Research of bittern concentration processes lake Karaumbet and Barsakelmes

Ziyodullo Otakuziyev[1], *Diyorbek* Absattorov[1], *Mohamed* Rifky[1,2], *Shokir* Rakhimkulov[1], *Ilkham* Usmanov[1], *Dilbar* Ramazonova[1], *Zaynobiddin* Matkarimov[3], and *Murodjon* Samadiy[1*]

[1]Yangiyer branch of Tashkent Chemical Technological Institute, Department of Chemical Technology of Inorganic Substances, Yangiyer, Uzbekistan
[2]Eastern University, Sri Lanka, Chenkalady, Sri Lanka
[3]Tashkent Chemical Technological Institute, Tashkent, Uzbekistan

Abstract. The conducted studies on the concentration of brine from lakes Karaumbet and Barsakelmes under conditions close to industrial ones showed the possibility of obtaining practically pure sodium chloride and magnesium chloride melt. To do this, the evaporation process must be carried out in two stages. The evaporation to a density of 1.550 g/sm^3 increases the content of magnesium chloride from 7.20% to 28.24%. At the same time, the content of sodium ions decreases from 8.05% to 0.91%. The evaporation at the first and second stages must be carried out to a density of 1.340-1.345 g/sm^3, which contributes to the release of sodium chloride into the precipitate. The evaporation of the mother liquor makes it possible to obtain practically pure sodium chloride. The content of magnesium chloride after evaporation in the first stage is 15-16%.

1 Introduction

The formation of industrialized firms and competitive economy is common in the global economy; the task arises to organize the production of import-substituting and export-oriented products, which is important for the development of the economy and technical progress of any state. Therefore, the development stage of a country measured by their availability of natural resources and the advanced technologies present there in assets. In this aspect, the creation of innovative technologies for processing local resources into competitive products is a priority [1].

In the global contest, in the production of pure sodium, calcium, and magnesium salts from natural sources - seawater, brines of salt lakes, and salt deposits, main focus was made to develop technologies that ensure the comprehensive use of raw materials, contributing to the reduction in the cost of basic products. Therefore, it is quite natural that measures to improve the environment are closely related to measures to utilize the natural resources [2].

In the world, on the basis of research on the processing of mixed brine of lakes, sea water and salt deposits, a number of significant results have been obtained, including: the

* Corresponding author: samadiy@inbox.ru

scientific foundations for obtaining bischofite by evaporating the brine of the Great Salt Lake in Utah and the salt water of the Dead Sea using solar evaporation ponds and vacuum evaporators (Great salt Lake Minerals Corp., Kaiser Refractories and US Magnesium LLC, United States, Dead Sea Magnesium Ltd, Israel); methods have been developed for obtaining magnesium hydroxide and oxide from sea water by mixing it with burnt dolomite or limestone, ammoniating the mixed brine of Sivash Lake and Volgograd bischofite (South Bay Salt Works Chula Vista, USA and Jinzhou Huacheng Magnezium Company, China, Brom JSC, Ukraine, NPO Caustic, Russia); the production of primary (metallic) magnesium, titanium sponge and steel has been established through deep processing of brines from salt lakes and sea waters (Rima Industrial Brazil; Magnohrom, Serbia; POSCO, South Korea; Chaoyang Jinda Titanium Co. Ltd, China); the production of mirabilite, epsomite and bischofite from surface and buried brines of the Kora-Bogaz-Gol Bay (PA "Karabogazsulfat", Turkmenistan) was organized [3].

There is a large amount of data on deep processing of not only sulfate-chloride brines, mixed brine of salt lakes and seawater, but also mineral raw materials-dolomite, brucite, and serpentinite into magnesium compounds available as a literature in this field [4].

Magnesium chloride or the traditional name bischofite can be obtained from seawater or from brines of salt lakes. Bischofite deposits differ in composition: some of them are saline basins, where $MgCl_2$ is mixed with various minerals (mixed). These are the so-called carnallite-bischofite rocks, the accompanying minerals of which are halite, kieserite, and anhydrite [5].

