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STUDY OF THE INFLUENCE OF EVAPORATION ON THE CONCENTRATION OF SOLUTIONS OF THE LAKES KARAUMBET AND BARSAKELMES

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Abstract. This investigation into brine from two specific lakes such as Karaumbet and Barsakelmes suggests that NaCl and $MgCl_2$ melts can be made into industrial-like conditions. A two-step evaporation method is key to this process. In the first step, evaporating to a density of 1.550 g/cm^3 raises magnesium chloride concentration from 7.20 to 28.24% and drops sodium ion levels from 8.05 to 0.91%. The evaporation should continue at the first and second stages until a density of 1.340-1.345 g/cm^3 is reached, which causes sodium chloride to form. Further evaporation of the remaining liquid can yield almost pure sodium chloride. After the initial evaporation phase, magnesium chloride in the brine is at 15-16%.

Keywords: *Magnesium chloride, evaporation, sedimentation, sodium chloride, cooling.*

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1. Introduction

Setting up factories and building a strong economy are key traits of the global economy. This highlights the need to effectively produce goods that replace imports and support exports, which are essential for boosting economic growth and speeding up technology advances in any country. A nation's development level is typically judged by its natural resources and its existing technology infrastructure. Therefore, developing new technologies to turn local resources into competitive global products is a major focus (Vallès *et al*., 2024; Abdullayev *et al*., 2024; Wang *et al*., 2023; Xiao *et al*., 2022).

Evaporation plays a strong role in determining the hydrological and chemical properties of salty lakes mainly in arid and semi-arid regions. Comprehension of the consequences of evaporation on lake solutions is important to predict ecological changes, water quality as well as resource management. In Central Asia, the lakes Karaumbet and Barsakelmes are good examples where evaporation is important for changing water salinity and mineral statuses. Weather conditions and human activities influence both lakes with severe seasonal differences of water level and salinity. The implication on the local biodiversity, ecosystem stability and the usability of water resources is severe for the change in concentration within these lakes.

All these lakes are of critical importance yet there is minimal research on evaporation rate and the direct relationship to solution concentration. The current research is therefore designed to fill this gap by studying the effect of evaporation on chemical constituents of Karaumbet and Barsakelmes lakes in a systematic manner. The findings are a complete analysis of how evaporation changes the chemistry of the lake water over time using field measurements and laboratory analysis.

In the worldwide race to make pure sodium, calcium and magnesium salt from natural spots like seawater, brine in salt lakes and salt pits, there is a big focus on tech that helps use materials better. This helps cut down costs for important products and fits with green goals. So, pushing for better environmental care is tied to plans for using nature's resources more efficiently (Zhao *et al*., 2024; Telesca *et al*., 2024).

A lot of progress has been made in processing mixed brines from lakes, seawater and salt deposits. Research shows how to extract bischofite by evaporating brines from places like the Great Salt Lake (GSL) in Utah and the Dead Sea. Companies like GSL Minerals Corp., Kaiser Refractories, US Magnesium LLC (US) and Dead Sea Magnesium Ltd (Israel) use different techniques, such as solar evaporation ponds and vacuum evaporators. Also, methods to make magnesium hydroxide and magnesium oxide have been developed by reacting seawater with calcined dolomite or limestone and by treating brines from Sivash Lake and Volgograd bischofite with ammonia. Organizations like South Bay Salt Works in Chula Vista (USA), Jinzhou Huacheng Magnesium Company (China), Brom JSC (Ukraine) and NPO Caustic (Russia) carry out these techniques (Luo *et al*., 2024). Moreover, the making of primary metallic magnesium, titanium sponge and steel lead by the deep processing of brines from salt lakes and seawater. Firms like Rima Industrial from Brazil, Magnohrom from Serbia, POSCO from South Korea and Chaoyang Jinda Titanium Co. Ltd from China have led these changes (Feng *et al*., 2023; Song *et al*., 2022). Also, PA *"Karabogazsulfat"* in Turkmenistan has managed to extract minerals like mirabilite, epsomite and bischofite from surface and underground brines in Kora-Bogaz-Gol Bay. These changes are important steps in using brine resources well for industry and business purposes.

