ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

ҚАЙЫРЫМДЫЛЫҚ ҚОРЫ
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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН»
ЧФ «Халық»

NEWS

OF THE ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
«Halyk» Private Foundation

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

1 (463)

JANUARY – FEBRUARY 2024

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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 қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

«ҚР ҰҒА» РҚБ Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

«Известия РОО «НАН РК». Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 1. Number 463 (2024), 111–127
https://doi.org/10.32014/2024.2518-170X.369

МРНТИ 67.15.35

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ECOLOGICAL AND LIMNOLOGICAL RESEARCH OF THE SUSTAINABILITY OF THE ECOSYSTEM OF THE LAKE INDER

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Abstract. The article presents ecological and limnological studies of the ecosystem of three sources of the Lake Inder for the periods 2013–2023. Of the salt dome landscapes of the Caspian lowland, the largest is the Inder salt dome region, which includes the karst Inder Mountains. The Inder lakes are represented by an ellipsoid shape with an area of 115 km^2 and a water cut of – 23 m below sea level. Along the northern coast of Lake Inder there are more than 50 springs, which are grouped into three most significant spring tracts — Tilepbulak, Tuzdybulak and Ashytuzdybulak. Samples of salt solutions were taken from the springs of three springs and studies were conducted to study the hydrochemical composition and content of heavy metals. A comparative analysis of the hydrochemical composition showed that the salt solution of Lake Inder belongs to the sodium chloride and calcium sulfate and magnesium sulfate types. The content of sodium cations in the brines exceeds 89 to 545 times; calcium from 2.7 to 7.4 times;

magnesium cations from 3 to 26–28 times in 2023. Among the anions, chloride anions exceed from 16.6 to 105 times; sulfate anions from 1.5 to 101 times. It should be noted that chlorine anions and sodium cations mainly predominate. Thus, the salts of the sources are mostly chloride, except for the source of Tilepbulak. For all the studied heavy metals, no MPC exceedances were observed at all sources of Lake Inder, except for chromium, the content of which in all sources in 2013 exceeded from 5 to 7.5 times. For all other heavy metals, such as copper, zinc, lead, cadmium and manganese in all periods of research at all three sources.

Keywords: ecological and limnological studies, sustainability of Lake Inder, hydrochemical composition, content of heavy metals, chlorine anions; sodium cations

© Л. Жиенкулова[1], М. Есенаманова[2], М. Джексенов[2], Е.Г. Королева[3], Ф. Нурбаева[1], 2024

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ИНДЕР КӨЛІНІҢ ЭКОЖҮЙЕСІНІҢ ТҰРАҚТЫЛЫҒЫН ЭКОЛОГИЯЛЫҚ ЖӘНЕ ЛИМНОЛОГИЯЛЫҚ ЗЕРТТЕУ

Жиенкулова Лаззат — 8D05201- "Экология" дайындық бағыты бойынша докторант, Ш. Есенов атындағы Каспий технологиялық университеті, Ақтау, Қазақстан Республикасы
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Аннотация. Мақалада 2013–2023 жылдар аралығында Индер көлінің үш көзінің экожүйесіне экологиялық-лимнологиялық зерттеулер жүргізілді. Каспий маңы ойпатының тұзды күмбезді ландшафттарының ішіндегі ең үлкені-Күн сәулесі түсетін Индер тауларын қамтитын Индер тұзды күмбезді ауданы. Индер көлдері 115 км^2 эллипсоидты пішінмен және теңіз деңгейінен -23 м төмен су ойығымен ұсынылған. Индер көлінің солтүстік жағалауында 50 — ден астам бұлақ бар, олар ең маңызды үш бұлақ трактатына-Тілепбұлақ, Жүздібұлақ және Ащытұздыбұлаққа топтастырылған. Үш көзден алынған бұлақтардан тұз ерітінділерінің сынамалары алынып, гидрохимиялық құрамы мен ауыр металдардың құрамын зерттеу бойынша зерттеулер жүргізілді. Гидрохимиялық құрамы бойынша жүргізілген салыстырмалы талдау Индер көлінің тұзды ерітіндісі хлорид-натрий және сульфат-кальций және сульфат-магний түріне жататынын көрсетті. Тұзды ерітінділердің құрамында натрий катиондарының мөлшері 89-дан 545 есеге дейін; кальций 2,7-ден 7,4 есеге дейін; магний катиондары 2023 жылы 3-тен 26–28 есеге дейін. Аниондар арасында хлорид аниондары 16,6-дан 105 есеге дейін; сульфат аниондары 1,5-тен 101 есеге дейін. Айта кету керек, негізінен хлор аниондары мен натрий катиондары басым. Осылайша, көздердің россолдары Тилепбулак көзінен басқа хлоридке жатады. Индер көлінің барлық көздерінде зерттелген барлық ауыр металдар бойынша 2013 жылы барлық көздердегі құрамы 5-тен 7,5 есеге дейін асатын хромнан басқа ШРК асып кету байқалған жоқ. Мыс, мырыш, қорғасын, кадмий және марганец сияқты барлық басқа ауыр металдар үшін барлық үш зерттеу кезеңінде.