The main producers of magnesium chloride are the United States, Ukraine, Russia, Israel, China, Germany, Chile, the Czech Republic, and Turkmenistan. In the USA, liquid $MgCl_2$ is mainly produced 90-93% of the production volume, flaked - 7-10%. It is obtained from the brine of salt lakes (Intrepid Potash inc., and Great salt Lake Minerals Corp.) and seawater (South Bay Salt Works Chula Vista). Necessary specify US Magnesium LLC and Mineral Research and Development. The first releases metallic magnesium, and the second-$MgCl_2 \cdot 6H_2O$.

US Magnesium LLC uses 75,000 acres (30,000 ha) of solar ponds to increase magnesium concentration in Great Lake brine salt lake. For this purpose, from 75 to 130 million m^3 of lake water are annually imported to the ponds [6].

Liquid $MgCl_2$ is used for dust control and as an anti-icing agent. In China, there are several enterprises specializing in production and sales. Yes, Chaoyang Jinda Titanium Co. Ltd produces titanium sponges, magnesium powders and ingots, dry $MgCl_2$, Jinzhou Huacheng Magnesium Company magnesium alloys, calcium chloride, de-icing salts, refractory materials, $MgCl_2$, Weifang Bell Chemical co Ltd produce calcium and magnesium chloride for good drilling, de-icing and dust suppression, water treatment, agriculture, construction, food additives [7].

Solid $MgC1_2$ is utilized in so many industries by evaporating its aqueous solution to produce $MgC1_2 \cdot 6\ H_2O$. Dead Sea Work ltd. is the only magnesium producer in Israel. The raw material is extracted from Dead Sea. One liter of seawater contains 170 g of $MgCl_2$. The company uses solar evaporation ponds where the $MgCl_2$ salt solution is evaporated to obtain 33% concentration, followed by evaporation was done to obtain 47% and the formation of $MgC1_2$ flakes. This is the raw material to produce metallic Mg, magnesia binders, refractories, anti-icing materials, balneological preparations, and also for used in the agriculture.

In Uzbekistan, magnesium chlorate is applied in the cotton defoliation practices in agriculture by conversion magnesium chloride to bischofite with sodium chlorate "wet".

$$MgCl_2 \cdot 6H_2O + 2NaClO_3 = Mg(ClO_3)_2 \cdot 6H_2O + 2NaCl \quad (1)$$

The annual demand of "Farg'onaazot" JSC for bischofite is 30 thousand tons. Uzbekistan has significant reserves of raw materials for the production of magnesium salts [8]. These are brine and dry mixed salts (DMS) of lakes Karaumbet and Barsakelmes in Karakalpakstan. The amount of approved reserves in Karaumbet is around 295,000 tons of MgO or 700,000 tons of $MgCl_2$ of which 74,000 tons are in brine. The amount of reserves of Mg salts in the Barsakelmes brine is around1.04 million tons of MgO and 2.47 million tons of $MgCl_2$. All of these natural sources are promising raw materials for production of Mg compounds: magnesium oxide, hydroxide and chloride - goods for national and agricultural use.

The brine of Lake Karaumbet is having 7.40-11.45% of Na, 15.2-18.9% of Cl, 4.55-6.27% of MgO, 3.14-6.66% of SO_4, up to 0.60% of CaO. Also, the brine of Lake Barsakelmes is having 6.61-11.45% of Na, 15.2-18.9% of Cl, 1.37-4.57% of MgO, 1,44-3.73% of SO_4, 0.02% of CaO. DMS of Karaumbet contains on average (wt.%): $Na_2 SO_4$ - 43-61; $MgCl_2$ - 11-15; NaCl - 13-19 in terms of dry salt and are a valuable raw material for the production of sodium sulfate, bischofite and table salt.

Due to the lack of acceptable technologies for processing brine and DMS of Karakalpakstan, they are not yet mined and processed. Therefore, research aimed at developing a technology for obtaining magnesium compounds ($MgCl_2$, Mg $(OH)_2$, MgO), as well as sodium sulfate and chloride from brine and DMS of Karaumbet and Barsakelmes lakes, is a very urgent task.

Bischofite is used in the production of magnesian fertilizers for the seed pre-sowing treatment in vegetable and also the oil crops [9].

