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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруды. Web of Science зерттеушілер, авторлар, баспашилар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енүі біздің қогамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

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2023

¹Toraighyrov University, Pavlodar, Kazakhstan;

²Institute of Radiation Safety and Ecology, Kurchatov, Kazakhstan;

³National Research Tomsk Polytechnic University, Tomsk, Russia.

E-mail: kairat_akhmetov@mail.ru

HYDROGEOCHEMICAL FEATURES OF THE WATER OF SALINE LAKES IN PAVLODAR REGION

Akhmetov Kairat Imangalievich — Master of biology. Senior lecturer of department of biology and ecology. Toraighyrov University. Lomov str. 64. Pavlodar, Kazakhstan

E-mail: kairat_akhmetov@mail.ru, <https://orcid.org/0000-0003-3354-4023>;

Yessilkanov Gani Mukhtarovich — Engineer of the department for analytical research. Institute of radiation safety and ecology. Kurchatov, Kazakhstan

E-mail: al-g_007@mail.ru, <https://orcid.org/0000-0001-6834-2312>;

Kassanova Assiya Zhursunova — PhD, senior lecturer of Kizhner research center. National research Tomsk polytechnic university, Russia

E-mail: asiyakass@mail.ru, <https://orcid.org/0000-0002-9563-5521>;

Ubaskin Aleksandr Vasilevich — Candidate of biological sciences, associate professor of department of biology and ecology. Toraighyrov University. Lomov str. 64, Pavlodar, Kazakhstan

E-mail: awupawl@mail.ru, <https://orcid.org/0000-0001-9835-9043>;

Abylkhassanov Talgat Zhumageldinovich — Master of biology, senior lecturer of department of biology and ecology. Toraighyrov University. Lomov str. 64. Pavlodar, Kazakhstan

E-mail: talgat.abylkhassanov@gmail.com, <https://orcid.org/0000-0002-7465-1047>

Abstract. The article is devoted to the hydrogeochemical study of salt lakes in Pavlodar region. Salt lakes are an integral part of the steppe ecosystem and have economic, recreational, scientific, environmental and ecological value. The study of the chemical composition of salt lakes in the Pavlodar region is a particularly urgent task, since these lakes are inhabited by populations of the branchial crustacean Artemia sp. This type of crustacean is a valuable commercial object: Artemia cysts have a commercial value. The purpose of this study is to study the hydrogeochemical state of saline lakes in Pavlodar region. The object of the study was monitoring data (2014–2021) of the chemical composition of the water of salt lakes in Pavlodar region. A total of 64 samples were taken. Sample analysis was carried out on the basis of the Kazakhstan Design and Research Institute «Kazakhstanproekt». The index of total mineralization was determined by the gravimetric method. The potentiometric method was used to determine the pH of the samples. Determination of the content of ions Cl⁻, and SO₄²⁻ and cations Na⁺, K⁺, Ca₂₊, Mg₂₊ was carried out by capillary electrophoresis. The total content of CO₃²⁻ and HCO₃⁻ ions was determined by titrimetric methods of analysis. The chemical composition of salt lakes in Pavlodar region has been studied. Water mineralization varies from 60 to 260 g/l, which corresponds to weak and strong brines. According to the pH values, the waters of the studied lakes are classified as weakly alkaline and alkaline. As a result of studying the chemical composition of waters, 2 types of water chemistry of chloride-sodium-potassium and sulfate-chloride-sodium-potassium compositions were established. Factor analysis was carried out to identify hydrogeochemical features. Two main factors have been identified, where the first reflects the relationship between the main components of the chemical composition of waters. The second factor characterizes the behavior of sulfates. Sulfates as a macrocomponent can reflect the feeding habits of a particular lake, as well as the degree of interaction between water and bottom sediments. Factor analysis was also used to identify the spatial differentiation of water bodies. The following 3 groups are distinguished: 1) Highly mineralized lakes Tuz and Kalatuz; 2) Aksor and Ashchitakyr with a high content of sulfates; 3) Shcherbakty, Seiten and Borli with unstable water balance. The identified features of the chemical composition of the waters of salt lakes will help in studying the biological characteristics of water bodies, as well as in conducting regional geochemical studies. Reservoirs less resistant to climate change have been identified.

Key words: chemical composition of water, salt lakes, hydrogeochemical analysis, macrocomponent composition of water, factorial analysis, multivariate analysis

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¹Торайғыров Университеті, Павлодар, Қазақстан;

²Радиациялық қауіпсіздік және экология институты, Курчатов, Қазақстан;

³Ұлттық зерттеу Томск политехникалық университеті, Томск, Ресей.

