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PHYSICO-GEOGRAPHICAL ASSESSMENT OF THE NATURAL-TERRITORIAL COMPLEX OF LAKE PASHENO (CENTRAL KAZAKHSTAN) IN THE CONTEXT OF ITS GEOTOURISM POTENTIAL

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Abstract: This study examines the physico-geographical and geoecological characteristics of Pasheno Lake, located within the Karkaraly National Natural Park in Central Kazakhstan. As one of the region's key natural and recreational resources, the lake plays an important role in the sustainable development of local geotourism. The research aimed to evaluate the ecological condition and tourism potential of the area through an integrated analysis of geomorphological, hydrological, climatic, soil, and hydrochemical factors. Fieldwork and laboratory studies were conducted in 2024 using standard sampling and Atomic Absorption Spectrometry to identify concentrations of major ions and trace metals (Pb, Cd, Cu, Zn, Mn, Fe, Cr, Ni, As), along with pH and salinity levels. The Müller and Hakanson indices were applied to assess ecological risk. The climatic analysis (1991–2024) showed moderate warming trends typical of a temperate continental climate, while soil testing revealed alkaline conditions (pH = 10.039) favorable for recreation. Results indicate that the water quality of Pasheno Lake meets national safety standards, confirming its suitability for tourism and recreation. Based on Reynard's (2007) methodology, the lake demonstrates high scientific, aesthetic, and educational significance. The results provide a scientific basis for sustainable management and support the development of eco- and geotourism initiatives in Central Kazakhstan.

Keywords: Pasheno Lake, Karkaraly National Park, hydrochemical analysis, geotourism, sustainable development, Central Kazakhstan

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INTRODUCTION

Specially Protected Natural Areas (SPNAs) are significant territorial structures established with the aim of conserving natural resources, ensuring ecological balance, and protecting biological diversity (Kaizhakparova, 2020). According to the legislation of the Republic of Kazakhstan adopted in 2006, the definition of SPNAs is as follows: "a specially protected natural area is a land plot, water body, and the airspace above them that contains natural complexes and objects of the state nature reserve fund with a designated special protection regime." These areas are intended to preserve the integrity of natural systems, protect the habitats of rare and endangered species, and support scientific research, ecological education, and the development of sustainable tourism. In Kazakhstan, there are several types of specially protected natural areas: national parks, state nature reserves, state nature sanctuaries, natural monuments, reserve zones, and biosphere reserves. Currently, the country has 13 state reserves, 10 national parks, and several sanctuaries and other protected areas in operation (Makenova et al., 2019). Among them, the Korgalzhyn, Naurzum, and Barsakelmes reserves, as well as the Altyn-Emel, Kolsai Lakes, and Karkaraly national parks, are widely known.

SPNAs play a special role in ensuring Kazakhstan's environmental security, maintaining climate stability, and promoting the development of ecotourism (Tastanbekova, 2016). They serve as an important mechanism for passing on natural heritage to future generations and for fostering a culture of harmonious coexistence with nature. Recently, the growing demand for ecotourism and the development of infrastructure in national parks within SPNAs have further enhanced their ecological and touristic significance (Niyazbekova, 2019). In Kazakhstan, the ecotourism industry is a newly emerging sector in national parks. Although it has great potential, this field has not yet fully developed (Koshim et al., 2023). Compared to reserves, national parks have significantly greater tourism potential. This is primarily due to their functional features. While nature in reserves is fully protected and human interference is not allowed, national parks permit

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ecological tourism and scientific-educational activities. Such areas are equipped with designated eco-trails, tourist routes, observation platforms, and information centers. In addition to protecting nature, national parks contribute to fostering harmonious interaction between people and the natural environment, promoting environmental education, and revitalizing regional economies. For example, the Karkaraly, Charyn, and Ile-Alatau national parks have become key attractions for tourists due to their unique landscapes, cultural heritage, and recreational infrastructure. Therefore, national natural parks serve as important platforms for the sustainable development of tourism, offering opportunities to appreciate and study nature while ensuring its preservation (Sapieva & Aktymbayeva, 2016).

Kazakhstan is capable of impressing tourists with its rich natural resources, mineral wealth, picturesque mountainous regions, recreational zones, and national natural parks. State national natural parks play a vital role in the conservation and sustainable use of the country's biodiversity (Seitimova et al., 2021). The Karkaraly National Natural Park is one of the specially protected natural areas of the Republic of Kazakhstan and is located in the Karagandy Region. It was established in 1998 to preserve the unique biogeocenoses, flora, and fauna of Central Kazakhstan (Myrzabayev & Rakhimzhanova, 2015). The park is distinguished by the diversity of its nature: granite mountains, coniferous forests, lakes, and steppe ecosystems are harmoniously integrated. The geomorphological structure and high-mountain massif relief of the Karkaraly region serve as valuable resources for nature conservation and ecotourism. The park is home to plant and animal species listed in the Red Book of Kazakhstan, including rare species such as pine, Karkaraly barberry, argali, and golden eagle (Karimova et al., 2025). Karkaraly is also rich in historical and cultural monuments. The area is recognized for its ethnocultural and recreational potential as well. For these reasons, Karkaraly National Park is a significant site in terms of nature conservation, environmental education, and the development of sustainable tourism.

The territory of the national natural park contains various hydrographic features, including several large and small lakes, as well as seasonal and permanent flowing rivers. These water bodies not only ensure ecosystem stability but also enhance the recreational potential of the area. Among the water objects that attract tourist interest, Shaitankol, Ulken, Pasheno, and Komsomolskoye lakes are particularly noteworthy. These lakes are distinguished by their natural beauty, accessibility, and level of infrastructure development, which contributes to the growing number of visitors to the park.

