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# PROCESSING BRINE OF SALT LAKES OF KARAKALPAKSTAN IN PRODUCTS OF ECONOMIC PURPOSE

*Abstract*: The article discusses the problem of processing the brine of Karaumbet and Barsakelmes lakes into magnesium chloride with the associated production of precipitated gypsum, calcium carbonate and sodium chloride. The process of desulfurization and descalcation of salt brines using distillation liquid — waste of soda production and soda ash — was studied. The process of cleaning up desulfurization and descalcation brines from residual sulfate and calcium ions with barium chloride and sodium carbonate was also investigated. By evaporation of purified suspensions of magnesium and sodium chlorides, the possibility of obtaining a bischofite melt with a content of at least 43-46% MgCl2 and pure NaCl was proven. Based on laboratory studies, a block diagram of the integrated processing of brine from the lakes of Karakalpakstan to magnesium chloride, gypsum, chalk and sodium chloride was developed. By the content of impurities, bischofite corresponds to GOST 7759-73.

*Key words*: brine of salt lakes, desulfurization, descalcination, evaporation, purification, bischofite, sodium chloride, precipitated gypsum and chalk.

*Language*: English

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**Introduction**

In the context of the transition to a qualitatively new stage of economic growth and the solution of the tasks of becoming a developed country with a competitive economy, the problem arises: should science be a strategic priority in the formation of an industrial and economic economy, or should foreign technologies be borrowed? Many countries purchase technologies, organize mass production on their basis, produce export-oriented products and develop at a fast pace [1].

As the head of our country noted, it is necessary to develop a science-based phased industrial policy. An example of this is the Decree of the President of the Republic of Uzbekistan No. PP-3236 dated August 23, 2017 "On the program for the development of the chemical industry for 2017-2021", PP-3983 dated October 25, 2018 "On measures for the accelerated development of the chemical industry of the Republic of Uzbekistan" and PP-4265 dated April 3, 2019 "On measures to further reform and increase the investment attractiveness of the chemical industry".

It is mainly about the modernization of equipment and technologies. However, the list of breakthrough projects is estimated to be a shortage of innovative industries. That is, the main problem of today's economy is to increase innovative efficiency. Today, the development of the country must be judged not only by its natural resources, but primarily by the presence of advanced technologies in its assets. One of these tasks is to develop the creation of innovative

technologies for processing local raw materials into various products for the national economy.

Magnesium chloride is an important for industrial use compound of magnesium, which is used in the production of magnesium metal, the production of magnesia binders, anti-icing materials, in the construction, chemical, food, pharmaceutical (balneo), oil and gas and other industries [2].

A large consumer of bischofite is the construction industry. A small addition of magnesian binders allows cement plants to switch to low-grade heat technology, which based on magnesian cement can replace at least 10% of products manufactured on the basis of Portland cement [3]. The technological features of obtaining magnesium products (magnesium oxide and chloride) from multicomponent brines of calcium chloride, magnesium chloride and mixed types are shown [4]. Based on these products, a highly active corrosion-resistant composite binder and economical building materials were obtained [5].

The use of refractories made of high-purity magnesium oxide increases the reliability and productivity of steelmaking furnaces and refractories [6, 7].

In agriculture in Uzbekistan it is used for the production of cotton defoliant - in the form of magnesium chlorate by the conversion of bischofite "wet method" with sodium chlorate [8]. Bischofite is also used to obtain magnesia fertilizers, presowing treatment of seeds of vegetable and oil crops [9-11].

The work [12] also considers the prospect of a technology for producing non-environmentally aggressive fungicides by electrolysis from bischofite solutions for controlling pathogenic fungi in construction and agriculture.

And the article [13] poses questions of the possibility of using purified bischofite of the Volgograd deposit in medicine. It noted that the magnesium salts that make up bischofite, in particular magnesium chloride, determine the properties of bischofite: antioxidant, keratolytic, anti-inflammatory, reparative, immunomodulatory activity, and the ability to influence microcirculation. Available data from clinical studies confirm the effectiveness of using bischofite in the form of various balneological agents in therapy, with insomnia, and states of nervous tension.

In addition, a theoretical and experimental analysis of the anti-icing properties of the main anti-icers was carried out [14]. Based on experimental data, it was established that natural bischofite has the best anti-icing properties.

Solid magnesium chloride used in various industries is produced by evaporation of an aqueous solution of magnesium chloride to obtain hexahydrate crystalline magnesium chloride (bischofite) having a melting point (crystallization) of about 116°C.

