IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Design & Nature and Ecodynamics
Vol. 19, No. 5, October, 2024, pp. 1815-1825
Journal homepage: http://iieta.org/journals/ijdne

Hydrochemical Analysis of Salt Lakes in the Caspian Lowland of the Mangistau Region of the Republic of Kazakhstan

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https://doi.org/10.18280/ijdne.190537

Received: 9 September 2024
Revised: 11 October 2024
Accepted: 18 October 2024
Available online: 29 October 2024

Keywords:
salt lakes, hydrochemical analysis, heavy metals, anion, cation, Caspian Sea, Mangistau region, environmental monitoring

ABSTRACT

The article carried out a hydrochemical analysis of the content of cations and anions, as well as heavy metals in different volume salt reservoirs of the Mangistau region: the Caspian Sea, the Salt Lake Malaya Oymasha and the Radon thermal spring. The results of the analysis show that in all three reservoirs the contents of such heavy metals as chromium, manganese, cobalt, nickel, copper, lead, zinc and cadmium do not exceed the maximum permissible concentrations and are in minimum contents. Hydrochemical analysis shows that in terms of cation content, the minimum values are characteristic of potassium and sodium ions and the data for all three reservoirs are almost the same and are about 3 mg/kg for potassium and 9 mg/kg for sodium, respectively. The content of calcium and magnesium in two reservoirs is higher than magnesium ions, in the Salt Lake Malaya Oymasha and the Caspian Sea. In a radon hot source, calcium ions are higher, and magnesium is 3.5 times less. Salt Lake Malaya Oymasha which is 1.2 times higher than in the Caspian Sea and 5.6 times in comparison with the Radon thermal source. For anions, the highest values are characteristic of chloride ions, which is 8.14 times higher than the content of sulfate ions and 24.8 times of hydrocarbonate ions. Then, sulfate ions and hydrocarbonate ions are decomposed by the anion content. The analyses show that chloride and magnesium ions are the main salt-forming ions in the Caspian Sea, chloride and calcium ions in the Salt Lake Malaya Oymasha and the Radon hot spring in the salt reservoirs of the Mangistau region. The results of the analysis can be used for scientific research aimed at understanding the hydrogeochemistry of the region and the impact of anthropogenic activities on water resources. The quality of water in salt water bodies can affect the development of tourism in the region. The results of the analysis can help promote water bodies as safe and attractive places to relax.

1. INTRODUCTION

Salt lakes, an amazing natural phenomenon, are found on all continents [1]. It is customary to refer to salt lakes in which the salt content in the water exceeds their content in the ocean water, i.e. more than 3.5%. However, lakes are also considered saline, the condition of which varies seasonally and with the alternation of arid and humid years — from a lake with slightly salty water to a salt marsh with a crust of salt. Salt lakes also include small lakes that are several meters across [2].

Salt lake studies are important for such scientific disciplines as ecology (for example, issues of the poverty of the species composition of hydrobionts, simplified trophic relationships, etc.), physiology of aquatic organisms (problems of their adaptation to extreme conditions), evolutionary biology (for example, problems of enzymatic action on gallophiles), hydrophysics and hydrochemistry (patterns and features of formation thermohaline structure), as well as for the development of non-traditional methods of resource-saving technologies and environmental protection [3]. Salt Lake ecosystems can be defined as relatively discrete areas of nature, where causal interdependent relationships between all components are noted, where energy flows are distributed along certain paths and where biochemical cycles are essential elements of the ecosystem. The salinity of the reservoir and the species diversity of aquatic organisms in it are interrelated. The number of hydrobiont species and their species diversity are consistently decreasing from freshwater reservoirs to meso- and hypersalted reservoirs. A number of physical and chemical environmental conditions distinguish salt lakes regardless of the fact that their mineralization exceeds 3g/kg. For freshwater or marine aquatic organisms, the abiotic conditions of salt lakes exceed all acceptable limits of their survival and therefore their biota must adapt to conditions of high salinity, high temperature and light intensity, low oxygen concentration, variability of hydrological conditions and isolation. Adaptation to these conditions takes place in different ways in different taxonomic groups. When adapting to high levels of salinity, protozoa develop only an increase in cellular tolerance. Other organisms are divided into two types: those that possess osmosis consistency and those that possess the ability to osmoregulate.

Hydrochemical analysis of salt lakes in the Caspian lowland of the Mangistau region of the Republic of Kazakhstan is important for the following reasons:

Uniqueness of water bodies: Salt lakes of the Caspian lowland are unique ecosystems with a high level of biodiversity and endemic species. Hydrochemical analysis is necessary to understand their chemical composition and maintain their ecological health.

Economic importance: Salt lakes are a source of valuable mineral resources such as salts, bromine and iodine. Hydrochemical analysis helps to assess their economic potential and develop sustainable mining methods.

Effects on human health: Salt lakes are often used for recreational purposes such as bathing and mud therapy. Hydrochemical analysis makes it possible to assess the quality of water and its safety for human health.

Climate change: Salt lakes are sensitive to climate change, which can lead to changes in their chemical composition and ecosystems. Hydrochemical analysis helps track these changes and develop adaptation measures.

Scientific research: The results of hydrochemical analysis can be used for scientific research aimed at understanding the hydrogeochemistry of the region and the role of salt lakes in the ecosystems of the Caspian lowland.

Scientists suggest that millions of years ago, the entire Mangystau region was located at the bottom of the ancient ocean of Tethys [4]. This also explains the diversity of the landscape: plateaus, depressions, deserts, mountains and mountain ranges. And also, unique reservoirs and sources.

The Caspian basin is a flat loamy plain with extensive development within its limits of sorov (shore) and estuarine basins occupied by mineral lakes and salt marshes [5]. The chain of estuaries and sores of the Caspian lowland is a relic of the previously existing river hydrographic network, the topographic surface of the seabed, coastal ramparts and terraces of the retreating sea. The coastline of the Caspian Sea within the Caspian lowland is strongly indented by small bays (kultuks) and deltas of the Kura, Terek, Kuma, Volga, Ural, Emba and other smaller rivers. There are sub-basins in the Caspian basin: Primorsky, Delta, Mangyshlak, Kara-Bogaz, Chagishlyar, etc. These landscape facies are stretched out in a narrow strip 10-12 km wide around the Caspian Sea, and the delta basins have a peculiar landscape of the primary surface of the accumulative marine plain, modified by the work of "blind" rivers that do not have runoff into the sea. These are the landscapes of the delta sub-basins of the Volga, Kura, and Ural rivers [6-8].

The Caspian Sea (Figure 1) belongs to the brackish-water basin. It is completely separate from the World Ocean, so it cannot be salinity considered a sea: it is something in between a lake and a sea body. Its water tastes brackish, but, due to the special geographical and hydrological characteristics of the reservoir, its enrichment with salts and chemical elements, it is not identical to oceanic waters. It contains less sodium salts and chlorides, but more carbonates and sulfates of calcium and magnesium. Such a "cocktail" is obtained thanks to river and underground infusions. Sulfuric acid compounds make its taste bitter-salty, unlike the water of real seas [9].