E-mail: kairat_akhmetov@mail.ru

ПАВЛОДАР ОБЛЫСЫНДАҒЫ ТҮЗДҮ КӨЛДЕР СУЫНЫҢ ГИДРОГЕОХИМИЯЛЫҚ ЕРЕКШЕЛІКТЕРИ

Ахметов Кайрат Имангалиевич — Биология магистрі. Биология және экология кафедрасының аға оқытушысы. Торайғыров университеті, Ломов көшесі 64, Павлодар, Қазақстан

E-mail: kairat_akhmetov@mail.ru, <https://orcid.org/0000-0003-3354-4023>;

Гани Мухтарович Есильканов — Талдау зерттеулер бөлімінің инженері. Радиациялық қауіпсіздік және экология институты, Курчатов, Қазақстан

E-mail: al-g 007@mail.ru, <https://orcid.org/0000-0001-6834-2312>;

Касанова Асия Жүрсуновна — PhD докторы. Кижнер зерттеу орталығының аға оқытушысы. Ұлттық зерттеу Томск политехникалық университеті, Томск, Ресей

E-mail: asiyakass@mail.ru, <https://orcid.org/0000-0002-9563-5521>;

Убасъкин Александр Васильевич — Биология ғылымдарының кандидаты. Биология және экология кафедрасының ассоциацияланған профессоры. Торайғыров университеті, Ломов көшесі 64, Павлодар, Қазақстан

E-mail: awupawl@mail.ru, <https://orcid.org/0000-0001-9835-9043>;

Абылхасанов Талғат Жумагельдинович — Биология магистрі. Биология және экология кафедрасының аға оқытушысы. Торайғыров университеті, Ломов көшесі 64, Павлодар, Қазақстан

E-mail: talgat.abylkhassanov@gmail.com, <https://orcid.org/0000-0002-7465-1047>.

Аннотация. Мақала Павлодар облысының тұзды көлдерінің гидрогеохимиялық зерттеулер жүргізуге арналған. Тұзды көлдер дала экожүйесінің ажырамас бөлігі болып табылады және экономикалық, рекреациялық, ғылыми, табиғат қорғау мен экологиялық құндылыққа ие. Павлодар облысының тұзды көлдерінің химиялық құрамын зерттеу аса маңызды мақсат болып табылады, ейткені осы көлдерде *Artemia sp.* желбезекаяқты шаянының популяциялары тіршілік етеді. Шаянның бұл түрі құнды кәсіп объектісі болып табылады: артемия цисталары коммерциялық бағаға ие. Бұл зерттеудің мақсаты Павлодар облысының тұзды көлдерінің гидрогеохимиялық жағдайы зерттеу болып табылады. Зерттеу объектісі Павлодар облысының тұзды көлдеріндегі судың химиялық құрамы мониторингісінің берілгендері (2014–2021 жж.) болып табылды. Үлгілердің талдауы "Қазақстанпроект" Қазақстан ғылыми-зерттеу институтының базасында жүргізілді. Жалпы минерализацияланудың көрсеткішін гравиметрикалық әдіспен анықтады. pH үлгілерін анықтау үшін потенциометрикалық әдіс қолданылды. Cl⁻, SO₄²⁻ иондарын және Na⁺, K⁺, Ca²⁺, Mg²⁺ катиондарын анықтауда капиллярлы электрофорез әдісі пайдаланылды. CO₃²⁻ және HCO₃ иондарының жалпы құрамы талдаудың титриметрикалық әдіспен анықталды. Павлодар облысының тұзды көлдерінің химиялық құрамы зерттелді. Судың минерализациясы 60 г/л бастап 260 г/л дейін аралығында өзгереді, бұл әлсіз және қатты тұздық көрсеткіштеріне сәйкес. pH мәндері бойынша зерттелген көлдердің сулары әлсіз сілтілі және сілтілі. Сулардың химиялық құрамын анықтау нәтижесінде сулар химизмнің 2 түрі анықталды: хлоридті-натрийлі-калийлі және сульфатты-хлоридті-натрийлі-калийлі. Гидрогеохимилик ерекшеліктерді анықтау үшін факторлы талдау жүргізілді. 2 негізгі фактор ажыратылды. Бірінші фактор сулардың химиялық құрамының негізгі компоненттерінің өзара байланысын, ал екінші фактор сульфаттардың күй-өзгерістерін көрсетеді. Сульфаттар макрокомпонент ретінде бұл немесе басқа көлдің қоректенудің ерекшеліктерін, сондай-ақ су мен тұптік шөгінділердің өзара қатынас дәрежесін көрсетеді. Су айдындарының қеңістік дифференциацияны анықтау үшін тағы да факторлы талдау жүргізілді. Келесі үш топ бөлінеді: 1) жоғары минерализацияланған Тұз және Қалатұз көлдері; 2) құрамында сульфаттарды артық Ақсор және Ашытақыр көлдері; 3) судың балансы тұрақты емес Шарбақты, Сейтен және Бөрлі көлдері. Тұзды көлдер суларының химиялық құрамының анықталған ерекшеліктері су айдындарының биологиялық ерекшеліктерін зерттеуде, сондай-ақ өнірлік геохимиялық зерттеулерді жүргізуде көмектеседі. Климаттық өзгерістерге аз тұрақты су айдындары айқындалды.