Түйін сөздер: экологиялық-биологиялық зерттеулер; Индер көлінің тұрақтылығы; гидрохимиялық құрамы; ауыр металдардың құрамы; хлор аниондары; натрий катиондары

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ЭКОЛОГИЧЕСКИЕ И ЛИМНОЛОГИЧЕСКИЕ ИССЛЕДОВАНИЯ УСТОЙЧИВОСТИ ЭКОСИСТЕМЫ ОЗЕРА ИНДЕР

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Аннотация. В статье проведены эколого-лимнологические исследования экосистемы трех источников озера Индер за периоды 2013–2023 годы. Из солянокупольных ландшафтов Прикаспийской низменности самым крупным является Индерский солянокупольный район, включающий закарстованные Индерские горы. Индерские озера представлены эллипсоидной формой площадью 115 км2 и урезом воды -23 м ниже уровня моря. Вдоль северного побережья озера Индер располагается более 50 родников, которые сгруппированы в три наиболее значимые родниковые урочища — Тилепбулак, Туздыбулак и Ащытуздыбулак. С родников трех источников были взяты пробы солевых растворов и проведены исследовани по изучение гидрохимического состава и содержания тяжелых металлов. Проведенный сравнительный анализ по гидрохимическому составу показал, что солевой раствор озера Индер относится к хлоридно-натриевому и сульфатно-кальциевому и сульфатно-магниевому типу. В составе рассолов превышают содержание катионов натрия от 89 до 545 раз; кальция от 2,7 до 7,4 раз; катионов магния от 3 до 26–28 раз в 2023 году. Среди анионов превышают анионы хлорида от 16,6 до 105 раз; анионов сульфата от 1,5 до 101 раз. Необходимо отметить, что в основном преобладают анионы хлора и катионы натрия. Таким образом россолы источников в большинстве относятся к хлоридным, кроме источника Тилепбулак. По всем исследованным тяжелым металлам на всех источниках озера Индер превышений ПДК не наблюдалось, кроме хрома, содержание которого во всех источниках в 2013 году превышало от 5 до 7,5 раз. По всем остальным тяжелым металлам, таким как, медь, цинк, свинец, кадмий и марганец во все периоды исследований на всех трех источниках.

Ключевые слова: эколого-биологические исследования; устойчивость озера Индер; гидрохимический состав; содержание тяжелых металлов; анионов хлора; катионов натрия

Introduction

Sustainable development should be equally aimed at the survival of mankind and the preservation of nature. The first means the possibility of constantly maintaining balanced development, in which our descendants would have no less opportunities than the current generation to meet their needs in natural resources. The second means preserving the biosphere as the natural basis of life on Earth, preserving its stability and natural evolution. The geological environment is a system of extreme complexity and, in comparison with other components of the environment, has some features that determine the specifics of geoecological forecasts, the most important of which are:

- Irreversibility of processes caused by external influences (complete and partial). The restoration of the state and structure of the geological environment after their violations can be said with a certain degree of conditionality only in relation to groundwater, partly soils.
- Inertia, i.e. the ability to withstand the action of external factors for a certain time without significant changes in its structure and condition.
- Time-varying dynamics of the formation of polychrony components. The rock component, which has been formed mainly for many millions of years, is in equilibrium (mainly static) with the environment, the gas component is more dynamic, the intermediate position is occupied by soils.

- Low ability to self-regulate or self- repair compared to the biological component of ecosystems.

Atyrau region is characterized by difficult natural and climatic conditions. It is located in a semi-desert zone with a sharply continental climate. In this regard, the organization of a new health resort in Atyrau region is of great importance for the improvement of the population of the region. The region has the necessary mineral resources for the organization of a resort sanatorium in the village of Inderbor. Rapa Lake. Inder has a long history of study (Yessenamanova et al., 2020).

Limnogenesis is generally understood as the emergence and consistent transformation of continental water bodies of delayed runoff - lakes in connection with natural and anthropogenic factors (Salamov et al., 2019).

Concentrations of carbonates, sulfates and alkali metal chlorides in reservoirs of the arid zone can be very high. This ensures the stability of the life of carbonate-sodium, sulfate and chloride lakes. According to G.A. Maksimovich (Bayanova et. al., 2014), sulfate and chloride lakes with a halotrophic type of limnogenesis predominate. The halogenation of the arid zone depends on the geological substrate and is characterized by significant variability.

Therapeutic mud of salt lakes is formed under certain geological conditions. Brines accumulated on low-lying areas of the earth, fed by precipitation and other various water sources, mainly in arid conditions, evaporate and form various mineral salts in some parts, and therapeutic silt mud accumulates under them for a long time (Yessenamanova et al., 2020).