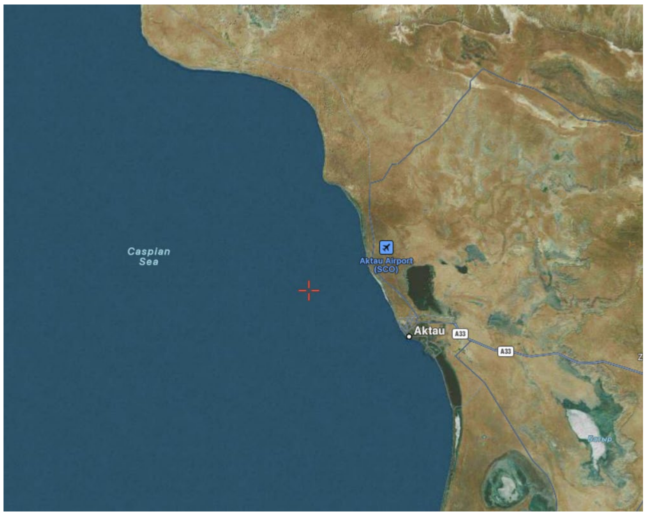


Figure 1. Location of the Caspian Sea coast of Aktau in Mangystau region

There are many rumors about the "dead lake" Malaya Oymasha, located in the suburbs of Aktau (Figure 2): it is supposedly radioactive and served as a sump before Koshkar-Ata. The water in it is salty and multi-colored. There are several versions about the origin of this reservoir, but there are no exact answers to the questions, hence doubts about its safety for the nearest settlements. In spring and autumn, Salt Lake Malaya Oymasha was painted in an unnatural pink color; during the wind surge, foam up to 1 meter high was formed here.

Figure 2. Salt Lake Malaya Oymasha location

In Mangistau, a place where you can swim year-round and this is a radon source. This place is located about 40 kilometers from the city of Aktau (Figure 3). The source was discovered in the last century, and for more than one year it has been pleasing residents and guests of the city with its hot water, the temperature of which is kept in the region of 40-50 degrees.

The geographical features of the Caspian basin and its sub-basins affect the hydrochemistry of the studied lakes by changing its salinity, which varies depending on their proximity to the Caspian Sea and the sub-basin in which they are located. Lakes closer to the sea have higher salinity than lakes farther away. The chemical composition of the lakes also depends on the sub-basin in which they are located. Lakes in the North Caspian sub-basin have a lower salt concentration than lakes in the Middle Caspian and South Caspian sub-basins. The geographical location of the lakes also affects the sources of pollution. Lakes located near population centers and industrial areas are more prone to pollution than lakes located in remote areas.

Figure 3. Location of Radon hot spring

Understanding these geographic features and their impact on lake hydrochemistry is critical to developing effective management strategies and protecting these unique ecosystems.

2. MATERIAL AND METHODS

2.1 Study area

Field studies of salt lakes were carried out in the Mangistau region of the Republic of Kazakhstan. The city of Aktau, Mangistau region, is located in the western part of the Republic of Kazakhstan on the shores of the Caspian Sea. For comparative analysis, three sources were investigated: the waters of the Caspian Sea on the coast in 1 and 4 microdistricts of the city of Aktau, the Salt Lake Malaya Oymasha and the Radon hot spring.

Aktau is a port city in western Kazakhstan on the shores of the Caspian Sea, the regional center of Mangistau region. The city is located on the shores of the Caspian Sea. Despite the name and the fact that the water in the Aktau Sea is brackish - the Caspian is not a sea. This is an inland closed reservoir.

Lake Malaya Oymasha, located at the junction of the territories of the city of Aktau and the village of Atameken, has several unofficial names - "Sump," "Dead Lake," "Rose Lake." The peculiarity of this lake is that it is painted in pink tones. The area of the lake is 62 hectares. The reservoir is surrounded by residential areas consisting of private houses. These are the residential sector of the villages of Priozerny 1, 2 and 3 and the Shagala housing estate, as well as several settlements of the Munailinsky district.

A feature of the radon source on Mangistau is that it is natural, located right in the open. The water in the spring reaches 50 degrees Celsius.

The locations of the study lakes are presented in Table 1.

Table 1. Coordinates of the Mangistau salt lakes of the Republic of Kazakhstan

No.	Reservoir	Location
1	Caspian Sea in Mangistau region	43.6243° 51.197888
2	Salt Lake Malaya Oymasha	43.651349° 51.198105
3	Radon Hot Spring	43.350536°51.337479

2.2 Methods

Water samples were taken at each of the lakes for two years in two positions: 0.5 m from the surface and 0.5 m from the bottom. Samples were taken from each lake: in plastic bottles with a volume of 1.5 liters. In the amount of 2 pcs., 1 tube for analysis for the content of trace elements. When taking water samples, the bottles are rinsed twice with lake water and completely filled to the cover so that there is practically no air in them. Each bottle has a label. Samples were taken and preserved in accordance with SS 31861-2012 "Water. General requirements for sampling." and S RK ISO 5667-9-2013 "Water quality sampling" [10], which applies to any type of water and establishes general requirements for the collection, transportation and preparation for storage of water samples intended to determine its composition and properties. During sampling, a list was kept, a brief description of sampling is given in Table 2.

Table 2. Summary of water sampling

Sampling Point	Sampling Date	Sample Volume, Liters	Number of Samples	Sample Volume, Liters	Number of Samples
Caspian Sea	July 2023, July 2024	1.5	2	0.05	1
Salt Lake Malaya Oymasha	July 2023, July 2024	1.5	2	0.05	1
Radon Hot Spring	July 2023, July 2024	1.5	2	0.05	1

The analysis of the chemical composition of water was carried out by the current SSs (State Standard), S RK (Standard Republic of Kazakhstan), ER F (Environmental Regulations Federal) and methods of the Republic of Kazakhstan. The content of potassium ions, sodium ions, calcium ions, magnesium ions and hydrogen carbonate ions were determined in accordance with SS 26449.1-85 "Methods of chemical analysis of salt water" [11]. The content of chloride ions was determined according to S RK ISO 9297-2008 "Water quality. Determination of chloride content. Titration with silver nitrate with chromate indicator (Mohr method)" [12]. sulfate ions according to S RK 1015-2000 "Water. Graphimetric Method for Determination of Sulfate Content in Natural Wastewater" [13]. The content of heavy metals is determined according to ER F 14.1: 2.253-09 "Procedure for Measuring Mass Concentrations of Aluminum, Barium, Beryllium, Vanadium, Iron, Cadmium, Cobalt, Lithium, Manganese, Copper, Molybdenum, Arsenic, Nickel, Tin, Lead, Selenium, Strontium, Titanium, Chromium, Zinc in Natural and Wastewater by Atomic Absorption Spectroscopy

Using an Atomic Absorption Spectrometer with Electrothermal Atomization MGA-915" [14].