Түйін сөздер: судың химиялық құрамы, тұзды көлдер, гидрогохимиялық талдау, судың макрокомпонентті құрамы, факторлы талдау, көп өлшемді талдау

© К.И. Ахметов^{1*}, Г.М. Есильканов^{2,3}, А.Ж. Касанова^{1,3}, А.В. Убаськин¹, Т.Ж. Абылхасанов¹, 2023

¹Торайғыров Университет, Павлодар, Казахстан;

²Институт радиационной безопасности и экологии, Курчатов, Казахстан;

³Национальный исследовательский Томский политехнический университет, Томск, Россия.

E-mail: kairat_akhmetov@mail.ru

ГИДРОГЕОХИМИЧЕСКИЕ ОСОБЕННОСТИ ВОДЫ СОЛЁНЫХ ОЗЁР ПАВЛОДАРСКОЙ ОБЛАСТИ

Ахметов Кайрат Имангалиевич — Магистр биологии, старший преподаватель кафедры биологии и экологии, Торайғыров Университет, ул. Ломова 64, Павлодар, Казахстан

E-mail: kairat_akhmetov@mail.ru, <https://orcid.org/0000-0003-3354-4023>;

Есильканов Гани Мухтарович — Инженер отдела аналитических исследований. Институт радиационной безопасности и экологии, Курчатов, Казахстан

E-mail: al-g_007@mail.ru, <https://orcid.org/0000-0001-6834-2312>;

Касанова Асия Журсуновна — доктор PhD, старший преподаватель исследовательского центра Кижнера. Национальный исследовательский Томский политехнический университет, Томск, Россия

E-mail: asiyakass@mail.ru, <https://orcid.org/0000-0002-9563-5521>;

Убаськин Александр Васильевич — Кандидат биологических наук. Ассоциированный профессор кафедры биологии и экологии, Торайғыров Университет, ул. Ломова 64, Павлодар, Казахстан

E-mail: awupawl@mail.ru, <https://orcid.org/0000-0001-9835-9043>;

Абылхасанов Талгат Жумагельдинович — Магистр биологии, старший преподаватель кафедры биологии и экологии, Торайғыров Университет, ул. Ломова 64, Павлодар, Казахстан

E-mail: talgat.abylkhassanov@gmail.com, <https://orcid.org/0000-0002-7465-1047>.

Аннотация. Статья посвящена гидрогохимическому изучению соленых озер Павлодарской области. Соленые озера являются неотъемлемой частью степной экосистемы и имеют экономическую, рекреационную, научную, природоохранную и экологическую ценность. Исследование химического состава соленых озер Павлодарской области является особо актуальной задачей, поскольку в этих озерах обитают популяции жаброногого рака *Artemia sp.* Данный вид рака является ценным промысловым объектом: цисты артемии имеют коммерческую стоимость. Целью данного исследования является изучение гидрогохимического состояния соленых озер Павлодарской области. Объектом исследования являлись данные мониторинга (2014–2021 гг.) химического состава воды соленых озер Павлодарской области. Всего отобрано 64 пробы. Анализ проб проводился на базе Казахстанского проектно-исследовательского института «Казахстанпроект». Показатель общей минерализации определяли гравиметрическим методом. Потенциометрический метод использовали для определения pH проб. Определение содержания ионов Cl⁻, и SO₄²⁻ и катионов Na⁺, K⁺, Ca²⁺, Mg²⁺ проводилось методом капиллярного электрофореза. Общее содержание ионов CO₃²⁻ и HCO₃⁻ определялось титриметрическими методами анализа. Изучен химический состав соленых озер Павлодарской области. Минерализация воды изменяется в пределах от 60 до 260 г/л, что соответствует слабым и сильным рассолам. По значениям pH воды изученных озер относятся к слабощелочным и щелочным. В результате изучения химического состава вод были установлены 2 типа химизма вод хлоридно-натриево-калиевого и сульфатно-хлоридно-натриево-калиевого составов. Для выявления гидрогохимических особенностей был проведен факторный анализ. Выделены 2 основных фактора, где первый отражает взаимосвязь главных компонентов химического состава вод. Второй фактор характеризует поведение сульфатов. Сульфаты как макрокомпонент могут отражать особенности питания того или иного озера, а также степень взаимодействия воды и донных отложений. Для выявления пространственной дифференциации водоемов был также использован факторный анализ. Выделяются следующие 3 группы: 1) высокоминерализованные озера Туз и Калатуз; 2) Аксор и Ащитакыр с повышенным содержанием сульфатов; 3) Щербакты, Сейтень и Борли с нестабильным водным балансом. Выявленные особенности химического состава вод соленых озер помогут в изучении биологических особенностей водоёмов, а также при проведении региональных геохимических исследований. Выделены водоемы, менее устойчивые к климатическим изменениям.

Ключевые слова: химический состав воды, соленые озера, гидрогоеохимический анализ, макрокомпонентный состав воды, факторный анализ, многомерный анализ

Introduction

The study of saline lake ecosystems is of global importance due to their economic, recreational, scientific, environmental and ecological value (Hammer, 1986; Williams, 2002).

For example, saline lakes are capable of mitigating the anthropogenic effect on ecosystems by neutralizing various substances, especially nitrogen compounds (Valiente et al., 2022).