In by electrolysis, environmentally friendly fungicides were obtained from bischofite solutions to control the pathogenic fungi species in agriculture [10].

The each deposit of natural salt is unique in its way (due to the variability of the mineralogical composition and properties), therefore, known technologies cannot be transferred to the conditions of Karaumbet and also the Barsakelmes lakes. Based on the specifics of any deposit, separate scientific and technological studies are required to select the optimal conditions for their processing.

Studies on natural evaporation (concentration) in artificially created solar ponds and winter salt storage during cooling of the brine of lakes Karaumbet and Barsakelmes showed that to obtain more concentrated solutions of sodium and magnesium chlorides, the processes of summer evaporation and winter storage of sodium sulfate from brine are insufficient and require a long period time.

Therefore, the purpose of further research was to carry out the process of concentrating the brine of Karaumbet and Barsakelmes lakes under industrial conditions to isolate relatively pure sodium chloride crystals and obtain more concentrated solutions of magnesium chloride from natural brines, without the stage of their preliminary purification.

The results of a study on the treatment of brines from Lake Barsakelmes and Lake Karaumbet with Na_2CO_3 and $BaCl_2$ purified $Mg(OH)_2$ from distillate, NaOH and $Ca(OH)_2$ solutions are presented [11].

2 Materials and methods

Mineral salts Karaumbet and Barsakelmes were used for the experiments, located in the Kungrad region of the Republic of Karakalpakstan, 45 km and 80 km from the city of Kungrad. A detailed survey of the bed was carried out in 1992-1993. During this time there were remarkable changes in composition. Thus, the surface salt composition of the Barsakelme bed was changed towards a more than 10% increase in sodium chloride with insoluble residues and an overall reduction in calcium sulfate (3-4 fold). A similar trend is observed in the composition of intercrystalline brine, where the sodium chloride content

increases on average by about 3% and the calcium magnesium bicarbonate content decreases. The feedstock and the resulting product were analyzed for the content of the following components: calcium, magnesium, sulfur, chlorine, carbonates, insoluble residues and water.

Ca and Mg were determined by using the complexometric method [12]. This method is mainly focus on the color change of the indicator used there (fluorexone for the determination of Ca and acid Cr dark blue for the determination of Mg) during the interaction of Trilon B with Ca and Mg ions.

Sodium was measured by flame photometry [13].

Sulfate was determined gravimetrically [14]. This method is based on the precipitation of sulfate with barium chloride in an acidic environment, followed by washing and weighing of the precipitate.

Chlorine was measured by the volumetric argentometric method [15]. This method is based on the color change of silver chloride precipitates during the interaction of silver ions with potassium dichromate.

Moisture in solid samples was determined by drying in a constant weight oven at 100-105°C [16].

X-ray image analysis of raw materials and products was performed on a Dron-3 diffractometer using filtered Cu radiation at 40 kV voltage, 20 mA current and 2 degrees/min counter speed. X-ray image analysis of the obtained product was performed on a Dron-2 diffractometer using a cobalt anode at 30 kV voltage, 20 mA current, 2 degrees/min detector speed, 600 mm graph band speed./h, counter meter 1 103, time constant RS - 2.0 seconds, slot - 4x6x1. X-ray images were interpreted using the American Mineraologist Crystal Structure Database [17], ICSD-for-WWW (FIZ-Karlsruhe and Hewat A.W.) [18].

3 Results and Discussion

Tables 1 and 2 show changes in the compositions of the brines of lakes Karaumbet and Barsakelmes after their evaporation and cooling to temperatures of 40 and 20 °C, depending on the density of the suspension.

Table 1. The composition of brine from Lake Karaumbet depends on the degree of evaporation and cooling temperature.

