

WHAT ROLE CAN UHSOR PELOIDS AND BRINE PLAY IN SUSTAINABLE WELLNESS TOURISM? INSIGHTS FROM EASTERN KAZAKHSTAN

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Abstract: The Alakol Depression in Eastern Kazakhstan contains saline lakes and therapeutic mud deposits that represent valuable natural resources for wellness tourism; however, many of these deposits remain insufficiently investigated from a geocological perspective. This study aimed to conduct a comprehensive geocological assessment of the Ushsor peloids and brine and to evaluate their potential for sustainable wellness tourism development in the Alakol Depression. Particular attention was paid to determining the environmental safety, balneological characteristics, and recreational suitability of these natural resources under current sanitary and environmental requirements. Field investigations were conducted during 2024–2025, including systematic sampling of peloids and brine, physicochemical, hydrochemical, microbiological, and radiological analyses, and comparative assessment against sanitary and hygienic standards. The elemental composition was determined using atomic absorption spectrometry (AAS) and inductively coupled plasma optical emission spectrometry (ICP-OES), while the microstructure of the peloids was examined using scanning electron microscopy (SEM). Analytical determinations were performed in triplicate to ensure the reliability and reproducibility of the obtained results. The Ushsor peloids were identified as moderately mineralized sulphide silt muds with a favorable macro- and microelement composition and no exceedances of toxic elements. The brine demonstrated high mineralization and sulphate–chloride dominance, reflecting the hydrochemical characteristics of saline lakes within the Alakol Depression. Microbiological analyses confirmed sanitary safety and recreational suitability, while the integrated geocological assessment indicated that the deposit possesses favorable natural characteristics for balneological application. These findings highlight the importance of Ushsor as a promising natural resource capable of supporting sustainable wellness tourism in Eastern Kazakhstan. The Ushsor deposit possesses considerable geocological and wellness tourism potential; however, sustainable development requires infrastructure improvement, continuous environmental monitoring, conservation of natural resources, and long-term scientific support. The obtained results provide a scientific basis for the rational management and sustainable use of the deposit while promoting regional wellness tourism in accordance with environmental protection principles.

Keywords: geocological assessment, Ushsor deposit, Alakol Basin, wellness tourism, Eastern Kazakhstan

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INTRODUCTION

One of the priority scientific and practical tasks of modern geocology and recreational geography is the comprehensive assessment of natural therapeutic resources of small endorheic lakes and salt-affected landscapes in arid regions. In the context of peloids, particular importance is attached to their mineral and chemical composition, microstructural characteristics, microbiological safety, and quality control procedures preceding their therapeutic and dermocosmetic application. These aspects are reflected in studies on Kazakhstani peloids as well as in the international literature addressing pelotherapy quality control (Akimzhanova et al., 2024; Mourelle et al., 2024).

Eastern Kazakhstan, including the Alakol depression, is characterized by a substantial yet unevenly studied potential of hydromineral and mud resources (Mukayev et al., 2024; Jetimov et al., 2025; Jetimov et al., 2025). A synthesis of available data on therapeutic muds from saline lakes in Kazakhstan indicates the fragmented nature of existing studies; for the northern and eastern regions, there remains a lack of systematic information on the physicochemical and organic characteristics of natural peloids, which necessitates further localized and integrated research (Akimzhanova et al., 2024).

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One such site is the Ushsor deposit, situated in the southeastern region of the Alakol depression. Its environmental conditions – arid climate, high evaporation rates, salt accumulation, shallow groundwater occurrence, and pronounced seasonal fluctuations of the water surface – create favorable conditions for the formation of sulphide silt therapeutic muds and highly mineralized brine. The area of the deposit is 5.21 km²; during the summer period, the lake partially or completely desiccates, and in the northwestern sector a salt crust forms, beneath which sulphide peloids accumulate with a thickness of up to 1 m. Contemporary research on peloids is structured around several interrelated scientific directions. The first direction focuses on the investigation of their mineral, chemical, and physicochemical composition. A synthesis of available data on therapeutic muds in Kazakhstan indicates that most studied sites can be classified as continental sulphide peloids with varying degrees of mineralization; however, for a considerable number of deposits, the existing information remains fragmented and insufficiently systematized (Akimzhanova et al., 2024). The therapeutic potential of peloids is determined by the complex interaction between the mineral matrix, the liquid phase, and the microstructural characteristics of the material (Carretero et al., 2020; Park et al., 2024; Carbajo et al., 2024).

