ECOTOXICOLOGICAL CHARACTERISTICS OF SOME THERMAL WATERS OF THE GURIA REGION, SURROUNDING HABITATS AND POTENTIAL POLLUTION RISKS

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Abstract

This study aimed to conduct a comprehensive assessment of the ecotoxicological indicators of the thermal waters in the Khajalia and Dzimiti areas of the Guria region (Lanchkhuti and Ozurgeti), as well as the cenotic features of the surrounding landscapes. The organoleptic, physicochemical and bacteriological properties of the waters were evaluated in situ, and their ionic and elemental compositions were analysed in a laboratory setting. The results revealed that the pH of Dzimiti water is weakly alkaline, it is highly saline, and it has a mineral-thermal profile. In contrast, Khajalia water is non-mineral and exhibits an alkaline average response. High concentrations of NH_4^+ *and* NO_2^- *ions in both waters indicate ecological vulnerability due to the absence of sanitary protection zones. Boron concentration above the permissible limit was detected in Dzimiti water, while methane dominated the accompanying gases (>50%). Bacteriological indicators suggest a potential risk of contamination. Meanwhile, coenotypes were identified and their species and structural features described. A map was created using GIS to illustrate the coenotic structure of the landscapes surrounding the thermal waters.*

Keywords: thermal waters, cenotopic structure, field measurements, chemical and elemental composition, associated gases

I. Introduction

Thermal waters are an essential natural resource with energy, medicinal, and ecological importance. Studying their physicochemical and biological properties is important both scientifically and practically, since the use of thermal waters relates to health, tourism, energy security, and environmental concerns. Currently, special emphasis is placed on ecotoxicological studies, which aim to analyze the chemical, microbiological, and ecological parameters of thermal waters to assess their sustainable use and environmental impact. Over 700 thermal water deposits for balneological and industrial use have been identified in Georgia; however, only a few of them have been thoroughly studied and practically utilized. Experts report that over 250 natural and artificially drilled springs are known today, with water temperatures ranging from 30°C to 109°C, and the total debit is approximately 160,000 m³ per day and night. Most are located in western Georgia [4,5]. The country's thermal waters stand out for their diversity: they include both low- and high-mineralized types, each suited to different needs. In Georgia, thermal waters are viewed as an inexpensive and nearly limitless energy source. Most of them are characterized by medicinal properties, high temperature, relatively low mineralization, and high content of chemical elements. From a commercial and ecological perspective, thermal waters are regarded as one of the most accessible, environmentally safe, and stable energy resources, which plays an essential role in the fight against climate change [2,3,6].

The Guria region covers the southern peripheral part of the Kolkheti Plain and the northwestern branches of the Meskheti Range. Its area is 2,042 km², constituting 2.9% of the country's territory. Administratively, the region includes the municipalities of Ozurgeti, Lanchkhuti, and Chokhatauri. Guria is abundant in surface water resources, featuring many small lakes and about 25 medium to small mountain rivers. Forest ecosystems cover 48% of the territory. The climate is subtropical and is characterized by altitudinal zonation [10].

Guria is rich in mineral and thermal waters, known for their healthful properties, although many are currently neglected and need infrastructure improvements and cleaning. The full potential of these waters remains untapped for drinking, medicinal, and industrial uses. Along the banks of the Supsa River, in lowland and hilly areas, as well as in forest groves, there are several springs containing hydrogen sulfide suitable for both bathing and drinking [1].

The actuality of the work lies in the fact that the Guria region has substantial thermal water resources, most of which are minimally or not at all utilized. A significant problem is that a comprehensive study of the ecotoxicological indicators of groundwater has not been carried out in the region, considering their ecological assessment and pollution risks. This is a necessary prerequisite for evaluating the potential of water resources and ensuring their rational and effective use.

Based on this, the study aimed to perform a comprehensive ecotoxicological assessment of certain thermal waters in the Guria region, evaluate their potential, and identify promising directions for their usage. Two locations were chosen as research targets: Khajalia thermal water in Lanchkhuti municipality and Dzimiti thermal water in Ozurgeti municipality, along with the cenotic structure of their surrounding landscapes. There has been no comprehensive assessment of ecotoxicological indicators for these waters so far, which highlights the significance and accuracy of the presented study.

II. Research materials and methodology

The prerequisite for conducting the research was processing literary sources and searching for scarce theoretical materials on geothermal waters. During the information review, it was found that a comprehensive study of the organoleptic, physicochemical, and microbiological indicators, elemental composition, assessment of the sanitary-microbiological state at the current stage, determination of the content of associated gases in the waters, evaluation of the water use prospects, and consideration of pollution risks have not been performed on the Khajalia and Dzimiti study waters.