The steppe areas of central and northern Kazakhstan are rich in shallow lakes, which number over 14,000 in this area (Urivaev, 1959). In Kazakhstan, the estimated area of impounded surface water bodies, including permanent and interrupted wetlands, is approximately 1,008,800 km² which is 37 % of the total area of the country. Saline water bodies are one of the most important aquatic habitats in the steppes of Kazakhstan (Kolpakova et al., 2019).

The study of the chemical composition of saline lakes in Pavlodar region is a relevant objective since these lakes are inhabited by populations of the Branchiopoda crustacean, *Artemia* sp. These crustaceans have adapted to live in the salinity of water bodies from 10 to 340 g/l. This crustacean species – *Artemia* cysts – is a valuable commercial object.

Global climate change, along with the anthropogenic effect on the natural resources of saline lakes, leads to geochemical alterations in the environment of these living organisms. Therefore, careful monitoring of the state of these water bodies is necessary (Lebedeva et al., 2019). At the same time, it is important to systematize the studied lakes by their inherent parameters, which are, in general, hydrochemical characteristics of the ecosystem.

The purpose of the research is to study the geochemical features of saline lakes in Pavlodar region.

Study area description

Pavlodar region is located in the north-eastern part of Kazakhstan and occupies an area of more than 127.5 thousand km. Pavlodar region relief is represented by two major geomorphological zones – uplands, the eastern edge of the Central Kazakh Hummocks, and plains, the southern border of the West Siberian Plain.

Part of the lakes under study are located in the area of the accumulative lacustrine-alluvial plain, which dominates the territory of the region; there are a large number of intermittent lakes and swamps, the extent of which corresponds to the direction of the ancient depressions (from southwest to northeast) (Deferred expenses 011 report., 2008).

The climate of Pavlodar region according to Köppen is classified as cold semi-arid steppe - BSk. In July, the temperature varies from +20.4 to 22.4°C, and in January from -13.3 to -19.0°C. The average annual temperature is positive. Annual precipitation varies from 200 to 300 mm (Ubaskin, 2005).

Materials and basic methods

Seven saline lakes in Pavlodar region were chosen as the research objects. The work presents the results of years-long monitoring of the chemical composition of waters of the lakes: Aksor, Aschitakyr, Kalatuz, Tuz, Borli, Sherbakty and Seiten in the spring and autumn between 2014 and 2021. The sampling map is shown in figure 1. A total of 64 samples were analyzed.

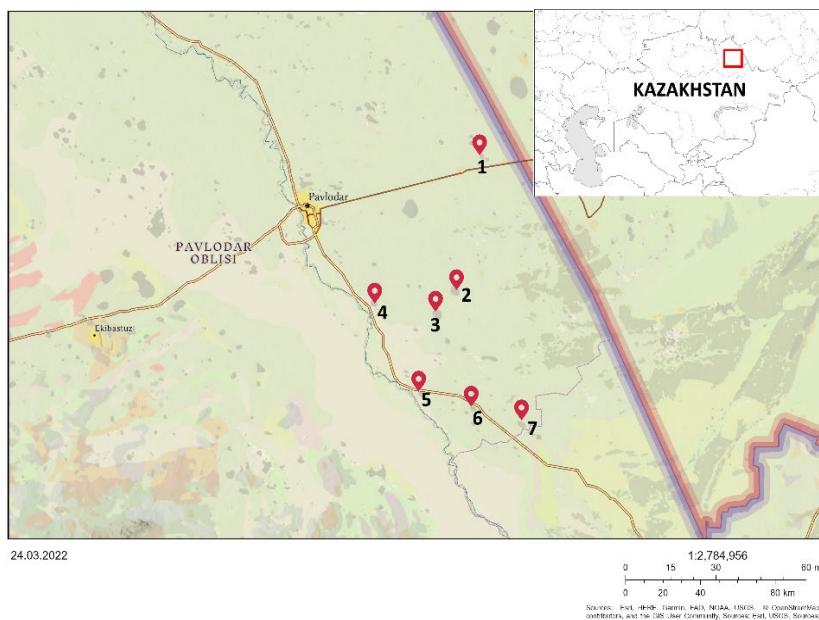


Fig. 1 – Water sampling map

Table 1 – Characteristics of the studied saline lakes

Nº	Lake	Coordinates	Area, km ²	Mean depth, m
1	Aschitakyr	52°33'N, 78°19'E	4.20	1.1
2	Seiten	51°55'N, 78°07'E	15.50	1.9
3	Borli	51°49' N, 77°58' E	15.0	3.0
4	Kalatuz	51°53'N, 77°30'E	8.50	2.2
5	Aksor	51°27'N, 77°52'E	11.60	0.8
6	Sherbakty	51°23'N, 78°15'E	6.80	2.8
7	Tuz	51°18'N, 78°38'E	10.63	1.1

Note: the numbers of the lakes correspond to the numbers on the map

Water sampling and preserving were carried out according to the generally accepted method (GOST 31861–2012). The water chemical composition was analyzed by the accredited laboratory of Kazakhstan Engineering Research Institute “Kazakhstanproject” LLP. The total salt content index was determined by the gravimetric method (GOST 26449.1–85). To determine the pH of the samples, the potentiometric method was used. The content of Cl⁻, and SO₄²⁻ ions and Na⁺, K⁺, Ca²⁺, and Mg²⁺ cations were determined by capillary electrophoresis (KZ.07.00.01998–2014, KZ.07.00.01529–2017). The total content of CO₃²⁻ and HCO₃⁻ ions was determined by the titrimetric method (GOST 26449.1–85). The reagents of AR grade were used for the analysis.