Bischofite or magnesium chloride can be obtained from sea water. Dead Sea Work Ltd. (DSW) since the 1970s is a major global manufacturer and supplier of potash products, as well as large chemical products, including magnesium chloride, industrial salts, deicers, table salt and raw materials for the cosmetics industry [2]. Production facilities are located in Israel, Spain and the UK. DSW is the only producer of magnesium chloride in Israel and is the largest bischofite producer in the world. The product is extracted from the Dead Sea. Each liter of Dead Sea water contains 170g $MgCl_2$. DSW uses solar ponds-evaporators in which the magnesium chloride brine is evaporated to 33% concentration and obtained by further evaporation to a content of about 47% and the formation of flakes of $MgCl_2$ granules.

Uzbekistan has unique reserves of natural resources. Such raw materials include natural brines - brines and dry mixed salts, containing, along with other salts and magnesium compounds, found in the Ustyurt layer of the Karaumbet and Barsakelmes deposits (Karakalpakstan), Khojaikon in the Surkhandarya region, Dengizkul and Hadjkab in the Bukhara region, etc. The challenge is the development and production of import-substituting products based on brines of lakes in Uzbekistan. Some products include bischofite or magnesium chloride. Due to the lack of bischofite production, bischofite is imported to the republic from abroad. The annual demand of the republic for magnesium chloride exceeds 30 thousand tons.

The explored reserves of the brine of the lakes of Karakalpakstan open up great opportunities for the production of magnesium chloride and other salts necessary for the national economy.

So, in the brine of Karaumbet and Barsakelmes lakes, located near the Kungrad soda plant (Republic of Karakalpakstan). The formation of mixed salts (solid phase) is considered as salt formation dried up in the lake as a result of long-term evaporation of water.

The approved reserves of Karaumbet Lake are estimated at 700 thousand tons of $MgCl_2$ or 295 thousand tons of MgO. The reserves of magnesium salts in the brine of Lake Barsakelmes are estimated at 2470 thousand tons of $MgCl_2$ or 1040 thousand tons of MgO.

Rapa Lake Karaumbet contains from 7.40 to 11.45% Na, from 15.2 to 18.9% C1, from 4.55 to 6.27% MgO, from 3.14 to 6.66% SO4, to 0, 60% CaO, while the brine of Lake

Barsakelmes contains from 6.61 to 11.45% Na, from 15.2 to 18.9% C1, from 1.37 to 4.57% MgO, from 1.44 to 3, 73% $SO_4$, 0.02% CaO. Their chemical composition changes significantly depending on the time of year with a change in climatic conditions - a decrease or increase in precipitation. And an increase in the evaporation rate increases the salinity in the lakes and the precipitation of sodium chloride.

These salt deposits can serve as raw materials for obtaining separately MgO, Mg(OH)$_2$, MgCl$_2$· 6H$_2$O, NaCl and Na$_2$SO$_4$ after their corresponding purification.

To isolate magnesium chloride in the first place, it is necessary to get rid of sulfate ions that impede the direct use of rap for the preparation of the above salts [15].

In the laboratory, we desulfurized brine from Karaumbet and Barsakelmes lakes with distillation liquid (DL) - waste from Ltd «Kungradsky Soda Plant». For information, to produce 1 ton of soda ash, at least 1.5 tons of sodium chloride and the same

amount of calcium carbonate are consumed, and at least 10 m$^3$ of DL and containing about 1500 kg of calcium and sodium chlorides, as well as about 250-300 kg of solid waste (CaCO$_3$, Ca(OH)$_2$, CaSO$_4$ and other metal impurities).

For the experiments, we took the brines of Karaumbet and Barsakelmes lakes, as well as the distillation liquid of Ltd «Kungradsky Soda Plant», the compositions of which are given in table 1.

