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GEOECOLOGICAL ASSESSMENT OF HYDROMINERAL RECREATIONAL RESOURCES OF ZHALANASHKOL LAKE

Abstract. *This study focuses on the geoecological assessment of hydromineral resources of saline lakes in arid regions under increasing recreational pressure and the growing demand for health and wellness tourism. Zhalanashkol Lake, located in the Zhetysu region of Kazakhstan, was selected as the study area due to the presence of mineral waters and therapeutic muds with potential balneological value.*

The aim of the research was to provide a comprehensive geoecological evaluation of lake water, bottom sediments, mineral springs, and therapeutic mud to justify their rational and environmentally safe use for recreational and medical purposes. Field sampling, laboratory physicochemical, microbiological and radiological analyses, as well as comparative geographical and statistical data processing methods were applied.

The results revealed spatial differentiation in the chemical composition between the western and eastern parts of the lake. However, concentrations of macro- and trace elements were below maximum permissible limits. Microbiological and radiological parameters met sanitary safety standards. Therapeutic mud and mineral water showed low levels of potentially toxic elements and demonstrated characteristics favorable for balneological use.

The work contributes to the development of the methodology for geo-ecological assessment of hydro-mineral resources in lake systems and expands scientific knowledge about the recreational potential of water bodies in South-Eastern Kazakhstan. The practical significance of the results lies in their use for environmental monitoring, planning of recreational nature management, and the development of medical and health tourism.

Keywords: *Zhalanashkol Lake, recreation, mineral water, therapeutic mud (peloid), hydromineral resources, heavy metals, radioactive contamination, tourism.*

Introduction

Under conditions of rapid growth in tourism and recreational activities and the increasing

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anthropogenic pressure on traditional leisure areas, the geoecologically grounded assessment of hydromineral recreational resources is becoming particularly important. For regions with arid and semi-arid natural conditions, such as the Alakol inter-mountain depression, water bodies with balneological properties are a strategically important natural tourist resource. Zhalanashkol Lake, located in the north-eastern part of the Zhetysu Region, is characterised by highly mineralised waters, the presence of therapeutic mud (peloids), and fracture-controlled mineral springs, creating favourable conditions for the development of health-related recreation and tourism during the summer bathing season. At the same time, the overuse of recreational zones around Alakol Lake highlights the need to involve alternative, less developed water bodies in recreational use in order to redistribute tourist flows and reduce environmental pressure on vulnerable regional ecosystems.

Despite its considerable natural and recreational potential, the hydromineral resources of Zhalanashkol Lake remain insufficiently studied from a geoecological perspective. Existing research is fragmentary and mainly focused on the general hydrological and hydrochemical characteristics of the region, lacking a comprehensive assessment of the current ecological state of lake waters, bottom sediments, and therapeutic muds, particularly with respect to sanitary-hygienic and radiological parameters. The lack of systematic data limits the possibilities for scientifically based planning of recreational development of the territory and increases the risk of degradation of natural complexes in the event of spontaneous use of resources in the absence of a developed infrastructure for the development of medical and recreational tourism.

The purpose of this study is to provide a comprehensive geological and environmental assessment of the hydro-mineral recreational resources of Zhalanashkol Lake based on the analysis of the physical, chemical, microbiological, radiological, and balneological characteristics of the lake water, fissure mineral springs, and therapeutic muds, in order to justify their rational and environmentally friendly use for medical and recreational tourism.

To achieve this aim, the following objectives were addressed: analysis of the natural-geographical and hydrogeological conditions governing the formation of the lake's hydromineral resources; investigation of spatial differences in water chemistry between the western and eastern parts of the lake; assessment of sanitary-microbiological and radiological indicators of lake water; determination of the chemical composition and environmental safety of fracture mineral waters and therapeutic muds; identification of environmental risk factors associated with recreational pressure; and development of recommendations for the rational use and protection of the hydromineral resources of Zhalanashkol Lake.

