possibilities for eliminating certain inherited disorders altogether.

Research into stem cell therapy and the potential to develop artificial gametes (sperm and eggs) is another exciting frontier, especially for individuals who cannot produce viable reproductive cells. This could provide a breakthrough for those previously considered untreatable by conventional methods. Furthermore, the development of uterine transplantation offers women who lack a functional uterus the opportunity to carry a pregnancy to term, which was previously impossible.

These innovative technologies are not only enhancing the clinical success of fertility treatments but are also driving a deeper understanding of human reproduction at the molecular and genetic levels. This progress is facilitating the rise of personalized reproductive medicine, where treatments can be tailored to an individual's specific genetic and biological profile.

As the field of reproductive medicine evolves, it brings with it significant ethical, legal, and social implications. Questions around the use of genetic editing, embryo selection, and reproductive autonomy raise complex debates about the future of human reproduction. At the same time, the promise of these technologies offers the potential to overcome previously insurmountable barriers to parenthood, fundamentally transforming the landscape of reproductive health.

In light of these rapid advancements, reproductive medicine is entering a new era, where science and technology intersect to provide more effective, individualized solutions for a growing number of people around the world.

II. Methods

The study and application of innovative technologies in reproductive medicine involve a multidisciplinary approach, incorporating advanced scientific techniques, medical procedures, and cutting-edge research. Key methods used in the field include:

-In Vitro Fertilization (IVF):

This method involves retrieving eggs from the ovaries and fertilizing them with sperm in a laboratory setting. After successful fertilization, the embryos are cultured and then transferred to the uterus for implantation. IVF is one of the most common assisted reproductive technologies used to treat a variety of infertility issues.

-Preimplantation Genetic Testing (PGT):

PGT is a technique used to screen embryos for genetic abnormalities before implantation during IVF cycles. There are different forms of PGT, such as PGT-A for detecting aneuploidy (chromosomal abnormalities) and PGT-M for identifying specific monogenic genetic disorders. This method increases the chances of a healthy pregnancy by selecting genetically viable embryos.

-Uterine Transplantation:

Uterine transplantation involves transplanting a healthy uterus into a woman who does not have a functional uterus, often due to congenital conditions or previous surgery. After the transplant, IVF is typically used to implant embryos into the uterus, allowing the woman to carry and deliver a child. This method is particularly groundbreaking for individuals who otherwise could not achieve pregnancy.

III. Results

Artificial intelligence (AI) is gradually being incorporated into various fields of medicine, including reproductive medicine. In this domain, AI can enhance the selection and prediction of sperm cells, eggs (oocytes), and embryos, as well as improve predictive models for in vitro fertilization (IVF). The use of AI in reproductive medicine is driven by the emotional and psychological toll experienced by individuals or couples who are unable to conceive. However, the application of AI in this field remains in the early experimental stages, raising complex ethical and normative issues. Ethical concerns arise due to the lack of robust evidence supporting the effectiveness of certain AI systems, as well as challenges in obtaining fully informed consent from affected individuals.

Additional ethical considerations include the potential risks to future offspring and the difficulty of ensuring that patients receive adequate information about the AI-driven processes. The ability to fulfill the desire for children has a significant impact on patient well-being and reproductive autonomy. More accurate predictions and the possibility of freeing up physicians to spend more time with their patients are positive outcomes. However, it is essential that clinicians handle patient data responsibly. Since multiple actors are involved in diagnosis and treatment decisions when AI is used, accountability becomes a concern, particularly in the case of errors.

Fairness issues also emerge regarding resource distribution and reimbursement for AI-based treatments. Therefore, before integrating AI into clinical practice, it is critical to thoroughly evaluate the quality and scope of the data being used and address transparency concerns. In the medium and long term, it is necessary to consider the potential negative impacts and societal changes that may arise from the widespread use of AI in reproductive medicine.

IV. Discussion

Artificial intelligence (AI) is advancing rapidly, with applications being integrated across various sectors, including several fields of medicine. Complex AI algorithms are capable of analyzing vast amounts of data to enhance diagnoses, prognoses, and preventive measures. In recent years, the analysis of image data has emerged as a promising application area, with some studies suggesting that AI-generated results may surpass those of human experts. Additionally, AI is expected to streamline workflow processes in hospitals and improve patient monitoring.

In reproductive medicine, new applications of AI methods are being explored. Individuals or couples desiring children but facing infertility often experience significant life crises and a diminished quality of life. The inability to conceive can be seen as a barrier to fulfilling the widely accepted need for reproduction and child-rearing, leading to psycho-existential concerns as it threatens individuals’ visions for their future. The birth of Louise Brown over 40 years ago marked a pivotal moment, ushering in a new era of hope for infertile individuals and couples by making in vitro fertilization (IVF) a viable option. Estimates suggest that infertility affects up to 186 million people globally.

The ongoing advancement of reproductive technologies—such as oocyte and embryo cryopreservation, IVF, preimplantation genetic diagnostics (PGD), and the ability to select preimplantation embryos based on morphokinetic criteria—has significantly improved clinical pregnancy rates over the past four decades.

However, several challenges remain. In Germany, the average likelihood of achieving a live birth after a fresh embryo transfer through IVF or intracytoplasmic sperm injection (ICSI) is approximately 24%, while the probability for previously cryopreserved embryos is about 20%. Essentially, despite successful fertilization and cell division, only one in four fresh embryo transfers and one in five cryo-transfers will result in a live birth. The age of the woman’s oocytes and the quality of the embryos are critical factors influencing the success of IVF treatments. Unfortunately, reliable methods for accurately assessing the quality of oocytes, sperm, and embryos are still lacking. Although preimplantation diagnostics can be employed before embryo transfer, this approach is ethically contentious. In Germany, it is only permitted under specific conditions, is technically complex, costly, and carries risks of injury or destruction to the embryo.

The impetus for developing AI technologies in reproductive medicine lies in the goal of enhancing treatment outcomes and prognoses for infertile patients by synthesizing large datasets to derive meaningful insights. This context shapes our ethical discussion, which considers both the needs of individuals with unfulfilled parental desires and the application of specific AI technologies to achieve medical objectives. The principles of healing, helping, and alleviating—

aligned with the overarching principle of beneficence—provide the ethical framework for this dialogue. Practices such as extracorporeal fertilization and selective reproduction (e.g., following PGD) remain contentious, and research alongside the potential implementation of AI in clinical settings introduces complex normative questions regarding both content and procedures. Therefore, a proactive ethical debate is essential, even as AI research and its application in reproductive medicine are still in their infancy.

In light of this, we will begin with a brief overview of the current state of research and development in this field, followed by a structured ethical analysis of the potential uses of AI methods in reproductive medicine. We will then explore the impact of these technologies on the physician-patient relationship. Finally, we will consider possible future developments in AI-driven reproductive medicine and briefly address the associated social challenges.

In recent decades, advancements in reproductive medicine, such as preimplantation genetic diagnosis (PGD) and intracytoplasmic sperm injection (ICSI), have frequently transitioned from laboratory settings to clinical applications without undergoing thorough evaluations of their effectiveness and safety. Research involving human subjects in reproductive medicine is particularly sensitive from an ethical standpoint and presents unique challenges. Initially, the intended mother is the primary subject affected by the study, shouldering most of the physical and psychological burdens. However, the research and expected innovations in assisted reproduction, including AI applications, can result in the birth of offspring who are also impacted by the potential risks of these experiments, even though they cannot consent to participate. Additionally, the long-term effects on these offspring, resulting from experimental procedures in assisted reproduction, may not be fully understood for years. This situation is complicated by ethical questions surrounding the testing of new procedures involving human embryos.

In all future research concerning the use of AI in reproductive medicine, it will be crucial to provide well-considered information to intended mothers or parents. It's essential to recognize the unfavorable scenarios that can arise when conveying information to potential parents; participants in studies might develop false hopes or unrealistic expectations, especially when innovative, attention-grabbing technologies are being tested. This is particularly relevant for women or couples who have endured long-standing difficulties with childlessness, as they represent a vulnerable group. Individuals participating in such studies may feel they are facing their "last chance" to realize their parental aspirations, necessitating special precautions to ensure that participation is truly voluntary.

Patients' Well-Being and Autonomy

One of the primary objectives of incorporating AI systems into predictive models for IVF is to enhance outcomes compared to traditional reproductive medicine techniques. A key indicator of such improvements would be an increased baby-take-home rate, which reflects a higher likelihood that assisted fertilization will result in a live birth. This enhancement could alleviate both the psychological and physical suffering of patients. The normative principle of prioritizing patient welfare in assisted reproductive medicine involves delivering the most suitable treatment based on objectively measurable medical criteria and considering the patient's subjective experience, preferences, and satisfaction with the treatment. The future integration of AI technology could potentially benefit both aspects.

An analysis of 122,560 treatment cycles in Germany revealed that 45,699 patients discontinued therapy after having a child, while 76,861 (62.7%) stopped before achieving their desire to conceive. Various factors contributed to therapy discontinuation, such as a lack of transferable embryos due to immature oocytes, unsuccessful oocyte retrieval, failed fertilization attempts, and halted embryo development. These challenges can dissuade patients from continuing treatment. Other reasons for discontinuation included inadequate response to stimulation, overstimulation syndrome, premature ovulation, and incorrect hormone administration, which could lead to unsuccessful treatment outcomes. The emotional toll of not conceiving despite multiple reproductive medical interventions is believed to contribute significantly to therapy discontinuation. Studies have also highlighted relationship difficulties and other personal issues alongside the physical and psychological burdens of infertility treatment. Furthermore, societal stigmas related to infertility—such as shame and social exclusion—often exacerbate patients' experiences.

Enhanced and expedited treatment options, potentially offered through future AI applications, could help some couples mitigate these stresses, thereby contributing positively to their overall well-being.

Reproductive Autonomy

The use of AI in reproductive medicine can also be evaluated in terms of patients' reproductive autonomy. Reproductive autonomy is a normative concept defined as individuals' capacity to make informed, uncoerced decisions about their own reproductive choices. From this perspective, measures that empower patients to exercise their reproductive freedom, such as AI applications in reproductive medicine, should ideally be accessible to all individuals seeking to conceive. Conversely, restrictions on reproductive autonomy should only be permissible if new technologies in reproductive medicine demonstrably harm patients or their potential offspring. This autonomy can be viewed as an entitlement, as the ability to exercise control over reproduction is fundamental to personal identity. Therefore, efforts should be made to assist couples in achieving their parenting aspirations, which includes ensuring equitable access to emerging reproductive technologies, including AI applications. However, it is vital to avoid the risks associated with inadequate information, as highlighted earlier, to allow patients to fully exercise their reproductive autonomy in this experimental field.

Benefits and Challenges for the Physician–Patient Relationship

The potential integration of AI into reproductive medicine will undoubtedly influence a cornerstone of medical practice: the physician-patient relationship. AI may necessitate a re-evaluation of the reproductive specialist's professional role, as they will serve as the intermediary between algorithmic outputs and treatment decisions. Physicians will need to address not only the biological factors contributing to infertility but also the psychosocial and emotional stresses patients face during treatment. The future utilization of AI could provide significant benefits, enabling better predictions of individual patients' likelihood of becoming pregnant. Existing data can inform these probability assessments, such as using the woman's age. A more precise prognosis could empower physicians to deliver better-informed recommendations and therapies, ultimately enhancing treatment efficiency by optimizing the selection of sperm, oocytes, and embryos. Even minimal contributions from potential AI applications could provide valuable support amid the stresses associated with infertility treatment. Additionally, it is anticipated that automated support systems in medicine will free up physicians to devote more time to building stronger relationships with their patients.

References

[1] Gakaev, R. Assessing Carbon Dynamics in Diverse Ecosystems: The Role of Carbon Polygons / R. Gakaev , L. Gatsaeva // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03013. – DOI 10.1051/e3sconf/202453703013. – EDN OOIDOS.p.

[2] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[3] Kornienko T.V. Questions of linguistic kinship, 2013. No. 9. P. 155-162.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian

connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A.S., Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

[11] Gunya, A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

USING INNOVATIVE GAMES TO BUILD KNOWLEDGE BASES IN SPATIAL RISK ANALYSIS

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Abstract

The article presents an approach to assessing risk management to ensure sustainable development of territories and businesses using artificial intelligence and gaming technologies for continuing professional education. Features of risk assessment related to ensuring effective development of territories and businesses are shown, in conditions of impossibility to apply statistical methods to determine the probability of occurrence of dangerous events and low degree of formalization of description of severity of their consequences.

The choice of a two-factor risk management model based on an expert approach to determining the likelihood of hazardous events and the severity of their consequences is justified. The problems of gaining expert knowledge are formulated and a method for solving them using innovative open-type games that have proven themselves in continuing professional education of managers in the process of solving complex semi-structured problems is proposed.

An approach to structuring expert knowledge in artificial intelligence systems is proposed. The structure of the project for the formation of knowledge bases for the analysis of spatial development risks has been formed.

Keywords: risk analysis, development of territories and business, innovative games, gaining expert knowledge, continuing professional education, artificial intelligence systems

I. Introduction

The most important component of the climate agenda in recent years is the management of climate risks with a shift in focus from mitigation to adaptation to climate change in the constituent entities of the Russian Federation and production systems.

These issues were discussed at the strategic session “Climate risks” at the beginning of 2024. Regional Context” in early 2024, where the ESG Alliance and Kept presented the methodology and guidelines for assessing risks associated with climate change. The innovation of the proposed methodology is that it is based on the PDCA management cycle, on which all international management standards are based, and a process approach is used to assess risks, allowing to identify the impact of climate change on each production process and the entire production system as a whole. The transition from risk identification and assessment to risk management, including strategic goal-setting, planning and continuous monitoring of the effectiveness of response measures within the framework of the chosen strategy, followed by work to improve activities at all system levels, is a key point in the methodological transition from plans for the social and economic development of the territory to their practical implementation at the business level (Figure 1).

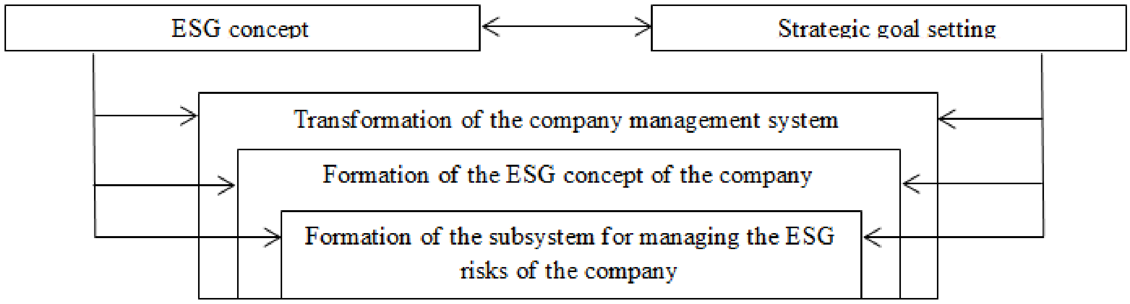

Figure 1: *Formation of the company's risk management subsystem within the framework of the sustainable development concept*

Risk management based on ESG principles with a focus on taking into account environmental, social and governance aspects in the activities of companies and assessing their sustainability and impact on the environment, society and internal governance structure [1] is part of the approach to sustainable development and the basis for the practical implementation of the climate risk management methodology. The ESG principles built into the company's management system, focusing on specific aspects of activities and investments, link the corporate strategy with the strategy of social and economic development of the territory.

According to the assessment of the professional community, the strategies for the social and economic development of the constituent entities of the Russian Federation and the action plans for their implementation, which should ensure "reducing the vulnerability of the country's national security system, economic entities and citizens due to changes in the global climate, the climate on the territory of the Russian Federation, the territories of neighboring states, in the adjacent waters of the World Ocean, as well as the use of favorable opportunities caused by these changes" [2], by the beginning of 2024 determined the system of operational and long-term measures to adapt territories to climate risks to no more than a "weak C" [3].

By order No. 397 dd. June 28, 2024, the Ministry of Economic Development of Russia adjusted the Methodological Recommendations for the Development and Adjustment of the Strategy for the Social and economic Development of a Subject of the Russian Federation and the Action Plan for its Implementation, previously approved by order No. 132 dd. March 23, 2017, supplementing them with an emphasis on adaptation. The adjustments also affected the orders of the Ministry of Economic Development of Russia No. 267 dd. May 13, 2021 "On approval of methodological recommendations and indicators on adaptation to climate change" and No. 927 dd. December 28, 2023 "On approval of Methodological recommendations for assessing possible damage from the impact of climate risks, including recommendations for the formation of a list of climate-vulnerable objects in economic sectors, in the constituent entities of the Russian Federation and Methodological recommendations for monitoring and assessing the effectiveness and efficiency of measures to adapt to climate change."

However, despite the ESG Alliance's in-depth study of enterprise risk management issues related to climate change and the regulator's active position regarding the systemic consideration of climate and economic risks in the territories, the issue of developing tools for the practical application and replication of the proposed methods is acute.

II. Methods

The development of strategies for the social and economic development of the constituent entities of the Russian Federation and action plans for their implementation should be based on an analysis of data across all major climatic parameters and threats.

The Methodological Recommendations for the Development and Adjustment of the Strategy for the Socioeconomic Development of a Subject of the Russian Federation and the Action Plan for its Implementation propose using the results of scientific research, including publications from the Climate Center and official reports from Roshydromet, to forecast the dynamics of climate risks. It is assumed that "within the framework of the target scenario of long-term development, the main macroeconomic parameters of the development of a constituent entity of the Russian Federation, indicators of its social, sectoral and territorial (spatial) development for the long term can be determined, priority areas can be identified, including the development of human capital and social sphere, key sectoral complexes and types of infrastructure, scientific and innovative sphere and institutional environment, rational use of natural resources and ensuring environmental safety, adaptation to climate change, foreign economic and interregional cooperation, as well as territorial (spatial) development of a constituent entity of the Russian Federation" [4].

The assemblies of global climate models recommended by the regulator for calculating indicators of future climate change in the territory of the subjects of the Russian Federation and the family of scenarios of anthropogenic impact, the evolution of society and ecosystems, taking into account the goals and objectives of the long-term development of the subject, the internal conditions of its development, cause difficulties in practical use and require the involvement of specialists with competencies and experience in the field of climate modeling.

The regional strategies and company reports we studied generally do not use forecasting, but rely only on historical information contained in Roshydromet databases.

Since the use of statistical methods in the analysis of the effective development of territories and businesses is limited by the lack of representative samples, expert knowledge is also required to determine climate risks, firstly, when forming scales for assessing the probability of threats and the severity of their consequences, and secondly, when establishing the levels of the risk ranking matrix.

Building expert knowledge bases is hampered by the narrow specialization of experts and the high degree of individualization of their knowledge. Technically, the system integration of existing disparate knowledge is possible on specially created platforms. However, the problem of gaining expert knowledge has not yet been solved unless it is reflected in printed texts or electronic databases. There are two main difficulties in gaining expertise from specialists in relevant fields

- the reluctance to give unique knowledge to public databases due to the risk of reducing personal demand;
- the inability of an expert in some cases to build sound relationships between elements due to the "compiled" nature of the knowledge.

And if the first difficulty can be removed by motivational mechanisms, in the second case the problem is directly dependent on the complexity and uniqueness of knowledge about the vulnerabilities, risks and opportunities for spatial development (territory and related business) in the future. To solve the problem of building an expert knowledge base, innovative games (IG) can be used, which have proven themselves well in continuing professional education of managers in the process of solving complex, weakly structured problems.

The practice of using innovative games (innovative seminars) in continuing professional education (CPE) of managers and specialists allowed formulating the concept of innovative-project training of personnel (IPT), based on the following principles.

1. *Learning through activity:* the effectiveness of the learning process is significantly higher if its participants are engaged in solving their own problems during the learning process, and knowledge is given for a specific problem (the principle of "action-knowledge-action").
2. *Project-based organization of training:* training is a component of a real project and is aimed at supporting the process of its implementation; the result of training, along with new competencies, is the completion of a project task by a group (subgroups) (the "here and now" principle).

3. *The principle of representation sampling:* in practice, to implement a specific project, a team is formed in such a way that the solution to the problem is provided by a combination of all the necessary competencies. Accordingly, in the case of project-based organization of training, both for diagnostic tasks (analytical sessions) and for project work (project-innovation sessions), the group of seminar participants should be sufficient to collectively represent a "living" functional model of the type of activity that the project is aimed at.
4. *Immersion principle:* the training consists of a set of completed modules lasting from 1 to 3 days, during which group members are completely separated from their current work and immersed in the process of solving a specific problem within the project.
5. *Multitasking of training:* along with substantive issues, the training process addresses the issues of building effective interaction between team members (regardless of their status, age and experience), the issues of personal self-determination in relation to new ideas and solutions, and the development of new individual management tools.

Unlike business, role-playing, and simulation games, IG does not imply a known, pre-determined substantive result. This is a technology for organizing the process of solving complex semi-structured problems based on group dynamics. Here, teachers act primarily as consultants on the effective organization of collective work on the tasks set to the group, and only secondarily as the holders of substantive knowledge, which is given in very measured doses when a corresponding request arises [5].

The multitasking of the IN involves work in three planes, for each its own type of result is formed (Fig. 2):

- a meaningful solution to the task set, which can be a formed structure of knowledge about risks in a certain area, the main provisions of the development strategy of the region or company in the conditions of identified climatic risks, a process model of the activities for the implementation of the strategy, taking into account risks of appropriate levels, and more, depending on the projects being worked out;
- solving the problems of team interaction through building effective communications based on a process approach, regulations, and protocols;
- solving problems of personal ability by developing new personal tools and methods of working with a particular problem based on personal self-determination in relation to it and to the team of partners involved in this work.

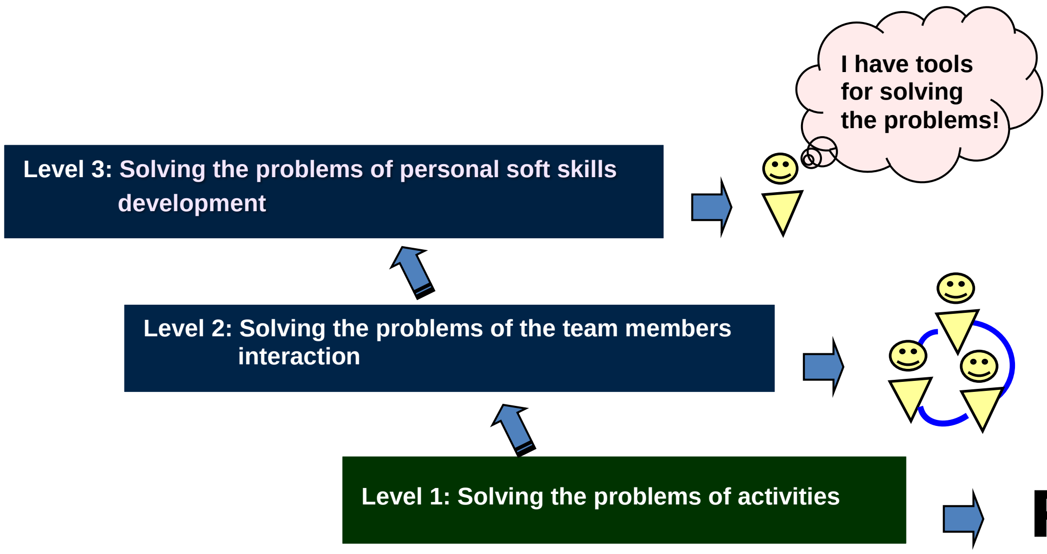

Figure 2: *Three types of outcomes of the Innovative Workshop*

Each plane uses its own methods and tools. Logical and technical tools in the substantive area, social and technical tools in the communicative area, and psychotechnical tools in the personal area.

A participant in the educational process gains an increase in knowledge on a given issue not only through communication with teachers, but also through intensive exchange of information in working groups. And unlike traditional forms of training, two additional results appear here (which are most valuable for working with experts) - these are the skills of organizational social and psychological management of a team of specialists with specialized knowledge, building effective communications with them, as well as new personal tools and methods for diagnosing unstructured problem areas.

III. Results

The organization of the process of gaining expert knowledge in the course of continuing professional education of the holders of this knowledge, built on the basis of the IPT concept, includes the following main stages.

1. *Selecting a topic* for improving the qualifications of holders of expert knowledge that would not only interest them, but would also involve their active involvement in diagnosing the problem and developing ideas for solutions in relation to the development of the chosen area. For example, having chosen the topic of developing a regional development strategy for IG, experts, working as part of a group of stakeholders, will participate in the analysis of the impact of the external environment on the sustainability of the regional economy, discuss the risks of adapting business and the region to climate change, generate scenario forecasts of the impact of risks on the sustainability of regional development and enterprise strategies, etc.
2. *Formation of the session structure of the IG* based on the decomposition of the topic into a sequence of tasks and planned results, group work on which will create conditions for the gaining of expert knowledge for the formation of databases in the relevant areas.
3. *Determination of the participants* based on the principle of representation sampling. Along with experts, the group shall include the representatives of government bodies responsible for this area, business leaders, systems analysts and other interested categories. In this work, systems analysts or knowledge engineers have a special function, which is to systematize all the information discussed based on the structure of the knowledge base.
4. *Process planning:* selection of methods and tools and development of the temporary structure of the seminar (timing).
5. *Preparing a team of moderators and systems analysts:* defining their functions in the work of the seminar, analyzing the expected results and discussing the necessary and sufficient conditions for obtaining them. Selection of necessary materials. Elaboration of technical requirements for extractable knowledge.

The IG organizational structure includes:

- presentation by the moderator setting a common task, a brief introduction to the content of each session and setting the tasks of individual sessions,
- information insertion of the leader and experts on emerging requests,
- subgroup work on the objectives for each session
- common discussions on the results of the work of the groups at each session with an expert analysis of the content,
- systematization of the results of discussions for each session by leaders and experts,
- reflective work of the seminar participants.

It is very important for the success of the work to correctly decompose the general topic into local tasks for discussion, to form the composition of focus groups according to the principle of equivalence and to ensure group dynamics both when working in focus groups and during the discussion. The total scope of work between focus groups is distributed in such a way that the results are combined in a complementary manner. For example, groups can conduct an analysis of threats and their consequences by types of climate adaptation at the regional level or by industry specifics, expertly determining the likelihood of their occurrence and the severity of possible consequences. And it is preferable to coordinate scales for assessing the probability and severity of consequences during a general discussion - this will allow identifying a larger number of expert opinions and thereby increasing the reliability of the assessments.

The part of the work that is more effectively carried out on an individual basis, such as a financial assessment of the severity of consequences or justification of the cost of risk management strategy activities, is best transferred to the stage of individual revision of projects with reference to specific conditions.

The principle of forming focus groups at the stage of project work is based on the commonality of substantive tasks. Group dynamics are achieved through the correlation of common parts of the content and the building of connections between individual tasks during discussion.

Integrated use of IG together with information modules and consulting within the continuing professional education programs of managers and specialists, being steps of a real consulting and educational project, at the output of which developed forecasts, strategies, designed risk management systems or any strategic changes in the organization/entity formed the basis of innovation and project technology. The need to structure climate risks in conditions of high uncertainty, to develop costly measures to respond to them, including regulatory ones, and sometimes to revise the development strategy of a territory or organizations located there increases the responsibility for adequately adjusting the innovative project technology to solve the problems of gaining expert knowledge.

IV. Discussion

Strategic management of territorial development risks is inextricably linked with the business strategies of companies operating on the territory, which shall also identify and assess their risks, build strategies for responding to them and analyze the effectiveness of specific reactions with the subsequent improvement of the entire management cycle. The key point in the risk management system is a clear delineation of responsibilities in the risk management system, the development of a risk culture in the company and communicating to employees the importance of risk management in the organization. The considered innovative project technology in general and specific IG in particular in climate risk management can serve not only as a tool for gaining expert knowledge, but also facilitate the creation of risk coordinators within the community with the involvement of external experts in the field of risk management.

Climate risk management tasks are increasingly being considered as a subject of artificial intelligence systems, where rules and ontologies are powerful tools for structuring expert knowledge. The choice between them depends on the specific task and the available data and constraints. Structuring expert knowledge in artificial intelligence systems is a challenging task that requires a balance between accuracy, interpretability, and efficiency. The application of the proposed process for gaining expert knowledge contributes to the development of hybrid approaches to the design of artificial intelligence systems that combine the advantages of structured and unstructured methods.

References

[1] Trifonov Yu., Brykalov, Trifonov V. Risk management within the framework of the concept of sustainable development S. // Problems of risk analysis. 2022. T. 19. No. 5. P. 10-18.

[2] Methodological recommendations for the formation of industry, regional and corporate plans for adaptation to climate change, approved by order of the Ministry of Economic Development of Russia dd. May 13, 2021 No. 267.

[3] https://disk.yandex.ru/i/lrv5zQv3Uau_CQ (accessed on August 31, 2024).

[4] Order of the Ministry of Economic Development of Russia dd. June 28, 2024 No. 397 "On Amendments to the Methodological Recommendations for the Development and Adjustment of the Strategy for the Social and Economic Development of a Subject of the Russian Federation and the Action Plan for its Implementation, approved by Order of the Ministry of Economic Development of Russia dated March 23, 2017 No. 132".

[5] Dudchenko V. Innovative games: practice, methodology and theory. – Tallinn: Valgus, 1989- 103 p.

THE IMPACT OF DIGITAL TECHNOLOGIES ON SUSTAINABLE CONSUMPTION AND PRODUCTION

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Abstract

Innovative educational technologies have emerged as essential drivers in the development of human capital, significantly enhancing the educational landscape by equipping individuals with the necessary skills and knowledge to thrive in today's rapidly changing economic environment. These technologies encompass a wide array of tools, such as e-learning platforms, artificial intelligence (AI)-based learning systems, virtual and augmented reality applications, and personalized educational approaches. By integrating digital methods into traditional educational frameworks, these innovations foster a more interactive, engaging, and effective learning experience. The implementation of innovative educational technologies not only enhances access to quality education but also promotes lifelong learning, critical thinking, and problem-solving abilities, which are vital in today's workforce. For instance, e-learning platforms offer flexibility and accessibility, allowing learners to acquire skills at their own pace, while AI-driven personalized learning systems adapt to individual learning styles and needs, enhancing overall educational outcomes. Moreover, the incorporation of collaborative tools and gamification strategies within these technologies encourages teamwork and creativity, further preparing individuals to navigate the complexities of the modern labor market. This is especially important in fostering an entrepreneurial mindset and innovative thinking, which are crucial for driving economic growth and sustainability. As educational institutions increasingly adopt these innovative technologies, they play a pivotal role in transforming educational curricula, aligning them with industry demands, and preparing students for future challenges. Consequently, the development of human capital through innovative educational technologies is not merely an enhancement of educational practices but a foundational element for achieving sustainable economic growth and ensuring competitiveness in a globalized economy.

Keywords: innovative educational technologies, human capital development, e-learning, artificial intelligence, personalized education, digital tools, workforce skills, sustainable growth

I. Introduction

In an era marked by rapid technological advancements and globalization, the importance of developing human capital has become increasingly evident. Human capital refers to the skills, knowledge, and competencies possessed by individuals that enhance their productivity and ability to contribute to the economy. As industries evolve and labor markets become more competitive, equipping individuals with the necessary tools for success is essential. Innovative educational technologies have emerged as pivotal instruments in this endeavor, transforming traditional educational paradigms and providing new avenues for learning and skill acquisition.

Innovative educational technologies encompass a broad spectrum of digital tools and platforms, including e-learning systems, online resources, virtual reality (VR), artificial intelligence (AI), and gamification techniques. These technologies not only enhance the delivery of educational content but also facilitate personalized learning experiences that cater to the diverse needs of learners. By integrating these innovative approaches into educational curricula, institutions can significantly improve the quality of education, making it more relevant and aligned with the demands of the modern workforce.

The shift towards innovative educational technologies is driven by several factors. First, the growing need for a skilled workforce capable of adapting to the fast-paced changes in various industries necessitates an educational framework that fosters critical thinking, creativity, and problem-solving skills. Second, the rise of online and blended learning environments allows for greater accessibility, enabling individuals from diverse backgrounds to engage in lifelong learning and professional development. Finally, the integration of technology into education aligns with the principles of personalized learning, empowering students to take control of their educational journeys.

This introduction sets the stage for an in-depth exploration of how innovative educational technologies can foster human capital development. By examining their applications, benefits, and potential challenges, we aim to provide a comprehensive understanding of the transformative role these technologies play in shaping a skilled and adaptable workforce. Ultimately, harnessing the power of innovative educational technologies is not just about enhancing educational outcomes; it is about creating a sustainable future where individuals are equipped to thrive in an ever-changing global economy. For several decades, economic growth has emerged as a prominent topic of discussion within the field of economics, garnering significant attention from numerous economists. The long-standing disparities in the performance of various territorial units and the living standards of their populations are evident both among countries and within their administrative divisions. To maintain a successful economy, it is essential to continuously enhance and focus on key areas that ensure sustainability and bolster the country's competitive standing.

Although the magnitude of these disparities fluctuates and, according to statistics (OECD, 2020), has been decreasing over time, economists continue to investigate the underlying causes of these inequalities. The rationale is straightforward: regions with lower rates of economic growth tend to have prolonged lag periods, which diminishes their capacity for independent development. This situation places added pressure on state institutions to fulfill social responsibilities, particularly concerning the allocation of public resources that are intended to supplement or even replace the development of internal resources. Consequently, many theorists and practitioners in economics seek to identify the driving forces behind regional growth.

II. Methods

The examination of innovative educational technologies as a means for fostering human capital development involves a multifaceted approach. The research employs both qualitative and quantitative methods to provide a comprehensive analysis of the effectiveness, implementation, and impact of these technologies in educational settings. Below is a detailed outline of the methods used in this study:

1. Literature Review

A thorough review of existing literature on innovative educational technologies and human capital development forms the foundational framework for this study. Key sources include academic journals, industry reports, and case studies that explore the intersection of technology and education. This review aims to identify best practices, theoretical frameworks, and empirical evidence supporting the integration of innovative educational technologies into learning environments.

2. Data Collection

- Surveys and Questionnaires: Surveys will be distributed to educators, students, and educational administrators to gather data on their experiences with innovative educational technologies. The surveys will assess perceptions of effectiveness, accessibility, and the impact on learning outcomes. Key areas of focus include:

- Frequency of technology use in the classroom
- Types of technologies implemented (e.g., e-learning platforms, VR, AI)
- Perceived benefits and challenges of using these technologies
- Impact on student engagement and motivation

- Interviews: Semi-structured interviews will be conducted with a select group of educators and technology integration specialists. These interviews will provide deeper insights into the strategies employed for technology integration, the challenges faced during implementation, and success stories related to human capital development.
- Case Studies: Detailed case studies of educational institutions that have successfully integrated innovative educational technologies will be conducted. These case studies will highlight specific programs, teaching methodologies, and outcomes achieved through the use of technology.

3. Data Analysis

- Quantitative Analysis: Statistical methods will be employed to analyze survey data. This includes descriptive statistics to summarize participant demographics and responses, as well as inferential statistics to identify correlations between the use of educational technologies and improvements in learning outcomes.
- Qualitative Analysis: Thematic analysis will be conducted on interview transcripts and open-ended survey responses. This analysis will identify recurring themes, patterns, and insights related to the experiences and perceptions of educators and students regarding innovative educational technologies.

4. Comparative Analysis

To contextualize the findings, a comparative analysis of institutions that have adopted innovative educational technologies versus those that have not will be conducted. This will involve examining differences in educational outcomes, student satisfaction, and overall effectiveness in fostering human capital development.

5. Evaluation Framework

An evaluation framework will be developed to assess the impact of innovative educational technologies on human capital development. This framework will include key performance indicators (KPIs) such as:

- Improvement in student retention and graduation rates
- Enhancement of critical thinking and problem-solving skills
- Increases in student engagement and participation
- Positive feedback from students regarding the learning experience

6. Synthesis of Findings

The study will synthesize the findings from the literature review, data collection, and analysis to provide a comprehensive understanding of the role of innovative educational technologies in fostering human capital development. The results will be presented in a structured format, including visual representations (charts, graphs) to illustrate key trends and outcomes.

III. Results

Digitalization is significantly lowering the production costs associated with goods and services while also minimizing local and cross-border trade expenses. The Internet of Things (IoT) and e-commerce are central to this transformation, shifting traditional trading systems toward modern business frameworks within the global economy.

Big data, alongside its analysis by humans and artificial intelligence, is further reducing communication costs. Individuals and nations can engage in communication at minimal expenses, enhancing the marketability of products both domestically and internationally. Companies leverage big data analysis to cut production costs and foster the innovation of competitive goods. Such innovations can bolster a country's productivity and pave the way for technological advancements. This technological progress serves as a vital instrument for fostering global cooperation in technology.

The interplay between big data analysis, informed production decision-making, innovation of competitively priced products, increased domestic productivity, and readiness for global technological collaboration can drive sustainable digital transformation worldwide.

The emergence of big data and artificial intelligence is reshaping traditional business models, benefiting both consumers and traders alike. Unlike conventional database management systems, big data encompasses vast amounts of varied information, including numerical data, text, audio, and video. Advanced analytical tools make it easy to process and derive insights from this wealth of information.

Artificial intelligence enhances the analysis of big data and can autonomously make decisions based on the insights gathered. This interaction between computers and AI algorithms allows retailers to gain deeper insights into consumer behavior, while suppliers can better understand retailers' demands. Traders can align their requirements with manufacturers based on customer needs, enabling manufacturers to produce goods that meet market demands effectively. Should consumer preferences shift, businesses can conduct research and innovate new products accordingly. Central to this process is big data, which evolves automatically through transactions, thus lowering the costs associated with data collection and communication across various layers of business. This leads to a significant reduction in transaction costs.

Moreover, the use of cryptocurrencies, digital currencies, digital assets, and intellectual properties is witnessing a dramatic increase in business and trade on a global scale.

IV. Discussion

The United Nations Sustainable Development Goal (SDG) 2030 aims to reduce poverty and inequality while ensuring a safe environment for all. Achieving this goal requires a dual focus: increasing productivity and income to foster individual and national growth, and simultaneously mitigating environmental degradation to promote better health for the global population.

However, there exists a complex relationship between economic growth and environmental health. Increased productivity often necessitates the installation of heavy machinery, leading to a higher consumption of fossil fuels such as oil, coal, and gas to operate these machines and generate electricity. Consequently, while economic growth can enhance real output, it also escalates the consumption of nonrenewable resources, resulting in increased pollution, global warming, and the degradation of environmental habitats.

Importantly, not all forms of economic growth are detrimental to the environment. As individuals and nations experience rising income levels, their capacity to invest in environmental protection increases. This can foster a greater awareness of environmental issues and lead to the development of effective policies aimed at sustainability. Furthermore, advancements in automation and digital technologies can boost productivity while minimizing pollution, enabling higher output with a reduced environmental footprint.

In summary, while economic growth can pose challenges to environmental sustainability, it also presents opportunities for enhancing awareness, developing protective policies, and leveraging technology to achieve a balance between economic development and environmental health.

The International Monetary Fund (IMF) estimates that the global economy contracted by 4.4% in 2020, marking the steepest decline since the Great Depression of the 1930s. To navigate toward a new normal, accelerating economic growth through enhanced productivity is imperative. Increasing productivity is crucial for raising individual and national incomes, thereby restoring growth levels and alleviating poverty and inequality.

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Achieving GDP growth will require a synchronized approach between industrial production and service sectors. However, the looming risk of future pandemics could challenge this drive for over-productivity, potentially compromising public health and environmental sustainability.

Debates surrounding the limits to growth will likely intensify in the post-pandemic era. In this context, environmental economics begins to view the natural environment as a distinct sector, emphasizing the need to address externalities at the international level. In contrast, ecological economics adopts a more interdisciplinary perspective, integrating ecological factors that influence resource regeneration and waste absorption into economic models.

The concept of the Fourth Industrial Revolution aligns well with the principles of ecological economics. This revolution represents an interconnected system of manufacturing and services leveraging automation and digital technologies. By doing so, it has the potential to enhance productivity, minimize waste, and promote the use of environmentally friendly energy sources.

Emphasizing a green economy within the framework of the Fourth Industrial Revolution can create synergies through integrated automation and digital technologies. This approach could lead to a more nuanced relationship between Gross National Product (GNP), Gross Domestic Product (GDP), and environmental sustainability, paving the way for a more balanced and resilient economic future. COVID-19 has underscored the transformative power of disruptive technologies in business and manufacturing, demonstrating their potential to enhance environmental protection and food production. This experience serves as a model for leveraging such technologies across various sectors to foster a more sustainable world. Embracing the Fourth Industrial Revolution (4IR) technologies can significantly reduce waste and pollution in industrial processes.

However, realizing the benefits of this revolution necessitates substantial financial investment and collaboration, particularly from wealthier nations. A restructured international monetary and financial system that includes participation from both low-income and high-income countries is crucial for facilitating this transition.

For low-income and developing nations, changes in real income could lead to prolonged economic downturns. To effectively adapt to the demands of the 4IR, it is essential to focus on human capital development through education, training, and skill enhancement. Although transitioning to new technologies may result in job losses in some areas, it simultaneously creates new opportunities, making it vital to cultivate national skills across government, public, and private sectors.

The global economy is increasingly shifting toward a knowledge-based model, where innovation plays a pivotal role in capital formation. The adoption of disruptive technologies can significantly enhance value, productivity, and income, aiding socio-economic recovery in the post-pandemic landscape and supporting the achievement of the United Nations' Agenda 2030.

This transformation toward a knowledge-based economy is rapidly reshaping global socio-economic structures. However, it is essential to ensure that this shift aligns with sustainable development goals. Investing in education, training, and skills development is critical for improving productivity and sustainability.

Education serves as a fundamental tool for promoting protective behaviors and countering negative health expectations. A knowledge-based economy requires not only innovation but also ethical standards that support sustainable production and enhance competitiveness. Ongoing research in educational institutions is vital for steering nations toward sustainable innovation.

While technology integration in education has opened new pathways for development, low-income and developing countries often struggle to take full advantage due to financial and policy barriers. For example, during the COVID-19 pandemic, developed nations achieved over 80% access to educational facilities, while less than 30% were available in low-income and developing countries.

Training for teachers, trainers, and employees is crucial for enhancing instructional capabilities. The pandemic has accelerated the adoption of automation, digitalization, and robotics across sectors, including government, healthcare, academia, and manufacturing.

Skill development is essential for national advancement across all sectors. The pandemic has highlighted the potential of disruptive technologies in global socio-economic activities. Countries like Bangladesh, classified as middle-income, are making significant strides in adopting these technologies. By rapidly developing national skills to manage and guide this technological transition, such countries can play a crucial role in alleviating the global economic slowdown.

References

[1] Taranova I.V., Kasaeva T.V., Shavrina J.O., Tekeeva H.E., Boeva K.Y. Methods of fraud management in the financial services market of the region// Business 4.0 as a Subject of the Digital Economy. Cham, 2022. C. 291-295.

[2] Kasaeva T.V., Taranova I.V., Valishina G.L., Atabaev A.R., Novoseltseva A.P. Development of the medical healthcare sector in russia based on the experience of socio-economic transformations of foreign countries and regions// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 252-256

[3] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

COMMUNITIES WITH EURPHORBIA MACULATA IN THE NORTH CAUCASUS AND THEIR SYNTAXONIC CLASSIFICATION IN EASTERN EUROPE

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Abstract

The article studies the distribution of the alien species Euphorbia maculata L. in the North Caucasus. The species was first recorded in the region in 2006 and is now widely distributed. This study presents the species relationship to habitats and the floristic composition of plant communities. Communities were compared with similar ones in Europe and a new weed association Euphorbio maculata-Acalyphetum australis ass. nova was analysed. Diagnostic species: Euphorbia maculata, Acalypha australis. Summer-dry trampled vegetation with Euphorbia maculata in crevices of sealed asphalt and tile coating of sandy subsoil (on sandy soils), on gravel ground of tram and railway tracks of the Nortn Caucasus region. The Euphorbia maculata communities are often found in cracks of pavement, laid on sand substrate, asphalt cracks of suburban areas and along highways.

Keywords: biological diversity, digitario sanguinalis-eragrostietea minoris mucina, plant communities, invasion, Euphorbia maculate, Acalypha australis, syntaxonomy, North Caucasus, slit biotype, anthropogenic ecosystems

I. Introduction

Euphorbia maculata is an invasive species that is widely distributed throughout the world. Its natural range covers eastern and southern parts of North America [1], where it is classified as weedy species [2]. Its typical habitat is sand on the seashore, mounds along roads [3]. It has been naturalized in Central and South America, the Middle East, East Asia, New Zealand and Australia. In Europe, *Euphorbia maculata* appeared several centuries ago. In the last two decades, the species has significantly expanded its range [3-6]. In the North Caucasus, the species was first recorded in 2006 [7]. It is found in an environment with sharp temperature fluctuations during the day, different from the general habitat of plants and prefers to grow in open sunny places, digs the tile, crevice and gravel biopaths of railways and highways. *Euphorbia maculata* is a bitter weed of agrocenoses. It inhibits the growth of wheat seeds [8, 9], reduces soybean yields [10], cotton [11], tomatoes (*Lycopersicon esculentum*) and chilli pepper (*Capsicum annuum*) [12].

Climate change promotes the spread of alien species adapted to xerophytization. This is particularly relevant for the Krasnodar Region where a big area is occupied by agrocenoses, which are favorable locations for further invasion of *Euphorbia maculata*. The study of plant communities with *Euphorbia maculata* in the North Caucasus in the context of the European syntaxon of vegetation will help to better understand the patterns of formation of urban flora and develop strategies for management of invasive species. The integration of studied plant communities with *Euphorbia maculata* in the North Caucasus into the European Vegetation Syntaxon will allow a better understanding of the patterns of formation of flora of anthropogenic ecosystems and develop strategies for management of invasive species.

II. Methods

The work is based on 70 relevés, carried out by the author in 2021-2023 in the territory of Krasnodar Region (city of Krasnodar, Novorossiysk, Dzhubga, Big Sochi) of the republic of Abkhazia (city of Pitsunda) (Figure 1).

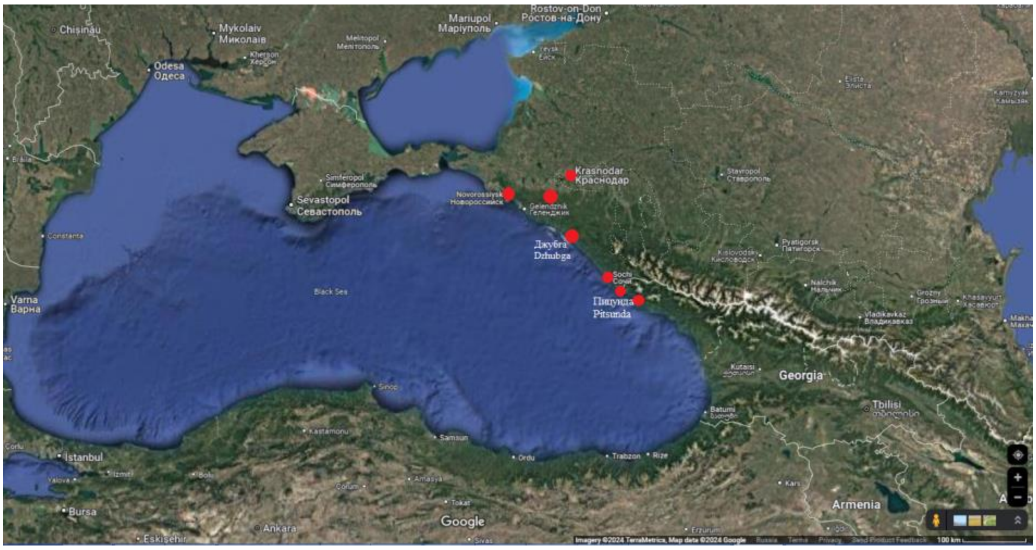

Figure 1: *Distribution of Euphorbia maculate in the North Caucasus*

The cracks between the pavement tiles, which are placed on sand substrate (figure), cracks of railway stations, suburban and residential areas (figure), sidewalks along roads (figure), bridges, city parks were investigated. 23 relevés were selected for the characteristics of the plant species that were studied. The sample area is ranged from 6 to 100 m^2.

In the relevé of the floral composition, the abundance of species was assessed by the Brown-Blank scale: r - single species, mostly only one specimen; + - species are thinned or cover only a small part of the area; 1 - species are numerous but cover up to 5 % or quite thinned, but with a higher coverage; 2 - projective coverage up to 5-25% or individuals are very numerous, but coverage is lower; 3 - projective coverage up to 26-50%; 4 - projective coverage up to 51-75%; 5 - projective coverage more than 75%. The relevés were processed by Brown-Blank [10], using MEGATAB [14] and TWINSPAN [15] software packages. The names of the highest syntaxa are given in «Vegetation of Europe...» [16]. The names of new syntaxa are given in accordance with the rules of the «International Code of Phytocenolological Nomenclature» [17]. Species names are updated according to the summary of S. K. Cherepanova [18].

III. Results

Syntaxa with Euphorbis maculate were first identified in North Korea as ***Polygono-Poetea annuae*** in 1991 [19], which was later reviewed by Vegetation of trampled soil dominated by C 4 plants in Europe – class ***Stellarietea*** [20], in Prodromus of Europe [16] and entered into a new class of anthropogenic vegetation ***Digitario sanguinalis-Eragrostietea minoris*** Mucina, Losová et Šilc in Mucina & al. 2016. Comparison of selected plant phytocoenons of communities with *Euphorbia maculata* with literature data [20] revealed differences in taxa lists (table 1). This made it possible to include them in a new association.

Table 1: *Synoptic table of plant communities dominated by Euphorbia maculate*

Class	Column number	1	2	3	4	5	6	7	8	9
	Number of relevés	26	1	6	14	5	19	12	1	39
DIG	Euphorbia maculata	100	2	11	11	11	21	43	56	11
Class ***Digitario sanguinalis-Eragrostietea*** minoris Mucina, Lososová et Šilc in Mucina & al. 2016										
DIG	*Portulaca oleracea*	78	21	21	21	21	21	31	21	11
DIG	*Digitaria sanguinalis*	74			21	11	11	21	53	42
DIG	*Eleusine indica*	65			11	11	55	11		
DIG	*Setaria viridis*	52			21	31	11	42	31	21
DIG	*Taraxacum officinale*	39			21	11	21	41	54	21
DIG	*Eragrostis minor*	22			21	21	42	53	21	56
DIG	*Setaria pumila*	13								11
DIG	*Sorghum halepense*	9								
DIG	*Tragus racemosus*	9					11	11		11
DIG	*Senecio vernalis*	4			11					11
DIG	*Tribulus terrestris*	4			11					11
DIG	*Amaranthus blitoides*	4								
	Acalypha australis	57								
	Gleditsia triacanthos	9								
	Cyclospermum leptophyllum	9								
	Coronopus didymus	4		21	11					11
	Platanus occidentalis	4								
	Amaranthus deflexus	0	+	21	21	56	21	11	31	
DIG, BID	*Echinochloa crus-galli*	0							11	11
DIG, POL	*Polygonum aviculare*	70	1	21	42	42	56	42	57	54
DIG, POL	*Cynodon dactylon*	9	+	11	21	11	21	11	31	31
Class ***Sisymbrietea***										
SIS	*Conyza canadensis*	61	+	11	11	11	11	21	11	11
SIS	*Ambrosia artemisiifolia*	17								
SIS	*Chenopodium album*	13		11	11	11			11	31
SIS	*Amaranthus retroflexus*	4			11	11			11	11
SIS	*Lactuca saligna*	4								
SIS	*Crepis foetida*	4								
SIS	*Malva neglecta Wallr.*	0					11			
SIS	*Lactuca serriola*	0		11						11
SIS	*Atriplex tatarica*	0							11	11
SIS, PAR	*Convolvulus arvensis*	22		11	11	11		21		11
SIS, PAR	*Stellaria media*	4			11		11			11
SIS, SED	*Erodium cicutarium*	0								11
Class ***Artemisietea vulgaris***										
ART	*Plantago lanceolata*	13					11	31		
ART, BUL, FES	*Medicago lupulina*	9			11		11		11	21
ART, EPI	*Erigeron annuus*	4								
ART	*Verbascum blattaria*	4								
ART	*Picris hieracioides*	4								
ART	*Melilotus officinalis*	4								

ART	*Artemisia absinthium L.*	0			21	11	11		11
ART	*Artemisia vulgaris*	0			11	11	11		11
ART	*Artemisia vulgaris L.*	0				11	31		11
ART, MOL	*Daucus carota*	0						11	11
ART, SIS	*Crepis setosa*	26							
Class ***Papaveretea rhoeadis***									
PAR	*Oxalis corniculata*	30	31	54	11	11			
PAR	*Galinsoga quadriradiata*	4		11		11			
PAR	*Veronica polita*	4							
PAR	*Alopecurus myosuroides*	4							
PAR, SIS	*Sonchus oleraceus*	26	21	11	42	11	11		11
PAR, SIS	*Capsella bursa-pastoris*	0	11	11	11			31	11
PAR, SIS	*Solanum nigrum*	0		11					11
PAR, SIS	*Sonchus asper*	0							11
Class ***Polygono-Poetea annuae***									
POL	Poa annua	48	53	21	31	21	31	31	11
POL, MOL	Plantago major	35	11	21	11	11	53	42	32
MOL	Lolium perenne	13		11	21	11		21	11
MOL	Paspalum dilatatum	9							
MOL	Potentilla reptans	4							
MOL	Juncus tenuis	4							
POL	Sagina procumbens	4		11		21	11	21	11
POL	Cotula australis	0	11						
POL	Sclerochloa dura (L.) Beauv.	0		11	11				
POL	Spergularia rubra	0	21					11	11
POL	Plantago coronopus	0	42	11		11	11		
POL	Herniaria glabra	0		11		11	21		
POL	Lepidium ruderale	0							11
MOL	Trifolium repens	0	11	11	11	11	21	31	21
MOL	Verbena officinalis	0		11		21	31		
Other species									
CHE	*Hordeum leporinum*	17		11	11	11		11	
CHE	*Parietaria judaica L.*	0		21	31	11			
EPI	*Calystegia sepium*	4							
EPI, CYM, ROB	*Chelidonium majus*	4							
EPI, POP	*Humulus lupulus*	4							
FEP	*Galium humifusum*	4							
FES	*Crepis pannonica*	4							
ROB	*Ailanthus altissima*	9							
SED	*Petrorhagia saxifraga*	0		11		11	43		
SED, TRA	*Arenaria serpyllifolia*	9				11	11	21	11
SED, TRA, TUB	*Medicago minima*	9							

1 ***Euphorbio maculata-Acalyphetum australis***, Russia (this paper), 2 Eup***horbietum chamaesyco-prostratae*** Rivas-Martínez, Madrid, ES, 3 ***Gnaphalio luteo-albi-Polycarpetum tetraphylli*** Ortiz & Rodríguez-Oubiña (1990: Tab. 2) C & N Portugal, 4 ***Euphorbio chamasyce-Oxalidetum corniculatae*** Lorenzoni 1964, 5 ***Polycarpo tetraphylli-Amaranthetum deflexi*** Pignatti 1953, Italy (Poldini, 1989), Croatia (Čarni, 1995), 6 ***Eleusinetum indicae*** Pignatti 1953, 7 ***Euphorbietum maculatae*** Poldini 1989, 8 ***Polygono avicularis-Euphorbietum maculatae*** (Tímár, 1950) Čarni & Mucina (1998), Hungary (Tímár, 1950), (Čarni, Mucina, 1998), 9 ***Eragrostio-Polygonetum avicularis*** Oberd. 1954, 10 ***Portulaco-Euphorbietum maculatae*** (Brandes 1993) Čarni & Mucina (1998)

The position of the characterized communities with Euphorbia maculate in the system of higher syntaxa is presented as follows:

Class ***Digitario sanguinalis-Eragrostietea minoris*** Mucina, Lososová et Šilc in Mucina et al. 2016

Order ***Eragrostietalia*** J. Tx. ex Poli 1966

Alliance ***Polycarpo-Eleusinion indicae*** Čarni et Mucina 1998

Acc. ***Euphorbio maculata-Acalyphetum australis*** ass. nova hoc loco

IV. Discussion

Digitario sanguinalis-Eragrostietea minoris is a new class of anthropogenic vegetation uniting therophyte communities of annual plants in southern non-moral, Mediterranean, steppe and semi-desert zones of Europe (Mucina et al., 2016). Diagnostic types of class: *Amaranthus albus, Anisantha sterilis, A. tectorum, Bromus squarrosus, Conyza canadensis, Corispermum hyssopifolium, Digitaria ischaemum, D. sanguinalis, Echinochloa crusgalli, Eragrostis minor, Eragrostis pilosa agg., Lepidium densiflorum, Panicum miliaceum, Plantago arenaria, Polygonum aviculare agg., Portulaca oleracea, Salsola australis, Senecio vernalis, S. viscosus, Setaria pumila, S. pycnocoma, S. verticillata, S. viridis, S. weinmannii.*

In the Krasnodar Region, the class is represented by the order ***Eragrostietalia*** - communities of juveniles on dry and warm sandy or other drained soils.