Lots of information exists on how to process sulfate-chloride brines, brines from salt lakes, seawater and also different mineral stuff like dolomite, brucite and serpentinite into magnesium compounds. This information can also be found in several scientific papers. You can get magnesium chloride (called bischofite usually) from seawater or salt lake brines. The make-up of bischofite deposits is different; some are salty areas where $MgCl_2$ is mixed with other minerals, creating what people call carnallite-bischofite rocks. These deposits usually have other minerals too like halite, kieserite and anhydrite (Guan *et al*., 2021; Cherif *et al*., 2024; Yang *et al*., 2024).

Magnesium chloride makes mostly by big places like USA, Ukraine, Russia, Israel, China, Germany, Chile, Czech Republic and Turkmenistan. In USA, liquid $MgCl_2$ makes up 90-93% of all $MgCl_2$ made. Flake $MgCl_2$ is just 7-10%. Liquid $MgCl_2$ comes from salt lake brines by companies such as Intrepid Potash Inc. and Great Salt Lake Minerals Corp. and from seawater by South Bay Salt Works in Chula Vista. Also, US Magnesium LLC and Mineral Research and Development are important in this area. US Magnesium LLC makes magnesium metal, however, Mineral Research and Development (MRD) focuses on $MgCl_2 \cdot 6H_2O$ (Perera *et al*., 2024; Yang *et al*., 2024).

US Magnesium LLC uses a huge area of approximately 75,000 acres of solar ponds to boost magnesium levels in Great Lake brine. They import between $75x10^7$ m^3 and $130x10^7$ m^3 of lake water each year for this purpose. Liquid $MgCl_2$ is applied for dust controlling and as an anti-icing agent. In China, several establishments focus on production and sales ventures. For instance, Chaoyang Jinda Titanium Co. Ltd makes titanium sponges, magnesium powders and dry $MgCl_2$ as part of their whole project. Likewise, Jinzhou Huacheng Magnesium Company produces magnesium alloys, calcium chloride, de-icing salts and refractory materials. Weifang Bell Chemical Co. Ltd attempts to create calcium and magnesium chloride for drilling, de-icing, dust control, water treatment, agriculture, construction and food additives. Solid $MgCl_2$ is used widely by evaporating its solution to get $MgCl_2 \cdot 6H_2O$. Dead Sea Works Ltd. is the only magnesium producer in Israel, by extracting raw materials from the Dead Sea. One liter of seawater has 170 g of $MgCl_2$. This company uses solar evaporation ponds to concentrate $MgCl_2$ from 33 to 47% and forms $MgCl_2$ flakes, which turn out to be the raw material of metallic Mg, magnesia binders, refractories, anti-icing agents and agricultural products (Perera *et al*., 2024; Edoziuno *et al*., 2024). As far as companies of this sort in Uzbekistan are concerned, they produce magnesium chlorate used in cotton defoliation by converting magnesium chloride to bischofite with sodium chlorate in a wet process.

$$MgCl_2 \cdot 6H_2O + 2NaClO_3 \rightarrow Mg(ClO_3)_2 \cdot 6H_2O + 2NaCl$$

The need for bischofite of the company *"Farg'onaazot"* JSC is 30,000 tons per year. Uzbekistan has large reserves of raw materials available for the production of magnesium salts. These lakes Karaumbet and Barsakelmes brine and dry mixed salts (DMS) of Karakalpakstan. Approved reserves of Karaumbet are equivalent to approximately 295,000 tons of Magnesium Oxide (MgO) and 700,000 tons of $MgCl_2$, 74,000 tons of which are produced by brine. The reserves of magnesium salts in the Barsakelmes brine are quite substantial, estimated at around 1.04 million tons of MgO and 2.47 million tons of magnesium chloride ($MgCl_2$). These natural resources hold great potential as raw materials for producing essential magnesium compounds like magnesium oxide, magnesium hydroxide and magnesium chloride, which have significant benefits in agriculture and other industries (Abdullayev *et al*., 2024).