The scientific novelty of this work lies in the acquisition of up-to-date, comprehensive data on the geoecological condition of Zhalanashkol Lake's hydromineral resources based on field and laboratory investigations conducted in 2025. A comparative assessment of the chemical composition of lake waters from the western and eastern sectors was performed for the first time, taking into account spatial heterogeneity in natural conditions. The sanitary and hygienic, microbiological, and radiological characteristics of lake waters, fissure mineral springs, and therapeutic muds have been clarified, which has made it possible to justify their suitability for medical and recreational tourism development. The results form a scientific basis for environmentally oriented recommendations aimed at integrating Zhalanashkol Lake into a framework of sustainable tourism and recreational development in the region.

From the perspective of tourism studies, the value of such assessment lies not only in describing the ecological state of the water body, but also in defining the environmental prerequisites for the

development of a safe and competitive health-tourism destination. For Zhalanashkol Lake, hydrochemical, sanitary-microbiological, radiological, and balneological indicators determine whether the area can be used for bathing, peloid procedures, short-term recreation, wellness routes, and future small-scale resort infrastructure [1; 2; 3; 4].

Materials and methods

The study area is Zhalanashkol Lake, a closed natural water body situated at an elevation of 368 m above sea level in the southern part of the Alakol intermountain basin. From an orographic perspective, the lake is bounded to the west by the Aksay Ridge (1,072 m) and the Belkain Ridge (2,040 m), which represent eastern spurs of the Zhetysu Alatau mountain system, and to the east by the Katu Mountains (915 m) and the Birliktau Range (3,242 m).

The lake is primarily fed by groundwater, supplemented by temporary surface inflows, including the Terekty, Olenty, and Kusak rivers, which enter the basin during the spring flood period. The north-western, southern, and south-eastern sections of the shoreline are characterised by marshy conditions and silty bottom sediments due to the shallow depth of the groundwater table. The geographical position of the lake is defined by the coordinates of its extreme points: northern point – 45°36′19″ N, 82°09′32″ E; southern point – 45°31′57″ N, 82°12′11″ E; western point – 45°34′43″ N, 81°20′24″ E; eastern point – 45°32′58″ N, 82°12′46″ E. The lake covers an area of 37.55 km², with a length of 9 km, a width of 5.5 km, and a shoreline length of 23.8 km. The water volume is estimated at 0.098 km³. The mean depth is 2.2 m, while the maximum depth of 3.4 m occurs in the north-western sector of the basin (Fig. 1).

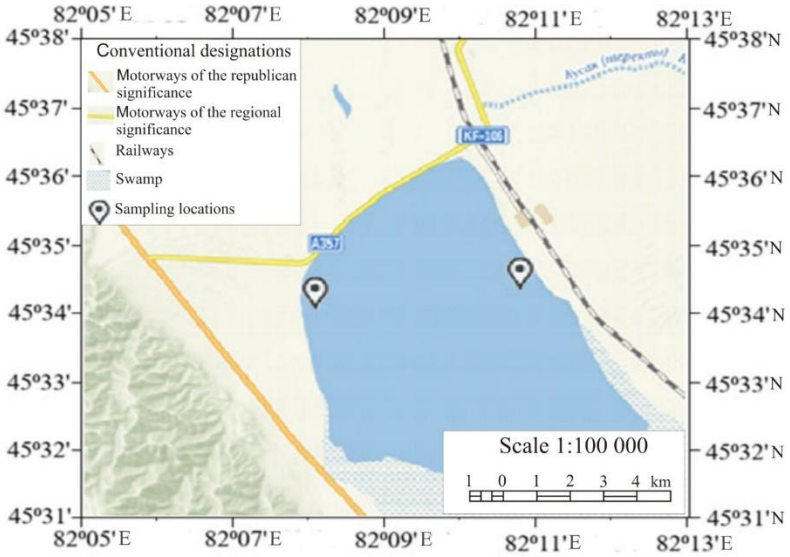

Figure 1 – Satellite images of the Zhalanakol Lake area

Note: compiled by the authors based on th satellite image

The research was designed as an integrated field and laboratory-based investigation aimed at the geoecological assessment of the quality of surface waters, bottom sediments, and therapeutic muds of Zhalanashkol Lake in terms of their suitability for recreational use. Fieldwork was conducted between May and October 2025. In total, 30 samples of water, bottom sediments, and therapeutic mud were collected from the western and eastern sectors of the lake. Sampling was performed at

distances of 3–5 m from the shoreline, as well as in areas influenced by fracture-controlled mineral groundwater discharge and within the therapeutic mud deposits along the eastern shore. The selection of sampling locations was determined by the need to represent diverse natural conditions, variations in hydrological regime, differences in shoreline characteristics, and the degree of potential anthropogenic impact.