Statistical data processing was performed using Statistica 2019 and Microsoft Excel 2019.

Results

The average content of macrocomponents in the water of saline lakes is presented in Table 2. TDS concentration in the lakes varies from 60 to 260 g/l. Among the studied lakes the following types can be distinguished:

- Weak brines (50 to 100 g/l): Borli, Aschitakyr;
- Strong brines (100 to 320 g/l): Sherbakty, Aksor, Seiten, Kalatuz, Tuz.

According to pH values, the waters of the studied lakes belong to slightly alkaline and alkaline. As a rule, lakes with high TDS concentrations have lower pH values.

Table 2 – Chemical composition of waters in lakes of Pavlodar region (n=64), mg/l

Lake	TDS, g/l	Chemical water composition	pH	HCO ₃	Cl ⁻	SO ₄ ²⁻	Ca	Mg	Na+K
TDS concentrations from 60-80 g/l									
Borli	60	Cl ⁻ - Na+K	9.0	2060	27800	6400	16	170	22000
Aschitakyr	80	Cl ⁻ - Na+K	8.4	540	33600	13200	90	2670	34900
TDS concentrations from 80-120 g/l									
Sherbakty	110	Cl ⁻ - Na+K	8.9	775	57000	5150	25	460	40700
Aksor	110	SO ₄ ²⁻ Cl ⁻ - Na+K	8.6	610	25500	45000	110	2500	34300

Seiten	120	Cl ⁻ - Na+K	8.9	1950	49400	6500	45	130	48000
TDS concentrations >120 g/l									
Kalatuz	220	Cl ⁻ - Na+K	7.8	610	116000	10000	280	12000	62700
Tuz	260	Cl ⁻ - Na+K	7.8	510	142000	20600	90	6600	88000

Note: the table provides median values, TDS is total dissolved solids

Alternation of high-water and low-water periods is typical for the lakes in the region. It is connected with a significant excess of inflow over evaporation in high-water years and, on the contrary, with a sharp predominance of losses over inflow in low-water years. The multiyear amplitude of lake water level fluctuations varies within wider limits – from 0.5 to 4.5 m (long-term average annual - 1.5–2.0 m). Climatic factors – temperature and precipitation in particular - play a crucial role in the functioning of saline lakes, and their physical and geographic location predetermine their present state. We can consider the modern period starting from 1989 as a certain climatic turbulent period towards global warming (Abylkhassanova et al., 2020).

Chronological fluctuations of hydrometeorological parameters affect the hydrochemical behaviour of saline lakes. In recent years in the studied region, there has been significant variability in air temperature and atmospheric precipitation (Figure 2). At the same time, fluctuations of these most important abiotic factors also affect changes in other environmental components. There was revealed a negative correlation between air temperature and precipitation in the studied period (Figure 2). A simultaneous increase in air temperature and decrease in precipitation negatively affects the hydrological state of saline water bodies, leads to an increase in the total TDS of water and negatively affects the living conditions of biota.

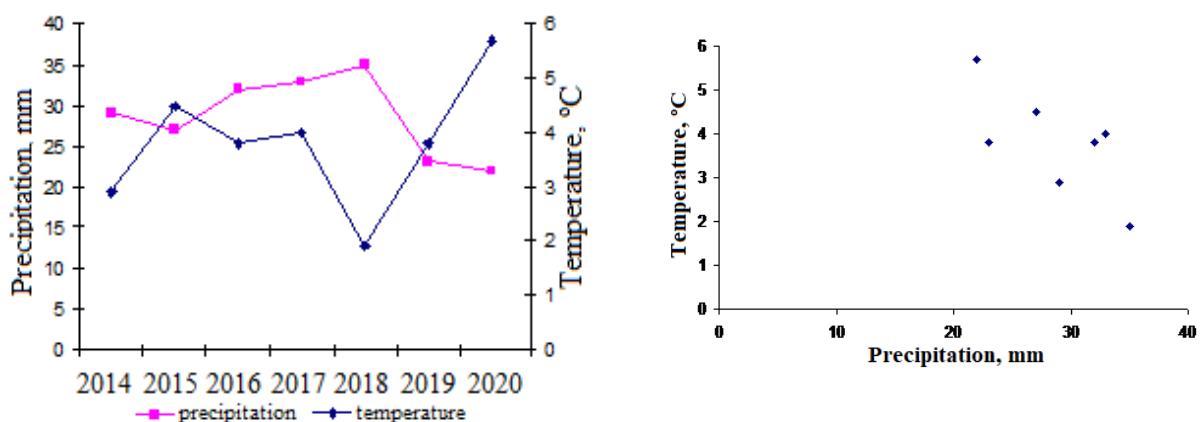


Figure 2 – Correlation of temperature and precipitation (correlation coefficient minus 0.77)

As a result of studying the chemical composition of the waters of 6 lakes, 2 types of water chemistry were established, which are determined by the predominant cations and anions (Alekin, 1970). Most of the studied lakes have waters of chloride-sodium-potassium composition. In the works on the study of saline lakes in Altai Krai, this type of water was characteristic of the dry-steppe zone on chestnut soils. Sulfate-chloride-sodium-potassium composition of waters was found only in Lake Aksor.