In this scientific article, Pasheno Lake, which has high recreational potential in the Karkaraly region, is selected as the research subject. This water body stands out for its natural appeal, scenic landscapes, and favorable geographical location, making it one of the region's key tourist resources. The main goal of the study is to scientifically assess the geotourism potential of Pasheno Lake through a comprehensive analysis of its physical-geographical and hydrochemical characteristics. The article first describes the geomorphological structure of the lake, its climatic and hydrological features, as well as the composition of surrounding landscape environments. The results of a hydrochemical analysis of water quality are presented, determining the lake's ecological condition and its level of resilience to anthropogenic impacts. Parameters such as the concentrations of major ions, salinity level, and pH indicator are used to evaluate its sanitary-hygienic and recreational suitability. The results of the study not only provide a scientific description of Pasheno Lake as a natural-recreational site but also offer recommendations for its sustainable use in the context of tourism development.

Scientific questions addressed in the article:

RQ1: What natural factors determine the physical-geographical features and landscape structure of Pasheno Lake?

RQ2: To what extent do the hydrological and hydrochemical characteristics of the lake ensure its ecosystem stability?

RQ3: What are the scientific foundations for the effective use of Pasheno Lake's natural-recreational potential within the framework of sustainable tourism?

LITERATURE REVIEW

The physico-geographical assessment of natural-territorial complexes serves as a foundation for understanding the patterns of natural development and the stability of landscapes. It enables the identification of the specific interactions among natural components–relief, climate, hydrological regime, soil, and vegetation cover–and determines their role in shaping an integrated ecological system. In the conditions of Central Kazakhstan, where natural processes are often characterized by high contrast and instability, such an approach provides the basis for a comprehensive territorial analysis and the development of scientifically grounded strategies for land use and management.

The diverse geological structure and relief of Central Kazakhstan have a significant influence on the region's natural processes and landscape formation. Central Kazakhstan is distinguished by a hilly (low-mountainous) relief that contributes to the formation of groundwater and to active water exchange. The main structural and tectonic feature of the region is the presence of an uplifted Caledonian-Hercynian folded mountain area, bordered to the west and southwest by large Cimmerian-Alpine depressions of the basement associated with younger platform structures, while to the north the region is bounded by basement troughs filled with thick Mesozoic and Cenozoic sedimentary strata (Absametov, 2023).

These physical and tectonic characteristics create favorable conditions for the development of distinctive geomorphological features, which play a crucial role in shaping landscapes, determining their stability, and fostering the development of tourism potential (Dunets, 2011). Understanding the physico-geographical conditions of a territory has not only theoretical but also practical significance. It is essential for predicting ecological changes, identifying areas with high recreational value, and determining pathways toward sustainable environmental management. This is particularly important for steppe and arid regions, where even minor fluctuations in the water balance or climatic conditions can substantially affect the functioning of natural complexes (Pugacheva et. al. 2022). he lakes of Central Kazakhstan represent unique natural formations, the formation and functioning of which are determined by the interplay of geological structure, climatic

conditions, and hydrological factors. The region is characterized by water bodies of diverse genesis–tectonic, karst, and residual in origin. These lakes vary in their water balance, seasonal dynamics of water levels, and specific chemical composition. Under the semi-arid climatic conditions, lacustrine ecosystems perform essential environmental functions: they serve as centers of biodiversity, regulate local microclimatic conditions, and act as indicators of climatic fluctuations. Nearly half of the world's lakes are losing their ecological stability due to anthropogenic impacts, posing a serious threat to freshwater biodiversity and sustainable development (Han, 2024; Xie, 2024). At the same time, lakes play an important socio-economic role, functioning as sites of economic activity, sources of freshwater, and valuable resources for recreational use.

Lake Pasheno is one of the characteristic representatives of such ecosystems. Its present state reflects the geomorphological development patterns of Central Kazakhstan and the specific features of the hydrological regime within the steppe zone. The lake's formation reveals the influence of the geological structure of its basin, the characteristics of its hydrological feeding, and the climatic conditions of the region. Therefore, the study of Lake Pasheno makes it possible to consider it not only as an individual natural object but also as an integral element within the broader system of lacustrine complexes of the Eurasian Steppe. Tourism, as an important driver of sustainable development, relies on the rational use of natural and geographical resources-particularly water bodies and, through the application of modern technologies such as GIS and remote sensing, contributes to the socio-economic and environmental development of regions, including Kazakhstan (Azbantayeva, 2022). The modern concept of geotourism, in this regard, regards natural objects not merely as resources but as elements of scientific and cultural heritage, emphasizing their educational and cognitive value: tourists are introduced not only to the aesthetic beauty of landscapes but also to their geological history, formation processes, and ecological significance. Nature-based tourism refers to travel motivated by an interest in natural environments, where visitors are attracted to destinations notable for their ecological richness and biodiversity. Such activities – whether conducted individually or in groups with the purpose of appreciating flora, fauna, and natural landscapes, are defined as ecotourism (Kurniawati, 2020). Lakes and reservoirs, both natural and artificial, play a significant role in the socio-economic development of surrounding areas by promoting tourism, creating employment opportunities, and improving local living standards, provided that their use follows the principles of sustainable development (Duda et.al., 2010).

Lake systems possess high geotourism potential due to their combination of visual appeal, accessibility for observation, and rich scientific value. They can serve as natural laboratories for interpreting geomorphological processes, analyzing aquatic ecosystems, and studying the adaptation of natural complexes to arid environmental conditions. In Central Kazakhstan, such sites are of particular importance, as they allow visitors to experience the striking contrasts of steppe landscapes and the distinctive natural diversity that exists under semi-arid climatic conditions.

Considering Lake Pasheno, it is important to emphasize its potential as a geotourism site. The surrounding landscape, the unique characteristics of its water balance, the geomorphological structure of its shores, and its biological diversity form a solid foundation for tourism interpretation. The lake can be used as an educational platform for field-based learning routes focused on the geological history of the region, climatic fluctuations, and hydrological processes.