Diagnostic types of order = Diagnostic types of class.

According to the latest survey of vegetation in Europe (Mucina et al., 2016) this order has a complex structure of alliances which are divided into 3 groups, combining the segmental vegetation of the temperate zone, segmental vegetation of the Mediterranean and the ruderal vegetation. The investigated phytocoenoses are classified to the Alliance ***Polycarpo-Eleusinion indicae*** Čarni et Mucina 1998.

Ass. ***Euphorbio maculata-Acalyphetum australis*** ass. nova hoc loco (table. 1) Diagnostic species: *Euphorbia maculata, Acalypha australis*.

Type of nomenclature (holotypus hoc loco) - op. 9 in table. 1: *Euphorbia maculata* - 1, *Portulaca oleracea* - +, *Digitaria sanguinalis* - 1, *Polygonum aviculare* - 2, *Eleusine indica* - +, *Setaria pumila* - +, *Acalypha australis* - +, *Conyza canadensis* - +, *Sonchus oleraceus* - +, *Chenopod*ium album - +, *Lactuca saligna* - +, *Crepis setosa* - +, *Plantago major*- +. Krasnodar Region, the city of Krasnodar. 15.07.2023.

Summer-dry trampled vegetation with *Euphorbia maculata* in crevices of sealed asphalt and tile coating of sandy subsoil (on sandy soils), on gravel ground of tram and railway tracks of the North Caucasus region.

This marginal community is often found in the cracks of pavement tiles, laid out on sand substrate (figure), asphalt cracks of adjacent and near the fence areas (figure), sidewalks along roads (figure), bridges, railway platforms, parks. The basis of the grass stand consists of *Euphorbia maculate, Digitaria sanguinalis, Polygonum aviculare, Setaria viridis, Portulaca oleracea* (with abundance 3-15%, on average 7%). The grass stand is thinned unevenly, the total projective coverage is 5-35%. Its height depends on the intensity of poaching and varies from 5 to 40 (60) cm. The average height is 17 cm. The floristic richness of communities is low (10-16 species).

In the associations, the main phytocenotical positions are occupied by the alien plant species *Euphorbia maculate, Digitaria sanguinalis, Acalypha australi, Setaria pumila, Eleusine indica, Ambrosia artemisiifolia, Amaranthus retroflexus, Conyza canadensis, Sorghum halepense, Setaria pumila, Paspalum dilatatum, Juncus tenuis*.

References

[1] Welβ W. (1992). Euphorbia maculata L. - eine Wolfsmilch zwischen Pflastersteinen // Natur und Mensch: 121-124.

[2] Elmore CD, McDaniel S. (1986) Identification and Distribution of the Weedy Spurges in the Delta of Mississippi. Weed Science, 34(6):911-915. doi:10.1017/S0043174500068090

[3] Eliáš, P. J. (2009). First record of Euphorbia maculata L.(Euphorbiaceae) in Slovakia // Thaiszia - Journal of Botany, 19 (1): 21-25.

[4] Lisovets, O. I. (2016). First finds of Acalypha australis L. and Euphorbia maculata L.(Euphorbiaceae) in Dnipropetrovsk region. Ecology and Noospherology, 27(1-2): 42-48.

[5] Tabbache, S. (2019) First recorded of spotted spurge Euphorbia maculata L.(Euphorbiaceae) and adding it to Syrian flora // Tishreen University Journal for Research and Scientific Studies - Biological Sciences Series Vol., 14 (6). DOI: 10.15421/031605.

[6] Berezutsky MA, Durnova NA, Belonogova YV, Mishkina VV. V. (2021) Finding of a medicinal species - spotted milkvetch (Euphorbia maculata L.) on the territory of the Saratov Region // Modern Science, 11(1):14-17. (in russ).

[7] Zernov A.S. (2006). Flora of the northwestern Caucasus. M., 2006. (in russ).

[8] Gholamalipour Alamdari E, Seifolahi B, Avarseji Z, Biabavi A. (2018). Evaluation of allelopathic effect of Euphorbia maculata weed on traits of germination, chlorophyll and carotenoids pigments of wheat cultivars. Iranian J. Seed Res., 5(1):71-85. doi:10.29252/yujs.5.1.71

[9] Tanveer, A.I; Khaliq, A.II; Javaid, M.M.III; Chaudhry M.N.IV; Awan I.V (2013) Implications of weeds of genus euphorbia for crop production: a review. Planta Daninha, 31:723-731. https://doi.org/10.1590/S0100-83582013000300024

[10] Khakzad, R., Alebrahim, M. T., & Oveisi, M. (2020). Investigating the Effect of Management Operations on the Time of Spotted Spurge (Euphorbia maculata) Emergence in Soybean. Iranian Journal of Weed Science, 16(2): 27-43.

[11] Mohammad T. Bararpour, Ronald E. Talbert, and Robert E. Frans. (1994) Spotted Spurge (Euphorbia maculata) Interference with Cotton (Gossypium hirsutum). Weed Science, 42: 553-555.

[12] Yueqin C., Hongwei W., Hongjun Z. et al. (2009). Allelopathy of Aqueous Extracts from Euphorbia maculata L. on Several Vegetable Species // Chinese Agricultural Science Bulletin, 2: 1.

[13] Westhoff V., Maarel E. (1973). The Braun-Blanquet approach. Handb. Veg. Sci.,5: 617–726.

[14] Hennekens S.M., Schaminée J.H.J. (2001) TURBOVEG, a comprehensive data base management system for vegetation data // J. Veg. Sci., 12:589-591.

[15] Hill M.O. (1979). TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and the attributes. Ithaca: Cornell University, 1979. 48 p.

[16] Mucina L., Bültmann H., Dierßen K., Theurillat J.-P., Raus T., Čarni A., Šumberová K., Willner W., Dengler J., Gavilán García R., Chytrý M., Hájek M., Di Pietro R., Iakushenko D., Pallas J., Daniëls F. J. A., Bergmeier E., Santos Guerra A., Ermakov N., Valachovič M., Schaminée J. H. J., Lysenko T., Didukh Y. P., Pignatti S., Rodwell J. S., Capelo J., Weber H. E., Solomeshch A., Dimopoulos P., Aguiar C., Hennekens S. M., Tichý L. (2016). Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities / // Applied Vegetation Science, 19 (S.1):3-264.

[17] Theurillat J.-P., Willne W., Fernández González F., Bültmann H., Čarni A., Gigante D., Mucina L., Weber H. (2021). International Code of Phytosociological Nomenclature. 4th ed. // Appl. Veg. Sci. Vol., 24: 1–62. https://doi.org/10.1111/avsc.12491.

[18] Cherepanov, S.K. (1995). Vascular plants of Russia and neighboring states (within the former USSR). Moscow, 349 p. (in russ).

[19] Mucina, L., Dostálek, J., Jarolímek, I., Kolbek, J. & Ostrý, I. (1991). Plant communities of trampled habitats in North Korea // Journal of Vegetation Science, 2(5): 667-678.

[20] Carni, A. & Mucina, L. (1998). Vegetation of trampled habitats dominated by C4 plants in Europe. Vegetation of trampled habitats dominated by C4 plants in Europe. Journal of Vegetation Science, 9(1): 45-56. http://hdl.handle.net/20.500.11937/31147

THE «GREEN» ECONOMY: THE SPECIFICS OF FINANCING AND SUBSIDIZING PROJECTS IN MODERN CONDITIONS

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Abstract

In recent years, commercial banks have been actively involved in financing projects related to the green economy, reflecting the global trend of transition to sustainable development.
Many banks are switching to electronic document management and using alternative energy sources for their operations. Despite the positive changes, banks face certain challenges. There is a risk that financing green technologies may negatively affect the performance of traditional companies. The State provides support commercial banks in the implementation of green economy projects.
The Bank of Russia and other government organizations are developing concessional lending programs that allow banks to provide loans on more favorable terms for projects aimed at sustainable development. This may include reducing capital reserve requirements for "green" projects, which makes them more attractive to banks. Commercial banks can receive subsidies to cover part of the interest rates on loans issued to finance environmentally friendly projects. This reduces the financial burden on borrowers and encourages them to implement sustainable initiatives. In some cases, Russian banks may cooperate with international financial institutions.
The implementation of green economy projects by commercial banks is not widespread enough. The successful development of green banking requires an integrated approach, including the adaptation of products, internal processes and corporate culture to new environmental standards. This study is devoted to an overview of the mechanisms and methods of stimulating and implementing green banking.

Keywords: green loans, green finance bonds, certification of green financial products, commercial banks, taxonomy of green projects

I. Introduction

Such instruments as green loans, green finance bonds and certification of green financial products serve the goals of widespread introduction of green banking financing. Green loans are becoming an important tool to support businesses striving for sustainable development and reducing their environmental footprint. Commercial banks are actively developing this area, offering a variety of products that can help both individual entrepreneurs and large companies.

The objectives of financing green economy projects are green construction, environmentally friendly transport, waste management and much more.

Banks can act as organizers of the issue of green bonds by other companies, providing consulting services and helping with the placement of securities. In order to ensure transparency and investor confidence in green financial products of banks, their certification for compliance with the principles and standards of green finance.

Non–financial reporting of clients helps banks reduce the risks of implementing green financing projects and confirm a responsible approach to the implementation of green projects.

Non–financial reporting of banks helps to: establish trust from investors and customers, assess and manage risks; comply with international standards and expectations, which helps to increase their competitiveness in the market. Large Russian banks are already actively implementing non–financial disclosure practices. They publish reports containing not only statistical data, but also information about projects, initiatives and interactions with key stakeholders. This allows them not only to meet the requirements, but also to stand out from the competition. However, a large number of commercial banks have not yet introduced the usual practice of disclosing non–financial information.

Thus, it is relevant to research and develop mechanisms and methods to stimulate and implement green banking for implementation by commercial banks, including creating incentives for private investors and financial organizations.

The purpose of this study is to study the best practices of commercial banking financing of green economy projects and to develop mechanisms and methods for stimulating and implementing green banking for implementation by commercial banks.

The objectives of this study:

– conduct benchmarking of leading countries in the field of green banking, such as Germany, Sweden and The Netherlands, in order to identify the best practices for financing environmentally sustainable projects by commercial banks;

– to investigate the impact of government support on the activity of commercial banks in the field of green banking by analyzing the effectiveness of various subsidy mechanisms and tax incentives;

– compare the volumes and dynamics of green lending in the leading countries of Russia, identifying the key factors contributing to or hindering the growth of this segment;

– to assess the degree of involvement of commercial banks in sustainable development projects through a quantitative analysis of the structure of their loan portfolio and participation in green bonds;

II. Methods and materials

The research uses information data, as well as methods of theoretical research, namely: monographic.

III. Literature review

A lot of research has been devoted to green banking in a wide range of areas, including those that are the focus of this study.

Thus, emphasize that a significant amount of financial resources is needed to promote green projects, in which banks play a key role, acting as active participants in financing projects.

This includes the creation of a "green" banking system that unites various financial institutions, such as "green" banks and development banks. An important aspect is the need to regulate banking activities, including "green" financing, which should be supported by government politicians and banking regulators. This allows you to direct financial flows to sustainable projects and minimize environmental risks.

Some authors notes that Russia, as a participant in the international environmental agenda, should actively develop the green finance market, taking into account international standards and practices [2-14]. The paper points to the underdevelopment of the Russian financial market and the lack of active participation in international organizations, which may hinder this process. Success in the field of green finance can lead to attracting foreign investment and improving the country's reputation in the international arena.

Zaitseva [1], emphasize that banks, being financial intermediaries, cannot stay away from the implementation of ESG projects. However, a full understanding of the importance of the ESG agenda in the banking sector has not yet been achieved. The main factors slowing down development include the poor quality of information for analyzing borrowers.

IV. Results and discussion

The study showed that benchmarking of leading countries in the field of green banking, such as Germany, Sweden and the Netherlands represent a valuable area of research that can enrich Russian banking practice with the best global approaches.

However, despite their successes, the adaptation of this experience to the Russian economy it is associated with a number of challenges due to the peculiarities of the national context.

Germany, one of the largest economies in Europe, has demonstrated outstanding results in the field of green banking, especially in the framework of energy efficiency and renewable energy development programs. The main driver here is government support, expressed in large–scale subsidy programs, guarantees and benefits that make financing green projects more attractive to commercial banks. An important aspect is the participation of such large institutions as KfW Bankengruppe, which not only provides financial support, but also actively participates in the development of sustainable development strategies. This approach minimizes risks for banks and entrepreneurs, providing a high degree of confidence in the return on investment.

At the same time, the adaptation of the German green banking model presents certain difficulties for Russia. One of the key obstacles is the insufficient level of government support and subsidies for green projects, as well as the relatively weak development of renewable energy infrastructure. Unlike Germany, where a significant part of electricity is produced by wind and solar, in Russia the energy sector is still dominated by traditional hydrocarbons.

However, on the other hand, there is potential for growth in this segment, given Russia's rich natural resources, which can be used to transition to more sustainable energy supply models.

Sweden, being one of the most environmentally oriented countries, is actively developing green banking practices. Sweden is a leader in green bond issuance, which helps to raise significant funds to finance sustainable projects. Adapting the Swedish experience in Russia may also face certain difficulties. Firstly, the Russian green bond market is at the stage of formation, and the volume of issues is still significantly behind its Western counterparts. Secondly, the level of awareness and acceptance of ESG principles among Russian companies and banks remains low. Although interest in sustainability is growing, many companies still view ESG as an additional burden rather than an opportunity to create long–term value. Nevertheless, taking into account global trends and the growing interest of investors in sustainable financing, the introduction of ESG factors into Russian banking may become a strategically important area.

The Netherlands, in turn, demonstrates an innovative approach to green banking, actively developing new financial instruments and mechanisms, such as public–private partnerships. Dutch banks cooperate extensively with international financial institutions, which allows them to borrow best practices and integrate them into the national banking system. An important area is the financing of sustainable agriculture and water resources management, which corresponds to the natural and economic conditions of the country.

For Russia, where agriculture and water resources also play an important role, the experience of the Netherlands is of particular value. However, it should be borne in mind that the adaptation of these practices requires significant institutional changes and the development of new mechanisms for interaction between the state, banks and the private sector. Moreover, unlike the Netherlands, Russia faces problems of regional inequality, which can make it difficult to scale successful projects throughout the country. For example, successful green finance models in Central Russia may not be as effective in Siberia or the Far East. In the East, where the infrastructure is much less developed.

It is important to take into account that the successful adaptation of international practices requires an integrated approach, including not only the borrowing of specific financial instruments, but also the creation of an appropriate institutional environment, raising awareness and adoption of ESG principles, as well as the development of public partnerships with the private sector. In this context, the role of the state becomes key, since it is it that is able to set the vector of development and provide the necessary conditions for the growth of green banking in Russia. Fig.1 schematically shows the role of a commercial bank in the field of sustainable development.

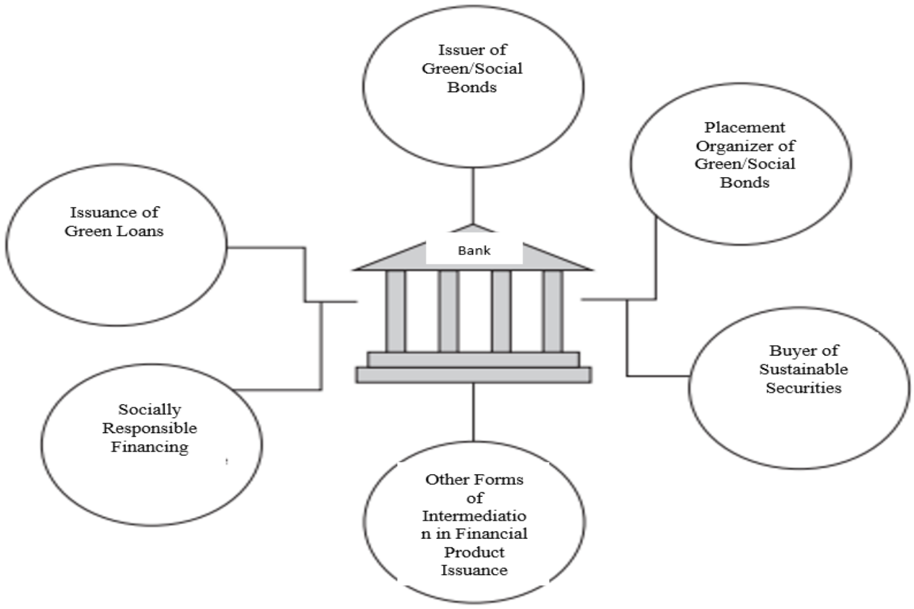

Figure 1: *The role of a commercial bank in the field of sustainable development*.
Source: Zaitseva I.G., Maksimov I.A. Trends in the development of esg–activity of banks // Economics and management. 2022. No.12. URL: https://cyberleninka.ru/article/n/tendentsii–razvitiya–esg–deyatelnosti–bankov (date of application: 08/24/2024).

To quantify the impact of green finance on the financial results of commercial banks, a model based on regression analysis is proposed, which takes into account the volumes of green loans issued and green bonds issued in different countries. The main estimation method is multiple linear regression, where dependent variables (ROA, ROE, profit) will be modeled depending on independent variables.

The general formula of the model:

$$Y_i - \beta_0 + \beta_1 * X_{1i} + \beta_2 * X_{2i} + \beta_3 * X_{3i} + \epsilon_i \quad (1)$$

where,
Y_i − depend variable (e.g., ROA);
X_{1i} – volume of green loans issued;
X_{2i} − volume of green bonds issued;
X_{3i} − share of green financing in the total loan portfolio;
β_0, $\beta_1, \beta_2, \beta_3$ − regression coefficients;
ϵ_i − random error.

The obtained regression coefficients will allow us to assess how changes in the volume of green financing affect the financial results of banks. For example, a positive and significant value of the β1 coefficient will mean that an increase in the volume of green loans contributes to an increase in the profitability of the bank's assets. Control variables can be added to the model, such as the total assets of the bank, interest rates, and the economic situation in the country, in order to take into account external factors that can also affect financial results. After evaluating the model, hypotheses about the importance of green finance for banks' financial performance can be tested.

Also, based on the model, it is possible to make forecasts and assess how an increase in green financing may affect the bank's future results. It is important to keep in mind that the volume of green loans and bonds in Russia is still small compared to other countries, which may reduce the importance of regression coefficients. However, as the green banking sector grows, the model may become an important tool for evaluating the effectiveness of such investments and developing strategies for Russian commercial banks. In order to ensure the rapid growth of the green banking sector, state support for the activity of commercial banks in the field of green banking is necessary, including various mechanisms of subsidies and tax incentives.

Financial institutions are facing new challenges and requirements, and the effectiveness of various subsidy mechanisms and tax incentives is becoming a determining factor for the successful integration of green finance principles into the banking sector. One of the main instruments of government support is subsidizing interest rates on green loans. In a number of countries, such as Germany and France, this mechanism has proven to be highly effective.

In turn, this makes such projects more attractive to commercial banks, reducing their risks and increasing their potential profitability. An example of the successful implementation of this approach is the program implemented in Germany through KfW Bankengruppe, which provides subsidies and guarantees to green projects. Tax incentives are another important mechanism of state support that can stimulate the development of green banking. In countries such as Sweden and the Netherlands, tax incentives are provided not only to enterprises implementing green projects, but also to banks actively involved in financing such initiatives.

However, at the moment their use remains limited, which reduces the motivation of banks to participate in green projects. The introduction of systemic tax incentives for banks supporting sustainable development could It would significantly increase their interest in expanding green lending and issuing green bonds. This, in turn, would create conditions for increasing investments in projects aimed at environmental modernization and reducing the carbon footprint.

Despite the obvious advantages of government support, it must be borne in mind that its effectiveness depends not only on the scale of subsidies and benefits, but also on the quality of program implementation. It is important to ensure transparency and accessibility of support mechanisms so that they really contribute to the growth of green banking, and do not create additional barriers for commercial banks.

The development of green lending in the world today is determined by many factors that differ in their importance and impact on the financial results of banks and the economy as a whole.

Comparing the volumes and dynamics of green lending in leading countries such as Germany, Sweden and the Netherlands with the situation in Russia allows not only to assess the current state of affairs. Such criteria include institutional support, the development of a regulatory framework, the level of awareness of the importance of ESG principles.

Over the past decades, Germany, Sweden and The Netherlands has consistently strengthened its position in the field of green lending, which has led to significant successes in this area. In Germany, the volume of green loans annually shows steady growth exceeding 15–20%.

Which, through state–owned banks such as KfW, provides subsidies and guarantees for green projects, the development of renewable energy sources and sustainable construction. This allows banks to reduce their risks and attract more customers interested in sustainable development. In Sweden, the dynamics of green lending is also impressive, with an annual increase of 12–18 %, and the share of green loans in the total loan portfolio of Swedish banks is 10–12 %.

This was achieved through the active integration of ESG principles into banking practice and government support in the form of tax incentives and special financing programs. The Netherlands shows similar results, with green lending growing at 10–15% per year and significant investment in projects related to sustainable agriculture and water management. At the same time, the Russian green lending market lags far behind its Western counterparts. The volume of green loans in Russia is less than 1% of the total loan portfolio of banks, and the growth rate remains modest, ranging from 5–7 % per year.

These indicators indicate a significant lag, which requires an analysis of the factors hindering the growth of green lending in the country. One of the key barriers is insufficient institutional support. While in In Germany and Sweden, state–owned banks play an active role in stimulating green lending, while such mechanisms have not yet become widespread in Russia. The availability of subsidy programs is limited and access to them is difficult, which constrains banks' interest in this segment. Another important factor is the regulatory framework. Leading countries have long developed and implemented clear standards and taxonomies for green projects, which ensures transparency and reduces risks for market participants.

In Russia, such a regulatory framework is still being formed, and the lack of clear criteria creates uncertainty for both banks and investors. This leads to the fact that banks are afraid to participate in green lending due to high risks and uncertain prospects for return on investment. In addition, the level of awareness about the importance of ESG principles in Russia remains low. In Germany and Sweden, environmental responsibility and sustainable development have long been an integral part of banks' corporate culture and strategy. In these countries, customers and investors are aware of the importance of sustainable development and require banks to meet high standards. In Russia ESG principles are still perceived as additional requirements rather than an opportunity to create long–term value. This hinders the development of green lending, as demand for such products remains limited.

In Sweden and the Netherlands, tax incentives and other financial instruments create additional incentives for banks interested in developing green finance. There are practically no such benefits in Russia, which reduces the motivation of banks to participate in green projects.

Global trends in sustainable development, international commitments to reduce carbon emissions and growing investor interest in sustainable projects create prerequisites for the activation of this segment. The introduction of successful practices from other countries, the adaptation of the regulatory framework, increased government support and increased awareness of the importance of ESG principles can be key factors contributing to the growth of green lending in Russia. Thus, a comparative analysis of the volumes and dynamics of green lending in leading countries and Russia shows that the successes of most countries in this area are achieved thanks to a well–structured system of institutional support, a developed regulatory framework, a high level of awareness of the importance of ESG principles and the availability of economic incentives. In Russia, on the contrary, insufficient government support, a weak regulatory framework, a low level of acceptance of ESG principles and a lack of significant economic incentives are the main barriers. The growth rate of green loans – an analysis of changes in the volume of green loans in dynamics allows us to assess how actively the bank is expanding its sustainable financing programs. Sustained growth indicates a strategic focus on sustainable development. The analysis requires collecting the following data: the total volume of the bank's loan portfolio, the volume of green loans issued, the volume and number of green bond issues

Green Lending Engagement Index (IGC):

$$IGC = \frac{Volume\ of\ green\ loans}{Total\ volume\ of\ the\ loan\ portfolio} \quad (2)$$

Green Credit Growth Index (GRI):

$$GRI = \frac{Volume\ of\ green\ loans\ for\ the\ current\ year}{Volume\ of\ green\ loans\ for\ the\ previous\ year} - 1 \quad (3)$$

Green Bond Engagement Index (IGO): $\mathrm{IGO} = \frac{\text{Volume of participation in green bonds}}{\text{Total volume of the bond portfolio}}$ (4)

Strategic Commitment Index (CSI):

$$CSI = \frac{IGC+IGO}{2} \quad (5)$$

This composite index combines green lending engagement and green bonds, providing an overview of the bank's strategic commitment to sustainable development. The obtained values of the indicators can be used for a comparative analysis of banks. Higher index values indicate a greater degree of involvement of the bank in sustainable development projects development.

The results can be presented in the form of ratings, which will highlight the leaders and outsiders in the field of green finance. The methodology can be used both for internal evaluation of banks and for comparative analysis at the industry level. If applied at the level of the entire banking system, it is possible to create aggregated indices reflecting general trends in sustainable financing. This data can be useful for both regulators and investors interested in sustainable development. The methodology for analyzing green finance should include both retrospective and forward–looking approaches.

The forward–looking approach includes modeling the future growth of green lending based on current trends and evaluating possible market development scenarios. This approach will make it possible to determine which measures can stimulate an increase in the share of "green" loans in the loan portfolio and how actively banks are ready to support the transition to sustainable development. An equally important aspect of the engagement assessment is the analysis of the participation of Russian banks in the issuance of "green" bonds. Green bonds are debt instruments designed to finance environmentally sustainable projects. Participation in the issuance of such bonds indicates that the bank not only supports sustainable development at the lending level, but also actively participates in raising capital for the implementation of environmental initiatives through the capital market.

It is important to note that participation in the issue of green bonds can be either direct, when the bank itself acts as an issuer, or indirect, when the bank supports the issue of third parties by providing guarantees or acting as an organizer of the issue. To quantify the involvement of Russian banks in green bonds, it is necessary to analyze the structure of their investment portfolio and determine what share green bonds occupy in it. Thus, for a comprehensive assessment, it is necessary to analyze not only the volume of bond issuance, but also the structure of the use of borrowed funds. It is also interesting to consider the degree of involvement of Russian banks in international partnerships and projects related to sustainable development. Within the framework of such projects, banks can not only improve their skills in the field of green finance, but also gain access to best practices and technologies that can be adapted for use in the Russian market. This is especially important in the context of the growing global trend towards increased regulation and accountability in the field of sustainable development.

Banks that actively implement ESG principles in their activities have a higher ability to adapt to changing market conditions. Therefore, in order to increase the involvement of Russian banks in sustainable development projects, it is necessary not only to expand credit programs and issue green bonds, but also to invest in the development of internal competencies and corporate culture focused on the principles of sustainable development. Thus, a quantitative analysis of the loan portfolio structure and participation in green bonds allows a deeper understanding of the degree of involvement of Russian commercial banks in sustainable development projects. This, in turn, opens up opportunities for further development of this segment and integration of the principles of sustainable development into banking activities on a long–term basis.

This will not only attract capital to finance environmentally significant projects, but also strengthen the bank's reputation as a sustainable financial institution. The implementation of a monitoring and reporting system for green projects will ensure transparency of the bank's activities and strengthen the trust of investors and customers. In addition, providing technical assistance and advice to clients on sustainable development issues will help them better understand the requirements of green finance and increase their willingness to participate in such projects. It is necessary to adapt international standards of green finance to Russian conditions, taking into account the specifics of the national market. At the same time, it is necessary to actively raise awareness and train the bank's staff on sustainable development issues, which will allow banks to work more effectively with environmentally significant projects. An important aspect is also the introduction of tax incentives for clients implementing projects in the field of sustainable development. This may include benefits and subsidies that will help make green finance more affordable. The active involvement of private investors and the expansion of cooperation with government support programs are also important elements of the strategy for adapting international best practices.

V. Conclusion

Supporting the development of infrastructure for green finance, including project verification and certification systems, will also be an important step towards strengthening the position of Russian banks in this area. Participation in educational and information campaigns on sustainable development issues will help banks not only strengthen their reputation, but also raise public awareness of the benefits of green financing. It is also important to develop non–financial disclosure practices, including sustainability indicators, which will allow banks to meet international standards and investor expectations.

Thus, green projects and Green Banking in Russia are at the stage of formation, which is manifested in the relatively low share of green loans and bonds in the total portfolio of commercial banks. Nevertheless, global trends and international commitments stimulate the growth of interest in sustainable financing, which creates prerequisites for the accelerated development of this segment.

References

[1] Zaitseva I.G., Maksimov I.A. Trends in the development of esg–activity of banks // Economics and management. 2022. No.12. URL: https://cyberleninka.ru/article/n/tendentsii–razvitiya–esg–deyatelnosti–bankov (date of application: 08/24/2024).

[2] Zakiryanov, B.K., et al. Development of Rural Green Tourism of Regions of Kazakhstan. Environmental Footprints and Eco–Design of Products and Processes, 2022, pp. 33–38 DOI:10.1007/978–981–19–1125–5_2

[3] Moldashbayeva, L., et al. Green bonds – A tool for financing green projects in countries. E3S Web of Conferences, 2021, 244, 10060 DOI:10.1051/e3sconf/202124410060

[4] Troyanskaya, M., et al. Instruments for financing and investing the green economy in the country's environmental projects. E3S Web of Conferences, 2021, 244, 10054 DOI:10.1051/e3sconf/202124410054

[5] Jazykbayeva, B., et al. The Growth of green finance at the global level in the context of sustainable economic development. E3S Web of Conferences, 2021, 244, 10058 DOI:10.1051/e3sconf/202124410058

[6] Abramova M., Varzin V. et al. Features of the mechanism for implementing sustainable development through the green economy. E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

[7] Zverkova A., et al. Features of the "Green" strategies for the development of banks. E3S Web of Conf., 402 (2023) 08029 DOI: 10.1051/e3sconf/202340208029

[8] Antonenko A.P. Ideological foundations of a new stage in the development of civilization // Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences. – 2021. – № 3 (29). – Pp. 5–8. doi: 10.21777/2587–9472–2021–3–5–8

[9] Archimandritova A.V., Suptelo N.P. Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – 1 (40). 85–94. doi: 10.21777/2587– 554X–2022–1–85–94

[10] Baburin S.N. Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences.– 2019. – 4 (22). – 6–12. doi: 10.21777/2587–9472–2019–4–6–12

[11] Berstembayeva, R., et al. (2024). The impact of the green economy on the sustainable development of Kazakhstan. In *BIO Web of Conferences* (Vol. 116, p. 07040). EDP Sciences.

[12] Bunevich K.G., Gorbacheva T.A. «Green» trends in the development of the world financial system // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – № 1 (40). – Pp. 52–60. doi: 10.21777/2587–554X–2022–1–52–60

[13] Burykin, E.S.: Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. 4(35), 81–86 (2020). https://doi.org/10.21777/2587–554X2020–4–81–86

[14] Gavrilova E.N. «Green» financing in Russia: specifics, basic tools, problems of development // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2020. – № 2 (33). – Pp. 48–54. doi: 10.21777/2587–554X–2020–2–48–54

[15] Zubets A.Zh. State policy of support and directions of development of the transport industry of the Russian Federation // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2019. – № 3 (30). – Pp. 28–34. doi: 10.21777/2587–554X–2019–3–28–34

[16] Zueva, I.A. On the development of the method of analysis and evaluation of the socioeconomic development of regions. Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2017. – № 4 (23). Pp. 27–36. doi:10.21777/2587–9472–2017–4–27–36

[17] Zverkova A., et al. Features of the "Green" strategies for the development of banks. E3S Web of Conf., 402 (2023) 08029 DOI: 10.1051/e3sconf/202340208029

[18] Gladkov I.. World economic evolution: trends at the present stage // Economic and socio-humanitarian studies. 2023. No. 4 (40). pp. 6-15. https://doi.org/10.24151/2409-1073-2023-4-6-15 EDN: QVLHPH.

[19] Varavin Ye.V., Makovetsky M.Y., Komarova A.S. The problems of ensuring the transition to circular economy // Economics and Management. – 2022. – № 1 (40). – P. 42-51. doi: 10.21777/2587-554X-2022-1-42-51

[20] Suptelo N.P., Dolgikh I.M. Foreign experience of using the mechanism public-private partnerships in the electric power industry // Economics and Management. – 2021. – № 1 (36). – P. 15-22. doi: 10.21777/2587-554X-2021-1-15-22

[21] Tsvetkov V.Ya., Kozlov A.V. The algorithm of subsidiary metaheuristics // Education Resources and Technologies. – 2022. – № 4 (41). – p. 65-71. doi: 10.21777/2500-2112-2022-4-65-71

[22] Zinovyeva, I. S., Savin, A. G., Brizhak, O. V., & Shchinova, R. A. (2020). Natural management of a modern region: Assessment of effectiveness and perspectives of improvement. *Growth poles of the global economy: Emergence, changes and future perspectives*, 717-723.

[23] Brizhak, O. V., & Ermolenko, A. A. (2018). Strategical aspects of building-in the corporative capital into the russian economy. *Economics of Contemporary Russia*, (3), 48-61.

[24] Polyakov, R., & Brizhak, O. (2023, February). Industrial Clusters and the Process of Their Self-organization. In *International conference Ecosystems without borders* (pp. 60-72). Cham: Springer Nature Switzerland.

IMPLEMENTING ECONOMIC STRATEGIES TO PROMOTE SUSTAINABLE CONSUMPTION

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Abstract

This paper examines innovative resource tax approaches as crucial fiscal tools for mitigating unsustainable natural resource consumption. As global ecosystems face increasing pressure from overexploitation, the need for effective policy measures has never been more urgent. Traditional taxation models often fail to account for the environmental costs associated with resource extraction and consumption, leading to detrimental ecological impacts.

This study investigates various resource taxation frameworks adopted in different countries, analyzing their effectiveness in promoting sustainable resource use and environmental conservation.

The paper begins with a comprehensive review of existing literature on resource taxation, exploring concepts such as environmental externalities and the "polluter pays" principle. It then delves into case studies of successful resource tax implementations, focusing on how these measures have influenced consumption patterns and incentivized sustainable practices among businesses and consumers. The analysis highlights the importance of aligning tax structures with environmental goals, demonstrating how innovative tax strategies can drive both economic growth and ecological preservation. Furthermore, the research identifies key factors that contribute to the success of resource tax initiatives, including stakeholder engagement, public awareness, and the integration of tax measures into broader environmental policies. By presenting empirical evidence and real-world examples, the paper illustrates how effective resource taxation can lead to significant reductions in resource overuse and promote investment in renewable and sustainable alternatives.

The findings underscore the potential of innovative resource taxes to serve not only as a deterrent against unsustainable consumption but also as a catalyst for transitioning towards a circular economy. This transition requires a collaborative effort between governments, businesses, and society, emphasizing the importance of transparency, accountability, and shared responsibility in resource management.

Keywords: sustainable consumption, tax incentives, subsidies, corporate sustainability, circular economy, consumer behavior, environmental policy, resource efficiency, green innovation

I. Introduction

In the face of mounting environmental challenges, including climate change, pollution, and the unsustainable depletion of natural resources, the need for sustainable consumption has never been more urgent. Modern consumption patterns, characterized by excessive use of resources, waste generation, and reliance on fossil fuels, have led to significant ecological damage, threatening the planet's ability to sustain future generations. Addressing these challenges requires a shift towards sustainable consumption—defined as the use of products and services in a way that meets present needs without compromising the environment for future generations.

The pursuit of sustainable consumption is inherently complex, involving not just environmental considerations but also economic and social dimensions. It requires a holistic approach that encourages consumers to adopt environmentally friendly behaviors, while also promoting sustainable production practices within industries. Governments, businesses, and consumers all have critical roles to play in creating a more sustainable economy, and at the heart of these efforts are economic strategies designed to influence market behavior.

Economic strategies are powerful tools for shaping both consumer and producer choices. These strategies include taxes, subsidies, financial incentives, regulatory frameworks, and market-based mechanisms aimed at internalizing the environmental costs of production and consumption. For instance, carbon pricing mechanisms such as carbon taxes and cap-and-trade systems are designed to put a price on greenhouse gas emissions, encouraging businesses to reduce their carbon footprint and invest in cleaner technologies. Similarly, green subsidies and tax incentives for renewable energy, energy-efficient products, and sustainable business practices can accelerate the adoption of eco-friendly solutions across industries.

Moreover, economic strategies can drive innovation, fostering the development of sustainable technologies and products that reduce environmental impact. This is particularly relevant as consumer demand for sustainable products continues to grow. Companies are increasingly recognizing the competitive advantage of offering sustainable products, which not only aligns with consumer preferences but also contributes to corporate social responsibility (CSR) goals. Through policies that promote green innovation, economies can stimulate new business opportunities and growth while simultaneously addressing environmental concerns.

However, achieving sustainable consumption is not only about influencing producers; it is also essential to encourage consumers to make environmentally conscious decisions. Economic incentives such as eco-labeling, carbon pricing on consumer goods, and differential taxation (e.g., higher taxes on environmentally harmful products) can help guide consumers toward more sustainable choices. These strategies aim to make sustainable products more accessible and affordable, while discouraging the consumption of goods with a high environmental footprint.

This paper aims to explore the economic strategies that promote sustainable consumption and their potential to reshape consumer behavior, stimulate green innovation, and drive the global transition to a more sustainable economy. The following sections will delve into the various economic tools available, including fiscal policies, subsidies, market-based incentives, and regulatory approaches, providing a comprehensive analysis of their effectiveness. We will also examine case studies from different regions and industries to highlight successful implementations and lessons learned. By understanding the role of economic strategies in promoting sustainable consumption, this paper seeks to contribute to the broader conversation on how to balance economic growth with environmental stewardship and resource conservation.

In conclusion, economic strategies are essential in promoting sustainable consumption, offering a range of tools that can influence both consumer and producer behavior. By aligning market incentives with environmental goals, these strategies can help shift societies toward more sustainable practices, ensuring that economic development does not come at the expense of the planet's long-term health.

II. Methods

To explore the effectiveness of economic strategies in promoting sustainable consumption, this paper employs a mixed-methods approach, combining both qualitative and quantitative analysis. The research methodology consists of four main components: literature review, case study analysis, policy assessment, and data-driven evaluation of economic tools. Each component is designed to provide a comprehensive understanding of how various economic strategies can influence consumer behavior, business practices, and overall market trends toward sustainability.

1. Literature Review

The first stage of the research involves an extensive literature review, focusing on existing academic studies, policy reports, and industry publications that examine the relationship between economic strategies and sustainable consumption. The review aims to identify key economic tools and mechanisms, including taxation policies, subsidies, carbon pricing, and green incentives, as well as their theoretical foundations and practical applications. The literature review also covers consumer behavior theories and market trends to understand how economic incentives can affect decision-making processes and lead to more sustainable consumption patterns.

The review includes sources from multiple disciplines, including environmental economics, behavioral economics, and sustainability studies, to provide a broad, interdisciplinary perspective on the topic. Key areas of focus include:

- The effectiveness of tax incentives and carbon pricing in reducing environmental impact.
- The role of subsidies and grants in encouraging businesses to adopt sustainable practices.
- Consumer responses to eco-labeling, differential pricing, and other economic signals designed to promote green consumption.

2. Case Study Analysis

To complement the theoretical insights from the literature review, this paper conducts a series of case study analyses. These case studies are selected from different regions and industries that have successfully implemented economic strategies to promote sustainable consumption. The criteria for selecting case studies include diversity in geographical location, type of economic strategy used, and the scale of implementation (local, national, or international).

The selected case studies will examine:

- **Carbon Tax in Sweden**: An analysis of how Sweden’s carbon tax has effectively reduced carbon emissions while maintaining economic growth, offering insights into the design of carbon pricing policies.
- **Subsidies for Renewable Energy in Germany**: A case study on Germany’s "Energiewende" program, which provides subsidies for renewable energy development, exploring how financial incentives can transform the energy market.
- **Plastic Bag Tax in the UK**: An evaluation of the UK’s plastic bag tax, assessing its impact on consumer behavior and plastic waste reduction.
- **Circular Economy Initiatives in the European Union**: An exploration of how the EU’s circular economy policies have encouraged businesses to shift toward more sustainable production practices, focusing on material reuse and waste reduction.

Each case study provides empirical evidence on the outcomes of specific economic policies, highlighting the factors that contribute to their success or failure. These examples are used to draw conclusions about the generalizability of economic strategies across different contexts.

3. Policy Assessment

The next step involves assessing the policies and regulatory frameworks that have been implemented by governments and international organizations to promote sustainable consumption. This analysis looks at both mandatory and voluntary policies, such as carbon trading schemes, environmental taxes, eco-labeling programs, and corporate sustainability reporting requirements.

The policy assessment focuses on:

- Evaluating the efficiency and effectiveness of these policies in achieving their intended environmental and economic goals.
- Identifying potential barriers to policy implementation, such as political resistance, market distortions, or unintended consequences.
- Examining how well policies integrate environmental goals with economic growth objectives.

This section also includes an analysis of international frameworks such as the United Nations' Sustainable Development Goals (SDGs), which provide a global context for sustainable consumption efforts.

4. Data-Driven Evaluation of Economic Tools

Finally, the research uses quantitative data to evaluate the performance of specific economic tools, such as carbon taxes, subsidies, and market-based mechanisms, in reducing environmental impacts and promoting sustainable consumption. The data is drawn from national and international databases, including the World Bank, the Organisation for Economic Co-operation and Development (OECD), and environmental agencies.

Key indicators analyzed include:

- Changes in carbon emissions and resource use following the implementation of carbon pricing or tax policies.
- Adoption rates of renewable energy and eco-friendly technologies as a result of subsidies or green financing programs.
- Consumer spending patterns on sustainable products after the introduction of economic incentives or eco-labeling.
- Overall economic performance, including GDP growth and job creation, in regions that have adopted green economic strategies.

By comparing quantitative outcomes before and after the implementation of economic measures, this section aims to provide empirical evidence of their effectiveness. Additionally, statistical models may be used to explore correlations between specific economic strategies and improvements in sustainability metrics.

III. Results

The global imperative to address climate change and mitigate environmental degradation has led to a marked increase in emphasis on supporting eco-friendly practices and sustainable development in recent years. The BRICS countries—South Africa, Russia, India, Brazil, and China—are emerging economies with abundant natural resources. To achieve sustainable development, these nations must navigate the complex relationships between carbon pricing, the financial sector, and the equitable allocation of revenues from natural resource extraction. The dire consequences of the COVID-19 pandemic have exacerbated an already critical climate crisis, as extreme weather events and anthropogenic factors pose significant threats to humanity. These issues interact synergistically, with human activities such as the spread of disease vectors, environmental degradation, and excessive carbon dioxide emissions rendering the planet increasingly perilous for human habitation (Yu et al., 2024).

The need for transformation in our emissions-driven, energy-intensive culture has become glaringly evident due to the pandemic. Policy initiatives should prioritize addressing severe conditions, reducing carbon emissions, and enhancing transparency in the use of renewable energy sources (Muhammad and Dilanchiev Azer, 2023). One such policy measure designed to lower carbon emissions and promote sustainable practices is carbon pricing. By assigning a cost to carbon emissions, we aim to incentivize the economy's shift toward low-carbon and environmentally friendly approaches. However, the effectiveness of carbon taxes in fostering ecologically sustainable economic growth can be influenced by various factors, including the optimal allocation and utilization of revenues generated from natural resource extraction. The distribution of sustainable natural resource rents, or the income derived from resource extraction, significantly impacts fiscal policy and investment decisions. Rental revenues can support sustainability initiatives, such as research and development in green technologies and environmental conservation, thus enhancing the resilience of the financial services sector for long-term, stable growth (Yuan et al., 2023).

This paper aims to examine the roles of carbon taxes and fiscal policy as economic instruments in promoting natural resource efficiency and environmental sustainability. The study is driven by the urgent need to tackle resource depletion and environmental degradation, as well as the recognition of economic tools' potential to effect change. The research acknowledges the complexities involved in policy development and the necessity for a holistic approach to resource management. By conducting a comprehensive review of empirical data, case studies, and policy evaluations, this study seeks to provide valuable insights into the effectiveness of economic instruments in mitigating the environmental impacts associated with resource-intensive industries. In doing so, it contributes to the ongoing discourse on sustainable resource management and policy formulation, equipping policymakers, researchers, and stakeholders with a deeper understanding of the roles that carbon taxation and fiscal policy play in the pursuit of resource efficiency and sustainability (Yu et al., 2023).

IV. Discussion

The research aims to shed light on how economic instruments can incentivize sustainable practices and mitigate environmental externalities in the natural resource sector through thorough examination and analysis. This foundational goal sets the stage for an in-depth exploration of these topics in subsequent sections of the study. Effectively utilizing natural resources while ensuring environmental sustainability is a pressing challenge in today's world. The relentless depletion of finite resources, along with the environmental repercussions tied to their extraction and use, underscores the urgency of this issue. In response to these challenges, policymakers, economists, and environmentalists have been exploring innovative strategies to promote responsible resource management, with economic instruments emerging as a key solution.

This study delves into the motivations behind conducting this research and highlights its significance within the broader context of sustainable resource management. The rapid and often unsustainable exploitation of natural resources has led to a host of challenges (Li and Umair, 2023a, b). The depletion of non-renewable resources, such as fossil fuels and minerals, not only threatens the availability of these essential commodities but also intensifies competition and conflict over access to them (Liu et al., 2023). Furthermore, the extraction and utilization of these resources are closely linked to environmental degradation, manifesting in greenhouse gas emissions, deforestation, habitat loss, and water pollution, among other detrimental effects. The depletion of non-renewable resources could lead to the complete exhaustion of vital economic inputs, disrupting global supply chains and jeopardizing energy security (Taghizadeh-Hesary and Yoshino, 2020). Additionally, the continuous rise in greenhouse gas emissions from resource-intensive industries exacerbates climate change, increasing the frequency and severity of extreme weather events, sea-level rise, and other catastrophic consequences (Zhang and Umair, 2023).

In light of these challenges, the deployment of economic instruments has become increasingly essential as a strategy to address the root causes of unsustainable resource management. Economic instruments encompass a variety of policy tools, such as taxes, subsidies, cap-and-trade systems, and fiscal policies, specifically designed to modify the economic incentives and disincentives associated with resource use (Umair and Dilanchiev, 2022). These tools function by internalizing externalities, meaning they account for the environmental costs related to resource extraction and utilization in economic decision-making.

Carbon taxes represent a significant economic tool aimed explicitly at reducing greenhouse gas emissions. By imposing a carbon price, these taxes create a financial incentive for companies to lower their emissions. The objective of implementing carbon taxes is to align economic incentives with environmental objectives. By leveraging a carbon pricing mechanism, businesses are encouraged to adopt cleaner technologies, improve energy efficiency, and transition to renewable energy sources. Empirical evidence supports the effectiveness of carbon pricing in reducing emissions. For example, research by Usman et al. (2020) indicates that carbon taxes can lead to substantial emissions reductions without adversely impacting economic growth. Case studies from countries like Sweden and Australia demonstrate the success of carbon pricing systems in curtailing emissions from resource-intensive industries.

Fiscal policy complements carbon taxes by offering a broader array of tools to enhance natural resource efficiency. Governments can implement fiscal policies to promote sustainable practices, drive innovation in resource-efficient technologies through research and development, and facilitate the adoption of circular economy principles. The effectiveness of fiscal policies in advancing sustainable resource management is underscored by studies such as Ślusarczyk et al. (2022), which emphasize the importance of integrating fiscal policy tools with regulatory measures to achieve environmental sustainability.

The key contributions of this study include:

- Analyzing the BRICS nations from 1995 to 2018 to assess how fragmented energy policies have supported their needs, with a specific focus on examining the impact of fiscal policy and carbon taxes on environmental degradation. This research seeks to enrich the existing body of knowledge by exploring the previously under-examined relationship between fiscal policy and environmental degradation in BRICS countries, while also highlighting the significance of robust environmental regulations.
- Introducing a novel indicator called consumption-based Environmental Index (EI), which accounts for the effects of global trade, differentiating it from prior studies that utilized a traditional EI. Moreover, this study employs advanced econometric techniques, specifically the Augmented Mean Group (AMG) and Cross-sectionally-Dependent Mean Group (CCEMG) estimators, which effectively handle cross-sectional dependence, heterogeneity, and multicollinearity, thereby ensuring accurate results.
- Utilizing a panel quantile regression model to investigate the socioeconomic factors influencing EI levels in BRICS countries across different quantiles, employing a non-parametric approach that diverges from conventional parametric methods. This method is necessitated by the significant variations in per capita economic instrument rates among BRICS nations.

References

[1] Lazareva N.V., Kushch E.N., Semenova L.V. Economic security and compliance in business processes//Journal of Monetary Economics and Management. - 2023.- No. 4. - P.134-137

[2] Guryanova A.V., Timofeev A.V. Noospheric globalization in the context of the sustainable development model // Economic and social-humanitarian studies. 2023. No. 1 (37). P. 103-110.

[3] Tolchinskaya M.N. Possibilities of digital technologies as a tool for developing enterprise economics//Journal of Monetary Economics and Management. - 2023.- No. 4. - P. 222-228

[4] Zahra SA (2021) The resource-based view, resourcefulness, and resource management in startup firms: a proposed research agenda. J. Manag 47(7):1841–1860

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. С. 239-245.

[7] Lolaev B.B., Omarov Z.Z. Prospects and problems of regional economic development in

the digital era//Journal of Monetary Economics and Management. - 2023.- No. 4. - P.229-234

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Kivarina M.V., Babaeva Z.Sh. Transformation of the world and its impact on sustainable economic development // Military-Economic Bulletin. - 2022 No. 4

[10] Isaev M.G. The role of digital services and technologies to improve business efficiency in the digital environment // Military-Economic Bulletin. - 2023 No. 2

SUSTAINABLE DEVELOPMENT OF PRIMARY HEALTH CARE SYSTEMS

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Abstract

Sustainable development of primary health care systems is the basis for ensuring universal access to health services and improving the health of the population. The most important aspects of a sustainable approach are equity, accessibility and focus on the needs of the local community, which includes both disease prevention and treatment. Key areas of development are strengthening the medical infrastructure, improving the skills of personnel and introducing digital technologies to improve the quality of services. Adopting a strategy aimed at eliminating the social determinants of health helps to increase the resilience of health systems and their readiness to respond to emergencies. Involving the population in decision-making processes helps to more accurately take into account local needs and improve health literacy. Sustainable primary health care systems can significantly reduce health care costs, improve quality of life and contribute to a healthier society.

Keywords: primary health care, sustainable development, universal health coverage, health systems strengthening, health equity, community engagement, health workforce, social determinants of health, health infrastructure, digital health technologies

I. Introduction

Primary health care (PHC) is the foundation of any sustainable health system, providing accessible, comprehensive and equitable health care. The need for PHC development has increased significantly in recent decades due to global health challenges, including demographic changes, the rise of chronic diseases, pandemics and climate change. Sustainable development of primary care systems aims to create flexible and resilient structures that can adapt to the changing needs of society and effectively respond to new challenges.

One of the key challenges is to achieve universal health coverage (WHO), which requires expanding access to quality PHC services for all segments of the population, including vulnerable and disadvantaged groups. Sustainable development of PHC also involves eliminating health inequalities, when socioeconomic factors such as income, education and living conditions affect access to health care and people's health. This requires the implementation of integrated approaches aimed at improving the social determinants of health and involving local communities in decision-making.

The integration of modern technologies and innovations in primary health care also plays a key role in sustainable development. Digital technologies, telemedicine and electronic record-keeping systems can significantly improve the efficiency of health care delivery, especially in remote and hard-to-reach areas. The introduction of such technologies improves coordination between different levels of health care, facilitates timely provision of care and reduces the burden on specialized institutions.