Water sampling and analysis were carried out in accordance with widely accepted hydrochemical methodologies and current regulatory standards. Determination of the physicochemical parameters of water was performed in compliance with GOST 26449.1-85, ST RK 1983-2010, ST RK 1963-2010, and ST RK 1015-2000. The concentration of petroleum hydrocarbons was measured following ST RK GOST R 51797-2005, while surface-active substances were analysed according to ST RK 1983-2010. Heavy metal concentrations in water samples were determined using the standards GOST 26931-86, GOST 26932-86, GOST 26933-86, and GOST 26934-86, ensuring comparability of the results with established sanitary and hygienic threshold values.

Bottom sediments and therapeutic muds were analysed using a complex of laboratory techniques. The content of heavy and trace metals was determined using a JEOL JSM-IT200 scanning electron microscope (Japan) coupled with an energy-dispersive spectrometer, which enabled identification of elemental composition and spatial distribution of microelements within the samples. Levels of radioactive contamination in water and bottom sediments were assessed using X-ray diffraction analysis, a method commonly applied in evaluating the environmental safety of hydromineral resources.

Laboratory analyses were conducted at the accredited facilities of the JSC “Department of Sanitary and Epidemiological Control of the Zhetysu Region” (Taldykorgan), based on official analytical protocols No. 1540/1 dated 5 August 2022, No. 1541/1 dated 5 August 2022, and No. 940/1 dated 24 July 2023. The involvement of an accredited laboratory ensured the reliability and reproducibility of the analytical results.

To assess spatial differences, the following statistical approaches were applied: calculation of mean values and standard deviation; coefficient of variation (%); coefficient of spatial variability between the western and eastern parts of the lake; and comparison with regulatory threshold values (maximum permissible concentrations). Data processing was performed using Microsoft Excel with built-in statistical functions.

The applied methodology, based on a combination of field observations, standardized laboratory analyses, spectral and microscopic methods, as well as comprehensive statistical processing, provides a comprehensive geological assessment of the hydro-mineral recreational resources of Zhalanashkol Lake and allows for a reasonable assessment of their suitability for recreational and therapeutic tourism.

To strengthen the connection between geoecological assessment and tourism planning, the laboratory indicators were additionally interpreted as criteria of recreational suitability. The assessment considered four tourism-oriented groups of parameters: sanitary safety of bathing water; chemical and radiological safety of mineral waters and peloids; balneological value of mineral components; and environmental constraints that should be considered in shoreline zoning, visitor-flow management, and infrastructure placement [5; 6; 7].

Literature review

The study of hydromineral resources and the balneological properties of lake systems has a long-standing scientific tradition rooted in hydrology, hydrochemistry, and the geochemistry of inland waters. Fundamental concepts regarding the formation of mineralisation, ionic composition,

and salinity regimes of lakes are linked to the influence of climate, water exchange, evaporative processes, and the geochemistry of drainage basins [8]. These principles have been further developed in international research, where the chemical composition of lake waters is interpreted as the outcome of complex interactions among catchment landscapes, biogeochemical cycles, and climatic factors, highlighting the interdisciplinary nature of these processes [9].

Over time, scientific interest has shifted from purely descriptive hydrochemical analyses towards the assessment of the ecological status of water bodies and the evaluation of their suitability for recreational and balneological use. In this context, integrated water quality indices and ecological assessment methodologies have been developed to characterise the condition of aquatic ecosystems [10].

A parallel line of research has focused on natural peloids. Contemporary reviews consider therapeutic muds in terms of their mineralogical, organic, and physicochemical composition, which forms the basis for evaluating their preventive and therapeutic potential [11].