The brine from Lake Karaumbet is rich in minerals, containing between 7.40 and 11.45% sodium (Na), 15.2 to 18.9% chloride (Cl^-), 4.55 to 6.27% magnesium oxide (MgO), 3.14 to 6.66% sulfate (SO_4^{2-}) and up to 0.60% calcium oxide (CaO). Similarly, the brine from Lake Barsakelmes also offers an enormous wealth of minerals, with sodium levels ranging from 6.61 to 11.45%, chloride at 15.2 to 18.9%, magnesium oxide at 1.37 to 4.57%, sulfate at 1.44 to 3.73% and calcium oxide at a negligible 0.02%. The dry mineral salts (DMS) from Karaumbet are especially promising, containing an average of 43 to 61% sodium sulfate (Na_2SO_4), 11 to 15% magnesium chloride ($MgCl_2$) and 13 to 19% sodium chloride (NaCl). These salts are valuable for the production of sodium sulfate, bischofite and table salt. However, despite the abundance of these resources, they remain untapped due to the absence of effective processing technologies (Abdullayev *et al*., 2024).

This highlights the urgent need for research and innovation to develop efficient methods for extracting magnesium compounds like $MgCl_2$, $Mg(OH)_2$ and MgO, as well as sodium sulfate and chloride from the brines and DMS of the Karaumbet and Barsakelmes lakes. Bischofite, in particular, has shown great promise in agriculture, where it is used to produce magnesium-based fertilizers for pre-sowing seed treatments in vegetable and oil crops. Additionally, environmentally friendly fungicides have been successfully derived from bischofite solutions through electrolysis, offering a sustainable way to combat harmful fungi in agriculture.

Developing the appropriate technologies to process these rich mineral reservoirs could unlock enormous potential for both industrial and agricultural advancements.

2. Experimental part

Mineral salts extracted from Karaumbet and Barsakelmes were used in experiments, located in the Kungrad area of Karakalpakstan, at distances of 45 km and 80 km from Kungrad city. A survey of the bed was conducted between 1992 to 1993. There were clear changes in composition during this period. For example, the surface salt mix in Barsakelmes saw an increase of over 10% of sodium chloride with some insoluble stuff and a reduction overall in calcium sulfate by approximately 3 to 4 times. A similar pattern shows up in inter-crystalline brine where sodium chloride increased by around 3% on average while calcium magnesium bicarbonate witnessed a drop. The raw material and the product afterward were checked for components like calcium, magnesium, sulfur, chlorine, carbonates, insoluble things and water. They used a complexometric method to find Ca and Mg.

Ca and Mg were figured out using a complexometric method. This method is mainly based on the color change of the indicators used (fluorexone for Ca and acid Cr dark blue for Mg) when Trilon B interacts with Ca and Mg ions. Sodium was checked by flame photometry (FP series flame photometers, Drawell, FP6410). Sulfate was figured by gravimetric method. This method involves sulfate precipitating with barium chloride in an acidic solution, then washing and weighing the precipitate.

The level of chlorine was analyzed by applying the volumetric argentometric scheme. This method relies on the color change of silver chloride precipitates when silver ions meet potassium dichromate. The moisture content in solid samples was measured by oven-drying at 100-105°C until a constant weight was achieved.

3. Results and discussion

The concentrations of various ions in the brines of the Karaumbet and Barsakelmes lakes during their evaporation and cooling to the temperature of 40 and 20°C for various values of suspension density are given in Tables 1 and 2.

Table 1. The influence of the concentration process and cooling temperature on the composition of the brine of Lake Karaumbet

Pulp density, g/cm^3	The composition of the liquid phase, wt.%					Na/Mg	SO_4^{2-} in solid phase, wt. %
	Na^+	Mg^{2+}	Cl^-	SO_4^{2-}	$MgCl_2$		
Cooling temperature - 40°C							
1.240	8.05±0.79	3.27±0.51	17.72±1.43	6.66±0.19	7.20±2.31	2.45	-
1.295	5.08±0.78	3.78±0.51	18.45±1.43	6.98±0.19	15.08±2.31	1.37	-
1.340	4.22±0.78	4.39±0.50	19.17±1.43	6.78±0.188	18.97±2.31	0.96	-
1.360	4.39±0.78	4.23±0.50	20.56±1.44	6.67±0.18	19.78±2.31	1.04	0.28