One of the largest salt dome landscapes of the Caspian lowland is the Inder salt dome area (Yessenamanova et al., 2021). The formation of the Inder salt dome area is associated with two large salt domes – Inder and Zhaman-Inder, between which is located one of the largest in the Caspian depression Inder compensatory (depressed) mulda, the deflection of which is at least 500 m at the speed is about 1 mm per year. From a physical and geographical point of view, the Inder salt dome district is distinguished as a separate landscape district within the Ural-Emben flat desert province (Tauova et al., 2022). Like the five largest salt dome landscapes of the Caspian Basin, the Inder salt dome region is a paradynamic interface consisting of heavily karst Inder Mountains corresponding to a large diapir uplift, and a large ellipsoid-shaped Inder Lake with an area of 115 km^2 and a water cut of -23 m below sea level. Mainly meltwater and rainwater, springs and groundwater coming from the Inder Mountains feed the lake. The lake stretches from northeast to southwest. Its northern and western shores are steep and precipitous, reach a height of more than 20 m, and are cut by short slit-like and trough-shaped logs and ravines. Near the northern shore of the lake in the ravines there are springs with mineral waters, the total number of which reaches 80, of which Ashe-Bulak – on the northeastern shore of the lake - is used for balneological purposes. The average annual flow rate of the sources is 78.2 l/s, varying widely (33–144 l/s) (Yessenamanova et al., 2020). The northern shores are composed of gypsum overlain by Quaternary deposits. Two streams Belaya Rostosh and Aksai flow into the lake from the northwest, which reveal Jurassic and Cretaceous deposits. The eastern and southern shores are flat, cut through by wide beams. The karst field of the Inder Mountains is the largest in the Caspian lowland. The total number of karst forms reaches 5,000. The density of surface karst forms reaches 200–300 manifestations per square km. The total amount of surface reduction due to karst processes is 1.87 mm/year (Kanbetov et al., 2023). There are four types of sinkholes – saucer-shaped, cone-shaped, ponor-shaped and well shaped. Saucer-shaped funnels, widespread everywhere, but most often along the periphery of the Inder Mountains, reach a diameter of 10–15 m and a depth of 2–3 m. The cone-shaped funnels are up to 20 m deep and 30-40 m across. The funnel-shaped funnels have a cone-shaped shape with a narrow slit (ponor) in the bottom, which serves as a drainage channel. Karst wells are peculiar – with small sizes (up to 5 m in diameter), their depth reaches 15 m (Seitov et al., 2021). There are separate karst depressions and sinkholes to the south and southeast of Lake Inder. The morphological structure of the Inder salt dome landscape is complemented by a two-tiered lake terrace stretching along the southern and southwestern shores of the lake (Issayeva et al., 2022). The terrace is also fragmentary along the northern and eastern shores. The lower tier of the terrace is located at a height of 1–1.5 m above the water edge in the Inder, the upper one is 7–8 m. It is obvious that the abruptness of the shores of Lake Inder, as well as on other lake depressions (Baskunchak, Elton, Aralsor) associated with compensatory mulds, has a tectonic conditionality. The surface of the Inder salt dome directly under the northern shore is inclined at an angle of 850, and within the Inder Mountains – by 15-300 . The Inder denudation karst upland is obviously a relic of the ancient peneplene, which, under the influence of salt tectonics, was first raised and eroded, and then underwent karst-denudation dissection with the formation of various micro- and mesoforms of the relief (*Issayeva* et al., 2022). The salt dome geosystems of the Caspian lowland are characterized by a pronounced geochemical contrast between paragenetic conjugations within the landscape catenae "the area of salinization (gypsum caprock) – the area of accumulation (salt lakes, sores)".

Along the northern coast of Lake Inder there are more than 50 spring outlets of sodium chloride composition with high mineralization. The spring outlets are grouped into three most significant spring tracts — Tilepbulak, Tuzdybulak and Ashytuzdybulak. The largest tracts are Tilepbulak (3 hectares within Lake Inder) and Tuzdybulak (25 hectares, including 5 hectares within the Inder Mountains and 20 hectares within Lake Inder). Therapeutic mud is available on the northern coast of Lake Inder. These mud accumulate at the outlets of the large Tuzdybulak, Telepbulak and Ashybulak springs. The therapeutic mud outlets associated with the Telepbulak source are approximately 200–250 m long from west to east, up to 60 m wide from north to south with an apparent power of 17 cm. The dimensions of the mud outlet associated with the Ashbulak source are 200 m long, 10m wide and 10 cm thick. The length of the mud outlet at the Tuzbulak source is 210 m, width from 54 to 74 m, thickness 10-20 cm. The therapeutic mud outlets associated with the Telepbulak source are approximately 200–250 m long from west to east, up to 60 m wide from north to south with an apparent power of 17 cm. The dimensions of the mud outlet associated with the Ashbulak source are 200 m long, 10m wide and 10 cm thick. The length of the mud outlet at the Tuzbulak source is 210 m, width from 54 to 74 m, thickness 10–20 cm (*Akhmedenov,* 2020).

Materials and methods

The work used methods of comparative analysis of data on the hydrochemical composition of salt brines of Lake Inder, based on the results of research conducted in different years from 2013 to 2023. All the results were compared with the normative documents GOST 26449.1-85, ST RK 1015-200, SanPiN 2.1.4.1074-01 and RD 5224.365-2008 (GOST 26449.1-85, 1987; ST RK 1015-200, 2000; SanPiN 2.1.4.1074-01, 2001; RD 5224.365-2008, 2008).

According to the ratio of anion concentrations in water, its bicarbonate, sulfate or chloride nature is determined, and magnesium, sodium and calcium water are distinguished by the predominant cation. All ions, even in insignificant concentrations, have an impact on the consumer qualities of the aqueous solution. According to these criteria, four types of waters are distinguished:

Type I: $HCO^{3-} > Ca^{2+} + Mg^{2+}$ (alkaline, soft waters; salt composition is represented by $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $NaHCO_3$, Na_2SO_4, NaCl);

Type II: $HCO^{3-} < Ca^{2+} + Mg^{2+} < HCO^{3-} + SO_4^{2-}$ (waters of most rivers and lakes of low and moderate mineralization containing $Ca(HCO_3)_2$, $Mg(HCO_3)^2$, $CaSO_4$, $MgSO_4$, $MgCl_2$, NaCl);

Type III: $HCO^{3-} + SO4^{2-} < Ca^{2+} + Mg^{2+}$, $Cl^{-} > Na$ (waters of seas, oceans, salt lakes containing $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $CaSO_4$, $MgSO_4$, $MgCl_2$, NaCl);

Type IV: acidic with a complete absence of bicarbonate ions (swamp, volcanic, acidic wastewater) (*Shcherbakov* I. A., 2021).