Hydrochemical characteristics of mineral lake waters and therapeutic muds of saline lakes in Kazakhstan have been examined at the regional level. Studies of salt lakes in Western Kazakhstan have demonstrated that, in certain cases, the physicochemical parameters and organoleptic properties of peloids meet the criteria for their use in recreation and medical tourism [12]. Comprehensive geoecological reviews emphasise the need for a spatially differentiated approach to the assessment of hydromineral resources, taking into account local natural conditions controlling the formation of waters and bottom sediments [13].

For Kazakhstan and adjacent regions of Central Asia, significant attention has been devoted to the influence of natural–climatic factors and anthropogenic pressure on the chemical composition of lake ecosystems [14, 15, 16]. Particular importance is attributed to research on the Alakol lake system, where patterns of mineralisation formation, the role of groundwater inflow, and the influence of climatic conditions on the hydrochemical regime have been identified [17].

Investigations of groundwater mineral resources in the Alakol intermountain basin have also revealed considerable diversity in chemical composition and a potential for therapeutic use [18]. However, most of these studies focus on individual springs and do not provide a comprehensive assessment of lake systems as recreational resources.

Modern methodological approaches to the geoecological assessment of water bodies increasingly rely on GIS technologies and spatial analysis, enabling researchers to account for environmental heterogeneity and to identify areas of increased ecological vulnerability [19, 20]. The application of geoinformation methods therefore contributes to more scientifically grounded planning of recreational use of natural resources.

Therapeutic muds are regarded as a key component of hydromineral recreational systems. International studies provide detailed descriptions of their chemical, mineralogical, and microbiological composition, as well as the mechanisms underlying their therapeutic effects on the human body [21, 22].

Within the geoecological assessment of recreational water bodies, particular attention is paid to the quality of surface waters in areas of intensive tourism. An example is the study of Alakol Lake, where the influence of recreational activities on the hydrochemical state of the lake and the spatial structure of pollutants was analysed [23]. However, this research does not address the hydromineral resources of Zhalanashkol Lake.

The balneological potential of Kazakhstan’s saline lakes has also been examined in studies devoted to the development of medical tourism based on natural therapeutic factors [24]. Nevertheless, the geographical remoteness of the investigated sites limits the direct transferability of

these findings to the conditions of Zhalanashkol Lake. Similar limitations apply to studies concerning resort development at other saline lakes in south-eastern Kazakhstan.

Thus, a review of the scientific literature indicates that, despite the substantial body of research on the hydrochemistry of saline lakes, mineral waters, and therapeutic muds, comprehensive geoecological investigations specifically focused on Zhalanashkol Lake as a hydromineral recreational resource are virtually absent. This gap underscores the scientific novelty and relevance of conducting an integrated assessment of its waters, bottom sediments, mineral springs, and peloids from the perspective of modern geoecology and sustainable recreational environmental management.

In tourism research, natural medical resources are regarded as part of the destination resource base when they can be used under scientifically controlled safety conditions. Health and medical tourism studies emphasize that the attractiveness of such destinations depends not only on the existence of therapeutic factors, but also on evidence-based quality control, risk reduction, accessibility, and the management of visitor pressure [1; 25]. The tourist area life-cycle concept also shows that destinations based on natural resources require early regulation before spontaneous growth leads to environmental degradation [2].

Studies on tourism and the environment further demonstrate that recreational development should be assessed through the interaction between tourist demand, ecosystem vulnerability, infrastructure capacity, and monitoring systems [3; 4]. For lake-based recreation, bathing-water quality and microbiological control are essential prerequisites for safe visitor use [5], while the evaluation of peloids requires attention to physicochemical properties, microbiological safety, and suitability for controlled therapeutic procedures [6; 7].

Results and discussions

A comprehensive geoecological assessment of the hydromineral resources of Zhalanashkol Lake was carried out, including the analysis of lake water, bottom sediments, mineral spring water, and therapeutic muds (Table 1). The obtained data made it possible to identify spatial differences in chemical composition, evaluate sanitary–microbiological and radiological safety, and determine the recreational suitability of the investigated components.