The second direction is concerned with the analysis of microstructure, maturation processes, and physical properties of peloids (Maraver et al., 2021; Lampropoulou et al., 2023). A peloid is defined as a mature dispersed system with therapeutic and cosmetic properties, composed of fine-grained mineral and organic matter interacting with mineral water, seawater, or saline lake water, often involving products of biological activity. Key quality indicators include thermotherapeutic properties, cation exchange capacity, pH stability, and structural parameters of the material (Mourelle et al., 2025; Maraver et al., 2021). The third direction addresses the microbiological characteristics and sanitary assessment of peloids. The safety of their application is determined by the absence of pathogenic microflora and compliance with established sanitary standards, while the presence of functionally significant microbial communities is considered an additional characteristic of the natural material (Kataržytė et al., 2024). This aspect becomes particularly important when peloids are used outside specialized medical and balneological facilities.

The fourth direction encompasses clinical and quasi-clinical evaluations of balneotherapy and pelotherapy (Keilani et al., 2025; Aribi et al., 2025). The potential effectiveness of peloids in the treatment of rheumatological and degenerative diseases is recognized; however, the interpretation of results requires strict consideration of the quality of the natural material (Keilani et al., 2025). From a geocological perspective, this necessitates prior verification of the chemical composition and sanitary safety of the resource before any clinical interpretation.

The fifth direction relates to the development of wellness tourism and the principles of sustainable use of natural therapeutic landscapes. Wellness tourism is conceptualized as an integrative segment combining recovery processes, psychophysiological well-being, and interaction with the natural environment (Karagianni et al., 2025; Rosalina et al., 2026; Sthapit et al., 2025; Liu et al., 2023). Visitor satisfaction, engagement, and memorability of experiences are regarded as key characteristics of this segment, while sustainability is considered a fundamental condition for its long-term development (Karagianni et al., 2025; Rosalina et al., 2026; Sthapit et al., 2025).

The significance of this work is established by the necessity to furnish a scientific foundation for the judicious utilization of natural therapeutic resources in the context of increasing interest in wellness tourism and the expansion of interdisciplinary approaches linking tourism, well-being, and sustainability. The interconnection between tourism, well-being, and sustainability is considered one of the key directions in tourism studies, while wellness tourism is viewed as a segment requiring a balanced consideration of the interests of visitors, local communities, and natural ecosystems (Dildabek et al., 2025; Karagianni et al., 2025; Rosalina et al., 2026; Sthapit et al., 2025).

However, despite the growing scholarly attention to therapeutic muds and wellness tourism, there remains a lack of comprehensive studies addressing the geocological characteristics, sanitary safety, and recreational suitability of specific saline lake deposits in Eastern Kazakhstan. In particular, the Ushsor deposit has not previously been examined within an integrated framework that combines physicochemical assessment, environmental safety evaluation, and interpretation in the context of sustainable wellness tourism. This study aims to fill this gap by providing an analysis of the Ushsor deposit, taking into account its specific features as a natural therapeutic and recreational resource. The aim of this study is to conduct a comprehensive geocological assessment of the peloids and brine of the Ushsor deposit in order to determine their suitability and potential for use in the development of sustainable wellness tourism within the Alakol depression. The scientific novelty of the research lies in considering the Ushsor deposit not only as a local balneological site, but also as an element of the geocological and tourism-recreational system of the Alakol depression. Unlike descriptive studies focused on the general therapeutic properties of muds, this research integrates the assessment of composition, safety, and natural resource potential with an applied perspective on acceptable forms of recreational use.

MATERIALS AND METHODS

Research area

The Ushsor deposit is located in the north-western part of the Alakol depression within the Balkhash–Alakol basin (Eastern Kazakhstan) (Figure 1). The spatial extent of the deposit is defined by the following geographical coordinates of its extreme points: the northern boundary (46°14'25" N, 80°17'40" E), the southern boundary (46°12'25" N, 80°19'06" E), the western boundary (46°13'27" N, 80°15'38" E), and the eastern boundary (46°12'42" N, 80°20'10" E). The study area is characterized by an arid climate, with high evaporation rates, low precipitation, and pronounced seasonal variability of the hydrological regime. The deposit is situated within a closed lacustrine system, where processes of salt accumulation and modern sedimentation play a key role in the formation of sulphide silt peloids (Mukayev et al., 2024). Geomorphologically, the territory represents a flat depression with elements of saline surfaces and periodically waterlogged areas (Figure 2).