To conduct a comprehensive study, field scientific expeditions were planned in the Lanchkhuti and Ozurgeti municipalities of the Guria region. These included a reconnaissance study of the surrounding areas to gather background information on vegetation [23,25]. Field measurements were taken on the Khajalia and Dzimi thermal waters, and samples were collected for further analysis [8]. Additionally, the organoleptic characteristics of the waters were also evaluated [17], along with the measurement of several parameters: temperature, air pressure, pH, electrical conductivity, and salinity [7].

The main analyses were performed at the laboratories of Analytical Chemistry and Plasma Atomic Emission Spectrometry at Batumi Shota Rustaveli State University. Methods widely accepted in hydrochemical practice were used for analysis: active acidity (pH) was measured with a portable device - Cloud Prime Portable pH Test Meter with 0.01 precision - pH-009(I)A [16]; mercurimetric and acidimetric methods were used for the determination of chloride and hydrocarbonate ions [18, 19]. The calcium and magnesium content, along with the total water hardness in samples, was measured using the complexometric method [12]. The concentration of fluorides and hydrogen sulfide, as well as biogenic (diluting) compounds (NH4+, NO3-, NO2-, PO43-, SO42- ions), were determined using photometric methods on an ultraviolet spectrometer [13, 20, 11]; the concentration of macro- and microelements was measured by plasma atomic emission spectrometry ICPE-9820 [24].

Sanitary and bacteriological analysis of water measured the number of saprophytic microorganisms and lactose-positive Escherichia coli bacteria using the titration method [21]. The hydrocarbon content in thermal waters was determined using gas chromatography; the analysis was performed on a Thermo Focus GC gas chromatograph (with an aluminum ionization detector, Column DH-100, 0.25mm, 0.25µm, 0.5 µm). The stationary phase was methylsiloxane, and the chromatography was conducted in pressure mode at 345 kPa. The mobile phase was helium, and the injector temperature was 250°C [9]. Determination of gases accompanying water was carried out in field conditions using a Portable 6-in-1 Gas Detector [14]. Temperature, electrical conductivity, and salinity were measured in the field with a HI 98194 pH/EC/DO Multiparameter device [22]. Mapping of locations was performed using geographic information systems (GIS**)** [15].

III. Results and Discussion

Structural Features of Cenotypes of Landscapes Surrounding the Study Sites. The aim of the study conducted in the Ozurgeti and Chokhatauri Municipalities of the Guria Region is to assess the ecological conditions of the landscapes surrounding the study sites, including the analysis of structural features of vegetation, cenotypes, anthropogenic impacts, and conservation needs.

The landscapes around the thermal springs of Khajalia village (Lanchkhuti Municipality) are dominated by human agricultural activities, including farming plots, vegetable gardens, and small settlements. These activities influence the structure of the vegetation layer, grass coverage, and soil stability (Fig. 1).