In order to identify landscape and geochemical features influencing the main macro-component composition a factor analysis with varimax rotation was conducted (Toropov, 2022; Reimann, 2008). The distribution of the studied hydrogeochemical parameters and lakes according to the value of factor loadings (principal component method) are presented in table 3 and figure 3.

Table 3 – Distribution of factor loadings of the chemical composition of water of Pavlodar region's saline lakes, (n=64)

	Factor 1	Factor 2
pH	-0.82	-0.39
HCO ₃ ²⁻	-0.33	-0.59
SO ₄ ²⁻	-0.07	0.79
Cl ⁻	0.90	0.05
Ca ²⁺	0.32	0.61
Mg ²⁺	0.78	0.39
K ⁺ +Na ⁺	0.77	0.17
TDS	0.62	0.08
% of total variance	49	13

Note: Indicators with standard factor loading above 0.70 are marked in red

Table 3 shows that 2 factors explain 62 % of the variance in the experimental data.

Analysis of the obtained data allowed us to identify the main factors determining the chemical composition of the lakes:

- Factor 1 (49 % of the total variance) is the relationship between the main components of the chemical composition of waters, the evolution of water types as a result of evaporative concentration;

- Factor 2 (13 %) reflects the behaviour of sulfates. Sulfates as a macro-component can reflect the peculiarities of collecting of this or that lake, as well as the degree of interaction between water and bottom sediments. So, when crossing certain thresholds of mineralization sulfur-containing minerals – gypsum and tenardite are formed (Kolpakova et al., 2019).

In order to show the spatial differentiation of water bodies, we plotted the ratio of factor loadings between the lakes (Figure 3).

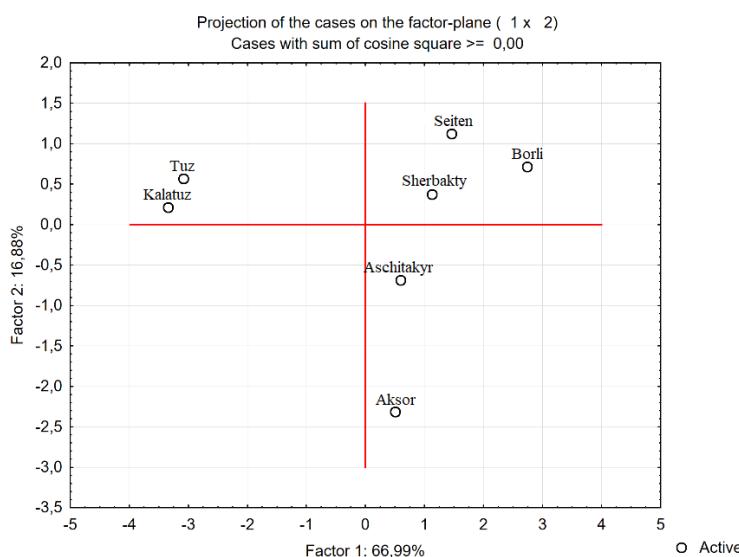


Figure 3 – Distribution of lakes by magnitude of factor loadings

The graph shows that there is a clear differentiation of the studied lakes, since the mechanisms of formation and the direction of changes in the chemical composition of such waters differ. The following three groups were identified:

Highly saline lakes Tuz and Kalatuz. These water bodies have high salinity above 120 g/l but the high influence of Factor 2 affects the behavior of sulfates. Perhaps these lakes have a stable inflow of groundwaters. Lake Kalatuz located in the zone of influence of the floodplain of the Irtish River.

Saline lakes Aksor and Aschitakyr with a high sulfates content. These lakes may have a mixed type of inflow and a higher level of water evaporation.

The largest group includes Lakes Sherbakty, Seiten and Borli. The analysis of factor loadings shows that the composition of their waters is strongly influenced by Factor 1 and 2. Most likely these water bodies have an unstable water balance which depends on precipitation and the evaporation intensity but with groundwaters inflow.

Identified groups of lakes, as a set of different processes, will respond differently to climate change. In order to show the differences between the selected lakes groups we plotted the water salinity range diagrams by years (Figure 5).