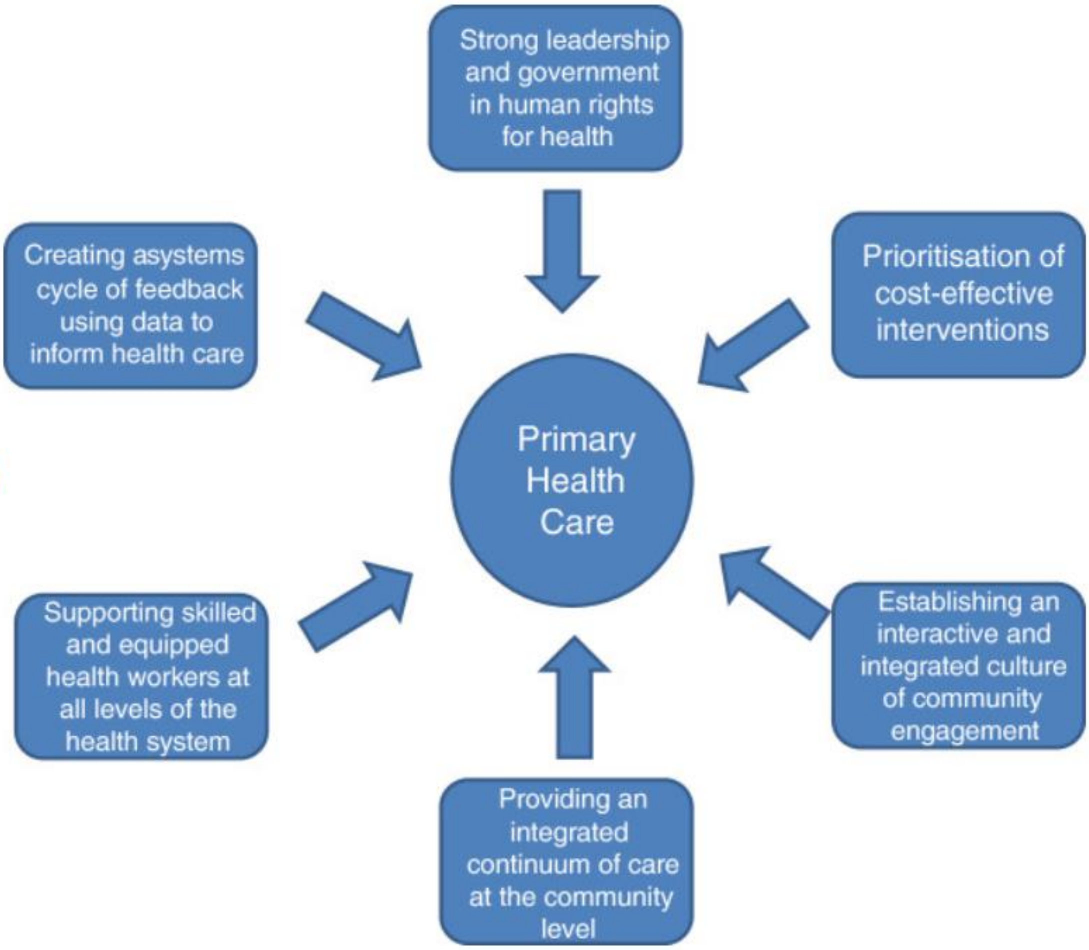

Figure 1: *Core principles & components for effective implementation of primary health care*

However, despite significant achievements, many countries continue to face challenges related to insufficient funding, shortages of health workers and weak infrastructure. These problems are exacerbated by inequalities in access to quality health services, especially in low- and middle-income countries. Developing sustainable primary health care systems requires a comprehensive approach that includes health policy reform, improved workforce training and the creation of stable financial mechanisms to ensure sustainability.

Sustainable development of primary health care is therefore a prerequisite for achieving the Sustainable Development Goals (SDGs) related to health and well-being. This paper examines key strategies and approaches to strengthen PHC systems, including the introduction of technology solutions, policy reform, and community engagement in health governance and decision-making processes.

II. Methods

This study employed a comprehensive approach to analyze the contributions of primary health care to achieving health-related Sustainable Development Goals (SDGs). The methods utilized included:

1. **Literature Review**: An extensive review of existing literature on primary health care and its role in public health was conducted. This involved analyzing peer-reviewed articles, reports from international organizations, and relevant policy documents.

2. **Data Collection**: Quantitative data was gathered from national health statistics and databases, focusing on indicators related to health outcomes, access to primary care services, and SDG progress. Qualitative data was also collected through interviews with healthcare professionals and stakeholders to gain insights into barriers and facilitators of primary health care implementation.
3. **Stakeholder Analysis**: Key stakeholders, including government agencies, non-governmental organizations, and community representatives, were identified and engaged. Their perspectives on the effectiveness of primary health care services and their impact on health equity were sought.
4. **Case Studies**: Specific case studies were conducted in various regions to illustrate best practices and challenges in primary health care delivery. These case studies provided context-specific insights and highlighted successful interventions that align with SDG objectives.
5. **Policy Recommendations**: Based on the findings, policy recommendations were developed to enhance the effectiveness of primary health care services. These recommendations aimed to address identified barriers and promote multisectoral collaboration to achieve health-related SDGs.

The analysis emphasized a holistic view of primary health care, integrating both health service delivery and broader determinants of health to provide a comprehensive understanding of its role in advancing public health goals.

III. Results

The global significance of primary health care (PHC) has grown, proving to be an effective strategy for enhancing community access to health services. Multilateral organizations and national governments have reached a consensus on the fundamental principles of PHC; however, its implementation varies across countries due to the unique characteristics of local health systems. This article is motivated by an investigation into the PHC models and strategies applied in the Americas and an examination of health network configurations from a PHC perspective.

A systematic literature review was conducted utilizing keywords across at least nine databases. Exclusion criteria included languages other than English, Portuguese, and Spanish, and non-refereed articles, while regional gray literature was included. This process identified 1,146 articles, of which 142 were selected after three rounds of analysis. The selected articles were categorized into six thematic areas.

The evidence gathered on health reforms within the region highlights the necessity to strengthen care strategies backed by PHC and resilient care networks that can adapt to the changing needs of the population and respond to medium- and long-term epidemiological trends.

The Commission's deliberations explored ways to use health financing mechanisms to incentivize national health systems to deliver equitable, comprehensive, integrated and high-quality primary health care (PHC). These services should be delivered through platforms that are responsive to people's needs and fully aligned with the goals of universal health coverage (UHC). We argue that countries must invest more and better in PHC, and that the financing mechanisms that support PHC – from resource mobilization and pooling to budgeting, allocation and purchasing – must put people at the centre.

We detail the key characteristics of people-centred PHC financing. We recognize that the scope for reorienting health financing policies towards PHC depends on the economic, social and political context of a particular region, country or subnational level, and that there is no single path to achieving optimal PHC financing.

Thus, the approach to funding must take into account both local conditions and the need to ensure equity and social justice in the provision of primary care.

PHC is based on the principle that health is a fundamental right, emphasizing disease prevention and health promotion while necessitating intersectoral coordination and community involvement. As the first point of contact between the population and the health system, it plays a vital role in health care delivery.

Primary health care (PHC) is regarded as a crucial strategy in the health sector, as it fosters social development, encourages community participation, and promotes overall well-being within societies.

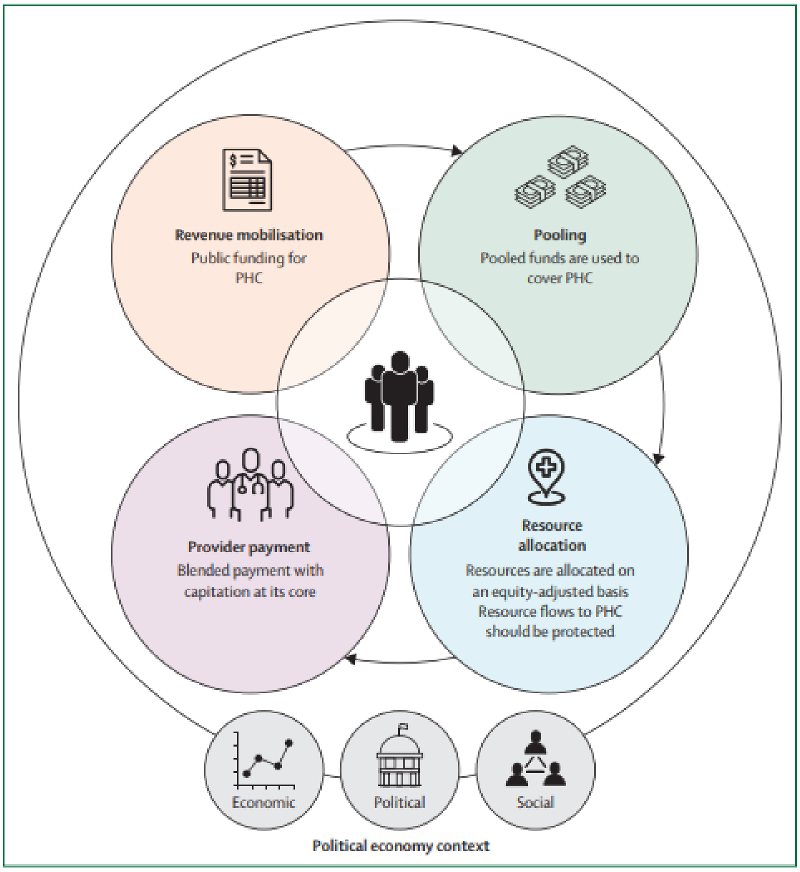

Figure 2: *Framework for people-centered financing of PHC*

Towards the late 1980s, the WHO/PAHO underscored the need to organize health services into various levels of care and develop referral systems to facilitate regional health service planning. The importance of integrated and decentralized care levels was reaffirmed by PAHO Member States in 2005 through the Montevideo Declaration and the Health Agenda of the Americas 2008–2017. The document titled "Integrated Health Services Networks," part of the "Renewal of Primary Health Care in the Americas" series, serves as the foundation for health system reforms that, within the PHC framework, aim to reorient, strengthen, and deepen four primary areas: care models, network governance and strategy, resource organization and management, and economic incentives.

Countries in Latin America have historically faced significant inequalities, not just in health outcomes but also in income distribution, education, access to clean water, and sanitation. By the early 1990s, nearly all Latin American and Caribbean nations had initiated or were considering health sector reforms. Key policies included the separation of functions, decentralization, improvements to health insurance schemes through patient nominalization, and the establishment of explicit service packages. In some instances, these reforms encompassed broader changes to state structures, including national constitutions.

Various studies indicate that health system reforms in Latin American countries have promoted inclusion, citizen empowerment, and health equity, leading in many cases to the establishment of legal rights associated with health and universal coverage, thereby reducing disparities in health indicators among different income groups. Motivated by social justice and equity, civil society has played a pivotal role in advocating for citizen rights and the right to health. An example of this is the work of the Latin American Social Medicine (LASM).

At the international level, several organizations, including PAHO, WHO, UNICEF, and the World Bank, have significantly influenced the region's health system performance and outcomes, promoting the adoption of PHC proposals. With the dawn of the new century, PHC gained even greater global importance as a mechanism for effectively addressing the needs of health systems. Various approaches to PHC implementation have emerged, including comprehensive (CPHC), selective (SPHC), and renewed (RPHC) models.

The comprehensive approach views PHC as part of an integrated health care system linked to the socio-economic development of society, emphasizing cooperation with other sectors. However, it has faced criticism for being overly idealistic and difficult to implement across different communities. The selective approach subsequently emerged, focusing on specific interventions for high-risk populations but lacking the social equity, intersectoral collaboration, and community participation integral to CPHC. Lastly, the renewed approach combines family and community perspectives to strengthen existing health systems, aiming for equity and sustainability in access and the delivery of health services to defined populations and territories, incorporating elements of citizenship, social participation, and empowerment.

IV. Discussion

While access and continuity of care are fundamental goals in any primary care strategy, the high level of unmet health needs among populations relying on both public and private sector coverage highlights that the care demands surpass the capacity of any single provider. Health outcomes—and outputs—are the result of collaborative efforts, requiring the coordination of multiple levels of care and interdisciplinary cooperation. Therefore, implementing effective healthcare networks and ensuring care provision in fragmented systems through a robust regulatory framework are critical elements of a comprehensive primary health care (PHC) strategy.

The complexity of coordinating healthcare networks, which often operate across multiple overlapping jurisdictions as a result of decentralized and/or segmented systems, poses additional challenges. Common obstacles to efficiency in networked healthcare systems include breakdowns in referral and counter-referral mechanisms, the absence of standardized patient information, poor performance of the bodies responsible for coordinating services, a lack of commitment or training among healthcare personnel, and the failure to incorporate perspectives on ethnic and cultural diversity. As a result, understanding why healthcare networks fail requires a comprehensive approach.

Key elements that contribute to the effective functioning of healthcare systems include financial incentives and mechanisms for integrating new technologies. Financial incentives, along with a wide array of policies aimed at strengthening healthcare careers, can encourage healthcare workers to adopt preventive practices, make sound diagnostic decisions, and provide informed treatment. Reputation-based incentives also play a role, particularly when performance data on healthcare professionals is made public. Technology integration has proven beneficial in facilitating learning, promoting cooperation, and improving monitoring procedures, especially in rural areas, complementing care at the primary level.

Beyond this, the presence of multiple jurisdictions within a network raises important discussions about the vertical integration of services, not only in terms of ownership but also in governance, oversight, and coordination. When funding sources are not aligned, service integration must focus on establishing regulatory and procedural links to distribute tasks and responsibilities effectively, ensuring complementarity and requiring a shared monitoring framework.

Thus, network governance becomes a crucial aspect for managers and policymakers to consider when setting priorities in a PHC plan. Strong leadership is essential to bring together different interests and change entrenched practices, serving as the foundation of network governance. The institutional design of regional health systems, political and economic conflicts, and the values of the involved actors are all critical factors that shape the regulation of PHC. Consequently, disconnects between stakeholders and weak leadership within health systems influence the effectiveness of PHC strategies.

Since 1978, the concept of primary health care (PHC) has undergone various interpretations and definitions, causing confusion in the understanding of the term and its practical application. To ensure more coordinated action at the global, national and local levels, the following definition has been proposed:

"PHC is an integrated approach to health that covers the whole of society and aims to achieve equitable access by every member of society to the highest possible level of health and well-being. It addresses the needs of the population at the earliest stages, providing a wide range of services, from health promotion and disease prevention to treatment, rehabilitation and palliative care, as close as possible to people's daily lives." This definition has been developed by WHO and UNICEF within the framework of the PHC concept for the 21st century, with a focus on achieving universal health coverage (UHC) and the Sustainable Development Goals (SDGs).

The PHC system includes three interrelated components:

1. A comprehensive set of health services, with an emphasis on primary health care, public health and related functions.
2. Intersectoral policies and actions that address the key determinants of health.
3. Engaging and empowering individuals, families and communities to actively participate in managing their health and social lives.

The concept of PHC is based on the values of social justice, equity, solidarity and cooperation. It is based on the recognition that the enjoyment of the highest attainable standard of health is a fundamental human right, regardless of status or condition. Achieving true universal health coverage requires a shift from disease-focused systems to people-centred and participatory systems. This requires governments at different levels to recognise the importance of action beyond the health sector to implement a whole-of-government approach to health, with a particular focus on equity and the entire life course. The concept of PHC aims to address a wide range of determinants of health and pays attention to the integrated aspects of physical, mental and social health. This approach ensures high-quality and comprehensive care at all stages of a person's life, not just the treatment of individual diseases, with a focus on maximum proximity to the patient's place of residence.

While there have been notable achievements in building primary health care (PHC) systems and health networks in Latin America, as reflected in key health indicators, there are still critical issues that need to be addressed based on the evidence analyzed. First, while the concept of PHC is embedded in institutional discourse and sectoral debates across the region, it faces significant challenges from the organizational structures of health systems. Intense fragmentation, ineffective decentralization, and the accumulation of isolated programs along the care continuum have led to the consolidation of a care model that deviates from best practices.

Profound income inequality acts as a segmentation mechanism, creating different levels of coverage based on individuals' ability to pay. In recent decades, most countries in the region have made efforts to promote coordinated care models, but results have been uneven, and monitoring and evaluation of the impact achieved have been scarce. The limited coordination between subsystems amplifies disparities, leading to the development of fragmented health networks that often operate informally and without standardized protocols. Collaboration between providers within different subsystems is minimal, and the private sector does not function as a space for coordination and complementarity with the public sector or, in some cases, social security systems. Instead, it often exacerbates care gaps.

The evidence gathered for this review has highlighted several key themes discussed throughout the document. Most notably, there is a pressing need to strengthen PHC models and care networks, as indicated by the documented results. Additionally, the review identified gaps in coverage of other critical topics, such as how health systems adapt to evolving population needs and the accumulation of epidemiological challenges, including mental health issues, addictions, and environmental impacts.

Furthermore, this review found a lack of literature on the impact of financial and non-financial incentives on health service provision, resource allocation efficiency, and quality improvements, opening avenues for future research. This gap suggests a need for deeper interaction between research and political action in the Latin American and Caribbean region to facilitate information exchange, strengthen the evaluation of interventions, and jointly design a research-action agenda that has a meaningful social impact.

References

[1] WHO. Global spending on health 2020: weathering the storm. Geneva: WHO, 2020

[2] Rahim F, Allen R, Barroy H, Gores L, Kutzin J. COVID-19 funds in response to the pandemic. Washington, DC, WA: International Monetary Fund, 2020.

[3] Andrews M, Cangiano M, Cole N, De Renzio P, Krause P, Seligmann R. This is PFM. CID Working Paper no 2852014. ttps://www.hks.harvard.edu/centers/cid/publications/facultyworking-papers/pfm (accessed July 20, 2021)

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A.S., Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

[11] Gunya, A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

SOCIO-ECONOMIC ASPECTS OF SUSTAINABLE DEVELOPMENT OF THE REGION

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Abstract

The article discusses the issues of ensuring security at the regional level, which are quite complex and related to reforms in the economic, social, and environmental spheres. The analysis of the views of researchers whose scientific works relate to the coverage of the problems of ensuring social, environmental, and economic security is carried out. It has been established that socio-ecological-economic security should be understood not only as restoring the broken relationship between man and nature and harmonizing their coexistence, contributing to the measured, reasonable use of the resources available on the territory by man, but also ensuring a balance at a level to which a person can adapt physically, without losses (social, economic). The author's definition of the concept of "socio-ecological-economic security of the region" is presented and the features of its provision on the basis of sustainable development are revealed.

Keywords: economic development, regional policy, sustainable development, environmental safety, nature management

I. Introduction

The environmental situation not only in our country, but throughout the world became so aggravated at the end of the 20th century that at the beginning of the 21st century, the leading countries of the world are forced to look for opportunities to influence all entrepreneurial projects to ensure environmental safety. Moreover, we are talking about achieving sustainable development, when, without yielding in competition in various markets, companies will implement environmentally friendly technological measures. The problem of ecology is an important aspect of the existence of any country. In order to ensure normal ecological and economic living conditions for people, the concept of sustainable development was developed, which has been trying to implement in countries of all continents for several decades. The concept of sustainable development can play an important role in determining regional priorities and strategies for their socio-economic development of the regions.

The dominant vector of the fundamental vector of the regional policy of sustainable development is the imperative to preserve the functioning of the ecosphere (habitat) at a safe and sufficient level to meet the needs of mankind.

II. Methods

The problems of ensuring security at the regional level are quite complex and are associated with reforms in the economic, social, and spiritual spheres. This is especially relevant now, when there is a strengthening of the role of regional development in the implementation of the socio-economic and environmental policy of the state by ensuring socio-ecological-economic security and determining its impact on the sustainable development of territories.

Numerous works of domestic and foreign researchers are devoted to the problems of sustainable development. They are mainly concerned with sustainable development at the global level and at the level of countries and regions. However, there are also scientific studies on the implementation of the principles of sustainable development in the activities of enterprises. For example, in [3], the authors explore the relationship between human capital management and sustainable development, substantiating environmental management of human resources and management of human capital recovery at enterprises as a tool for sustainable development at the micro level. The essence of sustainable development of the enterprise is explained on the basis of ensuring the increase in human capital and the preservation of natural resources for future generations in work [8]. On the other hand, the economic feasibility of implementing the global goals of sustainable development at the level of each individual enterprise through the mechanism of public-private partnership is substantiated in the work [5]. The paper [6] substantiates the expediency of diversifying the sources of financial support for the sustainable development of the enterprise.

Of particular importance are scientific works in which the mechanisms of sustainable development of enterprises and regions or the economies of countries are integrated, since they make it possible to achieve synergy of a combination of multi-level systems of socio-ecological-economic development. For example, the work [2] demonstrates the scientifically based possibilities of forming an enterprise development strategy in such a way as to ensure the sustainable development of the region. The assessment of the impact of risk factors on the sustainable development of enterprises and its economic and mathematical formalization is given in [4].

However, most scientific works relate mainly to certain aspects and most often have a descriptive nature of the problems of ensuring social, environmental, and economic security. For a more detailed analysis, there is a need to consider the integral concept of "socio-ecological-economic security" as one of the most important needs for sustainable development of regions.

The main purpose of the article is to study the fundamental principles and priority areas of ensuring the socio-ecological-economic security of the region as a condition for sustainable development.

In 2015, at the UN summit on sustainable development, the sustainable development paradigm of preserving available resources for future generations was decomposed into 17 global goals that humanity needs to achieve. Thus, it can be argued that over the past 32 years, sustainable development has not lost its relevance, but continues to be the main ideology of our time, which has acquired more specific contours in the expression of global goals. In turn, the global goals for overcoming poverty, hunger, providing quality education and others require a search for mechanisms and tools for their implementation. If the global economic system is not reorganized in accordance with the principles of sustainable development as a socio-economic-ecological balance, then it will face an economic recession, environmental depression and social instability.

The formation of a highly civilized society today is impossible without solving the problem of environmental security, which is one of the main problems not only in the national economy, but also in the system of world economic relations as a whole. The intensification of globalization in the world economy causes the aggravation of the problem of protecting the environment from the consequences of anthropogenic human activity. Sustainable development of the economy involves such changes in the technological re-equipment of production that will not affect the environment and will not have a negative impact on the life of people, and will not interfere with life and reproduction of the natural environment. To meet these requirements, the world community has adopted a number of international agreements, to which our country has acceded.

One of the leading areas of sustainable development is the preservation of the environment, which is most influenced by man-made factors, and their sources are industrial enterprises. The implementation of measures aimed at changing the technological schemes of production taking into account the requirements of sustainable development undoubtedly requires significant financial resources. It is well known that the enterprises themselves are not able to financially support environmental protection programs. Expenditures on environmental protection measures are perceived by them as a diversion of working capital and the creation of prerequisites for a decrease in solvency. They need appropriate funds, which can be obtained, including at the expense of credit funds. Instead, the problem usually arises that environmental measures are not profitable. Only a change in the production apparatus (equipment, composition of raw materials, etc.) can serve both to make a profit and to protect the environment.

III. Results

The effectiveness of the implementation of environmental programs depends on the influence of such institutional factors as the level of education and culture, public awareness, the desire of the population to influence environmental policy in the state, historical and national traditions, the experience of other countries, the structure and functions of state bodies, regulatory legal acts and the right of ownership of natural resources. A successful combination of all the above elements will make it possible to obtain optimal results in the implementation of environmental programs. It should be noted that it is not enough to change or improve the vector of action of only individual official and unofficial restrictions (for example, legislation or the powers of public authorities), it is necessary to correct the influence of the entire set of factors. In order to finance environmental projects, it is necessary to use the partial receipt of funds from enterprises polluting the environment by motivating them to ecologize production and allocating funds for environmental protection measures. The model of motivation of business entities is based on the use of various groups of administrative regulators and economic instruments. The above approach provides for the use of coercion of entrepreneurs to reduce environmental pollution through prohibitions and restrictions, and the further introduction of incentives (provision of benefits) to environmental activities. The best results can be achieved with an adequate combination of economic interest with control and coercion.

Sustainable development should be aimed at achieving a high quality and safety of life of the population, a clean environment with positive dynamics of a set of indicators of sustainable development - indicators that make it possible to judge the state or changes of an economic, social or environmental variable. In the context of this study, the integral index is considered - socio-ecological-economic, with the help of which it is possible to comprehensively judge the development of the region. With this in mind, each economic project should be supported by appropriate technological support, taking into account socio-environmental-economic security.

In view of this, in the work the author [7] appropriately notes that the economy should be environmentally safe, and the environment should be economically feasible. In this aspect, the model of development of the country and its regions, based on a combination of social, environmental and economic policies, is of the greatest relevance and significance.

According to another scientist [8], such a model of sustainable development is possible only in the case of the formation of the noosphere (the sphere of reason), where the measure of national and individual wealth will be the spiritual values and knowledge of a person living in harmony with the environment. And since this is a prospect of the distant future, it is proposed to implement the idea of security as one of the most important basic needs of mankind in the conditions of the present. According to the Constitution of the Russian Federation, "The dignity of the person is protected by the state. Nothing can be the basis for its derogation" [1]. Security is becoming an all-encompassing category that unites most of the problems of protecting the population from any threats. Security is primarily the result of active intraregional social and political stability and effective economic development of the region.

It is within the region that it is possible to establish an optimal combination of social, environmental and economic types of security, which are closely interrelated and affect each other in a single concept of "socio-ecological-economic security". Accordingly, the state of each type of security acts both as a condition and as a consequence of the development and functioning of the other two.

IV. Discussion

The initial thesis of the above is the recognition of socio-ecological-economic security as the main prerequisite for the sustainable development of the region, which includes a set of actions and a set of appropriate measures, processes that ensure the prevention and neutralization of real and potential threats to regional interests. Socio-ecological-economic security establishes the relationship between man and nature and harmonizes their coexistence, as well as contributes to the measured, reasonable use of the resources available in the territory by man. Socio-ecological-economic security reveals the integral potential of the territory as an important factor in its sustainable development.

Thus, the synthesis of all the above characteristics makes it possible to understand socio-ecological-economic security not only as establishing a broken relationship between man and nature and harmonizing their coexistence, contributing to the measured, reasonable use of the resources available in the territory by man, but also ensuring a balance at a level to which a person can adapt physically, without losses (political, social, economic).

Socio-ecological-economic security in the regional dimension provides for the identification of its features due to the presence, in addition to the generalizing criteria for ensuring such security, of specific grounds that affect the strengthening or weakening of the state of security in a particular region. Among the factors of socio-ecological-economic security of sustainable development of the region, the following should be highlighted:

– economic – the level of economic development of a particular region and its disproportions that arise between regions in one way or another; stability of the economy, providing for the reliability of all elements of the economic system, protection of property, creation of guarantees for effective entrepreneurship;

– social – factors of indirect influence of the economic and geographical location of the region. That is, such a factor provides for a sufficient amount of material benefits, social guarantees necessary for the life and reproduction of the potential of the population living in certain regions;

– environmental – preservation of an optimal habitat, expanded reproduction of renewable resources of the biosphere, development of alternative production technologies; ecologization of all spheres of human activity, development of an organizational and economic mechanism for the use of natural resources, environmental and resource profitability; development of environmental awareness and culture.

It is impossible to abstract from the relationship between environmental and economic security, since they are components of the national security of the country. Their interrelation consists in determining the measure of responsibility for compliance with the proper state of environmental safety by business entities at all levels of their interaction. In this case, the concept of environmental safety is directly related to the anthropogenic activity of society, its socio-economic, cultural and historical consequences and measures to overcome them. At the same time, the problem of environmental safety is actualized at all levels without exception - from the micro level to the global level, that is, it is characterized by a hierarchy of goals, tasks and means of solving them.

The problem of preserving the human habitat is important for both present and future generations. Therefore, it is necessary to find a way out, for which it is worth paying attention not only to environmental measures, but also to the replacement of technological schemes. To protect against harmful emissions, there is no alternative to the need to introduce treatment facilities, all kinds of filters, aerators, etc. However, this first direction is unlikely to ever directly serve to obtain a source of repayment of funds to credit institutions. The second direction – lending to the technological process taking into account the requirements of environmental protection – can ensure profit and thus directly serve as a source of funds for settlements with creditors.

Ensuring the socio-ecological and economic security of the region is possible only when the interests of all participants in the process of regional development are taken into account - enterprises, industries, cities, districts, etc.

State regulation of the development of regions should be considered a purposeful systematic influence on the part of the state aimed at maintaining the socially oriented, sustainable and balanced development of the regions in order to ensure the highest and most equal social standards of life of the population regardless of place of residence, which consists in the creation of the necessary regulatory framework, institutional, information and personnel support for the development of regions. The use of program-target methods and appropriate financial and economic tools. Intensification of the use of the regional potential for the development of the territory should take place in the following directions: increasing the efficiency of the functioning of the system of managing the socio-economic potential in the regions; search for the optimal balance of local, regional and state interests; improving the methods of forming local and regional markets and their infrastructure in the context of ensuring the competitiveness of the national economy; formation of investment policy taking into account the specifics of specific regions; formation of an effective system of property management of various forms of ownership; intensification and improvement of the efficiency of the use of local resources.

The priority tasks of the regional policy aimed at improving socio-ecological and economic security are the development and implementation of long-term development programs: the development of both the most profitable and promising industries at the moment, and industries with long-term economic advantages; linking the development of the social sphere at its own expense with state regulation and subsidies for social development; protection of the natural environment and vital human interests from the possible negative impact of economic activity.

In the course of implementing these tasks, in order to ensure the socio-ecological-economic security of the region, it is necessary to adhere to the principles aimed at: improving the legal framework for ensuring the adoption of unequivocal decisions in the event of conflict situations; preservation of resource potential, restoration and development of the production potential of the region; development of the budgetary and financial policy of the regions; training of qualified personnel; conducting a comprehensive environmental assessment of the territory; environmental monitoring; creation of a cadastre of natural resources in the form of databases and a set of maps compiled using GIS technologies; implementation of a specialized system of public administration.

Along with the above, it is worth determining the basic indicators that characterize the level of development of socio-ecological-economic security, a comprehensive assessment of which will allow us to talk about the level of this type of security in the region. Only in this case will the analysis of the socio-ecological-economic security of the region reflect quantitative and qualitative changes. The complexity of developing such a methodology is associated with the set and accounting of a variety of multidirectional indicators.

As a basis for an objective assessment of socio-ecological-economic security, it is proposed to use the procedure of indicative analysis, which allows not only to assess the level of security, but also to compare it with other regions. The system of public management of socio-ecological-economic security in the context of sustainable development of the region provides for the formation of indicators related to various spheres of life. It is within the region that the indicator of the quality of life of the population should be, on the one hand, an integral indicator of the socio-economic development of the region, and on the other hand, a criterion for assessing the socio-ecological and economic security of the region.

To this end, it is proposed to identify blocks of indicators that characterize the level of quality of life of the population, in particular, blocks of complex indicators, such as: socio-economic development; entrepreneurial activity; balanced distribution of income; environmental safety; material well-being and level of consumption; demographic situation; social infrastructure; public health. Methodologically, it is important to ensure the conduct of information-analytical and mathematical-statistical studies of this process in the case of determining indicators of the quality of life of the population, which is one of the necessary components of assessing the socio-ecological security of the region. A comprehensive analysis of the quality of life of the population is determined in dynamics by years and in mutual comparison, which provides additional arguments for making management decisions and determines the degree of threat to the socio-ecological-economic security of the region. In general, the highest indicators of integral indices of the quality of life mean the presence of real potential in the use of available environmental, economic, social, and administrative resources.

The fundamental task of the sustainable development strategy is to ensure the conditions for the balanced functioning of the social, economic and environmental components of the "society-economy-nature" system. Among the basic conditions for sustainable development is equalizing the level of quality of life in different countries and ensuring the growth of well-being in the future. Therefore, poor countries need to step up their efforts and catch up with more developed countries. But improving the quality of life must be based on new scientific advances, especially in the context of the fourth industrial revolution. Modern conditions require everyone to reduce resource consumption, switch to alternative types of materials and energy sources, introduce advanced resource-intensive waste-free technologies, reducing the burden on the environment and human health.

The study made it possible to propose a definition of the concept of "socio-ecological-economic security of the region" as a state of dynamic balance and security, in which the available opportunities to protect the territory from the negative impact of external and internal destabilizing factors are based on a "reasonable" balance between maintaining a favorable ecological environment, economic growth rates and ensuring social standards and guarantees in conditions of sustainable development of the region. Taking this approach as the basis for the regional level, it is proposed to continue and deepen theoretical and methodological studies of indicators of socio-ecological-economic security in the regional dimension, to develop a universal integral indicator of the level of socio-ecological-economic security, which would most fully reflect the state of socio-ecological-economic security of each individual region of our country.

References

[1] The Constitution of the Russian Federation: adopted on December 12, 1993. Moscow, Omega-L Publ., 2021. – 39 p.

[2] Artemova I. D. Znachenie strategii i biznes-modeli v ustoychivogo razvitii predpriyatiya [The importance of strategy and business models in the sustainable development of the enterprise]. // Ekonomicheskiy analiz, – 2023. – №. 3. – P. 428-438.

[3] Baranova N.M., Sorokin L.V. An impact of human capital on the sustainable economic development. // Ekonomicheskiy analiz, – 2017. – T. 16, No 12. – P. 2224-2237

[4] Guzey V.A. Analysis of factors influencing the sustainable development of the organization. // Ekonomicheskiy analiz, – 2024. – №1(43). – P. 2-8

[5] Lepikhin V.V., Uzhegova K.A. Public-Private Partnership as a Mechanism for Ensuring Sustainable Development of the Economy. – 2014. – № 11-1. – P. 146-149;

[6] Peshkova A.A. Vybor finansovoy strategii ustoychivogo razvitiya predpriyatiya [Choice of financial strategy of sustainable development of the enterprise].

[7] Salamatov A.A. Ecologization of Economic Training of Senior Schoolchildren in the System of Profile Education. … D. Ped. N.: 13.00.01. – Chelyabinsk, 2010. – 418 p.

[8] Ursul A.D. Formation of Sustainable Civilization: New Global Goals // Philosophy and Society, – 2016. – № 1. – 29–56

THE ROLE OF GREEN ECONOMY IN ACHIEVING SUSTAINABLE DEVELOPMENT GOALS: PROSPECTS AND CHALLENGES FOR BUSINESS

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Abstract

The concept of a green economy plays a pivotal role in advancing the Sustainable Development Goals (SDGs) by promoting environmentally sustainable economic growth while addressing social and environmental challenges. This article explores the prospects and challenges businesses face in transitioning towards a green economy. It highlights how adopting green practices can lead to innovation, resource efficiency, and new market opportunities, while also addressing climate change, pollution, and resource depletion. However, businesses must also confront obstacles such as high initial investment costs, regulatory complexity, and the need for technological advancements. The paper examines case studies from various industries to demonstrate successful implementations of green strategies and provides recommendations for businesses to align with global sustainability objectives. By embracing green economy principles, companies can enhance competitiveness, contribute to environmental preservation, and support the achievement of the SDGs.

Keywords: green economy, sustainable development goals (SDGs), business sustainability, environmental sustainability, resource efficiency, climate change

I. Introduction

The growing awareness of environmental degradation and the need for sustainable development has brought the concept of the "green economy" to the forefront of global economic discourse. As the world faces pressing challenges such as climate change, resource depletion, and social inequality, the green economy offers a pathway to align economic growth with environmental sustainability. Central to this approach is the achievement of the Sustainable Development Goals (SDGs), a global framework set by the United Nations to address critical issues such as poverty, hunger, environmental protection, and social equity by 2030.

A green economy promotes economic development that minimizes environmental risks and ecological scarcities while fostering social inclusiveness. By integrating sustainable practices into business operations, the green economy seeks to decouple economic growth from environmental harm, ensuring that future generations have access to the resources and opportunities needed for their own development. For businesses, this shift represents both a challenge and an opportunity. On the one hand, companies are confronted with the need to adopt cleaner technologies, more efficient resource use, and more responsible corporate governance. On the other hand, these changes open up new markets, drive innovation, and enhance long-term competitiveness.

This paper examines the role of the green economy in achieving the SDGs, with a particular focus on the opportunities and challenges for businesses. By analyzing case studies and reviewing current trends, the paper aims to highlight how businesses can contribute to a greener future while maintaining profitability and market relevance. The discussion will also explore the regulatory, financial, and technological barriers that must be overcome for the green economy to become a mainstream model of economic development.

II. Methods

To explore the role of the green economy in achieving Sustainable Development Goals (SDGs) and to analyze the prospects and challenges for businesses, a comprehensive methodological approach was adopted. This approach includes both qualitative and quantitative research methods, structured around the following key components:

1. Literature Review:

A thorough review of existing literature was conducted to identify the theoretical foundations of the green economy and its relationship with the SDGs. Sources included academic journals, books, and reports from reputable organizations such as the United Nations, World Bank, and various environmental NGOs. This review provided insights into the current state of knowledge and highlighted gaps that the study aimed to address.

2. Case Studies:

Several case studies of businesses that have successfully integrated green economy principles into their operations were selected for in-depth analysis. These case studies span various sectors, including renewable energy, sustainable agriculture, waste management, and green technology. The selection criteria included businesses known for innovative practices, measurable impacts on sustainability, and alignment with specific SDGs.

3. Surveys and Questionnaires:

Surveys were distributed to a diverse range of businesses, including small, medium, and large enterprises, to assess their awareness, implementation, and challenges related to green economy practices. The survey included questions on:

- Current sustainability initiatives.
- Perceived benefits and challenges of adopting green practices.
- Financial investments and returns on sustainability initiatives.
- Awareness of regulatory frameworks and incentives related to the green economy.

4. Interviews:

Semi-structured interviews were conducted with key stakeholders, including business leaders, sustainability experts, and policymakers. These interviews aimed to gather qualitative insights into:

- The motivations behind adopting green practices.
- The barriers encountered during the transition to sustainable business models.
- Perspectives on governmental support and incentives for the green economy.

5. Data Analysis:

Quantitative data collected from surveys were analyzed using statistical methods to identify trends and correlations between green economy practices and business performance. Qualitative data from interviews and case studies were subjected to thematic analysis to extract common themes and insights.

6. Comparative Analysis:

The study conducted a comparative analysis of businesses operating in different regulatory environments and economic contexts to understand how these factors influence the adoption of green practices and the achievement of SDGs.

7. Policy Review:

An examination of existing policies related to environmental sustainability and economic development at national and international levels was undertaken. This review helped to contextualize the role of government in facilitating or hindering the transition to a green economy

By employing this multifaceted methodological approach, the study aims to provide a robust understanding of the interplay between the green economy, sustainable development, and business practices, ultimately contributing to the broader discourse on achieving the SDGs.

III. Results

In 1992, the United Nations Conference on Environment and Development highlighted national strategies for achieving sustainable development within the context of the key principles established by the Rio Declaration and Agenda 21. Despite significant efforts by governments worldwide and international cooperation to support these strategies, many nations continue to face concerns and challenges related to ecological sustainability and economic growth. This includes the recent crises in fuel, food, and finance, along with the effects of climate change, resource depletion, and the destruction of ecosystems and biodiversity. Governments around the globe have made various attempts to find effective solutions to help their nations recover from these crises while addressing biodiversity issues and ecological constraints. Consequently, there arose a need for a new concept that encompasses these concerns.

Since its introduction in 2008, the Green Economy (GE) concept has garnered significant international attention, particularly as a response to the financial crisis, and was further emphasized at the UN Conference on Sustainable Development (Rio +20) in 2012. The UNEP defines GE as an approach that integrates three critical aspects: human capital, environmental health, and social equity. The transition to a GE has been a subject of debate, with certain misconceptions surrounding it. For instance, some believe that there is an unavoidable trade-off between environmental sustainability and economic growth. Others argue that the transition to a GE is prohibitively expensive for developing nations and that it could hinder their economic growth, serving primarily the interests of developed countries.

However, a UNEP report from 2011 indicated that macroeconomic projections showed transitioning to a GE could lead to increased growth, job creation, and poverty reduction within a few years. In a GE framework, income growth per capita and employment levels depend on new private and public green investments that are less reliant on the exploitation of natural resources and environmental assets, while also lowering carbon emissions and promoting efficient energy use to mitigate environmental degradation. This approach can enable countries to attain more sustainable economic growth.

Consequently, many developing nations have embraced GE as a new model for economic growth aimed at achieving sustainable development, benefiting various sectors, including renewable energy and agriculture. In the renewable energy sector, solar PV power is expected to become one of the most significant global energy supply sources by 2030 and a leading energy provider by 2050. As part of this vision, China plans to develop a photovoltaic industry with a cumulative installed capacity of 1,050 GW by 2030, positioning itself as a top producer of solar PV technology and the largest exporter, with over 98% of its production sold internationally.

Similarly, Malaysia is enhancing energy access for impoverished communities in rural areas, exemplified by successful renewable energy projects in places like Bario Asal. The Egyptian government aims to produce approximately 42% of its electricity from renewable sources, particularly solar energy, by 2034/35. Additionally, Uganda has made strides in organic agriculture, becoming the 13th largest producer globally by 2003, with a 60% increase in organic farming areas and a 64% reduction in greenhouse gas emissions per hectare compared to conventional agriculture.

Moreover, the GE framework has spurred investments in new sectors such as green technology, green transportation, and green urban development in countries like China, India, Egypt, and Malaysia, resulting in the creation of green job opportunities, economic advancement, and reduced environmental damage, all while addressing climate change challenges. For instance, according to the German Development Institute's 2012 report and a UNEP report from 2014, initiatives in waste management are expected to generate an additional 24,000 jobs in Egypt, while sustainable agriculture could create 8 million jobs by 2050, alongside employment opportunities in recycling, composting, and biofuel production. In Bangladesh, around 3.5 million jobs were generated in eco-friendly sectors, with approximately 800,000 considered green jobs. Additionally, the solar photovoltaic sector created 3.37 million jobs globally in 2017, with Asia accounting for about 3 million, or 88%, of the total, predominantly in China.

In terms of poverty alleviation and social equity, GE policies in developing countries focus on supporting poor and vulnerable populations. For instance, reducing fuel subsidies can redirect funds towards public transportation and healthcare, enhancing the well-being of impoverished communities. Sustainable certification programs and eco-labeling initiatives in countries like Uganda, Nepal, and Egypt have generated new revenue streams from agricultural and forestry products. Furthermore, nations like China and Malaysia have implemented climate change adaptation and mitigation strategies that directly benefit disadvantaged groups.

However, defining the GE concept can be challenging due to its multidimensional nature and varying interpretations, particularly concerning its relationship with sustainable development in developing nations. This complexity leads to difficulties in identifying a singular theory that encompasses all factors influencing this relationship. Empirical evidence suggests that the impacts of GE on economic growth, employment, and poverty levels can vary among countries with similar economic and social conditions, depending on the specific economic policies and structural adjustments adopted during the transition. Consequently, each emerging country's unique social and economic context must be considered when assessing the effects of transitioning to a GE.

IV. Discussion

Aligned with the aspirations of a green economy, one of the primary objectives of sustainable development is to promote economic growth while preserving environmental quality. As a result, there has been extensive debate regarding the environmental implications of economic growth over recent decades, particularly in developing countries. Economic growth has become increasingly vital for nations to build their infrastructure in recent years. This relationship between environmental consequences and economic development presents a dilemma for both economists and environmentalists. Numerous studies have aimed to ascertain the causal link between economic growth and environmental degradation, yielding mixed outcomes. Some research indicates that economic growth negatively impacts environmental protection, suggesting that economic strength acts as a catalyst for environmental harm, particularly during the initial phases of development when economies are heavily reliant on fossil fuels and natural resources, as observed in the N11 nations, Bangladesh, the MENA region, leading African natural gas suppliers, Pakistan, Egypt, the USA and Europe, South Asia, and other developing countries.

Conversely, other studies propose that sustainable development is contingent upon green economic growth. Advancements in environmentally friendly and energy-efficient technologies, the dissemination of environmental knowledge and skills, the promotion of sustainable energy generation, and the diversification of the energy mix through increased use of renewable sources are all critical to fostering green economic growth, as highlighted in several case studies, G7 countries, Africa, the top 20 green innovator nations, and BIRCS. Given the development achievements of developing countries and their anticipated progress in the coming decades, these conclusions are particularly relevant. Thus, this investigation is aimed at addressing a significant research problem within the realm of developing economics.

The foremost goal of the 2030 Agenda for Sustainable Development is to eradicate poverty in all its forms. Target 1 of the Sustainable Development Goals emphasizes the need to eliminate poverty. Mobilizing substantial resources from various sources, including improved development cooperation, is essential to provide developing nations, especially the least developed, with the necessary means to implement programs and policies aimed at combating poverty comprehensively. The Sustainable Development Goals also strive to create effective policy frameworks at national and regional levels to ensure that by 2030, all individuals have equal rights to economic resources, including access to basic services, ownership and control over land and other properties, inheritance rights, natural resources, modern technologies, and financial services. Consequently, numerous scholars have sought to explore the critical role of the green economy in reducing poverty, yielding positive findings. Research indicates that the green economy enhances per capita income and reduces poverty ratios through mechanisms such as green financing, renewable energy utilization, and green hydrogen development.

The green economy has garnered significant scholarly attention due to its implications for employment. According to the United Nations Environment Program, a green economy fosters social equity and job creation, highlighting its positive impact on the labor market. The International Labor Organization supports this notion, asserting that the green economy has the potential to create millions of new jobs. Consequently, many studies have examined the relationship between the green economy and employment levels, exploring connections between environmentally-friendly innovations and job creation, as well as the association between green employment and the green economy's capacity to generate new investments, leading to favorable outcomes.

However, some research suggests that, despite the positive effects of a green economy on employment, there can also be negative impacts, particularly in developing nations. These studies argue that environmental protection may be perceived as a luxury that only developed countries can afford. These findings underscore the significance of this research endeavor in addressing a critical knowledge gap, especially concerning developing economies. The relationship between the green economy and employment levels, a crucial aspect of sustainable development, is particularly meaningful in our analysis, especially regarding its effects on developing countries.

There is a lack of publications in the academic sphere that examine how a green economy influences sustainable development through economic growth, poverty reduction, and employment levels in developing nations. Existing literature often focuses on a singular aspect of sustainable development, raising questions about whether the green economy can effectively accelerate the achievement of these goals. The findings from previous empirical studies indicate a scarcity of research on the drivers of sustainable development and insufficient evidence specifically related to developing nations. Given the critical importance of the green economy in these contexts, it is essential to evaluate these factors, providing recommendations to policymakers and formulating effective policies to reach sustainable development goals. Our theoretical framework and hypotheses, which build on the literature reviewed in this section, will be presented in the following section.

The positive coefficient of the Green Economy (GE) indicates that it contributes to economic progress, illustrating that green economic growth is essential for achieving sustainable development. This growth can stem from an increased reliance on environmentally friendly and cost-effective innovations, the promotion of sustainable energy production, and the diversification of the energy mix through greater adoption of renewable energy. This aligns with findings from previous studies.

It is important to note that among the four key dimensions of the Green Growth and Employment Index (GGEI), leadership and climate change, efficient sectors, and environmental and natural capital positively influence per capita income. The leadership and climate change dimension encompasses policies and regulations that assist developing countries in transitioning to a green economy without compromising their economic growth.

The efficient sectors dimension, which includes both public and private sectors such as energy, tourism, green transportation, and green building, is also significant for GDP per capita. These new green sectors contribute to boosting the country's economy and raising average per capita income. The positive impact of the green economy on employment can be attributed to various factors that promote social equity and create job opportunities, underscoring its beneficial influence on the labor market.

Additionally, regarding the environmental dimension of natural capital, it is logical that nations endowed with high-quality natural resources tend to exhibit advanced economic development levels, as these resources are vital inputs in the production function. Consequently, a favorable environment and rich natural capital are likely to enhance economic performance.

However, the relationship between the green economy and unemployment remains unclear, with findings indicating that only one aspect of the green economy has a significant positive impact on unemployment. The green economy influences job creation indirectly through economic output; thus, while productivity improvements can lead to increased employment and decreased unemployment, this secondary effect is limited and not solely driven by the green economy. These outcomes align with reports from the International Labour Organization, which suggest that the green economy has the potential to create millions of new jobs.

Furthermore, the promotion of the green economy aids in eradicating poverty, which contributes to sustainable development. This negative correlation exists because increased development cooperation provides the necessary and reliable resources to implement programs and policies aimed at alleviating poverty in all its forms. Numerous studies have concluded that the implementation of green economy strategies is essential for reducing poverty and advancing sustainable development.

Moreover, the green economy lowers poverty rates in countries based on their national criteria; thus, a higher environmental quality correlates with lower poverty levels. Among the key dimensions of the GGEI, two dimensions significantly affect poverty rates. First, the market and investment dimension shows a negative relationship with poverty levels. As green investment advances, per capita GDP and the standard of living in a country improve. This enhancement in economic standards leads to a decrease in the number of individuals living below the poverty line.

Second, the environmental and natural capital dimension also exhibits a negative correlation with poverty. The conservation of the environment and sustainable utilization of natural resources contribute to securing access to quality food and safe drinking water, thereby reducing malnutrition rates and directly lowering poverty levels in developing countries. Here's a rephrased version of your text while maintaining its original meaning:

The significance of the Green Economy (GE) concept arises not as an alternative to Sustainable Development (SD), but rather as a focused and direct approach and a vital tool for achieving SD. Transitioning towards a GE holds the potential for unprecedented economic growth and poverty alleviation, executed rapidly and effectively. This potential stems from two concurrent transformations. First, our society and the risks we encounter have dramatically changed due to evolving circumstances, necessitating a fundamental re-evaluation of our economic strategies. Second, there is growing acknowledgment that natural resources form the basis of our physical infrastructure and must be managed as a primary source of prosperity and well-being.

Consequently, countries are currently in a race to harness their available natural resources and renewable energy, particularly amid a global trend focusing on environmental issues to mitigate ecological degradation and biodiversity loss, alongside challenges such as acid rain and rising temperatures driven by greenhouse gas emissions that contribute to climate change with potentially catastrophic consequences. Therefore, GE can be viewed as a new economic paradigm and a critical element in economic development, job creation, and poverty reduction globally, especially in emerging nations.

In this context, the findings indicate that GE positively influences average per capita GDP and overall unemployment levels while negatively impacting poverty rates in developing countries. This suggests that the green economy is a key driver of sustainable development by fostering economic growth, creating new job opportunities, and reducing poverty in developing nations.

To emphasize the importance of a green economy, governments in developing countries should standardize its definition, measurement tools, and datasets used in calculations. Enhancing institutions and policies to encourage public and private sector investment in green sectors is essential, as is promoting scientific research and development initiatives and technological innovation. Allocating significant portions of public spending for research and development in the green economy, designing specialized programs to enhance labor quality through intensive training in advanced technologies for various green sectors, and improving workforce skills are critical steps.

Additionally, formulating and refining policies for transitioning to a GE that stimulate public spending and foreign direct investment is crucial for generating new economic sectors and investment opportunities, particularly to create job prospects for poor and vulnerable groups. Establishing a national green financial system that introduces new financial instruments such as green bonds, green insurance, and green credit is vital for meeting the sustainable financing needs for the green transition.

Moreover, promoting investments in renewable energy sectors, especially wind and solar energy, should be institutionalized across all sectors. Renewable energy products often lack institutional support, which may leave consumers unaware of their rights and responsibilities regarding these products. Therefore, relevant authorities and ministries must provide this institutional framework to enhance the adoption and expansion of renewable energy in developing countries.

Green policies should incorporate environmental, social, and economic factors to ensure equitable wealth distribution and equal opportunities for diverse population segments. Furthermore, it is important to encourage private sector investment in green sectors through economic incentives such as procurement policies, differential pricing, and tax benefits to promote renewable technologies and financing mechanisms. This includes encouraging the use of renewable energy technologies by reducing tariffs on equipment and components and eliminating or reducing fossil fuel subsidies.

This analysis focused on the connections between the green economy and sustainable development, particularly regarding the social and economic dimensions related to the first and eighth Sustainable Development Goals—namely, no poverty, decent work, and GDP—by examining emerging economies. For future studies, we recommend expanding the framework to incorporate additional sustainable development goals and including both developed and developing countries for comparative analysis to derive further insights.

References

[1] Podkolzina, I.M., Gladilin, A.V., Reshetov, K.Y., Taranova, I.V., Gladilin, V.A. Building a Financial Security System to Ensure Russia's Food Security // Lecture Notes in Networks and Systems, 2021, 205, страницы 539–548

[2] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[3] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, pp. 2197–2205.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144.

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THE IMPACT OF HUMAN CAPITAL ON ECONOMIC GROWTH IN THE FACE OF GLOBAL CHALLENGES

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Abstract

This paper investigates the significant role of human capital in driving economic growth, particularly in the face of pressing global challenges such as technological advancements, climate change, and rising economic inequality. The authors emphasize that human capital, defined as the collective skills, knowledge, and experience of individuals, is increasingly recognized as a critical factor in enhancing productivity and fostering innovation. The study begins by establishing a theoretical framework that links human capital to various models of economic growth, underscoring how investments in education, vocational training, and health can yield substantial economic benefits. The authors employ both quantitative data analysis and qualitative case studies to provide evidence that countries with higher levels of human capital tend to experience more robust economic growth trajectories. Key findings indicate that technological change necessitates a workforce that is not only skilled but also adaptable to rapidly evolving industry demands. The paper discusses how failure to invest in human capital can lead to skills mismatches and hinder economic competitiveness. Additionally, the authors explore the implications of climate change, asserting that a transition to a sustainable economy requires new skill sets in renewable energy, environmental management, and sustainable practices.

Keywords: human capital, economic growth, global challenges, technological change, climate change, economic inequality, education, vocational training

I. Introduction

In an era characterized by rapid technological advancements, increasing environmental concerns, and deepening economic inequalities, the role of human capital in driving economic growth has never been more critical. Human capital, encompassing the skills, knowledge, and health of individuals, serves as a pivotal resource that can significantly influence a nation's economic trajectory. As economies face unprecedented challenges such as automation, climate change, and global pandemics, understanding the interplay between human capital and economic growth becomes essential for policymakers, educators, and businesses alike.

Historically, economic theories have recognized the importance of physical capital and technology as key drivers of growth. However, recent studies underscore the growing recognition that human capital is equally, if not more, vital in enhancing productivity and fostering innovation. Countries that prioritize education, skills development, and health often demonstrate greater economic resilience and adaptability in the face of change. For instance, a well-educated and skilled workforce is better equipped to harness new technologies, adapt to shifting labor markets, and drive sustainable development initiatives.

Moreover, the global challenges of our time require a nuanced understanding of how human capital can mitigate their impacts. Technological change, while offering opportunities for growth, also poses risks of job displacement and widening inequality. Similarly, the effects of climate change demand a workforce capable of innovating and implementing sustainable practices. As such, the development of human capital emerges as a strategic priority for nations seeking to navigate these complexities effectively.

This paper aims to explore the intricate relationship between human capital and economic growth within the context of these global challenges. It will examine how investments in education and health can serve as catalysts for economic development while addressing the disparities that hinder progress. By analyzing both theoretical frameworks and empirical evidence, the study will highlight the critical need for comprehensive policies that promote human capital development as a means to achieve sustainable and inclusive economic growth.