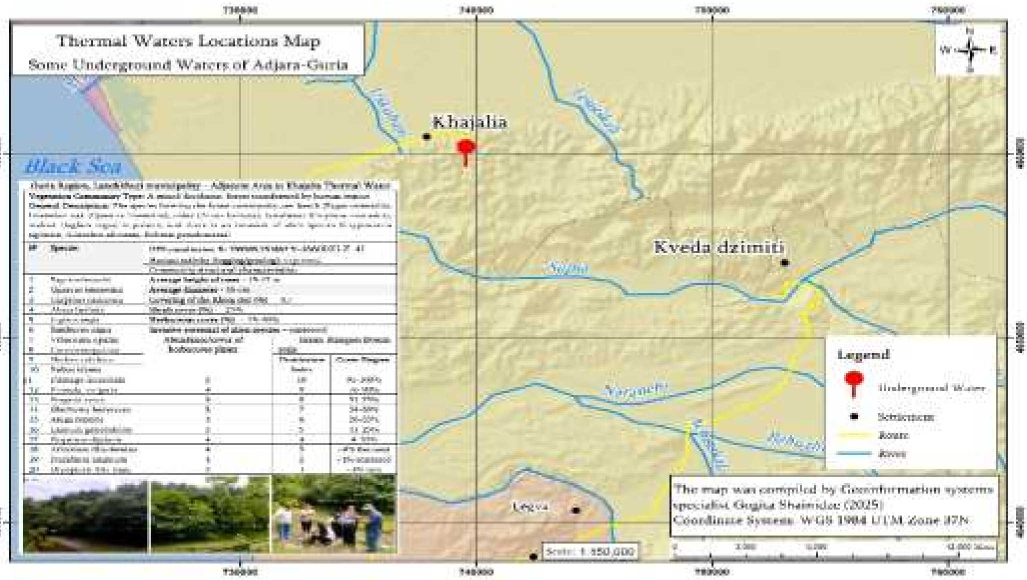


Figure 1: *Guria, Lanchkhuti Municipality, area near Khajalia thermal water.*

Local biodiversity is maintained, although there is a decrease in native species due to the impact of invasive plants and human activities. Presented cenotype: Mixed polydominant forest transformed by human impact - represents a plant community dominated by several tree species (Fagus orientalis, Quercus imeretina, Carpinus caucasica, Alnus barbata, Juglans regia), shrub species (Sambucus nigra, Viburnum opulus, Cornus sanguinea, Hedera colchica, Rubus idaeus), and herbaceous species (Plantago major, Primula magaseifolia, Paspalum digitaria, Athyrium filix-femina, Pteridium tauricum). Despite minor cutting and grazing, the structure of the cenotype is somewhat modified, especially regarding the tiers and sections of the herbaceous layer.

Secondary meadow communities around the Dzimiti thermal water in Ozurgeti municipality have developed due to intensive human activity (such as farming, grazing, and road development. They represent a modified natural grasslands). The meadow ecosystems are primarily made up of Cultural-agrarian and synanthropic vegetation (including Lolium perenne, Festuca pratensis, Dactylis glomerata, Trifolium repens, and Medicago sativa). The community (phytocoenosis) includes native species with moderate coverage (Plantago lanceolata, Achillea millefolium, Taraxacum officinale). The herbaceous cover ranges from 60% to 80%. The dominant species are Lolium perenne, Trifolium repens, and Dactylis glomerata. No layer differentiation is observed. Intense invasive pressure is observed, with Solidago canadensis and Ambrosia artemisiifolia actively spreading, occupying vacant niches, and reducing the distribution of native species (Table 2).

Figure 2: *Guria region, Ozurgeti municipality, area surrounding Dzimiti thermal water.*

Ecological-conservation features are manifested in: high anthropogenic transformation (roads, agrocenoses, grazing); spread of invasive species (remains one of the main threats); tendency to reduce biodiversity (degradation of local vegetation cover). The tendency to reduce biodiversity is manifested in the degradation of local vegetation cover.

Field measurements. As a result of field measurements at the study locations, it was found that the waters of Khajalia and Dzimi are transparent, colorless, and have a distinct hydrogen sulfide odor. The water in Dzimiti is highly brackish, and gas bubbles are actively observed on the water surface at both locations (Table 1).

Table 1: *Organoleptic features of Guria thermal waters*

Indicator	Location	Characteristic
Colour	Khajalia	Colorless liquid
	Dzimiti	Colorless liquid
Smell	Khajalia	Specific, pungent odor characteristic of isooctane, faint odor characteristic of hydrogen sulfide
	Dzimiti	Weakly pronounced odor characteristic of

		hydrogen sulfide
Taste	Khajalia	Weakly pronounced taste characteristic of hydrogen sulfide
	Dzimiti	Strong salty taste
Appearance	Khajalia	Gas bubbles are actively observed on the surface.
	Dzimiti	Gas bubbles are actively observed on the surface.
Transparency	Khajalia	Transparency
	Dzimiti	Transparency

The water at Dzimiti is warm (26.40°C), while at Khajalia it is cool (17.0°C). Khajalia's thermal water is moderately alkaline (pH 8.5), whereas Dzimiti's is weakly alkaline (pH 7.92). Based on electrical conductivity, Dzimiti's salinity is high, measuring 1290 mg/l (Table 2).

Table 2: *Assessment of physicochemical characteristics of Guria thermal waters in field conditions*

Location	**Physical and chemical parameters**				
	Temperature, °C	**Air pressure, mbar**	**pH**	**Electrical conductivity µS/Sm**	**Salinity, mg/L**
Khajalia	17.0 (cool)	1021.5	8.5 Medium alkali	715	356
Dzimiti	26.40 (warm)	1019	7.92 Weak alkali	25910	12990

The gases accompanying thermal waters are mainly methane, with a concentration exceeding 50% (by volume) at both locations. The CO2 content ranges from 136% to 143%, and the waters do not contain CO. The oxygen concentration in the gases accompanying Khajalia water is 1.78 times higher, and the hydrogen concentration is 2.5 times higher compared to similar measurements in Dzimiti water. A specific component in both waters is hydrogen sulfide, but this parameter is much higher in the gases accompanying Dzimiti water compared to Khajalia water.