Moreover, the site holds significant value within the context of sustainable tourism. The involvement of local communities in organizing tourism activities around the lake contributes to the preservation of the natural environment, promotes environmental education, and supports the diversification of the local economy. Thus, the physico-geographical assessment of Lake Pasheno becomes a key step in understanding its uniqueness and in developing strategies for its effective use for recreational and educational purposes. Establishing a brand of protected natural areas based on the principles of ecological responsibility and sustainable development enhances public trust, strengthens visitor loyalty, and fosters a respectful attitude toward the natural and cultural heritage of Kazakhstan (Seidualin, 2025).

METHODS

To determine the recreational potential of the region, it is essential to develop its physical-geographical characterization. A physical-geographical assessment of the natural-territorial complex of Pasheno Lake, located within the territory of the Karkaraly National Natural Park in Central Kazakhstan, was carried out using a systematic approach that integrated methods of landscape analysis, geoecological evaluation, and geoinformation modeling. In constructing the physical-geographical profile, the scientific concepts of representatives of the national landscape school (L.S. Berg, I.P. Gerasimov, V.A. Nikolaev), along with the capabilities of modern GIS technologies, were taken into account. The components of the natural complex–relief, soil-topographic features, vegetation cover, water system, and climatic characteristics–were examined within the framework of landscape structure.

The climatic characteristics of the region were developed based on long-term meteorological data from the Karkaraly meteorological station provided by "Kazhydromet" for the period from 1991 to 2024. Average annual and seasonal temperatures, precipitation levels, humidity, and the moisture coefficient calculated using the Budyko method were analyzed.

In order to assess the ecological condition of the lake water, water samples were collected during the summer of 2024 from three main points of the water body. The samples were gathered in accordance with the standards provided by the Ministry of Environmental Protection of the Republic of Kazakhstan and RSE "Kazhydromet", and analyzed in an accredited laboratory using the atomic absorption spectrometry (AAS) method. During the study, the concentrations of the following heavy metals were determined: Pb, Cd, Cu, Zn, Mn, Fe, Cr, Ni, and As. These were compared with the maximum permissible limits established by the sanitary norms of the Republic of Kazakhstan. To assess the level of pollution, the geoaccumulation index (according to the Müller method) and the potential ecological risk index (according to the Hakanson method) were applied, providing a quantitative evaluation of the lake ecosystem's geoecological condition.

Following the development of the physical-geographical characterization of Pasheno Lake, its geotourism potential was assessed using the methodology proposed by Reynard et al. (2007). This methodology incorporates the scientific, aesthetic, cultural, ecological, and recreational values of geomorphological features. The assessment was carried out using a point-based system, and features were evaluated based on their significance for geotourism. All research findings were visualized using cartographic and graphic tools. The comprehensive nature of the applied methods enabled a thorough evaluation of the natural-territorial complex of Pasheno Lake and provided a scientific basis for its optimal use in tourism and recreation.

STUDY AREA

This research is dedicated to Pasheno Lake, located within the Karkaraly District of Karagandy Region in the Republic of Kazakhstan. Pasheno Lake lies in the central part of the Saryarka region, on the northeastern slope of the forested mountainous massif of Karkaraly, with approximate geographical coordinates of 49°25′ N and 75°30′ E. The lake is situated at an altitude of approximately 820 meters above sea level. Pasheno Lake is located about 12–15 km northeast of the town of Karkaraly and is surrounded by a naturally attractive forested-mountainous landscape. Its surroundings are primarily composed of pine forests and granite mountain ridges. Although the lake is relatively small in size, its natural and climatic features and high recreational potential make it a significant site.This area is part of the Karkaraly State National Natural Park, which increases its ecological importance. During the study, the geographical, climatic, and geoecological conditions of the lake were comprehensively examined, and its natural resource and geotourism potential were assessed.

Pasheno Lake is accessible from the town of Karkaraly by a light vehicle within 15–20 minutes, making it a highly convenient destination for local tourism. The satisfactory condition of the road, along with the park's tourist routes and signage, contribute to the growth of recreational flow to the lake. The presence of former recreation base infrastructure around the lake, if restored, could help maintain tourist load at a sustainable level.

The area surrounding Lake Pasheno is characterized by a relatively well-developed tourist infrastructure. Several recreational facilities are located in close proximity to the lake, including resorts such as «Shakhter», «Arlan», «Ak Kayıng», «Sunkar», «Kaskad», «Medeo», and «Zhemchuzhina», as well as tourist bases «Gornyak» and «Raduga», the natural park «Koryavy Pen», and the hotel complex «Polyana Sletov». These facilities contribute to the development of ecotourism and recreational activities in the region. Visitor flows are generally steady throughout the tourist season, reflecting a consistent interest in the area's natural and recreational offerings.

Lake Pasheno is situated on the northern slopes of the Karkaraly Range in Central Kazakhstan, within a moderately continental climatic zone. The geographic location of the lake and its surrounding natural features are shown in Figure 1.