1,400	3.01±0.77	4.40±0.49	21.43±1.44	6.17±0.18	22.51±2.31	0.68	0.56
1,450	1.85±0.77	6.42±0.49	21.17±1.45	5.95±0.17	24.51±2.31	0.29	1.07
1.510	0.93±0.77	7.03±0.49	20.25±1.46	5.31±0.17	27.57±2.31	0.13	1.92
1,550	0.91±0.76	7.20±0.48	20.13±1.47	5.63±0.17	28.24±2.31	0.13	2.67
Cooling temperature - 20°C							
1.240	8.01±0.78	3.27±0.49	17.7±1.24	6.66±0.17	7.20±1.74	2.45	-
1.295	5.07±0.76	3.54±0.48	18.1±1.24	6.62±0.16	13.51±1.74	1.43	-
1.340	4.08±0.76	4.26±0.48	19.7±1.25	7.21±0.16	17.20±1.78	0.96	-
1.360	4.22±0.75	4.13±0.47	19.1±1.25	7.44±0.16	19.04±1.83	1.02	0.36
1,400	2.88±0.75	5.41±0.46	20.4±1.25	7.93±0.15	21.43±1.89	0.53	0.71
1,450	1.91±0.74	6.39±0.46	20.4±1.26	6.60±0.14	24.78±1.92	0.30	1.12
1.510	1.01±0.74	6.88±0.46	20.2±1.26	6.00±0.14	27.64±1.98	0.15	2.36
1,550	0.96±0.71	7.00±0.45	19.9±1.26	5.72±0.14	28.98±1.99	0.14	3.54

As seen in Table 1, the chemical composition of the brine of Lake Karaumbet (initial density 1.240 g/cm^3) is modified after several concentration steps. In the process, the sodium ion concentration reduced from 8.05 to 0.91%, sulfate ion (SO_4^{2-}) concentration dropped from 6.66 to 5.63% and Na/Mg ratio decreased from 2.45 to 0.13. After cooling the brine to 20°C, the magnesium chloride concentration went up considerably from 7.20 to 28.98%, the sodium ion content went down from 8.01 to 0.96%, SO_4^{2-} also lowered marginally from 6.66 to 5.72% and the Na/Mg ratio reduces from 2.45 to 0.14. These data indicate that brine composition appears to be more responsive to evaporation degree than cooling temperature. The chemical composition of solid phases isolated at the densities of 1.51-1.55 g/cm^3 indicates the predominance of sodium chloride and bischofite. In relation to, sodium sulfate crystalline hydrate. This implies that it is possible to evaporate the brine for a magnesium chloride ($MgCl_2$) concentration of 26-30%. Tactlessly, this method will also induce the precipitation of other compounds like sodium sulfate (Na_2SO_4) and calcium sulfate ($CaSO_4$), as we can see from the sulfate ions present in the precipitate in combination with Na^+, Cl^-. Moreover, the content of quadrupole sulfate ions in the solid phase witnessed a hike (0.28-0.36% at 1.360 g/cm^3 and 2.67-3.54% at 1.550 g/cm^3) as the brine concentration became more nominal (20-40°C).

Table 2 shows the shifts in the composition for the liquid and solid phases of brine in Lake Barsakelmes at different depths as a function of evaporation (liquid phase density) during cooling to 40°C and increased liquid phase density 1.245-1.295 g/cm^3 during evaporation. Meanwhile, the concentrations of magnesium chloride showed an increase from 10.9 to 16.8% and sulfate ions (SO_4^{2-}) concentration also increased from 4.21 to 7.69%, but, sodium ion concentration dropped from 8.90 to 3.38% and Na/Mg ratio decreases from 3.21 to 0.79. Fractionation at these optimal concentrations yields a solid phase, NaCl, precipitated from Lake Barsakelmes brine of over 99.82% purity, wherein the percentage of $MgCl_2$ is reduced to the maximum if only occluded water, 0.18%. Importantly, the solid phase does not contain sulfate ions.