ρ_{pulp}, g/sm^3	The composition of the liquid phase, wt.%					Na^+: Mg^+	SO_4^{2-} in solid phase, %
	Na^+	Mg^{2+}	Cl^-	SO_4^{2-}	$MgCl_2$		
Cooling temperature - 40°C							
1.240	8.05	3.27	17.72	6.66	7.20	2.45	-
1.295	5.08	3.78	18.45	6.98	15.08	1.37	-
1.340	4.22	4.39	19.17	6.78	18.97	0.96	-
1.360	4.39	4.23	20.56	6.67	19.78	1.04	0.28
1.400	3.01	4.40	21.43	6.17	22.51	0.68	0.56
1.450	1.85	6.42	21.17	5.95	24.51	0.29	1.07
1.510	0.93	7.03	20.25	5.31	27.57	0.13	1.92
1,550	0.91	7.20	20.13	5.63	28.24	0.13	2.67
Cooling temperature - 20°C							
1.240	8.01	3.27	17.7	6.66	7.20	2.45	-
1.295	5.07	3.54	18.1	6.62	13.51	1.43	-
1.340	4.08	4.26	19.7	7.21	17.20	0.96	-
1.360	4.22	4.13	19.1	7.44	19.04	1.02	0.36
1.400	2.88	5.41	20.4	7.93	21.43	0.53	0.71
1.450	1.91	6.39	20.4	6.60	24.78	0.30	1.12
1.510	1.01	6.88	20.2	6.00	27.64	0.15	2.36
1.550	0.96	7.00	19.9	5.72	28.98	0.14	3.54

Table 2. The composition of the brine of Lake Barsakelmes depends on the degree of evaporation followed by cooling at a temperature of 40°C.

pulp, g/sm^3	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	2.77	16.9	4.21	10.9	3.21	38.93	0.13	60.83
1.246	6.40	2.97	12.9	4.66	11.6	2.16	42.56	0.15	57.30
1.276	6.20	2.97	15.9	4.68	11.6	2.09	43.41	0.11	55.20
1.290	5.01	3.72	13.9	6.01	14.6	1.35	43.60	0.15	54.90
1.295	4.44	4.46	15.8	7.58	17.5	1.00	43.30	0.18	54.90
1.288	3.38	4.29	15.7	7.69	16.8	0.79	38.93	0.13	57.30

Table 1 explains that when concentrating the brine of Lake Karaumbet with an initial density of 1.240 g/sm^3. At the same time, the content of sodium ions in it decreases from 8.05 to 0.91%, SO_4^{2-} from 6.66 to 5.63%, and Na:Mg ratio from 2.45 to 0.13.

In the case of cooling the brine to 20°C, the indicators for magnesium chloride are from 7.20 to 28.98%, for sodium ions from 8.01 to 0.96%, for SO_4^{2-} from 6.66 to 5.72% and for Na:Mg from 2.45 to 0.14. It follows from the data that the composition of the brine depends on the degree of its evaporation, while the cooling temperature does not have a significant effect. Chemical analysis of the solid phases isolated at 1.51-1.55 g/sm^3 indicates the predominance of sodium chloride and bischofite over sodium sulfate crystalline hydrate. This means that evaporation of brine to 26-30% $MgCl_2$ is possible. But in this case, along with NaCl, other compounds precipitate, such as Na_2SO_4, and $CaSO_4$, as evidenced by the appearance of sulfate ions along with the precipitate with Na^+ and Cl^-. Depending on the cooling temperature (20-40°C), as the brine is concentrated, the content of sulfate ions in the solid phase increases from 0.28-0.36% (1.360 g/sm^3) up to 2.67-3.54% (1.550 g/sm^3).
The change in the composition of the liquid and solid phases of the brine of Lake Barsakelmes, depending on the depth of evaporation (density of the liquid phase) when they are cooled to 40°C, is shown in Table 2.

The density of the liquid phase during evaporation was changed from 1.245 to 1.295 g/sm^3. At the same time, the content of magnesium chloride increases from 10.9 to 16.8%, SO_4^{2-} - from 4.21 to 7.69%, and sodium ions, on the contrary, decreases from 8.90 to 3.38% and the ratio of Na:Mg from 3.21 to 0.79. In this case, the solid phase, which is deposited from the brine of Lake Barsakelmes when cooled to 40°C, corresponds to almost pure NaCl. In it, magnesium chloride is present as an occluded liquid. Its content does not exceed 0.18 %, and sulfate ions are absent.