As we embark on this exploration, it is imperative to consider not only the economic implications but also the social and ethical dimensions of human capital development. In doing so, we can better understand how to leverage human potential to build resilient economies capable of thriving amid uncertainty.

II. Methods

1. Econometric Modeling

This method involves using statistical techniques to analyze the relationship between human capital indicators (such as education and health metrics) and economic growth rates. Data will be sourced from international databases like the World Bank and OECD. Multiple regression analysis will be employed to quantify the impact of human capital on GDP growth while controlling for factors such as physical capital investment and technological advancement.

2. Comparative Case Studies

This qualitative method focuses on in-depth analyses of specific countries or regions that have successfully utilized human capital to drive economic growth. Countries will be selected based on diverse economic contexts and effective human capital policies. Each case study will evaluate key interventions—such as education and training programs—and their impact on economic outcomes, using both quantitative indicators and qualitative assessments.

3. Surveys and Interviews

This method involves gathering primary data through surveys and semi-structured interviews with key stakeholders, including policymakers, educators, and business leaders. Surveys will assess perceptions and experiences related to human capital development, while interviews will provide deeper insights into the effectiveness of current policies and practices. The collected qualitative data will be analyzed thematically to identify trends and best practices in human capital investment.

III. Results

Education and skill disparities likely account for some of the differences observed between countries. Researchers have found evidence indicating a correlation between educational attainment and individual GDP. In less developed nations, educational levels tend to be low due to economic struggles, creating a cycle where limited education further hinders economic growth. Hall and Jones (1999) suggest that we can incorporate metrics of education and training to evaluate the extent of human capital, allowing for comparisons of human capital development across various countries. Since 1990, the United Nations Development Programme (UNDP) has collected and presented data on the Human Development Index (HDI), which integrates three fundamental dimensions of human development: life expectancy at birth, which indicates overall health and longevity; years of education and expected years of schooling, which reflect knowledge and learning; and gross national income per capita, which assesses the ability to maintain a sustainable standard of living. The HDI scale ranges from 0 to 1, where 0 signifies the lowest level of human development and 1 signifies the highest. Table 1 below displays the HDI values for selected developed, developing, and least developed countries.

Table 1: *Human Development Index in developed, developing and less developing countries*

Countries	1990	1995	2000	2005	2010	2015	2016	2017
Bangladesh	0.387	0.425	0.468	0.505	0.545	0.592	0.597	0.608
China	0.502	0.55	0.594	0.647	0.706	0.743	0.748	0.752
India	0.427	0.46	0.493	0.535	0.581	0.627	0.636	0.64
Japan	0.816	0.84	0.855	0.873	0.885	0.905	0.907	0.909
Malaysia	0.643	0.683	0.725	0.821	0.729	0.772	0.799	0.802
Pakistan	0.404	0.428	0.45	0.5	0.526	0.551	0.56	0.562
Singapore	0.718	0.773	0.819	0.868	0.909	0.929	0.93	0.932
South Korea	0.728	0.778	0.817	0.855	0.884	0.898	0.9	0.903
Turkey	0.579	0.607	0.655	0.69	0.734	0.783	0.787	0.791

Individuals play a crucial role in driving economic performance and progress (Schultz, 1961). The quality of social assets relies on the premise that a skilled and productive workforce can operate more efficiently, contribute economically, and engage in more productive activities, thereby fostering economic advancement (Baldacci et al., 2008). Various inclusive growth strategies have proven to be more effective than others and are essential for improving the economic conditions in developed nations. Data indicates that Singapore's growth and asset development surpass those of many developed countries, with its economy thriving due to significant human capital investment.

The apparent benefits of neoliberal globalization have heightened the interest of developing countries, as this perspective emphasizes the connection between markets, competitiveness, economic efficiency, and consumer choice. Consequently, these economic sectors necessitate human capital. Training the workforce in emerging economies to meet the increasing demands for poverty alleviation, enhanced employability, productivity, and global competitiveness has become a national priority in skill development and training initiatives to promote growth. Notably, China and Turkey have achieved impressive results in their Human Development Index (HDI), while Malaysia is also making strides in human capital development. This focus on human investment is a key reason why the developing world is attaining greater economic stability.

IV. Discussion

Global competitiveness can only be achieved through collaborative efforts among countries worldwide, working together to reach their goals in line with evolving technologies and advancements. The World Economic Forum publishes the Global Competitiveness Report, which tracks the ongoing factors and institutions vital for sustainable growth and competitiveness, enabling countries to be assessed and calibrated to maintain their competitive edge.

The Global Competitiveness Index (GCI) serves as a composite measure consisting of twelve components, grouped into three overarching categories. The first category, fundamental requirements, encompasses institutions, infrastructure, the macroeconomic environment, health, and basic education. The second category, efficiency enhancers, focuses on higher education and training, product market efficiency, labor market efficiency, financial market development, technological capabilities, and market size. Finally, the third category includes elements related to business sophistication and innovation.

The GCI is rated on a scale from 1 to 7, where 1 represents the lowest score and 7 signifies the highest. Table 2 below presents the GCI values for selected developed, developing, and least developed countries.

Table 2: *Global Competitiveness Index in developed, developing and less developing countries*

countries	2013	2014	2015	2016	2017
Bangladesh	3.547942	4.835891	4.736538	4.698532	4.565805
China	4.897789	4.835891	4.736538	4.698532	4.565805
India	4.304978	4.328038	4.303131	4.326408	4.33399
Japan	5.396211	5.36931	5.369902	5.375314	5.426291
Malaysia	5.084289	4.883098	4.873699	5.044747	5.097477
Pakistan	3.578805	3.483689	3.581879	3.652812	3.770316
Singapore	5.625705	5.477664	5.545332	5.534784	5.447093
South Korea	5.02079	4.930196	5.003964	5.275884	5.396472
Turkey	4.280638	4.24749	4.160859	4.148129	4.246872

Human capital is intricately linked to economic and industrial advancement. Therefore, understanding their relationship is essential for enhancing productivity and capabilities, leading to competitive advantages and surplus value that can drive technological progress and diversify economic activities, ultimately fostering economic growth. As a result, the development of human capital has become vital for achieving growth. Many researchers agree that government investment in health and education to strengthen human capital has a positive and significant impact on the economy.

Human capital is represented by a nation's skilled and capable workforce. It is routinely assessed and can be enhanced through both formal and informal education or training. Importantly, human capital is not confined to traditional schooling; it also includes on-the-job training and non-traditional technical programs that enhance skills. Kazmi et al. (2017) analyzed both formal and informal education, along with various socioeconomic factors such as school enrollment, life expectancy, health, knowledge, and skills, using time series data from 1992 to 2024. Their study underscores the significance of human capital as an intangible resource collaboratively managed by individuals and organizations within a community.

The evidence indicating a relationship between human resources and development is compelling. Furthermore, human capital is essential in empirical studies that explore the factors influencing economic advancement. While many researchers argue that human capital has a positive and substantial effect on economic growth, empirical findings have yielded mixed results. Theoretical literature often addresses the measurement of human capital. The research explored the strong correlation between human capital and economic recovery using the Johansen multivariate cointegration test and Granger causality test.

Economic growth is essential for determining a country's position on the Global Competitiveness Index (GCI). It enhances productivity, fosters innovation, supports infrastructure development, and encourages investment in human capital, all of which are critical for competitiveness. Expanding economies attract investment, broaden their global reach, and demonstrate resilience in the face of challenges. Ultimately, sustained economic growth serves as a fundamental driver of success on the GCI, as it underpins various factors that enhance a nation's competitiveness and global prosperity.

Furthermore, an economy that evaluates its workforce size, physical capital, human capital, and technological capabilities can better understand its production capacity. When comparing two countries, the one with greater physical capital, a larger labor force, a more educated and skilled workforce, and superior technology will likely produce more and achieve a higher ranking on the GCI. This study highlights the crucial role of human capital in driving economic growth. Human capital encompasses the knowledge, skills, education, and health of a nation's workforce, emphasizing that investing in and developing human capital is vital for maximizing economic growth and securing a favorable position on the GCI.

Consequently, it is essential to prioritize key inputs such as human capital and economic growth to achieve the desired outcomes in global competitiveness across various economies. Additionally, the study employs statistical tools, particularly classical techniques, to support its findings and analysis. This approach indicates that the research utilizes established statistical methodologies to examine data and draw conclusions about the relationships between economic growth, human capital, and competitiveness. For effective policy formulation, it is also crucial to employ a diverse array of statistical tools in data analysis to optimize modeling.

References

[1] Podkolzina I.M., Gladilin A.V., Reshetov K.Yu., Taranova I.V., Gladilin V.A. Building a financial security system to ensure russia's food security// The Challenge of Sustainability in Agricultural Systems. Heidelberg, 2021. С. 539-548.

[2] Kasaeva T.V., Taranova I.V., Valishina G.L., Atabaev A.R., Novoseltseva A.P. Development of the medical healthcare sector in russia based on the experience of socio-economic transformations of foreign countries and regions// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. С. 252-256

[3] Gakaev, R. Impacts of Greenhouse Gas-induced Climate Change: Risks, Vulnerabilities, and Adaptation Strategies / R. Gakaev , L. Gatsaeva , M. Eskiev // E3S Web of Conferences. – 2024. – Vol. 537. – P. 03009. – DOI 10.1051/e3sconf/202453703009. – EDN OJVETT.

[4] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, страницы 2197–2205

[5] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[6] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[7] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[8] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[9] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[10] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[11] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[12] Taranova I.V., Tokova L.D., Shavrina J.O., Syrovatskaya V.I., Ivanova E.A. Banking management as the basis for effective management of a commercial bank// Modern Global Economic System: Evolutional Development vs. Revolutionary Leap. Institute of Scientific Communications Conference. Cham, 2021. C. 2137-2144

DYNAMIC MODELLING AND MULTIPHASE FLOW OPTIMISATION – GARANTEUR OF SAFE AND SECURE HYDROCARBON PRODUCTION

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Abstract

These days petroleum and condensate formations, especially offshore ones, are actively being developed. The main feature of such formations is multiphase flow in tubing and riser. During production flow liquid slugs, adverse pressure pulses, and often hitting impacts are detected as a result of high gas content, interphase tension forces and complicated pipeline geometry, leading to pressure surges. The energy and very functioning efficiency of both gaslift and fountain operated wells is thus drastically reduced with the disturbance of the optimal production regime. In this paper it has been determined that a novel approach to multiphase flow management allows for decrease in emergency failures and operational expenses. Thus, right modelling and optimization of phase slippages can become a good guaranteur of safe and secure well operations.

Keywords: optimization, multiphase, TPR, flux, dynamic pressure

I. Introduction

Multiphase systems (liquid-gas, liquid-solid particles, etc.) periodically exert significant dynamic pressures on production facilities, such as tubings, gathering pipelines, flare jackets, compressor inlets, separators, pipelines transporting unrefined gas from site to the refinery, etc. There are facts of discard of sucking collectors of vacuum gas lift compressor stations, flare pumping units, support piles kinks at "earth-air" split under the pipelines, catastrophic riser failures, etc. As a rule of thumb, dynamic loads arise at pipeline turns when density of the transported multiphase medium is subject to swift and significant changes.

Pipeline location affects the inner liquid flow characteristics including pressure changes, speeds, and phase concentrations. This is an interesting and multifaceted modern pipeline construction and operation challenge, especially relevant for multiphase well liquids gathering and transportation pipelines [1]. Complicated geometry of manifolds, well piping and underwater equipment of offshore petroleum production systems is in it of itself a configuration matrix, each element of which is capable of drastically changing not only direction but also type and characteristics of the multiphase flow.

II. Methods

It is known that multiphase flow regime boundaries are under visible influence of each individual phase's speed, density, viscosity, flow direction, physical and chemical properties, as well as pipeline geometry, and many other parameters.

According to [2] bubble regime borders in vertical pipe lie between gas speed of 1 to 10 m/s and liquid speed up to 2 m/s. Diameter increase of more than 10 sm leads to widening of the with probable bubble regime zone: gas speed boundaries are 0,1 to 10 m/s and remain roughly the same for liquid speed. When one zone boundaries move, the respective changes happen in boundaries of slug flow, churn flow, annular flow, and mist flow – i.e. all types of multiphase flow.

Problems of formation of a "severe" slug flow or pulsing flow that manifest in subsurface pipelines (gaslift pipelines) of various geometries are discussed in detail in [3, 4].

When considering multiphase flow dynamics, it is vital to clearly understand that flow structure may change with changes in flow rates. Dispersed structure forms at higher mixture flow rates, when its speed exceeds critical, during which structural changes manifest.

In this case the components mixture is a homogenous structure characterized by constant density across all of the flow's volume. If the flux is maximal, speed of the mixture is below critical, thus gradient-speed field tension [5, 6] of the flow is not sufficient for the homogenous mixture to form. The flow consists of alternating gas and liquid slugs. Flow components are divided by a phase boundary.

Flow regime also characterizes its layered structure. Unbalanced dynamic loads appear at turns of the pipelines during slug flow. To determine the maximal value of these dynamic forces affecting multiphase pipeline, it is vital to determine critical mixture speed value at which structure changes evolve. To determine this speed the following equation is used:

$$v = 1.26\sqrt{g(\rho_l - \rho_g)D/\rho_g} \quad 1)$$

Where, ρ_l, ρ_g – respectively liquid and gas density kg/m^3
D – pipeline diameter, m;
g – gravitational acceleration, m/s^2

The force acting on the pipeline with change of mixture density is defined as multiplication of residual of dynamic pressures by cross-sectional area of the pipeline.

$$F = (\rho_l - \rho_g)v^2\pi D^2/4 \quad (2)$$

Considering features of multiphase flow in vertical pipelines and as a result of analysis of different models it is possible to diagnose optimal operational zone of a multiphase gaslift which corresponds to enhanced energy efficiency of hydrocarbon production. Having that in mind as a result of gaslift well testing in coordinates liquid flow rate (Q_l), gas flow rate (Q_r) and at constant pressure drop performance relationship curves are built (Fig. 1).

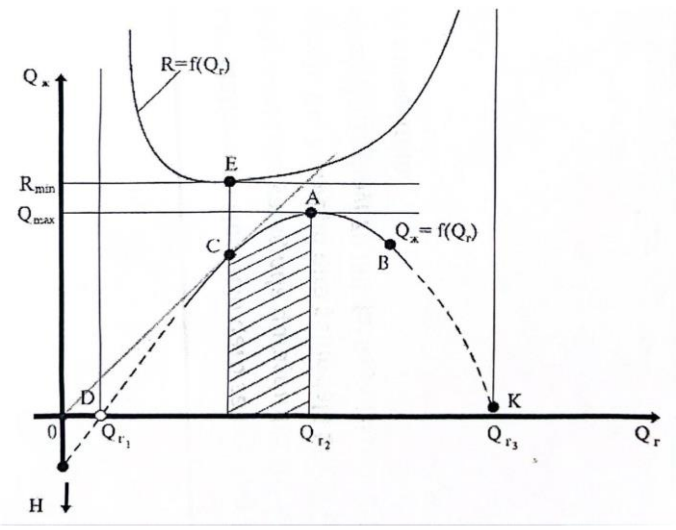

Figure 1: *Gaslift working regime performance relationships*

The following points of interest can be observed on the curve:
- Point D – flow initiation;
- Point A – maximal flow;

- Point K – flow termination.

III. Results

In order to increase efficiency and safety of the gaslift or fountain wells performance relationship curves in coordinates $Q_l = f(Q_g)$ are tied to TPR of the gaslift well that is constructed in coordinates pressure drop (ΔP) vs gas flow Q_g at various liquid flow rates (Fig. 2). In this figure zero liquid flow rate ($Q_l = 0$) corresponds to sparging.

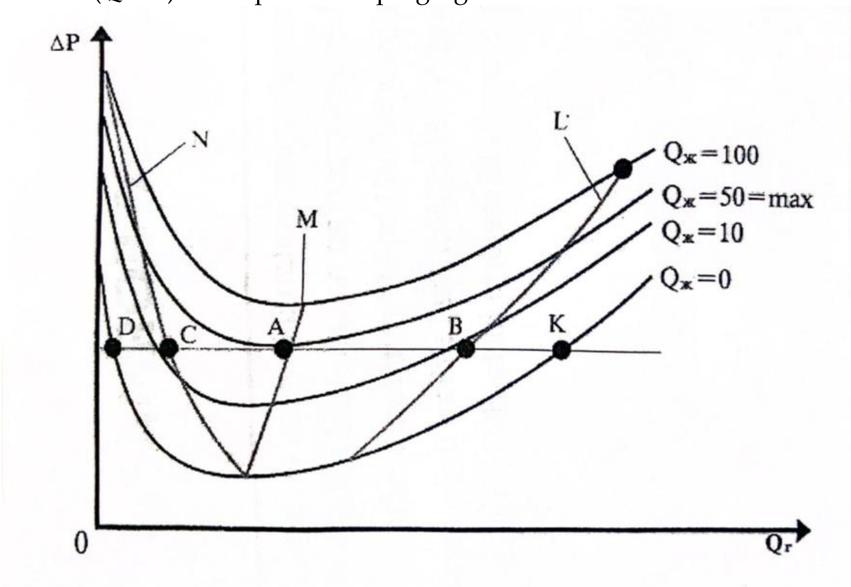

Figure 2: *Multiphase well TPR at constant liquid flow rates*

Should we draw a constant pressure drop line on the TPR curve, three characteristic points D, A and K ae obtained, as on performance relationship curve. Points D and K cross the line of zero liquid flow rate, point A is tangential to the maximal flow rate curve in minimal pressure drop regime. Line N corresponds to minimal specific gas flow rate R_{min}, line M – to minimal pressure drop, P_{min} and line L to minimal specific pressure drop. Zone between lines N and M corresponds to optimal work regime from minimal pressure drop to minimal specific energy expenditure.

Inflow and tubing performance relationship are also important elements of well performance prognosis. Inflow and tubing performance relationship curves intersection point prognoses the future well performance (Fig. 3).

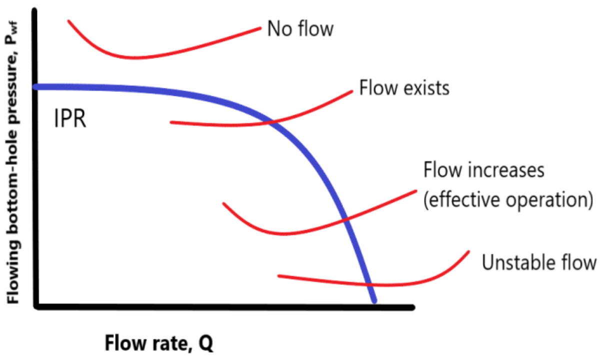

Figure 3: *Modes of TPR crossing IPR*

Fig. 3 represents different TPRs and their correlation modes with IPR. It is apparent that the TPR must intersect the IPR to the right of the extremum of the multiphase TPR otherwise well should be considered unstable.

IV. Discussion

Determination of direction and numerical value of dynamic loads in multiphase pipelines is paramount with regard to safety of transportation. A mathematical model has been proposed to determine these loads considering critical speed and structural changes in multiphase flows.

It has been demonstrated, that to increase safety and efficiency of the gaslift operations performance relationship curves in coordinates $Q_l = f(Q_g)$ must be tied to gaslift TPR curve at various liquid flow rates.

Multiphase flow features must be carefully considered when designing the most economically sound and technologically safe flow diagram.

References

[1] Falcone, G. Multiphase flow metering principles/ G. Falcone, G. F. Hewitt, C. Alimonti. – Amsterdam: Elsevier Science, 2009. – 328p. – Direct text.

[2] A critical review of flow maps for gas-liquid flows in vertical pipes and annuli/ B. Wu, M. Firouzi, T. Mitchel [et al.]. DOI: 10.1016/j.cej.2017.05.135. – Direct text // Chemical Engineering Journal. – 2017. – T.326. – Pp. 350-377.

[3] Han, P. Numerical simulation of terrain-induced severe slugging coupled by hydrodynamic slugs in a pipeline-riser system/ P. Han, L. Guo. – DOI: 10.1016/j.ijheatfkuidfkiw.2015.10.005. – Direct text // International Journal of Heat and Fluid Flow. – 2015. – T.56. – Pp. 355-366.

[4] Li, W. Effects of a long pipeline on severe slugging in an S-shaped riser/ W. Li, L. Guo, X. Xie. – DOI: 10.1016/j.ces.2017.05.017. – Direct text // Chemical Engineering Science. – 2017. -T.171. – Pp. 379-390.

[5] Sitenkov V.T. Gradient velocity field theory M.: OJSC «VNIIOENG», 2004, 308 p.

[6] Sitenkov V.T., Lebedeva E.V. Reduction of dynamic loads on field pipelines / Oil industry, 1998, №6, pp.67-68.

TRENDS IN SCIENTIFIC RESEARCH ON TECHNOLOGICAL ASPECTS OF GREEN ENERGY TRANSITION

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Abstract

The significant potential of renewable energy sources (RES) in Azerbaijan served as the basis for the green energy transition (GET) and the integration of renewable energy into the country's energy supply system. A bibliometric analysis of trending scientific research issues on the technological aspects of GET was carried out using the metadata of publications indexed in the Web of Science (WoS) Core Collection abstract database over the past 4 years using the VOSviewer program. As a result of the analysis, four main directions of scientific research were identified: optimization of energy resource consumption; the impact of renewable energy sources on sustainable development; the environmental benefits of the energy transition; and technological innovation. The publications of the first cluster mainly address the problems of optimizing energy generation from renewable sources, primarily solar and wind energy, as well as issues of storage, distribution, and energy consumption. The second cluster presents an empirical analysis of the impact of renewable energy consumption on carbon dioxide emissions and, as a consequence, on environmental sustainability, considering energy consumption and cointegration. In the works of the third cluster, environmental sustainability is assessed as a key priority of modern energy policy in light of the need for an energy transition from traditional energy to the use of renewable energy sources and the fight against climate change. Research in the fourth cluster reflects the benefits of using floating solar power plants. The results can serve as a basis for developing efficient government strategies for GET.

Keywords: green energy transition, renewable energy, VOSviewer program

I. Introduction

The modern global energy system is undergoing a socio-technical transformation called the "energy transition" or "green energy transition" (GET), which involves the use of renewable energy sources (RES) to replace fossil fuels and nuclear energy [1]. The GET has two goals: expanding sources of RES, increasing the share of their use, and reducing greenhouse gas emissions [2]. Globally, consumers spent nearly 20% more on energy in 2022 than the previous five-year average [3]. Almost one in ten people out of 40 million in the European Union could not provide sufficient heat in their homes [4, 5]. Therefore, energy transition issues are the center of attention for the world community. The most common and used renewable energy sources are hydropower, solar, wind, bioenergy, geothermal, and tidal. According to the International Energy Agency (IEA), for 2023, the share of energy production from renewable energy sources in countries that are members of the agency was 30.2% [6]. As follows from Fig. 1, the share of solar and wind energy capacity is increasing, while hydropower is decreasing. According to IEA forecasts, the commissioning of green energy capacity will steadily increase and should reach more than 40% by 2030 [7]. For Azerbaijan, the share of RES in the country's energy balance is 18%. By 2030, it is planned to increase this figure to 30%, by 2050, it will be more than 40% [8].

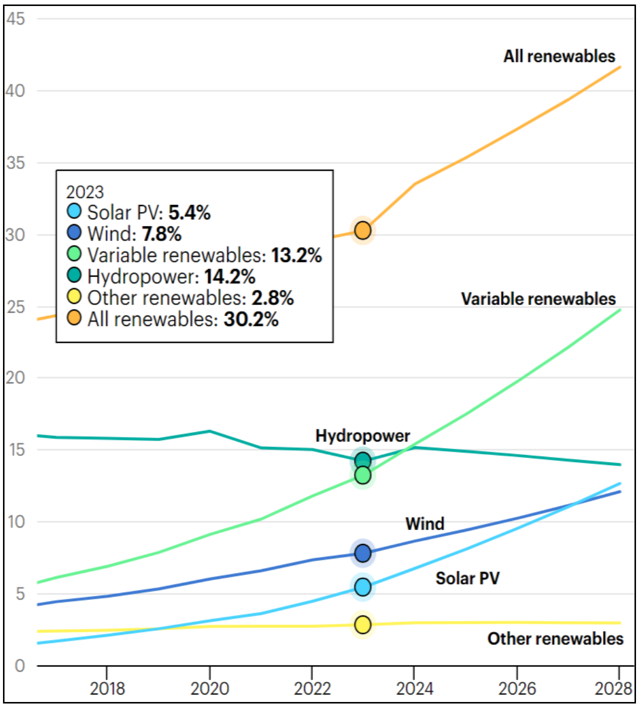


Figure 1*: Renewable electricity generation by segment*
(https://www.iea.org/reports/renewables-2024/executive-summary)

For a long time, in the development of the national economy of Azerbaijan, the main driver of growth was the extraction and export of fossil energy resources, which led to risks of environmental degradation and imbalance of the ecosystem. The year 2024 in Azerbaijan was declared the "Year of Solidarity for the Green World" (https://azertag.az/ru/xeber/azerbaidzhan_lider_v_regione_po_perehodu_na_zelenuyu__energiyu_2882779), which involves the introduction of green energy technologies, environmentally friendly waste processing, the introduction of environmentally friendly production with zero greenhouse gas emissions, and the implementation of measures to restore contaminated areas [9, 10]. The significant potential of Azerbaijan's renewable energy sources served as the basis for their successful integration into the country's energy supply system: the technical potential of green energy (GE) on land is 135 GW, and on the shelf of the Caspian Sea,- 157 GW [11]. Since 2021, the Karabakh region of the country has been declared a "Green Energy Zone," and corresponding creative work is underway. The region's energy supply is planned to be fully provided by green energy [12]. In international projects on green energy and the energy transition implementation, Azerbaijan works with Norway, Great Britain, the United Arab Emirates, and Slovakia [13]. The scale of Azerbaijan's development in GET makes it relevant to study promising scientific research and international experience in using green energy.

The purpose is to identify trending research tasks on the technological aspects of countries' transition to green energy, analyze foreign experience in introducing various types of green energy, and forecast potential areas for green energy development.

II. Methods

To study the scientific field of GET, this study applies the publication analysis methodology by using keywords for scientific articles in the WoS database [14,15]. Keywords are a mandatory and important informative component of each article [16,17]. If the author does not give the keywords, they are assigned by the WoS database. To analyze the topic of GET and determine the main trends in scientific research, the tools of the VOSviewer 1.6.20 program were used. The keywords used in the search were: green technologies, renewable energy, alternative energy, low-carbon energy, environmentally friendly energy, sustainable energy, technology, sustainable energy transition, low-carbon transition, transition to renewable energy sources, and decarbonization. The initial query to the WoS database was carried out on May 16, 2024, and 7244 scientific publications were identified for 2021–2024. To narrow the scope of research, scientific articles from the WoS Categories section were selected from this number, and the section "Green sustainable scientific technologies" was selected (Table 1). The remaining 894 publications are downloaded from the WoS database as a tab-delimited file in Full Record format. Next, in the VOSviewer program, select the data type: - Creating a map using bibliographic data. The program then reads data from the downloaded WoS files. As a type of analysis of keywords, their co-presence in publications is selected, and the calculation method is complete (Table 2).

Table 1: *Data collection process [18,19]*

Data	Line search - Search string
Topic	Green energy transition
Added keywords	green technologies renewable energy, alternative energy, low-carbon energy, environmentally friendly energy, sustainable energy, technology
Timesp a n	2021-2024
Sources	
Types of articles	Review article, Open access, Early access, Enriched cited references, Open publisher-invited reviewers
Initial results	7244 publications
WoS category	Green Sustainable Science technology
End results	894 publications
Records were exported to	Tab to limited file
Record content as	Full record and cited references

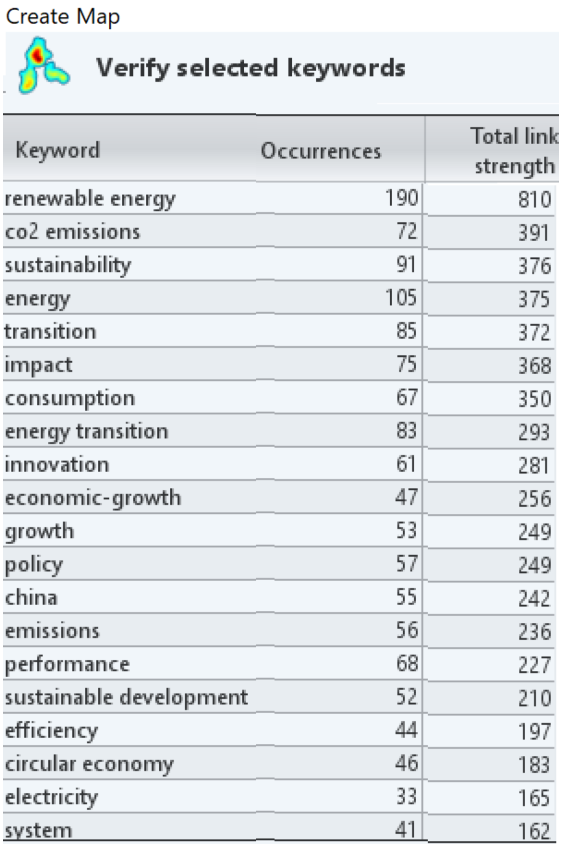
Table 2: *Chosen command parameters of tabs on VOSviewer*

Choose data source	Read data from bibliographic database files
Choose type of data	Create a map based on bibliographic data
Select files	WoS Core Collection files
Choose type of analysis and counting method 1. Type of analysis 2. Unit of analysis 3. Counting method	1. Co-occurrence 2. All keywords - Author keywords and keywords plus 3. Full counting
Choose threshold: Of the 4981 keywords, 107 meet the threshold with minimum number of occurrences of keywords	11

III. Results and discussion

Energy transition means the transition from energy systems based on fossil fuels, such as oil, natural gas, and coal, to systems based on renewable energy sources, such as solar energy, wind, and biofuels. Azerbaijan's policy shift towards renewable energy sources was accelerated after 2020 with the return of 20% of its territory. In 2023, during COP-28, President I. Aliyev formulated strategies for the country's energy transition, promoting carbon neutrality. Therefore, there is an urgent need for large-scale research to increase the use of cleaner energy sources. This bibliometric review analyzes research on the technical aspects of countries' energy transitions over the past four years and identifies future promising research [21, 22]. By mapping the keywords of scientific publications on the energy transition, this study uses bibliometric software such as VOSviewer to display the research results of scientific publications listed on the Web of Science in 2021-2024. Analysis of research shows that aspects such as climate change, alternative energy, green energy management approaches, and emissions reduction are becoming increasingly important. Additionally, areas requiring future research include the development of policy frameworks, energy infrastructure (storage and transmission), renewable energy ecosystems, GE adaptation, economic analysis of clean energy, and impact assessments for a timely energy transition around the world [23, 24]. Therefore, cooperation between countries and research institutions should be promoted, with a special focus on the development of clean technologies and knowledge transfer for a rapid energy transition around the world.

From the metadata of the downloaded 894 publications, the VOSviewer program identified 4981 keywords. With a minimum number of co-present keywords of 11, 107 words were involved in constructing the map. Of these, the 20 most frequently used keywords with co-presence frequency and full degree of connections are shown in Fig. 2, these are mainly the terms and phrases of the authors themselves.


Create Map
Verify selected keywords

Keyword	Occurrences	Total link strength
renewable energy	190	810
co2 emissions	72	391
sustainability	91	376
energy	105	375
transition	85	372
impact	75	368
consumption	67	350
energy transition	83	293
innovation	61	281
economic-growth	47	256
growth	53	249
policy	57	249
china	55	242
emissions	56	236
performance	68	227
sustainable development	52	210
efficiency	44	197
circular economy	46	183
electricity	33	165
system	41	162

Figure 2: *20 top keywords*

In the 894 publications reviewed, the most frequently used terms were renewable energy, carbon dioxide emissions, impact, energy consumption, economic growth, optimization, productivity, sustainability, generation, management, system, power, China, energy transition, etc.

The 107 words selected by the program are grouped into 4 clusters and indicated in different colors (Fig. 3):

1st cluster - red - 37 terms on optimization of energy resources;

2nd cluster - green - 33 terms on renewable energy sources and sustainable development;

3rd cluster - blue - 30 terms on environmental benefits of the energy transition;

4th cluster - yellow - 7 terms on technological innovations.

The publications of the first cluster mainly address the problems of optimizing the generation of energy from renewable sources, mainly focusing on solar and wind energy, as well as issues of energy storage and distribution [25]. In [6], the energy sector is presented as the core of the global goal of reducing carbon dioxide emissions, and renewable energy sources are becoming an increasingly preferred source of energy generation throughout the world, and their use leads to decarbonization of the energy sector.

According to the publication, generated in the second cluster, the energy transition to the predominant use of green energy is an integral component of the strategy of states on the path to sustainable development. The publications provide an empirical analysis of the impact of renewable energy consumption on carbon dioxide emissions and, as a consequence, on environmental sustainability, considering energy consumption and cointegration. The articles [16] examine the relationship between renewable energy consumption and economic growth using the concept of the environmental Kuznets curve. Based on the analysis of empirical data, strategies are proposed for an effective energy transition aimed at reducing greenhouse gas emissions and promoting environmental sustainability (Fig. 4).

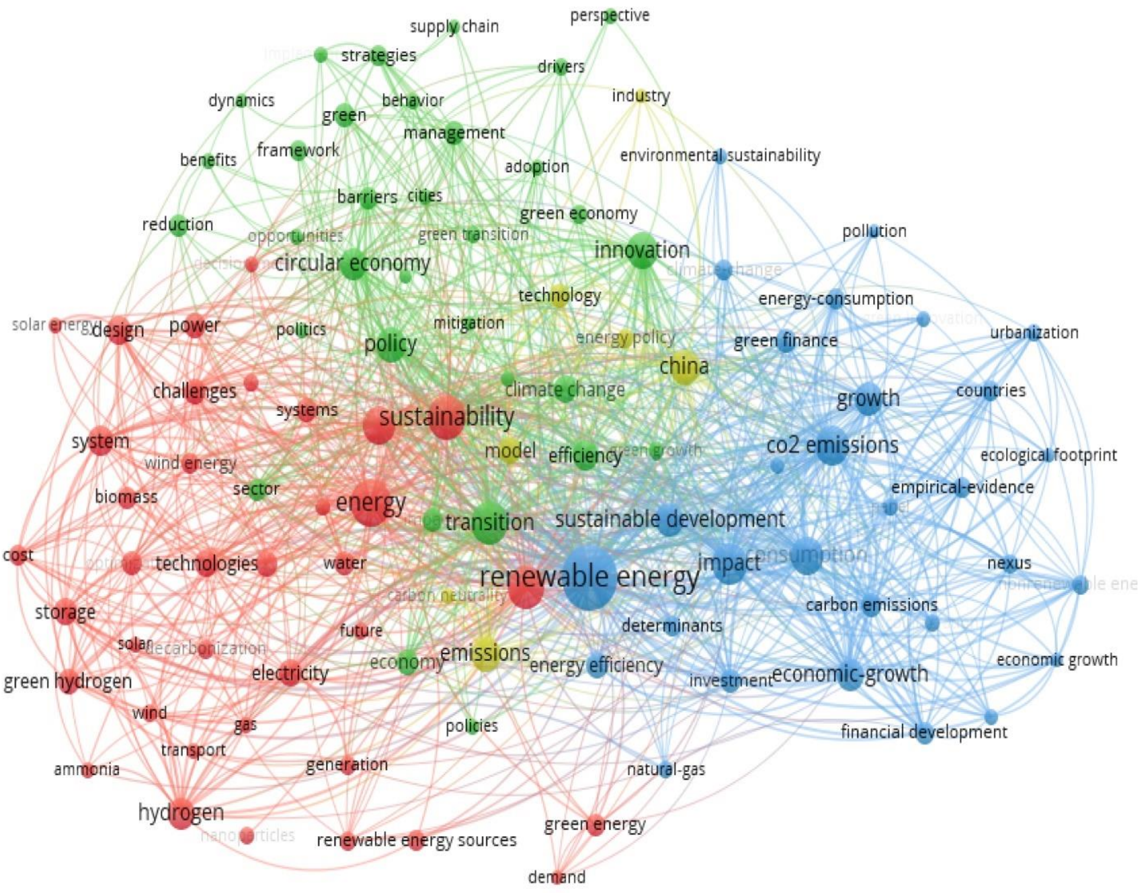


Figure 3: *Clustering of co-occurrence of all keywords (Author KW + KW Plus)*

In the works of the third cluster, environmental sustainability is assessed as a key priority of modern energy policy in light of the need for an energy transition from traditional energy to the use of renewable energy sources and the fight against climate change [1]. Article [26] analyzes the factors influencing the achievement of carbon neutrality, based on the concepts of energy efficiency and the use of innovative technologies. [9] examines the role of public energy policy in promoting environmental sustainability and achieving the energy transition. Based on an analysis of current trends and best practices, recommendations are offered for the development of strategies aimed at promoting sustainable development and reducing negative impacts on the environment. The environmental disadvantages of green energy are studied in [24]:

-for hydroelectric power plants (HPP)- flooding of territories during construction; construction is only possible nearby rivers and large reservoirs; not suitable for construction in northern regions; changes in the microclimate around hydroelectric power stations lead to changes in flora and fauna, changes in river beds and, as a consequence, ecosystem body of water;

-for solar power plants- environmental pollution is observed during the extraction of the main element for the production of solar panels - silicon; environmental pollution occurs during the disposal of solar panels and batteries due to the high cost of processing elements;

-for wind power plants- environmental pollution during the disposal of wind generator blades; high-noise wind generators; low-frequency vibrations cause soil corrosion.

The publications in the fourth cluster discuss Floating Solar Power Plants (FSPPs). The energy efficiency of FSPP is up to 10 % higher than ground-based ones. FSPP can occupy unused space in water bodies, including reservoirs at hydroelectric dams, other than those intended for drinking water supply. FSPP often requires fewer materials than a similarly sized above-ground project, less maintenance, and less cleanup since the panels are typically located away from potential sources of debris.

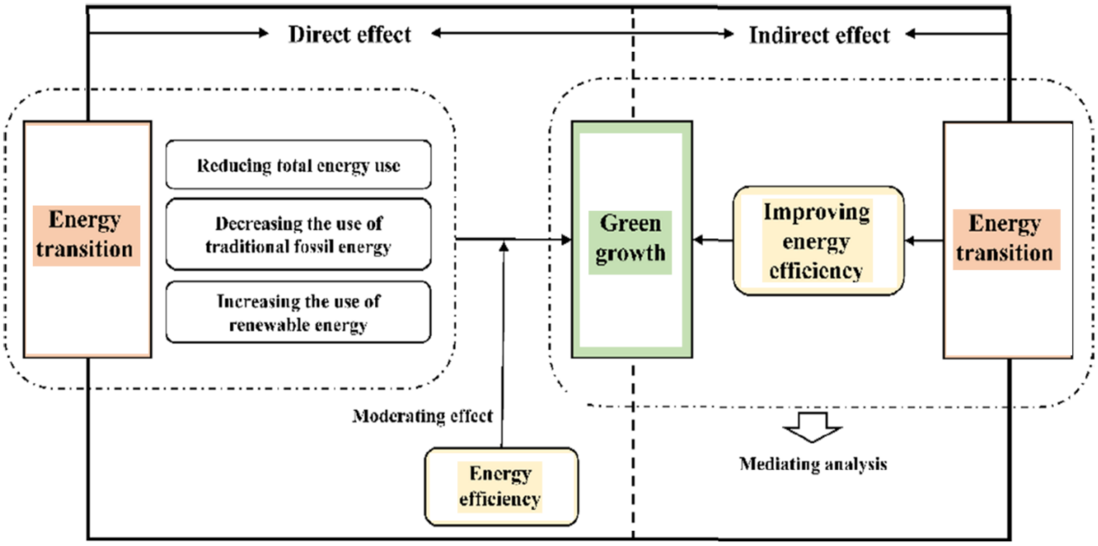


Figure 4: *The theoretical link between energy transition and sustainable development [6]*

IV. Conclusion

The "green" energy transition is a global economic policy trend that entails the need for a radical restructuring of many industries, primarily energy, construction, and transport, to achieve carbon neutrality. The study of the scientific field of "energy transition" in the context of modern global energy policy is a topical issue, the focus of which is the replacement of traditional energy resources with renewable energy sources. An analysis of 894 scientific publications selected by the

VOSviewer program using metadata analysis methodology revealed the main trends and prospects for this scientific area of research (Fig. 5): this is primarily a solution to the problems of optimal sustainable energy consumption. The results obtained indicate significant interest in the optimization of energy resources, the development of renewable energy, and sustainable environmental development [25]. Four key clusters have been identified, which examine aspects of the optimization of energy resources, the use of renewable energy sources, and their impact on the environment. This study highlights the importance of the transition to sustainable energy sources, in the context of combating climate change and achieving environmental sustainability. The results, based on the analysis of current trends and practices, can serve as the basis for the development of effective government strategies and programs aimed at achieving sustainable development and reducing the negative impact on the environment in the energy sector [26].

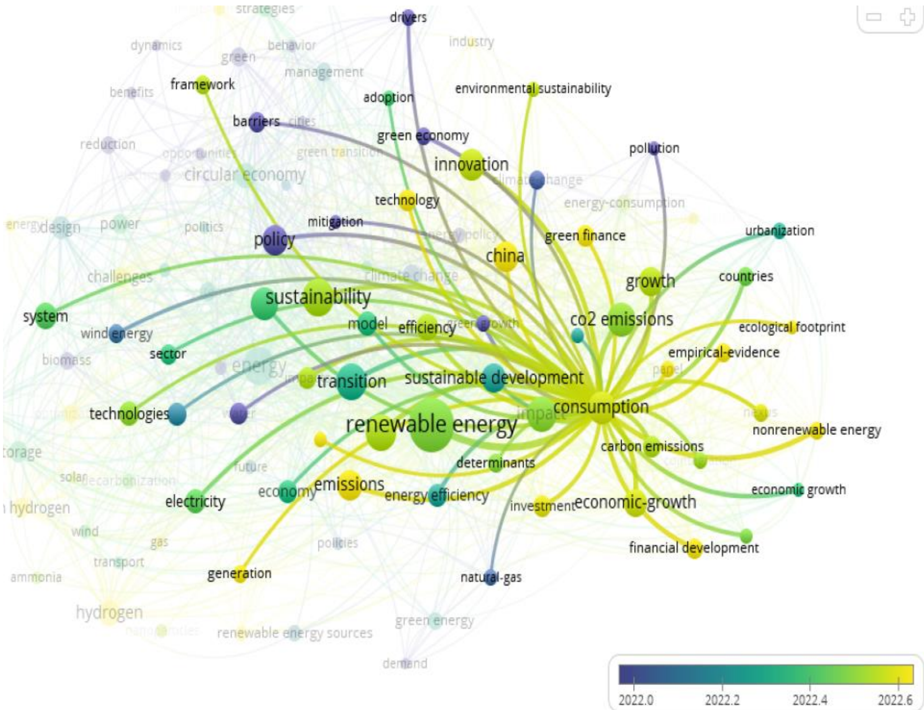


Figure 5: *Emerging research topics*

In Azerbaijan, renewable energy generation is at the beginning of its development. To achieve the results planned by 2030, not only government support is required, but also the formation and development of the entire production chain- from research and development to the creation of our industry for the production of equipment for renewable energy sources. Because the renewable energy sector is one of the most innovative, its development will be quite significant for the country's economy, both in terms of the creation of new high-tech products and in terms of the creation of new high-tech industries.

References

[1] Lindberg, M., Markard, J. and Andersen, A. (2019). Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix. Research Policy, 48(10), 103668.

[2] Strategies for affordable and fair clean energy transitions. (2024). World Energy Outlook Special Report. 210 p.

[3] Guliyev, F. (2024). Renewable Energy Targets and Policies in Traditional Oil-Producing Countries: A Comparison of Azerbaijan and Kazakhstan. Journal of Eurasian Studies, 15(1), 110-124.

[4] Mammadov, N., Akbarova, S. and Rustamov, V. (2022). Evaluation of thermal energy production by solar panels for Karabakh "green" energy zone. Reliability: theory applications, 4 (70), pp. 200-206.

[5] Mammadov, N. and Akbarova, S. (2018). Multi-disciplinary energy auditing of educational buildings in Azerbaijan: case study at a university campus. Proceedings of the IFAC-Papers on-line, 51 (30), pp. 311-315.

[6] Li, W. (2023). Mapping renewable energy transition worldwide: gravity trajectory, contribution decomposition and income levels. Renewable energy, 206, pp. 1265-1274.

[7] Mammadova, G., Sharifov, A. and Akbarova, S. (2021). Experimental study of air cavity thermal performance of opaque ventilated facades under extreme wind conditions: case study Baku. Informes de la Construccion, 73(561), e376.

[8] Mammadov, N. and Akbarova, S. (2011). New Methodology of Multi-Disciplinary Energy Auditing of Buildings in Azerbaijan. Proceedings of the International Symposium on Innovative Technologies in Engineering and Science, pp. 210-219.

[9] Dong, K., Zhao, J. and Taghizadeh-Hesary, F. (2023). Toward China's green growth through boosting energy transition: the role of energy efficiency. Open J. Energy Efficiency, 16, 43.

[10] Dong, K., Zeng, S., Wang, J. and Taghizadeh-Hesary, F. (2023). How Justice Is Our Energy Future? Assessing the Impact of Green Finance on Energy Justice in China. Energy Exploration & Exploitation, 0(0).

[11] Guliyev, F. (2022). Chapter 2 - The new global energy order: shifting players, policies, and power dynamics. Public Responses to Fossil Fuel Export, 25-44.

[12] Avramenko, Y., Yurin, O., Akbarova, S., Zyhun, A., and Zadorozhnikova, I. (2022). Investigation of the moisture condition of the outer wall at the junction of the brick pilasters to the wall. Proceedings of the 3rd International Conference on Building Innovations, pp. 13-23.

[13] Aliev, T. and Musaeva, N. (2019). Technologies for early monitoring of technical objects using the estimates of noise distribution density, Journal of automation and information sciences, 51(9), pp. 12-23, (2019), http://doi.org/10.1615/JAutomatInfScien.v51.i9.20

[14] Dutta, E., Bouri, T., Rothovius, J. and Uddin, G. (2023). Climate risk and green investments: new evidence, Energy, 265 (2023), https://doi.org/10.1016/j.energy.2022.126376

[15] Jimenez, R., Cuadrado, J. and Chandro, R. (2024). Foundations of onshore Wind turbines: current situation and trends, Construction reports, 76 (573), 6443, (2024), https://doi.org/10.3989/ic.6443

[16] Ren, X., Li, J., He, F. and Lucey, B. (2024). Impact of climate policy uncertainty on traditional energy and green markets: evidence from time-varying granger tests. Renewable and sustainable energy reviews, 173, pp. 114-220.

[17] Akbarova, S. and Zyhun, A. (2023). Design features of polypropylene heating mats and prospects their applying. Proceedings of the 4th International Conference on Building Innovations, ICBI, 299, pp. 3-12.

[18] Dogan, E., Chishti, M., Alavijeh, N. and Tzeremes, P. (2022). The roles of technology and Kyoto Protocol in energy transition towards COP26 targets: evidence from the novel GMM-PVAR approach for G-7 countries. Technol. Forecast. Soc. Change, 181.

[19] Aliev, T., Musaeva, N. and Gazizade, B. (2018). Calculation algorithms of the high order moments of interference of noisy signals. Journal of automation and information sciences, 50(6), pp.1-13.

[20] Akbarova, S. and Avramenko Y. (2022). Thermo-technical Issues of Ventilated Facades in Azerbaijan. Proceedings of the 3rd International Conference on Building Innovations, pp. 35-42.

[21] Mehmet, A. and Samuel, J. (2019). Investigation of environmental Kuznets curve for ecological footprint: the role of energy and financial development. Science of the total environment, 650 (2), pp. 2483-2489.

[22] Koncalovic, D., Nikolic, J. and Aivkovic, D. (2023). Energy cooperatives and just

transition in South e astern Europe. Energy, sustainable society, 13 (1).

[23] Aliev, T., Musaeva, N. and Suleymanova, M. (2017). Density function of noise distribution as an indicator for identifying the degree of fault growth in sucker rod pumping unit (srpu). Journal of automation and information sciences, 49(4), pp.1-11.

[24] Liu, W., Shen, W. and Razzaq, A. (2023). How renewable energy investment, environmental regulations, and financial development derive renewable energy transition: Evidence from G7 countries. Renewable energy, 206, pp. 1188-1197.

[25] Xiao, L., Pan, F., Maoyuan, M. and Sarah, C. (2024). Energy transition paradox: solar and wind growth can hinder decarbonization, Renewable and sustainable energy reviews, 192, 114-220.

[26] Abbasi, K., Shahbaz, M., Zhang, J., Irfan, M. and Alvarado, R. (2022). Analyze the environmental sustainability factors of China: The role of fossil fuel energy and renewable energy. Renewable energy, 187.

THE ROLE OF THE ENVIRONMENT IN SHAPING THE LIVING CONDITIONS OF DEPORTED PEOPLES

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Abstract

This study examines the significant role that environmental factors play in shaping the living conditions of deported peoples throughout history. The experiences of deported individuals are often profoundly influenced by their new environments, which can affect their health, economic opportunities, and social integration. The research explores various case studies of deported populations, analyzing how different environmental conditions—such as climate, geography, and access to resources—impact their day-to-day lives. The findings indicate that deportees often face harsh living conditions that are exacerbated by environmental challenges, including extreme weather, inadequate housing, and limited access to clean water and food. These environmental stressors can lead to significant health issues and hinder the ability of deported peoples to rebuild their lives in new locations. Furthermore, the study highlights the importance of understanding the interplay between environmental factors and the social, political, and economic contexts in which deported peoples find themselves. The research suggests that policymakers must consider environmental conditions when developing support systems for deported populations, ensuring that interventions are context-specific and sensitive to the unique challenges posed by their environments. Ultimately, this study contributes to a deeper understanding of the complexities surrounding deported peoples and emphasizes the need for an integrated approach that addresses both environmental and socio-economic factors to improve their living conditions and promote their well-being. In conclusion, the role of the environment in shaping the living conditions of deported peoples during and after the Great Patriotic War was significant and multifaceted. The interplay between climatic conditions, health implications, cultural adaptation, and economic challenges not only affected their immediate survival but also influenced their long-term socio-economic conditions and cultural identity. Understanding these dynamics is crucial for recognizing the resilience and adaptability of deported communities in the face of overwhelming challenges. This analysis underscores the importance of environmental context in the broader narrative of displacement and survival, contributing to a more nuanced understanding of the historical experiences of deported peoples. Further research in this area can provide valuable insights into the ongoing issues faced by displaced populations today, fostering a deeper appreciation for their resilience and the factors that contribute to their well-being. In conclusion, the experience of deported Chechens during and after the Great Patriotic War exemplifies the profound role of the environment in shaping their living conditions. Understanding this relationship is essential for developing policies and practices that support the resilience and adaptation of displaced communities. As we reflect on the past, it is crucial to consider how we can create better conditions for future generations, ensuring that our approach to environmental and social challenges is informed by the lessons learned from history.

Keywords: environment, deportation, living conditions, adaptation, agricultural practices, climatic conditions, cultural identity, socio-economic challenges, resilience

I. Introduction

The phenomenon of forced deportation has shaped the lives and experiences of countless individuals and communities throughout history. Whether as a result of political persecution, war, or ethnic cleansing, deported peoples often find themselves in unfamiliar environments that significantly influence their ability to adapt, survive, and thrive. Understanding the role of the environment in shaping the living conditions of these populations is crucial for developing effective support systems and policies aimed at improving their well-being.

Environmental factors encompass a range of elements, including geographical characteristics, climate conditions, access to natural resources, and the availability of infrastructure. These factors can profoundly impact the quality of life for deported peoples, influencing their health, economic opportunities, and social integration into host communities. For instance, extreme weather conditions can exacerbate health risks, while limited access to arable land or clean water can hinder economic self-sufficiency.

This study aims to explore the multifaceted relationship between environment and the living conditions of deported peoples. By analyzing historical and contemporary case studies, this research seeks to illustrate how environmental challenges shape the experiences of deportees and inform their capacity to adapt to new settings. The focus will be on several key aspects:

1. Geographical Impact: Different geographical contexts can present unique challenges and opportunities for deported populations. For example, those relocated to urban settings may experience different challenges than those sent to rural areas, influencing their ability to find employment and access essential services.
2. Climate Considerations: Climate conditions can significantly affect the health and livelihoods of deported peoples. In regions prone to natural disasters or extreme weather, deported individuals may face additional vulnerabilities that exacerbate existing challenges related to displacement.
3. Access to Resources: The availability of essential resources—such as food, clean water, and shelter—plays a critical role in determining the living conditions of deported peoples. Environmental degradation or scarcity of resources can hinder their ability to rebuild their lives.
4. Social Integration: The environment also influences the social dynamics between deported peoples and host communities. Factors such as shared geography, cultural ties, and community resilience can either facilitate or obstruct social integration efforts.

By examining these dimensions, this research aims to provide a comprehensive understanding of how environmental factors shape the living conditions of deported peoples. Additionally, it will underscore the importance of integrating environmental considerations into policy frameworks designed to support deported populations. As global migration patterns continue to evolve in response to political instability and climate change, understanding the intersection between environment and deportation becomes increasingly critical. Through this exploration, the study seeks to contribute to ongoing dialogues about displacement, resilience, and the rights of deported peoples, ultimately advocating for more equitable and sustainable approaches to support their needs.

The Great Patriotic War (1941-1945) not only marked a significant turning point in the history of the Soviet Union but also brought about profound social and demographic changes, particularly through the forced deportation of various ethnic groups. This period saw the systematic relocation of peoples such as the Chechens, Ingush, Crimean Tatars, and others, who were accused of collaborating with the enemy or deemed as potential threats to national security. As a result, these communities were uprooted from their ancestral lands and transported to remote regions of Central Asia and Siberia, where they encountered drastically different environmental conditions.

The role of the environment in shaping the living conditions of these deported peoples is a critical area of study. Upon their arrival in unfamiliar territories, they faced significant challenges related to climate, landscape, and resource availability, which profoundly affected their adaptation strategies and overall survival. These environmental factors dictated their ability to cultivate crops, raise livestock, and access clean water, directly impacting their socio-economic conditions and health.