More than half of all components dissolved in seawater, namely 55 %, is chlorine ion. Taking into account the constancy of the salt composition, it is possible to determine the concentration of chlorine (chlorinity) in a sample of seawater, then calculate not only the total concentration of salts (salinity), but also the mass fraction of each of the main ions. This principle is based on the most common argentometric method for determining salinity in the first half of the last century, so named because it uses a solution of silver nitrate as the main chemical reagent. The relationship between salinity and chlorine content was determined at the end of the 19th century by a special commission of the International Conference on the Study of the Seas and is expressed by the equation

$$S‰ = 0.030 + 1.805Cl‰ \quad (1)$$

The presented ratio is often called the Knudsen formula, after the chairman of the commission. When determining the chlorinity by the argentometric method, the content of all halogens present in seawater is eventually obtained, that is, the sum of chlorine, bromine and iodine ions, but the amount of chlorine in this amount is 99.9 %.

The Knudsen formula and the tables compiled according to it were used to determine salinity by oceanologists around the world for more than sixty years, until in 1963 a new, more compact ratio between salinity and chlorine was proposed (*Gladkov*, 2021):

$$S = 1.80655Cl‰ \quad (2).$$

Results

Along the northern coast of Lake Inder there are more than 50 spring outlets of sodium chloride composition with high mineralization. Spring outlets are grouped into three most significant spring tracts — Tilepbulak (49.6 g/l, in the amount of 1.2 l/s), Tuzdybulak (66.4 g/l, in the amount of 2 l/s) and Aschytuzdybulak (52.3 g/l, 0.05 l/s) (Petrishchev, 2012). The largest tracts are Tilepbulak (3 hectares within Inder Lake, about 1000 visits per year, about 100 mud baths) and Tuzdybulak (25 hectares, including 5 hectares within the Inder Mountains and 20 hectares within the Inder Lake, about 5,000 visits per year, about 50 mud baths). The springs are either poorly captioned (Tilepbulak), or completely devoid of any equipment (Tuzdybulak and Ashytuzdybulak). In the spring waters of Tilepbulak, Aschytuzdybulak and Tuzdybulak, the formation of feeding aquifers is associated with the halogen-sulfate thickness of the Inder salt structure (Table 1) (Kenzhegaliev et.al., 2018; Petrishchev et.al., 2017).

Table 1 - Hydrochemical composition of the waters of the Inder upland springs in the period from 2013 to 2023, mg/l

Place of selection	Year of selection	Na+	K+	Ca2+	Mg2+	Cl-	SO4-	HCO3 -	mine-raliza-tion	dry residue
Source Tuschibulak	2013	22997	500	1499	358	36868	4096	153	66395	66496
	2017	28680	650	1300	530	29050	20077	153	76400	78808
	2023	8.89	2,64	714	1399	5814	736.6	262.3	-	-
Source Ashy-tuzdybulak	2013	17831	500	1325	360	28080	4382	140	57700	52424
	2017	21697	536	1250	348	25900	10841	140	52348	59406
	2023	9.34	2.64	620	1315	15893	1996.4	366	-	-
Source Tilepbulak	2013	18280	400	198	96	26000	4462	288	49580	49654
	2017	109141	1420	7580	150	11900	50816	292	260200	281000
	2023	9.56	3.19	720	1412	6452	809.5	262.3	-	-
MPC		200	1500	180	50	350	500	350	1000	

In these three springs, the hardness values significantly exceed the MPC. The water of these springs belongs to the group of very hard waters. The values of chlorides, sulfates and dry residue also exceed the MPC. The ammonium content in the Aschytuzdybulak spring exceeds the MPC by 1.8 times. In other springs, the concentration of ammonium is within the limits of norms. By mineralization, the water of the Tilepbulak spring belongs to the type of highly saline waters. The water of the Aschytuzdybulak and Tuzdybulak springs belongs to the type of brines. According to the chemical type of water of these springs, they belong to chloride. The springs on the shore of Lake Inder represent a hydrogeochemical anomaly, which is associated with the migration of brackish waters of the quaternary aquifer through halogen-sulfate deposits lying near the northern side of the Inder Depression.

Using the Knudsen formula (formula 2), we will find the ratio between salinity and chlorine content for all sources for the period from 2013 to 2023, the data obtained are presented in Table 2.

Table 2 - The ratio between salinity and chlorine content at the sources of Lake Inder for the period from 2013 to 2023

Place of selection	Year of selection	Cl-	S‰
Source Tuschibulak	2013	36868	66,6
	2017	29050	52,48
	2023	5814	10,5
Source Ashytuzdybulak	2013	28080	50,7
	2017	25900	46,79
	2023	15893	28,71
Source Tilepbulak	2013	26000	46,97
	2017	11900	21,5
	2023	6452	11,66

The content of heavy metals (copper, zinc, lead) in the studied waters of the springs is within the established norms (Table 3).