In the next stage, the process of evaporating the Barsakelmes brine was carried out in two stages, carried out in sequential order. In the first stage, the brine was evaporated to a density from 1.245 to 1.400 g/sm^3, and in the second liquid phase from the 1st stage, after separating the precipitate, it was evaporated from 1.34 to 1.35 g/sm^3. The results are shown in Table 3.

The results obtained indicate that during the primary evaporation of the brine to a density of 1.340-1.345 g/sm^3, only sodium chloride is present in the sediment. But with an increase in density to 1.38-1.40 g/sm^3 sulfate ions appear in the precipitate. And after separating the sodium chloride precipitate at 1.340-1.345 g/sm^3 and the second stage of brine evaporation, only sodium chloride precipitates again to a density of 1.34-1.35 g/sm^3.

From a technological point of view, the isolation of sodium chloride in its pure form is preferable, therefore, the concentration limit of brine in the first and second stages should be limited to a suspension density of 1.34-1.35 g/sm^3, which corresponds to the concentration of $MgCl^2$ in the 1st steps - 15-16% and on the 11th - 19-19.5%. In these cases, NaCl is released practically without impurities, except for NaCl entrained in the

sediment with a liquid suspension (occluded liquid). In this case, the amount of liquid suspension depends on the method of phase separation (centrifugation, filtration, settling), which is estimated by pilot testing.

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

Pulp, g/sm^3	$\rho_{f.f.}$, g/sm^3	The composition of the liquid phase, wt. %					The composition of the solid phase, wt. %				$m_{tv.f}G$
		Na^+	Mg^{2+}	Cl^-	SO_4^{2-}	$MgCl_2$	Na^+	Mg^{2+}	Cl^-	SO_4^{2-}	
1 stage evaporation											
1.245	1.245	8.90	4.60	16.90	4.21	10.62	-	-	-	-	-
1.345	1.295	6.01	5.24	14.60	6.21	14.95	38.46	-	49.72	-	7.67
1.380	1.270	5.55	6.41	14.97	7.10	15.13	40.17	-	50.33	0.94	16.45
1.400	1,300	4.12	8.53	1.40	7.15	20.14	42.21	-	49.05	1.72	26.70
11 stage evaporation											
1.340	1.296	3.90	8.27	16.12	6.87	19.54	39.35	-	48.92	-	6.70
1.350	1.297	3.68	8.18	14.73	7.33	19.35	37.10	-	50.63	-	2.28

Thus, the conducted studies have shown that by evaporating the brine of the Karaumbet and Barsakelmes lakes, it is possible to obtain solutions of magnesium chloride with a content of 15-16%, as well as technical sodium chloride, without their preliminary purification.

To obtain more pure sodium chloride and concentrated solutions of $MgCl_2$ (19-19.5%), the brine must be evaporated in two stages. In the first stage, evaporation must be carried out to a pulp density of 1.34-1.35 g/sm^3, followed by the separation of NaCl. The resulting mother liquor with a density of 1.29-1.30 g/sm^3 at the second stage must also be evaporated to 1.34-1.35 g/sm^3. In this case, almost pure NaCl precipitates. However, after separating NaCl at the first or second evaporation stages, it is necessary to carry out a purification process, since the mother liquors are characterized by a residual amount of sulfate ions, the content of which is strictly regulated.

Thus, the process of concentrating the brine of lakes Karaumbet and Barsakelmes should be intensified under industrial conditions and for this, the evaporation of brine should be carried out at temperatures close to boiling under a slight vacuum. At the same time, NaCl of the first grade with a purity of at least 98% and meeting the requirements of GOST 51574-2000 can be isolated at the first stage of concentration (Table 4).

Table 4. Technical requirements for sodium chloride.