**Table 1. Composition of brine of Karaumbet, Barsakelmes lakes and distiller liquid**

| Name | The ionic composition, mass. % | | | | |
| --- | --- | --- | --- | --- | --- |
| | Na$^+$ | Mg$^{2+}$ | Ca$^{2+}$ | Cl$^-$ | SO$_4^{2-}$ |
| Brine lake Karaumbet | 8,01 | 3,25 | 0,02 | 17,53 | 6,66 |
| Brine lake Barsakelmes | 9,06 | 1,64 | 0,01 | 17,07 | 2,34 |
| Distiller fluid | 2,18 | 0,007 | 3,03 | 8,74 | 0,03 |

| Name | Salt composition, mass. % | | | |
| --- | --- | --- | --- | --- |
| | MgCl$_2$ | NaCl | CaCl$_2$ | MgSO$_4$ |
| Brine lake Karaumbet | 6,28 | 20,37 | 0,05 | 8,33 |
| Brine lake Barsakelmes | 4,13 | 23,05 | 0,03 | 2,54 |
| Distiller fluid | - | 5,54 | 8,41 | 0,04 |

The experiments were carried out as follows. The original DL was loaded into a glass reactor placed in a water thermostat. The reactor is equipped with a screw stirrer for mixing. The rotational speed of the electric motor (250 rpm) was regulated by a rheostat. Then, the calculated amount of salt brines was gradually dosed to it. The norm of distillation liquid ranged from 75 to 110% of the stoichiometry for SO$_3$ binding in CaSO$_4$, and the process temperature was from 20 to 60°C. When the starting components are mixed, a reaction occurs between calcium chloride and sodium and magnesium sulfate:

CaCl$_2$ + Na$_2$SO$_4$ (MgSO$_4$) + nH$_2$O = CaSO$_4$·2H$_2$O + 2NaCl (MgCl$_2$·6H$_2$O).
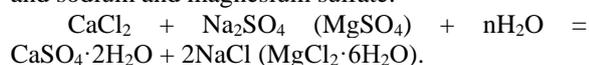
First, we studied the effect of the duration of the desulfurization process (from 5 to 180 minutes) at a 100% DL rate using the example of the brine of Lake Karaumbet. It was found that with an increase in time from 5 to 20 minutes, the process of desulfurization of the brine occurs intensively, then it drastically slows down. So, at 20°C after 5 minutes, the degree of desulfurization of Karaumbet brine is 58.37%, after 20 minutes - 88.59%, after 30 minutes - 89.8%, after 60 minutes - 90.33%, and after 180 minutes only by 0.48%.

The rest of the calcium sulfate dihydrate remains in the brine because of its partial solubility (at 20°C, the solubility of CaSO$_4$·2H$_2$O is 0.206 g / 100 g H$_2$O)

[16]. And an increase in temperature leads to a decrease in the degree of desulfurization of salt brine. Therefore, the optimum temperature is 20-30°C, and the duration is 20-30 minutes.

In figure 1 shows the degree of desulfurization of brine from Karaumbet and Barsakelmes lakes depending on the DL norm and the process temperature for 30 minutes. It can be seen from it that at 20 ° C with an increase in the DL norm from 75 to 110% of stoichiometry, the degree of desulfurization of the Karaumbet brine increases from 67.1 to 96.0%, at 40°C - from 61.24 to 89.19% and at 60°C - from 54.91 to 81.83%. For Barsakelmesky brine, this indicator changes from 50.03 to 95.56%, from 46.32 to 85.64% and from 47.11 to 72.47%, respectively. It can be seen from the data that the higher the temperature, the lower the degree of desulfurization. This is apparently due to the increased solubility of calcium sulfate due to temperature changes.

After desulfurization of the brine with distillation liquid, the resulting suspension is quite well divided into liquid and solid phases. Скорость осаждения караумбетского рассола после обессеривания изучали путем осаждения в условиях: the rate of DL is 100%, the duration of desulfurization is 30 minutes, the process temperature is 20; 40 and 60°C. The clarification rate was

calculated by the formula $W = \ell / \tau$, where $\ell$ is the clarification height, m; $\tau$ - time, hour. The results are shown in table 2
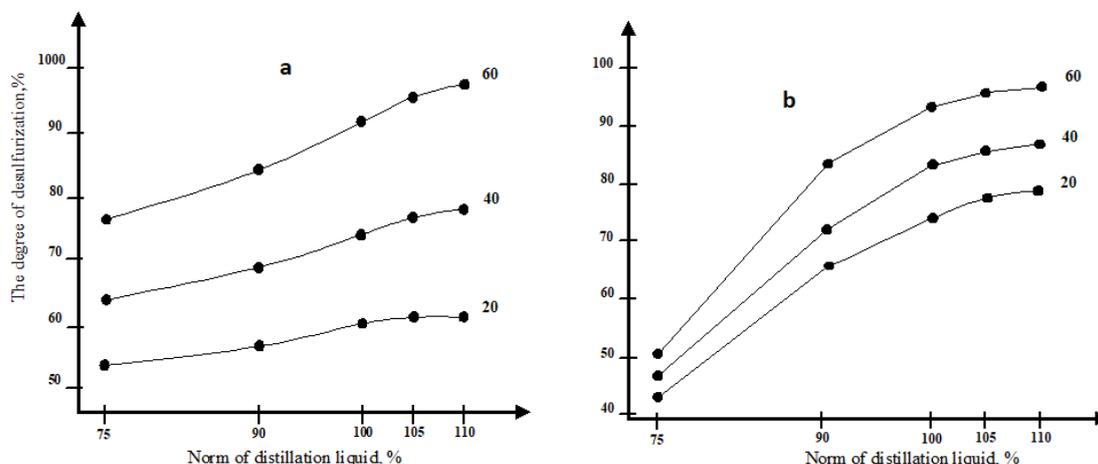


