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Methods for purifying table salt from the Bakhyt-Tany deposit

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ABSTRACT
This article discusses modern methods of purifying table salt from the Bakhyt-Tany deposits. Currently, the demand for various methods of production and processing of table salt is increasing. Therefore, high-quality purification of table salt and its effective use is one of the urgent tasks. As an object of study, salts were taken from the Bakhyt-Tany deposit, located in the Sozak district of the Turkestan region. The main goal of the scientific work is to study methods for purifying and processing sodium chloride from impurities. Modern analytical methods were used during scientific research. To determine the physicochemical properties of table salt, PEM JSM 6610 LV, X-ray microanalysis Inca Energy-450, energy dispersive system-fluorescence spectroscopy, IR-Fourier spectrometer were chosen. As a result of the research work, it turned out that using only the lime-soda method itself, it is possible to purify salt from calcium and magnesium ions up to 90-93%. It has been established that when using the phosphate method of purifying a saline solution, the degree of purification from calcium and magnesium ions increases to 95-97%. To further increase the degree of purification, it was recommended to first purify the solution using the lime-soda method, and then purify the solution using the phosphate method. It has been established that with this method the degree of purification can be increased to 99%.

Keywords: sodium chloride, brines, table salt, salt purification methods, sodium phosphate.

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Introduction

Every country in the world mines and processes table salt to some extent. The main producers of table salt in the CIS countries are enterprises in Russia, Belarus, Ukraine, Kazakhstan and Turkmenistan [[1], [2]]. The technologies used in the production of table salt in these countries depend primarily on the type and nature of the salt deposit, its geographical location, the quality of raw materials and the presence of various impurities, as well as on consumer requirements to salt quality [[3], [4]]. Currently, the production of table salt is based on various methods of its extraction and processing, and the world market is growing by an estimated 1% per year. At the same time, the technogenic impact on the environment is also growing, which makes its negative contribution to the deterioration of its condition [[5], [6], [7]]. There are several traditional methods to purify sodium chloride from unwanted ions, and they include lime-soda method, barium carbonate method and so on. The lime-soda method is difficult to achieve high purity of salt, and barium is a highly toxic element and barium sulfate compounds can lead to the development of pneumoconiosis [9]. Sodium phosphate is mainly used for water softening, to precipitate calcium and magnesium ions from solution. The advantages of

the phosphate method are that phosphate compounds are widely used by the food industry, and in small quantities are not dangerous to human health. The article considers lime-soda and phosphate methods of salt purification from calcium and magnesium ions. The purity of salt and reagents is one of the most important criteria in production. The lime-soda method has long been known as a purification method, but a multi-stage purification system is required to obtain high purity salt [[9], [10]].

Also disadvantages of already existing methods of salt purification from undesirable ions are multistage process, application of concentrated hydrochloric acid for treatment of sodium chloride solution, which at further evaporation and centrifugation causes corrosion of equipment; at the same time additional washing of NaCl crystals from acid by expensive high-purity water is required, which together with multistage process significantly increases the cost of the process of table salt purification [[7], [8]].

Although NaCl can be purified to any desired degree, it is associated with certain costs that increase the cost of the product. Thus, it is very important to provide purification in the most practical way [[11], [12]]. Therefore, the aim of this paper is to study the peculiarities of table salt production and to analyze its main environmental impacts.

Salt lakes of Bakhyt-Tany deposit located on the territory of Suzak district of Turkestan region (Figure 1) were taken for study as raw materials. The deposit is located far from the settlements of tasty village at a distance of 15 km to the north of the field. Lake Bakhyt-Tany is a continental dry self-sedimenting lake with developed new-sedimentation and old-sedimentation. Its composition is chloride, without root salt. The surface area of the lake is 1.87 km². The surface is flat, smooth with traces of mining. Near the banks, the surface is swollen, broken by cracks, along which liquid silt protrudes, forming rolls up to 5-8 cm high on the surface. The thickness of new sediment is mainly from 3 to 15 cm. The thickness of old sediment is from 11 to 47 cm, including the average thickness of 0.2 m for Block B and 0.25 m for Block C1. The thickness of garnet is 0.78-1.0 m. The average thickness of the salt deposit is 1.26 m - 0.93 m. In general, the salt deposit is a stratum gradually wedging out to the lake periphery.