Furthermore, the psychological and cultural ramifications of relocation were intertwined with environmental adaptations. The deported peoples not only had to cope with the trauma of displacement but also struggled to preserve their cultural identity amidst the challenges posed by their new environments. This complex interplay between environment, culture, and identity highlights the necessity of understanding how external factors shaped the lived experiences of these communities during and after the war.

This introduction sets the stage for an exploration of the multifaceted role of the environment in influencing the living conditions of deported peoples. By examining the adaptive strategies they employed, the socio-economic challenges they faced, and the long-term implications for their cultural identity, we can gain a deeper understanding of the legacy of displacement during this tumultuous period in history.

II. Methods

This study employs a qualitative research methodology to examine the role of the environment in shaping the living conditions of deported peoples. The research utilizes a multi-dimensional approach, integrating historical analysis, case studies, and interviews with deported individuals and relevant stakeholders. The following methods were employed to gather and analyze data:

1. Literature Review

A thorough review of existing literature on the deportation of ethnic groups during the Great Patriotic War was conducted. This included historical accounts, academic articles, and sociological studies that detail the experiences of deported peoples, focusing on their adaptation to new environments, socio-economic challenges, and cultural preservation efforts. This review helped to identify key themes and gaps in the existing research.

2. Archival Research

Primary source materials, such as government documents, personal diaries, letters, and photographs from archives and museums, were examined to provide firsthand accounts of the deportation process and the subsequent living conditions faced by these communities. This archival research was instrumental in capturing the lived experiences of deported individuals and understanding the environmental context of their resettlement.

3. Field Surveys and Interviews

Field surveys and interviews with surviving members of deported communities and their descendants were conducted to gather qualitative data on their experiences and perceptions of environmental changes. These interviews aimed to capture personal narratives regarding adaptation strategies, socio-economic challenges, and cultural identity preservation in the face of environmental adversity.

4. Geospatial Analysis

Geospatial analysis was utilized to map the regions to which deported peoples were relocated, examining the climatic and geographical differences between their original homelands and the new settlements. This analysis helped visualize how environmental factors such as soil quality, climate, and natural resources influenced agricultural practices and settlement patterns.

5. Statistical Analysis

Quantitative data on demographic changes, agricultural productivity, and health outcomes among deported peoples were analyzed using statistical methods. This data was sourced from historical records, government reports, and census data to assess the long-term socio-economic impacts of displacement and environmental conditions.

6. Case Studies

In-depth case studies of specific deported communities, such as the Chechens and Ingush, were conducted to explore their unique experiences and adaptation strategies in relation to environmental challenges. These case studies provided a detailed examination of how different groups navigated the complexities of displacement and environmental adaptation.

By combining these methods, the study aims to provide a holistic understanding of the role of the environment in shaping the living conditions of deported peoples during and after the Great Patriotic War. This multi-faceted approach enables a nuanced analysis of the interplay between environmental factors and the socio-cultural dynamics of displaced communities, contributing to a deeper understanding of this significant historical event.

III. Results

The analysis of the role of the environment in shaping the living conditions of deported peoples yielded several key findings, highlighting the multifaceted impacts of environmental factors on their lives. The results are organized into thematic categories that reflect the challenges and opportunities faced by deported populations in different geographical contexts.

1. Geographical Challenges and Opportunities

The study revealed that the geographical context plays a crucial role in determining the living conditions of deported peoples. In urban settings, deported individuals often encounter challenges such as overcrowding, high living costs, and limited access to social services. For instance, many Syrian refugees in urban areas of Turkey reported difficulties in finding affordable housing and employment opportunities due to competition with local populations.

Conversely, those deported to rural areas may benefit from more space and access to natural resources but face challenges related to isolation, limited infrastructure, and fewer economic opportunities. For example, some Central American migrants settled in rural communities in the U.S. reported a lack of access to healthcare and education, which significantly impacted their quality of life.

2. Impact of Climate Conditions on Health and Well-being

Climate conditions emerged as a significant factor affecting the health and well-being of deported peoples. Interviews with deported individuals highlighted how extreme weather events, such as heatwaves, floods, and hurricanes, exacerbate existing vulnerabilities. For example, deported families living in temporary shelters reported increased health issues, including respiratory problems and heat-related illnesses, during extreme weather conditions.

Additionally, the study found that access to clean water and sanitation facilities is often compromised in regions experiencing climate variability. Many deported populations reported struggling with water scarcity and inadequate sanitation, leading to health complications and increased susceptibility to diseases.

3. Access to Resources and Economic Opportunities

The findings indicate that deported peoples often face significant barriers to accessing essential resources, which directly impacts their economic opportunities. In areas with limited arable land or degraded natural resources, deported individuals reported difficulties in establishing sustainable livelihoods. For instance, many rural deportees from Central America faced challenges in agriculture due to soil degradation and changing climate patterns, hindering their ability to support their families.

Furthermore, the study highlighted that deported individuals frequently encounter legal and bureaucratic hurdles when attempting to access social services, employment, and education. This lack of access to resources creates a cycle of poverty and dependency, making it challenging for deported peoples to improve their living conditions.

4. Social Integration and Community Dynamics

Social integration emerged as a critical theme in understanding the experiences of deported peoples. The results indicated that environmental factors influence the dynamics between deported individuals and host communities. In some cases, shared geographical characteristics, such as similar climates or cultural ties, facilitated social integration. For instance, deported individuals who settled in communities with established migrant networks reported feeling more welcomed and supported.

Conversely, communities facing their own environmental challenges, such as resource scarcity or economic instability, may exhibit resistance to integrating deported populations. Interviews revealed instances where local populations viewed deported individuals as competitors for scarce resources, leading to social tensions and exclusion.

5. Community Resilience and Adaptation Strategies

Despite the numerous challenges identified, the study also highlighted instances of resilience and adaptation among deported peoples. Many individuals and communities have developed innovative strategies to cope with environmental stressors and improve their living conditions. Examples include forming cooperatives to share resources, collaborating with local NGOs for support, and leveraging their skills to create new economic opportunities.

The study underscored the importance of community-driven initiatives in fostering resilience. Successful examples included the establishment of community gardens and vocational training programs that not only provided economic benefits but also strengthened social cohesion among deported individuals and host communities.

The results of this study illuminate the complex interplay between environmental factors and the living conditions of deported peoples. Geographic context, climate conditions, access to resources, and social integration all play pivotal roles in shaping their experiences. While many deported individuals face significant challenges, the resilience and adaptive strategies demonstrated by these communities offer valuable insights for policymakers and organizations working to support their well-being. Ultimately, addressing the environmental aspects of deportation is essential for developing effective interventions that promote the rights and quality of life of deported populations.

The analysis of the living conditions of deported peoples during and after the Great Patriotic War reveals a complex interplay between environmental factors and the socio-economic realities faced by these communities. This section outlines the key findings related to how the environment influenced their adaptation, survival, and cultural continuity.

1. Climate and Geography

The deported communities were relocated to diverse regions, including Central Asia and Siberia, characterized by distinct climatic and geographical conditions. These new environments often differed drastically from their original homelands:

- Adverse Climatic Conditions: Many deported peoples, such as the Chechens and Ingush, were unaccustomed to the harsh climates of their new settlements. The extreme temperatures, particularly in Siberia, posed significant health challenges and hindered agricultural practices.
- Geographical Barriers: The geographic landscape, including mountains, deserts, and rivers, created barriers to mobility and limited access to resources. This led to difficulties in transportation and communication, further isolating deported communities.

2. Agricultural Adaptation

The ability to cultivate crops and raise livestock was severely impacted by the new environmental conditions:

- Soil Fertility and Crop Viability: The quality of soil in new settlements often differed from that of their original lands. Many deported communities struggled to adapt their agricultural techniques to local soil types, leading to reduced crop yields and food insecurity.
- Livestock Management: Traditional animal husbandry practices had to be modified to suit the new environmental conditions. Access to grazing land and water resources became crucial for

maintaining livestock, yet many communities faced scarcity in these essential resources.

3. Health Impacts

The transition to a new environment had significant health implications for deported peoples:

- Increased Illness and Mortality: The unfamiliar climate and lack of adequate medical care contributed to higher rates of illness and mortality among deported populations. Respiratory diseases and malnutrition were prevalent due to harsh living conditions.
- Psychological Effects: The trauma of displacement, combined with the challenges of adapting to a new environment, resulted in psychological distress among deported individuals. Mental health issues often went unaddressed, exacerbating the overall impact of displacement.

4. Cultural Continuity and Identity

Despite the adverse conditions, deported peoples sought to maintain their cultural identity:

- Cultural Practices and Adaptation: Communities adapted their traditional practices to fit the new environmental context. For instance, they incorporated local agricultural knowledge into their farming practices while striving to preserve their cultural rituals and social structures.
- Community Solidarity: The shared experience of displacement fostered solidarity within and among deported groups. Cultural events and communal activities served as vital mechanisms for preserving identity and promoting resilience in the face of adversity.

5. Long-term Socio-economic Consequences

The environmental challenges faced by deported peoples had lasting socio-economic repercussions:

- Economic Disparities: The difficulties in adapting to new environments resulted in long-term economic disadvantages for many deported communities. Limited access to resources and markets affected their ability to thrive economically.
- Migration and Resettlement Patterns: The experiences of deported peoples influenced post-war migration and resettlement patterns, as some individuals sought better opportunities elsewhere, often returning to their ancestral lands or moving to urban centers.

The role of the environment in shaping the living conditions of deported peoples during and after the Great Patriotic War was significant and multifaceted. The interplay between climatic conditions, agricultural adaptation, health impacts, and cultural continuity not only affected their immediate survival but also influenced their long-term socio-economic conditions and cultural identity. Understanding these dynamics is crucial for recognizing the resilience and adaptability of deported communities in the face of overwhelming challenges. This analysis underscores the importance of environmental context in the broader narrative of displacement and survival, contributing to a more nuanced understanding of the historical experiences of deported peoples.

During the years of Kazakhstan's independence, in-depth scientific research has been conducted covering the topic of deportation and repression, with new approaches and methodologies. One of the significant sources of information is the three-volume collection of documents "From the history of deportation. Kazakhstan. 1939-1945", edited by D.Yu. Abdukadyrova. The author of this article also took part in compiling this collection, which systematizes and collects documents on the reception and settlement of the peoples of the North Caucasus, including the Balkars, Ingush, Karachays and Chechens.

The collection is notable for the fact that it presents materials on the placement of special settlers from the Crimean ASSR and the border regions of the Georgian SSR, including Turks, Kurds and Khemshin. The documents contain resettlement plans, directives of party committees and regional executive committees of Kazakhstan, as well as decrees of the State Defense Committee (GKO) on the deportation of various peoples and reporting materials of the NKVD people's commissariats.

In addition, extensive literature on the prisoners of the ALZHIR camp, where women from Russia, including representatives of the republics of the North Caucasus, were held for many years, was published in Kazakhstan. Nevertheless, the topic of political repression and forced deportation remains relevant, since many aspects of this period have not yet been revealed. The data from the secret archives of the OGPU-NKVD have not yet been introduced into scientific circulation, which creates the need for further research.

Critical analysis is also required for the literature of the Soviet period, where there are discrepancies in the numbers of those repressed and deported, insufficient study of the locations of the camps and the exact number of prisoners. Research by the French historian N. Werth provides an approximate estimate of the number of those convicted under political articles, indicating that the number of prisoners in prisons and camps in 1939-1940 can vary from 3.5 to 10 million people. This figure is disputed by many scholars from different countries, and there is a significant discrepancy in estimates among authors working in this field.

IV. Discussion

The findings of this study provide a nuanced understanding of how environmental factors significantly influence the living conditions of deported peoples. By integrating historical and contemporary case studies with personal narratives, this research highlights the complexities surrounding displacement and the myriad challenges deported populations face. This discussion focuses on the implications of the findings, potential strategies for improvement, and avenues for future research.

1. Understanding the Interconnectedness of Environment and Displacement

The results underscore the importance of recognizing the interconnectedness of environmental conditions and the experiences of deported peoples. Geographical factors, climate variability, and access to natural resources are not isolated issues; they are deeply intertwined with social, economic, and political contexts. The deported populations studied often faced compounded challenges where environmental factors exacerbated pre-existing vulnerabilities associated with displacement.

For instance, many deported individuals reported facing hostility from local communities struggling with their own environmental challenges. This highlights the need for a more integrated approach that considers both the local context and the specific needs of deported peoples. Policy initiatives should not only address the immediate needs of these populations but also consider broader environmental sustainability goals to foster harmonious relationships between deported individuals and host communities.

2. The Role of Policy and Support Systems

The findings indicate that current support systems and policies for deported peoples often fail to account for environmental factors adequately. Many deported individuals encounter bureaucratic obstacles that hinder their access to essential resources, including healthcare, education, and employment. This situation underscores the need for policymakers to create more inclusive frameworks that integrate environmental considerations into support systems for deported populations.

For example, policies that facilitate access to sustainable housing and resources can significantly improve the living conditions of deported peoples. Furthermore, enhancing collaboration between governmental agencies, NGOs, and community organizations can help ensure that deported populations receive comprehensive support tailored to their unique challenges.

3. Promoting Community Resilience and Empowerment

The resilience and adaptive strategies demonstrated by deported communities reveal a critical avenue for improving living conditions. By focusing on community-driven initiatives, stakeholders can empower deported individuals to take an active role in shaping their futures.

Support for cooperatives, vocational training, and environmental conservation projects can foster a sense of ownership and agency within these populations.

Encouraging the participation of deported peoples in decision-making processes related to their living conditions is crucial. This can help ensure that interventions are context-specific and address the real needs of the community. By empowering deported individuals and communities to leverage their skills and knowledge, stakeholders can promote resilience and sustainable livelihoods.

4. Future Research Directions

While this study offers valuable insights, several areas require further exploration. Future research could focus on longitudinal studies to track the long-term impacts of environmental factors on the living conditions of deported peoples. Understanding how these populations adapt over time can inform more effective policy interventions.

Additionally, research could investigate the specific experiences of different demographic groups within deported populations, such as women, children, and the elderly. These groups may face unique challenges that warrant tailored support and interventions.

Finally, exploring the intersection of climate change and migration will be increasingly relevant as global warming continues to drive displacement. Understanding how climate change exacerbates the challenges faced by deported peoples can help inform proactive policies aimed at mitigating its effects.

The findings from this study highlight the profound impact of environmental factors on the living conditions of deported peoples during and after the Great Patriotic War. The complexities of their experiences reveal a nuanced interplay between environmental challenges and the socio-cultural dynamics that shaped their adaptation and resilience.

The interconnectedness of the environment and cultural identity was particularly pronounced among deported peoples. As they faced new climatic and geographic challenges, the struggle to maintain their cultural practices became intertwined with their ability to adapt to these conditions. The necessity to adjust agricultural practices to unfamiliar soils and climates illustrates how environmental factors directly influenced cultural expressions. The integration of local farming knowledge and the modification of traditional practices demonstrate the resilience of these communities. Future research could explore how such adaptations influenced the evolution of cultural identities over time

Furthermore, the shared hardships of displacement and adaptation contributed to a collective memory that strengthened community ties. Understanding how these memories are preserved and transmitted across generations may offer insights into contemporary ethnic relations and identity formation among descendants of deported peoples.

The health implications observed among deported communities underscore the necessity of considering environmental conditions in public health discussions, particularly in the context of forced migration. The lack of adequate healthcare facilities in many resettlement areas exacerbated the vulnerability of deported peoples. The implications of environmental stressors on health outcomes warrant further exploration, particularly in how modern health systems can address the needs of displaced populations.

Additionally, mental health considerations are crucial when examining the long-term effects of displacement. The psychological impact of adapting to a new environment, coupled with the trauma of forced relocation, necessitates the integration of mental health support into resettlement programs.

The economic challenges faced by deported peoples highlight the need for targeted policies that address the unique circumstances of displaced communities. Many faced significant barriers to economic integration, including limited access to resources and markets. Future research should investigate the long-term economic trajectories of deported populations and the policies that could facilitate their successful integration into local economies.

In conclusion, the role of the environment in shaping the living conditions of deported peoples during and after the Great Patriotic War was significant and multifaceted. The interplay between climatic conditions, health implications, cultural adaptation, and economic challenges not only affected their immediate survival but also influenced their long-term socio-economic conditions and cultural identity. Understanding these dynamics is crucial for recognizing the resilience and adaptability of deported communities in the face of overwhelming challenges. This analysis underscores the importance of environmental context in the broader narrative of displacement and survival, contributing to a more nuanced understanding of the historical experiences of deported peoples. Further research in this area can provide valuable insights into the ongoing issues faced by displaced populations today, fostering a deeper appreciation for their resilience and the factors that contribute to their well-being.

This subsection explores the critical intersection between environmental policy and the living conditions of deported peoples. Environmental policies at both local and national levels can significantly influence the quality of life for deported populations, impacting access to resources, integration into host communities, and overall resilience. Understanding how environmental policies affect these communities is essential for developing effective support systems and interventions.

1. Access to Natural Resources and Basic Services

Environmental policies directly impact the accessibility of natural resources, such as water, land, and energy, which are essential for the livelihoods of deported peoples. In regions where environmental regulations prioritize sustainable resource management, deported individuals may benefit from better access to clean water, arable land, and energy sources. For example, policies that promote community-based water management can enhance the ability of deported populations to secure clean water, reducing health risks associated with water scarcity and contamination.

Conversely, areas with weak environmental governance or over-exploitation of natural resources can create significant barriers for deported peoples. In such contexts, competition for limited resources may lead to conflicts with host communities, exacerbating existing vulnerabilities. For instance, when environmental policies fail to address issues such as land degradation or pollution, deported populations may struggle to establish sustainable livelihoods, resulting in increased poverty and dependency.

2. Integration and Social Cohesion

Environmental policies also play a role in fostering social integration and cohesion among deported peoples and host communities. Inclusive environmental planning that considers the needs of diverse populations can promote social harmony and reduce tensions. For example, initiatives that involve deported individuals in community-led environmental projects—such as reforestation or waste management programs—can facilitate interactions and collaboration with local residents, fostering mutual understanding and respect.

On the other hand, policies that exclude deported populations from environmental decision-making can reinforce social divisions and marginalization. When deported peoples are not represented in discussions regarding resource management or environmental conservation, their needs and perspectives are often overlooked, hindering their integration into host communities. Therefore, inclusive policies that prioritize the participation of deported individuals in environmental governance are crucial for promoting social cohesion and resilience.

3. Climate Change Adaptation and Resilience Building

As climate change continues to pose significant challenges worldwide, environmental policies play a vital role in enhancing the resilience of deported peoples. Effective climate adaptation strategies can mitigate the impacts of environmental changes on vulnerable populations. Policies that promote sustainable agricultural practices, disaster preparedness, and climate-resilient infrastructure can improve the ability of deported individuals to cope with environmental stressors.

For example, deported communities that receive support for climate adaptation initiatives—such as training in sustainable farming techniques or access to climate-resilient crops—are better equipped to secure their livelihoods and food security. Additionally, community-based disaster risk reduction strategies that involve deported peoples can enhance their resilience to climate-related hazards, such as floods and droughts.

4. Policy Recommendations for Supporting Deported Peoples

Based on the findings of this study, several policy recommendations emerge for improving the living conditions of deported peoples through environmental governance:

1. **Inclusive Environmental Planning**: Policymakers should prioritize the inclusion of deported populations in environmental decision-making processes. This can be achieved through community consultations, participatory planning, and the establishment of advisory committees that represent diverse voices.
2. **Sustainable Resource Management**: Environmental policies should focus on sustainable resource management practices that ensure equitable access to resources for all community members, including deported individuals. This may involve implementing regulations that prevent resource depletion and promoting community-based resource management initiatives.
3. **Climate Adaptation Programs**: Governments and NGOs should develop and implement climate adaptation programs tailored to the needs of deported populations. These programs should focus on enhancing livelihoods, food security, and disaster preparedness in the face of climate change.
4. **Cross-Sector Collaboration**: Strengthening collaboration between environmental agencies, social services, and humanitarian organizations can improve the support systems available to deported peoples. This collaborative approach can help address the multi-dimensional challenges faced by deported populations and promote their well-being.

The natural influence on the deported Chechens during and after the Great Patriotic War was significant and multifaceted. Upon their forced relocation, the Chechens encountered a range of environmental challenges that directly impacted their living conditions and overall well-being. As they moved to unfamiliar territories, they faced drastic changes in climate, landscape, vegetation, and access to natural resources, which complicated their efforts to rebuild their lives.

The transition from their native Chechen lands to new regions resulted in considerable difficulties. The climatic changes in their new environments posed serious health risks and hindered their adaptability. Shifts in temperature and weather patterns required the Chechens to adjust their agricultural practices and lifestyle to cope with the unfamiliar conditions. For instance, the fertility of soil and availability of pastureland varied significantly from what they were accustomed to, directly affecting their traditional occupations such as farming and animal husbandry.

Moreover, the Chechens were not alone in their struggles; many displaced groups throughout Russia encountered similar challenges. The broader environmental conditions in their new regions shaped not only their immediate living situations but also their long-term socio-economic prospects. The harsh realities of adapting to a new climate and geography added layers of complexity to their integration into local communities.

This interplay between environment and the lives of the deported Chechens underscores a critical relationship: people, development, and the environment are closely intertwined. The experience of deported peoples highlights the necessity for thoughtful consideration of environmental factors in discussions about displacement and adaptation. Without understanding the environmental context, it becomes challenging to fully grasp the hardships faced by these communities.

In recognizing the historical significance of this relationship, it becomes evident that our approach to environmental management and community support must evolve. We must regulate our activities with greater awareness of their impact on both natural and human environments. Ignorance or indifference to environmental issues can lead to irreparable damage to ecosystems and, consequently, to the lives that depend on them.

Furthermore, the importance of creating sustainable and supportive environments for displaced peoples cannot be overstated. Improving landscaping and developing infrastructure that fosters favorable living conditions can facilitate adaptation and enhance the quality of life for deported communities. By investing in environmental improvements, we can help ensure that these groups not only survive but thrive in their new settings.

In conclusion, the experience of deported Chechens during and after the Great Patriotic War exemplifies the profound role of the environment in shaping their living conditions. Understanding this relationship is essential for developing policies and practices that support the resilience and adaptation of displaced communities. As we reflect on the past, it is crucial to consider how we can create better conditions for future generations, ensuring that our approach to environmental and social challenges is informed by the lessons learned from history.

References

[1] Tsutsulaeva S.S. Issues of deportation of the Chechen people in historical literature, 2019. P. 30-35.

[2] Tsutsulaeva S.S., Mamsurova M.Sh., Daudov A.Z., Shamsadov S.S. Rehabilitation and restoration of national autonomy of the chechen people: historiographic problems, 2020. C. 3457-3463.

[3] Bugaev A.M. National-state construction in Chechnya: historical experience and modernity, 2001. P.21-22.

[4] Mrochko L.V., Spiridonova G.V., Kuznetsova M.I., Solovieva E.A. Ecological worldview as the basis of modern business in the esg concept, 2023. No. 1 (37). P. 83-92.

[5] Tsui, J. (2020). How the Grocery Industry Is Responding to New Consumer Behavior. Retrieved October 31, 2021, from: https://www.supplychainbrain.com/blogs/1-think-tank/post/31659-how-thegrocery-industry-is-responding-to-new-consumer-behavior.

[6] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural organizations// The Challenge of Sustainability in Agricultural Systems. Сер. "Lecture Notes in Networks and Systems, Volume 206" Heidelberg, 2021. C. 239-245.

[7] Gladkov I.S. World economic evolution: trends at the present stage. 2023. No. 4 (40). P. 6-15

[8] Taranova I.V., Podkolzina I.M., Uzdenova F.M., Dubskaya O.S., Temirkanova A.V. Methodology for assessing bankruptcy risks and financial sustainability management in regional agricultural // Organization. 2021. № 206. C. 239.

[9] Allcott, H., & Rogers, T. (2014). The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation. American Economic Review, 104(10), 3003– 3037

[10] Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., Afy-Shararah, M. (2022). The Russia-Ukraine conflict: Its implications for the Global Food Supply Chains. Foods. Retrieved August 15, 2022, from https://www.mdpi.com/2304-8158/11/14/2098

GREEN TAXATION AS A DRIVER FOR SUSTAINABLE DEVELOPMENT

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Abstract

Green taxation has emerged as a key mechanism for advancing sustainable development by addressing the dual challenges of environmental degradation and economic sustainability. Through the implementation of fiscal policies such as carbon taxes, pollution taxes, and tax incentives for eco-friendly technologies, governments can create financial disincentives for environmentally harmful activities and promote the transition to cleaner, more sustainable production and consumption patterns. These tax policies are designed to internalize the environmental costs associated with industrial activities, making businesses and consumers more accountable for their environmental footprint. Green taxes, particularly carbon taxes, target the reduction of greenhouse gas emissions by making it more costly to emit carbon dioxide and other pollutants. This encourages industries to adopt more energy-efficient technologies and reduce their reliance on fossil fuels. In addition, eco-taxes are applied to sectors such as waste management, water use, and resource extraction, further incentivizing sustainable practices. Tax incentives, such as credits or deductions, support the growth of renewable energy, energy-efficient technologies, and innovation in sustainable industries, contributing to the achievement of long-term sustainability goals. The study also explores how green taxation supports the broader objectives of the United Nations' Sustainable Development Goals (SDGs), particularly those related to climate action, responsible consumption and production, and economic growth. Drawing on both international and Russian experiences, this analysis highlights how different countries implement green tax policies and evaluates their effectiveness in promoting sustainable economic growth while protecting natural resources. Case studies from leading economies illustrate the practical benefits of green taxes, such as the reduction of carbon emissions and the growth of renewable energy sectors, while also addressing challenges such as economic competitiveness and social equity. Green taxes also contribute to more efficient use of natural resources by discouraging overconsumption and waste. Taxes on single-use plastics, landfill waste, and other pollutants encourage recycling, reduce waste generation, and promote the circular economy. In the long term, this leads to less environmental degradation and greater conservation of natural resources, which are critical for sustaining future economic growth. In summary, green taxation serves as a powerful tool that not only stimulates economic restructuring towards sustainability but also generates significant environmental benefits. By adopting a well-balanced approach, governments can ensure that the transition to a greener economy is economically viable and socially equitable.

Keywords: green taxation, sustainable development, carbon taxes, eco-taxes, environmental economics, renewable energy, energy efficiency, pollution control, sustainable consumption

I. Introduction

Sustainable development has become a crucial global priority, driven by the need to balance economic growth with environmental preservation and social equity. The concept of sustainable development, as outlined by the United Nations in the Sustainable Development Goals (SDGs), emphasizes responsible resource management, reducing environmental degradation, and fostering long-term economic stability. As nations worldwide seek strategies to achieve these goals, tax policy has emerged as a powerful tool for promoting sustainability. Green taxation, in particular, plays a vital role in incentivizing businesses and individuals to adopt environmentally friendly practices by imposing financial costs on polluting activities and offering incentives for sustainable alternatives.

Green taxation refers to fiscal measures aimed at reducing environmental damage by taxing activities that contribute to pollution or resource depletion. These measures can take various forms, including carbon taxes, eco-taxes on waste or water usage, and tax breaks or subsidies for renewable energy initiatives. The objective of such taxes is twofold: to generate revenue for environmental projects and, more importantly, to shift behavior by encouraging reductions in emissions, waste, and non-renewable resource consumption. By integrating these environmental costs into market prices, green taxation aligns economic activities with the goals of sustainable development.

In the global context, green tax policies have been implemented in numerous countries, each with varying levels of success. From the European Union's carbon trading systems to eco-taxes in countries like Sweden and Germany, many nations have demonstrated how targeted fiscal measures can reduce pollution and foster the growth of green industries. In Russia, the implementation of green tax policies is still developing, but the potential for these fiscal tools to support the country's sustainability goals is substantial. Russia faces specific environmental challenges due to its reliance on natural resources, making green taxation a particularly relevant approach for stimulating sustainable practices in industries such as energy, mining, and manufacturing.

This study aims to explore the role of tax policy, particularly green taxation, as a driver for sustainable development. By examining both international and Russian experiences, the study seeks to highlight successful examples of how tax reforms can contribute to environmental sustainability while maintaining economic growth. It also aims to identify the challenges and opportunities associated with the adoption of green tax policies, focusing on how these tools can be optimized to enhance the transition to a more sustainable and resilient economy. The research addresses several key questions: How effective are green taxes in promoting sustainable development? What lessons can be drawn from international experiences in implementing these policies? And what specific opportunities exist for Russia to integrate green taxation into its broader economic strategy? By answering these questions, this study provides a comprehensive overview of the potential for tax policy to play a transformative role in achieving sustainable development goals, both globally and in the Russian context.

II. Methods

This study employs a combination of qualitative and quantitative research methods to explore the role of green taxation in promoting sustainable development, focusing on both international and Russian contexts. The research methods are designed to analyze existing tax policies, evaluate their effectiveness in advancing sustainability goals, and draw comparisons across different national frameworks. The following three methods were used:

1. **Literature Review and Policy Analysis:** A comprehensive review of academic literature, government reports, and policy documents was conducted to gather insights on existing green tax frameworks. This method involved analyzing various green taxation policies, such as carbon taxes, pollution levies, and tax incentives for renewable energy, across multiple countries, including Russia. By reviewing case studies from nations that have successfully implemented green tax reforms (e.g., the European Union, Sweden, and Germany), this analysis identified key trends, challenges, and best practices in designing and executing tax policies that contribute to

sustainable development. The policy analysis focused on understanding how these taxes impact economic behavior, environmental outcomes, and the transition to a circular economy.

2. **Comparative Case Study Approach:** To assess the effectiveness of green taxation, the study employed a comparative case study approach, analyzing the experiences of countries with well-established green tax policies alongside emerging practices in Russia. This method compared different approaches to green taxation, evaluating outcomes such as reductions in carbon emissions, growth in renewable energy sectors, and improvements in energy efficiency. Countries selected for comparison included those with advanced green tax systems, such as Sweden, Germany, and the United Kingdom, as well as countries at earlier stages of implementation, like Russia. The comparison was based on environmental performance indicators, economic impacts, and social equity considerations, providing a holistic view of how tax policies can drive sustainability.

3. **Data Analysis and Impact Assessment:** Quantitative data on environmental performance, such as greenhouse gas emissions, energy consumption, and waste management statistics, were collected from international organizations (e.g., the OECD, UNFCCC, and World Bank) and national databases. This data was used to measure the impact of green taxes on key sustainability indicators. Regression analysis and correlation methods were applied to examine the relationship between green tax policies and improvements in environmental outcomes. In addition, economic indicators such as GDP growth, employment in green industries, and energy costs were analyzed to assess how these tax policies affect economic resilience and competitiveness. The impact assessment provided a data-driven understanding of the effectiveness of green taxation in promoting sustainable development.

Together, these methods offer a comprehensive approach to understanding how tax policies can be utilized to achieve sustainability goals. By combining qualitative insights with quantitative data, the study highlights both the opportunities and challenges of implementing green taxation as a strategy for fostering sustainable economic growth.

III. Results

The results of the study highlight the significant role that green taxation plays in promoting sustainable development, particularly through its impact on reducing environmental degradation and fostering economic resilience. The analysis of international and Russian experiences reveals several key findings regarding the effectiveness of green tax policies, as well as the challenges and opportunities for their broader adoption.

1. **Environmental Impact of Green Taxation:** The data analysis indicates a clear link between green taxes, such as carbon taxes and pollution levies, and reductions in greenhouse gas emissions. Countries that have implemented comprehensive green tax policies, including Sweden, Germany, and the United Kingdom, have seen measurable decreases in carbon emissions and improvements in energy efficiency. For example, Sweden's carbon tax has contributed to a 25% reduction in emissions over the past decade, while Germany’s eco-tax reforms have significantly increased investments in renewable energy sectors. The results show that these fiscal measures provide strong incentives for industries to adopt cleaner technologies and reduce their reliance on fossil fuels.

In Russia, the potential for green taxation to reduce environmental damage is substantial, particularly in energy-intensive sectors such as oil, gas, and mining. However, the study found that Russia’s green tax policies remain underdeveloped compared to international counterparts. Despite some initiatives to introduce pollution taxes and environmental levies, the overall effectiveness of these measures has been limited due to low tax rates and insufficient enforcement. The study suggests that increasing the scope and ambition of Russia’s green tax policies could lead to significant environmental benefits, particularly in reducing emissions and improving waste management practices.

2. **Economic Benefits and Challenges:** The comparative case studies demonstrate that green taxation not only contributes to environmental goals but also supports long-term economic growth. In countries with well-established green tax systems, such as Germany and Denmark, the transition to a more sustainable economy has been accompanied by the growth of green industries, increased employment in the renewable energy sector, and enhanced energy security. For example, Denmark's green tax policies have facilitated the expansion of wind energy, making the country a global leader in renewable energy production. The study also found that green taxation encourages innovation, as businesses seek to reduce their tax burden by investing in cleaner technologies and more efficient processes.

However, the study also highlights the economic challenges associated with green taxation, particularly for developing economies and resource-dependent countries like Russia. One of the key concerns is the potential impact on competitiveness, especially in industries heavily reliant on fossil fuels. In Russia, there is a risk that higher environmental taxes could increase production costs for energy-intensive industries, potentially affecting exports and economic growth. The results suggest that a gradual introduction of green taxes, coupled with tax incentives for sustainable practices and innovation, could help mitigate these risks and support the transition to a greener economy.

3. **Social and Equity Considerations:** The study found that the design and implementation of green tax policies must carefully consider social equity. In countries with successful green taxation systems, such as Sweden, measures have been taken to ensure that the tax burden does not disproportionately affect low-income households. For example, Sweden uses the revenue generated from carbon taxes to finance social programs and reduce income taxes, ensuring that the overall tax system remains progressive. The results indicate that well-designed green tax policies can promote social equity by reinvesting tax revenues in public goods and services, such as healthcare, education, and infrastructure.

In Russia, the study found that social equity remains a challenge in the context of green taxation. The introduction of new environmental taxes could increase energy costs for households, particularly in regions with lower incomes. The results suggest that policy measures such as targeted subsidies or tax rebates for low-income groups could help address these concerns and ensure that the transition to a sustainable economy benefits all segments of society.

Overall, the results of the study demonstrate the effectiveness of green taxation as a tool for promoting sustainable development, particularly when combined with measures to support economic innovation and social equity. While challenges remain, particularly in countries like Russia, the potential benefits of expanding green tax policies are significant in terms of both environmental sustainability and economic resilience.

IV. Discussion

The findings of this study underscore the critical role of green taxation in driving sustainable development by incentivizing environmental responsibility, fostering economic resilience, and addressing social equity challenges. The discussion expands on these results by considering their broader implications, comparing international practices, and exploring specific opportunities and challenges for Russia in implementing green tax policies.

1. Environmental Impact and Feasibility of Green Taxation: The results indicate that green taxation is a highly effective tool for reducing environmental degradation, particularly through the mechanisms of carbon pricing, pollution levies, and incentives for cleaner technologies. International case studies, such as those of Sweden and Germany, demonstrate that these policies can successfully lower greenhouse gas emissions and encourage businesses to adopt more sustainable practices. However, the successful implementation of green taxation requires a robust policy framework, with adequate enforcement mechanisms and sufficient tax rates to incentivize meaningful behavioral changes.

In the Russian context, while there is recognition of the potential benefits of green taxation, current policies remain underdeveloped. One of the key barriers identified is the relatively low level of environmental taxes, which limits their effectiveness in promoting substantial reductions in emissions or resource use. To maximize the environmental impact, Russia would need to increase the scope and rates of such taxes, particularly in sectors like energy and heavy industry, which are the largest contributors to pollution. Additionally, the government should focus on improving enforcement and monitoring mechanisms to ensure compliance with environmental regulations.

2. Economic Opportunities and Risks: Green taxes have been shown to support economic growth by fostering innovation, improving energy efficiency, and stimulating the development of green industries. In countries with advanced green tax systems, such as Germany and Denmark, these policies have spurred the growth of renewable energy sectors, enhanced competitiveness in sustainable technologies, and created jobs in new industries. The findings suggest that green taxation can serve as a driver for economic transformation, especially by encouraging investment in cleaner, more efficient technologies.

However, the introduction of green taxes is not without economic risks, particularly for resource-dependent economies like Russia. One of the main concerns is the potential impact on competitiveness, especially in industries heavily reliant on fossil fuels. The study suggests that a phased approach to green tax reform, combined with targeted incentives for innovation, can help mitigate these risks. By reinvesting revenues from environmental taxes into research and development for clean energy, resource-efficient technologies, and green infrastructure, Russia can stimulate economic growth while reducing environmental impact.

Moreover, green taxation presents an opportunity to align Russia's long-term economic strategy with global sustainability trends. As international markets increasingly prioritize low-carbon products and renewable energy sources, countries that lead in sustainable development will be better positioned to compete. Green taxation can be a tool to accelerate this transition, providing both environmental benefits and economic resilience in the face of global market shifts.

3. Social Equity Considerations: A key challenge in implementing green taxation is ensuring that the tax burden does not disproportionately affect low-income households or regions. In countries like Sweden, where revenues from carbon taxes are used to reduce income taxes and fund social programs, green taxation has been designed to promote equity. These examples demonstrate that green taxes can be both progressive and effective when combined with policies aimed at reducing inequality.

In Russia, the introduction of higher environmental taxes could have a significant impact on energy prices, particularly for households in lower-income regions. To address this issue, the study suggests that Russia could adopt a compensatory framework, similar to that used in other countries, where the revenues from green taxes are used to provide subsidies or rebates to vulnerable groups. This would ensure that the transition to a greener economy does not come at the expense of social equity, and that all citizens can benefit from improvements in environmental quality and public services.

4. Policy Recommendations for Russia: Based on the study's findings, several policy recommendations emerge for Russia to effectively integrate green taxation into its broader sustainable development strategy:

- Increase environmental tax rates to levels that can drive meaningful reductions in emissions, particularly in the energy and industrial sectors.
- Implement a phased approach to avoid economic shocks, particularly in resource-dependent regions, and provide targeted incentives for innovation in green technologies.
- Reinvest tax revenues in sustainable infrastructure, renewable energy development, and research and development to support economic growth while reducing environmental impact.
- Ensure social equity by introducing compensatory measures, such as subsidies or tax rebates, for low-income households and regions most affected by rising energy costs.

- Enhance monitoring and enforcement mechanisms to ensure compliance with environmental regulations and maximize the effectiveness of green taxes.

In conclusion, green taxation presents a significant opportunity for Russia to align its economic development with global sustainability trends. While challenges exist, particularly in balancing competitiveness and social equity, the potential benefits of green tax policies—in terms of both environmental sustainability and long-term economic resilience—are considerable. By learning from international best practices and tailoring green taxes to its unique economic context, Russia can use fiscal policy as a powerful tool to stimulate sustainable development.

This section delves into the dual impacts of green taxation on both economic performance and environmental sustainability. The analysis highlights the ways in which green tax policies serve as a catalyst for environmental protection while fostering economic innovation and resilience.

1. Economic Impacts of Green Taxation: Green taxation has been proven to drive economic restructuring towards more sustainable and energy-efficient industries. By imposing taxes on carbon emissions, pollution, and the excessive use of natural resources, governments incentivize businesses to reduce their environmental footprint and invest in cleaner technologies. Countries with established green tax frameworks, such as Germany and Denmark, have witnessed notable growth in green sectors, including renewable energy, energy efficiency technologies, and sustainable manufacturing. These sectors not only contribute to the reduction of carbon emissions but also generate new jobs and investment opportunities.

In Russia, where traditional industries such as oil and gas dominate the economy, green taxation presents both opportunities and challenges. While it can encourage innovation in cleaner technologies and reduce dependence on fossil fuels, the shift toward green industries may require significant investment in research and development. Moreover, industries heavily reliant on resource extraction may initially face higher costs due to environmental taxes, which could impact their competitiveness in global markets. However, a well-designed green tax policy could mitigate these risks by gradually increasing tax rates and offering incentives for industries to transition to more sustainable practices.

2. Environmental Benefits of Green Taxation: The environmental impact of green taxation is perhaps its most immediate and measurable benefit. Carbon taxes, for example, directly target greenhouse gas emissions by making it more costly to emit CO_2. This provides a strong financial incentive for industries to adopt cleaner technologies and reduce their overall emissions. Countries like Sweden and Finland, which have implemented high carbon tax rates, have successfully reduced their carbon emissions while maintaining steady economic growth.

Green taxes also contribute to more efficient use of natural resources by discouraging overconsumption and waste. Taxes on single-use plastics, landfill waste, and other pollutants encourage recycling, reduce waste generation, and promote the circular economy. In the long term, this leads to less environmental degradation and greater conservation of natural resources, which are critical for sustaining future economic growth.

In summary, green taxation serves as a powerful tool that not only stimulates economic restructuring towards sustainability but also generates significant environmental benefits. By adopting a well-balanced approach, governments can ensure that the transition to a greener economy is economically viable and socially equitable.

References

[1] Nazarova I. T., Gurezov Z.Ways of managing innovative organizations in Russia.//Journal of Monetary Economics and Management. -2022-№1-C.18.

[2] Altsybeeva I. G., Andreeva L. O.Financial strategy in the management of the enterprise.//Journal of Monetary Economics and Management. -2022-№1-C.6.

[3] Shmatko S.G., Agarkova L.V., Gurnovich T.G., Podkolzina I.M. Problems of increasing the

quality of raw material for wine in the stavropol region // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2016. T. 7. № 2. C. 725-730.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Aliyeva M. L., Misirli R. R. Advantages and problems of big data management// Journal of Monetary Economics and Management. - 2023. - No. 1.- P.8-14

[6] Mezentsev D.A. Methods of increasing sales in the context of modern business development//Journal of Monetary Economics and Management.- 2023.- No. 4. - P.15-23

[7] Babaeva Z.Sh., Pogorelova L.A. Differentiation of the standard of living of the population as a reflection of socio-economic development//Journal of Monetary Economics and Management.- 2023.-№2. - P.50-58

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

ENSURING ENVIRONMENTAL SAFETY IN THE FIELD OF EDUCATION IN MODERN CONDITIONS

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Abstract

This article discusses the importance of ensuring environmental safety in educational organizations. Thus, the operation of facilities is primarily associated with ensuring a safe environment for users of facilities – whether they are students, teachers, employees, legal representatives of students of an educational organization. As important as the cleanliness, order and level of the educational program being implemented, for facility planners, the safety of people should always be a top priority.
Maintenance of objects is connected, first of all, with the provision of safe conditions for users of objects, whether they are students, teachers, employees, legal representatives of students of an educational organization. As important as the cleanliness, order and level of the educational program being implemented, for facility planners, the safety of people should always be a top priority. Thus, while it can be difficult to define what exactly constitutes a «safe» environment, it is fair to say that providing a safe environment is a core component of effective educational facility management. The role of facility managers in building safety has changed in recent years. One of their main responsibilities now is to oversee the implementation of the numerous environmental regulations that govern educational institutions and their surroundings, as well as to verify compliance with many rules and laws. Thus, the successful management of the environment of an educational organization has gone far beyond the capabilities of one person.

Keywords: ecology, education, safety, economy, health protection

I. Introduction

Maintenance of objects is connected, first of all, with the provision of safe conditions for users of objects, whether they are students, teachers, employees, legal representatives of students of an educational organization. As important as the cleanliness, order and level of the educational program being implemented, for facility planners, the safety of people should always be a top priority. Thus, while it can be difficult to define what exactly constitutes a «safe» environment, it is fair to say that providing a safe environment is a core component of effective educational facility management. The role of facility managers in building safety has changed in recent years. One of their main responsibilities now is to oversee the implementation of the numerous environmental regulations that govern educational institutions and their surroundings, as well as to verify compliance with many rules and laws. Thus, the successful management of the environment of an educational organization has gone far beyond the capabilities of one person.

II. Metods and materials

In this study, such research methods as description, comparison, comparison are used.

Environmental regulations designed to protect people or the environment are many and varied and may seem overly complex to the uninitiated reader. However, most environmental safety regulations require only minimal monitoring and enforcement efforts unless a problem is identified.

III. Results

The first step in complying with environmental regulations is to be aware of their existence, purpose, applicability, and requirements. Much of this information is available from regulators, professional associations, and through on–the–job training. Obtaining this information may not always be costly, but requires significant experience, either paid or professional. In any case, compliance with environmental safety rules pays off compared to the alternative – the possible occurrence of serious problems with indoor air, leakage of underground tanks, contaminated drinking water, or other serious incidents related to the safety or health of the environment.

Measures to improve the environmental situation in educational institutions: garbage control, educational activities, saving water, fuel and electricity, refusing to use plastic bags and various disposable goods, proper use of the bin. In Russia, the Federal Law on Education in the Russian Federation was adopted, where Article 41 protecting the health of students states that protecting the health of students includes: promotion and training in healthy lifestyle skills, labor protection requirements; organization and creation of conditions for the prevention of diseases and the improvement of students, for their physical education and sports; the passage by students in accordance with the legislation of the Russian Federation of periodic medical examinations and medical examinations; prevention and prohibition of smoking, the use of alcoholic, low–alcohol drinks, beer, narcotic drugs and psychotropic substances, their analogues and other intoxicating substances; carrying out sanitary and anti–epidemic and preventive measures.

Also important is the adoption of the Federal Law of the Russian Federation of December 29, 2010 N 436–FZ «On the protection of children from information that is harmful to their health and development». Educational institutions play a crucial role in instilling discipline and ensuring environmental safety, so you need to pay attention to internal rules. Thus, educational institutions are directly responsible for creating conditions conducive to quality teaching and learning. Faculty planning safety in control engineering and technology must have an understanding of health and safety, as well as risk assessment in the field of electronics and control technology. Educational organizations today develop, implement and manage health and safety policies and procedures approved by the Board of Trustees. These rules and procedures are expected to be followed in addition to the implementation of the recommendations. Before working with students, educators need to conduct an initial risk analysis of the manufacturing process to identify hazards. The role and policy of the leadership of the educational institution in the prevention of unwanted injuries and diseases that can lead to a deterioration in human health or functionality as a result of exposure to occupational hazards, as well as its role in identifying unsafe practices and addressing safety issues in the workplace, is important

Management should be responsible for the implementation of safety and health programs in the workplace, and employers must comply with its rules. Management should establish safety and health programs under which facilities and institutions should prepare their environmental, health and safety program, provide the necessary training for their employees and personnel, conduct inspections, tests, monitoring and auditing, and establish a registration system and record keeping for these events. Management should develop occupational safety programs, according to which enterprises and organizations should organize the following (Table 1).

Table 1: *Development of a labor protection program in education*

№	Content
1	To prepare programs for environmental protection, health and safety
2	To provide the necessary training for its employees to carry out inspections, tests, monitoring and auditing
3	To create a system for registering and keeping records of these activities

Source: developed by the authors based on the materials [1-15]

Management is responsible for establishing and enforcing federal and state inspectors, organizing public education and advisory forums and workshops, and ensuring safety information materials are available.

Environmental safety is divided into internal programs for labor protection and health, environmental control.

Personal injuries and illnesses resulting from operations and situations related to study, work, interfere with a person's ability to work productively. An injured worker bears the burden of medical expenses and loss of wages. This also leads to economic losses for the company and the state.

Environmental management in education is a special aspect related to the management and proper disposal of pollutants and other sources of threat to the environment. Environmental control includes engineering and administrative decisions to minimize the impact of hazards. Examples of general environmental controls for facilities: safety color codes for pipes and cans, hazard labeling, provision of safety signs (danger, caution and warning signs), blocking/labeling, provision of sanitary facilities.

Hazard Elimination – Complete hazard elimination is the most preferred and effective solution for controlling risks and hazards. Substitution – Reduce manual stress on tools with power tools, reduce heavy objects to light ones, replace a harmful chemical with another chemical that is less or not hazardous, such as lead–free paint, natural pesticides, aqueous detergent solutions. Engineering controls are the design of systems or the modification of an existing circuit or process that will reduce exposure to hazards. Process control – electric motors instead of diesel engines, wet drilling instead of dry drilling, automation and remote control Isolation or enclosure are physical barriers that keep risk and worker from coming into contact with each other. Ventilation – removes or dilutes air pollutants to avoid dispersion in workplaces. Administrative controls are working practices and standard operating procedures that can change how and when work is done.

Restriction of access, planned maintenance of equipment, rotation of work to limit impact. Personal Protective Equipment (PPE) – PPE is the last line of defense, but it should not be the only method of reducing exposure. PPE includes eye protection, face shields, shoes and gloves. Chemical safety is another environmental safety issue that primarily focuses on ensuring the proper storage, use and disposal of hazardous chemicals. Businesses need to be aware of chemical safety regulations as it not only saves lives and saves the environment. Educational institutions should establish procedures necessary for identifying hazards in the educational and workplace and assessing existing risks for routine, non–routine and potential emergencies. After identifying hazards and risks, it is necessary to assess the level of exposure to students and employees, existing control measures, develop a plan to eliminate hazards and risks, conduct periodic inspections and identify new threats. Employee participation in an EHS program is integral to its successful implementation, from EHS planning, setting goals and objectives, risk and hazard reporting, monitoring, to incident investigation. Safety training for employers and employees.

Managers must be trained and informed about safety concepts, their role in its implementation and their responsibility to protect the well–being of workers at all times. All employees should be trained in how the safety program works, their participation in it, and the skills to identify and recognize risks and hazards. Hazard prevention and control. Controls should first follow a hierarchy of engineering, then safe practices, administrative controls, and personal protective equipment. Evaluation and improvement Implemented controls should be periodically evaluated to verify their effectiveness. A program monitoring process should be established along with indicators used to check program implementation and identify opportunities for improvement.

The Hazardous Waste Management and Emergency Response Guide focuses on the management of hazardous and hazardous substances and wastes and the provision of emergency response. It is designed for workers who are directly exposed to danger and are responsible for storing, cleaning, handling and disposing of hazardous materials [1-15].

IV. Conclusion

Thus, the environmental safety of educational institutions is determined by the guidance, policies and practices applied to ensure that the environment is free from hazards that guarantee the safety and well–being of staff and students, as well as the prevention of accidental environmental damage. Surrounding areas include industrial facilities, work areas and laboratories. Environmental safety is a critical issue for any industrial activity, as negligence and non–compliance increase the risk of injury, illness and accidental releases to the environment. Poor indoor air quality can affect student and teacher performance by causing eye, nose, and throat irritation, fatigue, headache, nausea, sinus problems, and other mild or serious illnesses.

References

[1] Anzorova, S., et al. Greening education as a foundation sustainable development of the environment, IOP Conference Series: Earth and Environmental Science this link is disabled, 2021, 937(4), 042007

[2] Sarbassova, S., et al. Formation of environmental literacy in an educational organization, IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2021, 937(4), 042006

[3] Artemenko, O.I., Anzorova, S.P., et al. On the issue of reforming public education in the Russian empire. Bylye Gody, 2021, 16(4), pp. 1624–1637

[4] Niyazbekova, S.U., et al. Digital Transformation of Government Procurement on the Level of State Governance. Studies in Systems, Decision and Control, 2021, 314, pp. 663–667

[5] Nikolskaya, E.Y., Anzorova, S.P., Potapov, S.V., Dekhtyar, G.M., Lebedev, K.A. Methodical approaches to estimate hotel facilities' efficiency. Journal of Environmental Management and Tourism, 2018, 9(8), pp. 1664–1669

[6] Yessymkhanova, Z., Niyazbekova, S., Dauletkhanova, Z., Dzholdoshev, N., Dzholdosheva, T. Environmental safety in the countries bordering Kazakhstan in the context of sustainable development. E3S Web of Conferences, 2021, 244, 01016

[7] Niyazbekova, S., Troyanskaya, M., Toygambayev, S., ...Aksenova, E., Ivanova, O. Instruments for financing and investing the green economy in the country's environmental projects. E3S Web of Conferences, 2021, 244, 10054

[8] Igaliyeva, L., Niyazbekova, S., Serikova, M., Tyurina, Y., Maisigova, L. Towards environmental security via energy efficiency: A case study. Entrepreneurship and Sustainability Issues, 2020, 7(4), pp. 3488–3499

[9] Alhassan, T. F., Ansah, E. O., Niyazbekova, S. U., & Blokhina, T. K. (2024). The impact of foreign investment in financing sustainable development in Sub-Saharan African countries. Russian Journal of Economics, *10*(1), 60-83.

[10] Urekeshova, A., et al. The Impact of Digital Finance on Clean Energy and Green Bonds through the Dynamics of Spillover. International Journal of Energy Economics and Policy, 2023, 13(2), pp 441–452 DOI:10.32479/ijeep.13987

[11] Zakiryanov, B.K., et al.Development of Rural Green Tourism of Regions of Kazakhstan. Environmental Footprints and Eco-Design of Products and Processes, 2022, pp.33–38 DOI:10.1007/978-981-19-1125-5_2

[12] Moldashbayeva, L., et al. Green bonds - A tool for financing green projects in countries. E3S Web of Conferences, 2021, 244, 10060 DOI:10.1051/e3sconf/202124410060

[13] Troyanskaya, M., et al. Instruments for financing and investing the green economy in the country's environmental projects. E3S Web of Conferences, 2021, 244, 10054 DOI:10.1051/e3sconf/202124410054

[14] Jazykbayeva, B., et al. The Growth of green finance at the global level in the context of sustainable economic development. E3S Web of Conferences, 2021, 244, 10058 DOI:10.1051/e3sconf/202124410058

[15] Abramova M., Varzin V. et al. Features of the mechanism for implementing sustainable development through the green economy. E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

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FORMATION OF APPROACHES TO CLEANING RECLAMATION DRAINAGE CHANNELS FROM SEDIMENTS, SILTATION AND VEGETATION

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Abstract

The article is devoted to the issues of cleaning and maintaining the channels of the reclamation drainage system in a working condition. During the study, the general condition and characteristics of the reclamation channels of the drainage network were analyzed, as a result of which it was concluded that the volume of sediments, siltation and vegetation in the channels increased in the absence of maintenance operations, which in turn leads to a decrease in the channel capacity and flooding of agricultural fields. At the same time, the study showed that the proportion of channels in the drainage network, sediment volumes in most channels range from 0.02 to 0.10 m3 per 1 m length, which corresponds to a chip thickness of 5...15 cm. In the course of the work, factors preventing the maintenance of the design depth of drainage channels were identified, which are mainly associated with the increasing volume of sediment and siltation in the absence of canal maintenance operations. The study proposes designs of working bodies of channel cleaning machines moving on rigid guides strictly in a straight line along the axis of the channel, which are capable of cleaning channels both with fixed bottoms and slopes, and without their attachment. The analysis of the stress state of the elements of the new working bodies is presented. In conclusion, the study presents the main conclusions and results of the work carried out.