**Fig. 1. The influence of the norm and temperature of the distiller liquid on the degree of desulfurization of the brine of the lakes Karaumbet (a) and Barsakelmes (b).**

**Table 2. Effect of temperature and process duration on the clarification rate of desulfurized brine of the Karaumbet deposit**

| Temperature, °C | Time, min | | | | |
| --- | --- | --- | --- | --- | --- |
| | 5 | 10 | 15 | 20 | 30 |
| | Clarification speed, m/h | | | | |
| 20 | 0,65 | 0,62 | 0,58 | 0,47 | 0,09 |
| 40 | 1,22 | 0,97 | 0,65 | 0,52 | 0,12 |
| 60 | 1,73 | 1,44 | 0,91 | 0,64 | 0,20 |

It can be seen from it that the longer the settling process, the lower the rate of clarification of the suspensions. So, at 20°C, an increase in the duration of the settling process from 10 to 30 minutes leads to a decrease in the rate of clarification of the suspension from 0.62 m/h to 0.09 m/h, and at 60°C from 1.73 to 0.20 m/h. An increase in temperature from 20 to 60°C, on the contrary, increases the rate of clarification of the suspension at 10 min from 0.62 to 1.44 m/h, at 20 min from 0.47 to 0.64 m/h and at 30 min from 0.09 to 0.20 m/h. And this is due to the fact that an increase in temperature significantly reduces the viscosity of the solutions.

In figure 2 shows curves for the degree of desulfurization of brine depending on the exposure time and process temperature. They show that with increasing process temperature, the degree of clarification of the suspension increases. For each temperature, the process has a rectilinear region to increase the degree of clarification of the suspension.

So, at 20°C, after 20 minutes, the degree of clarification of the suspension reaches its maximum - 91.7%, at 40°C - 92.9% and at 60°C - 94.1%. And with a further increase in the settling time, the degree of clarification of the suspension remains virtually unchanged and amounts to 92.9%, 93.8%, and 94.7%, respectively, for temperatures of 20, 40, and 60°C.

Thus, in the temperature range of 20-60°C, clarification of desulfurized brine at a 100% norm of distillation fluid proceeds at a sufficient speed, reaching a maximum degree of deposition of 91-93% within 15-20 minutes.
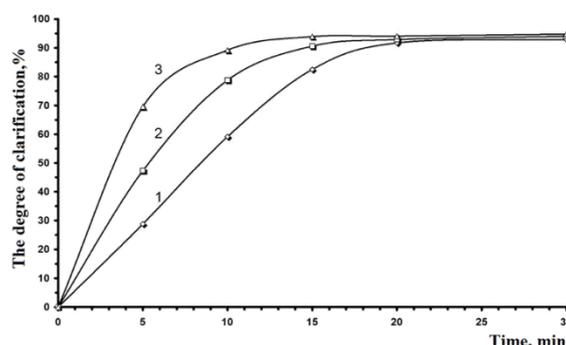
**Fig. 2. The degree of clarification of the suspension obtained by desulfurization of brine using distillation liquid at its rate of 100%. 1 - 20°C, 2 - 40°C, 3 - 60°C.**

Next, the condensed part of the suspension with a different ratio of Liquid : Solid (L:S) was filtered on a Buchner funnel, maintaining a vacuum in the Bunsen flask equal to 400 mmHg. The area of the filtering surface is 0.005 m². Data on the filtration rate of the thickened part of the suspension are given in table 3.

