NEW APPROACHES TO OILY WASTE TREATMENT TO MINIMISE TECHNOLOGY-RELATED THREATS AND RISKS

Sahiba Kalaeva[1], Eduard Tshovrebov[2], Alena Gennadieva[1], Ramil Kalaev[1]

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[1]Yaroslavl State Technical University, RUSSIA
[2]All-Russian Scientific Research Institute for Civil Defense and Emergencies of the EMERCOM of Russia (Federal Science and High Technology Center), RUSSIA
kalaevasz@ystu.ru
zerowaste-audit.rrr@yandex.ru
gennadivalena@gmail.com
ram0299@yandex.ru

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}.

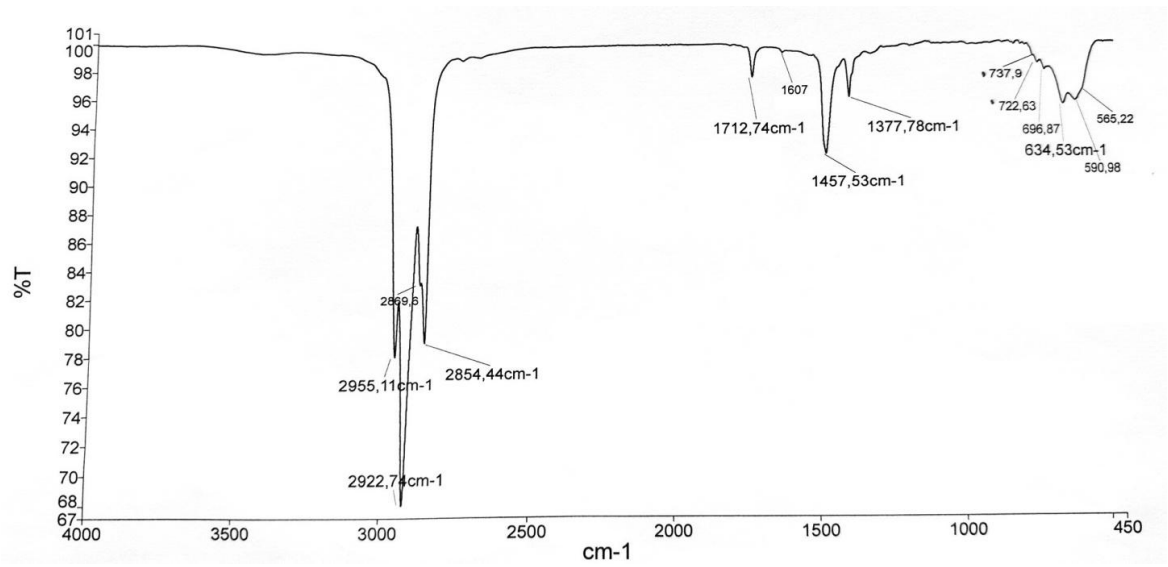


Figure 1: *Infrared spectrum of the magnetic fluid*

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.

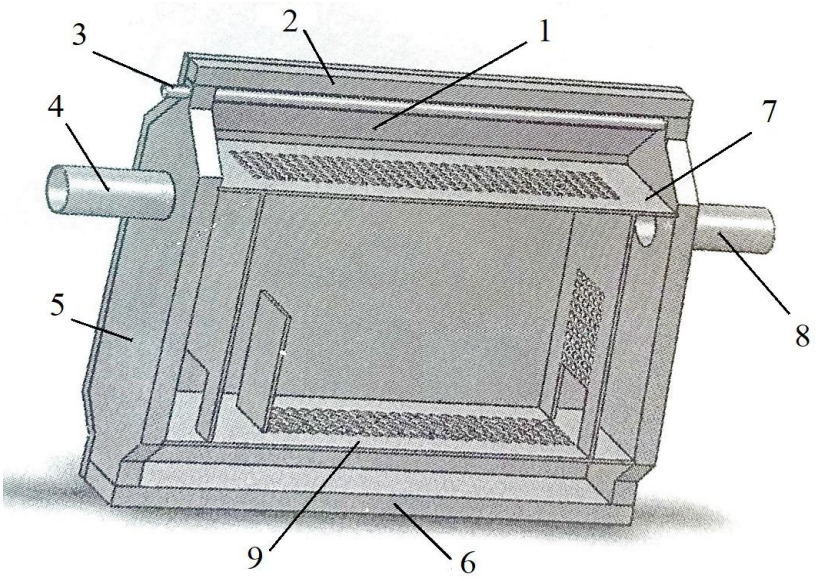
Implementation of the proposed technology will cause a reduction in the impact of heavy metal ions and petroleum products on water bodies. This will improve water quality, reduce population morbidity and mortality, decrease costs on drinking water treatment, contribute to aquatic ecosystems conservation, 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

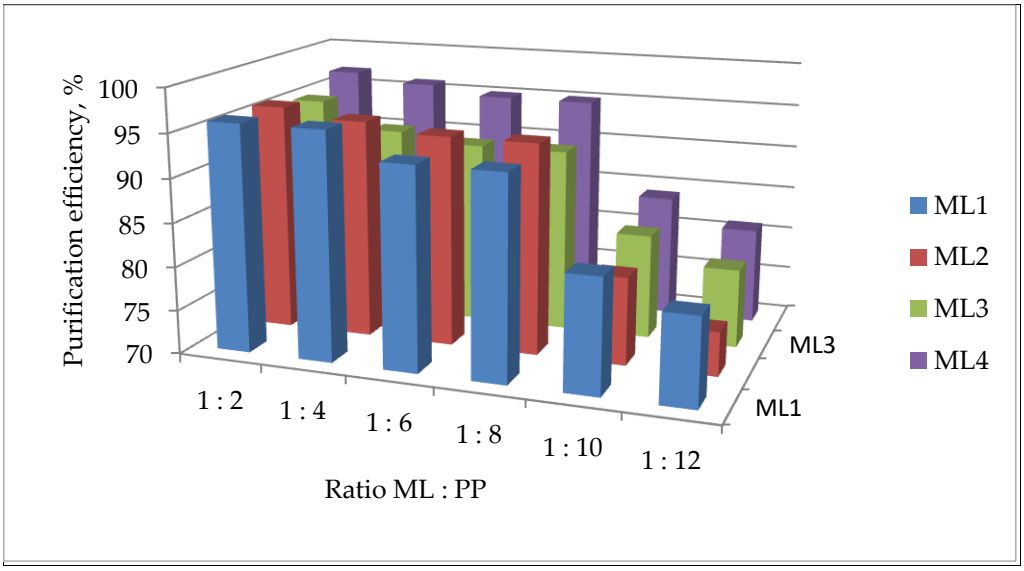
field. As the polluted effluent moves through the apparatus, the content of oil products in the water gradually decreases due to coalescence and adsorption processes. The purified water is discharged from the chamber through branch pipe *4*.



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.

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