Table 3 - The content of heavy metals in the water of the Inder upland springs in the period from 2013 to 2023, mg/l

Place of selection	Year of selection	Cu, мг/л	Zn, мг/л	Pb, мг/л	Cd, мг/л	Cr, мг/л	Mn, мг/л
Source Tuschibulak	2013	0,15	0,011	0	0,0023	3,77	0,15
	2017	0,00064	0,00052	<0,0002	<0,0002	н/д	н/д
	2023	<0,0005	<0,1	<0,002	<0,0001	<0,005	<0,002
Source Ashytuzdybulak	2013	0,12	0,02	0	0,002	2,90	0,09
	2017	0,00056	0,00064	<0,0002	<0,0002	н/д	н/д
	2023	<0,0005	<0,1	<0,002	<0,0001	<0,005	<0,002
Source Tilepbulak	2013	0,10	0,03	0	0,001	2,46	0,14
	2017	<0,0005	<0,0005	<0,0002	<0,0002	н/д	н/д
	2023	<0,0005	<0,1	<0,002	<0,0001	<0,005	<0,002
MPC		1.0	5.0	0.03	0.001	0.5	0.1

The content of cadmium in the water of the springs Aschytuzdybulak and Tuzdybulak exceed the established norms by 2 and 3 times, respectively. The concentration of manganese in the water of the Aschytuzdybulak and Tilepbulak springs exceeds the established norms by 1.9 and 5.4 times.

Discussion

The main sources of salt nutrition are lakes Inder are salt springs located in its northern part. Two groups stand out among them: the north-western White Wasteland with microlocks, Tilepbulak springs and the north-eastern – Aschytuzbulak and Tuschibulak springs (Yessenamanova et al., 2020). The study of the chemical composition of the mineral springs of the Inder salt dome region showed that, despite the simple chemical composition (a sharp predominance of sodium chloride) and high mineralization, they are not so monotonous (Table 1). By mineralization, the water of the Tilepbulak spring belongs to the type of highly saline waters. The water of the Aschytuzdybulak and Tuzdybulak springs belongs to the type of brines. According to the chemical type of water of these springs, they are chloride. The springs on the shore of Lake Inder represent a hydrogeochemical anomaly, which is associated with the migration of brackish waters of the quaternary aquifer through halogen-sulfate deposits lying near the northern side of the Inder depression.

Figure 1 shows a bar chart of the hydrochemical composition of the Tuschybulak source of Lake Inder in the period from 2013 to 2023.

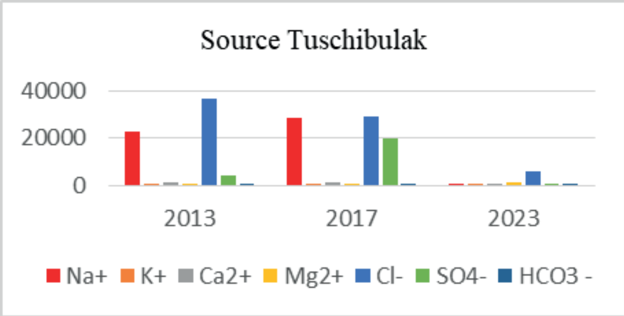

Figure 1. Analysis of the results of the hydrochemical composition of source Tuschibulak of Lake Inder for the period from 2013 to 2023

As can be seen from the bar chart in Figure 1, in 2013 and 2017, the Tuschybulak source showed an increased content of sodium cations (22997 and 28680 mg/l, respectively, 115 and 143 MPC). Calcium cations (500 and 650 mg/l – 2.7 and 3.6 MPC, respectively) are the next in terms of the content of cations at this source in 2013 and 2017. Potassium ions are in third place in terms of cation content (500 and 650 mg/l, respectively, in 2013 and 2017). In last place are magnesium cations with a content of 358 and 530 mg/l (7.1 and 10.6 MPC) in 2013 and 2017. Studies of the hydrochemical composition of the Tuschybulak spring water in 2023 differ, where the highest values are characterized by magnesium cations of 1399 mg/l (28 MPC), followed by calcium cations of 714 mg/l, while the contents of sodium and potassium cations are minimum 8.89 and 2.64 mg/l, respectively. According to the anion content in different years at the Tuschybulak source, chlorine anions are the maximum, the content of which are 36,868, 29050 and 5814 mg/l, respectively, the highest value was observed in 2013 and the minimum in 2023. In second place are data on the content of sulfate anions, the maximum content of which at the Tuschybulak source was noted in 2017 at 20077 mg/l, then in 2013 at 4096 mg/l and in 2023 at 736.6 mg/l. For bicarbonate anions, we note minimum values compared to other anions and their amount in 2013 and 2017 is the same as 153 mg/ kg, and in 2023 it is higher and amounts to 262.3 mg/ kg. Thus, sodium chloride salts predominate at the Tuschybulak source in 2013 and 2017, and magnesium chloride salts in 2023. At the same time, the content of chloride ions in all years exceeds the MPC almost more than a hundred times in 2013 and 2017 and more than sixteen times in 2023. According to the mineralization and dry residue at the Tuschybulak source, there is also an increased content of more than 60-70 times according to 2013 and 2017, which indicates an increased total salinity, that is, that the substances in the ode are in the form of salts.

Figure 2 shows a bar chart of the hydrochemical composition of the Aschybulak source of Lake Inder in the period from 2013 to 2023.