Table 2. The influence of the evaporation process on the composition of concentrated solutions and the salt precipitate of the Barsakelmes Lake brine at a cooling temperature of 40°C

Liquid phase density, g/cm³	The composition of the liquid phase, wt. %					Na/Mg	Composition of the solid phase, wt. %		
	Na^+	Mg^{2+}	Cl^-	SO_4^{2-}	$MgCl_2$		Na^+	Mg^{2+}	Cl^-
1.245	8.90±0.72	2.77±0.34	16.9±1.04	4.21±0.14	10.9±0.14	3.21±0.10	38.93	0.13	60.83
1.246	6.40±0.72	2.97±0.34	12.9±1.03	4.66±0.14	11.6±0.14	2.16±0.10	42.56	0.15	57.30
1.276	6.20±0.71	2.97±0.35	15.9±1.03	4.68±0.15	11.6±0.15	2.09±0.09	43.41	0.11	55.20
1.290	5.01±0.71	3.72±0.35	13.9±1.02	6.01±0.15	14.6±0.15	1.35±0.09	43.60	0.15	54.90
1.295	4.44±0.70	4.46±0.36	15.8±1.02	7.58±0.15	17.5±0.16	1.00±0.08	43.30	0.18	54.90
1.288	3.38±0.70	4.29±0.36	15.7±1.01	7.69±0.16	16.8±0.16	0.79±0.07	38.93	0.13	57.30

In the following step, Barsakelmes brine was evaporated in two successive stages. In the first stage, the brine was concentrated to densities from 1.245 to 1.400 g/cm³. In the second step, the liquid phase from the separation of the precipitate in the first stage underwent further evaporation, resulting in a density of approximately 1.34-1.35 g/cm³. The detailed results of this process can be found in Table 3.

Table 3. The composition of the liquid and solid phases of the brine of Lake Barsakelmes depending on the density of the pulp and the degree of evaporation

Pulp density, g/cm³	Liquid phase density, g/cm³	The composition of the liquid phase, wt. %					The composition of the solid phase, wt. %				Solid phase weight, g
		Na^+	Mg^{2+}	Cl^-	SO_4^{2-}	$MgCl_2$	Na^+	Mg^{2+}	Cl^-	SO_4^{2-}	
I stage evaporation											
1.245	1.245	8.90±0.14	4.60±0.04	16.90±1.04	4.21±0.07	10.62±0.13	-	-	-	-	-
1.345	1.295	6.01±0.14	5.24±0.04	14.60±1.03	6.21±0.08	14.95±0.13	38.46±2.07	-	49.72±3.07	-	7.67±0.47
1.380	1.270	5.5±0.135	6.41±0.06	14.97±1.03	7.10±0.08	15.13±0.15	40.17±2.08	-	50.33±3.17	0.94±0.07	16.45±0.77
1,400	1,300	4.12±0.13	8.53±0.08	1.40±1.02	7.15±0.09	20.14±0.16	42.21±0.18	-	49.05±3.16	1.72±0.07	26.70±0.99
II stage evaporation											
1.340	1.296	3.90±0.07	8.27±0.07	16.12±1.07	6.87±0.08	19.54±0.15	39.35±0.17	-	48.92±0.17	-	6.70±0.78
1.350	1.297	3.68±0.07	8.18±0.07	14.73±0.07	7.33±0.07	19.35±0.15	37.10±0.17	-	50.63±0.18	-	2.28±0.45

It indicates that the precipitate is only NaCl during the early evaporation stage when the density of brine is 1.340-1.345 g/cm³. Yet, when the density exceeds 1.35-1.37 g/cm³, sulfate cousins (SO_4^{2-}) started to form in the precipitate. At a density of 1.340-1.345 g/cm³, the sodium chloride precipitate was separated and after the second stage of evaporation, the sodium chloride precipitates again and remains the only solid phase up to a density of 1.34-1.35 g/cm³.

Technologically speaking, the best way to extract sodium chloride is in its pure form. Hence, the concentration of Brine in both stages should be limited to a suspension density of 1.34 - 1.35 g/cm³. This translates to 15-16% $MgCl_2$ concentrations for the first stage and 19 - 19.5% in the second stage. Under these conditions, sodium chloride is precipitated with a negligible amount of impurities, other than NaCl, that is held in the sediment as an occluded liquid. The amount of entrained liquid will vary depending on the phase separation method used (centrifugation, filtration, settling, etc.) and needs to be established under pilot conditions to account for optimization of the separation process.