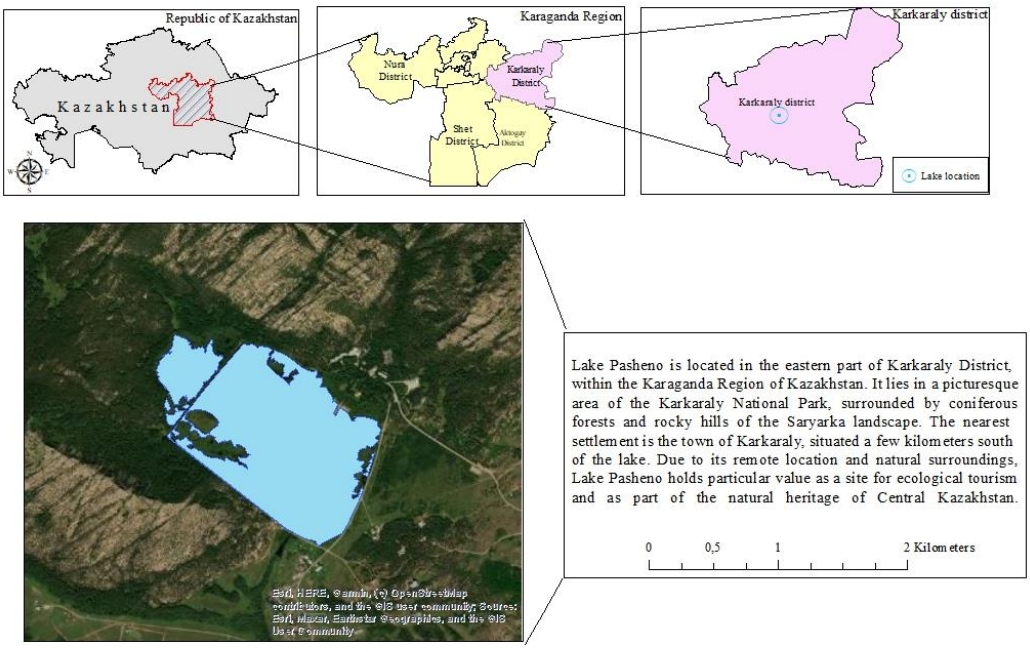

Figure 1. Geographical location of Lake Pasheno within the Karkaraly region, Central Kazakhstan

DATA COLLECTION

The materials required for this research were collected through direct field expeditions conducted in June 2024. During the field study, the physical-geographical features of Pasheno Lake, the morphological structure of its shoreline, surface water characteristics, and ecological conditions were examined. The lake's precise coordinates, elevation, and overall spatial location were determined using GPS tools. To assess climatic conditions, long-term observation data from the Karkaraly meteorological station and a second nearby station were used. Soil and water samples were collected and subjected to laboratory analysis to determine their physical and chemical composition. The collected materials were systematized according to the research objectives, allowing for a comprehensive description of the current state of the natural complex.

RESULTS

Climatic Characteristics

Pasheno Lake is one of the lakes located within the Karkaraly State National Natural Park in the territory of the Karkaraly District. According to data from RSE «Kazhydromet», there are two meteorological stations (MS) operating in the Karkaraly District. The Besoba MS, located at an elevation of 716 meters above sea level, was established in 1938, while the Karkaraly MS, situated at an altitude of 841 meters, began operation in 2005. Although the lake's water area falls within the territory of the Karkaraly meteorological station, for a more accurate assessment of climatic conditions, the authors found it appropriate to conduct a comprehensive analysis using data from both the Karkaraly and the nearby Besoba stations.

Table 1 presents changes in air temperature for the years 2014 and 2024. The region's climate is sharply continental, characterized by significant annual and diurnal temperature fluctuations, high solar radiation and heat availability, predominant summer precipitation, and frequent droughts. Thus, the average air temperature during the winter season was recorded at approximately –11.5 °C at the Karkaraly station and –12.3 °C at the Besoba station. During the summer months (June–August), the average temperature reached +17.1 °C in Karkaraly and +18.7 °C in Besoba.

The annual average temperature was approximately +2.4 °C, which characterizes the region's temperate continental climate. No extreme hydrometeorological events were recorded in either 2024 or 2014. Although precise precipitation data are not shown in this table, previous records indicate that the annual precipitation amount is approximately 347 mm.

The average monthly wind speed for 2024 in the Karkaraly region is presented in Table 2.

Table 1. Registered air temperatures at the Karkaraly and Besoba meteorological stations in 2024
(Source: Compiled and analyzed by the authors based on Kazhydromet data)

Month	Station	Unit of measurement - ^{0}C					
		Average	Max.	Min.	Average	Max.	Min.
		2024			2014		
1	Besoba	-11.6	-6.9	-16.1	-14.9	-9.7	-18.8
	Karkaraly	-10.3	-5.7	-15	-13.8	-8,7	-18,5
2	Besoba	-15.5	-9.7	-21	-19.6	-13.5	-25
	Karkaraly	-13.8	-8.7	-18.9	-17.9	-12.4	-23.4
3	Besoba	-4.8	-0.2	-8.9	-4.9	1.1	-9.4
	Karkaraly	-3.9	0.4	-8.1	-3.8	2.2	-9.5
4	Besoba	7.6	14.2	1.3	+3.9	10.7	-1.9
	Karkaraly	7.1	13.2	1.3	3.9	10	-2.2
5	Besoba	12.3	19.5	6.1	+12.6	20.6	4.6
	Karkaraly	11.9	18.5	6	12	18.6	5
6	Besoba	19.7	27.6	12	+18.4	26.7	10.3
	Karkaraly	19.3	25.6	13	17.5	24.7	9.9
7	Besoba	19.7	26.5	13.8	16.9	23.6	11
	Karkaraly	19.1	24.8	14	16.2	22.4	10.4
8	Besoba	18.1	25.9	11.4	17.7	25.7	9.2
	Karkaraly	17.9	24.6	11.3	16.7	23.3	9.3
9	Besoba	9	17	2.4	13,2	31	0
	Karkaraly	8.9	15.2	3.3	16.97	23	-2
10	Besoba	4.6	11.7	-1.1	6	20	-7
	Karkaraly	4.7	10.3	-0.1	2.75	18	-19
11	Besoba	-4	0.9	-8.4	-9	6	-32
	Karkaraly	-3.2	1.5	-7.3	-7.8	12	-32
12	Besoba	-9.9	-6.2	-14	-12.6	3	-27
	Karkaraly	-9.9	-6.1	-13.9	-10	3	-27

Table 2. Average monthly wind speed in the Karkaraly region in 2024
(Source: Compiled and analyzed by the authors based on Kazhydromet data)

Station / Months	1	2	3	4	5	6	7	8	9		10	11	12
Karkaraly	3.7	3.4	3.1	2.9	3.3	2.4	1.8	2.1	2.8		2.7	3.7	2.7