Table 3: *Gas concentrations in Guria thermal waters under field conditions*

Location	**Concentration of gases accompanying water, mg/l**					
	O_2 Vol %	**CO_2 mg/L**	**CH_4 Vol %**	**H_2 mg/L**	**CO mg/L**	**H_2S mg/L**
Khajalia	3.20	143	>50	7.0	–	0.3
Dzimiti	1.8	136	>50	2.8	–	3.1

Ionic, multielemental, and bacteriological analysis of waters. Dzimiti thermal water is very hard (49.0 mEq/L), with a high concentration of Ca^{2+} (1080 mg/L) and HCO_3^- ions (445.3 mg/L). Khajalia water is not hard (see Table 4). The Cl^- ion concentration in Dzimiti water is 2.18 times higher, making it significantly more saline than Khajalia water. Notably, the concentration of NH4+ and NO2- ions in the waters at both locations exceeds the maximum permissible concentration, which indicates the lack of sanitary protection zones around the thermal waters, making them vulnerable to the risk of pollution and its high degree. These risks are even more serious when we consider that nitrite ions are both intermediate products of conversion to nitrates (due to their oxidation) and have the ability to be transformed in the human body into nitro compounds, most of which have carcinogenic, mutagenic, and teratogenic effects. PO43- and F- ions were also detected in the waters, although their content did not exceed the Maximum permissible concentration (MPC). A specific component of the thermal water at both locations is hydrogen sulfide. The thermal water at Dzimiti is likely to have a chloride-calcium-sodium ionic composition, while the water at Khajalia is chloride-sodium. The thermal water at Khajalia is not mineral, whereas the thermal water at Dzimiti is mineral thermal (temperature: 26.40°C, mineralization: 1557.9 mg/l).

The multielement analysis of the waters showed the following order of macroelement concentrations: at the Dzimi location - Na>Ca>K>Mg>P; at the Khajalia location - Na>Ca>P>K>Mg (Table 6). The waters studied do not belong to the iron and silicon types because they have low contents of these elements.

Among microelements, the boron content in Dzimiti water is significantly higher than the maximum permissible concentration (>6.25 mg/l, LDQ - 0.5 mg/l) (Table 7). No heavy metals—Cd, Pb, V, Be, Ti, Sb, Hg—and microelements—Cu, Co, Cr, Mo, Ni, Zn, Se—were detected in the water. The content and concentrations of Mn, Li, Ba, and As do not exceed the MPC (Table 8).

Table 5: *Ionic Composition of Guria's Thermal Waters*

Parameter, dimension	Location		Norm
	Khajalia	Dzimiti	
HCO_3^-, mg/L	61.0	445.3	**400**
Hardness, mg/eq/l	0.25	49.0	**7-10**
Ca^{2+}, mg/L	2.82	1080.0	**140**
Mg^{2+}, mg/L	0.9	69.0	**85**
Cl^-, mg/L	4420.0	9615.0	**250**
NaCl, mg/L	7293.0	15864.8	
NH_4^+, mg/L	2.22	6.0	**2.0**
NO_2^-, mg/L	1.29	0.68	**0.2**
PO_4^{3-}, mg/L	2.78	0.038	**3.5**
F^-, mg/L	0.269	0.49	**0.7**
SO_4^{2-}, mg/L	–	–	**250**
H_2S, mg/L	2.9	23.1	**0.03**
Dry residue, mg/l (mineralization)	291.14	1557.9	**1000**

Table 6: *Macroelements, mg/l*

Location	K	Ca	Mg	Na	P
Dzimiti	274	1080.0	69.0	2790	0.062
Khajalia	0.952	2.82	0.9	234	1.743
Maximum permissible concentration (mpc)	**20.0**	**140**	**85**	**200**	**3.5**

Table 7: *Microelements, mg/l*

Location	Fe	Si	B	Al	Mn
Dzimiti	0.0114	4.23	6.25 H	0.0009	0.001
Khajalia	0.0205	4.94	0.23	0.0042	0.0015
Maximum permissible concentration (mpc)	***0.3***	***10***	***0.5***	***0.5***	***0.05-0.1***

Table 8: *Ultramicroelements, mg/l*

Location	As	Li	Ba
Dzimiti	–	0.0145	0.0036
Khajalia	0.0392	0.0228	0.0018
MPC	***0.05***	***<0.03***	***0.1***