The formation of peloids is associated with alternating processes of wetting, driven by groundwater and seasonal inflow, and subsequent drying during the summer period. These conditions contribute to the accumulation of sulphide compounds and increased mineralization. The spatial structure of the deposit is heterogeneous. In the north-western part, a dense salt crust is formed, underlain by sulphide silt deposits with a thickness of up to 1 m. In the central and peripheral zones, the sediments are looser and less mineralized, reflecting differences in hydrological and geochemical conditions within the deposit.

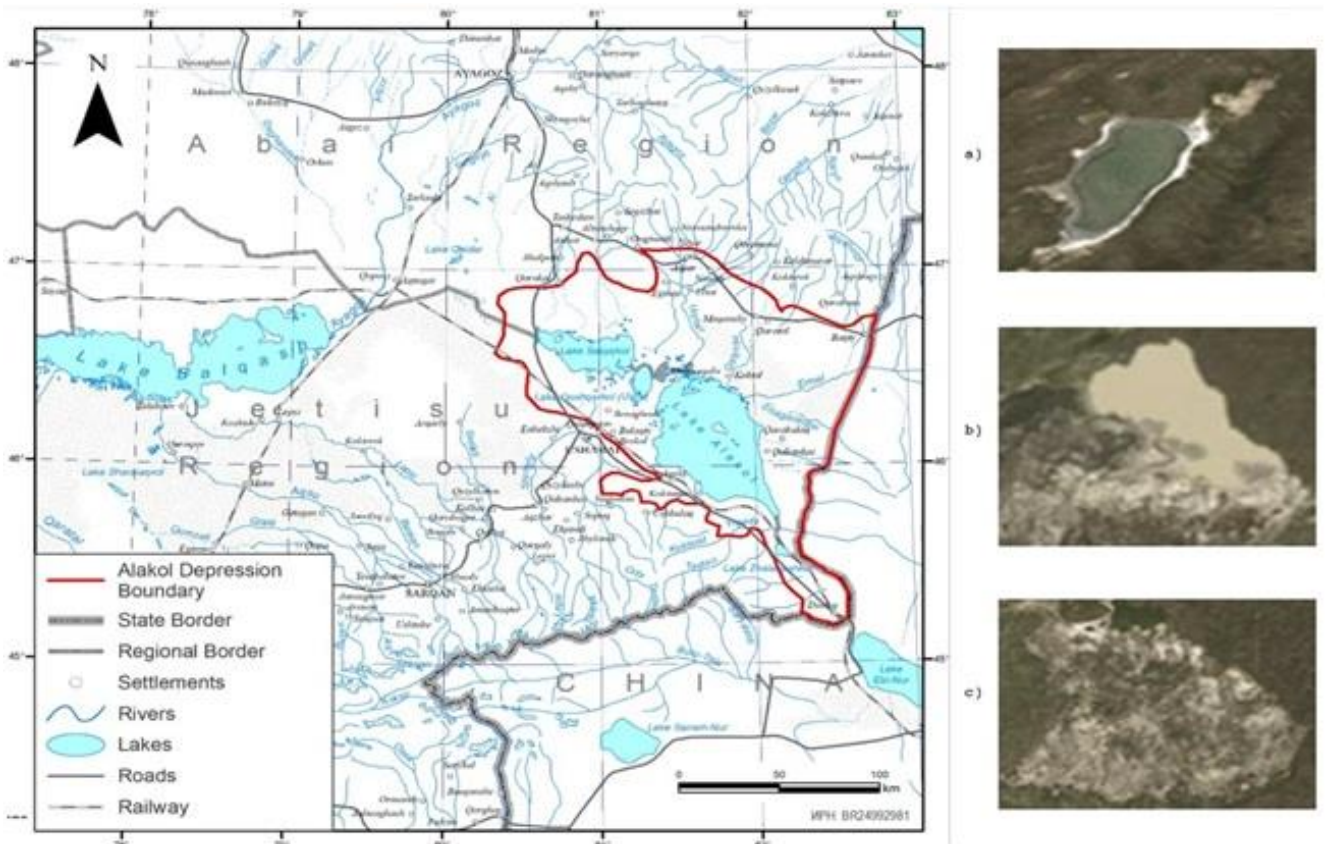


Figure 1. Geographical location of the Ushsor deposit within the Balkhash-Alakol basin, Eastern Kazakhstan
(Note: Author's compilation based on remote sensing data: (a) northwestern part of the Ushsor deposit; (b) northern part of the Ushsor deposit; (c) southeastern part of the Ushsor deposit) (Source: Google Satellite imagery, 2025, accessed via SAS.Planet)

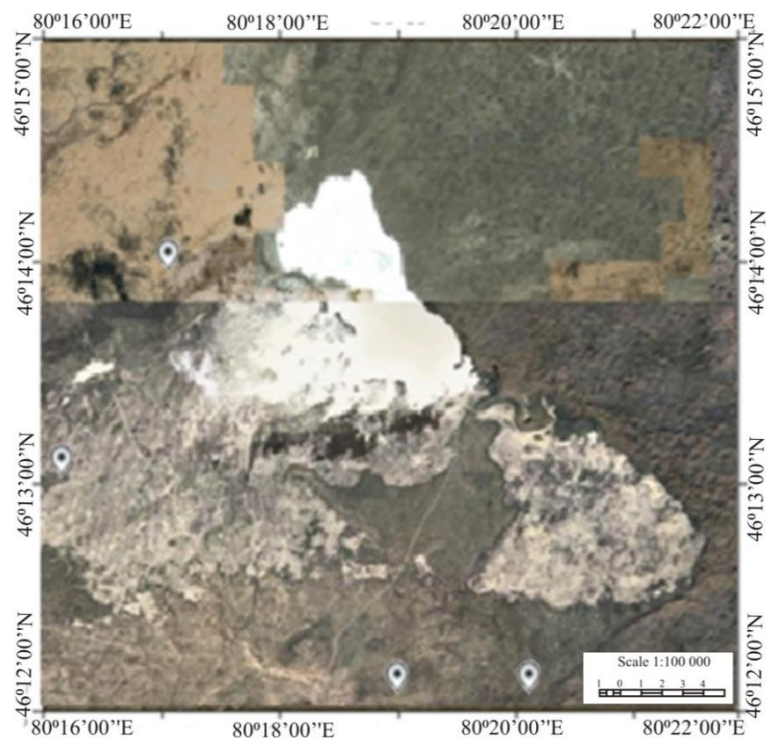


Figure 2. Geographical coordinates of the Ushsor therapeutic mud and brine deposits

Fieldwork Design and Sampling Strategy

Field investigations were conducted during 2024–2025. A total of 25 samples were collected from 12 sampling points distributed across the deposit at intervals of approximately 400 m, ensuring the spatial representativeness of the study. This sampling design allowed for the coverage of areas with varying degrees of mineralization, differing proportions of open brine, salt crust, and silt deposits, and enabled the identification of intra-deposit heterogeneity in the conditions of peloid formation. Of the total sample set, 13 samples represented peloids (bottom sediments) and 12 samples represented brine, collected from corresponding locations in order to enable a comparative assessment of the solid and liquid phases of the deposit.

Peloid samples were collected from the upper active layer of bottom sediments at a depth of 10–20 cm, corresponding to the zone of contemporary therapeutic mud formation. To prevent secondary contamination, inert plastic and metal tools were used during sampling. Each sample was prepared as a composite sample, consisting of several point subsamples collected within an area of 1–2 m². This approach enhanced sample representativeness and reduced the influence of local microfacies variability. At each sampling point, the composite sample was formed by combining 3–5 subsamples, which allowed minimizing the effect of local sediment heterogeneity and increasing the analytical representativeness of the material. Brine samples were collected simultaneously at the same sampling points.

All samples were placed in sealed polymer containers, labelled, and transported to the laboratory under conditions that prevented desiccation and structural alteration of the material.