So, at L : S = 2.5: 1, the filtration rate of the $CaSO_4 \cdot 2H_2O$ sludge with a height of 5 cm is 781 kg/m²•h, and the suspension is 2733.5 kg/m²•h. With an increase in the thickness of the sediment layer on the filter, the filtration rate noticeably decreases both in precipitation and in suspensions. Upon reaching a sediment height of 10 cm, the filtration rate of the desulfurized solution by sediment is 625 kg/m²•h, and by suspension - 2187.5 kg/m²•h. With an increase in the fraction of the liquid phase (L : T) to 3: 1, the filtration rate for precipitation decreases, but this indicator increases for suspensions. Reducing L : S to 2 : 1, although it increases the rate of filtration by sediment, but decreases by suspension. So, with L : S = 2: 1 the filtration rate of sediment with a height of 5 cm is 768 kg/m²•h, with L : S = 2.5 - 703 kg/m²•h, and with L : S = 3 : 1 - 637 kg/m²•h. In any case, they indicate that the filtration rate of gypsum solutions is high and does not create difficulties in the technological cycle.

**Table 3. The effect of sediment height on the filtration rate of the condensed part of the Karaumbet brine suspension depending on L : S at a temperature of 25°C**

| Height, cm | Filtration rate, kg/m²•h | |
| --- | --- | --- |
| | By suspension | By sediment |
| **L : S = 2 : 1** | | |
| 5 | 2304 | 768 |
| 10 | 2025 | 675 |
| 15 | 1773 | 591 |
| **L : S = 2,5 : 1** | | |
| 5 | 2461 | 703 |
| 10 | 2188 | 625 |
| 15 | 1915 | 547 |
| **L : S = 3 : 1** | | |
| 5 | 2548 | 637 |
| 10 | 2268 | 567 |
| 15 | 1984 | 496 |

Depending on the duration of the desulphurization process at the studied temperatures (20-60°C), the density and viscosity of the purified liquid phase are 1.18-1.20 g/cm³ and 1.01-2.29 mPa•s and are quite suitable for further processing.

The composition of desulfurized brine of Karaumbet and Barsakelmes lakes depending on the norm of distillation liquid and process temperature (within 30 minutes) is given in table 4.

**Table 4. The influence of the norm of the distiller liquid and the process temperature on the composition and degree of desulfurization of the brine of the Karaumbet and Barsakelmes lakes for 30 minutes**

| Norm DL,% | The salt composition of the liquid phase, mass. % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | at 20°C | | | | at 40°C | | | | at 60°C | | | |
| | $MgCl_2$ | NaCl | $CaCl_2$ | $MgSO_4$ | $MgCl_2$ | NaCl | $CaCl_2$ | $MgSO_4$ | $MgCl_2$ | NaCl | $CaCl_2$ | $MgSO_4$ |
| Based on the brine of Karaumbet Lake | | | | | | | | | | | | |
| 75 | 6,51 | 14,75 | 0,40 | 1,71 | 6,24 | 14,69 | 0,68 | 2,01 | 5,95 | 14,62 | 0,98 | 2,32 |
| 90 | 6,69 | 14,20 | 0,36 | 1,22 | 6,35 | 14,12 | 0,66 | 0,94 | 6,02 | 14,11 | 0,98 | 1,69 |
| 100 | 6,72 | 13,82 | 0,34 | 0,36 | 6,42 | 13,75 | 0,65 | 0,68 | 6,09 | 13,68 | 0,99 | 1,06 |
| 105 | 6,66 | 13,63 | 0,43 | 0,23 | 6,39 | 13,57 | 0,71 | 0,53 | 6,08 | 13,50 | 1,03 | 0,88 |
| 110 | 6,54 | 13,44 | 0,58 | 0,18 | 6,27 | 13,39 | 0,86 | 0,48 | 5,99 | 13,32 | 1,15 | 0,80 |
| Based on the brine of Lake Barsakelmes | | | | | | | | | | | | |
| 75 | 4,13 | 19,20 | 0,73 | 1,56 | 3,53 | 19,58 | 1,16 | 2,27 | 3,38 | 18,67 | 2,04 | 2,06 |
| 90 | 4,77 | 18,59 | 0,18 | 0,51 | 4,56 | 18,96 | 0,20 | 0,73 | 3,82 | 18,74 | 1,14 | 1,56 |
| 100 | 4,82 | 18,19 | 0,28 | 0,30 | 4,80 | 18,92 | 0,44 | 0,43 | 4,11 | 18,80 | 1,24 | 1,24 |
| 105 | 4,83 | 18,01 | 0,36 | 0,24 | 4,71 | 18,37 | 0,57 | 0,34 | 4,32 | 18,82 | 1,07 | 1,03 |
| 110 | 4,81 | 17,80 | 0,46 | 0,21 | 4,70 | 18,15 | 0,73 | 0,30 | 4,44 | 18,84 | 0,91 | 0,88 |