Carbonates and hydrocarbonates in terms of weight of carbonate and hydrocarbonate ions are determined by sequential acidimetric titration: visually - with phenolphthalein and methyl orange indicators. The method is used to determine the mass concentration of carbonates from 20 mg/dm3 and more and hydrocarbonates from 50 mg/dm^3 and more. The chlorides are titrated with a silver ion solution to form insoluble silver chloride which precipitates quantifiable. Adding a small excess amount of silver ions to form a red-brown silver chromate with chromate ions added as an indicator. This reaction is used to indicate the end point of the titration. The hydrogen value is maintained between 5-9.5 during titration to allow precipitation to occur. Calcium and magnesium are titrated with trilon B with an indicator - black chromogen. The influence of iron and aluminum is eliminated by the addition of triethanolamine; nickel, copper and zinc by adding sodium sulphide; manganese - by addition of hydroxylamine hydrochloride; carbonates and hydrocarbonates - by boiling hydrochloric acid solution; ammonium salts - by boiling of alkaline solution. The method is used to determine the total hardness with a molar concentration of equivalent C (1/2Ca^{2+}, 1/2Mg^{2+}) from 0.2 mmol/dm^3 or more. The lower detection limit is 0.02 mmol/dm^3. Calcium is titrated in alkaline medium (12 pH) with Trilon B solution with murexide indicator. The method is used to determine the mass concentration of calcium from 20 mg/dm^3 and more. The lower detection limit is 3.0 mg/dm^3. The sum of calcium and magnesium is titrated with Trilon B solution in the presence of ammonium-ammonia buffer solution (9-10 pH) with black chromogen indicator. When processing the results, the volume of Trilon B solution used to determine calcium is taken into account. The method is used to determine the mass concentration of magnesium from 20 mg/dm^3 and more. The lower detection limit is 2.0 mg/dm^3. Sulphates are precipitated from hot hydrochloric acid solution with barium chloride solution. The barium sulfate precipitate was collected by filtration, calcined and weighed. The method is used to determine the mass concentration of sulfates from 80 mg/dm^3 and more. The lower detection limit is 9.0 mg/dm^3. The method is based on precipitation of sulfate ion in a hydrochloric acid medium with barium chloride in the form of barium sulfate. Optimum content of sulphate ion, which allows determination from the volume of 10-100 cm^3, is 30-300 mg/dm^3. Interferences of suspended matter, colloidal and humic substances, iron (+3), sulphides, chromium are eliminated during the analysis. Lower limit for determination of sulfate ion - 20 mg/dm^3. Sodium in the test solution is determined by the change in the Electromotive force of a chain consisting of a sodium selection electrode, a reference electrode, a measuring cell with the test solution and a laboratory pH meter or ionomer. The effect of salts present in the test solution is taken into account by plotting a calibration curve against the background of the simulating solution. The method is used to determine the mass concentration of sodium from 200 mg/dm^3 and more in the range of 6-8 pH of the test and simulating solutions. The lower detection limit is 23 mg/dm^3. Potassium in the test solution is determined by the change in the Electromotive force of the chain consisting of a potassium selective electrode, a reference electrode, a measuring cell with the test solution and a laboratory pH meter or ionomer. The method is used to determine the mass concentration of potassium from 4 mg/dm^3 and more. The lower detection limit is 0.4 mg/dm^3.

Ferric ions form a complex compound with sulfosalicylates, the solution of which in an alkaline medium is colored yellow. Bivalent iron under anal conditions goes into trivalent iron. The absorbance of the solution is measured on a photoelectrocolory meter. The method is used to determine the mass concentration of iron from 200 mg/dm^3 and more. The lower limit of detection is 40 mg/dm^3. The test solution is treated with sodium diethyldithiocarbamate solution, resulting in a yellow-brown precipitate of copper diethyldithiocarbamate, which is extracted with chloroform. The absorbance of the solution is measured using a photoelectrocolorimeter. Influence of nickel, manganese and iron is eliminated by addition of solutions of trilon B and citric ammonium. To eliminate the effect of oil products, preliminary extraction is carried out without adding sodium diethyldithiocarbamate. The concentrations of chromium, cobalt, nickel, copper, lead, cadmium and manganese compounds were determined by the atomic absorption method using the MGA-915M electrothermal atomization spectrometer. Range of determined contents, mg/dm^3: Nickel from 0.015 to 0.05, Chromium from 0.02 to 0.25, Zinc from 0.004 to 0.01, Cadmium from 0.005 to 0.05, Lead from 0.02 to 0.15, Copper from 0.01 to 0.1, Cobalt from 0.015 to 0.35, Manganese from 0.01 to 0.05, Drinking iron and natural water from 0.01 to 0.025.

The water of salt lakes is a complex and highly dynamic physicochemical system, the ratio of elements in which depends on the concentration of dissolved salts, which, in turn, depends on the composition of the rocks of the lake basin, the nature of bottom silts, climatic factors and their corresponding weathering and soil formation processes [15]. In a single process of salt accumulation in the Salt Lake zone, salt accumulation in surface and underground waters, in soil waters and accumulation of solid salts in lake basins are distinguished. In groundwater, salt accumulation depends on the intensity of evaporation. The main ions of the chemical composition of salt lakes, which determine salinity (mineralization), are essentially the same as for fresh lakes: monovalent cations Na^+ and K^+, divalent cations Ca^{2+} and Mg^{2+}, anions Cl^-, SO_4^{2-}, HSO_3^- and CO_3^-. In the composition of salt lakes, Na^+ and Cl^- ions have the highest specific gravity, followed by SO_4^{2-}, HCO_3^- and CO_3^- ions. In general, as shown by numerous studies in the water of salt lakes, five combinations of ions are most common [16]:

Main Cation	Main Anions
Na^+	Cl^-
Na^+	$Cl^->CO_3^-$
Na^+	$Cl^->SO_4^{2-}$
Na^+	$HCO_3^-+CO_3^-$
Na^+	$HCO_3^-+CO_3^->Cl^-$

Based on such ratios, salt lakes were classified as chloride, chlorocarbonate, chlorosulfate, carbonate or carbonate-chloride lakes.

Over time, the ratio of ions can change: as salts accumulate, certain physicochemical conditions are created when the solubility limits of this combination of salt ions are exceeded and they precipitate, or when brines evolve over a long period under the influence of tributary waters. In this case, their composition changes under the influence of the initial sources of chemicals brought by surface runoff: salts of precipitation, geological deposits, leaching of rocks, hydrothermal springs or relict sea waters.

Long periods of humidification contribute to the dissolution of reserves of root salt and the removal of excess salts by runoff outside the lake basin, and long periods of low humidification led to a loss of lake flow, an increase in salt concentration and the formation of a saturated solution (brine) with the subsequent precipitation of salts in the carbonate-sulfate-chloride sequence and the formation of deposits of root salts.

According to the composition of lake brine, mineralized waters, and, accordingly, the salt lakes enclosing them, are divided into three main chemical types: carbonate, sulfate and chloride. The carbonate type is characterized by the following salt structure: Na_2CO_3, $NaHCO_3$, Na_2SO_4, $NaCl$, $MgCO_3$, $CaCO_3$. Sulfate type is divided into two "subtypes: sodium sulfate with a composition of Na_2SO_4, $NaCl$, $Mg(HCO_3)_2$, $MgSO_4$, $Ca(HCO_3)_2$, $CaSO_4$; sulphate-magnesium (chlorine-magnesium) with composition $NaCl$, $Mg(HCO_3)_2$, $MgSO_4$, $MgCl_2$, $Ca(HCO_3)_2$, $CaSO_4$. Each of the sub-types can be divided into two groups according to the relative richness of HCO_3^- ions relative to Ca and Mg ions. Chloride type is characterized by the composition: $NaCl$, $MgCl_2$, $Ca(HCO_3)_2$, $CaSO_4$, $CaCl_2$.

3. RESULTS AND DISCUSSION

In salt lakes of different volumes and different origin, hydrochemical analysis was carried out for ions and heavy metals.

The results for heavy metal content are presented in Table 3.

According to the data of Table 1, the content of heavy metals in the salt lakes of the Mangistau region does not exceed the maximum permissible concentrations.