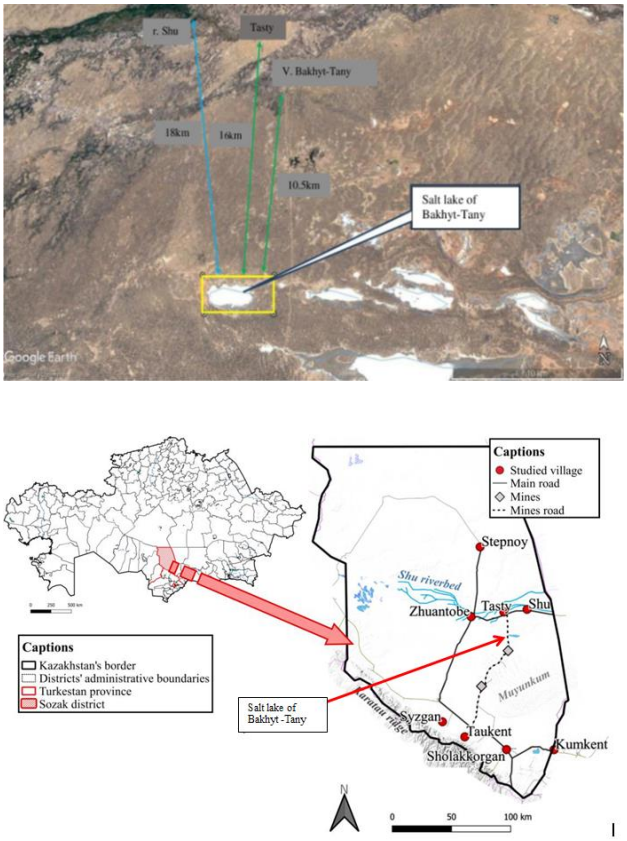

Figure 1 - Location of the lake of the Bakhyt-Tany deposit

The ground aquifer lies at a depth of 2 to 5 meters. The chemical composition of water is sulfate-chloride, rarely sulfate. Mineralization varies from 2 to 10 g/l. Water availability of the horizon is low. Within Bakhyt-Tany deposit ground waters were not opened by excavations of 2.5 m. The annual capacity of the enterprise is taken taking into account the need to develop commercial salt reserves for the Contract period, i.e. 25 years. Industrial reserves of salt deposit as of 01.01.2016 are 1349.6 thousand tons or 811 thousand m³ in the sum of categories B+C1 [6]. The purpose of this work is to study the methods of processing and purification of sodium chloride from impurities.

Experimental part

To conduct the study from the deposit Bakhyt-Tany were taken samples of sodium salt mineral, the depth of sampling 50 cm. Chemical analysis of samples was carried out according SS 13685-84 [13].

Methods of analysis. For determination of sulfate ions we used the method of barium sulfate turbiometry, for determination of calcium and magnesium ions we used titration with EDTA

(Tab.1), Elemental analysis was carried out by means of energodispersive X-ray fluorescence spectroscopy on energy dispersive microanalysis system INCA Energy 450, installed on scanning electron microscope JSM 6610 LV, JEOL, Japan (Fig.2-3. Tab.2). The error of determination - 0.01 %. A JSM 6610 LV scanning electron microscope, JEOL, Japan, was used to study the microstructure of the samples (Fig.3). The accelerating voltage was 20 kV. The imaging mode was secondary electrons. Chemical analysis of the sample was carried out according to SS-sodium chloride.

X-ray diffractometer Dron - 4-07 was used to obtain X-ray diffractometric analysis. With a tube with a cobalt anode (Fig.4). Diffractometer imaging mode:

- sweep speed 2 deg/min;
- tube operating parameters: 30 kV, 20 mA.

IR analysis of the sample was carried out by a FTIR spectrometer NEXUS E.S.P. (Thermo Scientific, USA) (Fig.5).

As a result of the research the chemical composition of the salt of Bakyt-Tany lake was determined using scanning electron microscope LEO 912 AB OMEGA (Carl Zeiss SMT AG Oberckochen, Germany) and SEM JEOL JSM. The elemental composition of sodium salt is given in Table 1.

Experimental methodology. To purify the brine from impurities using the lime-soda method, a saturated salt solution with a concentration of 315 g/l was prepared. The solution was prepared at a temperature of 80-100 ^{0}C so that all salt dissolved. After that we added sodium carbonate and calcium hydroxide calculated in advance by chemical reactions. The obtained mixture was stirred continuously for 10-15 min in the thermostat, then the mixture was allowed to stand for 30 min at room temperature and passed through a filter. Insoluble salt residue and insoluble calcium and magnesium compounds remained on the filter as a precipitate. The composition of the precipitate on the filtrate is shown in Figure 5. We determined the content of calcium and magnesium ions in the filtered brine by titration method. The obtained NaCl solution is sent for management and drying of the target product.