No, p/p	Names of the indicator	The norm in terms of dry matter for varieties			
		Extra	Higher	First	Second
1	Mass fraction of NaCl, % not less than	99.7	98.4	97.7	97.0
2	Mass fraction of Ca ion, % no more	0.02	0.35	0.50	0.65
3	Mass fraction of Mg ion, % no more	0.01	0.05	0.10	0.25
4	Mass fraction of SO_4^{2-}, % no more	0.16	0.80	1.20	1.50
5	Mass fraction of K ion, % no more	0.02	0.10	0.10	0.20
6	Mass fraction of FeO (111),% no more	0.005	0.005	0.01	0.01
7	Mass fraction Na_2SO_4, % no more	0.20	Not standardized		
8	Mass fraction of water-insoluble residue, % no more	0.03	0.16	0.45	0.85
9	Mass fraction of moisture, % max for salt:				
	Boiler	0.10	0.70	0.70	-
	Stone	-	0.35	0.35	0.35
	Self-planting and garden	-	3.20	4.0	5.0
10	Solution pH	6.5-8.0	Not standardized		

Based on the studies carried out, it can be concluded that to accelerate the process of concentrating the brine of lakes Karaumbet and Barsakelmes, the evaporation of the initial

brine must be carried out to a concentration of 15-16% $MgCl_2$, while separating the precipitated sodium chloride crystals, purifying the mother liquors from sulfate ions, and only after that, continue the evaporation process to obtain relatively pure NaCl with the concomitant receipt of pure NaCl. When brine is concentrated above a density of 1.38-1.40 g/sm^3, along with sodium chloride, sulfate compounds appear in the precipitate, polluting the composition of the intermediate product - table salt. From a technological point of view, the isolation of sodium chloride in its pure form is preferable. Therefore, it is proposed to carry out the process of curing the brine of both Lake Karaumbet and Barsakelmes in two stages, carried out periodically.

The composition, density and ratio L:S, depending on the amount of evaporated water, after the 1st stage of the evaporation of the brine purified from sulfate and calcium ions, are given in Table 5.

Table 5. Composition of the liquid phase purified after the first stage of evaporation and separation of sodium chloride.

The amount of evaporated water, kg	Amount of evaporated brine, kg	Brine density, g/sm^3	W:T ratio in brine	$CaCl_2$ content, %	$MgSO_4$ content, %
-	1000	1.250	-	0.667	0.228
301.0	699	1.271	35.6	0.594	0.206
315.3	684.7	1.279	24.1	0.55	0.20
326.1	673.9	1.286	18.7	0.51	0.20
335.1	664.9	1.292	16.2	0.49	0.19
359.2	640.8	1.308	12.3	0.46	0.18
386.9	613.1	1.332	8.4	0.41	0.15
400.3	599.7	1.347	6.7	0.40	0.14
425.6	574.4	1.373	4.8	0.36	0.12
456.7	542.3	1.422	3.9	0.32	0.11

The results show that at the 1st stage of evaporation, with an increase in the amount of evaporated water from 301 to 456 kg in relation to 1000 kg of a solution of sodium and magnesium chlorides (or from 30.1 to 45.6% H_2O), the L:S ratio in brine decreases from 35.6 to 3.9, and the density, on the contrary, increases from 1.250 to 1.422 kg/cm^3. This makes it possible to reduce the content of $CaCl_2$ and $MgSO_4$ in the solution from 0.667 to 0.32% and from 0.228 to 0.11%, respectively, as a result of their transition to the composition of the NaCl precipitate.

At the same time, the concentration of $MgCI_2$ in the brine increases from the initial 9.12% to 24.01%, and NaCl decreases from 15.49 to 8.01%, due to the precipitation of the latter (Figure 1), which is explained by the difference in the solubility of NaCl and $MgCl_2$ (the solubility of NaCl in 100 g water at 20°C - 35,87 g, 80°C - 38,12 g, $MgCl_2$ at 20°C - 54,5 g, 100°C - 73,0 g). Further evaporation of the brine below L:T=3.7 and above 1.45 g/sm^3 sent to the 2nd stage of concentration – up to evaporation to obtain a melt of Na and $MgCl_2$.

Data on the concentration of brine in the second stage are given in the table. 6 and in Figure 2. In this case, the amount of evaporated water is from 192 to 550 kg with 1000 kg of the solution (or from 19.2 to 55% H_2O). In this case, the ratio of the liquid phase to the solid decreases from 29.0 to 4.9, and the content of $CaCl_2$ and $MgSO_4$ in the melt decreases to a minimum (from 0.32 and 0.11% to 0.03 and 0.04%, respectively). The content of NaCl decreases from 8.01 to 0.11%, and $MgCl_2$ increases from 24.01 to 46.92%.