Table 1 – Chemical composition of Zhalanashkol Lake water

Chemical substances	Concentration, mg/dm³			Difference, %
	Regulatory limit (MPC)	Western part	Eastern part	
1	2	3	4	5
Cations				
B	0.5	0.0081	0.051	<37.03
Ca	130	0.01997	0.0348	>42.61
Si	0.02	0.00274	0.00074	<72.99
Mg	40	9.26	18.81	>50.77
K	20	7.84	3.22	<58.92
Cu	1.0	0.006	0.037	>83.78
Pb	0.06	0.001	0.005	>80
Zn	1.0	0.04	0.44	>9.09

Table 1 (continued)

Continuation of Table 1

Cr	0.05	0.002	0.038	>94.73
Cd	0.001	0.0002	0.0003	>33.3
Mn	0.1	0.05	0.041	<18
Li	0.1	0.003	0.017	<82.35
Sb	0.05	0.005	0.029	>82.75
Ba	0.1	0.003	0.035	<85.71
Sr	7.0	1.28	1.41	>76.81
Bi	0.1	0.005	0.035	>9.21
Co	0.1	0.004	0.021	>80.95
Na	200	11.37	19.47	>41.60
Se	0.01	0.006	0.004	<33.33
Ni	0.1	0.007	0.027	>74.07
As	0.05	-	-	
Al	0.5	0.008	0.037	>78.37
Mo	0.25	0.004	0.015	>73.33
Anions				
Chlorides	350	34.9	27.7	<20.63
Sulphates	2.0	0.05	0.4	>87.5
Ammonia	3.3	0.038	1.3	97.07
Nitrites	45.0	0.9	0.3	<66.66
Nitrates	45.0	2.9	1.43	<50.68
COD	15-30	18.3	17	<7.1
Total dissolved solids	1000	410	305	<25.6
pH		8.1	8.4	
Total mineralization	350,000	312,000	310,000	
Note: compiled by the authors				

Analysis of 30 water samples demonstrated statistically significant hydrochemical differences between the western and eastern parts of the lake. To quantify these differences, a coefficient of spatial variation (K_v, %) was calculated between the two sectors (Table 2).

Table 2 – Spatial variability (K_v) and proportion of maximum permissible concentrations (MPC) for key hydrochemical parameters of Zhalanashkol Lake

Parameter	Western sector (mg/dm³)	Eastern sector (mg/dm³)	K_v, %	% of MPC (max)
Mg	9.26	18.81	67.9	47.0
Na	11.37	19.47	52.4	9.7
K	7.84	3.22	83.5	39.2
Ca	0.019	0.035	57.3	<1
Cl^-	34.9	27.7	23.0	10.0

Table 2 (continued)

Continuation of Table 2

SO_4^{2-}	0.05	0.4	155.5	20.0
NO_2^-	0.9	0.3	100.0	2.0
NO_3^-	2.9	1.43	67.2	6.4
Dry residue	410	305	29.3	41.0
Note: compiled by the authors				

The highest spatial variability was observed for sulphates, potassium, nitrites, and magnesium. The eastern sector of the lake was statistically characterised by higher concentrations of Mg and Na, whereas the western sector showed elevated levels of K, nitrites, chlorides, and total dissolved solids.

Despite these differences, concentrations of all analysed elements remained below maximum permissible concentrations (MPCs), with measured values ranging from 0.5% to 47% of regulatory thresholds, indicating a favourable hydrochemical status of the lake. The difference in overall mineralisation between the two sectors was less than 1% and therefore statistically insignificant. However, variations in ionic composition result in local hydrochemical features that may influence the balneological properties of the water.

Bacteriological indicators were found to be less than half of the allowable limits (Table 3). No pathogenic microflora, helminth eggs, or thermophilic bacteria were detected, confirming the sanitary safety of the water.

Table 3 –- Bacteriological analysis results for Zhalanashkol Lake water

Indicator	Measured value	Regulatory limit (MPC)	% of MPC
Lactose-positive bacteria	2,200 CFU/L	5,000 CFU/L	44
Coliphages	Not detected	1,000 PFU/L	0
Note: compiled by the authors			

The specific activities of alpha- and beta-emitting radionuclides in all samples were 3–5 times lower than regulatory limits (Fig. 2). No radioactive contamination was identified, eliminating radiological risk during recreational use.