To purify the brine from impurities by phosphate method, a stoichiometric amount of sodium phosphate is added to the saturated solution to precipitate Ca and Mg salts. The mixture is stirred and kept at room temperature for 30 minutes. The resulting solution is then sedimented. Extracted in the solid phase from the saturated solution of NaCl impurity ions of calcium and magnesium, formed in the interaction with sodium phosphate, filtered, washed. Then the clarified NaCl solution is directed to the management and drying of the target product [[15], [16], [17]].

The discussion of the results

According to the results of the study the moisture content of the samples was 0.6-1%. According to the obtained results the approximate salt composition of halite mineral was calculated: $CaSO_4$ –2.5%, $MgSO_4$ –0.18%, $MgCl_2$ – 0.37%,NaCl – 88.4%. The mineral contains up to 2 % wt. % of insoluble residue, which does not allow to use it for production of table salt without preliminary desliming.

Table 1 - Results of chemical analysis of sodium salt of Bakhyt-Tany deposit

Ions	Mg^{2+}	Ca^{2+}	Cl^-	SO_4^{2-}	Na^+	Insolub. residue
Content, %	0.28	0.880	53.4	1.83	35.3	1.17-2

Insoluble residue of salt has two phases: the first is clay insoluble mass, the second is transparent crystals of insoluble calcium sulfate.

After determining the composition of table salt, the purification method was selected. Due to the fact that the composition of the natural mineral is similar to table salt, the physicochemical properties were studied to obtain sodium chloride used in food and soda ash production by removing calcium, magnesium ions and mechanical additives from the mineral [[18], [19]].

Table 2 - Elemental composition of sodium salt of Bakyt-Tany deposit

Element	O	Na	Mg	S	Cl	Ca	Total
Spectr 1	10.4	32.37	1.16	1.26	53.04	1.77	100
Spectr 2	3.74	38.78	0.42	0.15	56.42	0.48	100
Spectr 3	7.53	31.87	0.81	0.31	58.88	0.60	100
Total, %	7.22	34.34	0.80	0.57	56.11	0.95	100

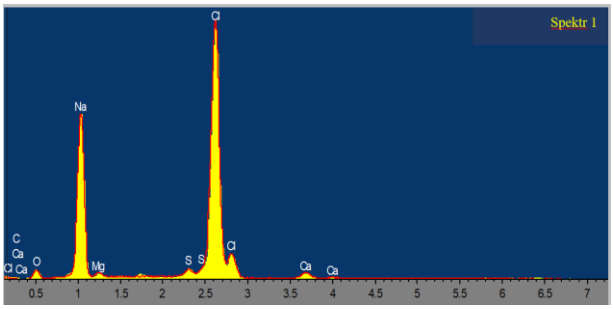

Figure 2 - Spectrogram of elements of natural sodium salt of the Bakhyt-Tany deposit

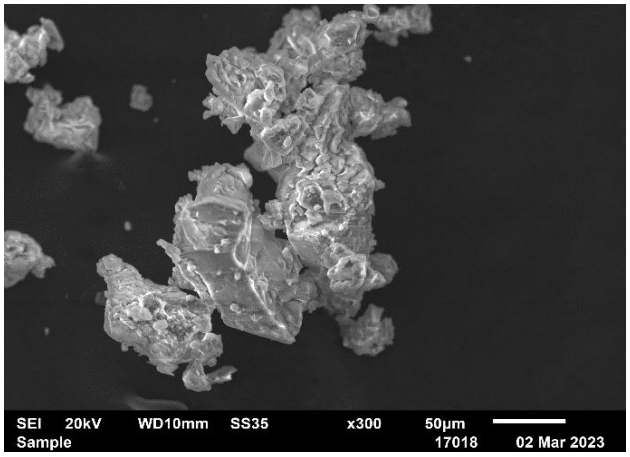

Figure 3 - Micrographs of the surface of the natural sodium salt of the Bakhyt-Tany deposit

The very high intensity of sodium and chlorine pickers in the figure compared to other elements indicates that the sample contains a higher proportion of sodium and chlorine.