In addition, the characteristics of weather indicators for 2024 and 2014 at the Karkaraly and Besoba meteorological stations in the Karkaraly region can be seen in Tables 3 and 4. In 2024, the average winter air temperature was recorded at –12.3 °C at the Besoba station and approximately –11.5 °C at the Karkaraly station. During the summer months (June–August), the average temperature reached +18.7 °C in Besoba and +17.1 °C in Karkaraly. These data clearly reflect the continental climatic features of the region. According to the diagram shown in Figure 2, a general warming trend in air temperature can be observed over the past 10 years. In comparison, in 2014, temperatures were higher in March and April, while values for September and October were approximately the same. As shown in Figure 3 below, at both meteorological stations the maximum summer temperature corresponds to the month of July, while the minimum temperature is recorded in February. Based on the presented graphs, the summer air temperatures recorded by the two meteorological stations in the Karkaraly region illustrate climate change resulting from global warming. According to the data presented in Table 3, the year 1993 stands out with the highest recorded annual average air temperature and is also characterized by a low number of rainy days.

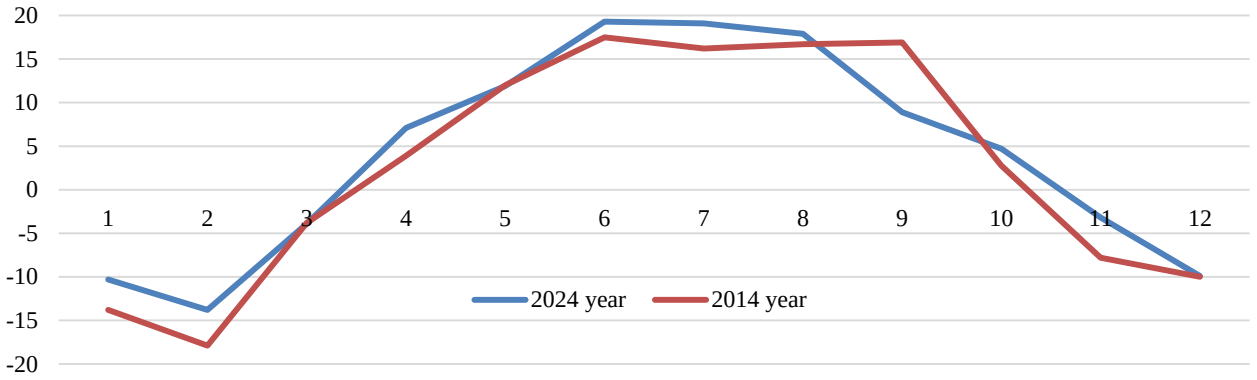

Figure 2. Annual average air temperature indicators for 2014 and 2024 based on data from the Karkaraly meteorological station.

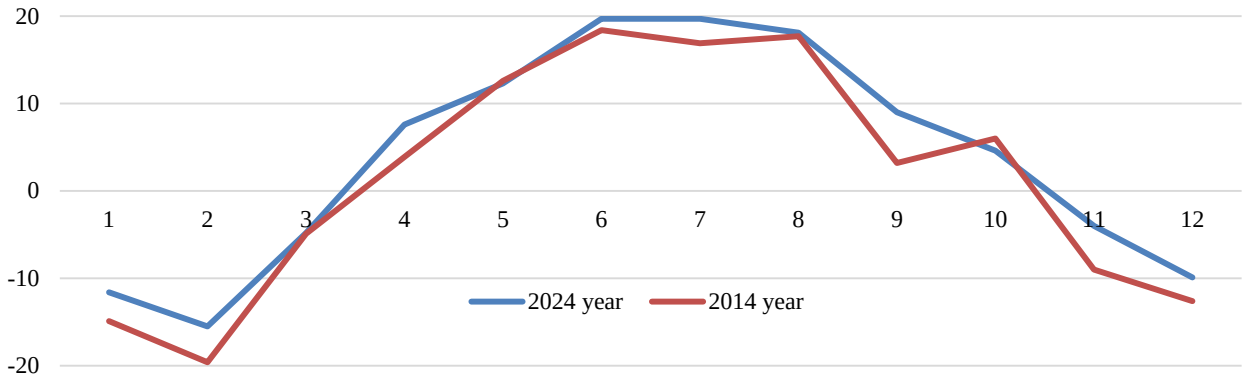

Figure 3. Annual average air temperature indicators for 2014 and 2024 based on data from the Besoba meteorological station

If we pay attention to the provided data, it is notable that there are no recorded sources on atmospheric weather indicators for the period between 1993 and 2010. In 2024, snow was recorded on 120 days; however, its maximum thickness was the lowest compared to other years. The cloudiness level has remained relatively constant over the past 50 years. The highest recorded precipitation corresponds to the year 2024. Next, Table 4 presents the number of days with various atmospheric phenomena observed in the region between 1974 and 2024.

Table 3. Weather indicators recorded in the Karkaraly region between 1974 and 2024
(Source: Compiled and analyzed by the authors based on Kazhydromet data)

Years	Average t. (^{0}C)	Air humidity. (%)	Average wind speed (m/s)	Cloudiness (total points)	Precipitation (mm)	Snow cover	
						Number of days	Max. thicknesss, cm
1	2	3	4	5	6	7	8
1974	1.5	65	4.7	4.4	159	4	23
1984	0.6	69	3.5	5.1	232	90	35
1993	+9,1	67	3,7	4,6	254	97	238
2014	3.9	61	3.1	4.7	248	94	188
2024	+4,0	63	2,9	5,6	356	144	27

Table 4. Duration (in days) of atmospheric phenomena in the Karkaraly region from 1974 to 2024
(Source: Compiled and analyzed by the authors based on Kazhydromet data)

Years	Atmospheric phenomena (days):					
	Rain	Snow	Fog	Blizzard	Thunderstorm	Dust storm
1	2	3	4	5	6	7
1974	81	84	15	7	27	3
1984	78	107	15	9	22	3
1993	36	5	1	0	21	0
2014	43	34	1	6	15	0
2024	113	80	13	23	29	2

Between 1974 and 2024, no hazardous atmospheric phenomena such as tornadoes, blizzards, or dust storms were recorded in the Karkaraly region. According to observations over the past 50 years, the rainiest year in Karkaraly was 2024, while the longest snow cover duration corresponds to the year 1984. The maximum wind gust of 25.65 m/s was recorded in 1970.