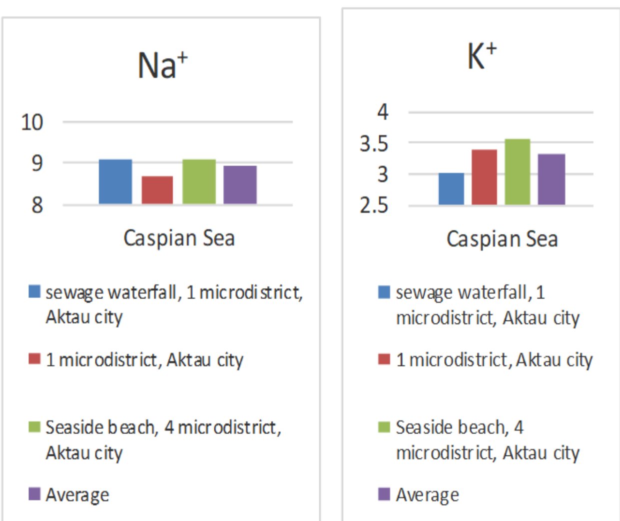
Table 3. Content of heavy metals in salt lakes of Mangystau region

Name of the Indicator to be Determined	MAC, mg/L	Caspian Sea	Salt Lake Malaya Oymasha	Radon Source
Chrome	0,5	<0,005	<0,005	<0,005
Manganese	0,1	<0,002	<0,002	<0,002
Cobalt	0,01	<0,0005	<0,0005	<0,0005
Nickel	0,1	<0,005	<0,005	<0,005
Copper	0,1	<0,0005	<0,0005	<0,0005
Lead	0,03	<0,002	<0,002	<0,002
Zinc	1,0	<0,1	<0,1	<0,1
Cadmium	0,001	<0,0001	<0,0001	<0,0001

3.1 Hydrochemical analysis of the Caspian Sea

Figures 4 and 5 present analyses of cation and anion content in the waters of the Caspian Sea.

On the coast of the Caspian Sea, the content of sodium ions is close to 9 mg/l and the average value is 8.96 mg/l, the content of potassium ions is also small with an average value of 3.32 mg/l. The remaining two cations are much higher than the content of the first two cations, so the content of calcium ions ranges from 340 to 680 mg/l with average values of 506.7 mg/l. The highest values are characteristic of magnesium ions, the content of which varies from 726 to 1416 mg/l, with an average value of 1024 mg/l.



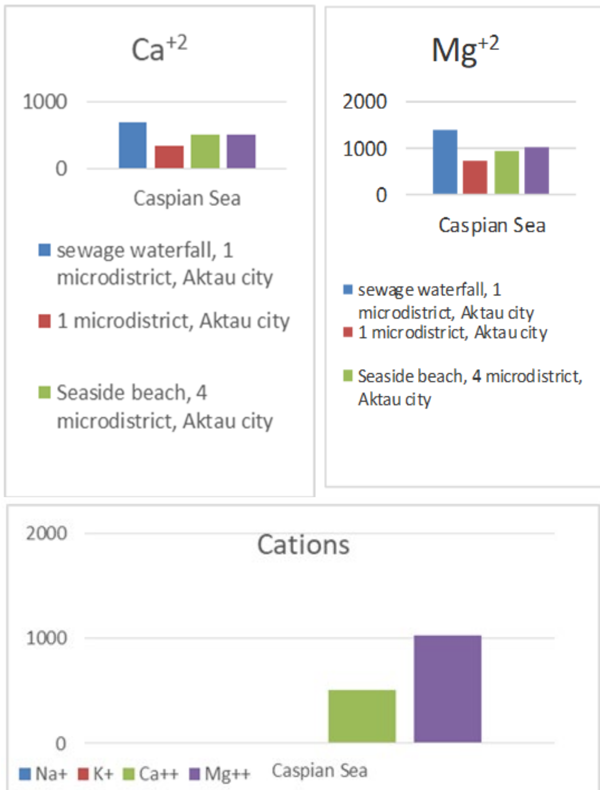


Figure 4. Cation content in the Caspian Sea

By the content of anions in the Caspian Sea, the maximum values are characteristic of chloride ions, the content of which ranges from 4254 to 12196 mg/l, with average values of

9241.3 mg/l. In second place in terms of anion content are sulfate ions, the content of which ranges from 571.7 to 1524.5 mg/l with average values of 1135.2 mg/l. The minimum values are typical for hydrocarbonate ions, the content of which is 280.6-335.5 mg/l, with average values of 372.1 mg/l.

Elevated levels of calcium and magnesium cations and chloride anions show that the following salts predominate in the Caspian Sea: magnesium chloride and calcium chloride.

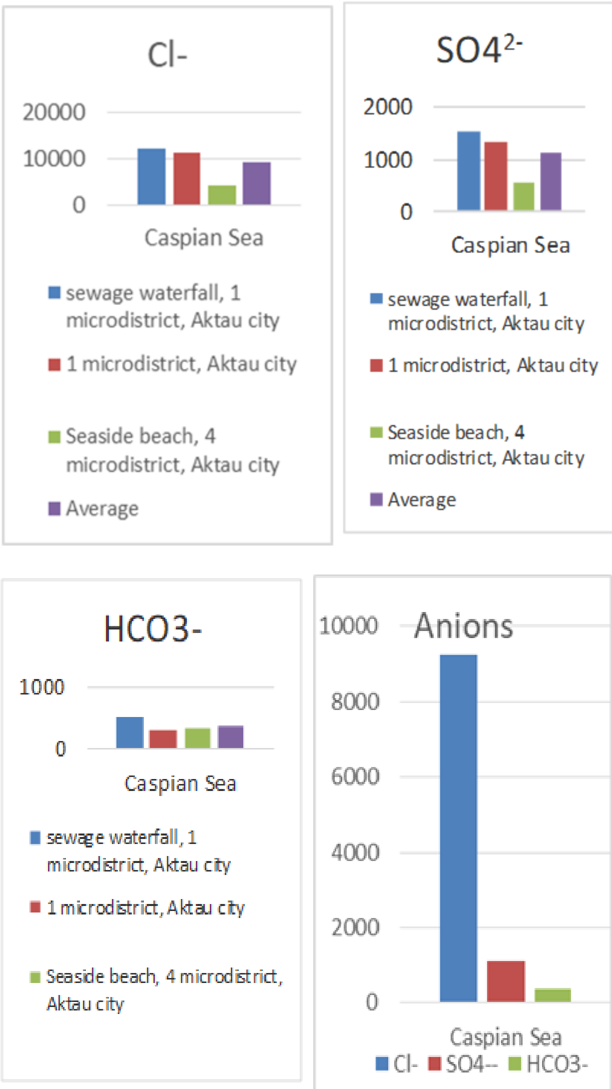


Figure 5. Anion content in the Caspian Sea

3.2 Hydrochemical analysis of Salt Lake Malaya Oymasha

In Figure 6 and Figure 7 we can see data on cation and anion contents in Salt Lake Malaya Oymasha.

In the Salt Lake Malaya Oymasha, in terms of cation content, the minimum values are characteristic of two cations of potassium and magnesium, the content of which is ten times higher than the content of the other two cations of calcium and magnesium. The lowest value is typical for potassium ion, the content of which is from 2.82-3.56 mg/l, with an average value of 3.19 mg/l. For sodium, the content exceeds 9 mg/l, with an average value of 9.33 mg/l. The calcium content is 650 mg/l, which is more than 1.2 times less than the content of magnesium ions, the average content of which is 822 mg/l.