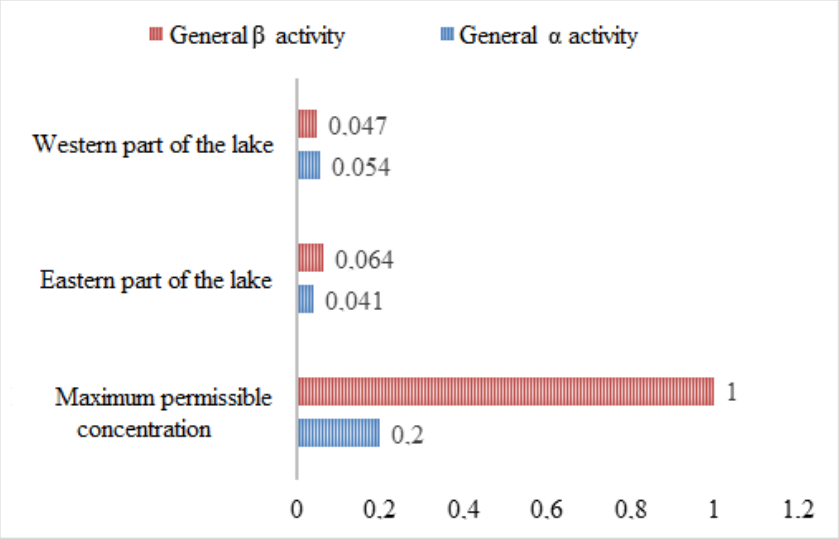

Figure 2 – Indicators of radioactive activity of the waters of Zhalanashkol Lake

Note: compiled by the authors

The mineral spring water belongs to the category of slightly mineralised calcium–sodium hydrocarbonate–sulphate waters. All trace elements were present at concentrations not exceeding 35% of MPCs. Nitrogen-containing compounds were detected only at trace levels, indicating the absence of anthropogenic pollution.

Heavy metal concentrations in the peloids were 2–10 times lower than permissible levels. The muds are characterised by elevated contents of biologically significant macroelements (Ca, Mg, Fe, K), confirming their potential balneological value.

The study provided an integrated geoecological evaluation of the hydromineral recreational resources of Zhalanashkol Lake, including lake water, bottom sediments, mineral springs, and therapeutic muds. The principal objective was to determine their suitability for recreational and therapeutic use and to identify spatial differences in chemical and microbiological composition.

The most significant findings relate to differences between the western and eastern parts of the lake in terms of chemical composition and mineralisation. The western sector exhibited higher mineralisation and increased concentrations of B, Si, K, Mn, Se, chlorides, nitrites, and total dissolved solids, while the eastern sector showed higher magnesium levels, contributing to a more alkaline environment. These differences are consistent with the spatial distribution of hydrological and geoecological conditions and underline the importance of considering sampling location when assessing recreational potential.

Comparison with previous studies indicates that concentrations of metals and chemical constituents comply with regulatory standards [23; 24], confirming the safety of water and therapeutic mud for use during the summer bathing season. Radiological and bacteriological analyses further support the suitability of these resources for recreational use, which is particularly important for the heavily visited northern and eastern shorelines.

However, areas of concern were identified: sections of the western shoreline and zones subjected to intensive recreational pressure are affected by domestic waste pollution. This highlights the need for the implementation of environmental monitoring systems and management measures aimed at reducing anthropogenic impact. The lack of comprehensive data on spatial differences in bottom sediments and therapeutic muds also indicates the necessity for further research employing GIS-based approaches and long-term monitoring.

Thus, the obtained results confirm the suitability of the hydro-mineral resources of Zhalanashkol Lake for recreational purposes and the development of medical and health tourism. The key ecological and geo-ecological features of the reservoir have been identified, indicating the need for monitoring and management measures to preserve the recreational potential.

From a tourism-development perspective, the obtained hydrochemical and sanitary results indicate that Zhalanashkol Lake may be considered as a potential site for controlled health-related recreation rather than mass unregulated beach tourism. The low concentrations of toxic elements, absence of pathogenic microflora, and safe radiological background form the basic environmental conditions for bathing and wellness use; at the same time, the spatial variability of the chemical composition requires differentiated management of the western and eastern shoreline sectors [2; 3; 5].