These analyses have been performed so that it is possible to receive solutions of magnesium chloride with a content of 15-16% and technical sodium chloride without conducting their prior purification, by evaporating the brines of Karaumbet and Barsakelmes lakes. The brine is evaporated in two stages to obtain purer NaCl and more concentrated solutions of $MgCl_2$ (19-19.5%). First of all, evaporation should be accomplished until a pulp density of 1.34-1.35 g/cm³ and separation of NaCl; also, the resultant mother liquor at the second stage with a density of 1.29-1.30 g/cm^3 needs to be concentrated to 1.34-1.35 g/cm^3 by evaporation. In this scenario, nearly pure NaCl separates out. Nevertheless, if NaCl was separated at the first or the second stages of evaporation, a purification process should be carried out, since a residual amount of sulfate ions remains in the mother liquid, the content of which is under strict control. Therefore, the three-stage evaporation of Karaumbet and Barsakelmes lake brines is to be intensified in industrial conditions and for this purpose, this process is to be performed at temperatures close to boiling point under a weak vacuum. However, at the first stage (the first degree of concentration), a first-grade NaCl of at least 98% pureness can be singled out (Table 4) (Codex Alimentarius Commission, 1985).

Table 4. Technical requirements for sodium chloride

Names of the indicator	Norm in terms of dry matter for varieties			
	Extra	Higher	First	Second
Mass fraction of sodium chloride, % not less than	99.7	98.4	97.7	97.0
Mass fraction of calcium ion, % no more	0.02	0.35	0.50	0.65
Mass fraction of magnesium ion, % no more	0.01	0.05	0.10	0.25
Mass fraction of sulfate ion, % no more	0.16	0.80	1.20	1.50
Mass fraction of potassium ion, % no more	0.02	0.10	0.10	0.20
Mass fraction of iron oxide, % no more	0.005	0.005	0.01	0.01
Mass fraction sodium sulfate, % no more	0.20	Not standardized		
Mass fraction of water-insoluble residue, % no more	0.03	0.16	0.45	0.85
Boiler	0.10	0.70	0.70	-
Stone	-	0.35	0.35	0.35
Self-planting and garden	-	3.20	4.0	5.0
Solution pH	6.5-8.0	Not standardized		

In general, the results of the studies conducted allow us to conclude that, for an effective concentration of brines of lakes Karaumbet and Barsakelmes, intermediate brine evaporation of up to 15-16% $MgCl_2$ is appropriate. The process also involves separating precipitated sodium chloride crystals and purifying the mother liquids in the sodium-ion form to remove sulfate ions. So, only then should the particle be taken to the evaporation and proceed to obtain NaCl in the purest form, at the same time resulting in the obtainment of pure NaCl. When brine reaches a density of 1,38-1,40 g/cm^3, the further concentration process leads to the precipitation of not only sodium chloride but also some of its sulfate compounds; this process contaminates the intermediate product of table salt. It is much more relevant on a tech level to attain total sodium chloride. Hence, as a statewide, it is suggested that, in order to limit the saline effluents of both the Karaumbet Lake and the Barsakelmes Lake, a two-step process should be done periodically. In Table 5, the composition, density and L/S ratio are provided as functions of the volume evaporated, after the first stage of evaporation for charge-balanced brine without sulfate and calcium ions.

The data reveals that in the first stage of evaporation, as the content of evaporated water in 1000 kg sodium and magnesium chloride solution increases from 301 to 456 kg (from 30.1% to 45.6% H_2O), the liquid-to-solid (L:S) ratio in the brine decreasing from 35.6 to 3.9 at the same time the density increases from 1.250 to 1.422 g/cm^3.

This shift allows for a reduction in the concentration of $CaCl_2$ and $MgSO_4$ in the solution from 0.67 to 0.32% and 0.23 to 0.11%, respectively as these salts are driven into the precipitated fraction of NaCl.