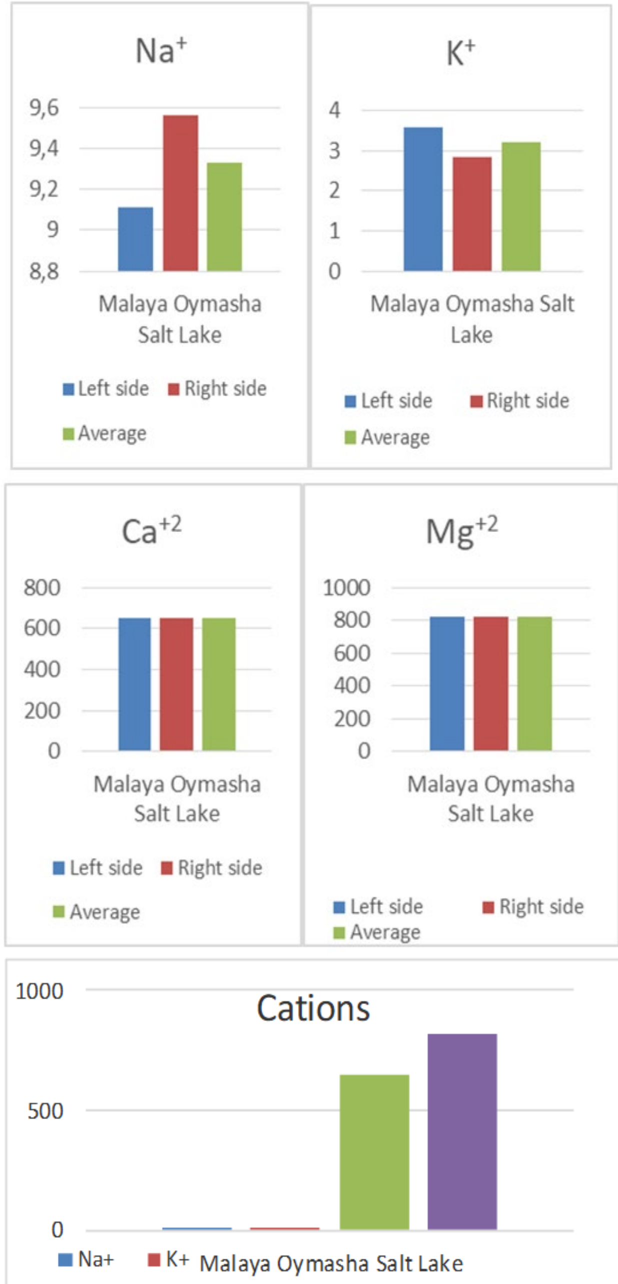
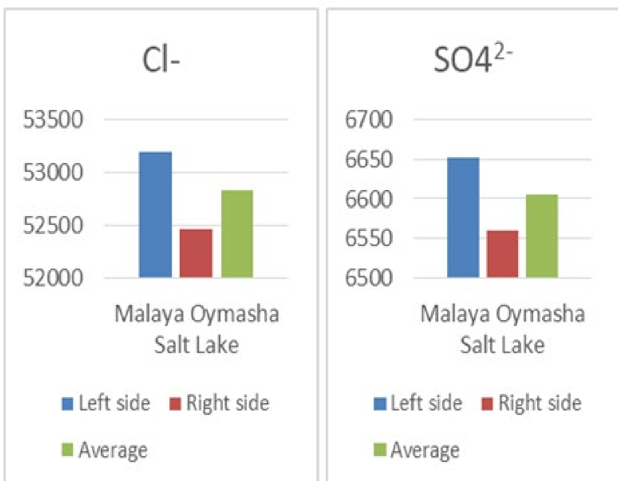


Figure 6. Cation content in the Salt Lake Malaya Oymasha



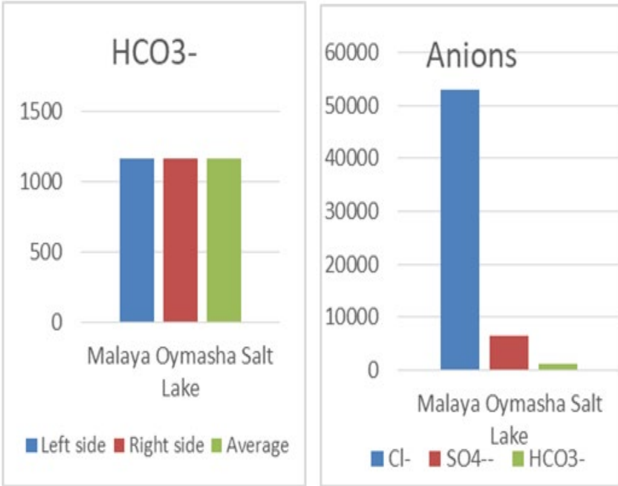


Figure 7. Anion content in the Salt Lake Malaya Oymasha

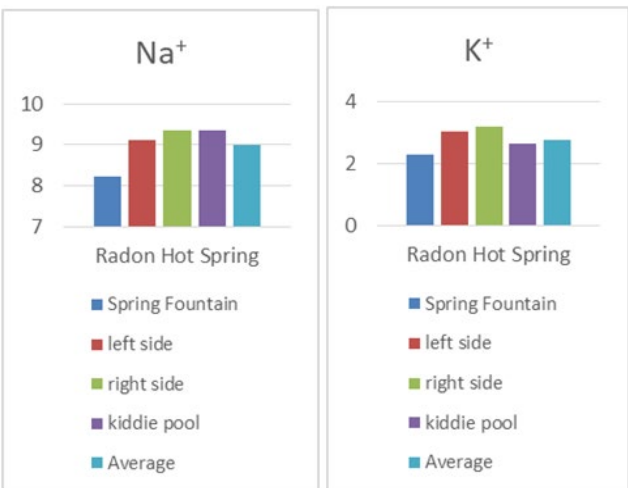
In the Salt Lake Malaya Oymasha, for three anions, the analysis shows minimum values for hydrocarbonate ions, the content of which is 1159 mg/l, which is almost 5 times less than the content of sulfate ions, the content of which is 6560.2-6651.4 mg/l with an average content of 6605.8 mg/l. The highest content is typical for chloride ions, the content of which is almost 8 times higher than the content of ion sulfates and amounts to 52470-53190 mg/l, with an average value of 52830 mg/l.

As in the Caspian Sea, the Salt Lake Malaya Oymasha is dominated by magnesium and calcium cations and chloride anions, which leads to the formation of salts of magnesium chlorides and calcium chlorides.

3.3 Hydrochemical analysis of Radon hot spring

In Figure 8 and Figure 9 we can see data on cation and anion contents in the Radon Hot Spring.

The lowest values among the cations in the Radon hot source are characteristic of potassium and magnesium ions, the content of which does not exceed ten milligrams per liter and are 2.27-3.19 mg/l for potassium with an average value of 2.77 mg/l and for sodium ions 8.23-9.34 mg/l with an average value of 9.0 mg/l. The content of calcium and magnesium ions exceeds tens and hundreds of times and amounts to 21.6-39.0 mg/l for magnesium ions, and 20-157 mg/l for calcium ions with average values of 33.08 mg/l for magnesium ions and 115.25 mg/l for calcium ions.