The presence of therapeutic muds with low concentrations of potentially toxic elements strengthens the balneological value of the lake, but their use in tourism should be organised through regulated extraction zones, hygienic control, seasonal monitoring, and restrictions on uncontrolled self-treatment areas [6; 7].

Conclusion

The present study has provided, at the current stage of research, a comprehensive understanding of the geoecological condition of the hydromineral recreational resources of Zhalanashkol Lake and an assessment of their suitability for health-related use. The main goal was to determine the suitability of the studied object for the development of recreational and medical tourism, as well as to identify spatial differences in the chemical and microbiological composition.

The results obtained support this hypothesis. It was established that the chemical composition of water in the western and eastern parts of the lake exhibits pronounced spatial differentiation; however, concentrations of the analysed macro- and microelements do not exceed maximum permissible levels. Bacteriological and parasitological indicators comply with sanitary standards, and no pathogenic microflora were detected. Radiological characteristics indicate the absence of technogenic radioactive contamination. Analysis of bottom sediments and therapeutic muds revealed low concentrations of toxic elements alongside adequate levels of biologically significant and physiologically important components, confirming their potential balneological value. The mineral water from the natural spring also meets regulatory requirements and may be considered a promising resource for therapeutic and preventive use.

Thus, the study expands current scientific understanding of the geoecological characteristics of saline lakes in the arid territories of south-eastern Kazakhstan and supplements existing knowledge of the region's hydromineral resources with new, integrated data derived from field and laboratory investigations. From a scientific perspective, the work clarifies the role of spatial hydrochemical heterogeneity in shaping the recreational potential of lake systems and demonstrates the importance of integrating hydrochemical, sanitary-microbiological, and radiological indicators into a unified framework for geoecological assessment.

The practical significance of the findings lies in their applicability to planning the development of health and wellness tourism in the Zhalanashkol Lake area, designing functional zoning schemes for the shoreline, and substantiating measures for the protection of natural complexes. The results may also be incorporated into regional environmental monitoring programmes and utilised by environmental management and sanitary control authorities.

At the same time, the identification of localised areas of anthropogenic impact along the shoreline indicates the need to establish a system of regular environmental monitoring, regulate recreational pressure, and develop waste management infrastructure. Future research should focus on seasonal monitoring of water and peloid quality, expansion of the sampling network using GIS-based approaches, and investigation of microbiological dynamics during periods of peak recreational use.

Overall, the findings provide a scientifically grounded basis for the rational and environmentally safe utilisation of the hydromineral resources of Zhalanashkol Lake and contribute to the advancement of geoecological research on recreational aquatic systems.

Lakes experiencing recreational overloads are traditionally used for recreation. Alakol Lake, the largest and warmest lake in the Zhetysu and Abai regions, stands out in particular. It has good sandy and pebbly beaches and marine-type saltwater. Zhalanashkol Lake can help redistribute tourist flows and reduce the recreational load to preserve the natural and therapeutic potential of Alakol Lake.

In terms of tourism development, the results justify the inclusion of Zhalanashkol Lake in regional planning as a supplementary health and wellness tourism site within the Alakol recreational system. Its role should not be limited to expanding visitor numbers; rather, the lake may serve as a controlled balneological and recreational zone that helps diversify tourism products, reduce pressure on overloaded coastal areas of Alakol Lake, and support environmentally safe destination

development.