The sampling scheme – 25 samples from 12 locations at a depth of 10–20 cm – ensured consistency and reproducibility of the field data. Brine samples were taken from the near-surface liquid phase directly above the sediment–water interface or from shallow brine accumulations within the same microenvironment as the peloid samples.

Sample Preparation

Under laboratory conditions, the samples were air-dried at a temperature not exceeding 40 °C. Subsequently, the material was homogenized by grinding and sieved through a 1 mm mesh to obtain a uniform analytical fraction. For instrumental analysis, all prepared samples were subjected to repeated analytical measurements, and each determination was performed in triplicate ($n = 3$) to ensure the reliability and reproducibility of the obtained data. The final analytical value for each sample was calculated as the arithmetic mean of the three repeated measurements.

For the determination of bulk chemical composition, sample preparation involved acid digestion using a mixture of nitric and hydrochloric acids, following standard protocols for the preparation of bottom sediment samples.

This preparation procedure is consistent with established practices in peloid research and is widely applied in studies aimed at evaluating their physicochemical and therapeutic properties (Park et al., 2024).

This preparation protocol was applied primarily to peloid samples intended for the determination of bulk elemental and oxide composition. Brine samples were analyzed separately in liquid form according to the relevant analytical procedures for dissolved ionic composition and mineralization.

Laboratory and Analytical Methods

Laboratory analyses were carried out in specialized facilities of the Department of Sanitary and Epidemiological Control of the Zhetysu Region in accordance with the current regulatory framework of the Republic of Kazakhstan (Law of the Republic of Kazakhstan, 2015; On approval of the Sanitary Rules, 2023). The original study design referred to national standards, including GOST ISO 22036-2014, ST RK 2.629-2019, GOST 26449.1-85 (Clause 4), ST RK 2518-2014, ST RK ISO 581-1-2010, as well as Order No. DSM-32 of the Ministry of Health of the Republic of Kazakhstan dated 21 April 2021. Regulatory documents are not included in the list of references but are retained here as an integral part of the laboratory protocol.

The analytical programme included the determination of macro- and microelement composition of peloids and brine, concentrations of potentially toxic elements, key physicochemical parameters, organoleptic properties, sanitary–microbiological indicators, and radiological characteristics. For peloid samples, the analytical programme specifically included the determination of major oxide components (including SiO₂, SO₃, CaO, Fe₂O₃, MgO, Al₂O₃, K₂O, and Cl), minor and trace elements, potentially toxic elements, pH, moisture-related characteristics, microstructural features, sanitary–microbiological indicators, and radiological parameters. For brine samples, the analysis included the determination of major ionic composition, including sulphates and chlorides, the content of the principal cations, total mineralization, physicochemical indicators, sanitary–microbiological characteristics, and radiological safety parameters.

Atomic absorption spectrometry (AAS) and inductively coupled plasma optical emission spectrometry (ICP-OES; Optima 2000 DV, PerkinElmer, USA) were employed to ascertain the elemental composition of the samples. The analysis focused on elements such as Ca, Mg, Na, K, Fe, Al, Si, Mn, Ti, and Sr, as well as Pb, As, Cr, Co, Ni, and other elements relevant for assessing balneological properties and environmental safety. Analytical determinations for each sample were carried out in triplicate, and the resulting values were averaged prior to statistical processing. The morphology and microstructure of the peloids were examined using a JEOL JSM-IT200 scanning electron microscope (JEOL Ltd., Japan). Sanitary–microbiological and radiological analyses were performed in the accredited laboratories of the Department of Sanitary and Epidemiological Control of the Zhetysu Region according to the applicable national standards. The obtained results were evaluated against current sanitary and hygienic standards. Such an approach is consistent with contemporary requirements for peloid quality control, where chemical, physicochemical, and biological suitability are regarded as interrelated components of a unified assessment framework (Kataržytė et al., 2024).

Descriptive statistical approaches were used to characterize the obtained analytical data. For each parameter, the arithmetic mean values and general variability trends were assessed in order to identify dominant components and

evaluate the degree of spatial heterogeneity within the deposit. Where appropriate, the coefficient of variation (CV) was used as an indicative measure of relative variability. The interpretation of variability was carried out according to commonly accepted thresholds, where values below 10% indicate low variability, values between 10% and 25% moderate variability, and values above 25% high variability. These indicators were applied primarily to identify general patterns in the distribution of major and minor components rather than to perform a detailed statistical comparison.