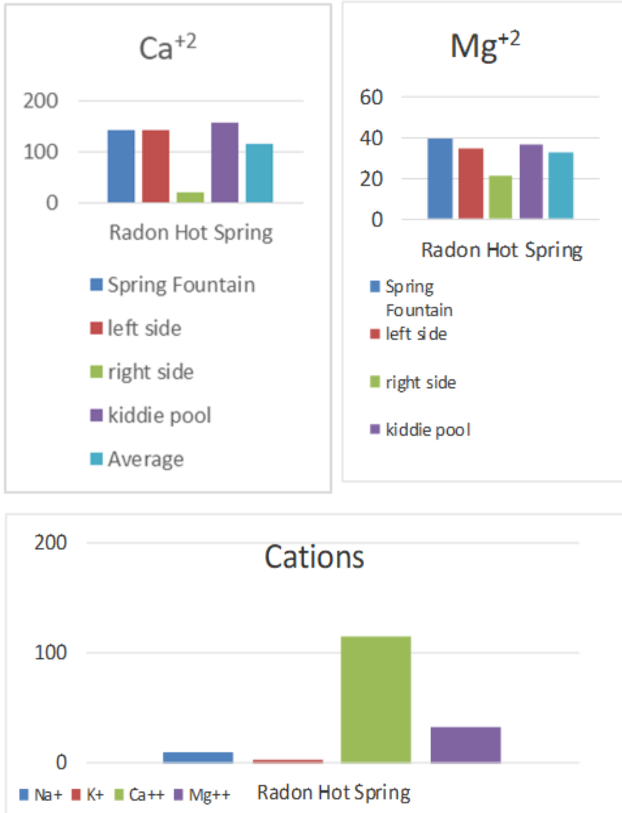


Figure 8. Cation content in the Radon hot spring

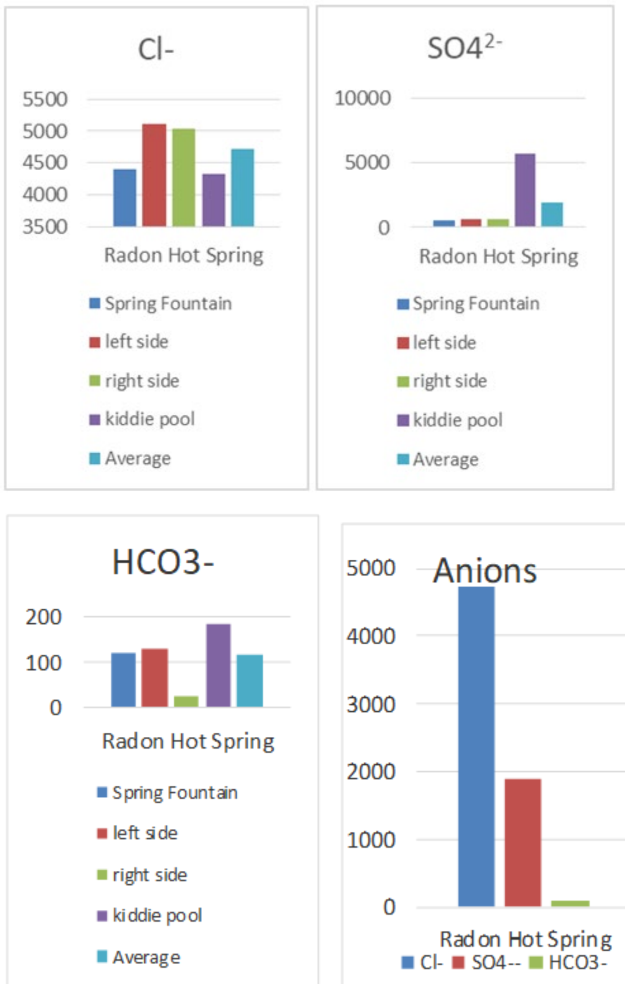


Figure 9. Anion content in the Radon hot spring

According to the content of anions, as in the two previous salt sources, excesses are typical for chloride ions with a content of 4325-5105 mg/l with an average value of 4715 mg/l. In second place are the content of sulfate ins, the content of which is 586.1-5716 mg/l, with an average value of 1896.4 mg/l. However, it should be noted that only in the children's pool located near the spring there is a high content of ion sulfates, in all samples of the spring itself they do not exceed 644.2 mg/l. According to the content of hydrocarbonate ions, the lowest values are noted and amount to 24.4-183 mg/l with an average value of 114.38 mg/l.

3.4 Comparative analysis of hydrochemical composition of salt water bodies of Mangystau region

In Figure 10 and Figure 11 we can see data on cation and anion contents of Mangystau region.

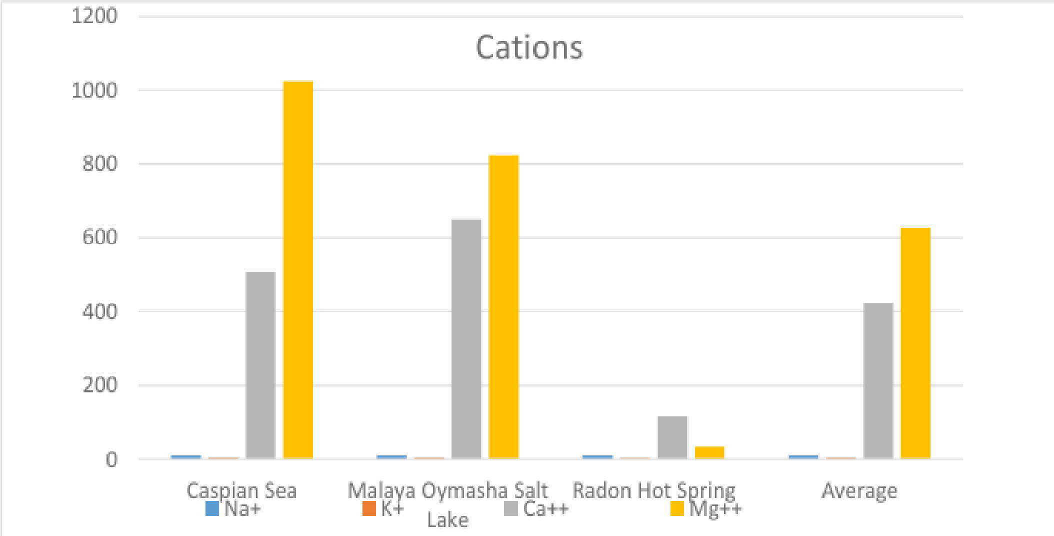


Figure 10. The content of cations in the salt lakes of Mangistau region

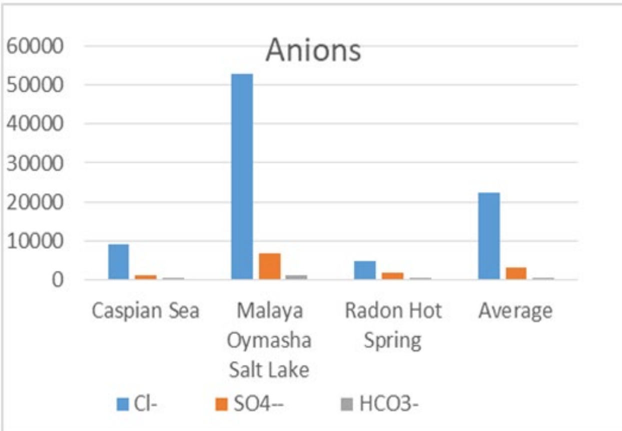


Figure 11. The content of anions in the salt lakes of Mangistau region

In all three sources of salt lakes, identical contents of all cations are noted. The lowest values are characteristic of potassium cations, the content of which is the same in all three salt water bodies and are 2.77-3.32 mg/l with an average value of 3.09 mg/l. The content of sodium cations is also similar for all three reservoirs and amounts to 8.96-9.32 mg/l with an average value of 9.09 mg/l. The content of calcium ions varies, the maximum content is typical for the Salt Lake Malaya Oymasha and is 650 mg/l, a slight decrease is observed in the Caspian Sea at 506.7 mg/l and the smallest values are typical for the Radon hot spring with a content of 115.25 mg/l. Different values are also observed in the content of magnesium cations. The lowest values are observed in the Caspian Sea and amount to 1024 mg/l, then in Lake Malaya Oymasha, with a content of 822 mg/l, while in the radon hot source its content is minimal and amounts to 33.08 mg/l. Thus, magnesium cations predominate in the Caspian Sea and the Salt Lake Malaya Oymasha, and calcium cations predominate in the Radon hot spring.