Overall, the region's climate is favorable for tourism as well as for various types of economic activities conducted by local residents. Currently, the climate provides suitable conditions for the stable operation of numerous farms, recreational facilities, and small and medium-sized businesses in the area.

Soil Cover

According to the descriptions of soil profiles, the Karkaraly region consists of a diverse soil cover. Its granulometric composition ranges from medium loamy in moist soils to light and heavy loamy in younger soils. Forested areas are characterized by a thick humus-rich layer, while the slopes of forested mountain areas are covered by turf-forming shrub-grass and steppe vegetation. Weak turf formation is observed in steppe soils. Signs of soil acidification were found across all layers of the steppe soil profile excavated to a depth of 114 cm. Overall, the region's soils are composed of light and dark chestnut soils formed on alluvial deposits (Myrzabayev et al., 2023). In July 2024, the authors collected soil samples from the vicinity of the selected water body (Pasheno Lake) as part of the study. The results of this analysis are presented in Table 5. The alkaline reaction of the soil near Pasheno Lake (pH > 7) is considered one of the favorable factors from a tourism and recreational perspective. Alkaline soils are typically not prone to waterlogging, have a less compact structure, and provide good drainage, making them suitable for organizing beach recreation, hiking, and ecological trails. Such soils support healthy growth of herbaceous plants, enhancing the aesthetic appeal of the natural landscape and strengthening its geotourism potential.

Table 5. Soil alkalinity level in the vicinity of sampled lakes

Name of sampled lake	pH level	Meaning < 7 – acidic soil; = 7 – neutral soil; > 7 – alkaline soil
Pasheno	10,039	Alkaline
Compiled by the authors. Water samples were taken from the mentioned water body and analyzed at the accredited laboratory of Karaganda Research University named after E.A. Buketov.		

Hydrochemical Analysis

Within the framework of the study, water and soil samples were collected from Pasheno Lake in full accordance with state standards. This standard is an official regulatory document governing the unified rules for the collection, preservation, and preparation of natural water samples for analysis. The accurate and proper collection of samples is a critical stage that ensures the validity and scientific soundness of the research results. The regional samples were analyzed in an accredited laboratory, indicating the reliability and compliance of the results with international requirements. The laboratory analysis employed the Atomic Absorption Spectrometry (AAS) method. AAS is a modern analytical technique that allows for the highly accurate determination of concentrations of heavy metals and microelements in water and soil. This method measures each chemical element's unique absorption spectrum, enabling precise quantification–widely applied in environmental monitoring and pollution level assessment. The advantages of this method include high sensitivity (up to ppb level), accuracy of results, and multi-element detection capabilities. Therefore, it is widely recognized in ecological and geochemical research, especially for assessing the qualitative state of natural waters and soils.

The data describing the hydrochemical and geoecological status of Pasheno Lake were obtained using a high level of methodological and analytical rigor, ensuring their suitability for scientific analysis.

Water and soil samples were collected at four designated sites in accordance with standard procedures. The obtained results were analyzed, and since the variation in chemical element concentrations across all sampling points was minimal, the authors decided to calculate average values for better visual representation and present only these averages in the results.

Figure 4 illustrates the geographic layout of the water and soil sampling sites around Lake Pasheno, showing the exact locations where the field samples were collected in accordance with the research methodology.

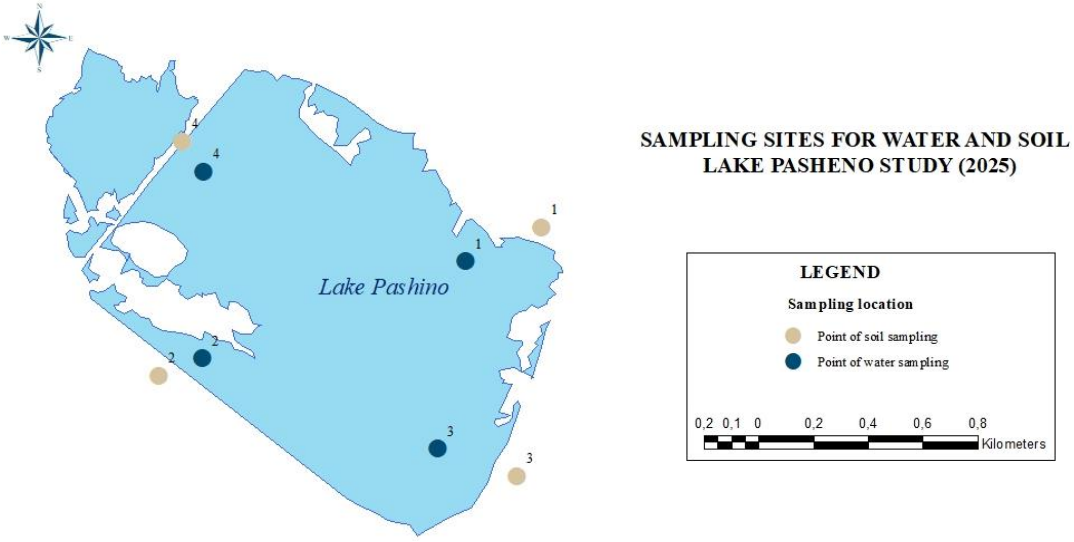

Figure 4. Water and Soil Sampling Locations – Lake Pasheno (Source: authors)

Research findings show that Pasheno Lake is actively used for recreational and agricultural purposes, which in turn increases ecological pressure on the ecosystem. According to the data in Table 6, the concentration of several chemical elements in the lake water significantly exceeds the maximum allowable concentrations (MAC). These MACs were

assessed according to the hygienic regulations established by Order №138 of the Ministry of Health of the Republic of Kazakhstan (2022) for household-drinking and cultural-domestic water use.