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ЖАЛАҢАШКӨЛ КӨЛІНІҢ ГИДРОМИНЕРАЛДЫ РЕКРЕАЦИЯЛЫҚ РЕСУРСТАРЫН ГЕОЭКОЛОГИЯЛЫҚ БАҒАЛАУ

Аңдатпа. *Зерттеу аридті аймақтардағы тұзды көлдердің гидроминералдық ресурстарын геоэкологиялық тұрғыдан бағалау мәселесіне арналған. Қазіргі уақытта емдік-сауықтыру туризмінің дамуы және табиғи нысандарға түсетін рекреациялық жүктеменің артуы жағдайында табиғи су айдындарының экологиялық қауіпсіздігін ғылыми негізде бағалау ерекше маңызға ие. Осы тұрғыда Жетісу облысындағы Жалаңашкөл көлінің гидроминералдық ресурстары кешенді зерттеу нысаны ретінде қарастырылды.*

Зерттеудің мақсаты - көл суының, шөгінділерінің, минералды бұлақтарының және емдік балшықтарының геоэкологиялық жағдайын анықтап, олардың емдік-сауықтыру рекреациясында қауіпсіз әрі ұтымды пайдаланылу мүмкіндігін ғылыми негіздеу. Зерттеу барысында далалық сынама алу, зертханалық физика-химиялық, микробиологиялық және радиологиялық талдау әдістері, сондай-ақ салыстырмалы-географиялық және статистикалық өңдеу тәсілдері қолданылды.

Нәтижесінде көлдің батыс және шығыс бөліктері арасында химиялық құрам бойынша

кеңістіктік айырмашылықтар анықталғанымен, барлық көрсеткіштердің санитарлық-гигиеналық нормативтерден аспайтыны дәлелденді. Су, минералды көздер және пелоидтар микробиологиялық және радиологиялық тұрғыдан қауіпсіз екені анықталды.

Зерттеу жұмысы тұзды көлдердің гидроминералдық ресурстарын бағалау әдістемесін толықтырып, аймақтық рекреациялық табиғат пайдалануды ғылыми негіздеуге үлес қосады. Алынған нәтижелер экологиялық мониторинг жүйесін қалыптастыруда, рекреациялық жүктемені реттеуде және Жаланашкөлді емдік-сауықтыру туризмі нысаны ретінде дамытуда практикалық маңызға ие.

Кілт сөздер: *Жаланашкөл, рекреация, минералды су, емдік балшық, гидроминералдық ресурс, ауыр металл, радиоактивті ластану, туризм.*

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ГЕОЭКОЛОГИЧЕСКАЯ ОЦЕНКА ГИДРОМИНЕРАЛЬНЫХ РЕКРЕАЦИОННЫХ РЕСУРСОВ ОЗЕРА ЖАЛАНАШКОЛЬ

Аннотация. *Геоэкологическая оценка гидроминеральных рекреационных ресурсов озера Жаланашколь является актуальной задачей ввиду растущего рекреационного и туристического освоения озёрных систем Казахстана и недостаточной изученности. Статья посвящена геоэкологической оценке гидроминеральных ресурсов солёных озёр аридных территорий в условиях роста рекреационной нагрузки и развития лечебно-оздоровительного туризма. В качестве объекта исследования рассмотрено озеро Жаланашколь (область Жетісу), обладающее минеральными водами и лечебными грязями, представляющими потенциальный бальнеологический интерес.*

Цель работы заключалась в комплексной оценке геоэкологического состояния озёрной воды, донных отложений, минеральных источников и лечебных грязей для обоснования возможности их рационального и экологически безопасного использования. В исследовании применялись полевые методы отбора проб, лабораторные физико-химические, микробиологические и радиологические анализы, а также сравнительно-географические и статистические методы обработки данных.

Полученные результаты показали наличие пространственной дифференциации химического состава воды западной и восточной частей озера, однако концентрации макро- и микроэлементов не превышают предельно допустимых значений. Микробиологические и радиологические показатели соответствуют санитарным нормативам. Лечебные грязи и минеральная вода характеризуются безопасным содержанием химических элементов и потенциальной терапевтической ценностью.

Работа вносит вклад в развитие методологии геоэкологической оценки гидроминеральных ресурсов озёрных систем и расширяет научные представления о рекреационном потенциале водоёмов Юго-Восточного Казахстана. Практическая значимость результатов связана с их использованием при экологическом мониторинге, планировании рекреационного природопользования и развитии лечебно-оздоровительного туризма.

Ключевые слова: *Жаланашколь, рекреация, минеральная вода, лечебная грязь, гидроминеральный ресурс, тяжелый металл, радиоактивное загрязнение, туризм.*