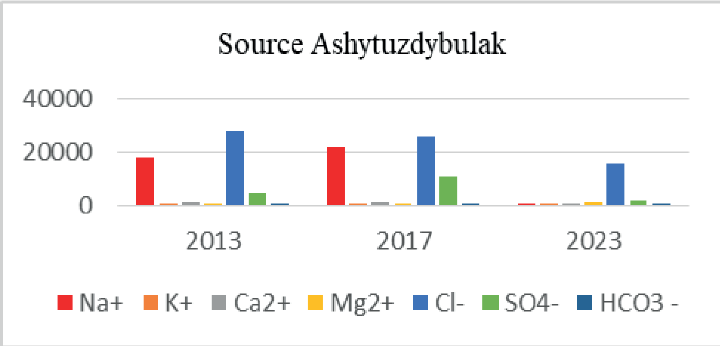

Figure 2. Analysis of the results of the hydrochemical composition of source Aschybulak of Lake Inder for the period from 2013 to 2023

The data from bar chart 2 show that sodium ions at the Aschytuzdybulak source for cations in the period from 2013 to 2023 are the maximum in 2013 and 2017, which amount to 17831 and 21697 mg/l (89 and 108 MPC), respectively, whereas in 2023 its content is minimal and amounts to 9.34 mg/l. In second place in 2013 and 2017 are calcium cations with a content of 1325 and 1250 mg/l (7.4 and 6.9 MPC), respectively, and in 2023 620 mg/l, which also corresponds to the second place in terms of cation content in 2023. Potassium cations are next in terms of cation content, which in 2013 and 2017 amounted to 500 and 536 mg/l, respectively, but in 2023 the potassium content is the lowest and amounts to 2.64 mg/l. In the last place in terms of cation content in 2013 and 2017 are magnesium cations, the content of which varies from 360 and 348 mg/l (7.2 and 6.9 MPC), but in 2023 the magnesium content is higher than the content of all cations and is 1315 mg/l (26 MPC). In terms of the anion content at the Aschytuzdybulak source, chloride ions predominate in all years, which amount to 28080 and 25900 mg/l, respectively (80 and 74 times higher than MPC), whereas in 2023 their content is 15,893 mg/l (45 times higher than MPC). The content of sulfates is diverse and amounts to 4382 mg/l in 2013 (8.7 times higher than MPC), 10,841 mg/l in 2017 (21 times higher than MPC) and the minimum value is typical in 2023 of 1996.4 mg/l (about 4 MPC). The lowest values are typical for bicarbonate anions, the content of which is 140 mg/l in 2013 and 2017 and 360 mg/l in 2023. Thus, in 2013 and 2017, sodium chloride salts predominate at the Aschytuzdybulak source, and in 2023-magnesium chloride, salts predominate. According to the mineralization and dry residue data at the Aschytuzdybulak source, according to available data from 2013 and 2017, the maximum permissible concentration was also exceeded more than fifty times, which indicates a high salt content in these solutions.

Figure 3 shows a bar chart of the hydrochemical composition of the Tilepbulak source of Lake Inder in the period from 2013 to 2023.

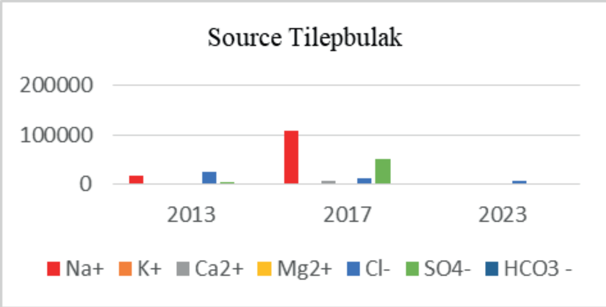

Figure 3. Analysis of the results of the hydrochemical composition of source Tilepbulak of Lake Inder for the period from 2013 to 2023

According to the bar chart in Figure 3, data on the source of Tilepbulak in the period from 2013 and 2023, we note that there are differences in cations, so in 2013 and 2017, the contents of sodium cations were exceeded, and the minimum values are typical for magnesium cations. In 2023, the maximum values are typical for magnesium cations, and the minimum values for potassium cations. If we consider for each cation, the content of sodium cations in 2017 is the highest in all years and even in all sources and is 109141 mg/l (545 MPC), then in 2013 it is 18280 mg/l (91MPC), and in 2023 it is only 9.56 mg/l. In terms of potassium content, the maximum value is typical in 2017 – 1420 mg/l, in the second place in 2013 - 400 mg /kg and the lowest value is characterized in 2023 - 3.19 mg/l. In terms of calcium cation content, the maximum amount is also typical for 2017, with 2023 in second place with 720 mg/l (4 MPC), and the minimum in 2013 – 198 mg/l. The content of magnesium cations is characterized by a maximum value in 2023 of 1412 mg/l (28 MPC), then in 2017 of 150 mg/l (3 MPC) and in last place in 2013 with a value of 96 mg/l. Various data are also available on the content of anions, so in 2013 and 2023 chloride anions predominate, and in 2017 sulfate anions. The most minimal are the anions of hydrocarbonates. For chlorides, the maximum values are typical in 2013 of 26,000 mg/l (74 MPC), then in 2017 of 11900 mg/l (34 MPC) and the minimum in 2023 of 6452 mg/l (18 MPC). For sulfates, the maximum values are typical for 2017 of 50,816 mg/l (101 MPC), in second place in 2013 of 4462 mg/l (8.9 MPC), in last place the content of sulfates in 2023 (1.6 MPC). The content of hydrocarbonates is minimal and almost equal for all years (288, 262.3 and 350 mg/l). Thus, sodium chloride salts prevailed at the Tilepbulak source in 2013, sodium sulfate in 2017 and magnesium chloride in 2023. According to the mineralization content and dry residue, according to the data of 2013 and 2017, the maximum content is typical in 2017 and is more than 260 MPC, and in 2013 49 MPC.

By determining only the salinity, it is possible to calculate the concentration of any basic ion of seawater. The solubility of gases depends on salinity and temperature. According to salinity and temperature, the density is calculated, the distribution of which determines the movement of water masses (Anwar et.al., 2023).