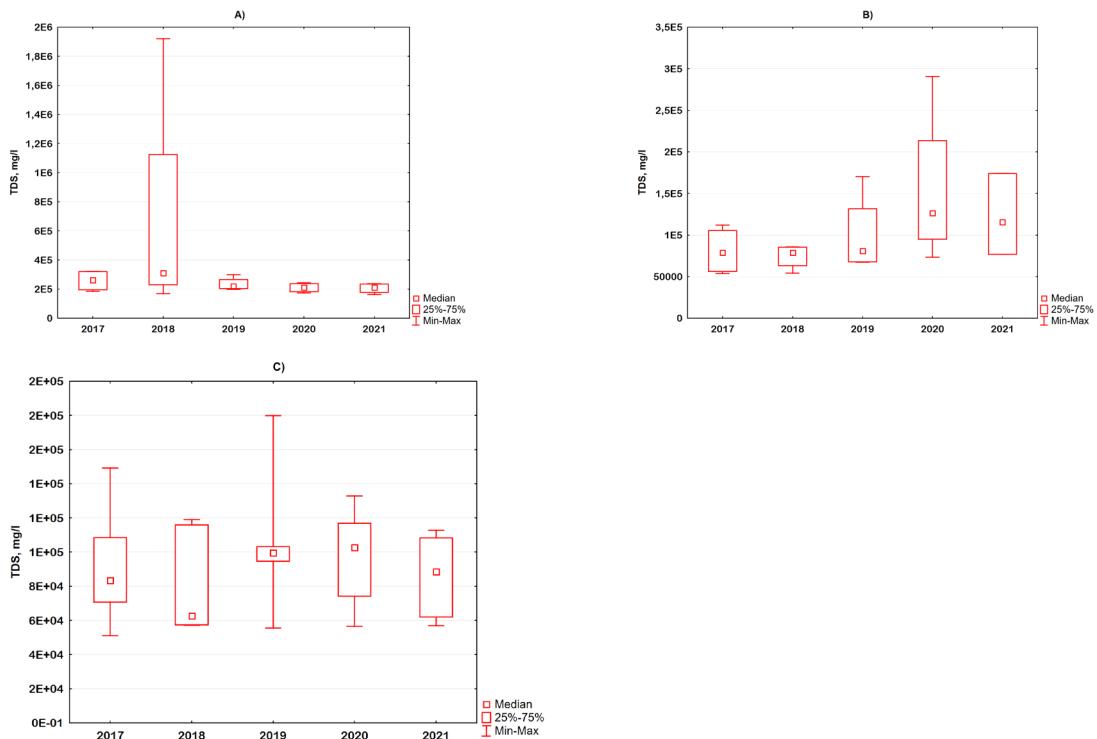


Figure 4 – Salinity range diagrams by years

A) Lakes Tuz, Kalatuz, C) Lakes Aksor, Aschitakyr , C) Lakes Sherbakty, Seiten, Borli.

The range diagrams confirm the results of factor analysis: Lakes Tuz and Kalatuz have the most stable salinity level without major picks, except in 2018, which is associated with an increase in precipitation.

Lakes Aksor and Aschitakyr tend to increase salinity in comparison with the beginning of observation in 2017. The diagram shows increase in the range and interquartile distance from 2019 to 2021, which indicates a possible intensification of the process of evaporative concentration in these lakes.

The largest group of lakes shown in Figure 3c characterized by a large range of salinity changes over the years which additionally indicates the instability of the dynamics of the chemical water composition. Most likely, different inflow sources of lakes (groundwaters and precipitation) have different dynamics depending on the year and season.

Important to note, that in order to make more accurate conclusions it requires expanding the range of studied elements in water and bottom sediments.

Conclusion

The studies have shown that the salinity of waters in the lakes of Pavlodar region varies greatly. In the studied series, the average waters salinity varies from 60 g/l (Lake Borli) to 260 g/l (Lake Tuz). The water composition characterized by a small variety: $\text{Cl}^- - \text{Na}^+ + \text{K}^+$ and $\text{SO}_4^{2-} - \text{Cl}^- - \text{Na}^+ + \text{K}^+$ type of waters.

Factor analysis has shown 2 main processes affecting the chemical composition of water: salinization processes (Factor 1) and the processes of water/bottom sediments interaction or groundwater inflow.

The use of the principal component method allowed us to identify 3 main spatial groups of lakes.