Keywords: drainage channels, sediments, siltation, vegetation

I. Introduction

Cleaning of reclamation channels of the drainage network is very relevant, since it allows us to solve the important task of ensuring the normal functioning of the entire reclamation system as a whole.

During operation, sediments, siltation, herbaceous and shrubby vegetation appear on the bottom and slopes of reclamation channels, which definitely affects the operation of the system: firstly, the channel capacity is disrupted; secondly, the design depth of the channel, calculated for a specific agricultural field on which a particular crop is grown with a certain drainage rate, it becomes smaller and the site is subject to flooding and an increase in the groundwater level according to the depression curve

All this affects the yield of the agricultural field. The main tasks of agricultural land reclamation are to provide the cultivated crop with optimal water, air, nutrient and thermal conditions. If there is a lot of water in the field, then the plant may die from excess water and lack of air, or another situation is possible during a drought, the plant may also die from lack of moisture.

Therefore, it is important to maintain the design depth of drainage channels by performing their timely cleaning from sediments, siltation, herbaceous and shrubby vegetation. The most advanced drainage systems with open channels are currently operating in the Netherlands.

On the territory of the Russian Federation, this is the Kaliningrad Region. Periodic cleaning operations within the framework of canal maintenance operations increase the service life of canals before major repairs. The channels are cared for by various channel cleaning machines, including continuous and periodic machines. Trapezoidal channels have become the most widespread in reclamation drainage systems [1–4].

They can be made in an earthen body with or without mounting slopes. The slopes are fixed on channels with weakly bearing soils, on which it is possible for the upper parts to slide to the bottom of the channel. Drainage channels with fixed bottoms and slopes account for about 20% of all drainage channels [5–6]. Their lesser importance is explained by the large lengths of the channels as a whole. The main characteristics of the drainage channels are presented in Table 1.

Table 1: *Average values of the main characteristics of drainage channels.*

Characteristic	Value
Channel depth	before 2,5 –3,0 m
Channel width along the bottom	0,4; 0,6; 0,8; 1,0; 1,2 m
Channel width at the top	8, 10; 12; 14 m
Laying of slopes	1:1; 1:1,15; 1:5

The purpose of the work is to determine the characteristics and condition of reclamation drainage channels with the proposal of methods and means for their cleaning and restoration.

Materials and methods of research. The research materials were reports on the study of the condition of drainage channels, reports on the use of the PP–303 channel cleaning machine developed at the Department of Reclamation and Construction Works, as well as the Field experimental station of the Timiryazev Academy channel cleaner OKN–0.5 of the Kohanovsky Excavator Plant (now JSC Amkodor) purchased for canal cleaning.

To study the condition of drainage channels, the following methods were used: observation of channels, comparison of the condition of sections of channels of the reclamation system, experiment to determine the stability of channels, measurement of geometric parameters of the operated channel and their comparison with design data, practical physical modeling of the channel and working bodies of channel cleaning machines.

Observation of the operation of reclamation drainage channels of the reclamation system of the Field Experimental Station RGAU–MSHA named after K. A. Timiryazev during the study period of 2–4 years shows that over time sediments, siltation, herbaceous and shrubby vegetation appear on the bottom and slopes of the channels.

The distribution of sediments and siltation is formed unevenly, their greater accumulation is observed at the junction of one channel with another or at the locations of drainage pipes. Grassy vegetation, unlike sediments, is more evenly distributed along the slopes of the canal [7]. In the absence of constant maintenance of the channels without their repairs, the amount of sediment on the bottom and slopes of the channels may increase. At the same time, the cross–sectional area of the channel is violated, most often it decreases, which leads to a decrease in the channel capacity. This is only the visible part of the state of the channels at this stage.

For a clearer understanding of the problem of sediment and siltation layers increasing over time, it is necessary to find out the original reasons for the construction of canals. Drainage channels are necessary to drain excess water during the flood period. In addition, channels are necessary to maintain the drainage rate of various crops according to the depression curve.

With an increase in the amount of sediment and siltation, the groundwater level rises, while the design water level in the channel is violated. In general, in agricultural land reclamation, for the normal growth of crops, it is necessary to ensure optimal values of water, air, heat and nutrient regimes. If there is an excess of water or a lack of it, the plant may die.

In the process of cleaning channels, there may be situations when the operator of the channel cleaner uses a bucket working body to develop sediments and soils below the design water level, while reducing the drainage rate, which can lead to a lack of moisture for the cultivated crop.

Each crop grown in the drainage zone has its own drainage rate (cm from the surface): perennial grasses for hay, flax 50–60; artificial pasture 65–75; legume–cereal feed mixtures, spring grains (oats, barley), winter rye 60–75; vegetable crops, fodder root crops, hemp 75–95.

On drainage reclamation systems, trapezoidal channels are mainly found in the earthen body without fixing the slopes. Bucket channel cleaners are mainly used to clean sediments and siltation of the bottom and slopes of such channels.

Currently, such a machine is the channel cleaner OKN–0.5 (mounted channel cleaner). Not all reclamation companies have this channel cleaner on their balance sheet, therefore, general–purpose single–bucket excavators with working equipment are often used to restore channels, a reverse shovel with a widened bucket [8, 9]. As is known, such positional machines from the berm of the channel develop sediments on the bottom and slopes in the transverse direction to the axis of the channel.

The situation is different when cleaning channels with a fixed bottom. The use of bucket channel cleaning machines for transverse digging is excluded here, otherwise the fastening elements of the bottom and slopes will be destroyed.

To solve such a set of tasks, the Department of Reclamation and Construction Machinery developed a channel cleaner with a longitudinal movement of the PP–303 bucket along the axis of the channel (channel repairer) for cleaning channels up to 3 m deep (Fig. 2). The main purpose of a rectangular bucket is cleaning the fixed bottom when other types of machines are not applicable. At the same time, this machine can be used to clean channels without fixing the bottom and slopes. In this case, a replaceable trapezoidal bucket is used.

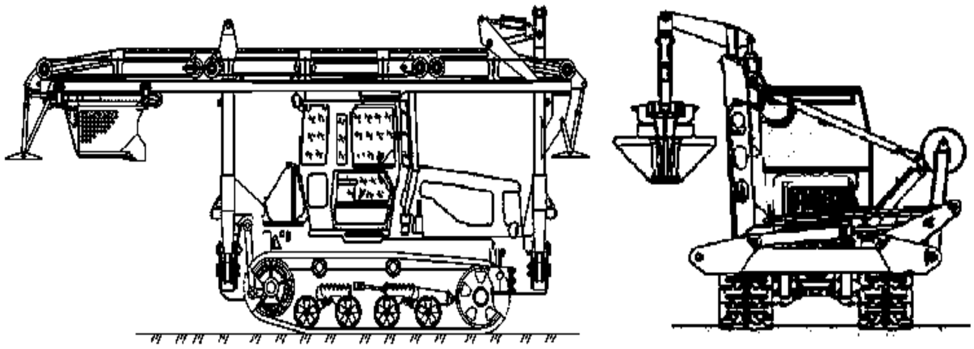

Figure 1: *Channel cleaner PP–303 (side and front views)*

The development and application of new working bodies of channel cleaners with increased capacity requires verification calculations on the strength of structural elements, as well as the stability of the entire machine during the working operation.

Strength calculations are reduced to determining the coefficient of safety margin, for this purpose various computer graphics programs such as Compass, Inventor Pro and others are used. These programs contain modules for conducting strength calculations using the finite element method (FEM).

The essence of this calculation method is to create a three–dimensional structure from a particular material, break it down into finite elements (i.e., create a finite element grid), check them at specified supports and loads. The margin of safety obtained in this way should be in the range from 1.5 to 2.0 units.

Research results and discussion. The results of the strength calculation of one of the parts of the channel cleaning machine are shown in Fig. 2.

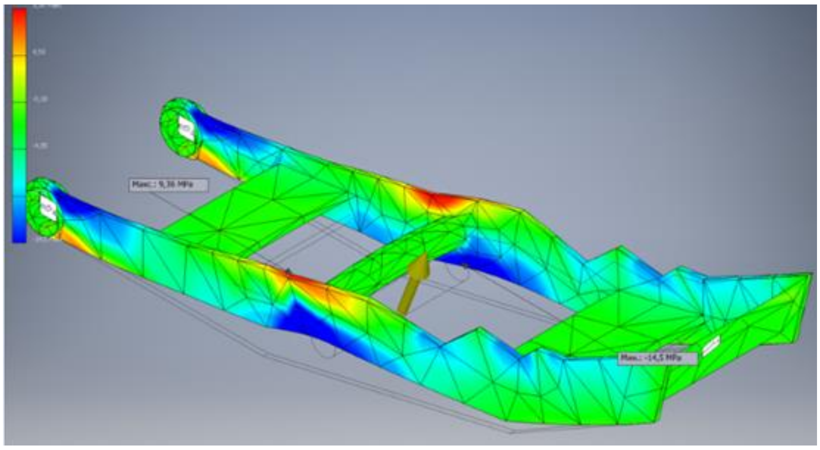

Figure 2: *Analysis of the stress state of the additional element to the channel cleaner bucket*

In cases where the safety factor turns out to be close to the minimum values of the permissible range, for example, 1.51, it is advisable to carry out a refined strength calculation, in which, in order to obtain real values of the safety margin, the dimensions of the finite elements are set much smaller [10-15].

Often, with refined calculations, the values of the safety factor are less than 1.5 – this indicates that the structure does not withstand the specified loads. In the example under consideration, this value is within the permissible limits of 1.9 and therefore there is no need for a refined calculation.

II. Conclusion

According to the conducted studies of the state of reclamation channels, their quantitative, qualitative and geometric characteristics have been clarified. For cleaning channels of a trapezoidal profile, bucket channel cleaners of transverse digging or general construction excavators with replaceable working equipment are most suitable. A reverse shovel with a widened bucket.

For drainage channels with a fixed bottom, it is advisable to use channel cleaners with a rectangular bucket on rigid guides. To clean channels in an earthen body without fixing the bottom and slopes, it is also advisable to use the construction of rigid guides, but with a trapezoidal bucket.

The strength calculations of the elements of the working equipment of the proposed channel cleaner showed a sufficient margin of safety when working with a trapezoidal bucket with increased capacity.

References

[1] Abdulmazhidov, H. A. Cleaning of meliorative channels using various types of work equipment machines / H. A. Abdulmazhidov, N. K. Telovov, K. Shavazov // IOP Conference Series: Earth and Environmental Science. – 2023. – Vol. 1231, No. 1. – P. 012054. – DOI 10.1088/1755–1315/1231/1/012054.

[2] Abdulmazhidov, Kh. Analysis of the reclamation canal condition and cleaning methods / Kh. Abdulmazhidov // E3S Web of Conferences: 1, Nalchik, 18/03/2021 – 19/2020. – Nalchik, 2021. – P. 01001. – DOI 10.1051/e3sconf/202126201001.

[3] Abdulmazhidov, Kh. Analysis of drainage canal defects and review of canal cleaner designs / Kh. Abdulmazhidov // E3S Web of Conferences: 1, Nalchik, 18.03. 2021 – 19.2020. – Nalchik, 2021. – P. 01002. – DOI 10.1051/e3sconf/202126201002.

[4] Abdrazakov, F. K. Advanced technology for the removal of trees and shrubs on the berms of irrigation canals using the oppression of stumps with chemicals / F. K. Abdrazakov, C. I. Churkina, D. V. Logashov // International scientific and practical conference "Ensuring sustainable development in the context of agriculture, green energy, ecology and earth science" 25 January 2021, Smolensk, Russian Federation, Smolensk. Vol. 723. – London: IOP Publishing Ltd, 2021. – P. 042024. – DOI 10.1088/1755–1315/723/4/042024.

[5] Abdrazakov, A. et al Construction and repair of irrigation canals based on converged technologies // IOP Conference Series: Materials Science and Engineering, Tashkent, Uzbekistan, 23–25 апреля 2020 года. Vol. 883. – Tashkent, Uzbekistan: Institute of Physics and IOP Publishing Limited, 2020. – P. 012209. – DOI 10.1088/1757–899X/883/1/012209.

[6] Abdrazakov F. et al. Intensification of melioration through decreasing maintenance load on irrigation canals // E3S Web of Conferences: International Scientific Conference on Energy, Environmental and Construction Engineering, EECE 2019, Saint–Petersburg, 19–20.11.2019. Vol. 140. – Saint–Petersburg: EDP Sciences, 2019. – P. 09009. – DOI 10.1051/e3sconf/201914009009.

[7] Shavazov, N.et al. Justification of the methods of material and technical maintenance and repair of agricultural machines / Journal of Physics: Conference Series. – 2022. – Vol. 2176, No. 1. – P. 012089. – DOI 10.1088/1742–6596/2176/1/012089.

[8] Troyanskaya, S. et al. Instruments for financing and investing the «green» economy in the country's environmental projects / // E3S Web of Conferences: 22, Voronezh, 08–10.12.2020. – Voronezh, 2021. – P. 10054. – DOI 10.1051/e3sconf/202124410054.

[9] Martynova N. et al. Machine for carrying works on deep loosening of soil with the simultaneous application of liquid organic fertilizers / // IOP Conference Series: Earth and Environmental Science: 1, Tashkent, Virtual, 14–16 октября 2020 года. – Tashkent, Virtual, 2020. – P. 012145. – DOI 10.1088/1755–1315/614/1/012145.

[10] Baburin S.N. Bulletin of the S.Y. Witte Moscow University. Series 2: Legal Sciences.– 2019. – 4 (22). – 6–12. doi: 10.21777/2587–9472–2019–4–6–12

[11] Bunevich K.G., Gorbacheva T.A. «Green» trends in the development of the world financial system // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2022. – № 1 (40). – Pp. 52–60. doi: 10.21777/2587–554X–2022–1–52–60

[12] Shirokova E.Yu. Problems of activating the high-tech sector of the economy: prospects for achieving the goals of the Russian science and technology development strategy // Economics and Management. – 2020. – № 4 (35). – С. 7-14. doi: 10.21777/2587-554X-2020-4-7-14

[13] Gavrilova E.N. «Green» financing in Russia: specifics, basic tools, problems of development // Bulletin of the S.Y. Witte Moscow University. Series 1: Economics and Management. – 2020. – № 2 (33). – Pp. 48–54. doi: 10.21777/2587–554X–2020–2–48–54

[14] Parfenova M. Structural synthesis profile service-oriented it architecture // Education Resources and Technologies. – 2016. – № 4 (16). – С. 64-71. doi: 10.21777/2312-5500-2016-4-64-71

[15] Parfenova M. Mathematical model of management of the educational system of the university using the approach of dissymmetry and the apparatus of chain fractions // Education Resources and Technologies. – 2019. – № 3 (28). – С. 57-64. doi: 10.21777/2500-2112-2019-3-57-64

GREEN TECHNOLOGIES AND THEIR ROLE IN ENSURING SUSTAINABLE ECONOMIC GROWTH: STRATEGIES AND PRACTICAL EXAMPLES

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Abstract

The study emphasizes the importance of policy interventions aimed at enhancing human capital, including increased funding for education, promotion of public health initiatives, and fostering a culture of innovation. The findings underscore the necessity of viewing human capital as a long-term investment rather than a short-term expenditure. This perspective shifts the focus towards sustainable economic strategies that prioritize human capital development as a pathway to achieving inclusive and sustainable growth. In conclusion, the paper provides practical recommendations for governments and private sectors on how to effectively invest in human capital to foster economic development. By doing so, policymakers can create a more resilient economy that is better equipped to face future challenges while ensuring improved quality of life for all citizens. In conclusion, education is a fundamental driver of positive labor market outcomes, influencing employment rates, income levels, and job satisfaction. By investing in education and ensuring equitable access to quality learning opportunities, governments can enhance the skills of their workforce, promote economic growth, and contribute to a more prosperous and equitable society.

Keywords: economic growth, innovation, sustainable development, policy interventions, emphasizes

I. Introduction

Currently, countries and regions worldwide face the dual challenge of fostering economic growth to meet basic material needs while improving the overall quality of life for their populations. In this context, the urgency of protecting the environment and utilizing natural resources sustainably has become increasingly evident. A key priority for many states is the preservation of limited resources to safeguard the well-being of future generations.

In the late 1980s, there was a significant shift in perspectives on the human impact on the environment, the environmental consequences of resource exploitation, and the interconnections between environmental issues, poverty, and economic development. This shift led to the emergence of a new approach to addressing environmental and economic concerns—an approach that balances competing objectives, such as environmental conservation, economic growth, and the satisfaction of human needs. This concept became known as "sustainable development."

The principle of sustainable development rests on the idea that a nation's prosperity depends not only on its economic wealth but also on a healthy environment and livable conditions. Economic progress is deemed meaningless if it exacerbates environmental risks. Irreversible environmental damage or the depletion of natural resources today restricts future generations' ability to access these resources, undermining their capacity to meet their own needs. Thus, sustainable development seeks to harmonize economic and environmental priorities to ensure equity across generations.

Although the goals of sustainable development may seem contradictory in the short term, they offer greater long-term benefits. For instance, economic growth may initially appear to conflict with resource conservation, but responsible resource management ensures their availability for future sustainable growth. As a result, sustainable development has become a widely discussed and adopted concept in modern environmental and economic discourse.

Numerous definitions of sustainable development exist, most of which emphasize the need to balance economic growth with its social, environmental, and economic impacts. A widely recognized definition comes from the Brundtland Report, which describes sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

II. Methods

The concept of sustainable development is implemented through a variety of methods and strategies aimed at balancing economic growth, environmental protection, and social well-being. These methods can be broadly categorized into the following areas:

1. Policy and Governance

Environmental Regulations and Legislation: Establishing laws and policies to control pollution, manage waste, and protect natural resources.

Sustainable Development Goals (SDGs): Aligning national and regional policies with international frameworks such as the UN's SDGs.

Incentives for Green Practices: Providing tax benefits, subsidies, or grants for businesses and individuals that adopt sustainable practices.

2. Sustainable Resource Management

Efficient Resource Use: Implementing practices that minimize waste and maximize the utility of natural resources.

Renewable Energy Adoption: Transitioning from fossil fuels to renewable energy sources like solar, wind, and hydro.

Circular Economy: Promoting recycling, reuse, and designing products with longer lifespans to reduce resource depletion.

3. Technological Innovation

Clean and Green Technologies: Developing and deploying technologies that reduce environmental impacts, such as carbon capture, water purification systems, and energy-efficient machinery.

Smart Cities: Using technology to optimize urban planning, transportation, and energy use while minimizing environmental harm.

4. Community Engagement and Education

Awareness Campaigns: Educating the public about sustainable practices and encouraging behavior change at the individual and community levels.

Local Involvement: Empowering communities to participate in decision-making processes related to sustainability initiatives.

5. Economic Instruments

Carbon Pricing: Implementing carbon taxes or cap-and-trade systems to reduce greenhouse gas emissions.

Green Investments: Encouraging investments in sustainable industries through green bonds or socially responsible investing.

Eco-Labeling: Certifying products that meet sustainability standards to guide consumer choices.

6. International Cooperation

Global Agreements: Participating in treaties and agreements like the Paris Climate Agreement to collectively address global challenges.

Technology Transfer: Sharing sustainable technologies and practices between developed and developing nations.

7. Monitoring and Assessment

Sustainability Metrics: Measuring progress through indicators such as the Environmental Performance Index (EPI) or Gross Domestic Product (GDP) adjusted for environmental factors.

Impact Assessments: Conducting environmental and social impact assessments for projects and policies to ensure alignment with sustainability goals.

By integrating these methods, sustainable development aims to create systems that support long-term economic, environmental, and social health.

III. Results

Another definition of sustainable development is "Caring for the Earth," which emphasizes an approach aimed at "improving the quality of human life while living within the carrying capacity of supporting systems" [4]. Sustainable development involves using limited resources and impacting the environment in ways that neither degrade their condition nor reduce their utility for future generations.

Early economic theorists suggested that economic development could coexist with environmental protection policies while fostering innovation and generating profit. In 1920, Arthur Pigou, in his work The Economics of Welfare, identified a disparity between private marginal costs and benefits and social marginal costs and benefits, which he referred to as externalities [5]. Externalities are the unintended side effects of economic activity, whether costs or benefits, not reflected in the prices of goods or services. To address negative externalities, Pigou proposed a tax on activities that produce them, set at a rate to equalize private and social costs. This tax, known as the Pigovian tax, would make market prices more accurately reflect the true costs and benefits of economic activities. However, implementing such a tax proved challenging in practice, especially as environmental problems grew both regionally and globally. It became evident that market mechanisms alone were insufficient to allocate environmental resources effectively or to assign proper monetary value to their destructive use.

Building on Pigou's arguments, Michael Porter and Claas van der Linde theorized that environmental pollution could be seen as a sign of inefficient resource use. They concluded that improvements in production processes that reduce environmental pollution are essential for reconciling ecological and economic interests [6]. Their research demonstrated that competitive advantages are directly linked to innovation capacity, and strict environmental regulations can stimulate innovation, leading to greater competitiveness and profitability [6].

The environmental dimension of sustainable development focuses on protecting ecosystems, air quality, and the integrity and resilience of natural resources. It also addresses how technologies can shape a "greener" future, highlighting that advancements in technology and innovation are key to sustainability and to mitigating potential harm caused by scientific and technological progress.

Since the late 20th century, the concept of a "green economy" has gained traction as an innovative technological model and a critical factor in achieving environmentally sustainable development. In light of pressing global challenges such as climate change, population growth, environmental pollution, and inefficient resource use, countries need to adopt technologies and economic approaches that minimize environmental harm and conserve resources. Sustainable development thus requires reducing environmental damage and considering the needs of future generations, supported by policies at both international and national levels [7].

For instance, the European strategy for "smart, sustainable, and inclusive growth" identifies key drivers of economic strength: *smart growth* (developing a knowledge- and innovation-based economy), *sustainable growth* (promoting a more resource-efficient, green, and competitive economy), and *inclusive growth* (fostering a high-employment economy ensuring social and territorial cohesion). This strategy includes sections on the rational use of natural resources, energy sources, and the benefits of renewable energy adoption [8].

Countries need well-defined action plans and monitoring indicators for sustainable development and "green" growth. Transitioning to green technologies should align global trends toward improving human well-being and social equity while reducing ecological risks. Success in this transition depends on increased public investment, ecological taxes, and regulatory measures to mitigate the environmental footprint of industries. It also relies on enhancing environmental protection laws [9].

Studies show that adopting green technologies, particularly green energy, is a priority for achieving sustainable development. Renewable energy sources and their associated technologies are recognized globally as an eco-friendly alternative to fossil fuels, which contribute to environmental pollution. The degree to which green energy development influences technologies, industries, and applications determines the extent of sustainability achieved. Negative impacts on industrial, technological, social, and economic development are partially or entirely mitigated throughout the transition to green energy and technologies. This makes sustainable energy strategies both preferable and increasingly adopted.

Strategies based on green energy can significantly contribute to the economies of countries that prioritize accelerated development of alternative renewable energy sources (e.g., wind, solar, tidal, and biomass energy). Governments should encourage investments in clean energy solutions and progress in replacing fossil fuels with environmentally friendly energy to secure a cleaner and more sustainable future [10].

IV. Discussion

The growth of the global economy leads to an increase in energy consumption, making it increasingly important to produce energy with minimal costs while reducing environmental pollution. According to expert forecasts, by 2035, renewable energy sources will account for more than half of global electricity production. However, as of today, energy production in some countries often falls short of environmental safety standards and resource efficiency requirements. In Russia, for instance, the current level of "green" energy utilization remains insufficient. This situation is not confined to the energy sector; the development of ecological technologies across various industries in the country is uneven. While developed nations have already launched campaigns to promote clean technologies, this process is only beginning in Russia. This lag is largely due to insufficient demand from businesses and consumers. Nonetheless, a growing trend of increased demand and investment, particularly in alternative energy and energy conservation, has recently emerged.

"Green" growth has the potential to reduce poverty, mitigate vulnerability to climate change, foster economic growth, and enhance energy security. Innovative processes and scientific knowledge are fundamental to ensuring the rational use of natural resources [12]. The transition to renewable energy aims to reduce the negative impact on the planet's energy balance, a critical component of the sustainable development framework for national economies. This shift has driven the active development of renewable energy both internationally and within Russia. Moreover, there is significant potential for creating and implementing environmental technologies in Russia, provided that new incentive tools are introduced as part of the state's science and technology, investment policies, and the development of the green finance market [13].

Each region in Russia has the potential to develop specific types of energy. For example, the natural and climatic conditions of the Republic of Kalmykia are well-suited for constructing power generation facilities utilizing renewable energy sources, particularly wind energy. At the national level, initiatives to provide the region with affordable electricity include investment projects for building new generation facilities. In December 2020, the Salynskaya and Tselinskaya wind power plants—the largest generation facilities in the region—were commissioned in Kalmykia [14].

Global experience demonstrates the successful transition of countries toward sustainable development through the creation and implementation of "green" technologies across various economic sectors. These efforts are reflected in the policies of modern states. By studying international practices, Russia can develop its own approach to advancing "green" energy and renewable energy generation that can compete with traditional energy systems. Such an approach would contribute to environmental protection and the rational use of natural resources.

In conclusion, the transition to sustainable development, underpinned by the principles of "green" growth and renewable energy, is crucial for addressing global environmental and economic challenges. By adopting innovative technologies and fostering the use of renewable energy, nations can reduce environmental pollution, mitigate the effects of climate change, and ensure long-term economic and energy security.

Russia, despite its current lag in the development of ecological technologies and renewable energy, has significant potential to harness its natural and regional resources for sustainable growth. Lessons from international experience highlight the importance of comprehensive state policies, investment incentives, and green financing in accelerating this transition. The development and implementation of renewable energy technologies, such as wind and solar energy, could not only meet current energy needs but also preserve resources for future generations.

Ultimately, achieving sustainable development requires a balanced approach that integrates economic growth, environmental conservation, and social equity. By prioritizing these goals and actively promoting "green" initiatives, Russia and other nations can pave the way for a more sustainable and prosperous future.

References

[1] Altsybeeva I. G., Andreeva L. O.Financial strategy in the management of the enterprise.//Journal of Monetary Economics and Management. -2022-№1-C.6.

[2] Nazarova I. T., Gurezov Z.Ways of managing innovative organizations in Russia.//Journal of Monetary Economics and Management. -2022-№1-C.18.

[3] Babaeva Z.Sh., Pogorelova L.A. Differentiation of the standard of living of the population as a reflection of socio-economic development//Journal of Monetary Economics and Management.-2023.-№2. - P.50-58

[4] Stefanova N. A. Innovations in the field of education//Journal of Monetary Economics and Management. - 2022. No. 3. P. 16-20.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/

E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

THE ROLE OF HUMAN CAPITAL IN ECONOMIC DEVELOPMENT: AN ANALYSIS OF FACTORS CONTRIBUTING TO ECONOMIC GROWTH

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Abstract

This study explores the pivotal role of human capital in driving economic development at both regional and national levels. Human capital, which encompasses the knowledge, skills, experience, and health of the workforce, is increasingly recognized as a crucial determinant of economic growth.

This paper begins by defining human capital and its components, highlighting how education, vocational training, and health contribute to the overall productivity of the labor force. The analysis delves into various factors that enhance human capital, including access to quality education, lifelong learning opportunities, and healthcare services. It examines the correlation between human capital investment and economic performance indicators such as GDP growth, labor productivity, and innovation rates. By reviewing existing literature and case studies from different countries, the study illustrates how regions with higher levels of human capital tend to experience faster economic growth and improved living standards. Furthermore, the research addresses the challenges and barriers to human capital development, particularly in developing countries, where inadequate educational systems and limited access to healthcare can hinder progress.

The study emphasizes the importance of policy interventions aimed at enhancing human capital, including increased funding for education, promotion of public health initiatives, and fostering a culture of innovation. The findings underscore the necessity of viewing human capital as a long-term investment rather than a short-term expenditure. This perspective shifts the focus towards sustainable economic strategies that prioritize human capital development as a pathway to achieving inclusive and sustainable growth. In conclusion, the paper provides practical recommendations for governments and private sectors on how to effectively invest in human capital to foster economic development. By doing so, policymakers can create a more resilient economy that is better equipped to face future challenges while ensuring improved quality of life for all citizens.

In conclusion, education is a fundamental driver of positive labor market outcomes, influencing employment rates, income levels, and job satisfaction. By investing in education and ensuring equitable access to quality learning opportunities, governments can enhance the skills of their workforce, promote economic growth, and contribute to a more prosperous and equitable society.

Keywords: economic growth, education, workforce productivity, health, innovation, sustainable development, policy interventions, labor force

I. Introduction

In an increasingly globalized and competitive economy, the significance of human capital has emerged as a critical factor in driving economic development and growth. Human capital refers to the collective skills, knowledge, experiences, and health of individuals within a workforce. Unlike physical capital, which comprises tangible assets such as machinery and infrastructure, human capital is inherently intangible yet immensely influential in determining a nation's economic performance.

The relationship between human capital and economic growth has garnered substantial attention from researchers, policymakers, and economists alike. As technological advancements reshape industries and the demand for skilled labor continues to rise, the quality of human capital becomes a pivotal determinant of a country's ability to innovate, compete, and sustain long-term economic growth. Nations that prioritize investments in education, healthcare, and training often experience higher productivity levels, increased innovation, and improved standards of living.

Despite the evident importance of human capital, disparities in its development persist across different regions and countries. Factors such as access to quality education, healthcare services, and economic opportunities vary significantly, leading to unequal economic growth trajectories. Developing nations, in particular, face unique challenges in harnessing human capital due to systemic issues such as inadequate educational infrastructure, high rates of poverty, and limited access to healthcare. Consequently, addressing these challenges is essential for fostering inclusive and sustainable economic growth.

This study aims to explore the multifaceted role of human capital in economic development by analyzing the factors that contribute to its enhancement. It will delve into the significance of education and training in building a skilled workforce, the impact of health on productivity, and the importance of lifelong learning in adapting to a rapidly changing economic landscape. Furthermore, the study will examine the role of government policies and private sector initiatives in fostering human capital development.

By providing a comprehensive analysis of these elements, this paper seeks to contribute to the ongoing discourse on economic development strategies, emphasizing the need for a robust human capital framework. Ultimately, the findings will highlight that investing in human capital is not only a moral imperative but also a strategic necessity for achieving sustainable economic growth and improving the overall quality of life for individuals and communities.

II. Methods

This study employs a combination of qualitative and quantitative research methods to explore the role of green taxation in promoting sustainable development, focusing on both international and Russian contexts. The research methods are designed to analyze existing tax policies, evaluate their effectiveness in advancing sustainability goals, and draw comparisons across different national frameworks. The following three methods were used:

1. **Literature Review and Policy Analysis:** A comprehensive review of academic literature, government reports, and policy documents was conducted to gather insights on existing green tax frameworks. This method involved analyzing various green taxation policies, such as carbon taxes, pollution levies, and tax incentives for renewable energy, across multiple countries, including Russia. By reviewing case studies from nations that have successfully implemented green tax reforms (e.g., the European Union, Sweden, and Germany), this analysis identified key trends, challenges, and best practices in designing and executing tax policies that contribute to sustainable development. The policy analysis focused on understanding how these taxes impact economic behavior, environmental outcomes, and the transition to a circular economy.

2. **Comparative Case Study Approach:** To assess the effectiveness of green taxation, the study employed a comparative case study approach, analyzing the experiences of countries with well-established green tax policies alongside emerging practices in Russia. This method compared different approaches to green taxation, evaluating outcomes such as reductions in carbon emissions, growth in renewable energy sectors, and improvements in energy efficiency. Countries selected for comparison included those with advanced green tax systems, such as Sweden,

Germany, and the United Kingdom, as well as countries at earlier stages of implementation, like Russia. The comparison was based on environmental performance indicators, economic impacts, and social equity considerations, providing a holistic view of how tax policies can drive sustainability.

Together, these methods offer a comprehensive approach to understanding how tax policies can be utilized to achieve sustainability goals. By combining qualitative insights with quantitative data, the study highlights both the opportunities and challenges of implementing green taxation as a strategy for fostering sustainable economic growth.

III. Results

The analysis of human capital's role in economic development yielded several significant findings that underscore its impact on economic growth and productivity. A strong positive correlation was found between educational attainment and economic growth rates. Countries with higher levels of education, particularly in science, technology, engineering, and mathematics (STEM) fields, demonstrated increased labor productivity and innovation. Moreover, investment in early childhood education was shown to yield substantial long-term benefits, enhancing cognitive skills and creating a solid foundation for lifelong learning. Regions that prioritized early education experienced accelerated economic growth compared to those that did not.

Health also emerged as a crucial component of human capital, directly influencing workforce productivity. Healthier populations tend to have lower absenteeism rates, increased energy levels, and higher engagement in their work, all of which contribute to overall economic output. The research indicated that access to quality healthcare services was linked to improved worker performance. Countries that invested in their healthcare systems saw significant reductions in healthcare costs associated with lost productivity, leading to increased overall economic performance.

Innovation was identified as another key area influenced by human capital. The research indicated that a well-educated and healthy workforce is better positioned to drive innovation. Regions that fostered an environment conducive to research and development (R&D) and entrepreneurship reported higher rates of technological advancements and economic diversification. Investment in human capital not only enhanced the skills of the workforce but also encouraged collaboration between educational institutions and industries, resulting in innovative solutions to complex economic challenges.

Effective government policies aimed at enhancing human capital were identified as critical to achieving sustainable economic growth. Countries that implemented comprehensive education and health policies, including vocational training programs and public health initiatives, experienced higher GDP growth and improved social outcomes. The study highlighted successful case examples where targeted investments in human capital led to significant economic transformation, particularly in emerging economies. For instance, nations that prioritized skills training and lifelong learning initiatives reported reduced unemployment rates and improved economic resilience.

Despite these positive impacts, the study also identified several challenges that hinder the development of human capital, particularly in developing regions. Inadequate educational infrastructure, socio-economic disparities, and limited access to healthcare services were notable barriers. Cultural factors and systemic issues often prevented marginalized populations from fully benefiting from educational and economic opportunities, highlighting the need for inclusive policies that address these inequities.

Overall, the cumulative effect of human capital investments was evident in the economic growth of the analyzed regions. A clear trend emerged where investments in education and health correlated with enhanced GDP growth rates and improved quality of life indicators, such as life expectancy and income levels. These findings underscore the critical role of human capital as a driver of economic growth. By investing in education, health, and innovative capacities, countries can significantly enhance their economic performance and ensure a more sustainable and inclusive growth trajectory. Policymakers are urged to prioritize human capital development as a strategic imperative for achieving long-term economic objectives.

IV. Discussion

The findings of this study illuminate the multifaceted relationship between human capital and economic development, underscoring the critical role that investments in education, health, and innovation play in driving sustainable economic growth. The strong correlation between educational attainment and economic performance reveals that a skilled workforce is not only essential for individual success but also pivotal for national prosperity. As countries increasingly compete in a globalized economy, the ability to adapt to technological advancements and market demands becomes increasingly tied to the quality of human capital. This underscores the necessity for governments to prioritize educational reforms that promote critical thinking, creativity, and technical skills, particularly in STEM fields.

The positive impact of health on productivity reinforces the notion that human capital is not solely about education but also encompasses physical well-being. Healthier workers contribute more effectively to the economy, resulting in lower healthcare costs and higher overall output. This relationship calls for integrated policies that not only invest in education but also enhance healthcare systems. By addressing public health issues, governments can ensure that their populations remain healthy and capable of contributing to economic growth. Moreover, the emphasis on preventive healthcare can lead to significant long-term economic benefits by reducing the burden of chronic diseases and enhancing workforce participation rates.

The role of innovation, as highlighted by this study, cannot be overstated. In today's rapidly changing economic landscape, countries that foster environments conducive to innovation through education and research are better positioned for economic success. Collaborative efforts between educational institutions and industries can drive technological advancements and foster entrepreneurship, creating a virtuous cycle of growth. Policymakers should encourage partnerships that promote knowledge transfer and support research initiatives that address pressing economic and social challenges.

However, while the findings demonstrate the potential benefits of human capital investment, they also reveal significant challenges that must be addressed. The disparities in access to quality education and healthcare services indicate that not all populations benefit equally from economic growth. This inequality can perpetuate cycles of poverty and limit social mobility, hindering overall economic development. Therefore, it is essential for policymakers to adopt inclusive strategies that ensure marginalized communities have access to educational and health resources. Targeted interventions, such as scholarships, mentorship programs, and community health initiatives, can help bridge these gaps and create more equitable opportunities for all.

The study also emphasizes the importance of lifelong learning as a necessary component of human capital development. In a world where job requirements are continuously evolving, the capacity for individuals to adapt and learn new skills is vital. Governments and private sectors must invest in continuous education and training programs to help workers reskill and upskill throughout their careers. Such investments will not only enhance individual employability but also improve overall workforce adaptability, making economies more resilient to shifts in the labor market.

In conclusion, the discussion highlights that human capital is a cornerstone of economic development and growth. By recognizing and addressing the complex interplay between education, health, and innovation, governments can formulate effective policies that foster a skilled and healthy workforce capable of driving sustainable economic progress. The path toward achieving these goals lies in a comprehensive approach that prioritizes human capital development, ensuring that all individuals can contribute to and benefit from economic growth. As the global economy continues to evolve, the importance of investing in human capital as a strategic imperative cannot be overstated.

Table 1: *Key aspects of the role of human capital in economic development*

Category	Factors	Impact on Economic Growth	Examples/Notes
Education	- Quality of education	- Increased productivity and innovation	Countries with higher education levels experience faster GDP growth.
	- Access to education	- Higher employment rates	Early childhood education improves long-term outcomes.
	- Vocational training	- Enhanced skills matching with labor market needs	Vocational training leads to lower unemployment rates.
Health	- Access to healthcare	- Improved worker productivity	Healthier populations have lower absenteeism.
	- Public health initiatives	- Decreased healthcare costs	Preventive healthcare reduces long-term expenses.
	- Nutrition and well-being	- Higher engagement and morale	Nutrition impacts cognitive performance and productivity.
Innovation	- Research and development (R&D)	- Economic diversification and competitiveness	Countries that invest in R&D see faster technological advancements.
	- Collaboration between sectors	- Creation of new markets and jobs	Partnerships between universities and businesses foster innovation.
	- Entrepreneurial support	- Increased startups and economic dynamism	Regions with supportive ecosystems have vibrant entrepreneurship.
Policy Interventions	- Investment in education and health	- Sustainable economic growth	Targeted policies lead to improved social outcomes.
	- Inclusive policies	- Reduction of inequalities	Programs targeting disadvantaged communities enhance access to resources.
	- Lifelong learning initiatives	- Adaptability of workforce	Continuous education prepares workers for changing job markets.

This table illustrates the interconnectedness of education, health, innovation, and policy interventions as components of human capital that collectively contribute to economic growth. Each category highlights specific factors that impact economic performance and provides examples of how these relationships manifest in different contexts. By addressing these factors through comprehensive policies, governments can effectively enhance human capital and, consequently, drive sustainable economic development.

The Influence of Education on Labor Market Outcomes

Education plays a pivotal role in shaping labor market outcomes, significantly impacting economic growth and development. A well-educated workforce is essential for fostering productivity, innovation, and overall economic competitiveness. This subsection explores the various ways in which education influences labor market outcomes, including employment rates, income levels, and job satisfaction.

One of the most direct effects of education on labor market outcomes is the correlation between educational attainment and employment opportunities. Higher levels of education typically lead to lower unemployment rates, as individuals with advanced qualifications are often more attractive to employers. In contrast, those with lower educational attainment face increased challenges in securing stable and well-paying jobs. For instance, studies have shown that individuals with a bachelor's degree or higher have significantly lower unemployment rates compared to those with only a high school diploma. This disparity underscores the critical importance of higher education in providing individuals with the skills and knowledge necessary to thrive in a competitive job market.

Moreover, education directly impacts income levels and earning potential. Data consistently indicate that individuals with higher educational qualifications tend to earn more over their lifetimes compared to those with less education. The wage premium associated with higher education reflects the added value that skilled workers bring to employers. For example, professionals in fields such as medicine, engineering, and technology often command substantial salaries due to their advanced training and specialized knowledge. This income disparity not only benefits individuals but also contributes to broader economic growth, as higher incomes lead to increased consumer spending and tax revenues.

In addition to employment rates and income levels, education also influences job satisfaction and overall career fulfillment. Research indicates that individuals with higher levels of education are more likely to report higher job satisfaction and a greater sense of fulfillment in their careers. This correlation can be attributed to several factors, including increased job responsibilities, opportunities for advancement, and the ability to engage in meaningful work. Consequently, investing in education not only enhances economic productivity but also promotes a more motivated and satisfied workforce.

Furthermore, education fosters social mobility, enabling individuals from disadvantaged backgrounds to improve their economic circumstances. Access to quality education can break the cycle of poverty, providing opportunities for upward mobility and reducing income inequality. Governments and organizations that prioritize equitable access to education contribute to the development of a more skilled workforce, thereby enhancing economic resilience and social cohesion.

Despite the clear benefits of education on labor market outcomes, significant disparities persist in access to quality education across different regions and demographics. Factors such as socio-economic status, geographic location, and systemic inequalities can hinder educational attainment for marginalized groups. Addressing these disparities through targeted policies and investments is essential for creating a more inclusive labor market and maximizing the economic potential of all individuals.

In conclusion, education is a fundamental driver of positive labor market outcomes, influencing employment rates, income levels, and job satisfaction. By investing in education and ensuring equitable access to quality learning opportunities, governments can enhance the skills of their workforce, promote economic growth, and contribute to a more prosperous and equitable society.

References

[1] Altsybeeva I. G., Andreeva L. O.Financial strategy in the management of the enterprise.//Journal of Monetary Economics and Management. -2022-№1-C.6.

[2] Nazarova I. T., Gurezov Z.Ways of managing innovative organizations in Russia.//Journal of Monetary Economics and Management. -2022-№1-C.18.

[3] Babaeva Z.Sh., Pogorelova L.A. Differentiation of the standard of living of the population as a reflection of socio-economic development//Journal of Monetary Economics and Management.-2023.-№2. - P.50-58

[4] Stefanova N. A. Innovations in the field of education//Journal of Monetary Economics and Management. - 2022. No. 3. P. 16-20.

[5] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

INVESTING IN THE GREEN ECONOMY: AN ANALYSIS OF RISKS AND OPPORTUNITIES

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Abstract

The green economy, focused on sustainable development and reducing environmental impacts, has become an increasingly attractive area for investment. This paper provides an in-depth analysis of the opportunities and risks associated with investing in the green economy. Key sectors examined include renewable energy (solar, wind, and bioenergy), sustainable agriculture, electric vehicles, energy efficiency technologies, waste management, and carbon capture solutions. The analysis explores how these sectors are benefiting from global trends such as climate change mitigation policies, corporate commitments to carbon neutrality, technological innovations, and growing consumer demand for sustainable products and services. On the opportunity side, investors stand to gain from significant market growth, government incentives, and regulatory frameworks such as carbon pricing and renewable energy targets. For example, renewable energy is becoming more cost-competitive with fossil fuels, and electric vehicle sales are projected to rise as countries phase out internal combustion engines. Green bonds and environmental, social, and governance (ESG) criteria have also opened new financing channels for green projects, providing investors with diversified portfolios that align financial performance with positive environmental impact.

Keywords: green technologies, sustainable agriculture, electric vehicles, carbon capture, regulatory risks, green bonds

I. Introduction

The transition to a "green" economy and its models, global divestments in the world (redistribution of investments from non-ecological and high-carbon sectors to low-carbon sectors), support for new technologies, "green" financing, etc. can significantly increase financial support for the greening of the economy. A significant reserve for investments in the "green" economy can be the elimination of various types of subsidies and grants for nature-exploiting sectors. For example, the "brown" economy relies to a significant extent on traditional types of fuel. The total amount of subsidies for the production and consumption of fossil fuels in the world has exceeded 400 billion US dollars per year, which hinders the improvement of energy efficiency and the wider use of renewable energy sources (see Section V). There are many obstacles to the formation of a "green" economy, including those associated with widespread stereotypes. Thus, perhaps the most widespread is the myth of the existence of an inevitable contradiction between environmental sustainability and economic progress. There is now ample evidence that greening the economy does not hinder the creation of wealth or jobs, and that investment in many green sectors is a source of increased financial well-being and employment. However, the transition to a green economy requires the creation of new conditions, and this requires large-scale and urgent action by governments in all countries of the world. It is also often said that a green economy is a luxury that only rich countries can afford, or, even worse, that it is something that developed countries impose on developing countries so that the latter will remain poor forever. Modern research, including that of international organizations, provides many examples of the transition to a green economy in various sectors of the developing world that refute this idea - examples that deserve to be repeated in other parts of the world. Research also convincingly shows that greening the economy may not be a brake, but a new stimulator of development. The transition to a green economy is impossible without the economic benefits of such a course for public and private enterprises. It is difficult to make the economy "green" using only legal regulators and administrative measures, as shown by the global experience of the last decades. Among the main reasons for the negative impact of the economy on the environment, one can note the latency (secrecy) of a large number of environmental problems; the traditional market simply does not see them. The modern economy cannot accurately determine the benefits, damages and prices for the environment, "digitize" and economically present environmental problems for the government, business and society. To make greening profitable, at least three levers are needed: 1) stimulation of greening of the economy.

II. Methods

The European Investment Bank has identified three main reasons for the need to transition to a circular economy:

1. Resource constraints. Global demand for resources is increasing rapidly, leading to a growing deficit of critical raw materials and water.

2. Technological development. The introduction of new technologies enables the creation and implementation of circular economy business models. Without technological advancements and innovative approaches, it would be impossible to recycle, replace, and reuse resources, or to leverage new IT technologies.

3. Socioeconomic development. Circular models play a crucial role in the context of increasing urbanization. Urban areas are well-positioned to develop, implement, and maintain systems that can efficiently collect and return goods, materials, and other resources, leading to cost savings.

A fourth reason can be added—**environmental considerations**. Unused production and consumption waste occupies significant land areas, while pollutants migrate into the air, groundwater, and surface water, causing harm to public health, agriculture, and natural resources. These negative externalities lead to substantial environmental damage, including socioeconomic impacts. The circular economy must internalize these externalities and aim to minimize all forms of harm.

Potential future resource constraints due to rising global demand are also highlighted in OECD forecasts. Over the past few decades, the demand for resources has surged due to rapid industrialization in emerging economies and the growing needs of developed countries. Since 1980, global consumption of various materials has more than doubled. This trend is expected to continue, driven by population growth—from 7 billion people today to approximately 10 billion by 2060—accompanied by rising incomes and demand. According to OECD projections, if current trends persist, global use of material resources will rise from 79 billion tonnes in 2011 to 167 billion tonnes by 2060. Demand for metals, in particular, is forecast to increase from 8 billion tonnes to 20 billion tonnes by 2060, or 2.5 times.

The goal of the circular economy is to establish closed ecological and economic cycles, making the most efficient use of incoming raw materials in production processes, minimizing waste generation, and integrating accumulated waste back into economic activity. This approach aims to replicate natural cycles through environmentally compatible technologies across industries and responsible consumption models, forming analogs of ecosystems. The biosphere is a closed system where all elements are interconnected, and no waste is generated. In contrast, the modern technogenic economy operates as a linear, open system, where the production of a relatively small final product requires vast resource consumption and generates large amounts of waste. Currently, only 2-6% of the total volume of extracted natural matter becomes a final product, with the remainder becoming waste (e.g., tailings, slag, wastewater, etc.).

Humanity is familiar with relatively closed economic systems, such as traditional agriculture. In this system, waste is minimized: agriculture supplies livestock with feed, including byproducts from crops like grains, sunflower, and sugar beet, while livestock, in turn, provides agriculture with organic fertilizers that enhance soil fertility. This creates a more or less closed cycle of materials, resembling natural ecosystems.

III. Results

One approach to assessing the effectiveness of a circular economy can be the product recycling rate. It can be determined using the following formula:

$$r = Rr / Ra,$$

where r is the product recycling rate, Rr is the volume of recycled waste, Ra is the total volume of waste.

Traditionally, materials such as glass, paper, cardboard, and aluminum (e.g. packaging and containers) are recycled around the world. In some countries, the recycling rate of these materials exceeds 0.9. However, in Russia, this figure is significantly lower.

Assessing the effectiveness of the transition to a circular economy and the costs associated with it is an important issue. The benefits of transitioning to such a model include the recycling of resources, energy production from waste, and other forms of reducing environmental impact. Although the introduction of low-waste technologies may be costly, taking external costs into account can significantly increase overall efficiency.

Waste and pollution have a significant negative impact on human health and lead to environmental degradation. Therefore, choosing "cheap" solutions that require minimal initial investment can result in large social losses. For example, an important problem is the disposal of solid municipal waste. If it is solved using simplified incineration technologies, this can lead to significant harm to public health due to emissions of dioxins, particulate matter and other harmful substances. Positive and negative externalities (external effects) of the development of a circular economy are presented in Table 1. There may be a certain symmetry between positive and negative externalities. For example, a reduction in the extraction and use of renewable and non-renewable natural resources, which reduces the burden on the environment, can simultaneously lead to a decrease in income and employment in sectors engaged in the exploitation of natural resources.

Table 1: *Externalities of the development of the circular economy*

Positive Externalities	Negative Externalities
Reduction in the extraction and use of renewable and non-renewable natural resources	Additional consumption of resources and energy during recycling of products and waste
Reduction of negative environmental and health impacts from waste, including decreased landfill areas	Decrease in revenues for natural resource exploitation sectors
Development of resource-saving technologies	Reduction in employment in natural resource sectors
Creation of additional jobs	Potential negative health impacts from improper waste disposal (e.g., low-tech waste incineration)

IV. Discussion

Limited resources and investments in the economy necessitate prioritizing certain areas in the transition toward sustainable development and the formulation of environmental and economic policy. A common demand today is for a substantial increase in environmental protection expenditures. Typically, these costs are compared to total investments in the economy, gross domestic product, or benchmarked against those of developed countries. However, environmental protection costs are often narrowly defined, referring only to direct measures such as treatment facilities, filters, reclamation projects, and similar initiatives. This approach is incomplete and flawed.

Investments should be directed where they will yield the greatest environmental and economic returns and prove most effective. So, what should be considered environmental protection costs in this context? In a resource-intensive, raw material-based economy, priority should be given to structural and technological transformation, focusing on the development of low-emission technologies. This approach would help withdraw large volumes of inefficiently used natural resources from active circulation and alleviate the environmental burden.

To frame it differently, current investments should be divided between addressing immediate issues (i.e., direct environmental protection measures) and ensuring long-term sustainability (mainly through structural and technological shifts, such as adopting best available technologies—BAT). By investing in the resource-saving structural and technological transformation of the economy, making it more sustainable, and reducing its natural resource intensity, we can simultaneously minimize the costs of addressing the negative environmental impacts of industrial economic development.

It is challenging to justify the need for simply increasing environmental protection costs, as financial resources are always limited in the economy. Instead, it is crucial to demonstrate the high economic efficiency of environmentally-oriented measures, even if these benefits are not immediately obvious. This is achievable when accounting for the true economic value of nature and ecosystem services (as discussed in Section III). In a transforming economy, unlike in developed economies, there is a significant opportunity to capture substantial environmental benefits ("ecological cream") through purely economic structural projects and programs.

The primary focus should now be on economic policies that offer a "double win"—policies that generate both economic gains and significant environmental benefits. These include modernization, the spread of innovation, energy conservation, and the development of high-tech, infrastructure, and manufacturing industries. In other words, economic measures should simultaneously produce associated positive effects in the ecological sphere.

The global green economy, encompassing markets focused on climate and environmental solutions, has seen substantial growth over the last decade, presenting a compelling investment opportunity. In 2023, it rebounded strongly after a decline in 2022, with its market capitalization reaching $7.2 trillion by Q1 2024. Despite its recovery, challenges remain, including issues of overcapacity and trade barriers in renewable energy and electric vehicle (EV) manufacturing. Downsizing at several major U.S. green companies in early 2024 caused the green economy's share of the overall market to drop slightly from 8.9% at the end of 2023 to 8.6% in early 2024.

Despite these hurdles, the green economy continues to grow, with a long-term compound annual growth rate (CAGR) of 13.8%, outpacing the broader stock market. If treated as an independent sector, the green economy would have ranked as the second-best-performing industry over the last decade, only surpassed by the technology sector. For example, in 2023, the FTSE Environmental Opportunities All Share (EOAS) Index, a key measure of green economy performance, rose by 32%, compared to the 22% rise in the broader FTSE Global All Cap Index.

Since its inception in 2008 through March 2024, the EOAS has outperformed the benchmark index by 82%.

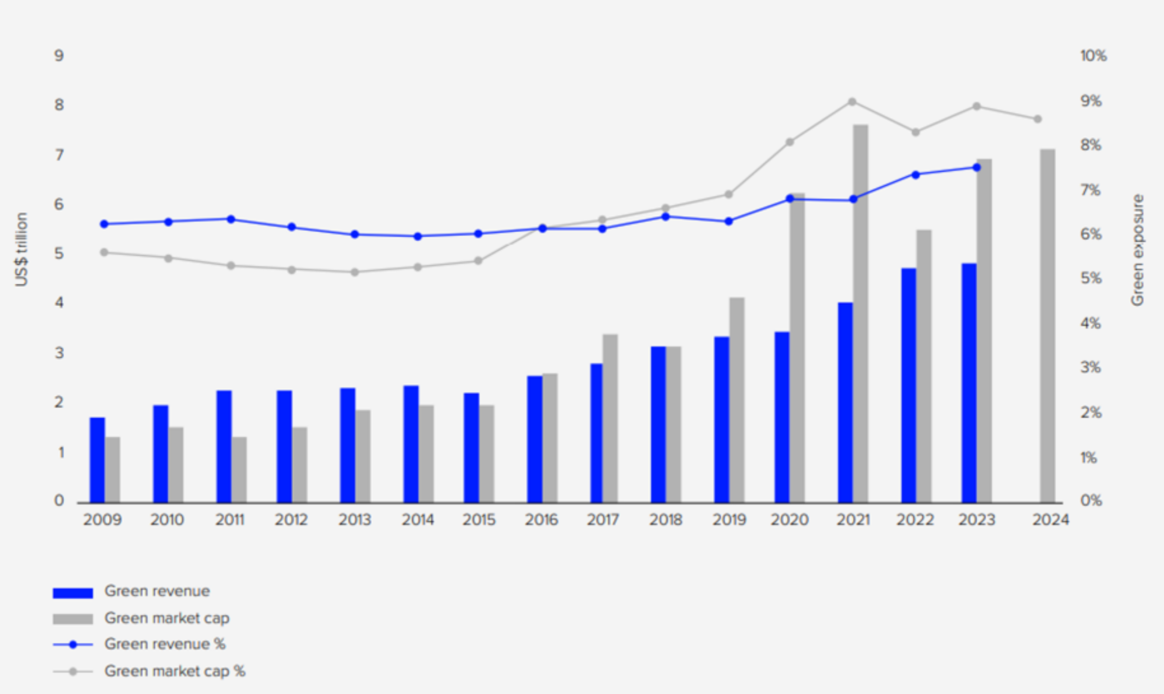

Figure 1: *Green economy 2009–2024*

However, not all green sectors have performed equally. The energy efficiency sector, which includes technologies such as efficient IT equipment and green buildings, has been the most successful, making up 46% of the green economy and generating 30% of green bond proceeds. In contrast, the renewable energy sector has lagged and underperformed in 2023, highlighting the uneven distribution of growth within the green economy.