The distribution of salinity in the surface layer of the ocean (excluding seas) is zonal. The lowest salinity values are observed in the polar regions, which is due to the melting of ice, and for the Arctic Ocean — also by continental runoff, and in the narrow equatorial zone, which is explained by a positive freshwater balance (precipitation prevails over evaporation). The highest salinity is observed in subtropical zones around 20° north and south latitude (Deih et.al, 2023).

The distribution of salinity in the seas is characterized by significant fluctuations due to the influence of river flow and climatic conditions. For example, in the Caspian Sea, the salinity in the middle part is about 13 % , and in the Kara-Bogaz-Gol Bay, the salinity reaches 300 % (Muhammad et.al., 2023).

The change in salinity along the vertical ocean is much more complicated than on the surface, and is associated with the distribution of water layers depending on density.

The bar chart in Figure 4 shows the data on the ratio between salinity and chlorine content for all sources for the period from 2013 to 2023, calculated using the Knudsen formula.

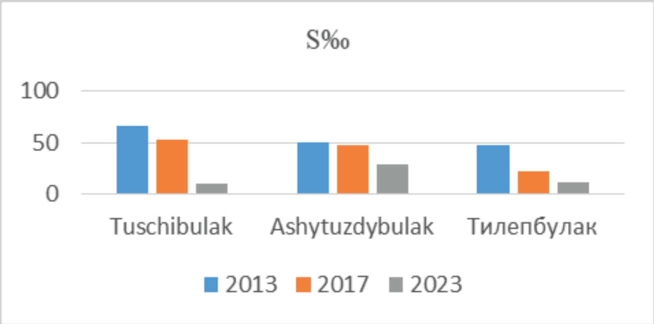

Figure 4. The ratio between salinity and chlorine content at the sources of Lake Inder for the period from 2013 to 2023

The bar chart in Figure 4 shows the calculated data of the ratio between the salinity and chlorine content of the sources of Lake Inder for the period 2013–2023. In 2013, the salinity data are maximum at the Tuschibulak source and equal to 66.6 %, at other sources they are about 50 %. In 2017, salinity data were also increased at the Tuschybulak source and amounted to 52.48 %, at the Ashytuzdybulak source these data were close and amounted to 46.79 %, and at the Tilepbulak source they were lower and amounted to 21.5 %. In 2023, the highest values were typical for the Ashytuzdybulak source and amounted to 28.71 %, the second place was taken by the Tilepbulak source, where salinity indicators amounted to 11.66 % and the lowest at the Tushybulak source, which were equal to 10.5 %.

The results of the analysis of the gross content of heavy metals in soil and plants showed the following results (Table 2). The presence of heavy metals is due to the fact that the landscape diversity of the Inder upland is affected by mining activities. The Inder borate deposit, discovered in 1934 and developed since 1964, is being developed here. Heavy metals, in particular copper, enter the soil due to man-made dispersion in various ways.

Figure 5 shows a bar chart of the heavy metal content in the Tuschybulak source.

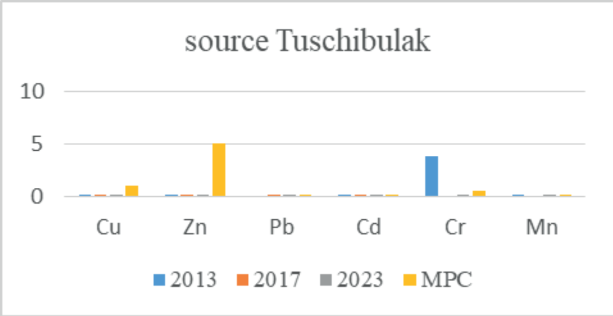

Figure 5. The content of heavy metals in the Tuschibulak source of Lake Inder for the period from 2013 to 2023.

According to the bar chart in Figure 5, we can estimate the content of heavy metals at the Tuschibulak source in the period from 2013 to 2023, where there are no MPC exceedances for all heavy metals, except chromium. The copper content in all periods does not exceed the MPC and ranges from 0.00054 in 2017 to 0.15 mg/l in 2013. The zinc content also does not exceed the MPC and ranges from 0.00052 in 2017 to 0.1 mg/l in 2023. The lead content does not exceed the MPC from 0 in 2013 to 0.002 mg/l in 2023. The cadmium content does not exceed the MPC and ranges from 0.0001 mg/l in 2023 to 0.0023 mg/l in 2013. The chromium content was not determined in 2017, in 2023 it does not exceed the MPC and is less than 0.005 mg/ l, and in 2013 it is 3.77 mg/l and exceeds the MPC by 7.5 times. The manganese content also almost does not exceed the MPC and ranges from 0.002 to 0.15 mg/l.

Figure 6 shows a bar chart of the heavy metal content in the Aschytuzdybulak source.

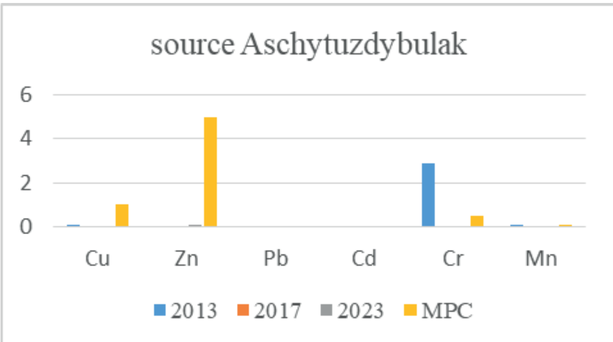

Figure 6. The content of heavy metals in the Aschytuzdybulak source of Lake Inder for the period from 2013 to 2023.