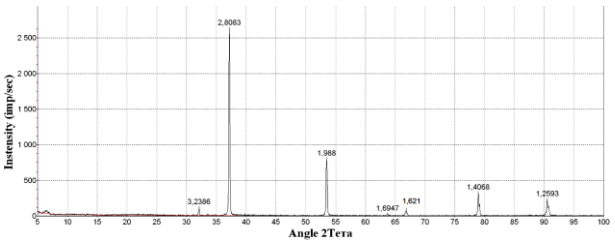

Figure 4 – Results of the XRD of the natural sodium salt of the Bakhyt Tany deposit

Reflexes: 3.24; 2.81; 1.99, 1.69; 1.62; 1.41; 1.26 Å - NaCl (Hyalite) - ASTM-5-628. All the intense and non-intense peaks in the X-ray radiograph of the salt sample belong to sodium chloride. The rest of the sodium mineral seodyniums in the composition of the salt are very low in content, below 2 %. Therefore, they are not visible in the X-ray diagram. All these data, including XRD, elemental analysis, chemical analysis, indicate a very high content of sodium chloride in the natural sodium mineral of the Bakhyt-Tany deposit.

Based on literature sources, several methods have been selected to purify salt from impurities and ions. There are several traditional methods of purifying sodium chloride from unwanted ions, these include lime-soda method, barium carbonate method, etc. The purity of salt and reagents is one of the most important criteria in production. The lime-soda method has long been known as a purification method, but a multi-stage purification system is required to obtain high purity salt. The following reactions occur in the brine:

$$CaCl_2 + Na_2CO_3 \rightarrow 2NaCl + CaCO_3 \quad (1)$$
$$CaSO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + CaCO_3 \quad (2)$$
$$MgCl_2 + Na_2CO_3 \rightarrow 2NaCl + MgCO_3 \quad (3)$$
$$MgSO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + MgCO_3 \quad (4)$$
$$MgCl_2 + 2NaOH \rightarrow 2NaCl + Mg(OH)_2 \quad (5)$$
$$MgSO_4 + 2NaOH \rightarrow Na_2SO_4 + Mg(OH)_2 \quad (6)$$

Figure 5 shows the IR analysis of the sludge on the filter after cleaning by the lime-soda method. The figure shows that the most intense peaks 1427, 878,716 cm^{-1} are characteristic for calcium carbonate, and in the region of 3200 - 3700 cm^{-1} absorption of OH-groups.

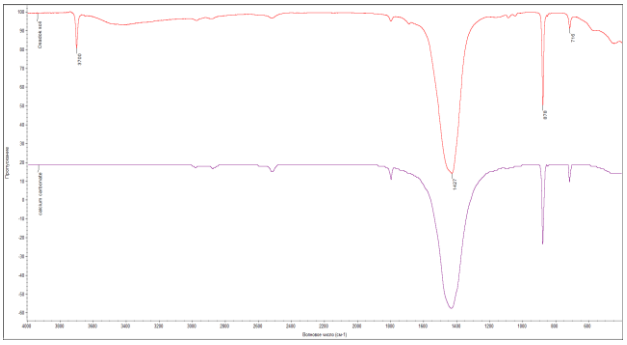

Figure 5 - IR analysis of the sludge on the filter after treatment with the lime-soda method

The phosphate treatment method is very advantageous because calcium and magnesium phosphates precipitate in the solution, which can be used in fertilizer production.

$$3CaCl_2 + 2Na_3PO_4 \rightarrow 6NaCl + Ca_3(PO_4)_2 \quad (7)$$
$$3CaSO_4 + 2Na_3PO_4 \rightarrow 3Na_2SO_4 + Ca_3(PO_4)_2 \quad (8)$$
$$3MgCl_2 + 2Na_3PO_4 \rightarrow 6NaCl + Mg_3(PO_4)_2 \quad (9)$$
$$3MgSO_4 + 2Na_3PO_4 \rightarrow 3Na_2SO_4 + Mg_3(PO_4)_2 \quad (10)$$

The soda-lime and phosphate methods were used for sodium chloride purification at the Bakhyt-Tany field. Only 90-93% of calcium and magnesium ions were removed from the brine using only the soda-lime method itself. When the cleaning reagents sodium carbonate and calcium hydroxide were added over 50%, the degree of purification increased to 94-98%.

When only phosphate method of solution cleaning was used, the degree of cleaning from calcium-magnesium ions increased up to 95-97% [[20], [22]]. To further increase the degree of purification, it was recommended to first purify the solution with the lime-soda method, and then purify the solution with the phosphate method. With this method, the purification degree can be increased up to 99%. The advantage of the method is that it reduces the consumption of cleaning reagents, does not require additional heating or reheating, the process is not multistage. Table 3 shows the degree of solution purification from calcium and magnesium ions by different methods.