Table 5. The composition of the purified liquid phases after the first stage of evaporation and separation of sodium chloride

Quantity of evaporated water, kg	Quantity of evaporated brine, kg	Brine density, g/cm^3	L:S ratio in brine	$CaCl_2$ content, wt. %	$MgSO_4$ content, wt. %
-	1000	1,250	-	0.667±0.07	0.228±0.03
301.0	699.0	1.271	35.6	0.594±0.06	0.206±0.03
315.3	684.7	1.279	24.1	0.55±0.06	0.20±0.02
326.1	673.9	1.286	18.7	0.51±0.05	0.20±0.02
335.1	664.9	1.292	16.2	0.49±0.05	0.19±0.02
359.2	640.8	1.308	12.3	0.46±0.04	0.18±0.01
386.9	613.1	1.332	8.4	0.41±0.04	0.15±0.01
400.3	599.7	1.347	6.7	0.40±0.04	0.14±0.01
425.6	574.4	1.373	4.8	0.36±0.03	0.12±0.01
456.7	542.3	1.422	3.9	0.32±0.03	0.11±0.07

Simultaneously, the concentration of $MgCl_2$ in the brine increases from 9.12% to 24.01% (w/w), while that of NaCl decreases from 15.49% to 8.01% with the simultaneous precipitation of NaCl (Figure 1). This behavior can be explained by the different solubility levels of NaCl and $MgCl_2$, in which NaCl has a solubility in water of 35.87 g at 20°C and 38.12 g at 80°C, while in the case of $MgCl_2$, it was 54.5 g at 20°C and 73.0 g at 100°C. When the brine is further evaporated until an L:T ratio of less than 3.7 and a density of more than 1.45 g/cm^2, the second concentration stage occurs, which is an evaporation step designed to concentrate the liquid until a melt of Na and $MgCl_2$ is achieved.

Table 6 and Figure 2 give information about the brine concentration in the second stage. In this stage, the amount of evaporated water is between 192 and 550 kg of water per 1000 kg of solution (corresponding to 19.2 to 55% H_2O). In this instance, the liquid-to-solid ratio is lowered from 29.0 to 4.9 and the concentrations of $CaCl_2$ and $MgSO_4$ dissolved in the melt is reduced (from 0.32 and 0.11% to 0.03 and 0.04%, respectively). Moreover, the NaCl content decreases from 8.01 to 0.11% and the $MgCl_2$ content increases from 24.01 to 46.92%, respectively.

The composition of the isolated bischofite crystals, comprising 0.09 NaCl, 0.03% $CaCl_2$, 0.03% $MgSO_4$ and 46.9% $MgCl_2$, is consistent with bischofite containing 97% $MgCl_2{\cdot}6H_2O$. So, we would like to draw attention to the fact that NaCl crystal material obtained in the first and second concentration stages meets the quality specifications of GOST 51574-2000 "Specifications for Edible Table Salt", as well. These standards classify the salt as "extra" grade and this requires 98.4% (minimum) NaCl. In addition, the maximum allowed mass fractions of calcium, magnesium, sulfate and potassium should not exceed 0.35, 0.05, 1.20 and 0.10%, respectively.

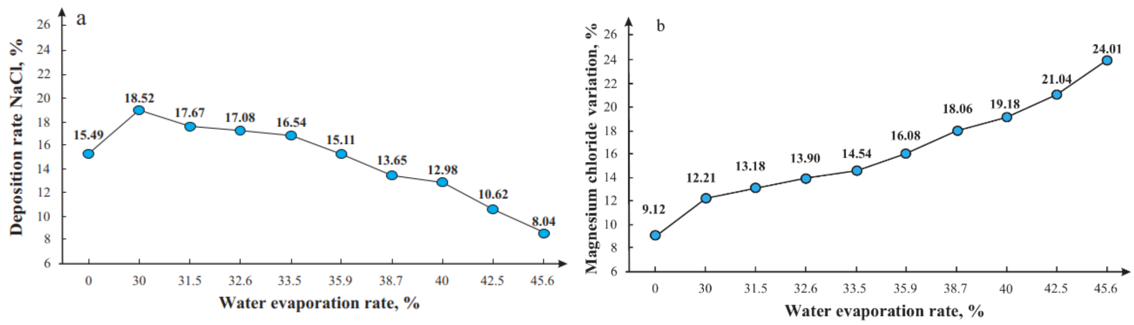

Figure 1. The concentration of NaCl (a) and $MgCl_2$ (b) in the brine depends on the amount of water evaporated in the first stage of concentration

The water-insoluble residue should be under 0.16% and the moisture content below 0.70%.