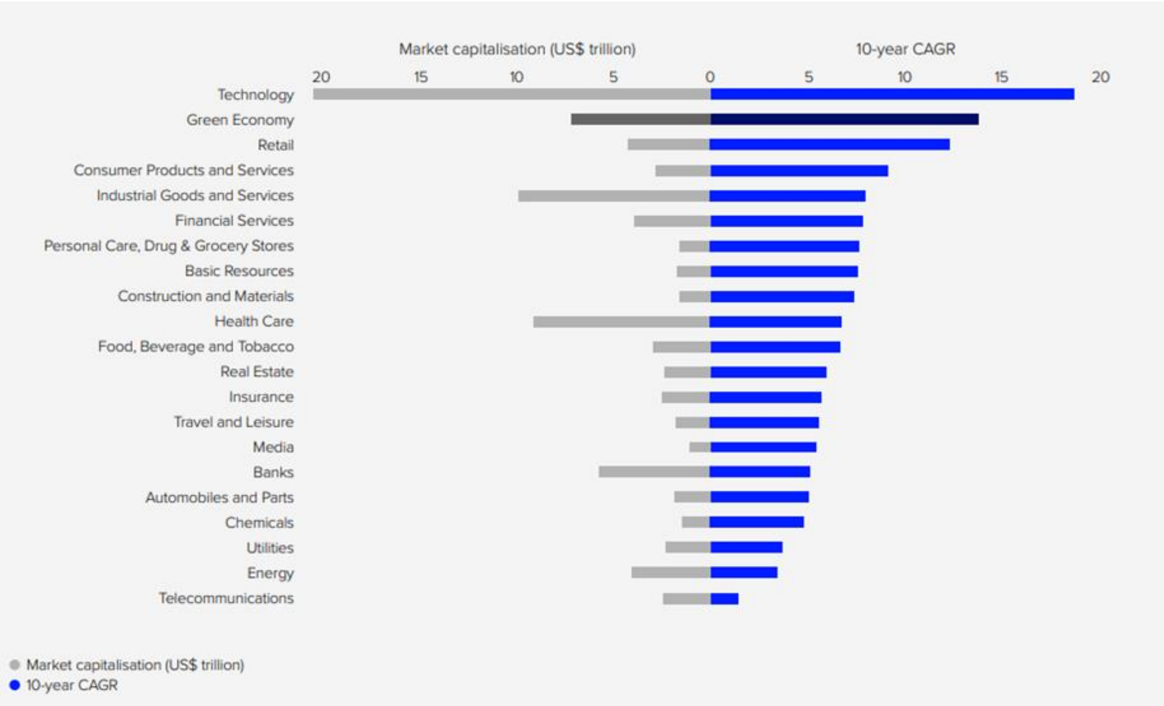

Figure 2: *Market capitalisation value and 10-year growth rate – Green Economy compared with ICB sectors*

If viewed as a standalone sector, the listed portion of the green economy in 2023 would have generated annual revenues nearing $5 trillion, with a market capitalization exceeding $7 trillion. This positioning would make it the fourth largest sector globally, surpassing industries such as Banks, Retail, and Energy, but still trailing behind Health Care, Industrials, and Technology.

Over the past decade, in terms of growth and financial performance, the green economy has only been outpaced by the Technology sector. If represented by the FTSE Russell Environmental Opportunities All Share Index (EOAS) and categorized as a separate ICB Industry, it would have ranked as the second-best-performing industry over the past ten years. Since 2008, the EOAS has consistently outperformed the broader FTSE Global All Cap Index by 82%, with significant outperformance occurring in 2020 and 2021.

The market capitalization of the green economy has expanded at a compound annual growth rate (CAGR) of 13.8% over the last ten years, compared to 8.3% for global equity markets. Revenues from the green economy have grown at a CAGR of 7.6% over the same period, exceeding the growth rate of combined revenues from all other companies (5.3% CAGR).

Within the green economy, the Energy Management and Efficiency sector has been the largest and highest-performing segment. Growing at 17% CAGR over the past five years, it now represents 46% of the green economy's listed equities and accounts for 30% of the proceeds from green bonds. This sector has driven the overall outperformance of the EOAS, leading ahead of other green sectors like Water and Renewable Energy.

A successful transition to a low-carbon economy requires a profound economic transformation, involving substantial mobilization of private finance. Achieving net-zero carbon emissions by 2050 is projected to necessitate additional global investments ranging from 0.6% to 1% of annual global GDP over the next two decades, equating to a cumulative total of $12 trillion to $20 trillion (IEA 2021; IMF 2021a). These investments must shift away from the fossil fuel sector towards renewable energy and low-emission technologies across various sectors. Therefore, a significant and urgent green investment push is essential to facilitate this transition (as outlined in the October 2020 World Economic Outlook).

The global financial sector is positioned to play a critical role in catalyzing private investment to accelerate the transition. In recent years, sustainability concerns—including environmental, social, and governance (ESG) factors—have increasingly become integrated into investment strategies, driving the growth of sustainable finance (October 2019 Global Financial Stability Report). Investors focusing on sustainability may have dual objectives: financial returns ("doing well" by accounting for sustainability's growing importance for profitability) and advancing sustainable economic development ("doing good," particularly by supporting a faster transition to a low-carbon economy).

Achieving net zero will likely require an annual investment of US$1 to $2 trillion in real terms, or about 1% to 2% of global GDP (see Figure 3). This level of spending would far exceed previous major economic stimulus initiatives, such as the Marshall Plan (equivalent to US$114 billion today). Moreover, the decarbonization effort will be a long-term endeavor, requiring sustained capital expenditure for at least the next two decades. With capital investment representing 7% to 14% of total global investment annually, the intensity of capex as a share of global GDP will reach around 28%—a level not seen since the global financial crisis or the 1970s. This combination of massive spending, supportive policies, and evolving consumer and investor preferences is expected to trigger a new capital cycle.

Government commitments to decarbonization, such as the recently passed US$1.2 trillion U.S. infrastructure plan and the European Green Deal, are playing a critical role in legitimizing and accelerating the green capital expenditure (capex) cycle:

- Governments are framing investment in the low-carbon transition as a key tool for economic recovery. Renewable energy projects, like solar, wind, and hydro, are more labor- and capex-intensive than traditional power generation, making them effective at creating jobs and stimulating economic activity.

- Consumers, increasingly aware of the physical and financial risks of unchecked climate change, are pressuring policymakers and investors to take meaningful action.
- Rising geopolitical tensions are pushing governments to prioritize energy security, climate-tech leadership, and resilient supply chains. The development of regional supply chains for electric vehicles (EVs), batteries, and critical raw materials will further drive capital investment by duplicating supply chains.

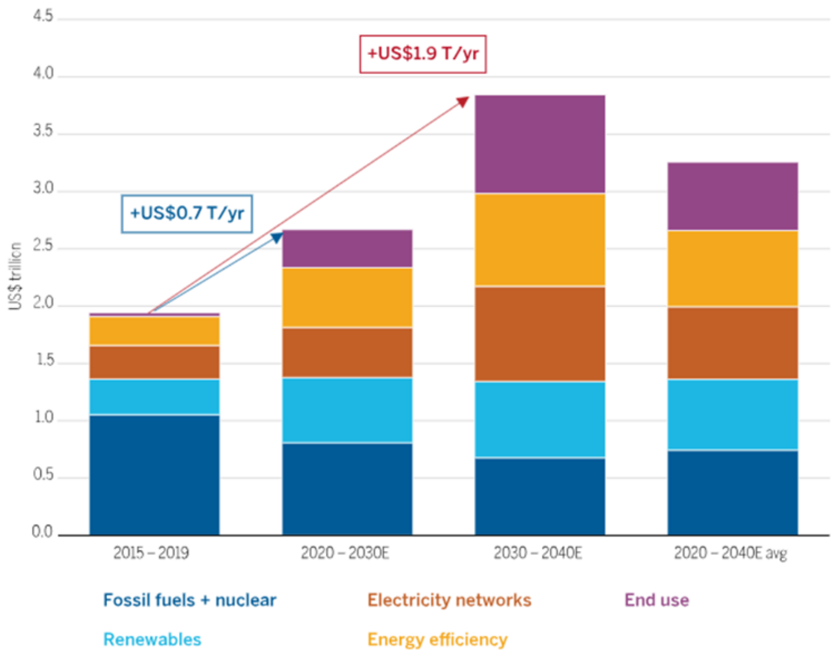

Figure 3: *Spending needed to achieve net-zero emissions by 2040*

Within the broader landscape of sustainable finance, the investment fund sector is particularly noteworthy due to its growing size and emphasis on sustainability-related issues. The sector has expanded substantially since the global financial crisis and now comprises around one-third of the assets held by nonbank financial institutions. It is at the forefront of incorporating sustainability considerations, including climate change mitigation, into investment decisions. This trend is evident from the increasing number of investor and asset manager networks committing to decarbonization efforts and integrating sustainability into their strategies.

Recent survey data and research indicate that investment funds, particularly those with a sustainable investment mandate, are increasingly attentive to climate change and the green transition. Financial markets have begun to reflect the pricing of the transition, which is crucial to steer capital toward firms and projects that positively impact climate change mitigation while avoiding overinvestment in non-sustainable ventures.

However, while the investment fund sector plays a pivotal role in advancing the green transition, financial stability risks associated with this transition are also significant. The path to a green economy remains uncertain, with variations across countries based on differing policies, adoption of clean technologies, and shifts in consumer and producer preferences towards low-emission products and services (October 2019 Fiscal Monitor; October 2020 World Economic Outlook). Transition paths could offer opportunities for high-return investments but also present risks, particularly for firms in sectors vulnerable to cleaner technologies (e.g., fossil fuels, energy-intensive industries).

Studies have documented the substantial exposure of investment funds to sectors most sensitive to the transition, such as fossil fuels, utilities, and energy-intensive manufacturing. A sudden transition shock, such as the rapid realization of the need for swift global change, could lead to a sharp repricing of these assets, potentially triggering financial stability risks.

This paper explores the interaction between the global investment fund sector and the transition to a low-greenhouse-gas economy, addressing two key questions: How do sustainable investment funds, which pursue both financial and sustainability objectives, support the transition? And what has been the impact of transition shocks on the investment fund sector so far? To answer these questions, the chapter develops a conceptual framework that examines the interlinkages between the investment fund sector and the green transition. Using a dataset of more than 54,000 open-end funds—including equity, fixed-income, and allocation funds—it conducts empirical analysis to assess the role of these funds in facilitating the transition and how they have responded to transition-related risks.

References

[1 Ilhan, Emirhan, Zacharias Sautner, and Grigory Vilkov. 2020. "Carbon Tail Risk." Review of Financial Studies 34 (3): 1540–71.

[2] Flammer, Caroline, Michaela W. Toffel, and Kala Viswanathan. 2021. "Shareholder Activism and Firms' Voluntary Disclosure of Climate Change Risks." Strategic Management Journal 1–30.

[3] Krueger, Philipp, Zacharias Sautner, and Laura T. Starks. 2020. "The Importance of Climate Risks for Institutional Investors."// Review of Financial Studies 33 (3): 1067–111.

[4] Lange, F. & Dewitte, S. Measuring pro-environmental behavior: Review and recommendations. // J. Environ. Psychol. 63, 92–100. https://doi.org/10.1016/j.jenvp.2019.04.009 (2019).

[5] Duan, Y., & Yang, X. H. (2012). The Evolution of Chinese Social Ethos since the Reform and Opening Up. Theoretical Discussion, No. 4, 39-41.

[6] Gerrig, R. J., & Zimbardo, P. G. (2009). Psychology and Life. London: Pearson Education.

[7] Green, L., & Kreuter, M. (1994). Health Promotion Program Design (Translated by Huang J.T.). Shanghai: Yixing University Press.

[8] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[9] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House, 2021.

[10] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[11] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[12] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[13] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[14] Podkolzina, I.M., Belousov, A.I., Uzdenova, F.M., Romanko, L.V., Chernikova, O.A. Forms of Financial Fraud and Ways to Minimize Risks // Lecture Notes in Networks and Systems, 2021, 198, pp. 2197–2205

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SOCIO-ECONOMIC FACTORS IN THE FIGHT AGAINST POVERTY

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Abstract

Poverty as a multidimensional phenomenon is the result of an influence from many factors that lie in all social reproduction systems, on one hand. And otherwise it can be produced by the socio-psychological nature of people himself. This is not due to the fact that studying the factors of poverty that determine its development is not given much attention. At the best, most specialists are focused on assessing the quantitative assessment of poverty, and studying the economic behavior of households. Poverty has been inherent in any society, but the scale of manifestations and consequences differ at different stages of development. At the moment, it is obvious that the definition of measures and instruments of influence to reduce poverty should begin with an analysis and disclosure of the causes of its occurrence, and in our country-the reasons for its great increase. It is clear that there are many factors at work on reducing poverty as well as construction of comprehensive strategies to overcome this problem.

Keywords: problem of poverty, social stratification, socio-economic factors

I. Introduction

Today, a significant number of people on Earth live near the poverty line, which is manifested in an increase in social differentiation between the incomes of the poor and rich segments of the population (Table 1). An increase in poverty in the future may lead to destabilization of world economic development. Poverty remains a significant problem for the Russian Federation as well. Despite the wealth of natural resources, high intellectual and technical potential, and the active creation of new jobs, up to 1/5 of the population in Russia still lives in poverty, which hinders the further development of society [8, p. 9]. Thus, the direction of statistical accounting of the scale of poverty, control of its dynamics, as well as theoretical understanding of the causes and forms of poverty in order to develop adequate measures to overcome it is recognized as relevant today. In the scientific literature, poverty is understood as such conditions of a person's existence, which, firstly, are caused by a lack of finance and other material resources, and, secondly, do not allow them to lead a normal, full life [5, p. 265]. In other words, poverty is the inability to independently satisfy basic needs - food, housing, clothing, etc. With the transformation of society, the set of basic needs expanded (for example, education and health care were added to them), and the methodology for recording poverty changed accordingly. It is traditionally accepted to divide poverty into two types:

1. Absolute (extreme) - the need for resources that ensure the biological survival of a person becomes the main problem

2. Relative poverty - a comparative characteristic of living conditions in relation to the generally accepted standard of living standards. Relatively poor in the West can be considered people who have enough money to feed themselves, but not enough for education, cultural activities, etc. At the same time, in lagging countries such a person can be considered almost a

middle class [1, p. 13]. The other two forms of poverty are stable and floating. The first is a systemic phenomenon, when poverty becomes the norm for several generations. From poor parents, life attitudes and values, possible problems with health, education and employment are transmitted to children [2, p. 41]. Floating poverty is due to the fact that the poor, through an incredible strain of internal forces, overcome poverty, becoming full members of society. Of course, personal qualities alone are not enough - to make such a leap, it is necessary to create social conditions conducive to overcoming poverty [7, p. 6]. Speaking about the scale of the spread of poverty, it must be emphasized that in the context of globalization, when the world space becomes economically unified, the deterioration in the standard of living can occur everywhere, anywhere in the world [1, p. 22]. According to the World Bank report (for 2018), 736 million people live in absolute poverty (with a daily income of less than $1.9 per day). (about 12% of the world's population). 43% of people (3.4 billion) earn less than $5.5 a day. The poorest countries on Earth are the Democratic Republic of the Congo (the absolute poverty rate is 77.1%) and Madagascar (77.6%) [7, p. 4–7]. In the Russian Federation, according to Rosstat data for 2020, about 20 million people (up to 15% of the population) live below the subsistence minimum (less than 11,329 rubles per month) [6]. Since 2015, there has been an annual increase in the number of the poor by 1 million people [3, p. 10]. The official subsistence level is in fact the poverty line. The economic stratification of the Russian population is uneven. Thus, in the central part, the poverty level is significantly lower than the level of some East Siberian regions, where this indicator reaches 40% [6]. Some researchers believe that the real level of poverty is significantly lower than the declared one, since official statistics do not take into account the "shadow" incomes of citizens, unofficially employed, etc. [8, p. 31].

Table 1: *Poverty estimates for reference year 2019, changes between September 2022 and March 2023 vintage by region and poverty lines*

Region	Survey Coverage (%)	$2.15 (2017 PPP) Headcount ratio (%)		$2.15 (2017 PPP) Number of poor (mil)		$3.65 (2017 PPP) Headcount ratio (%)		$3.65 (2017 PPP) Number of poor (mil)		$6.85 (2017 PPP) Headcount ratio (%)		$6.85 (2017 PPP) Number of poor (mil)	
	Mar 2023	Sep 2022	Mar 2023	Sep 2022	Mar 2023	Sep 2022	Mar 2023	Sep 2022	Mar 2023	Sep 2022	Mar 2023	Sep 2022	Mar 2023
East Asia & Pacific	97.4	1.1	1.2	24	25	7.6	7.6	160	161	32.1	32.1	675	676
Europe & Central Asia	87.4	2.4	2.3	12	11	6.2	6.1	31	30	15	15	74	74
Latin America & Caribbean	86.7	4.3	4.3	28	28	10.6	10.6	68	68	28	28	180	179
Middle East & North Africa	48.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Other High Income	82.3	0.6	0.6	7	7	0.8	0.8	9	9	1.4	1.3	15	15
South Asia	96.4	8.5	8.6	156	161	42	42.3	772	788	82.2	82.3	1508	1532
Sub-Saharan Africa	54.3	35.1	34.9	389	391	62.4	62.3	691	698	86.5	86.4	958	969
Eastern & Southern Africa	29.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Western & Central Africa	90.5	27.2	27.3	122	124	57.1	57.2	255	260	85.1	85.1	380	387
World	84.6	8.4	8.5	648	659	23.5	23.6	1803	1831	46.7	46.9	3590	3634

The study of what factors and cause for the development of poverty has not yet been given due attention. A socially organized cross-sectional survey is rare. Socially organized cross-sectional surveys are very rare. In general, one has to rely on the research of the World Bank. Research that has not been done in this area hinders the effectiveness of effective policy. The absence of such research is unnecessary for the development of effective policies. Experts, at best focus on the quantitative assessment of poverty and the study of the economic behavior in families. Poverty is seen as a result of the crisis situation in the economic system or other, distributive relations. All researchers in poverty issues, the latter is caused by an imperfection of economic, social or political systems (called as "structural reasons for poorness". Some experts (O. Lewis, B.Stapelton, J. William and others) consider poverty in the broad cultural-historical aspect as part of the culture that is determining its effectiveness by determining stereotypes and standard behavioral attitudes in different circumstances: not directly involving economic activity but determining its effectiveness. If a country has had low economic and high-growth rate for several decades, then poverty becomes part of the economic culture. It manifests itself as a specific norm of behavior, an individual institution. Poverty is a special form of social activity that has its own uniqueness. The institutional environment in such a country is developed and develops in such a way that poverty is part of its components.

II. Methods

Monitoring of poverty is the basis for monitoring the quality and standard living in population, identifying its most vulnerable categories exposed to the risks of social support; development of effective measures that increase income from work and social support for people with low labor potential and high demographic burden on working women. In order to solve a poverty problem and organize proper monitoring, options such as determining the poverty line, determining standards in terms of quality life and standardizations in relation to this level, taking into account the poverty line play an important role (Fig.1). The choices and methods for establishing the poverty line, determining what is required to measure the poverty line, take into account it. An assessment of the living standard for Russians in terms of social policy, federal programs and economic program development; determining minimum wages at an official level. The budget is compiled by collecting data on consumer baskets, mandatory payment systems and wages that are compared to national monetary income. Accordingly, the poor include those whose incomes do not reach this poverty line, i.e., the subsistence minimum. Data on the number of the poor, on the characteristics of their quality and standard of living, their groupings according to various criteria, etc. are tracked and published by the Federal State Statistics Service. Data are presented for the population as a whole, for its individual categories, for households and their various groups.

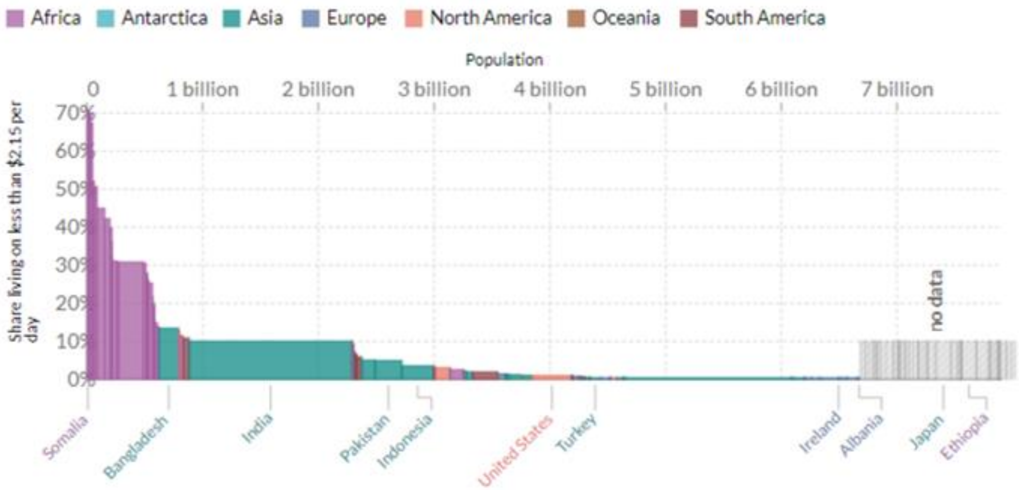

Figure 1: *Share of population living in extreme poverty, 2021*

The subculture of poverty as an economic category has shown that there are a number of issues about the possibilities for its possible presence. As a result, due to the heterogeneity of the poor group and the heterogeneity in this subcultural community, one cannot speak of a subculture that is poverty when its values are not accepted by all members from this subcultural community.

As a result of this, the group of the poor as a socio-economic group is (by definition) relativistic due to its fact that only people who fit the standard for material wellbeing stand out from the rest of the population. The "weak point" of the subculture theory of poverty is also that it often turns out to be unclaimed in practice due to its limitations, which expresses in the ineffectiveness of measures and systems to eliminate the latter. This is reflected in the ineffectiveness of measures and systems to eliminate the latter. It is possible to reduce these limitations of the poverty subculture theory, supported by many researchers, in terms of this [1]:

1. The purpose of this is not to eliminate poverty by increasing the income level of the poor. It is necessary to change the poor, themselves or children.

2. The fact that there is a phenomenon of subculture of poverty is disputed. 2. The existence of the very phenomenon of subculture of poverty is questioned. At the same time, it is arguable that the attitudes and value of the poor are so different from people within one community as to create "subcultures" of poverty. It is impossible to plan your future with materials, material resources and financial stability without material resources and money.

3. A possible intergenerational transmission of poverty is criticized. 3. The possibility for intergenerational transmission in a generation is criticized. For example, parents rarely raise children in exact the same way as before. Their behavior and value are not "passed on intact" to next generation, producing a cycle of deprivation. Because the idea of a "cycle of deprivation" is too deterministic and ignores the fact that social and economic conditions change, as well as people's condition.

4. It is not possible to accept that the poor are a stereotype of people who are passive and apathetic in public life. In fact, one person will not have time for savings or other resources on his own after poverty.

5. It is not the poor that are responsible for reducing social security, in particular and for creating subcultures of poverty in general. But rather it is state and government that support dependency. 6. The reason for this was no one else but the people who were to blame for them.

III. Results

Many models and approaches to eradicating poverty in the world have been developed over the years (Fig. 2). Some of these include improving education, access to healthcare, and job creation; boost economic growth through infrastructure development for rural areas. Other activities are aimed at strengthening the social protection of the population (including assistance programs), stimulating labor to create new enterprises, as well as expanding support programs. International organizations, governments and non-profit social initiatives also play a big role in helping to eliminate poverty through financial assistance to developing countries.

A number of scientists, in their scientific works, distinguishes a variety of levels that characterize the quality of life of the population [2]. These levels include: incomes of the population; the cost of living; consumption of the population; the main integral indicators of the life of the population; provision and coverage of the population with infrastructure facilities and technical means of the sectoral social sphere; demographic parameters. The standard of living of the population of Russia is determined by the following main indicators: the volume of gross domestic product per capita; the volume of production of essential goods; inflation rate; unemployment rate; the value of real income per capita, etc. The wealth of the population is the amount of money and material goods received or produced by households over a certain period of time. The level of consumption of the population directly depends on the level of income. It is important for the state to ensure that the level of income, as well as the standard of living of the entire population of the country, is approximately at the same level, and there is no poverty. This position is shared by a number of countries, including Norway, Finland, Denmark and other countries. In them, the level of stratification among the incomes of the population is insignificant [3]. However, there are also countries in which one can observe the stratification in terms of the level of income of the population, which ultimately leads to poverty of the population. In the European Union, poverty is defined as the lack of sufficient resources to maintain a generally accepted standard of living in society. For example, in Finland the poverty threshold is measured more accurately in relation to the level of the minimum budget, taking into account the criteria of absolute poverty, this approach allows to identify the part of the population whose income is below the level of the minimum budget. The results showed that there are significantly fewer people living in Finland below the minimum budget poverty line than those living below the relative poverty line.

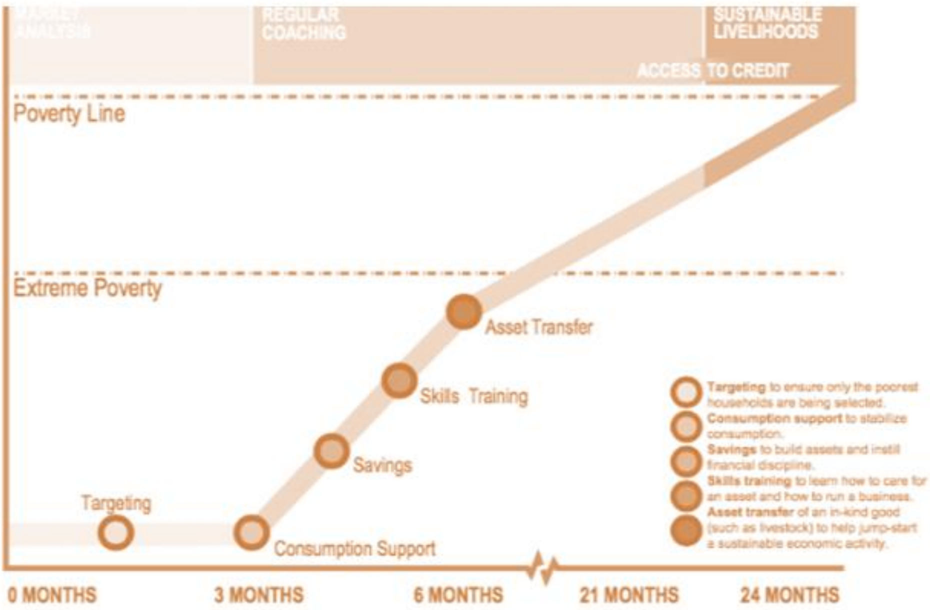

Figure 2: *The Graduation Model of ending extreme poverty*

According to the information provided, the subsistence level of persons living alone is 600-669 euros per month, regardless of age and housing costs. Housing costs are 156 euros, while renting an apartment costs an average of 388-540 euros. Students (24.9%), lone guardians (20%), unemployed (16.6%) and living alone (16.1%) were among the most vulnerable citizens with incomes below the minimum budget poverty threshold. Despite the enormous scientific and industrial growth that accompanied society in the 20th century, the social difference in today's society is only growing. Moreover, social division is becoming more complicated in absolutely all countries of the world, including developed countries. In the most common language, the poor are getting poorer, and the rich are getting richer [3]. Let's go back to the problem of poverty in Russia. Rosstat recorded an increase in poverty in the Russian Federation. The degree of poverty in the Russian Federation, after increasing the subsistence minimum more than the stagnation of the economy in the second quarter of 2019, amounted to 12.7% compared to 12.5% a year ago. According to the correlation, the coefficient decreased by 1.6% from the initial quarter [4]. The number of Russian residents with cash incomes below the subsistence level in the second quarter of 2019 amounted to 18.6 million people, or 12.7% of the total population. Thus, the poverty rate in Russia increased by 0.2% in annual terms. This is due to the fact that the cost of living in the second quarter of 2019 increased by 7.1% compared to the same period in 2018, and also amounted to 11,185 rubles, while the stagnation of the economy in annual turnover was 5.6%. In 2020, the authorities are thinking about abolishing the income tax for the poor and introducing a deduction for all workers. We can talk not only about the abolition of personal income tax for the poor (whose income is about 10 thousand rubles), but also the introduction of a deduction of 1.5 of the subsistence minimum for everyone. At the same time, the personal income tax rate may increase

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from 13% to 16%. "If we talk about tax cuts for very low wages, it is very indirectly related to the poor, but of course, any tax cut is always welcomed by everyone. But in this case, if we are talking about the fight against poverty, today I would see more effective subsidizing tools based on per capita income in the family and, accordingly, the allocation of appropriate subsidies on this basis, "said Aleksey, Chairman of the Accounts Chamber, about this project.

IV. Discussion

The usual model of fighting poverty includes a large set of strategies and activities aimed at improving the quality of life of people AND eliminating economic inequality. Key approaches to fighting poverty include [5]:

1. Education is an important component of increasing the level of employment and income. The main factors to reduce poverty are investment in education and affordable quality of education.

2. Stimulating economic growth and creating jobs can help reduce unemployment and raise the income level of the population.

3. Increasing social protection: support is provided to the poor. There are also benefits, health insurance and social assistance.

4. Investments in infrastructure contribute not only to the development of the region, but also to improving the quality of life of the population. An example is the construction of roads, water supply.

5. Financial and technical support for entrepreneurs - small business contributes to the creation of new jobs, as well as the development of the economy.

6. Statement of gender equality: A defining precondition for poverty reduction is that women have more equal opportunities to participate in the economy and education.

7. Agricultural support: Building infrastructure in rural areas helps reduce migration and creates new business opportunities.

Anti-poverty tactics involve an integrated approach between both government, international organizations and civil society to achieve meaningful momentum.

Most often, women who find themselves with children without material support from their spouses can be primarily attributed to the poor. A unique phenomenon of the "working poor" has emerged in the Russian economy. Employed citizens who perform their labor functions in the workplace receive such low wages that they can be interpreted as "working poor" [1]. So, poverty is a socio-economic phenomenon in which an individual or social group cannot satisfy the minimum needs necessary for life. Any country can become poor or rich. There are a number of countries that have historically been within the poverty line. Here we are talking mainly about African countries, such as the Congo, Zimbabwe, Mali and others. In these countries, the poverty level of the population, according to statistical reports, is in the range of 55–65%. Poverty has two aspects: economic (associated with the level of the individual's well-being, expressed in the presence of a minimum amount of liquid values) and social (a special way of life, its style and norms of people's behavior). Note that poverty looks different in different countries of the world: 1) China is one of the most developed countries in the world. Poverty accounts for 65% of the country's population; 2) The US is about 16% poor of the total population. In America, there is the concept of "a poor working person." Poverty is always associated with unemployment. A person who has found a job cannot be poor by definition; 3) Japan is the third power in the world in terms of economic power, but every year the level of poverty in the country is growing. The main reason is unemployment. Every sixth Japanese is considered poor. Today, one of the leaders in terms of the level and quality of life are such countries as Norway, Australia, Sweden [4]. In many countries of the world, the main directions for reducing income inequality and poverty levels are (Fig. 3):

• development of programs to promote employment of the population;

• improvement of social and housing conditions;
• Stabilization and improvement of the minimum wage and social benefits, etc.

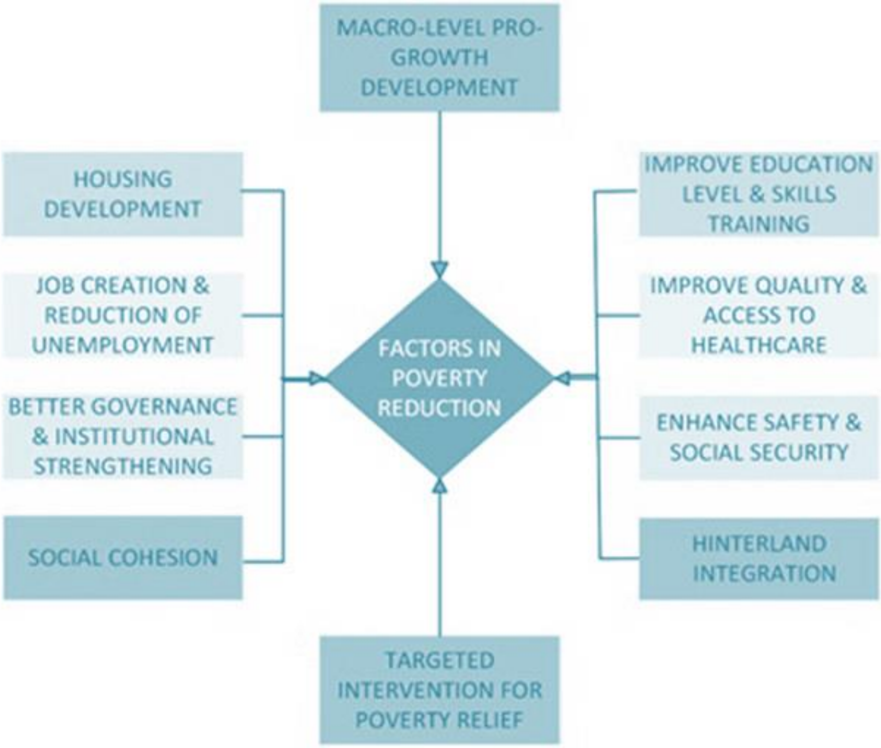

Figure 3: *Poverty Reduction*

The consequence of poverty, in the first place, is the disunity of the population into separate economic groups. There is a loss of common values and interests, a significant part of people are deprived of the opportunity to participate in the political and public life of the country. At the same time, we note that the attitude towards poverty has changed over the past hundred years. So, L.A. Zubkevich in his work "The influence of poverty as a social phenomenon on the worldview of people in modern conditions of social development (social-philosophical analysis)" notes that if at the beginning of the 20th century dissatisfaction with the position of the peasantry and the working class led to the October Revolution of 1917, today, in general, , society is more tolerant of differentiation in terms of welfare [4]. As the level of poverty grows, the level of social tension also grows: the catastrophic situation pushes people to commit crimes and anti-government actions. However, even if the poor do not commit offenses, society still gradually stagnates: the higher the risk of an increase in the level of absolute poverty, the higher the risk of involvement in this process of more affluent strata of society [5]. The specificity of poverty that has developed in the Russian Federation is a consequence of the low level of wages (primarily in the public sector) and social benefits. So, if in Europe up to 60% of social assistance is distributed, then in Russia this figure does not exceed 20% [7]. Thus, the specificity of Russian poverty is characterized by the term "market poverty" - that is, associated with the position of the able-bodied population in the labor market. Market poverty is associated with low wages, lack of career prospects, inability to maintain full employment, which leads to an increase in unemployment and the shadow sector of the economy. In this context, the concept of poverty can also be defined as the inability to work. The decrease in the income of the population and the increase in social differentiation lead to an increase in labor migration. According to estimates, up to 11 million citizens of the Russian Federation lived and worked abroad in 2019. This is 7-8% of the total population, many of them are in demand and highly qualified specialists. The outflow of labor reserves leads to the decline of science and education, and the general decline in living standards leads to a demographic crisis and economic regression. The problem of reducing the level of poverty is complex and requires the efforts of all public spheres. In world practice, in general, there are two main approaches to overcoming poverty:

1. In developed countries, measures are taken to support the level of the minimum income of the population, which ensures the satisfaction of basic needs.

2. In developing countries, social policy is primarily focused on helping the most economically vulnerable categories of citizens, in comparison with the rest [7]. State support for the poor segments of the population reduces the level of poverty, but does not completely solve the problem. Moreover, the amount of social benefits in developed countries is so high that it leads to an increase in the unemployed: the able-bodied population refuses to work, relying on government assistance. Thus, social policy in the field of poverty reduction should be aimed at stimulating the economic activity of the population, and not at turning them into dependents. More important is the increase in wages and pensions, as the demand for paid medical and educational services, as well as for consumer goods, increases, so does their price. It is necessary to involve the population in labor activity, to support active and talented youth from economically underdeveloped regions, to promote the employment of people with disabilities. The private sector should also play its role in this policy by organizing charity events, helping orphanages, and so on. Thus, the problem of poverty today is global. Not only the state is interested in its resolution, but also the economically active population. The threat of impoverishment today hangs over well-to-do categories of citizens. Poverty affects not only representatives of the "lumpen-proletariat", but also scientists, low-skilled workers, and teachers. Poverty is not only an economically determined phenomenon, it is, according to L.A. Zubkevich, "lifestyle, psychological type of personality". Effective statistical monitoring of the level of poverty, stimulation of social policy, organization of preventive educational activities on how to get out of a difficult life situation - these are promising areas that contribute to overcoming poverty and social differentiation.

References

[1] Tolchinskaya M.N. Possibilities of digital technologies as a tool for developing enterprise economics//Journal of Monetary Economics and Management. - 2023.- No. 4. - P. 222-228

[2] Altsybeeva I. G., Andreeva L. O.Financial strategy in the management of the enterprise.//Journal of Monetary Economics and Management. -2022-№1-C.6.

[3] Shmatko S.G., Agarkova L.V., Gurnovich T.G., Podkolzina I.M. Problems of increasing the quality of raw material for wine in the stavropol region // Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2016. T. 7. № 2. C. 725-730.

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Aliyeva M. L., Misirli R. R. Advantages and problems of big data management// Journal of Monetary Economics and Management. - 2023. - No. 1.- P.8-14

[6] Mezentsev D.A. Methods of increasing sales in the context of modern business development//Journal of Monetary Economics and Management.- 2023.- No. 4. - P.15-23

[7] Babaeva Z.Sh., Pogorelova L.A. Differentiation of the standard of living of the population as a reflection of socio-economic development//Journal of Monetary Economics and Management.-2023.-№2. - P.50-58

[8] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

[11] Salamova A., Khodjaliev S., Dokholyan S. The problem of poverty in the modern world in the context of sustainable development Reliability: Theory & Applications. 2023. T. 18. № S5 (75). C. 396-403

RENEWABLE ENERGY ECONOMY: POTENTIAL AND CHALLENGES

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Abstract

The renewable energy economy has emerged as a critical component for achieving sustainable economic growth and combating climate change. With the increasing urgency to reduce greenhouse gas emissions, renewable energy sources such as solar, wind, hydro, and biomass are gaining prominence as viable alternatives to fossil fuels. This transition presents substantial potential for enhancing energy security, creating jobs, and fostering innovation in various sectors. However, the shift towards renewable energy also encounters significant challenges. High initial capital investments, the need for advanced infrastructure, fluctuations in energy prices, and the necessity for supportive government policies are all obstacles that need to be addressed. Additionally, the intermittency of renewable energy sources raises concerns about grid reliability and energy storage solutions. This paper explores the potential of renewable energy as a driving force for economic development, examining the various challenges that impede its widespread adoption. It discusses the importance of integrating renewable energy into existing energy systems and highlights best practices and successful case studies from around the world. Furthermore, the paper offers actionable recommendations for policymakers, businesses, and stakeholders to create a conducive environment for the growth of the renewable energy sector. By addressing these challenges and harnessing the potential of renewable energy, societies can pave the way for a sustainable and resilient economic future while contributing to global efforts to mitigate climate change.

Keywords: renewable energy, sustainable economic growth, climate change, energy security, job creation, innovation, fossil fuels

I. Introduction

The transition to a renewable energy economy has emerged as a critical pathway for addressing pressing global challenges such as climate change, energy security, and sustainable economic growth. As nations grapple with the adverse impacts of fossil fuel dependency, the shift toward renewable energy sources like solar, wind, hydro, and geothermal presents not only environmental benefits but also significant economic opportunities.

Renewable energy technologies have matured, and their costs have declined dramatically over the past decade, making them increasingly competitive with traditional energy sources. This shift is catalyzing innovation, driving job creation, and fostering new business models. However, transitioning to a renewable energy economy is not without challenges.

Barriers such as the need for substantial capital investment, the development of robust infrastructure, fluctuating energy prices, and the imperative of grid reliability must be addressed to ensure a smooth transition. Additionally, the integration of renewable energy into existing energy systems requires careful planning and strategic government policies that promote investment and innovation.

This introduction sets the stage for a comprehensive exploration of the potential and challenges associated with the renewable energy economy. By examining key factors such as technological advancements, economic implications, and policy frameworks, this paper aims to provide a nuanced understanding of how renewable energy can pave the way for a sustainable and resilient future.

Ultimately, the journey towards a renewable energy economy is not only essential for mitigating climate change but also presents an opportunity for nations to rethink their energy strategies and foster economic resilience in the face of an uncertain future.

II. Methods

This study utilizes the following three methods to analyze the potential and challenges of transitioning to a renewable energy economy:

1. **Literature Review**: A systematic review of existing literature will be conducted to gather insights on renewable energy technologies, economic implications, and policy frameworks. This will involve examining peer-reviewed articles, government reports, and relevant industry publications to build a robust theoretical foundation for the research.
2. **Case Studies**: In-depth case studies will be performed on selected countries and regions that have successfully implemented renewable energy initiatives. By analyzing their policies, technological advancements, and economic impacts, this method will highlight best practices and lessons learned that can inform future transitions to renewable energy.
3. **Surveys and Interviews**: Qualitative data will be collected through surveys and interviews with key stakeholders in the renewable energy sector, including policymakers, industry leaders, and academic experts. This method will provide valuable perspectives on the challenges and opportunities associated with renewable energy transitions, helping to capture a comprehensive view of the current landscape.

These methods collectively aim to provide a well-rounded analysis of the renewable energy economy, addressing both its potential benefits and the obstacles that must be overcome for successful implementation.

III. Results

Renewable energy sources (RES) are defined as clean energy sources that are naturally obtained and continuously replenished. These sources include solar, wind, hydro, tidal, geothermal, and biomass energy. In contrast, non-renewable energy sources, such as natural gas, coal, metal ores, and oil, cannot be replenished. Currently, more than 75% of global energy consumption is derived from non-renewable sources, which has significantly harmed the ecosystem, particularly the ozone layer. Notably, China and the United States are among the largest consumers of these energy forms.

Understanding global energy consumption and utilization is critical. Three major institutions—the International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), and the European Environment Agency (EEA)—regularly record and publish energy data worldwide. Recent studies indicate that the use of renewable energy has substantially reduced carbon emissions. According to a 2019 report from the IEA, renewable energy capacity is expected to grow by about 50% between 2019 and 2024, with hydro, solar, and wind energy experiencing the fastest growth rates. As of the latest data, 26% of global energy consumption is based on renewable sources, with projections suggesting this could reach 30% by 2024. Furthermore, about one-fourth of the world's electricity was generated from renewable sources in 2017, with an expected increase of 1.3% that same year.

Despite the abundance of renewable energy resources in most developing nations, there remain significant challenges in harnessing these resources to their full potential. This limitation has adversely affected the overall growth rate of industrialization and development in these regions. More than 70% of the world's population resides in developing countries, primarily in Latin America, Africa, and Asia. Unfortunately, socio-economic activities in these areas, especially in Sub-Saharan Africa, are not very impressive. It is perplexing that, with such vast untapped renewable energy potential, governments and other stakeholders seem either uninterested in developing renewable energy technologies or resistant to the entire process. If there were a genuine commitment to investing in and advancing renewable energy initiatives, we would likely see a much higher flow of investments and improved development levels.

Countries worldwide are seeking strategies to move away from fossil fuels. This shift, driven by carbon emissions that worsen climate change, encompasses a wide range of renewable energy sources, including solar, wind, and hydro. However, is the transition to renewables as straightforward as merely selecting alternative energy sources? What other elements need to be addressed during this shift? Nutifafa Yao Doumon, an assistant professor in the College of Earth and Mineral Sciences at IEE, along with his students, have been contemplating the requirements for this transition, the potential challenges it may face, and the factors that could influence its success or failure.

We collectively recognized that achieving a successful energy transition is a complex challenge that necessitates a multifaceted approach. Although the following considerations may not encompass all aspects, they are essential for advancing renewable energy:

- Investment in renewable energy infrastructure
- Innovation in technology and research and development (R&D)
- Implementation of energy efficiency measures
- Supportive policy and regulatory frameworks
- Global collaboration and collective action

The transition to renewable energy is far from simple, facing numerous intricate challenges that encompass technological, environmental, societal, economic, and geopolitical dimensions. Here, I will briefly address the technological and geopolitical aspects to illustrate the complexity involved.

From a geopolitical standpoint, it is important to recognize the perspectives of many countries in the Global South. These regions often feel pressured by Western nations to adopt renewable technologies, arguing that they have not been significant contributors to greenhouse gas emissions. They contend that transitioning to alternative energy sources is not a priority, particularly when they have yet to achieve the developmental milestones experienced by the West. Many believe, especially in Africa, that this pressure could hinder the continent's efforts to escape poverty. These sentiments have been articulated in op-eds written by former Nigerian Vice President Prof. Yemi Osinbajo in *The Economist* and Ugandan President Yoweri K. Museveni in the *Wall Street Journal*, each emphasizing the need for a nuanced debate on the issue.

From a technological perspective, the notion of energy transition is often viewed as a complete shift from fossil fuels to renewable energy through innovative technologies. While this scenario is ideal for improving the planet's health, the reality may involve a significant reduction in fossil fuel use alongside a marked increase in renewable energy sources. Many renewable technologies are not yet fully developed and often cannot compete with fossil fuels in terms of societal integration. For instance, silicon-based solar technology, which is currently the most established, has an efficiency rating of 26% and a lifespan of 20 to 25 years. Other solar technologies, including organic, dye-sensitized, and perovskite solar cells, are still in the research phase and are not market-ready due to issues like low efficiency and instability.

One of the greatest challenges facing solar technology is that it cannot operate in isolation; it requires complementary storage solutions, such as batteries, to ensure availability around the clock. Additionally, solar installations demand substantial land, often impacting agricultural communities. The extraction of materials necessary for solar and battery technologies introduces a new array of challenges. Moreover, there are numerous concerns related to the lifecycle of solar panels, including their disposal and recycling.

IV. Discussion

There are numerous opportunities and lessons learned from past experiences that can facilitate a more equitable and sustainable transition to renewable energy. The deployment of renewable technologies often varies depending on regional, locational, or geographical factors. For instance, solar energy proves to be highly effective in hot climates, which are primarily located in the Global South, while wind energy thrives in areas with strong natural wind patterns.

Global collaboration and collective action are essential for investing in renewable energy infrastructure and fostering technological innovation and research and development (R&D) aimed at ensuring a just and sustainable transition. Historical experiences have demonstrated that the mining and processing of raw materials and minerals can have detrimental effects on marginalized, rural, local, or Indigenous communities. This understanding provides us with an opportunity to improve our practices this time around. Achieving this, however, necessitates active involvement from the communities themselves, alongside appropriate policies, supportive governments, and genuine political will.

These opportunities present a chance for researchers to diversify their work and collaborate across disciplines. It is vital to invest time and resources into the innovation and R&D of new technologies for renewable energy harvesting, conversion, and storage. Furthermore, it is important to ensure that communities understand and appreciate the technologies that could potentially supplement or replace existing fossil fuel-based systems and products.

Consequently, this shift will significantly impact how researchers approach their work, fostering a more interdisciplinary and community-focused methodology. Renewable technology companies and industries will also need to rethink their R&D strategies. Research should encompass evaluations before and after the development and deployment of new technologies. Researchers are increasingly aware of the carbon footprint of their work, prompting them to adopt new, efficient methods and integrate sustainability into their processes.

If we fail to acknowledge these challenges, we risk creating tension between the Global North and Global South, leading to potential geopolitical fractures. Global warming and climate change are threats that affect everyone and must be addressed collaboratively. Working together as equals, with a clear understanding of our respective strengths and weaknesses, is essential. Otherwise, countries in the Global South may resist the transition to green energy, potentially becoming immediate or future polluters, which runs counter to our desired goals.

From a technological perspective, there is a risk—however small—that we may not fully realize the potential of renewable energy technologies in time to effectively combat global warming. Additionally, in pursuing these technologies, we could inadvertently worsen environmental pollution, health risks, and the overall quality of life for various communities around the globe.

If we proactively address these challenges, the potential for positive outcomes is vast. We can tackle energy crises in key regions through global cooperation and collective action while protecting our environment through equitable treatment, climate justice, and efforts to mitigate global warming. A well-coordinated, collective approach can help us achieve our renewable energy and climate objectives, paving the way for a more sustainable and equitable energy landscape for future generations.

The COVID-19 pandemic has significantly disrupted the global economy, prompting governments to focus on job creation as a critical recovery strategy. As renewable energy technologies are still in their early stages, they hold the potential to generate a substantial number of jobs across various sectors, including planning, execution, construction, and maintenance. This job creation can serve as both a short-term and long-term stimulus to address rising unemployment, which currently affects one in every eight individuals.

To facilitate this transition, governments should implement policies aimed at limiting global warming to a manageable level of 1.5°C. Such policies should promote the complete transition to renewable energy while phasing out fossil fuels and converting them to synthetic or hydrogen fuels for power generation. Additionally, these policies must ensure that carbon emissions remain within global standards, prioritize greenhouse gas reduction, and foster collaboration among companies. The establishment of more renewable energy agencies can also help facilitate these goals.

Moreover, increasing public awareness about the benefits of renewable energy sources is crucial for enhancing overall health, economic stability, and environmental quality. Educational initiatives should emphasize the detrimental effects of global warming on humans, wildlife, and plant life, highlighting the risks associated with air and water pollution caused by conventional energy sources. In contrast, renewable energy sources do not contribute to such contamination, making them a healthier alternative.

Changing deeply held beliefs, especially those tied to religion, can be an arduous task. However, it is essential to promote awareness of the importance of renewable energy. Continuous and focused education efforts should aim to shift perceptions and highlight the significance of embracing renewable energy sources, encouraging creative educators to adapt to this necessary change.

Additionally, the electrification of rural areas using renewable energy sources should be a top priority for governments, particularly since these areas often lack access to the power grid. Governments should formulate policies that support rural electrification and engage stakeholders such as banks, investors, and industry owners. Access to grants and credit facilities must be made easier, enabling individual households to afford affordable home-based renewable energy products.

Governments should also create policies that bundle renewable energy sources with conventional energy sources in a hybrid generation model. This model could stipulate that 30% of total power generation comes from renewable sources while 70% is sourced from conventional means. Such regulations would help reduce greenhouse gas emissions and air pollution while increasing the penetration of renewable energy. Moreover, the pricing structure should favor renewable energy, offering lower tariffs compared to conventional sources.

Furthermore, there should be a concerted effort by governments to integrate renewable energy courses into educational curricula, starting from primary levels to higher education. This initiative, which is already seen in developed countries, will significantly boost public awareness of renewable energy's benefits. Educating children about the health and environmental impacts of conventional energy sources can foster a more informed future generation.

In conclusion, renewable energy represents a crucial path forward; however, it faces several challenges. These include high initial costs of acquisition and installation, inadequate government policies supporting its full utilization, low public awareness of its advantages, a shortage of trained personnel for installation and equipment procurement, limited research capabilities, and the proliferation of substandard products. Moreover, fears among investors due to political unrest and resistance from some groups who view renewable energy as a threat to their beliefs further complicate the transition.

To address these challenges, there must be a deliberate shift from conventional energy sources that contribute to greenhouse gas emissions toward renewable alternatives. With ongoing advancements in renewable energy utilization and the gradual reduction of non-renewable energy dependence, the global community can aim to significantly lower carbon emissions and mitigate climate change impacts in the future.

References

[1] Perri, L. (2023, August 17). What's New in Artificial Intelligence from the 2023 Gartner Hype Cycle. https://www.gartner.com/en/articles/what-s-new-in-artificial-intelligence-from-the-2023-gartner-hype-cycle.

[2] Flammer, Caroline, Michaela W. Toffel, and Kala Viswanathan. 2021. "Shareholder Activism and Firms' Voluntary Disclosure of Climate Change Risks." Strategic Management Journal 1–30.

[3] Krueger, Philipp, Zacharias Sautner, and Laura T. Starks. 2020. "The Importance of Climate Risks for Institutional Investors." Review of Financial Studies 33 (3): 1067–111.

[4] Lange, F. & Dewitte, S. Measuring pro-environmental behavior: Review and recommendations. J. Environ. Psychol. 63, 92–100. https://doi.org/10.1016/j.jenvp.2019.04.009 (2019).

[5] Rastogi, R. (2018, June 27). Machine Learning @ Amazon. *The 41st International ACM SIGIR Conference on Research & Development in Information Retrieval*. SIGIR '18: The 41st International ACM SIGIR conference on research and development in Information Retrieval, Ann Arbor MI USA. https://doi.org/10.1145/3209978.3210211.

[6] Gerrig, R. J., & Zimbardo, P. G. (2009). Psychology and Life. London: Pearson Education.

[7] Verganti, R., Vendraminelli, L., & Iansiti, M. (2020). Innovation and design in the age of artificial intelligence. The Journal of Product Innovation Management, 37 (3), 212–227. https://doi.org/10.1111/jpim.12523.

[8] Gakaev, R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[9] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House , 2021.

[10] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[11] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.

[12] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[13] Salamova A.S., Kantemirova M.A., Gishlakaev S. Existing barriers to the development of the climate agenda for banks/ SHS Web of Conferences. International Scientific and Practical Conference on Social Sciences and Humanities: Scientific Challenges of the Development of Modern Society (SHCMS 2023). Grozny, 2023.