Bischofite crystals thus isolated contain 0.09% NaCl, 0.03% $CaCl_2$, 0.03% $MgSO_4$, and 46.9% $MgCl_2$ and correspond to bischofite with a content of 97% $MgCl_2$ $6H_2O$. It should be noted that NaC1 crystals obtained both in the first and second stages of concentration meet the quality standards of GOST 51574-2000 “Edible table salt. Specifications” and corresponds to the brand “extra”, where the content of NaCl is not less than 98.4%, and the

mass fraction of calcium, magnesium, sulfate and potassium is not more than: 0.35; 0.05; 1.20 and 0.10%, water-insoluble residue not more than 0.16%, the humidity not more than 0.70%.

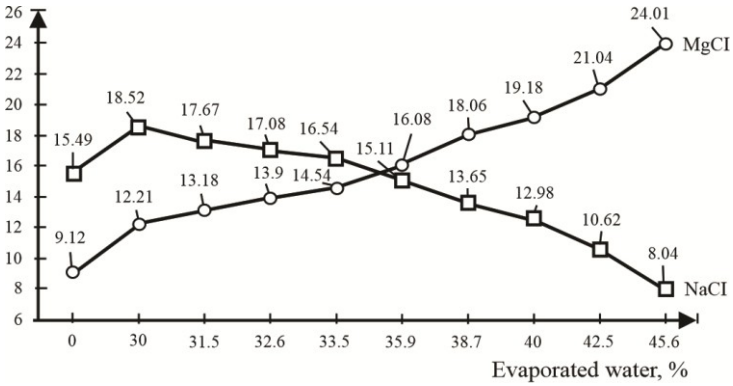

Fig. 1. The concentration of NaCl and $MgCl_2$ in brine depends on the amount of evaporated water in the first stage of concentration.

Table 6. 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	W:T ratio in brine	$CaCl_2$ content, %	$MgSO_4$ content, %
1	0	1000	-	0.32	0.11
2	191.8	808.2	29	0.29	0.10
3	383.6	616.4	11.4	0.21	0.08
4	421.2	578.8	8.9	0.18	0.07
5	458.9	541.1	7.4	0.14	0.06
6	489.7	510.3	6.5	0.10	0.05
7	520.6	479.4	5.7	0.05	0.04
8	550	450	4.9	0.03	0.04

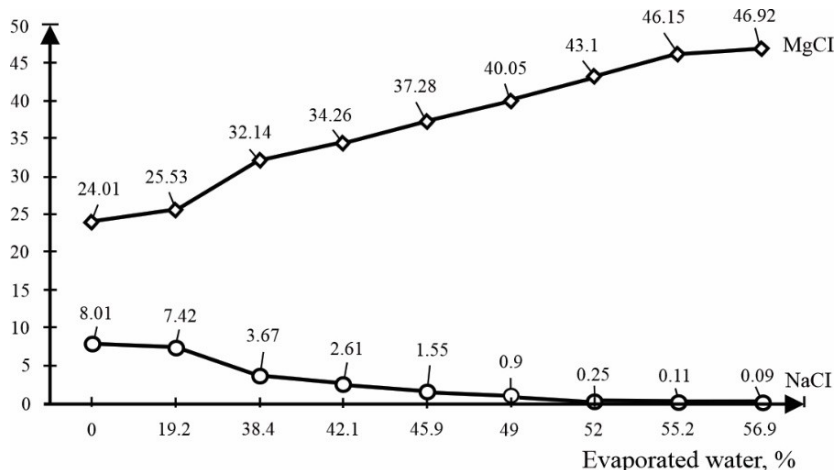

Fig. 2. The concentration of NaCl and $MgCl_2$ in brine depends on the amount of evaporated water in the second stage of concentration.

Thus, by stepwise evaporation of the purified Karaumbet and Barsakelmes brine, pure sodium chloride salts and magnesium chloride melt can be obtained.