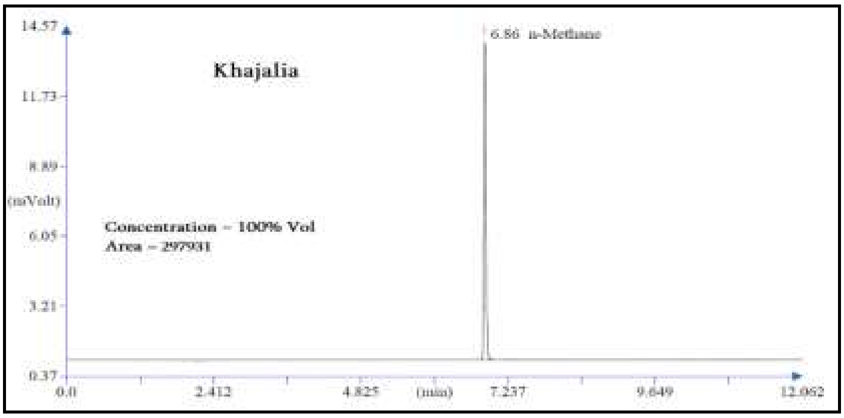
By determining the concentration of fecal contamination in the studied waters, it was found that the total number of saprophytic microorganisms in Khajalia water was 70/1 ml, and in Dzimiti water, it was 50/1 ml (Table 9). The total number of Escherichia coli bacteria in Khajalia water was 140/1 ml, and in Dzimiti water it was 75/1 ml.

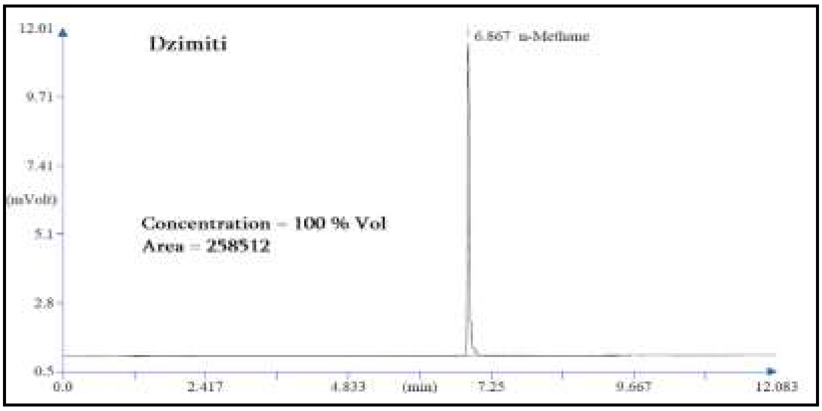
Although the indicators at the mentioned locations were within the standard (<300/1l), this circumstance once again indicates the possibility of an increase in the risk of bacteriological contamination of thermal waters if the boundaries of sanitary protection zones adjacent to the waters are not established, which would make it possible to protect them from the polluting influence of anthropogenic factors outside the boundaries.

Hydrocarbon composition of the gases accompanying the Guria thermal waters. In the gases surrounding the water samples taken at both locations, 100% of the hydrocarbon content was recorded as methane. However, comparing the peak areas, it can be seen that the methane concentration in the gases accompanying the Khajalia water is higher (297931 mVolt*min), which is due to the lower amount of other gases in it compared to the Dzimiti water.

Table 9: *Sanitary-bacteriological indicators of Guria thermal waters*

Parameter, dimension	Location		Norm
	Khajalia	Dzimiti	
Total number of saprophytic microorganisms, units/1ml	70	50	No more than 100/1mL
The number of bacteria of the lactose-positive coli group (Coli index), units / 1l	140	75	No **more** than 300/1L





IV. Conclusion

- The thermal waters of Khajalia and Dzimiti have significant potential; their quality indicators are mainly positive and contribute to both medicinal and energy use.
- Infrastructural and technological limitations hinder the efficient use of the resource, while the idle flow of water causes thermal and ecological pollution of the surrounding area.
- A high risk of anthropogenic impact characterizes thermal waters due to the lack of sanitary protection zones and headwater facilities.
- Using thermal energy as a renewable and environmentally friendly resource is vital for strengthening Georgia's energy security and represents an important direction of sustainable development.

Acknowledgements. The research received financial support from Batumi Shota Rustaveli State University under the Targeted Grant. Agreement No. 01-50/157, dated March 26, 2024.

CONFLICT OF INTEREST.

Authors declare that they do not have any conflict of interest.

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