According to the content of anions among the three salty reservoirs of the Mangistau region, the maximum values are characteristic of chloride ions, in second place are sulfate ions and minimum values are characteristic of hydrocarbonates. According to the content of chloride ions, the highest concentrations were noted in the Salt Lake Malaya Oymasha, the content of which is 52830 mg/l, which is 5.7 times more than in the Caspian Sea (9241.3 mg/l) and 11.2 times higher in the Radon hot spring (4715 mg/l). In terms of the content of sulfate ions, the excess of the content is also typical for the Salt Lake Malaya Oymasha, the content of which is 6605.8 mg/l, which is 3.5 times higher in the Radon hot spring (4715 mg/l) and 5.8 times more than in the Caspian Sea (1135.2 mg/l). For hydrocarbonate ions, the same pattern was noted, i.e. the highest values are characteristic of the Salt Lake Malaya Oymasha and amount to 1159 mg/l, this content is 10.1 times higher than the content of hydrocarbonate ion in the Radon hot source (114.38 mg/l) and 3.1 times higher in the Caspian Sea (372.1 mg/l). Thus, chloride anions predominate in all three salt ponds, the lowest in hydrocarbonate anions.

Differences in the hydrochemical composition of the three salt reservoirs in the Mangistau region may be due to the following factors:

The Caspian Sea is a remnant of the ancient ocean, while the Oymasha Salt Lake and Radon Hot Spring are of tectonic origin. Differences in geological origin can lead to differences in the mineral composition of the underlying rocks, which in turn affects the chemical composition of the water [17].

The drainage basin of the Caspian Sea includes various geological formations [18], including sedimentary, igneous and metamorphic rocks. The drainage basins of Salt Lake Oymasha and Radon hot spring are more limited and consist mainly of sedimentary rocks. Differences in catchment lithology can lead to differences in chemical weathering and mineral leaching, which affects water chemistry.

Water temperature affects the solubility of minerals. Higher temperatures can lead to increased solubility of some minerals such as carbonates and sulfates [19]. The radon hot spring has a higher water temperature than the Oymasha Salt Lake and the Caspian Sea, which may contribute to a higher dissolved salt content.

Precipitation can dilute salt water and flush out dissolved salts. The Caspian Sea receives more precipitation than Oymasha Salt Lake and Radon Hot Spring, which can lead to lower salinity.

Anthropogenic activities such as industry, agriculture, and domestic wastewater can contaminate saltwater bodies and alter their chemical composition [20]. The Oymasha Salt Lake is subject to more intense pollution than the Caspian Sea and Radon Hot Spring, which can lead to higher concentrations of pollutants.

Changes in the water level in salt water bodies can lead to changes in chemical composition. For example, evaporation can lead to an increase in salinity, while freshwater inflow can lead to a decrease in salinity [21]. The Caspian Sea undergoes greater water level fluctuations than the Oymasha Salt Lake and Radon Hot Spring, which can lead to larger changes in chemical composition.

Differences in the hydrochemical composition of the three salt reservoirs in the Mangistau region are due to the complex interaction of geological, climatic and anthropogenic factors. Geological origin, catchment lithology, water temperature, precipitation, pollution, and changing water levels play an important role in shaping the unique chemistry of each body of water.

4. CONCLUSIONS

In conclusion, it should be noted that the hydrochemical analysis of three salt reservoirs in the Mangistau region, diverse in area and ways of their occurrence, as well as the possibility of their renewal, is diverse both in terms of cation and anion contents. Analysis of the cation content showed that only two reservoirs are dominated by magnesium and then calcium cations, these are in the Caspian Sea and Salt Lake Oymasha (1024 mg/l and 506.7 mg/l in the Caspian Sea and 822 mg/l and 506.7 mg/l in Malaya Oymasha, respectively). In the Radov hot source, the content of calcium ions is 115, 25 mg/l, and magnesium ions are 3.5 times less (33.08 mg/l). If we consider salt water bodies, then the highest values are observed in the content of magnesium and calcium cations in the Caspian Sea, the content of which is several times higher, for example, in magnesium 1.2 times higher than in Salt Lake Malaya Oymasha and 30.9 times in the Radon hot spring. In terms of calcium content, the highest rates were noted for the Salt Lake Malaya Oymasha 650 mg/l, which is 1.3 times higher than in the Caspian Sea and 5.6 times higher than in the Radon hot spring. For the remaining two cations, we note the lowest indicators, which are the same for all three sources, they do not exceed 10 mg/l for sodium cations and 3.5 mg/l for potassium cations. All this indicates their low ability to form basic amounts of salts in all salt sources. If we consider salt water bodies, then the highest values are observed in the content of magnesium and calcium cations in the Caspian Sea, the content of which is several times higher, for example, in magnesium 1.2 times higher than in the Salt Lake Malaya Oymasha and 30.9 times in the Radon hot spring. In terms of calcium content, the highest rates were noted for the Salt Lake Malaya Oymasha 650 mg/l, which is 1.3 times higher than in the Caspian Sea and 5.6 times higher than in the Radon hot spring. For the remaining two cations, we note the lowest indicators, which are the same for all three sources, they do not exceed 10 mg/l for sodium cations and 3.5 mg/l for potassium cations. All this indicates their low ability to form basic amounts of salts in all salt sources.

In terms of anion content, chloride and sulfate ions predominate in all three sources and are minimal for hydrocarbonate ions. In the Caspian Sea, the maximum content of chlorides, the content of which 9241.3 mg/l is 8.14 times higher than the content of sulfates and 24.8 times the ions of hydrocarbonates, which indicates the formation of chloride and sulfate salts. The Salt Lake Malaya Oymasha is also dominated by chloride ions, the content of which is 52830 mg/l 8.0 times higher than the content of sulfates and 45.6 times higher than the content of hydrocarbonate ions. Chloride ions also predominate in the Radon hot source, the content of which is 4715 mg/l 2.5 times higher than the content of sulfate ions and 41.2 times higher than ion bicarbonate. In terms of anion content, the highest values are characteristic of chlorides, while the highest values are observed in the Salt Lake Malaya Oymasha e (52830 mg/l), which is 5.7 times higher in the Caspian Sea and 11.2 times higher in the Radon hot spring. In the salt lake Malaya Oymasha, sulfates also showed elevated concentrations of 6605.8 mg/l, which is 5.8 times higher in the Caspian Sea and 3.5 times in the Radon hot spring. According to the content of hydrocarbonate ions, an increased content is also noted in Malaya Oymash (1159 mg/l), which is 3.1 times higher in the Caspian Sea and 10.1 times in the Radon hot spring. Thus, the main anions involved in the formation of the salt are chloride ions, as well as sulfate ions.