As observed from the table, the concentrations of sodium, calcium, magnesium level significantly exceed the maximum permissible concentrations. Such conditions negatively impact the natural ecological balance, posing a threat to the survival of fish and plant species. This situation also limits the recreational potential of Lake Pasheno, as water quality and ecological safety are key factors in the development of tourism-related activities. Therefore, regular monitoring of water quality and the implementation of ecosystem restoration measures are of vital importance. The natural-territorial complex where Lake Pasheno is located is distinguished by its landscape-aesthetic features and ecological resource base. Since the lake is part of the Karkaraly National Nature Park, its area holds special significance as a protected natural territory.

Table 6. Elemental Composition of Lake Pasheno (mg/L)

Chemical element	Pasheno	MPC (Maximum Permissible Concentration)
1	2	3
Na	281.12	200
K	11.041	10
Ca	42.221	10
Fe	0.38	0.3
Mn	0	0.1
Pb	0	0.03
Mg	122.84	20

Geobotany and Geological Structure

Lake Pasheno is framed by granite ridges and situated on natural terraces, giving the area a spatially harmonious appearance. The landscape presents a balanced composition of the lake surface, forested ridges, open grassy fields, and sediment-rich shorelines. This diverse and rich natural mosaic creates a favorable environment for ecotourism and photo tourism. Although gnammas are not found in intrusive and effusive-sedimentary rocks beyond the granites of the Karkaraly Mountains, smaller isolated forms and their morphology in the Karamyrza massif, along with the characteristics of the sedimentary cover, are described as evidence of chemical weathering and biogenic transformation of granite (Belousova et al., 2020). The region is characterized by river valleys, natural meadows, lake basins, and flattened small hill areas (Akhmetov, 2019). The selected study area around the lake is mainly surrounded by pine forests and herbaceous plant communities.

This zone is distinguished by phytocoenoses typical of the forest-steppe belt of Saryarka. Coniferous forests (*Pinus sylvestris*) and herbaceous cover enhance the aesthetic value of the landscape, making it especially significant as a natural recreational space (Kenzhina, 2025). During summer, these plants form a colorful carpet, further enriching the scenic beauty of the area. In Figure 5, Lake Pasheno is depicted with its captivating natural beauty, surrounded by pine forests, granite ridges, and a clear water surface that reflects the surrounding landscape. The image highlights the aesthetic appeal of the lake, showcasing the harmonious combination of natural elements that contribute to its high geotouristic value. The visual scene illustrates the ecological richness and scenic diversity that make this site attractive for nature observation, photography, and eco-tourism.

Figure 5. Scenic View of Lake Pasheno and Its Surrounding Landscape
(Source: Authors, Republic of Kazakhstan, Karagandy region, Karkaraly district, 2025)

Geotourism Potential

To assess the geotourism potential of the Lake Pasheno natural-territorial complex, the methodology proposed by (Reynard, 2007) was applied. This method allows for a comprehensive evaluation of geotourism sites based on four main

criteria: scientific value, aesthetic appeal, accessibility and infrastructure, and the level of protection and management. The methodology is based on both qualitative and quantitative scoring, enabling a systematic characterization of the site.

1. Scientific value – 4 points. Lake Pasheno stands out due to its geographical location, geomorphological structure, hydrochemical characteristics, and the distribution of alkaline soil types. The concentration of chemical elements in water and soil, along with their natural and anthropogenic changes, serves as an important source of information for scientific research. The lake area is suitable as a natural laboratory for conducting fieldwork on topics such as biogeocenosis, climate adaptation, and ecosystem dynamics.

2. Scenic/aesthetic value – 5 points: Lake Pasheno is surrounded by granite ridges and forms a unique natural mosaic in harmony with forest-grassland landscapes. The surface of the lake and the nearby coniferous forest areas are highly visually appealing. Seasonal changes (summer blooming, autumn leaf fall, winter snowy scenes) enhance its aesthetic value. These features create strong potential for nature walks, landscape photography, and ecotourism.

3. Accessibility and facilities – 3 points: Lake Pasheno is located approximately 12–15 km from the town of Karkaraly and the road to the lake is accessible by car. However, the lake lacks modern infrastructure elements (walking trails, information boards, rest areas, sanitation facilities, etc.). This limits the structured development of recreational flow. In the future, improving infrastructure could increase this indicator.

4. Protection and management – 3 points: Since Lake Pasheno is located within the boundaries of the Karkaraly National Nature Park, it is part of a general ecosystem protection zone. However, in the immediate vicinity of the lake, there is a lack of information support and organized routes for efficient use of nature and management of tourist directions. The absence of ecological trails, route maps, and informational structures for tourists restricts the sustainable development of geotourism. Enhancing management mechanisms in this direction is one of the key prerequisites for realizing the site's full potential. According to the methodology of Reynard (2007), Lake Pasheno has a high geotouristic potential. Its natural-climatic, aesthetic, and scientific characteristics define it as a promising geotourism site. However, development of infrastructure and management systems is required. The obtained results are presented in Tables 7 and 8.