Data aggregation was performed at the level of individual samples and sampling sites, allowing for a generalized characterization of the deposit while preserving information on spatial differences between sampling locations.

Where necessary, the level of statistical significance ($p < 0.05$) was considered as a reference criterion for interpreting differences in selected parameters; however, the statistical evaluation was primarily oriented towards identifying general trends rather than conducting formal hypothesis testing.

Geocological Assessment Approach

The geocological assessment was carried out based on the integration of physical–geographical, geochemical, sanitary–microbiological, and applied recreational criteria. The key evaluation criteria included compliance with sanitary standards, the content of biologically active and potentially toxic components, the physicochemical suitability of peloids and brine for balneological use, the spatial heterogeneity of the deposit, and the sensitivity of the natural system to recreational development. The assessment framework comprised four sequential stages.

The first stage involved the analysis of the natural conditions governing the formation of the deposit, including climatic aridity, patterns of salt accumulation, contemporary sedimentation processes, and seasonal variations in the hydrological regime.

The second stage focused on the laboratory characterization of the composition and properties of peloids and brine.

The third stage addressed the evaluation of sanitary and environmental safety.

The fourth stage was oriented towards the applied interpretation of the obtained results in the context of sustainable wellness tourism. This approach is consistent with the contemporary international research agenda, in which natural therapeutic resources are increasingly considered not in isolation but as integral components of sustainable wellness destinations, requiring the simultaneous consideration of resource quality, visitor experience, and environmental sustainability (Karagianni et al., 2025; Rosalina et al., 2026).

RESULTS AND DISCUSSION

Natural–Geological and Field Characteristics of the Ushsor Deposit

Field investigations conducted in 2024–2025 indicate that the Ushsor deposit was formed under arid climatic conditions dominated by processes of intense evaporation, salt accumulation, and contemporary sedimentation. The formation of peloids is associated with periodic moisture input from meltwater and groundwater, followed by desiccation during the summer season, leading to the accumulation of sulphide compounds and a high degree of mineralization. A pronounced spatial heterogeneity of environmental conditions is observed within the deposit. In the north-western sector, a salt crust develops, beneath which sulphide silt sediments occur with a thickness of up to 1 m. In contrast, the central and peripheral areas are characterized by looser and less mineralized deposits. The peloids are represented by dark grey to black silty masses with a characteristic colloidal structure and high plasticity. The organo-mineral matrix exhibits a fine-dispersed structure, contributing to high sorption capacity and moisture retention.

Physicochemical and Elemental Composition of Peloids

Laboratory analyses showed that the peloids of the Ushsor deposit are characterized by a complex multicomponent chemical composition, including a broad range of major and trace elements.

The predominant fraction is represented by oxide compounds. The main components identified in the peloids are as follows: SiO_2 – 31.63%, SO_3 – 20.34%, CaO – 14.69%, Cl – 9.85%, Fe_2O_3 – 7.39%, MgO – 5.54%, Al_2O_3 – 5.36%, and K_2O – 3.20%. Together, these components account for approximately 98% of the total chemical composition, indicating a stable mineral structure of the studied material (Figures 3 and 4).

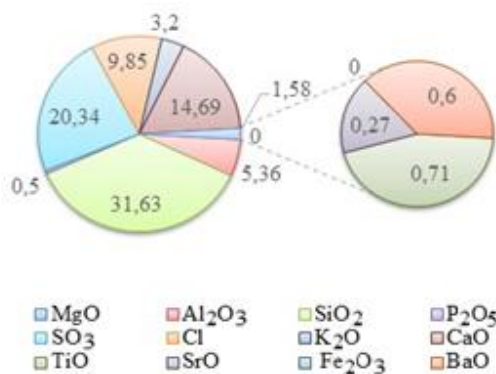


Figure 3. Chlorine and dominant oxides in the composition of peloids from the Ushsor deposit