Table 6. The composition of the liquid phase purified after the second stage of evaporation and separation of sodium chloride

No.	The amount of evaporated water, kg	Amount of evaporated brine, kg	L:S ratio in brine	$CaCl_2$ content, wt. %	$MgSO_4$ content, wt. %
1	0	1000	-	0.32±0.07	0.11±0.07
2	191.8	808.2	29.0	0.29±0.04	0.10±0.07
3	383.6	616.4	11.4	0.21±0.04	0.08±0.06
4	421.2	578.8	8.9	0.18±0.03	0.07±0.06
5	458.9	541.1	7.4	0.14±0.03	0.06±0.05
6	489.7	510.3	6.5	0.10±0.02	0.05±0.05
7	520.6	479.4	5.7	0.05±0.01	0.04±0.05
8	550.0	450.0	4.9	0.03±0.01	0.04±0.04

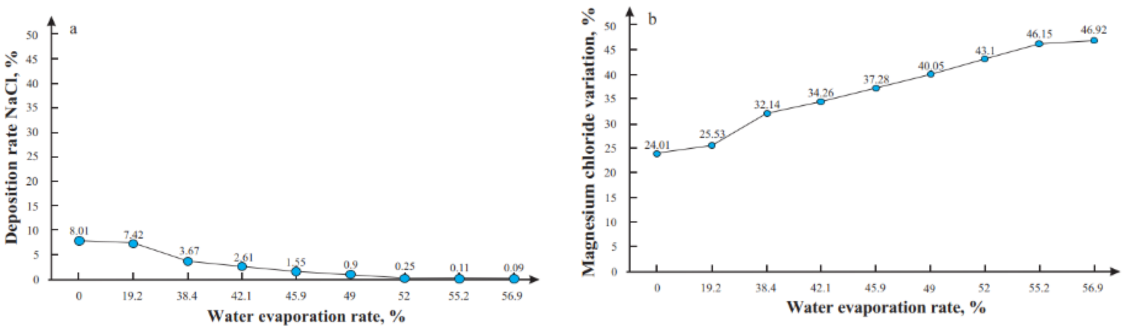

Figure 2. The comparison of NaCl (a) and $MgCl_2$ (b) in brine depends on the amount of evaporated water in the second stage of concentration

Therefore, it is possible to obtain pure sodium chloride and magnesium chloride melts as a sequential evaporation of the purified brine from Karaumbet and Barsakelmes.

4. Environmental Implications

Understanding the impact of evaporation on these Lakes helps protect the environment, mainly for arid and semi-arid areas where the concentration of water is very important. Evaporation-driven concentrations may seriously change the lake’s chemical balance and harm the species living in the water. Increased salt levels could encourage salt-loving species to grow, while causing generally sensitive species to decrease, bringing down biodiversity. As a result of this change, the arrangement of the food chain can be disturbed and the ecosystem might become unbalanced.

High levels of salts, especially those of sodium chloride and magnesium chloride, adversely affect fish and other animals living in the lakes and can endanger plants and soil nearby. Buildup of salt in the soil after lake evaporation can affect crop farming and reduce the growth of plants. Where halophytic plants are used instead of traditional vegetation, the landscape may be changed and its ecological value decreased.

If lake water becomes more polluted, towns that depend on it for irrigation and daily use could suffer a lot. When water has too much salt, it cannot be safely used or farmed, which may negatively impact society and result in people being displaced. A warmer climate and changes in rainfall tend to raise the speed at which evaporation occurs, which leads to more concentrated water sources. Climate change could make these effects worse by causing the lakes to dry out more often and severely, which in the future may threaten the region's water resources.

5. Conclusion

The studies conducted taking samples from Karaumbet and Barsakelmes lakes which is located in the Kungrad area of Karakalpakistan. Mineral salt from sample sites were taken to the analysis. The focus on evaporating brines of the Karaumbet and Barsakelmes lakes studied without preliminary purification are the confirmation of that - under these conditions magnesium chloride melts concentrate and at the same time sodium chloride sedimentates simultaneously. To do this the evaporation process must take place in two steps. During both stages, brine density should be maintained in the range of 1.34-1.35 g/cm^3 corresponding to magnesium chloride concentrations of 15-16% (first stage) and 19-19.5% (second stage). Under these conditions, almost pure sodium chloride is produced.

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