Table 3 - The degree of solution purification from calcium and magnesium ions by different methods

No	Method	Degree of purification,%	
		Ca^+	Mg^+
1	Lime-soda	90	93
2	Lime-soda lime, in excess	93-94	97-98
3	Phosphate	96-97	94-95
4	lime soda and phosphate	99	99

Conclusions

The obtained results allow us to conclude that the natural salt mineral of the Bakhyt-Tany deposit contains a high concentration of sodium chloride and a small number of impurities.

Thus, the obtained results, including XRF, elemental analysis, chemical analysis, indicate a very high content of sodium chloride in the natural sodium mineral of the Bakhyt-Tany deposit. In the article lime-soda and phosphate method of salt purification from calcium and magnesium ions are considered.

Only 90-93% of calcium and magnesium ions were removed from the brine using the soda-lime method alone. When sodium carbonate and calcium hydroxide cleaning reagents were added over 50% in excess, the degree of purification increased to 94-98%. When only phosphate method of solution cleaning was used, the degree of cleaning from calcium-magnesium ions increased up to 95-97%. It was found that this method can increase the degree of purification up to 99% [[19], [20]].

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Conflicts of Interest. On behalf of all authors, the correspondent author declares that there is no conflict of interest.

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Бақыт-Таңы кен орнындағы ас тұзын тазарту әдістері

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ТҮЙІНДЕМЕ

Бұл мақалада Бақыт-Таңы кен орнының ас тұзын тазартудың заманауи әдістері қарастырылған. Қазіргі кезде ас тұзын өндіру және оны өңдеудің әртүрлі әдістеріне деген сұраныс артып отыр. Сол себепті аз тұзын жоғары дәрежеде тазалау және оны тиімді пайдалану өзекті мәселелердің бірі болып табылады. Аз тұзын тазалау үшін зерттеу нысаны ретінде Түркістан облысындағы Созақ ауданының аумағында орналасқан Бақыт-

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Сараптамадан өтті: *8 мамыр 2024*
Қабылданды: *21 маусым 2024*

Таңы кен орнының тұзды көлдері алынды. Ғылыми жұмыстың негізгі мақсаты – аз тұзын, яғни натрий хлоридін қоспалардан тазарту және өңдеу әдістерін зерттеу. Ғылыми зерттеу жүргізу кезінде заманауи талдау әдістері қолданылды. Ас тұзының физика-химиялық қасиеттерін анықтау үшін PEM JSM 6610 LV, рентгендік микроанализ Inca Energy-450, энергетикалық дисперсиялық жүйе - флуоресцентті спектроскопия, ИҚ-Фурье спектрометрі таңдалды. Ғылыми-зерттеу жұмыстарының нәтижесінде әкті-содалы әдістің өзін ғана қолданғанда тұзды кальций мен магний иондарынан 90-93%-ға дейін тазартуға болатындығы анықталды. Тұзды ерітіндіні тазалау үшін фосфатты әдіс қолданып, кальций магний иондарынан тазалау дәрежесі 95-97% дейін өсетіндігі анықталды. Тазалау дәрежесін одан әрі арттыру үшін ерітіндіні алдымен әкті-содалы әдіспен тазартып, кейін ертіндіні фосфатты әдіспен тазарту ұсынылды. Бұл әдіс арқылы тазалау дәрежесін 99% дейін жоғарылатуға болатыны анықталды.

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АННОТАЦИЯ

В данной статье рассмотрены современные методы очистки поваренной соли месторождений Бахыт-Таны. В настоящее время возрастает спрос на различные способы производства и переработки поваренной соли. Поэтому качественная очистка поваренной соли и ее эффективное использование является одной из актуальных задач. В качестве объекта исследования для были взяты соли из месторождений Бакыт-Таны, расположенного на территории Созакского района Туркестанской области. Основная цель научной работы – изучение методов очистки и переработки хлорида натрия от примесей. В ходе научных исследований использовались современные аналитические методы. Для определения физико-химических свойств поваренной соли были выбраны PEM JSM 6610 LV, рентгеновский микроанализ Inca Energy-450, энергодисперсионная система-флуоресцентная спектроскопия, ИК-Фурье-спектрометр. В результате исследовательской работы выяснилось, что при использовании только самого известково-содового метода можно очистить соль от ионов кальция и магния до 90-93%. Установлено, что при использовании фосфатного метода очистки солевого раствора степень очистки от ионов кальция и магния увеличивается до 95-97%. Для дальнейшего повышения степени очистки рекомендовалось сначала очищать раствор известково-содовым методом, а затем очищать раствор фосфатным методом. Установлено, что данным методом степень очистки можно повысить до 99%.

Ключевые слова: хлорид натрия, рассолы, поваренная соль, методы очистки солей, фосфат натрия.

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