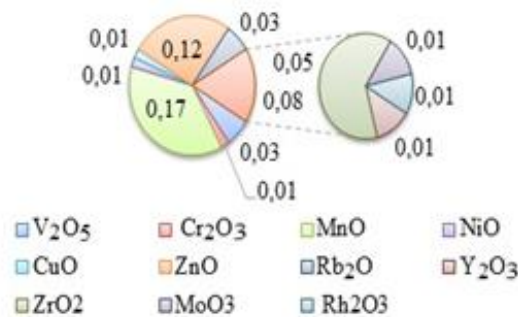


Figure 4. Minor chemical constituents in the composition of peloids

Minor components, including TiO, MnO, ZnO, V₂O₅, BaO, SrO, ZrO₂, Cr₂O₃, NiO, and CuO, were recorded in substantially lower concentrations, ranging from 0.01% to 0.71%. Their occurrence reflects the geochemical complexity of the deposit, while their concentrations remain markedly lower than those of the dominant oxide compounds. Particular attention was given to potentially toxic elements. The analysis demonstrated that the concentrations of Pb, As, Cr, Ni, Co, and related components did not exceed the established sanitary and hygienic threshold values. This confirms the environmental safety of the peloids with respect to the analyzed toxicological indicators.

Descriptive statistical analysis revealed low to moderate variability in the major oxide composition. The coefficient of variation (CV) for the dominant components (SiO₂, SO₃, and CaO) ranged from 8% to 18%, indicating relatively stable geochemical conditions of formation. In contrast, minor elements showed higher variability (CV > 25%), reflecting localized geochemical heterogeneity within the deposit. Overall, the Uhsor peloids are distinguished by a favorable balance of macro- and microelements and by a stable oxide-dominated composition, which supports their classification as a promising natural resource for balneological use.

Chemical Composition and Mineralization of Brine

The brine of the Uhsor deposit is formed under conditions of intense evaporation and occupies a significant portion of the lake area during the summer period (Figure 5). Chemical analysis indicates that sulphate compounds (SO₃) constitute 54.28%, chloride compounds (Cl) 43.91%, and other components approximately 1.81%.

The dissolved phase is represented by sodium, calcium, and magnesium salts, as well as organic substances formed as a result of microbiological processes. The Uhsor brine is characterized by a high degree of mineralization. The chemical composition of the brine showed low variability for major ions, with CV values below 10%.

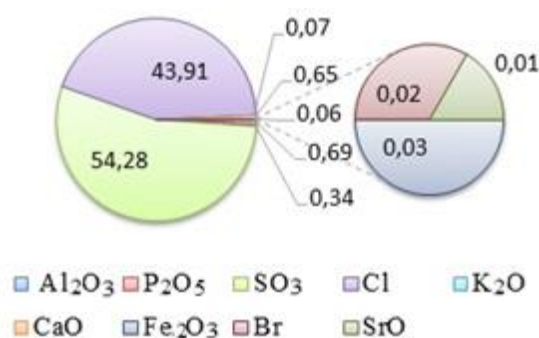


Figure 5. Proportion of chemical compounds in the brine of the Uhsor deposit

Sanitary–Microbiological Indicators

Microbiological analyses demonstrate that the peloids and brine comply with established sanitary and hygienic standards. No coliform bacteria, *Clostridium perfringens*, pathogenic microflora, or helminth eggs were detected in the analyzed samples (Table 1).

The concentrations of radionuclides, including radium-226, thorium-232, uranium-238, strontium-90, and caesium-137, were found to be within permissible limits. The total specific activity remains below regulatory thresholds.

Table 1. Sanitary–microbiological and radiological characteristics of Uhsor peloids and brine
Note: Regulatory limits are based on national sanitary standards of the Republic of Kazakhstan

Indicator	Sample type	Result	Regulatory requirement	Compliance
Coliform bacteria	Peloids	Not detected	Absence required	Yes
Coliform bacteria	Brine	Not detected	Absence required	Yes
<i>Clostridium perfringens</i>	Peloids	Not detected	Absence required	Yes
Pathogenic microflora	Peloids	Not detected	Absence required	Yes
Helminth eggs	Peloids	Not detected	Absence required	Yes
Ra-226	Peloids	Within permissible limits	≤ maximum permissible level	Yes
Th-232	Peloids	Within permissible limits	≤ maximum permissible level	Yes
U-238	Peloids	Within permissible limits	≤ maximum permissible level	Yes
Sr-90	Brine	Within permissible limits	≤ maximum permissible level	Yes
Cs-137	Brine	Within permissible limits	≤ maximum permissible level	Yes
Total specific activity	All samples	Below limits	≤ maximum permissible level	Yes