The analysis results showed that the main salts forming in the three salt lakes of the Mangistau region are magnesium chloride in the Caspian Sea and in the Salt Lake Malaya Oymasha, and calcium chloride in the Radon hot spring.

These findings have important implications for hydrochemistry and environmental science for the following reasons:

- These findings provide information on the chemical composition of unique salt water bodies in the Mangistau region.
- These findings help to understand the geological, climatic and anthropogenic factors that influence the hydrochemical composition of salt water bodies.
- These findings can be used to assess the impact of anthropogenic activities on salt water bodies and develop measures to protect them.
- These findings can be used to study weathering and sedimentation processes in salt water bodies.

Three salt reservoirs in Mangystau region differ in the following parameters:

- The Caspian Sea is the remnant of an ancient ocean, the Oymasha salt lake is of tectonic origin, and the Radon hot spring is a geothermal spring.
- The Caspian Sea is the largest of the three bodies of water, followed by Salt Lake Oymasha and then Radon Hot Spring.

- The Caspian Sea is the deepest of the three bodies of water, followed by Salt Lake Oymasha and then Radon Hot Spring.
- The salinity of the Caspian Sea is lower than the salinity of the Oymasha salt lake and the Radon hot spring.
- The hydrochemical composition of the three bodies of water differs substantially as described above.

These differences are due to various geological, climatic and anthropogenic factors that affect each body of water.

REFERENCES

[1] Jellison, R., Williams, W.D., Timms, B., Alcocer, J. (2008). Salt lakes: Values, threats and future. In: Aquatic Ecosystems: Trends and Global Prospects, pp. 94-110. https://doi.org/10.1017/CBO9780511751790.010

[2] Stober, I., Zhong, J., Bucher, K. (2023). From freshwater inflows to salt lakes and salt deposits in the Qaidam Basin, W China. Swiss Journal of Geosciences, 116(5). https://doi.org/10.1186/s00015-023-00433-4

[3] Kong, R., Xue, F.F., Wang, J., Zhai, H.Y., Zhao, L. (2017). Research on mineral resources and environment of salt lakes in Qinghai Province based on system dynamics theory. Resources Policy, 52: 19-28. https://doi.org/10.1016/j.resourpol.2017.01.006

[4] Koshim, A.G., Sergeyeva, A.M., Bexeitova, R.T., Aktymbayeva, A.S. (2020). Landscape of the Mangystau region in Kazakhstan as a geomorphotourism destination: A geographical review. GeoJournal of Tourism and Geosites, 29(2): 385-397. https://doi.org/10.30892/gtg.29201-476

[5] Kuzucuoglu, C., Leroy, S. (2023). Geographic and geomorphologic context of Caspian Sea level fluctuations over the Late Pleistocene and Holocene. Quaternaire, 34(2): 71-92. https://doi.org/10.4000/quaternaire.17991

[6] Yessenamanova, M.S., Sangajieva, L.K., Yessenamanova, Z.S., Tlepbergenova, A.E. (2020). Migratory activity at the landfill site of microelements of the Caspian depression. In News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 1(439): 155-163. https://doi.org/10.32014/2020.2518-170X.19

[7] Zhiyenkulova, L., Yessenamanova, M., Jexenov, M., Koroleva, E.G., Nurbayeva, F. (2024). Ecological and limnological research of the sustainability of the ecosystem of the lake Inder. In News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 1(463): 111-127. https://doi.org/10.32014/2024.2518-170X.369

[8] Kanbetov, A.Sh., Muldakhmetov, M.Z., Kulbatyrov, D.K., Duisekenova, R.G., Dyussengaliyeva, G.S., Zhaksiyeva, G.R. (2023). Soil condition studies in the area of the Tengiz deposit. In News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 5(461): 145-155. https://doi.org/10.32014/2023.2518-170X.338

[9] Tauova, N., Yessenamanova, M.S., Kozhakhmet, K., Kushakov, A.R., Kaliyeva, A. (2022). Geological state of the stratigraphic complex of the Tengiz deposit. In News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 5: 249-265. https://doi.org/10.32014/2518-170X.230

[10] SS 31861-2012. (2012). Water. General requirements for sampling. 36. https://water.korols.ru/assets/components/pdf/gost-31865-2012.pdf, accessed on Oct. 22, 2024.

[11] SS 26449.1-85. (1985). Methods of chemical analysis of salt water. https://ohranatruda.ru/upload/iblock/274/4294850335.pdf?ysclid=m0v3wt8o32751411998, accessed on Oct. 22, 2024.

[12] S RK ISO 9297-2008. (2008). Water quality. Determination of chloride content. Titration with silver nitrate with chromate indicator (Mohr method). https://files.stroyinf.ru/Data2/1/4293739/4293739357.pdf?ysclid=m0v422jpkk562680292, accessed on Oct. 22, 2024.

[13] S RK 1015-2000. (2000). Water. Graphimetric Method for Determination of Sulfate Content in Natural Wastewater. 12. https://files.stroyinf.ru/Data2/1/4293739/4293739431.pdf?ysclid=m0v47stadn702269778, accessed on Oct. 22, 2024.

[14] ER F 14.1: 2.253-09. CSTD "Regulations". https://cntd-reglament.ru/shop_op/ntd_shop.php?id_product=11195&ysclid=m278cr5mqa405985564, accessed on Oct. 22, 2024.

[15] Xie, C., Antić, N., Nadal-Romero, E., Yan, L., Tosti, T., Djogo Mračević, S., Tu, X.J., Kašanin-Grubin, M. (2022). The influences of climatic and lithological factors on weathering of sediments in humid Badland areas. Frontiers in Earth Science, 10: 900314. https://doi.org/10.3389/feart.2022.900314

[16] Yessenamanova, M., Yessenamanova, Zh., Tlepbergenova, A., Makhambet, M., Baitemirova, N. (2023). The relationship between the values of acidity and electrical conductivity in a hydroponic installation. Scientific Journal "Proceedings of the NAS RK", 347(3): 7-19. https://journals.nauka-nanrk.kz/reports-science/article/view/5847

[17] Bezrodnykh, Y.P., Sorokin, V.M. (2016). On the age of the Mangyshlakian deposits of the northern Caspian Sea. Quaternary Research, 85(2): 245-254. https://doi.org/10.1016/j.yqres.2016.01.004

[18] Kuprin, P.N. (2002). Apsheron threshold and its role in the processes of sedimentation and formation of hydrological regimes in the southern and middle Caspian basins. Water Resources, 29: 473-484. https://doi.org/10.1023/A:1020354411649

[19] Krumgalz, B.S. (2017). Temperature dependence of mineral solubility in water. Part I. Alkaline and Alkaline Earth Chlorides. Journal of Physical and Chemical Reference Data, 46(4): 043101. https://doi.org/10.1063/1.5006028

[20] Ougrad, I., Elassassi, Z., Allali, A., Elbouch, M., Abid, A., Fadli, M. (2022). Anthropogenic activities impact on the physicochemical and bacteriological quality of water in Dayat Roumi Lake, Morocco. Ecological Engineering & Environmental Technology, 23(4): 162-172. https://doi.org/10.12912/27197050/150561

[21] Obianyo, J.I. (2019). Effect of salinity on evaporation and the water cycle. Emerging Science Journal, 3(4): 255-262. https://doi.org/10.28991/esj-2019-01188

NOMENCLATURE

SS	State Standard
S RK	Standard Republic of Kazakhstan
ER F	Environmental Regulations Federal