4 Conclusion

The conducted studies on the evaporation of the brine from the Karaumbet and Barsakelmes lakes, without preliminary purification, showed the possibility of obtaining concentrated magnesium chloride melts with the accompanying release of sodium chloride. For this, evaporation must be carried out in two stages. The limit of brine concentration in the first and second stages must be limited to a density of 1.340-1.345 g/sm^3, which corresponds to the content of magnesium chloride after the first stage 15-16% and in the second 19-19.5%. In this case, almost pure sodium chloride is released.

References

1. Ch. Abhishek, M. Parth, S. Sunita, R. Arjit, S. Narittam, S. Man, Sustainable research methodology for potassium nitrate recovery from seawater, Chemical Engineering and Processing - Process Intensification (2022)
2. M. Samadiy, J. Makhmayorov, B. Abdullayev, Sh. Rakhimkulov, I. Usmanov, IOP Conf. Ser.: Earth Environ. Sci., **1111**, 012058 (2022)
3. M. Madakka, G. Sreenivasulu, N. Jayaraju, B. Lakshmanna, An integrated approach for sediment characterization of Dead Sea, Israel: Implications to the marine environment, Marine Pollution Bulletin (2022)
4. M.Y. Zolotov, M.V. Mironenko, Chemical models for martian weathering profiles: Insights into formation of layered phyllosilicate and sulfate deposits. Icarus, **275** (2016)
5. M. Babel, B.C. Schreiber, 9.17-Geochemistry of evaporites and evolution of seawater. Treatise on geochemistry (2014)
6. S. Jiangfeng, Ch. Jing, X. Xiaoming, P. Xiaodong, Ch. Daolun, P. Fusheng, Research advances of magnesium and magnesium alloys worldwide in 2021. Journal of Magnesium and Alloys (2022)
7. K. Jahan, Y. Mehta, Potential for Natural Brine for Anti-Icing and De-Icing. University Transportation Research Center (2012)
8. I. Shamshidinov, A. Kambarov, R. Najmiddinov, I. Rustamov, I. Usmanov, M. Samadiy, *Study of Physico-Chemical Properties of Phosphorate Solutions*, II International Conference on Agriculture, Earth Remote Sensing and Environment (RSE-II-2023), E3S Web Conf., **392**, 02036 (2023)
9. X. Mirzakulov, R. Tojiev, Processing brine of salt lakes of karakalpakstan in products of economic purpose, Theoretical & Applied Science, **12** (2019)
10. V.Drevin, V. Fomichev, I.V. Yudaev, L. Minchenko, G. Gizzatova, I. Kucherova, T. Shipaeva, V. Komarova, I. Rybintsev, Application of Solutions of the Electrochemical Processed Mineral “Bishofit” in Plant Production. In Advanced Agro-Engineering Technologies for Rural Business Development IGI Global (2019)
11. T. Mansurov, O. Bobokulova, D. Absattorov, I. Usmanov, M. Samadiy, Investigation of Processing of Brine of Lake Karaumbet and Barsakelmes for Magnesium Hydroxide. II International Conference on Agriculture, Earth Remote Sensing and Environment (RSE-II-2023). E3S Web Conf., **392**, 01001 (2023)

12. GOST 24596.4-81. Feed phosphates, Methods for determining calcium (IPK Publishing house of standards, Moscow, 2004)
13. F. B. Marty, J. Ramirez – Muñoz, Flame photometry (Mir, Moscow, 1972)
14. GOST 24024.12-81. Phosphorus and inorganic phosphorus compounds, Methods for the determination of sulfates (IPK Publishing house of standards, Moscow, 1981)
15. GOST 13685-84. Salt. Test methods (IPK Publishing house of standards, Moscow, 1997)
16. GOST 20851.4-75 Mineral fertilizers, Methods for determining water (IPK Publishing house of standards, Moscow, 2000)
17. R.T. Downs, M. Hall-Wallace, The American Mineralogist crystal structure database. American Mineralogist, **88** (2003)
18. A. Belkly, M. Helderman, V.L. Karen, P. Ulkch, New developments in the Inorganic Crystal Structure Database (ICSD): Accessibility in support of materials research and design, Acta Crystallographica. Section B: Structural science, **58** (2002)