Geocological Suitability for Wellness Tourism

The integrated assessment of natural, physicochemical, and sanitary characteristics indicates that the Uhsor deposit possesses a high geocological potential. Key factors include favorable mineral composition of the peloids, high mineralization of the brine, absence of exceedances in toxicological indicators, and confirmed sanitary–microbiological safety. At the same time, constraints include limited transport accessibility, lack of developed tourism infrastructure, and the need for environmental monitoring. The Uhsor deposit can be considered a potential resource base for the development of wellness tourism in the Alakol Basin.

CONCLUSION

The obtained results confirm that the Ushsor deposit represents a typical sulphide silt peloid system formed under arid conditions with intensive evaporation and salt accumulation. Similar formation mechanisms have been reported for saline lake environments in Southern Europe and the Mediterranean region, where peloids develop under conditions of seasonal drying and high mineralization (Pasquini et al., 2025).

In comparison with European peloid deposits, the Ushsor muds demonstrate a comparable predominance of silica, calcium, and sulphur compounds, which are considered key components determining the physicochemical stability and therapeutic potential of natural muds (Carretero et al., 2020; Maraver et al., 2021; Park et al., 2024). However, unlike coastal lagoon systems, the Ushsor deposit is characterized by a more pronounced continentality and stronger seasonal fluctuations in the water regime, which influence the spatial heterogeneity of sediment accumulation.

The high mineralization and sulphate–chloride composition of the brine are consistent with findings from other salt lake systems in arid and semi-arid regions, where evaporative concentration processes dominate hydro chemical evolution (Mourelle et al., 2025; Kataržytė et al., 2024; Mukayev et al., 2024). These characteristics are widely recognised as favourable for balneological applications, particularly in therapeutic and wellness contexts (Akhmedenov & Khalelova, 2021). At the same time, modern balneological research emphasizes that the presence of favorable physicochemical properties alone does not guarantee therapeutic efficacy. International studies highlight the necessity of site-specific verification, standardization of application protocols, and strict environmental control (Keilani et al., 2025). In this regard, the Ushsor deposit should be considered as having high potential rather than proven clinical effectiveness.

An important finding of this study is the spatial heterogeneity of the deposit. This feature has also been documented in other saline lake systems and is considered a key factor in resource management and sustainable use. From a geoecological perspective, this necessitates a zoned approach to the development of the territory, taking into account the variability of sediment properties and environmental sensitivity.

The conducted study demonstrated that the peloids and brine of the Ushsor deposit represent a valuable natural resource of the Alakol Basin, characterized by high geoecological and balneological potential. The peloids were identified as moderately mineralized sulphide silt therapeutic muds, exhibiting a favorable composition of macro- and microelements, with no exceedances of potentially toxic components. Their composition is dominated by silicon oxides, sulphur-containing, calcium, iron, and magnesium compounds, forming a stable mineral structure. The brine is characterized by a high degree of mineralization and the predominance of sulphate–chloride compounds, which enhances its balneological significance. These fundamental characteristics are supported by the field and laboratory data obtained in this study.

Sanitary–microbiological and radiological indicators confirm the environmental safety of the investigated natural resources. The absence of pathogenic microflora, parasitological contamination, and exceedances in controlled radiological parameters indicates that the deposit may be considered suitable for therapeutic and wellness applications, provided that appropriate monitoring and regulatory standards are maintained. An important outcome of the study is the identification of spatial heterogeneity within the deposit, which necessitates a differentiated approach to its development. Ushsor should not be regarded as a fully homogeneous resource; rather, its rational utilization requires consideration of intra-deposit variability, natural constraints, and permissible levels of recreational load.

The applied importance of the research lies in the possible presentation of the obtained outcomes for the elaboration of environmentally oriented strategies for sustainable wellness tourism in the Alakol Basin. Future research should focus on expanding the sample base, conducting seasonal observations, incorporating the analysis of mobile forms of elements, and refining the spatial zoning of the deposit with regard to the environmental resilience of individual areas.

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