As it was established above, regardless of the brine deposits of the lakes of Karakalpakstan for desulfurization, the optimal standard DL was 100% of stoichiometry, the mixing time was 30 minutes. The composition of desulfurized brine looks: for Lake Karaumbet (wt.%): At 20°C $MgCl_2$ - 6.72; NaCl - 13.82; $CaCl_2$ - 0.34; $MgSO_4$ - 0.36; and for Lake Barsakelmes – $MgCl_2$ - 4.82; NaCl - 18.19; $CaCl_2$ - 0.28; $MgSO_4$ - 0.30.

It should be noted that during desulfurization of brine by distillation liquid in the liquid phase, the content of calcium ions increases, and the degree of deposition of sulfate ions is insufficient. According to the requirements for technical magnesium chloride, the CaO content should not exceed 0.2%, and $SO_4$ - 1.1% [17]. Based on this, the final cleaning task was the precipitation of the calcium ion residue with sodium carbonate and the deep desulfation of the brine with barium chloride. The weight of added sodium carbonate, depending on the norm, is from 7.52 to 12.53 kg, which corresponds to 75 to 125% of the stoichiometric standards. The results of the degree of depreciation of the brine of Karaumbet Lake are presented in figure 3.

As can be seen from the experimental data, with an increase in the rate of sodium carbonate from 75 to 105%, the content of calcium chloride in the liquid phase noticeably decreases from 0.869 to 0.667%. A further increase in the rate of sodium carbonate to 125% does not lead to a significant decrease in the content of calcium chloride in the liquid phase. The content of the remaining components – magnesium and sodium chlorides and magnesium sulfate also varies insignificantly and is in the following ranges (wt.%): 9,106-9,151; 15.223-15.665 and 0.227-0.228, respectively.

Therefore, to reduce the degree of brine contaminated with calcium ions, the rate of sodium carbonate introduced should not be increased by more than 100-105%. The degree of removal of calcium ions is 59.4-60.5%. The resulting solution contains more than 9% magnesium chloride and more than 15.5% sodium chloride.

For deep cleaning of brine from sulfates used previously desulfurized and purified from calcium ions brine composition, mass. %: NaCl - 15.47; $MgCl_2$ - 9.13; $CaCl_2$ - 0.32; $MgSO_4$ -0.39.
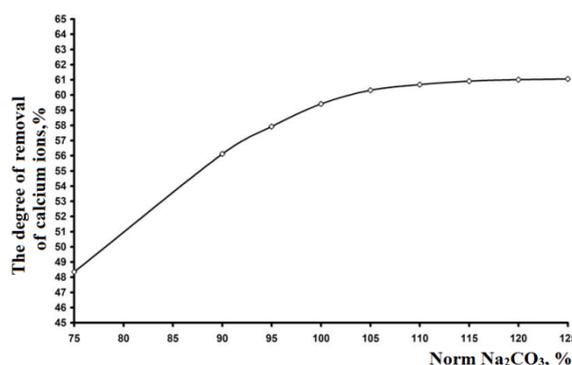


**Fig. 3. The effect of normal sodium carbonate on the degree of removal of calcium from desulfurized brine.**

It can be seen from it that when the norm of barium chloride reaches 100%, the process of desulfation is almost complete. At the same time, the degree of desulfurization reaches 99.5% and the residual $SO_4$ content in brine does not exceed 0.001%.

Thus, studies have shown the possibility of cleaning the brine of Karaumbet and Barsakelmes lakes from sulphates with solutions of distiller liquid and their purification with sodium carbonate and barium chloride. In this case, solutions purified of sulfate and calcium ions suitable for producing magnesium chloride that meet the requirements of GOST are obtained.