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CONTENTS

A.E. Abetov, Sh.B. Yessirkepova, J. Curto Ma	
REMOTE SENSING AT THE STUDY OF THE THERMAL FIELD OF THE SOUTH USTYURT REGION TO FIND HYDROCARBON DEPOSITS.....	6
K.I. Akhmetov, G.M. Yessilkanov, A.Zh. Kassanova, A.V. Ubaskin, T.Zh. Abylkassanov	
HYDROGEOCHEMICAL FEATURES OF THE WATER OF SALINE LAKES IN PAVLODAR REGION.....	17
S.V. Gladyshev, K.Sh. Akhmetova, L.M. Imangalieva, A.K. Kasymzhanova, N.K. Akhmadieva	
STUDY OF PURIFICATION OF COPPER ELECTROREFINING SOLUTION BY FLOW CENTRIFUGATION.....	26
D.A. Davronbekov, X.F. Alimjanov, K.S. Chezhimbayeva	
METHODS FOR REMOTE MONITORING OF BRIDGES UNDER THE INFLUENCE OF GROUNDWATER ON THEM.....	37
ZH.E. Daribayev, A.N. Kutzhanova, G.I. Issayev, I.G. Ikramov, D.U. Seksenova	
ASSESSMENT OF ENVIRONMENTAL DAMAGE OF NON-FERROUS METALLURGY WASTE TO THE ENVIRONMENT.....	48
K.R. Dzhabagieva, G.V. Degtyarev, A.M. Baytelieva, S.M. Laiyk, R.A. Pernebayeva	
FINITE ELEMENT STUDIES OF FLOW PROCESSES IN HYDROCYCLONES AND LOSS OF HEAD-ON FLOW MIXING.....	57
R.I. Yegemberdiev, I.N. Stolpovskikh, A.D. Kolga	
IMPROVEMENT OF THE SYSTEM OF EXPLOSIONS OF RING HOLES DURING THE DEVELOPMENT OF LOW-POWER ORE DEPOSITS.....	68
A.A. Yerzhan, P.V. Boikachev, S. Virko, Z.D. Manbetova, P.A. Dunayev	
A NEW METHOD OF MATCHING THE SYNTHESIS OF MATCHING DEVICES BASED ON MODIFIED APPROXIMATION IN TELECOMMUNICATION DEVICES.....	77
N.Zh. Zholamanov, S.M. Koibakov, S.T. Abildayev, G.A. Sarbassova, M.T. Omarbekova	
RECOMMENDATIONS FOR THE USE AND DESIGN OF FISH PROTECTION AND FISH PASSING STRUCTURES UNDER GEOLOGICAL CONDITIONS.....	85
L.Z. Issayeva, E. Slaby, S.K. Assubayeva, M.K. Kembayev, K.S. Togizov	
THE THREE-DIMENSIONAL MODEL OF THE AKBULAK RARE EARTH DEPOSIT (NORTHERN KAZAKHSTAN).....	96
A.A. Kabdushev, F.A. Agzamov, B.Zh. Manapbaev, D.N. Delikesheva, D.R. Korgasbekov	
STUDYING THE EFFECT OF REINFORCEMENT ON THE PROPERTIES OF PLUGGING MATERIALS WITH EXPANDING ADDITIVES.....	108
Y.M. Kalybekova, A.K. Zauirbek, N.N. Balgabayev, T.S. Ishangalyev, Y.K. Auelbek, A.V. Cravchuk	
IMPROVEMENT OF THE WATER DISTRIBUTION MANAGEMENT SCHEME ON IRRIGATION SYSTEMS USING HYDROLOGICAL INFORMATION.....	118
N.Zh. Karsakova, K.T. Sherov, B.N. Absadykov, M.R. Sikhimbayev, G.M. Tussupbekova	
THE ISSUES OF IMPROVING THE TECHNOLOGY FOR MACHINING THE LARGE DIAMETER HOLES OF THE LARGE-SCALE PARTS OF THE TECHNOLOGICAL EQUIPMENT.....	126
R.A. Kozbagarov, M.S. Zhiyenkozhayev, N.S. Kamzanov³, S.G. Tsygankov, A.S. Baikenzheyeva	
DESIGN OF HYDRAULIC EXCAVATOR WORKING MEMBERS FOR DEVELOPMENT OF MUDSLIDES..	134
E.I. Kuldeyev, M.B. Nurpeissova, Z.A. Yestemesov, A.A. Ashimova, A.V. Barvinov	
OBTAINING AGLOPORITE FROM ASH OF EKIBASTUZ COAL SELECTED FROM ASH DUMP OF CRPP-3 OF ALMATY CITY.....	142

A.S. Madibekov, L.T. Ismukhanova, A.O. Zhadi, B.M. Sultanbekova, E.D. Zhaparkulova MICROPLASTICS IN THE AQUATIC ENVIRONMENT: OVERVIEW OF THE PROBLEM AND CURRENT RESEARCH AREAS.....	149
Y.G. Neshina, A.D. Mekhtiyev, V.V. Yugay, A.D. Alkina, P.Sh. Madi DEVELOPING A SENSOR FOR CONTROLLING THE PIT WALL DISPLACEMENT.....	160
M.B. Nurpeissova, Z.A. Yestemesov, A.A. Bek, V.S. Kim, G.K. Syndyrbekova MAIN CHARACTERISTICS OF FLY ASH FROM EKIBASTUZ SRPP-2.....	168
N.D. Spatayev, G.S. Sattarova, A.D. Nurgaliyeva, L. Kh. Balabas, F.K. Batessova ENSURING HEALTHY AND SAFE WORKING CONDITIONS IN BREAKAGE FACE WITH DIRECT-FLOW VENTILATION SCHEME.....	177
V.M. Shevko, A.M. Nurpeissova, D.K. Aitkylov, A.A. Joldassov THERMODYNAMIC PREDICTION AND EXPERIMENTAL PRODUCTION OF SILICON ALLOYS FROM TAILINGS LEACHING OF OXIDIZED COPPER ORE ALMALY.....	188

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