REPRODUCTIVE MEDICINE AND REPRODUCTIVE TECHNOLOGIES IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract

Reproductive medicine and reproductive technologies play a significant role in achieving sustainable development by improving public health, promoting gender equality, and reducing social inequalities. These fields align with several Sustainable Development Goals (SDGs), including good health and well-being (SDG 3), gender equality (SDG 5), and reducing inequalities (SDG 10). Modern reproductive technologies, such as in vitro fertilization (IVF), genetic screening, and family planning methods, contribute to addressing infertility, improving maternal health, and providing access to reproductive rights. However, disparities in access to these technologies, particularly in developing countries, highlight the need for policies that enhance availability and affordability. Ethical concerns, especially around genetic interventions and surrogacy, must also be carefully addressed. Innovations in reproductive medicine can further contribute to population stabilization, resource management, and environmental sustainability, supporting a balanced approach to human development in the face of global climate change. The integration of reproductive technologies into sustainable development policies ensures equitable access to healthcare while considering the broader impacts on society, the economy, and the environment.

Keywords: reproductive medicine, reproductive technologies, sustainable development, gender equality, infertility treatment

I. Introduction

Reproductive medicine and reproductive technologies have become critical components of modern healthcare, addressing key challenges related to fertility, maternal health, and family planning. In the context of sustainable development, these fields are essential for achieving global goals that promote health, well-being, and gender equality. As global populations grow and environmental pressures mount, sustainable development demands a balanced approach to population health and resource management. Reproductive medicine, through innovations like in vitro fertilization (IVF), genetic screening, and assisted reproductive technologies, provides solutions not only for individuals facing infertility but also for broader societal issues, such as managing population growth and ensuring reproductive rights.

The United Nations' Sustainable Development Goals (SDGs) emphasize the importance of good health and well-being (SDG 3), gender equality (SDG 5), and reducing inequalities (SDG 10). Reproductive health is at the intersection of these goals, highlighting the need for universal access to healthcare services that support family planning, pregnancy care, and infertility treatments. However, disparities in access to these services remain a pressing issue, particularly in developing regions where economic and healthcare inequalities persist. The high cost of advanced reproductive technologies often limits their availability to affluent individuals or nations, exacerbating existing inequities.

Moreover, the ethical and social dimensions of reproductive technologies, including debates around genetic intervention and surrogacy, raise complex questions about the implications of medical advances on human rights and societal norms. As such, integrating reproductive health into the global sustainability agenda requires a careful balance between medical innovation, ethical considerations, and equitable access to healthcare.

This introduction explores the crucial role of reproductive medicine and technologies in the pursuit of sustainable development, highlighting both their potential and the challenges associated with ensuring that advancements in these fields benefit all populations equitably.

II. Methods

This study employed a comprehensive approach to analyze the Reproductive medicine and reproductive technologies to achieving health-related Sustainable Development Goals (SDGs). The methods utilized included:

1. **Literature Review**: An extensive review of existing literature on primary health care and its role in public health was conducted. This involved analyzing peer-reviewed articles, reports from international organizations, and relevant policy documents.
2. **Data Collection**: Quantitative data was gathered from national health statistics and databases, focusing on indicators related to health outcomes, access to primary care services, and SDG progress. Qualitative data was also collected through interviews with healthcare professionals and stakeholders to gain insights into barriers and facilitators of primary health care implementation.
3. **Stakeholder Analysis**: Key stakeholders, including government agencies, non-governmental organizations, and community representatives, were identified and engaged. Their perspectives on the effectiveness of primary health care services and Reproductive medicine and reproductive technologies.
4. **Case Studies**: Specific case studies were conducted in various regions to illustrate best practices and challenges in primary health care delivery. These case studies provided context-specific insights and highlighted successful interventions that align with SDG objectives.
5. **Policy Recommendations**: Based on the findings, policy recommendations were developed to enhance the effectiveness of primary health care services. These recommendations aimed to address identified barriers and promote multisectoral collaboration to achieve health-related SDGs.

The analysis emphasized a holistic view of primary health care, integrating both health service delivery and broader determinants of health to provide a comprehensive understanding of its role in advancing public health goals.

III. Results

Reproductive medicine is a rapidly evolving field focused on the diagnosis and treatment of infertility, a condition defined as the inability of a man and a woman of childbearing age to conceive a child after two years of regular, unprotected sexual intercourse. Infertility can be influenced by a variety of factors, including age, health conditions, and lifestyle. In many cases, healthcare professionals suggest seeking medical advice sooner—typically after 12 months of unsuccessful attempts to conceive. For women over the age of 35, it is often recommended to consult a specialist after six months of trying to become pregnant, as age can significantly impact fertility.

This field encompasses a wide range of diagnostic procedures and treatments, from hormone therapy and medication to advanced reproductive technologies such as in vitro fertilization (IVF). Its rapid development is driven by both increasing demand and advances in medical research, making it a crucial area of modern healthcare.

Reproductive technologies encompass a variety of methods designed to enhance the likelihood of fertilization and assist individuals or couples facing infertility challenges. These technologies include:

- In vitro fertilization (IVF): A process where eggs are retrieved from a woman's ovaries and fertilized by sperm outside the body, in a laboratory. The resulting embryos are then transferred to the woman's uterus to establish a pregnancy.
- Intracytoplasmic sperm injection (ICSI): A procedure in which a single sperm is injected directly into an egg to facilitate fertilization, often used when there are male infertility issues.
- Intracytoplasmic morphologically selected sperm injection (IMSI): A more advanced form of ICSI, where sperm is examined under high magnification to select the best-quality sperm for injection, increasing the chances of successful fertilization.
- PICSI (physiological intracytoplasmic sperm injection): A selection method for ICSI, where sperm are chosen based on their ability to bind to hyaluronic acid, mimicking natural selection processes to ensure better sperm quality for fertilization.
- Egg donation: The use of eggs donated by another woman to help individuals or couples conceive when the female partner's eggs are unsuitable for fertilization.
- Sperm donation: The use of sperm from a donor to facilitate fertilization, often used in cases of male infertility or for single women or same-sex couples wishing to conceive.
- Surrogacy: An arrangement where a woman (the surrogate) carries and delivers a baby on behalf of another individual or couple, often used when pregnancy is medically impossible or risky for the intended mother.

These reproductive technologies offer a range of solutions to increase the chances of conception and are widely used in modern reproductive medicine.

IV. Discussion

Experts identify several major causes of both female and male infertility, many of which are linked to environmental and lifestyle factors. Key contributors include exposure to unfavorable environmental conditions, harmful working environments (particularly for men), and sexually transmitted infections (STIs). Additionally, delaying childbirth for career or financial reasons and leading unhealthy lifestyles—characterized by alcoholism, smoking, and drug use—also play a significant role in infertility. Worryingly, the rising number of teenagers and young adults who engage in harmful habits is expected to further increase the number of couples struggling to conceive in the near future.

A critical factor contributing to the decline in reproductive health is the relatively high number of abortions, which continue to be used as a method of birth control. Over 50% of abortions occur among women aged 20 to 30, with an additional 20% in women aged 30 to 34—those in their most active reproductive years. Alarmingly, adolescent abortions are also a growing concern, with 8-10% of total abortions being performed on girls under the age of 19. This rate is much higher than in many Western countries.

The persistently high rates of abortion are largely attributed to the insufficient use of modern contraceptives. Data from the Ministry of Health and Social Development of the Russian Federation in 2009-2020 showed that only 25-30% of Russian women of childbearing age used contraception. This low usage is linked to several factors, including the underdevelopment of the domestic industry for producing modern hormonal contraceptives, irregular and costly government procurement, and a lack of public awareness about the availability of newer contraceptive options. Additionally, economic downturns—such as the financial crises of 1998 and 2020—led to steep increases in the prices of medical drugs, making them less accessible for many women. In recent years, there has been an increasing recognition within society of the importance of family planning, sex education, the cultivation of family and moral values, and the promotion of a healthy lifestyle. There is also a growing emphasis on responsible parenthood, particularly in encouraging young people to embrace responsible motherhood and fatherhood. This awareness has become particularly pressing in light of the significant challenges related to reproductive health. One notable response to these issues in Russia was the adoption of the Family Planning** program in 2024. This program aimed to address reproductive health challenges and promote the well-being of families.

Building on the success of the national initiative, a regional Family Planning and Reproductive Health Protection program was also adopted and partially implemented in the Sverdlovsk region. This program proved effective in reducing the number of abortions and lowering maternal mortality rates. It was later combined with the Safe Motherhood program, further contributing to improvements in reproductive health outcomes.

Global experience demonstrates the value and high medical and social effectiveness of such programs. In many Western European countries—including Finland, Sweden, the Netherlands, France, and England—family planning and reproductive health programs have been in place for over 40 years. These countries have achieved optimal levels of contraceptive use, which have significantly reduced maternal mortality and abortion rates. Furthermore, the concept of "abandoned children" is almost nonexistent in these nations, illustrating the far-reaching positive impact of comprehensive family planning policies. The success of these programs highlights the importance of sustained efforts in reproductive health education and family planning for the overall well-being of society.

Since 1978, the concept of primary health care (PHC) has undergone various interpretations and definitions, causing confusion in the understanding of the term and its practical application. To ensure more coordinated action at the global, national and local levels, the following definition has been proposed:

“PHC is an integrated approach to health that covers the whole of society and aims to achieve equitable access by every member of society to the highest possible level of health and well-being. It addresses the needs of the population at the earliest stages, providing a wide range of services, from health promotion and disease prevention to treatment, rehabilitation and palliative care, as close as possible to people’s daily lives.” This definition has been developed by WHO and UNICEF within the framework of the PHC concept for the 21st century, with a focus on achieving universal health coverage (UHC) and the Sustainable Development Goals (SDGs).

The PHC system includes three interrelated components:

1. A comprehensive set of health services, with an emphasis on primary health care, public health and related functions.

2. Intersectoral policies and actions that address the key determinants of health.

3. Engaging and empowering individuals, families and communities to actively participate in managing their health and social lives.

The concept of PHC is based on the values of social justice, equity, solidarity and cooperation. It is based on the recognition that the enjoyment of the highest attainable standard of health is a fundamental human right, regardless of status or condition.

Achieving true universal health coverage requires a shift from disease-focused systems to people-centred and participatory systems. This requires governments at different levels to recognise the importance of action beyond the health sector to implement a whole-of-government approach to health, with a particular focus on equity and the entire life course.

The concept of PHC aims to address a wide range of determinants of health and pays attention to the integrated aspects of physical, mental and social health. This approach ensures high-quality and comprehensive care at all stages of a person’s life, not just the treatment of individual diseases, with a focus on maximum proximity to the patient’s place of residence.

While there have been notable achievements in building primary health care (PHC) systems and health networks in Latin America, as reflected in key health indicators, there are still critical issues that need to be addressed based on the evidence analyzed. First, while the concept of PHC is embedded in institutional discourse and sectoral debates across the region, it faces significant challenges from the organizational structures of health systems. Intense fragmentation, ineffective decentralization, and the accumulation of isolated programs along the care continuum have led to the consolidation of a care model that deviates from best practices.

Profound income inequality acts as a segmentation mechanism, creating different levels of coverage based on individuals' ability to pay. In recent decades, most countries in the region have made efforts to promote coordinated care models, but results have been uneven, and monitoring and evaluation of the impact achieved have been scarce. The limited coordination between subsystems amplifies disparities, leading to the development of fragmented health networks that often operate informally and without standardized protocols. Collaboration between providers within different subsystems is minimal, and the private sector does not function as a space for coordination and complementarity with the public sector or, in some cases, social security systems. Instead, it often exacerbates care gaps.

The evidence gathered for this review has highlighted several key themes discussed throughout the document. Most notably, there is a pressing need to strengthen PHC models and care networks, as indicated by the documented results. Additionally, the review identified gaps in coverage of other critical topics, such as how health systems adapt to evolving population needs and the accumulation of epidemiological challenges, including mental health issues, addictions, and environmental impacts.

Furthermore, this review found a lack of literature on the impact of financial and non-financial incentives on health service provision, resource allocation efficiency, and quality improvements, opening avenues for future research. This gap suggests a need for deeper interaction between research and political action in the Latin American and Caribbean region to facilitate information exchange, strengthen the evaluation of interventions, and jointly design a research-action agenda that has a meaningful social impact. Article of law 35 of the "Fundamentals of the Legislation of the Russian Federation on the Protection of Citizens' Health" guarantees the right to assisted reproductive technologies for all adult women of childbearing age. Specifically, the article states that "every adult woman of childbearing age has the right to artificial insemination and embryo implantation." These procedures, which include artificial insemination and embryo implantation, can be carried out in licensed medical institutions, provided there is written consent from the woman involved. Furthermore, information regarding these procedures, as well as the identity of the donor, is protected as a medical secret.

If a woman has medical conditions that prevent her from carrying a pregnancy to term, as outlined in Order No. 67 from the Ministry of Health of the Russian Federation, she is eligible to use the services of a surrogate mother. The indications for surrogacy under this order include:

- Absence of the uterus (either congenital or acquired),
- Deformation of the uterine cavity or cervix, which may impede pregnancy,
- Somatic diseases in which carrying a pregnancy is medically contraindicated,
- Repeated unsuccessful IVF attempts despite the transfer of high-quality embryos.

In cases where these medical conditions are met, a woman may also opt to use the services of an oocyte donor or a donor embryo to achieve pregnancy. This legal framework thus provides women facing fertility challenges with multiple avenues for starting a family, ensuring access to modern reproductive technologies based on their medical needs.

As of today, approximately 100 clinics in Russia specialize in reproductive medicine. These clinics receive funding from the federal budget as well as from the budgets of various constituent entities of the Russian Federation. However, the cost of in vitro fertilization (IVF) procedures is relatively high, and almost all clinics have long waiting lists for those seeking free IVF quotas. As a result, many married couples and single women find this essential service to be financially out of reach.

Additionally, there exists a category of social infertility, which refers to healthy individuals who wish to have children but are unable to do so due to legislative shortcomings. A significant legal gap in Russian family law is the lack of clarity regarding the rights of unmarried individuals to access assisted reproductive technologies (ART), particularly in relation to surrogacy and donor programs. This issue affects millions of formally unmarried individuals of reproductive age. According to the 2002 census, around 30 million people expressed a desire to remain unmarried or had not yet found a partner, comprising approximately 15 million men (aged 18-54 years) and 14 million women (aged 18-44 years).

Over the past two decades, Russia has experienced a natural decline in its population, making it increasingly unlikely to see a substantial rise in the birth rate in the foreseeable future. To address this issue, it is essential to create conditions that enable individuals suffering from physiological infertility—regardless of marital status—to fulfill their desire to become parents. Advances in reproductive technologies present new opportunities to tackle the challenge of increasing birth rates in the country.

The Russian government should expand its support for individuals wishing to have children through surrogacy and reproductive programs. This includes increasing funding for clinics that specialize in therapies for male and female infertility. Furthermore, the reproductive rights of citizens require legislative protection, as their realization is directly tied to governmental support. Currently, there is no specific law in Russia that officially classifies infertility as a disease that warrants treatment, rather than merely a condition. Therefore, liberalizing the legal framework surrounding the desire to become parents is a crucial component of demographic policy. This would help ensure that all individuals, regardless of their marital status, have access to the reproductive technologies they need to start families.

References

[1] WHO. Global spending on health 2020: weathering the storm. Geneva: WHO, 2020

[2] Rahim F, Allen R, Barroy H, Gores L, Kutzin J. COVID-19 funds in response to the pandemic. Washington, DC, WA: International Monetary Fund, 2020.

[3] Andrews M, Cangiano M, Cole N, De Renzio P, Krause P, Seligmann R. This is PFM. CID Working Paper no 2852014. https://www.hks.harvard.edu/centers/cid/publications/facultyworking-papers/pfm (accessed July 20, 2021)

[4] Munchaev R.M., Amirov Sh.N. Once again about the Mesopotamian -Caucasian connections in the IV-III centuries thousand liters BC // Russian archeology. 2012. No4. pp. 37-46.

[5] Gakaev , R. Creating forest carbon landfills: forest carbon / R. Gakaev , MS Bahaev , I. Gumaev // Reliability: Theory & Applications. – 2023. – Vol. 18, No. S5(75). – P. 222-230. – DOI 10.24412/1932-2321-2023-575-222-230. – EDN LIMMLH.

[6] Fagan B. The Little Ice Age: How Climate Changed History. 1300-1850. Bombara Publishing House, 2021.

[7] Monin A.S., Shishkov Yu.A. History of climate. L .: Gidrometeoizdat , 1979. 408 p.

[8] Salamova A.S., Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[9] Khotinsky N.A., Savina S.S. Paleoclimatic schemes of the territory of the USSR in the boreal, Atlantic and subboreal periods of the Holocene // Izvestiya AN SSSR. Ser. Geography. 1985. No. 4

[10] Salygin V.I., Deniz D.S. Potential of renewable energy and transformation of the global fuel and energy balance: Theoretical aspects // Issues of Innovative Economics. 2021. Vol. 11. No. 4. P. 1893-1904.

[11] Gunya, A. Landscape analysis of exogenic processes distribution in mountain regions of the Chechen Republic / A. Gunya , R. Gakaev // Reliability: Theory & Applications. – 2022. – Vol. 17, No. S3(66). – P. 124-128. – DOI 10.24412/1932-2321-2022-366-124-128. – EDN KOFQNX.

CONCEPTUAL APPROACHES TO TRANSITION TO "GREEN ECONOMY" IN THE CONDITIONS OF SUSTAINABLE DEVELOPMENT OF KAZAKHSTAN

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Abstract

This article investigates important conceptual approaches to the transition to a "green economy" in the context of sustainable development of Kazakhstan. Theoretical foundations of the problems of transition to a low-carbon economy are carried out, important directions and stages in the transition to a "green economy" are shown, as well as considered foreign experience of mechanisms for the implementation of large-scale transformations on the transition to a "green economy" on the example of some countries. In order to ensure the reliability of the obtained results, the authors have addressed various sources on the available issues by the method of express analysis and interviews. The results of these scientific and experimental activities were reflected in the scientific work. The appendices and tables given in the work give quality to the work, clearly characterize and substantiate the theoretical conclusions and proposals. Certainly, we can state that this study has achieved its goal, the results of the study are fundamentally new, the work contains a number of sound recommendations for further transition to a "green economy" in the conditions of sustainable development of Kazakhstan will contribute to the economic growth of our country.

Keywords*:* investments, sustainable development, strategy, green economy, target indicators, SDGs, energy

I. Introduction

Transition to a "green economy" is the main way to achieve the SDGs, to fulfill Kazakhstan's promised contribution to reducing greenhouse gas emissions under the Paris Agreement with economic and environmental sustainability, a just and prosperous society, and a clean and healthy environment. The long-term vision of transition to a "green economy" for Kazakhstan is relevant for all key sectors of economic development.

Due to its undeniable merits, we believe that the adopted Strategy "Kazakhstan-2050: a new political course of the established state" (hereinafter - Strategy - 2050) sets clear guidelines for building a sustainable and effective model of the economy based on the country's transition to a "green" path of development. Due to its undeniable merits, we believe that the adopted Strategy "Kazakhstan-2050: a new political course of the established state" (hereinafter - Strategy - 2050) sets clear guidelines for building a sustainable and effective model of the economy based on the country's transition to a "green" path of development.

Transition to a "green economy", which can be defined as a successful economy with a high standard of living of the population, careful and rational use of natural resources in the interests of future generations and in accordance with the international obligations assumed by the country, is beneficial for Kazakhstan and will allow the country to move closer to its goal of becoming one of the 30 most developed countries in the world. It is estimated that by 2050, the transformation of the green economy will allow for an additional 3 percent increase in gross domestic product (GDP), the creation of more than 500,000 new jobs, the creation of new industries and services, and healthier and more equitable living conditions for the population. The transformation requires combined public and private investment averaging about 1 percent of GDP annually. Transition to a "green economy", which can be defined as a successful economy with a high standard of living of the population, careful and rational use of natural resources in the interests of future generations and in accordance with the international obligations assumed by the country, is beneficial for Kazakhstan and will allow the country to move closer to its goal of becoming one of the 30 most developed countries in the world. It is estimated that by 2050, the transformation of the green economy will allow for an additional 3 percent increase in gross domestic product (GDP), the creation of more than 500,000 new jobs, the creation of new industries and services, and healthier and more equitable living conditions for the population. The transformation requires combined public and private investment averaging about 1 percent of GDP annually.

II. Literature review

"Green economy" as an economic form of green development, includes low-carbon industry, energy-saving and environmental protection industry, ecological economy and renewable energy and other. The development of green economy is not only a strategic measure for long-term development, but also an important component of the current development of Kazakhstan's economy.

In recent years, many researchers have paid attention to the relationship between economic growth and the environment. Since the effects of environmental problems such as global warming, air pollution, increased use of natural resources and emissions, environmental and energy issues have gained paramount importance in the field of economic growth on international platforms [1-10].

It is often noted by researchers that green finance is becoming an important component for achieving global and national sustainable development goals and building a green economy, defining new environmentally sustainable growth prospects for the green segment and responsible investment [2].

There are opinions that to achieve the goals of sustainable development and transition to a "green" economy requires not only significant financial resources, but also the transformation of traditional investment. In the modern period, in the context of the world's global aspiration to sustainable development for investment projects and industries aimed at improving in the context of the world's global aspiration to sustainable development, the development of green economy and green financial instruments is relevant [3].

Many researchers have attempted to identify the main factors affecting energy consumption. They use population growth rate, balance of trade in goods and services, GDP, foreign direct investment and energy prices as determinants of energy consumption. And here we can agree with the opinions of these researchers, as their results show that the growth rate of direct investment in the energy sector affects both GDP growth and the levels of energy consumption of the population [4].

Some works clearly define the essence of responsible investment within the concept of ESG-investment, which takes into account the unity of environmental, social and corporate governance factors; they analyze the state and development of responsible investment factors and assess the possibilities of forming an ecosystem of financial support for environmentally responsible investments [5].

According to experts, they point the main problems in the transition to a "green" economy to the processes of regulation in the sphere of environmental management, in particular, in the oil industry. They note that the mechanisms of regulation of the industrial waste processing industry are practically absent, and the problems arising in this industry are ignored by authorized bodies, which can lead to an environmental disaster [7].

III. Methods

In conducting this study as a methodological basis were used general and specific methods, in particular: dialectical, system-functional, economic-statistical and formal-logical methods. Currently, the issues of conceptual approach to the transition to a "green economy" have been reflected in many scientific studies. However, it should be noted that there is not enough theoretical review on the problems of transition to a "green economy" in the context of sustainable development of the national economy. To date, the national economy has formed certain methods and approaches to further transition to the "green economy". However, none of them can be considered universal for the study of this process. Based on the above methods, we note that the research methods are built on the principles of system-structural analysis, methods of scientific analysis and synthesis were applied.

IV. Results

Currently, our country is implementing the National Project "Green Kazakhstan" for 2021-2025 in order to transition to a "green course" of economic growth is a very high priority and strategic task of the national economy.

The main priority areas in the transition to a "green economy" are the following (Fig. 1):

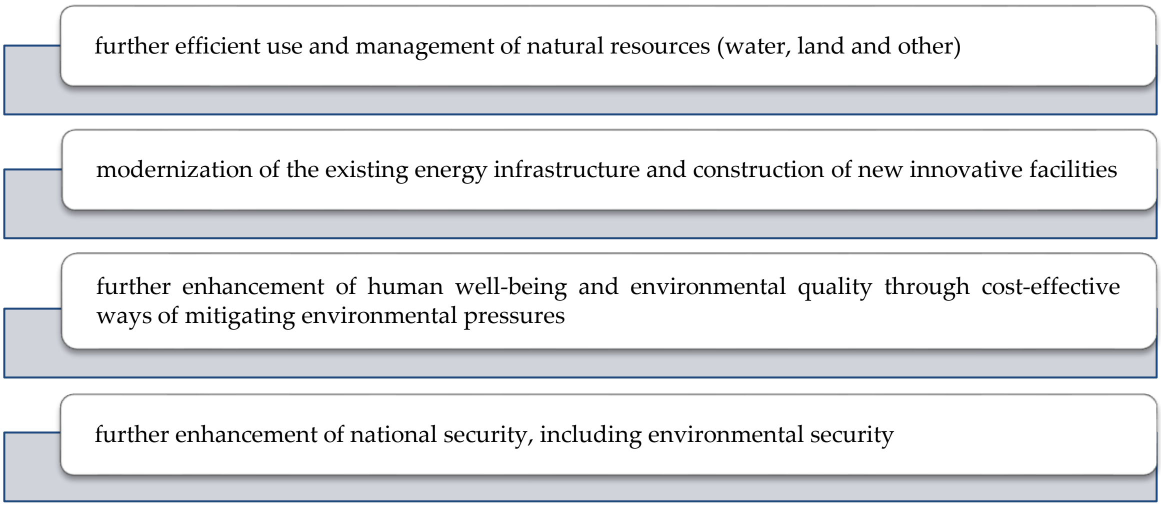

Figure 1: *Main directions for transition to "green economy"*
Source: Concept on Transition of the Republic of Kazakhstan to "green economy" [5, 6]

The total amount of investments required for the implementation of the Concept on the transition of the Republic of Kazakhstan to a "green economy" of May 30, 2013 (hereinafter the Concept) from now until 2050 will average 3-4 billion USD annually. The largest annual volume of investments will be equivalent to 1.8 % of GDP in the period from 2020 to 2024, and on average until 2050 investments will amount to about 1% of GDP. At that, the main share of investments will be attracted at the expense of private investors' funds [5, 6].

According to this Concept, the asset renewal cycle in resource-based sectors of the economy takes a long time, and in resource-based economies the transition to a clean economy takes decades. Kazakhstan is not an exception in this sense (Fig. 2).

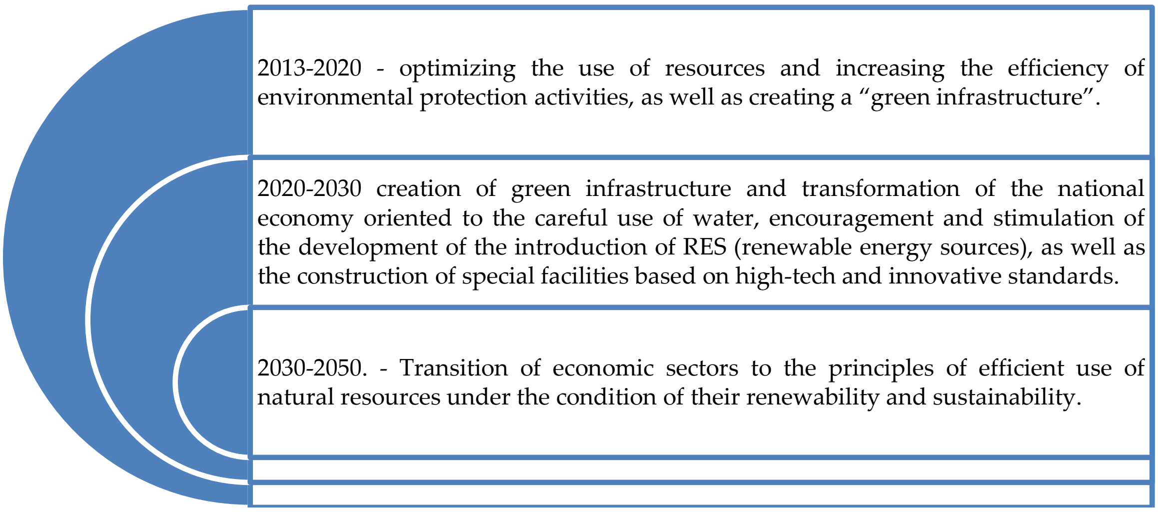

Figure 2: *Important stages of implementation of the Concept for the transition of the Republic of Kazakhstan to a "green economy" Source:* http://egov.kz/wps/portal/Content?contentPath=/egovcontent/bus_nat_eco/ecologiya/article/green_ekonomika&lang=ru [7]

Such measures should contribute to changing the behavioral patterns of the population with regard to the use of heating and cooling systems, waste disposal and water use [8].

To coordinate and control the transition to a "green economy" the Council on Kazakhstan's transition to a "green economy" will be established under the President of the Republic of Kazakhstan. This Council will review the National Report on the transition to a "green economy" every three years. Establishment of such a body is a mechanism for realization of large-scale transformations in the public sector. For example, this approach has been successfully used in Taiwan, Korea and Bahrain (Table 1).

Table 1: *Key effective approaches in the transition to a green economy in some countries*

Country	Program	Expected results
Taiwan	Reconstruction of rural areas	▪ The organization responsible for change should not replace ministries, but complement them ▪ Opportunities should be provided for innovative developments to address identified problems ▪ Local skills should be developed to sustainably implement the solutions developed in the future.
Korea	National economic development plan	▪ The organization has very broad powers and has the full support of the Prime Minister ▪ It is directly linked to the Ministry of Finance and has full control over the budget. ▪ The organization is made up of only the most effective professionals from both the public

		sector and the emerging private sector. ▪ The organization functions as an "incubator" - it has already established several independent companies that have subsequently become leading players in the private sector.
Bahrain	Bahrain's Vision 2030 Economic Development Plan	▪ There should be an optimal mix of experienced professionals and young professionals with high potential ▪ Opportunities should be created to attract top-notch talent without unduly high remuneration ▪ The responsible organization should be given significant weight through the broad powers granted to it by the country's leadership ▪ The necessary authority to make or influence budget allocation decisions should be ensured.

Source: [6-9]

Based on the data in Table 2, showing the dynamics of electricity production from 2018 to 2022 in Kazakhstan, it is possible to assess the state of production, consumption of electricity in Kazakhstan. During this period, the average tariff, which is 15.66 tenge per 1 kWh in 2022, increased several times, while electricity production increased by about 2 times. At the same time, if we correlate electricity production and consumption, we can highlight that from 2018 to 2021, consumption exceeded production [6-26].

Table 2: *Dynamics of electricity generation, consumption and estimated electricity tariff in Kazakhstan for 2018-2022*

Indicators	2018	2019	2020	2021	2022
Electricity production, billion kWh	107,27	106,48	108,63	115,08	113,45
Electricity consumption, billion kWh	103,20	105,10	107,30	113,50	112,94
Settlement tariff (average), tenge per 1 kWh	11,07	10,53	11,74	14,04	15,66

Source: [10]

However, taking into account the forecast of electricity generation and consumption in Table 2, it can be seen that after 2022 there is a probability of electricity shortage. The data in Table 2 show a downward trend, which will be realized starting from 2022 for 4-5 years. In general, the following will be envisaged to reduce consumption: increase in tariffs, which will be for all consumers of electricity; formation of new sources of production by attracting different types of electricity generation and saving of electricity received by the population [6-26].

V. Discussions

In the context of sustainable development of Kazakhstan's economy, the importance of both the implementation of the Concept and the realization of the 17 Sustainable Development Goals (SDGs), put forward by the UN in 2015 to all countries of the world to ensure economic security, in particular, environmental security, reducing emissions of environmental protection and environmental protection is increasing

For this purpose, let us consider the main goals of the SDGs realization (Figure 3). For the realization of 17 SDGs Kazakhstan has developed its national indicators, monitors and evaluates their implementation. These activities take place both on the national scale as a whole and at the regional level.

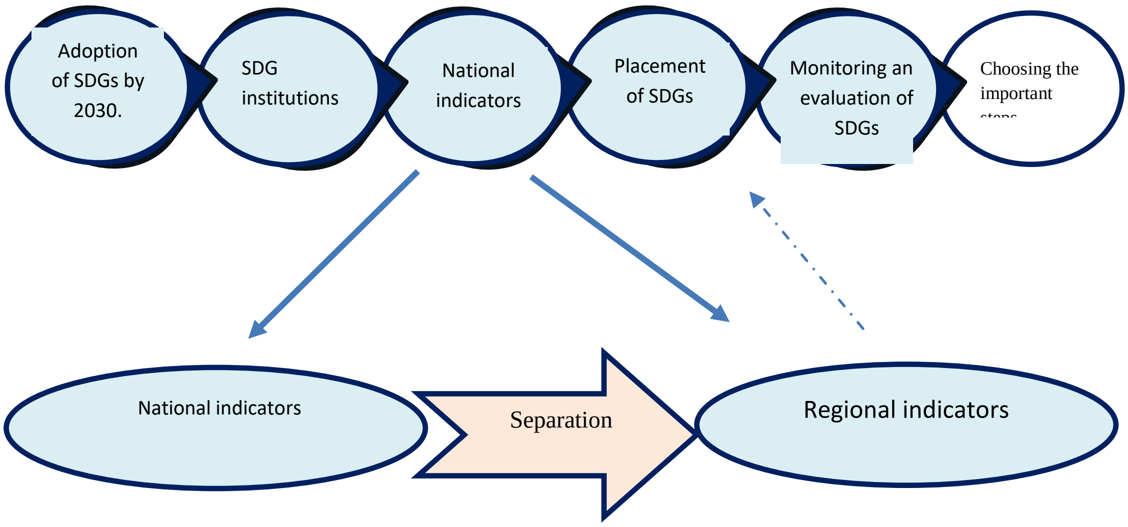

Figure 3: *Main objectives of SDG implementationy*
Source: [11]

Thus, the concept of transition of the Republic of Kazakhstan to a "green economy" is implemented in accordance with the provisions of the Constitution of the Republic of Kazakhstan, Strategy 2050 and the Strategic Development Plan of the Republic of Kazakhstan until 2020. Issues of implementation of the transition to a "green economy" will be regulated by legislative acts of the Republic of Kazakhstan on the transition to a "green economy". At the same time, the transition to a "green economy" reduces risks from global threats such as climate change, depletion of minerals and shortage of water resources

VI. Conclusion

In the process of transition of Kazakhstan some researchers consider the development and establishment of green finance in Kazakhstan. conceptual approaches to the transition to “green economy” in the conditions of sustainable development of Kazakhstan. Many literatures refer to numerous studies conducted on the principles of green economy, as current models of economic growth and development are unsustainable. The level of participation of private and public institutions in the process of implementing the principles of “green economy” varies depending on the level of economic development of the country.

“Green economy” is an inclusive system of economic growth, social protection and natural ecosystems when it does not create serious risks and environmental deficits for future generations. The link between environment and development is possible through sustainable development. Thus, it is noted that the green economy is based on the restructuring of growth and development within the framework of global resources. Various stakeholders are involved in the process of implementing the principles of green economy, and each of them plays a fundamental role. “Green economy” is an inclusive system of economic growth, social protection and natural ecosystems when it does not create serious risks and environmental deficits for future generations. The link between environment and development is possible through sustainable development. Thus, it is noted that the green economy is based on the restructuring of growth and development within the framework of global resources. Various stakeholders are involved in the process of implementing the principles of green economy, and each of them plays a fundamental role.

Thus, in the green economy, concepts such as sustainable products, clean technologies and green processes have pushed organizations to opt for change management initiatives. Organizational sustainability through application has been defined as a triad concept covering environmental issues, economic aspects and social issues. The European Union has developed a set of environmental policies, the main ones being environmental sustainability, a natural capital economy and resource-efficient and environmentally friendly development.

References

[1] Azretbergenova, G., et al. (2024). Testing the Environmental Kuznets Curve Hypothesis in BRIC Countries. International Journal of Energy Economics and Policy, 14(1), 371–376. https://doi.org/10.32479/ijeep.15111

[2] Birmagambetov, T., et al. Current status of green finance in Kazakhstan. E3S Web of Conferences, 2023, 402, 08033, DOI: 10.1051/e3sconf/202340208033

[3] Gulzhan, A., et al. Green loan - a green financing instrument. E3S Web of Conferences, 2023, 402, 08036, DOI: 10.1051/e3sconf/202340208036

[4] Azretbergenova, G., et al. (2024). Determinants of Energy Consumption in MIST Countries. International Journal of Energy Economics and Policy, 14(4), 317–323. https://doi.org/10.32479/ijeep.16132

[5] Kizimbaeva, A., et al. Developing environmentally responsibly investment in Kazakhstan. E3S Web of Conferences, 2023, 402, 08035, DOI: 10.1051/e3sconf/202340208035

[6] Burkaltseva D., et. al. (2022). Assessment of Regional and Sectoral Parameters of Energy Supply in the Context of Effective Implementation of Kazakhstan's Energy Policy. *Energies*, *15*(5), 1777. DOI:10.3390/en15051777

[7] Butova, T., et al. (2023). Effectiveness of Regulatory Mechanisms of the Oil and Gas Industry in the Context of Environmental Problems. In: Beskopylny, A., Shamtsyan, M., Artiukh, V. (eds) XV International Scientific Conference "INTERAGROMASH 2022". INTERAGROMASH 2022. Lecture Notes in Networks and Systems, vol 575. Springer, Cham. https://doi.org/10.1007/978-3-031-21219-2_4

[8] Abramova M. Features of the mechanism for implementing sustainable development through the green economy**.** E3S Web of Conf., 402 (2023) 08030 DOI: 10.1051/e3sconf/202340208030

[9] Berstembayeva, R., et al. (2024). The impact of the green economy on the sustainable development of Kazakhstan. In *BIO Web of Conferences* (Vol. 116, p. 07040). EDP Sciences

[10] Yerzhanova, S., et al. (2017). Perfection of the administrative mechanism of stimulation of tourist business. *Journal of Environmental Management and Tourism*, *8*(8), 1494-1503.

[11] Yerzhanova, S., et al. (2023). Development Prospects Labor Income of the Population of the Republic of Kazakhstan: Economic Efficiency and Priorities of Regulation. *Montenegrin Journal of Economics*, *19*(2), 21-32.

[12] Burkaltseva, D.et al. Methodological Foundations of the Risk of the Stock Markets of Developed and Developing Countries in the Conditions of the Crisis.., Journal of Risk and Financial Management, 2022, 15(1), 3 DOI: 10.3390/jrfm15010003

[13] Niyazbekova, S., Yerzhanova, S., Tyurina, Y., Abilmazhinov, M., Kyazimov, K., & Smernitskaya, E. (2021). The development of renewable energy and state policy in improving energy efficiency. In *E3S Web of Conferences* (Vol. 244, p. 10059). EDP Sciences.

[14] Kerimkhulle, S.et al., Assessment of Regional and Sectoral Parameters of Energy Supply in the Context of Effective Implementation of Kazakhstan's Energy Policy. Energies, 2022, 15(5), 1777 DOI: 10.3390/en15051777

[15] Baigireyeva, Z. et al., Analysis of the influence of ecology on human resources management in the healthcare system. Journal of Environmental Management and Tourism, 2021, 12(7), pp. 1980–1996 **DOI:** 10.14505/jemt.v12.7(55).23

[16] Zverkova A., et al. Features of the "Green" strategies for the development of banks. E3S Web of Conf., 402 (2023) 08029 DOI: 10.1051/e3sconf/202340208029

[17] Livestock products of households in ensuring food security in Kazakhstan. Yessymkhanova, Z., Niyazbekova, S., Tochieva, L., ...Varaksa, N., Zubets, A. E3S Web of Conferences, 2021, 284, 02020 DOI:10.1051/e3sconf/202128402020

[18] Yerzhanova, S. et al. The development of renewable energy and state policy in improving energy efficiency. E3S Web of Conferences, 2021, 244, 10059 DOI:10.1051/e3sconf/202124410059

[19] Suleimenova, B. et al. (2021). Oil and gas investment opportunities for companies in modern conditions. *Socio-economic systems: Paradigms for the future*, 669-676.

[20] Niyazbekova, S. U., Moldashbaeva, L. P., & Uspambaeva, M. K. (2019). On institutional and legal problems of state audit and financial control. Bulletin of Moscow University S. Yu. Witte. Series 1: Economics and Management, 3(30), 15-20. DOI: 10.21777/2587-554X-2019-3-15-20

[21] Niyazbekova, S. U., & Ivanova, O. S. (2020). Development of fintech and big data in the financial sphere: features, problems, opportunities. Moscow University Journal S. Yu. Witte. Series 1: Economics and Management, 1(32), 30-36. DOI: 10.21777/2587-554X-2020-1-30-36

[22] Yarovenko, S. E., & Niyazbekova, S. U. (2021). Comparative analysis of global financial crises, their causes and consequences. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (4 (39)), 48-57. DOI: 10.21777/2587-554X-2021-4-48-57

[23] Grekov, I.E., The influence of macroeconomic factors to the dynamics of stock exchange in the Republic of Kazakhstan. Economy of Region, 2016, 12(4), pp. 1263–1273 doi: 10.17059/2016–4–26

[24] Jazykbayeva, B., et al. The Growth of green finance at the global level in the context of sustainable economic development. E3S Web of Conferences, 2021, 244, 10058 DOI:10.1051/e3sconf/202124410058

[25] Jazykbayeva, B., The Growth of green finance at the global level in the context of sustainable economic development. E3S Web of Conferences, 2021, 244, 10058 DOI:10.1051/e3sconf/202124410058

[26] Niyazbekova, Sh. U., & Bunevich, K. G. (2020). A brief overview of the Danish financial sector. Bulletin of the Moscow State University named after S. Yu. Witte. Series 1: Economics and Management, (3 (34)), 50-56. DOI: 10.21777/2587-554X-2020-3-50-56

SUSTAINABLE DEVELOPMENT: ECONOMIC EFFICIENCY OF ECOSYSTEMS

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Abstract

To date, the generally recognized global trends have become the principles of sustainable development adopted by the UN, which are understood as the evolutionary development of civilization based on innovations while meeting the vital needs of the population of different states, including energy supply and environmental conservation. Being associated with a number of crises, the growing turbulence of the global economy and the political system of the modern world, constantly seeing an increase in the number of challenges to global trends towards sustainable development, it is worth reconsidering the approach to the concept of Sustainable Development. Attempts to undermine the significance of the UN 2030 Agenda for Sustainable Development adopted in 2015 under the influence of the COVID-19 pandemic quickly gave way to the importance of uniting efforts aimed at achieving the 17 Goals that are the basis of governance (SDGs). Efforts at many levels - from states and their regional entities to municipalities, corporations, or ultimately the level of specific people in society by and large. Attention to sustainable development issues is also growing against the backdrop of an obvious deterioration in the climate situation and the need to create energy security.

Keywords: sustainable development, greenhouse, gas emissions, environmental challenges, environmental protection, advanced technologies

I. Introduction

Modern technologies become part of any business and serve as a key factor in ensuring its competitiveness [1]. However, complex technologies have limitations that do not allow them to fully use their full potential to solve the problems of the ESG agenda. The first limitation is due to the fact that the use of advanced analytics technologies requires huge computing power, and this, in turn, leads to an increase in energy consumption and entails an increase in carbon dioxide emissions, negatively affecting the company's ESG indicators and the environment as a whole [2]. The second limitation is the ethical aspects of new technologies. Cloud computing can be one of the solutions to circumvent the above limitations. They respond to environmental challenges through more efficient energy management. The solution of the ethical aspects of new technologies in the clouds is achieved by standardizing the algorithms of the models used, using a huge amount of data, and constantly checking and validating the results. Now modern technologies are becoming a part of any business and serve as a key factor in ensuring its competitiveness. For example, with the help of advanced analytics, the most resource-intensive, complex and non-trivial tasks are already being implemented, the solution of which was previously impossible or impractical due to huge time and material costs [3]. Technologies allow you to analyze a huge amount of data in a short time, provide self-learning models and identify complex relationships, build accurate forecasts, collect information and analyze, respond to changes in production indicators online, as well as securely store this data and much more. Digital tools based on sophisticated analytics are also applied to companies' internal processes to improve their efficiency. For example, advanced technologies are widely used in the world to solve problems in the field of ESG. In the Russian market, the share of penetration of modern technologies into ESG is small, however, according to a joint study by the audit consulting company Trust Technologies (hereinafter referred to as TeDo) and the Center for Sustainable Development of the SKOLKOVO School of Management, 65% of leaders of large Russian companies believe that without digital solutions it is impossible to implement ESG transformation. For example, in the field of ecology and climate (E), artificial intelligence technologies can achieve the goal of the agenda by creating smart and low-carbon cities, Internet-of-Things-based devices that can regulate electricity consumption. They also help improve the integration of renewable energy sources through smart grids and identify desertification trends through satellite imagery.

II. Methods

As part of the social aspect (S), it becomes possible to create safer working conditions for employees. In the management part (G), thanks to the use of advanced technologies, reporting is automated, which becomes more transparent and accessible to the public. As the mentioned study shows, the following technologies have the greatest potential for achieving maximum efficiency in solving ESG problems [4]:

- artificial intelligence (29%);
- internet of things (23%);
- blockchain (14%).

However, it should be noted that for the implementation of specific digital solutions for ESG, combinations of these technologies are often used, which complement and enhance the effectiveness of each other. Let's consider the most common examples of using the technologies under consideration for the entire spectrum of tasks in the field of ESG.

The combination of artificial intelligence and the Internet of things is an indispensable tool for tackling climate and environmental issues, such as managing a company's carbon footprint. On the basis of artificial intelligence technologies, data are collected and consolidated reflecting the emission and absorption of greenhouse gases from production sensors in the context of individual processes. The specified array is further converted using machine learning into predictive models that allow high-precision assessment and optimization of the company's processes. According to Accenture research, more than 70% of companies report the effectiveness of digital emission reduction solutions implemented using artificial intelligence. Combining artificial intelligence with blockchain technologies makes it possible to more transparently track the carbon footprint formed by the components of the company's products throughout the supply chain and for all types of coverage (Scope 1, 2 and 3). An example of a digital carbon footprint management tool is a solution to reduce energy intensity implemented by a large steel company. Thousands of sensors collect data, which is then processed by artificial intelligence algorithms. This allows the company to accurately calculate and predict energy needs, and track and reduce emissions. Since implementing the solution, the company has implemented a number of initiatives that, according to BCG, resulted in a 3% reduction in carbon dioxide emissions, which is approximately 230 thousand tons of CO_2 per year, and reduced costs by $40 million.

III. Results

According to a McKinsey study, more than 20 examples of using artificial intelligence to improve the quality of life and health of company employees and 3 examples of gender equality stand out in order to achieve the sustainable development goals [5]. These goals are included in the social aspect of the ESG agenda. The most striking example of the use of artificial intelligence in the social sphere is the implementation of solutions that provide safe working conditions. On the basis of data received from surveillance cameras, self-learning models are formed that recognize standard operating conditions and deviations from the norm. Further, the data from surveillance cameras is analyzed online and, using predictive analytics, hazardous work areas and risks are identified that can lead to incidents at the workplace in the future. For example, it is possible to track the movements of employees and identify potential hazards along their routes, such as the danger of tripping or the presence of loose equipment. With the help of such solutions, it becomes possible to set up notification of managers and staff about emerging risks and security incidents in the workplace, which allows them to be eliminated in a timely manner. Updating and processing data in real time allows you to monitor employees who violate established security rules. Internet of Things technologies complement and increase the efficiency of the digital solutions discussed above based on artificial intelligence. With the help of special sensors and thermal imaging cameras, data is collected about the environment surrounding the company's employees and its safety is assessed. For example, some companies are using machine vision to monitor employee safety in hot work areas. In particular, thermal imaging cameras can be used to detect "heat stress" in workers and provide them with the necessary assistance in the form of a cool down break or additional personal protective equipment. Sensors are also used to analyze the composition of the air in the working room [6]. They scan, analyze and immediately report the presence of harmful particles, pollutants or hazardous gases such as carbon monoxide. By collecting and analyzing air quality data and alerting anomalies, such systems help prevent the release of harmful pollutants into the atmosphere, while maintaining the safety and health of every employee. Additionally, with the help of artificial intelligence and the Internet of things, it becomes possible to create smart offices focused on maintaining the health, well-being and safety of company personnel. Occupancy sensors keep track of the number of people in the office at a given time. The visualization of such data enables flexible working formats, such as shared desk systems, and facilitates social distancing and prevents overcrowding in the workspace. Employees have access to this data to decide whether to visit the office. Also, office attendance data allows real-time implementation of office cleaning planning models that take into account their use. The level of air quality also affects the safety of personnel. A high amount of carbon dioxide in the air is associated with poor decision making, lack of concentration and drowsiness. Air quality sensors measure the level of carbon dioxide and volatile organic compounds and display the data on the dashboard to adjust the working environment of office workers accordingly. An industrial security video analytics project implemented by a large Russian company, which includes monitoring of hazardous areas, the use of PPE (personal protective equipment), collision risks and a number of other aspects, is an example of the implementation of a solution based on modern technologies in terms of the S-component. All collected data is analyzed in order to completely prevent accidents. In the near future, it is planned to equip employees with portable devices that allow monitoring biorhythms and monitoring critical health conditions, including pre-infarction and pre-stroke, which carry a great danger, especially when operating complex equipment, because in the event of an unexpected deterioration in health, the life of the employee himself is at risk, and his colleagues [7]. By connecting portable devices to the on-board computers of the technician, an instant stop of traffic will be provided, notification of those responsible for the site, and, most importantly, a call for an ambulance brigade, which upon arrival will have all the necessary data on the state of a person for prompt assistance.

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IV. Discussion

Modern technologies also make it possible to successfully implement solutions aimed at impartial evaluation of work and professional development of employees. With the help of big data analytics and artificial intelligence, a large financial holding has developed a personnel assessment system that solved the problem of biased feedback due to collusion between employees. This decision, based on the analysis of information about 25 thousand employees and more than 125 million emails, identified informal leaders who are most actively and effectively involved in decision-making and task completion. It was found that the intersection of the list of candidates for promotion, compiled by employees, and opinion leaders, determined by the decision based on artificial intelligence, is only 60%. Thus, employees whose promotion is premature were identified, and in general, transparency and impartiality were added to the decision-making process on the promotion of employees. Artificial intelligence-based solutions aimed at training and professional development of employees allow the formation of personalized recommendations of the most relevant courses for an individual employee based on user clustering and training programs. The accuracy of the recommendations is achieved by analyzing the test results, personal profile, requirements for the position, as well as user experience. A similar solution is used by one of the largest banks in Spain. Another example of a more responsible attitude towards employees is the use of big data to prevent professional burnout [8]. The most striking example is the experience of a large construction company, which, using analytics and big data structuring, revealed that 14% of employees are in the last stage of burnout. The decision made it possible to apply employee support measures in a timely manner and reduce the level of staff turnover.

Good governance requires full transparency and accountability for key processes. With the help of artificial intelligence-based solutions, it becomes possible to automate the formation of key ESG indicators, which allows for a transparent, versatile and unbiased analysis of the company, eliminating the risk of human error in calculations, as well as their distortion. The main problem of automating the generation of ESG reporting is the heterogeneity of the required data sources. It is solved by using NLP (Natural Language Processing) algorithms, which allow machine learning to be applied to text written in natural language. Artificial intelligence-based solutions are already on the market, which, through full integration into company processes, allow collecting and processing data, calculating ESG metrics and comparing indicators with market averages. An additional reporting requirement under this aspect is to ensure the traceability of reporting and the possibility of its audit, which can be achieved through a combination of artificial intelligence with blockchain technologies. This decision allows you to confirm the immutability of the data reflected in the company's financial statements. All data stored on the blockchain platform can be verified by regulators or an independent party to confirm the company's compliance with the established standards and to verify that its statements, messages and advertisements correspond to its actual practice. For example, many corporations have committed to significantly reduce or eliminate their carbon footprint, which is reflected in corporate goals. Thanks to blockchain technologies, these goals can be compared with the organization's current carbon footprint. The above examples show that global problems in the field of sustainable development are currently being effectively addressed through the use of advanced technologies [9]. However, complex technologies have limitations that do not allow them to fully use their full potential to solve the problems of the ESG agenda. The first limitation is due to the fact that the use of advanced analytics technologies requires huge computing power, which leads to an increase in energy consumption and entails an increase in carbon dioxide emissions, negatively affecting the company's ESG indicators and the environment as a whole. In practice, training artificial intelligence models requires a huge amount of computing power, and some researchers argue that the environmental costs of applying advanced analytics outweigh the benefits. By some estimates, in just a few years, the digital industry will generate more carbon emissions than all road transport. Digitalization already accounts for 4% of global greenhouse gas emissions, according to EY analytics. The ecological footprint of the digital world is constantly increasing as energy consumption grows in parallel with the growth of the industry as a whole to meet the demand for technology. Some experts believe that by 2025 the technology sector could consume 20% of all electricity in the world. This growth from the current 7% is logical against the background of the development of complex technologies, such as artificial intelligence, which contribute to the demand for computing power. The second limitation is the ethical aspects of new technologies, in particular artificial intelligence. In most cases, historical data (often from a single company) is used to train artificial intelligence models, which can be limited and biased and lead to gender or racial inequality and discrimination from the decision based on such a model. An example is a scientific experiment led by researchers from Johns Hopkins University, Georgia Institute of Technology and the University of Washington. Robots, functioning on the basis of artificial intelligence, were asked to distribute people into certain social roles and professions according to their appearance. The main conclusions of the study are as follows [10]:

- fair-skinned women in most cases were classified as housewives;
- black men were 10% more likely to be identified as criminals;
- Women were practically not assigned to medical professions. This observation is a significant limitation for the use of new technologies in the field of the social aspect of the ESG agenda, since it directly contradicts the task of this aspect. Cloud computing can be one of the solutions to circumvent the above limitations. Cloud technologies respond to environmental challenges through more efficient energy management. The solution of the ethical aspects of new technologies in the clouds is achieved by standardizing the algorithms of the models used, using a huge amount of data, constantly checking and validating the results.

References

[1] Zhuravleva V. V., Kazazaev V. V. On modeling plant photosynthesis under global climate change. No. 4 (96), 2020, pp. 104-107.

[2] Pinyavina E.A. Creation of forest carbon (carbon) landfills: economic component // Actual directions of scientific research of the XXI century: theory and practice. 2021. No. 1. p.26-34.

[3] Salamova A.S., Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, 2023, 17(1), pp. 237-245.

[4] Salamova A.S., Global networked economy as a factor for sustainable development, 2020, p. 03053.

[5] Gakaev, R. Carbon sequestration in landscapes of the Chechen Republic. Reliability: Theory & Applications, 2022. Vol. 17. 3(66), pp. 193-196

[6] Hansen, J.; M. Sato; R. Ruedy; K. Lo; D. W. Lea and M. M. Elizade, Global Temperature Change, PNAS, 2020, 103(39), pp. 14288–14293.

[7] Leggett, J. A.; J. Logan and A. Mockey, China's Greenhouse Gas Emissions and Mitigation Policies, CRS Report for Congress 2008.

[8] Verfaillie, H., and R. Bidwell, Measuring Eco-efficiency: A Guide to Reporting Company Performance, World Business Council for Sustainable Development, Geneva, 2020.

[9] Kantyukov R R., Kolybanov K. Yu, Ravikovich V I Information technologies for preparing control decisions in automated systems of environmental monitoring, 2019.

[10] Kampschreur MJ, Temmink H, Kleerebezem R, Jettena MSM, van Loosdrecht MCM. Nitrous oxide emission during wastewater treatment. Water Res. 2019, pp.4093–4103