Table 7. Geotourism assessment of the lake's aquatory based on the method proposed by Reynard, 2007

Evaluation Criteria	Description	Score (0–5)
Scientific significance	The lake's geomorphological structure, hydrochemical characteristics, alkaline soil, and exposure to anthropogenic impact make it important for research.	4
Scenic/aesthetic value	Pine forest, granite ridges, and the natural lake mirror create a visually harmonious landscape with high appeal due to seasonal variations.	5
Accessibility and infrastructure	Accessible by vehicle from Karkaraly, but infrastructure around the lake (signage, rest areas, trails) is poorly developed.	3
Protection and management	Although part of a national park, the specific lake area lacks adequate tourist management and informational infrastructure.	3
Total score		3.75

Table 8. Research Results

Element	Conc. (mg/L)	MAC (B_n)	Igeo	Assessmen
Na	281.12	200	–0.09	Unpolluted
K	11.041	10	–0.44	Unpolluted
Ca	42.221	10	**1.49**	Moderately polluted
Fe	0.38	0.3	–0.24	Unpolluted
Mn	0	0.1	–∞	Unpolluted
Pb	0	0.03	–∞	Unpolluted
Mg	122.84	20	**2.03**	Considerably polluted

Assessment of Heavy Metal Pollution in Lake Pasheno (Based on Müller, 1969 and Hakanson, 1980 methods)

To assess the level of heavy metal pollution in the lake water, two widely recognized methods were applied: the Geoaccumulation Index (Igeo) and the Potential Ecological Risk Index (Er). These methods allow for a comprehensive description of the chemical pollution level in the study area and the environmental safety status.

1. Geoaccumulation Index (Igeo, Müller Method)

The geoaccumulation index describes the level of pollution by calculating the deviation of element concentrations in the aquatic environment from background (natural) levels. It is calculated using the following formula (Muller, 1969):

$$I_{geo} = log_2(\frac{C_n}{1.5 \times B_n})$$

Where: C_n – measured concentration (mg/L); B_n – background value or Maximum Allowable Concentration (MAC); 1.5 – coefficient accounting for natural background variability. The pollution levels of calcium (Ca) and magnesium (Mg) were assessed as moderate and considerable, respectively. The remaining elements are within natural or normal levels.

2. Potential ecological risk index (E_r, Hakanson method). The Hakanson method evaluates the impact of each chemical element on the ecosystem by taking into account its toxicity coefficient (Hakanson, 1980):

$$E_r^i = T_T^i \times \frac{C^i}{B^i}$$

Where: **T** – toxicity coefficient of the element; **C** – concentration; **B –** background value (MPC – Maximum Permissible

Concentration). The overall ecological risk level of Lake Pasheno was assessed as low (RI = 19.21); however, relatively higher risk factors were observed for Fe and Mg. The increase in these elements may have long-term impacts on the ecosystem, thus requiring continuous monitoring and protective measures. The results of the ecological risk assessment are presented in Table 9.

Table 9. Research results

Element	Conc. (mg/l)	MPC	Tr	E_r	Risk level (according to Hakanson's method (1980)
Na	281.12	200	1	1.41	Low
K	11.041	10	1	1.10	Low
Ca	42.221	10	1	4.22	Low
Fe	0.38	0.3	5	**6.33**	Moderate
Mn	0	0.1	1	0.00	Low
Pb	0	0.03	5	0.00	Low
Mg	122.84	20	1	**6.14**	Moderate

CONCLUSION

As a result of the physico-geographical study conducted on Lake Pasheno, the natural conditions of this territorial complex and the level of anthropogenic impact were comprehensively assessed. The collected data and analyses allowed for the following key scientific conclusions to be drawn:

The physico-geographical analysis demonstrated that orographic and climatic factors play a significant role in the formation of the lake. Lake Pasheno is situated on the slope of the Karkaraly ridge, within a temperate continental climate zone. The area's relief, granite formations, sedimentary ridges, and pine forests contribute to its unique landscape appeal.

The results of the soil cover study revealed that alkaline soils dominate the shoreline of Lake Pasheno. This geochemical feature can affect the biological productivity of the ecosystem and its potential for recreational use. According to literature sources, the growth of plants adapted to alkaline conditions plays a role in tourism and the rational use of natural resources. To assess water quality and pollution levels, samples were collected in accordance with standard and analyzed using atomic absorption spectrometry (AAS) in an accredited laboratory. The results showed that the concentrations of calcium and magnesium ions in Lake Pasheno significantly exceed the maximum permissible limits. The geoaccumulation index calculated by the Müller method indicated moderate (Ca, I_geo = 1.49) to considerable (Mg, I_geo = 2.03) contamination. The ecological risk index (RI = 19.21), calculated using the Hakanson method, indicates an overall low ecological risk, although there is a relatively higher risk associated with Fe and Mg.

The geotourism potential assessment identified the lake's landscape-aesthetic, scientific, and recreational values. Based on the Reynard (2007) methodology, the expert evaluation classified the geotourism potential of Lake Pasheno as high (average score – 3.75). The combination of natural woodlands, granite ridges, and a scenic lake mirror, along with the lake's proximity to the town of Karkaraly, make it a suitable site for ecotourism and landscape-oriented routes.

Lake Pasheno is a site of significant natural resource potential and ecological importance. The lake area requires sustainable development in terms of scientific research, environmental monitoring, and geotourism. The findings provide a basis for the future development of tourist infrastructure, improvement of ecological safety measures, and the conservation of natural heritage, taking into account the region's physico-geographical characteristics.

Limitations of the Study

This study has several limitations. Firstly, although Lake Pasheno is one of the most scenic natural sites not only in the city but also within the Karkaraly National Nature Park, it remains poorly studied. This under-researched status also applies to other mountain lakes in the region, which limits the possibility of comprehensive scientific evaluation. Secondly, the water quality assessment was based on the national standard sampling method (GOST), which, despite being reliable, may lack the level of detail found in more advanced international protocols. Thirdly, while there are scientific publications concerning the park's flora, fauna, and specific ecological components, interdisciplinary studies focusing on the geospatial and geotourism potential of individual sites–such as Lake Pasheno–are noticeably lacking. This creates the impression of a broader research gap in the region and highlights the need for further integrated investigations.

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