According to the bar chart in Figure 6, we can estimate the content of heavy metals at the Ashtuzdybulak source in the period from 2013 to 2023, where there are no MPC exceedances for all heavy metals, except chromium. The copper content in all periods does not exceed the MPC and ranges from 0.00056 in 2017 to 0.12 mg/l in 2013. The zinc content also does not exceed the MPC and ranges from 0.00064 in 2017 to 0.1 mg/l in 2023. The lead content does not exceed the MPC from 0 in 2013 to 0.002 mg/l in 2023. The cadmium content does not exceed the MPC and ranges from 0.0001 mg/l in 2023 to 0.002 mg/l in 2013. The chromium content was not determined in 2017, in 2023 it does not exceed the MPC and is less than 0.005 mg/l, and in 2013 it is 2.9 mg/l and exceeds the MPC by almost 6 times. The manganese content also almost does not exceed the MPC and ranges from 0.002 to 0.09 mg/l.

Figure 7 shows a bar chart of the heavy metal content in the Tilepbulak source.

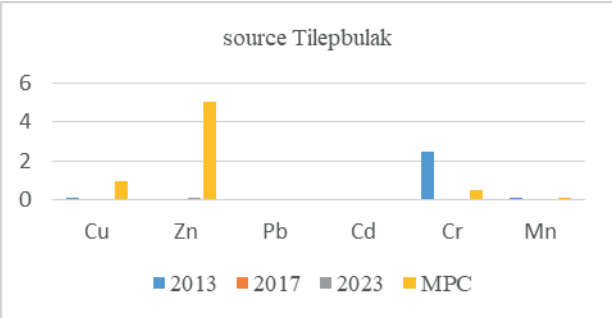

Figure 7. The content of heavy metals in the Tilepbulak source of Lake Inder for the period from 2013 to 2023.

According to the bar chart in Figure 7, we can estimate the content of heavy metals at the Tilepbulak source in the period from 2013 to 2023, where there are no MPC exceedances for all heavy metals, except chromium. The copper content in all periods does not exceed the MPC and ranges from 0.0005 in 2017 to 0.1 mg/l in 2013. The zinc content also does not exceed the MPC and ranges from 0.0005 in 2017 to 0.1 mg/l in 2023. The lead content does not exceed the MPC from 0 in 2013 to 0.002 mg/l in 2023. The cadmium content does not exceed the MPC and ranges from 0.0001 mg/l in 2023 to 0.002 mg/l in 2013. The chromium content was not determined in 2017, in 2023 it does not exceed the MPC and is less than 0.005 mg/l, and in 2013 it is 2.46 mg/l and exceeds the MPC by almost 5 times. The manganese content also almost does not exceed the MPC and ranges from 0.002 to 0.14 mg/l.

Conclusion

A comparative analysis of the hydrochemical composition showed that the salt solution of Lake Inder belongs to the sodium chloride and calcium sulfate and magnesium sulfate types. In the composition of brines, according to the MPC, the content of sodium cations exceeds from 89 to 108 times at the Aschytuzdybulak source, 115–143 times at the Tushybulak source and from 91 to 545 times at the Tilepbulak source; calcium from 2.7 to 3.6 times at the Tushybulak source, 4 times at the Tilepbulak source and from 6.9 to 7.4 times at the Aschytuzdybulak source; magnesium cations from 3 times at the Tilepbulak source to 7-10 times at the Tuschybulak and Ashytuzdybulak sources in 2013 and 2017 and 26–28 times in 2023. Among the anions, chloride anions exceed from 16.6 to 105 times in the source of Tushybulak, from 45 to 80 times in the source of Aschytuzdybulak, from 18 to 74 times in the source of Tilepbulak; sulfate anions from 1.5 to 40 times in the source of Tushybulak, from 3.9 to 21 times in the source of Aschytuzdybulak and from 8.8 to 101 times in the source of Tilepbulak. It should be noted that chlorine anions and sodium cations mainly predominate, but this is not typical for all sources and in all periods. For example, in 2013 and 2017, sodium chloride salts prevailed at the Tushybulak source, and in 2023 - magnesium chloride salts; in 2013 and 2017, sodium chloride salts predominated at the Aschituzdybulak source, and in 2023 - magnesium chloride salts; in 2013, sodium chloride salts prevailed at the Tilepbulak source, in In 2017 - sodium sulfate, and in 2023 - magnesium chloride. Thus, the salts of the sources are mostly chloride, except for the source of Tilepbulak.

Depending on the total mineralization and dry residue, it can be concluded that all sources belong to mineralized brines.

Calculated using the Knudsen formula, the data on the ratio between salinity and chlorinity show that the maximum values in 2013 and 2017 are typical for the Tuschybulak source, and the minimum values for the Tilepbulak source, whereas in 2023, increased salinity data are typical for the Ashytuzdybulak source, and low values for the Tuschybulak source.

For all the studied heavy metals, no MPC exceedances were observed at all sources of Lake Inder, except for chromium, the content of which in all sources in 2013 exceeded from 5 to 7.5 times. For all other heavy metals, such as copper, zinc, lead, cadmium and manganese, no exceedances were recorded at all three sources of Tuschybulak, Ashytuzdybulak and Tilepbulak during all periods of research.

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ISSN 2518-170X (Online),
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Подписано в печать 15.02.2024.
Формат 70x90$^{1}/_{16}$. Бумага офсетная. Печать – ризограф.
18,0 п.л. Тираж 300. Заказ 1.

РОО «Национальная академия наук РК»
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