**Table 5. Effect of barium chloride norm on brine composition and degree of sulfate deposition at a temperature of 25°C and a process duration of 30 minutes**

| Norm of BaCl$_2$, % | The composition of the liquid phase, mass% | | | | Degree of precipitation of SO$_4$, % |
| --- | --- | --- | --- | --- | --- |
| | NaCl | MgCl$_2$ | CaCl$_2$ | MgSO$_4$ | |
| 70 | 14,40 | 8,63 | 0,36 | 0,0550 | 75,65 |
| 80 | 14,26 | 8,56 | 0,36 | 0,0440 | 84,60 |
| 90 | 14,09 | 8,50 | 0,35 | 0,0160 | 93,04 |
| 95 | 14,02 | 8,46 | 0,35 | 0,0089 | 96,25 |
| 98 | 13,98 | 8,44 | 0,34 | 0,0010 | 98,63 |
| 100 | 13,95 | 8,43 | 0,34 | 0,0009 | 99,50 |
| 102 | 13,88 | 8,40 | 0,34 | 0,0008 | 99,65 |
| 105 | 13,82 | 8,37 | 0,60 | 0,0008 | 99,70 |

Due to the high content of sodium chloride in purified calcium sulfates and chloride, brine was evaporated in two stages, with an intermediate separation of "sodium chloride precipitate" at 100°C and a vacuum of 40 mm Hg.

The data on the effect of the amount of evaporated water on the composition, the ratio of L : S and pulp density are given in table 6.

**Table 6. The influence of the evaporation process on the composition of the liquid phase after the first stage of evaporation**

| Evaporated water, % | The composition of the liquid phase, mass. % | | | | Density, g/cm$^3$ | L : S |
| --- | --- | --- | --- | --- | --- | --- |
| | MgCl$_2$ | NaCl | CaCl$_2$ | MgSO$_4$ | | |
| 0 | 9,12 | 15,49 | 0,67 | 0,23 | 1,250 | – |
| 30 | 12,21 | 18,52 | 0,59 | 0,21 | 1,271 | 35,63 |
| 31,5 | 13,18 | 17,67 | 0,55 | 0,20 | 1,279 | 24,09 |
| 32,6 | 13,90 | 17,08 | 0,51 | 0,20 | 1,286 | 18,68 |
| 33,5 | 14,54 | 16,54 | 0,49 | 0,19 | 1,292 | 16,15 |
| 35,9 | 16,08 | 15,11 | 0,46 | 0,18 | 1,308 | 12,30 |
| 38,7 | 18,06 | 13,65 | 0,41 | 0,15 | 1,332 | 8,40 |
| 40,0 | 19,18 | 12,58 | 0,40 | 0,14 | 1,347 | 6,69 |
| 42,5 | 21,04 | 10,62 | 0,36 | 0,12 | 1,373 | 4,83 |
| 45,6 | 24,01 | 8,01 | 0,32 | 0,11 | 1,422 | 3,86 |

As you can see, an increase in the amount of evaporated water to 45.6% leads to a decrease in L : S to 3.86 and the concentration of magnesium chloride in the solution rises to 24.01%, and the content of sodium chloride decreases to 8.01% due to its precipitation, which is explained by the different solubility of sodium and magnesium chlorides. The concentration of calcium chloride decreases from 0.67% to 0.32%, and magnesium sulfate from 0.23 to 0.11%. In this case, the density of the liquid phase increases from 1.250 g/cm$^3$ to 1.422 g/cm$^3$.

Next, the filtrate after the first stage of evaporation and separation of sodium chloride was

evaporated to remove 56.9% of water. The data on the effect of brine concentration at the second stage of evaporation are given in table 7.

With the evaporation of water in an amount of 52-55.2% in the second stage of evaporation and after separation of sodium chloride, the concentration of magnesium chloride reaches 43.10-46.15%, which corresponds to bischofite with a content of 91.94-97.06% of magnesium chloride hexahydrate. By the content of impurities, bischofite corresponds to GOST 7759-73. And the content of sodium chloride does not exceed 0.11-0.25%. The concentration of calcium chloride and magnesium sulfate is reduced to 0.03%.

**Table 7. The influence of the evaporation process on the composition of the liquid phase after the second stage of evaporation**

| Evaporated water, % | The composition of the liquid phase, mass. % | | | | L : S |
| --- | --- | --- | --- | --- | --- |
| | MgCl$_2$ | NaCl | CaCl$_2$ | MgSO$_4$ | |
| 0 | 24,01 | 8,01 | 0,32 | 0,11 | – |
| 19,2 | 25,53 | 7,42 | 0,29 | 0,10 | 28,97 |
| 38,4 | 32,14 | 3,67 | 0,21 | 0,08 | 11,41 |
| 42,1 | 34,26 | 2,61 | 0,18 | 0,07 | 8,91 |
| 45,9 | 37,28 | 1,55 | 0,14 | 0,06 | 7,39 |
| 49,0 | 40,05 | 0,90 | 0,10 | 0,05 | 6,45 |
| 52,0 | 43,10 | 0,25 | 0,05 | 0,04 | 5,69 |
| 55,2 | 46,15 | 0,11 | 0,03 | 0,04 | 4,87 |
| 56,9 | 46,92 | 0,09 | 0,03 | 0,03 | 4,84 |

Based on the laboratory studies, a block diagram of the complex processing of brine from the lakes of Karakalpakstan to magnesium chloride with the simultaneous production of chemically precipitated gypsum, chalk and sodium chloride was developed (figure 4).

The process of complex processing of brine from Karaumbet and Barsakelmes lakes consists of the following stages: desulphurization of brine with distiller liquid; thickening and separating sediments; drying and filling gypsum; purification of brine from calcium ions; thickening and separation of chalk sediment; drying and packing chalk; the first stage of evaporation of brine; separating crystals of sodium chloride; the second stage of evaporation of brine; separating crystals of sodium chloride; drying and packaging sodium chloride; cooling and crystallization of bischofite; bischofite packing [18]. A patent of the Republic of Uzbekistan has been issued for a method for processing natural brines containing chloride and sodium and magnesium sulfates [19].
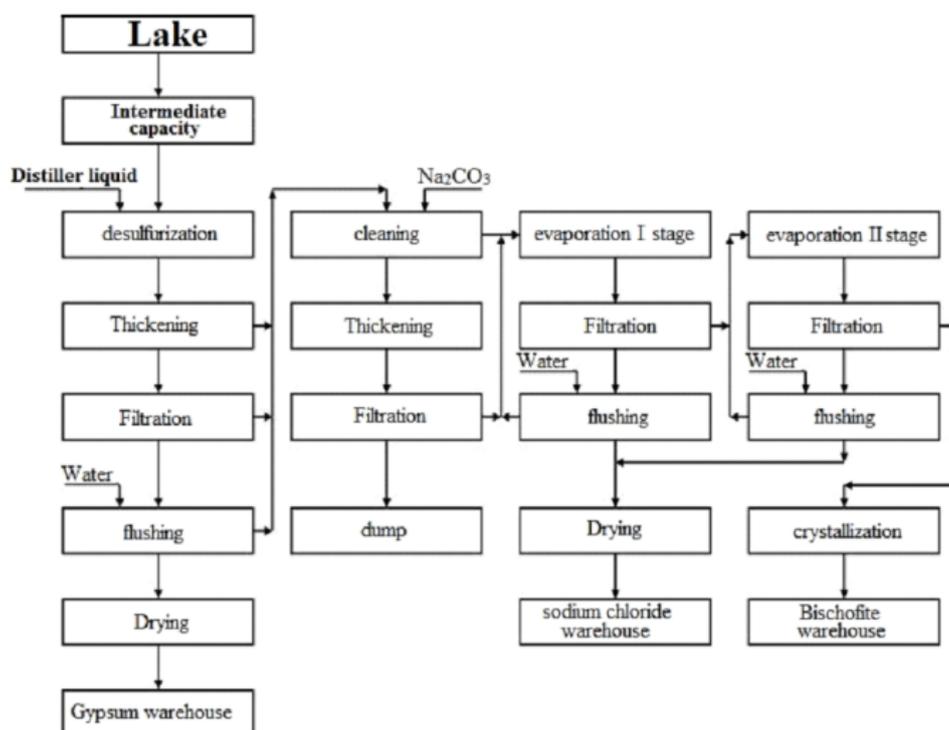


**Fig. 4. The block diagram of the processing of brine lakes Karakalpakistan.**

So, when processing 1000 kg of brine from Karaumbet Lake into magnesium chloride, gypsum, chalk and sodium chloride, 473.0 kg of distillation liquid, 14.5 kg of sodium carbonate and 25.6 kg of water are needed for washing. You can get 243.6 kg of bischofite, 199.5 kg of NaCl, 54.6 kg of synthetic gypsum and 17.9 kg of precipitated chalk.

Thus, the studies performed allowed us to obtain scientifically based data and develop a technology for processing brine from Karaumbet and Barsakelmes lakes to magnesium chloride with the simultaneous extraction of chemically precipitated calcium sulfate dihydrate and chalk, table salt from the brine. To do this, it is necessary to clean the brine from sulphates and calcium salts, using a distillation liquid - waste from soda production and soda ash, evaporation with an intermediate separation of sodium chloride, and this results in a bischofite melt containing at least 46.92% magnesium chloride, which corresponds physically -chemical indicators GOST 7759 - 73.

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