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STUDYING THE RHEOLOGICAL PROPERTIES AND FILTERABILITY OF INTERMEDIATE, FINAL SOLUTIONS AND SUSPENSIONS FORMED WHEN PROCESSING SULFATE-CONTAINING SALTS

Ulashova Nafisa Aktam kizi [1], ***Kucharov Bakhrom Hayrievich*** [1], ***Erkaev Aktam Ulashevich*** [2], ***Kim Rimma Nikolaevna*** [1], ***Zakirov Bakhtiyar Sabirzhanovich*** [1], ***Olimov Tolmas Farkhodovich*** [2]

[1] Institute of General and Inorganic Chemistry, Academy of Sciences of the Republic of Uzbekistan

[2] Institute of Chemical Technology, Tashkent, Uzbekistan

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Abstract

The purpose of the research was to study the rheological properties and filtration rate of glaserite and schenite suspensions depending on the L:T ratio. Experimental studies have established that changes in the density and viscosity of the formed suspension depend on the L:S ratio and the characteristics of the constituent salts of the system. And the filtration rate of glaserite suspensions fluctuates in the ranges of 1937.10÷2056.33 kg/h · m^2, and for the solid phase - with an increase in the L:S ratio, an increase in filtration rate is observed, which ranges from 404.98-2165.80 kg /h · m^2. When using chenite suspensions, the filterability in the liquid phase is in the range of 1940.10÷2234.90 kg/h · m^2. The solid phase filtration rate fluctuates in the ranges of 550.81÷1996.25 kg/h · m^2, sediment moisture is on average 2.5–2.6% lower, and the filtration rate is on average 100–200 kg/h · m^2 more than glaserite sediments.

Keywords: *system, rheology, density, viscosity, filtration, potassium sulfate, fertilizers, sulfate salts, astrakhanite, schenite, glaserite*

Introduction

The potash industry is characterized by very high rates of development. Potassium is one of the most important nutrients for agricultural crops. Its deficiency in the soil leads to a significant decrease in soil fertility (№ PP–3236 dated August 15, 2017).

In terms of the amount of potassium fertilizers used per hectare of arable land, our country lags behind developed countries. A persistent deficit in potassium fertilizers has determined their primary use for industrial crops and vegetables. The yield of grain crops is determined mainly by the natural fertility of the soil. Wider use of potash fertilizers for grain crops is one of the most important reserves for their productivity (Osichkina R.G., Popov V.S., Tilyakhodzhaev Kh. –№5003.–12.07.84).

The specialization of Uzbekistan in cotton production necessitated the creation of the development of the chemical industry in the republic and its subordination, first of all, to the tasks of intensifying cotton growing. For each hectare of crops, an average of 220–250 kg of nitrogen, 100–120 kg of phosphorus pentoxide and 90–70 kg of potassium fertilizers (K_2O) are applied. As a result of an agrochemical survey of irrigated lands in Uzbekistan, it was found that on 75% of the areas of cotton–growing areas and as a result of the use of insufficient doses of potassium fertilizers, the removal of potassium with the harvest and annual leaching of saline lands, the soils are depleted of exchangeable potassium.

The need for potash fertilizers in cotton growing in Uzbekistan alone reaches more than 800 thousand tons. The need to increase the norms of potassium fertilizers has been proven not only for cotton, but also for other crops (corn, melons, fodder), which will further increase the demand for potash approvals (Kurnakov N.S., Shoikhet D.N., SFHAD 984). Chlorine–free potassium fertilizers can also be obtained from glauconite and through complex processing of alunites and syenites. However, further research is needed to select the most rational ways of processing and using this type of raw material (Sokolovsky A.A., Unanyants T.P., 1977.).

Further development should be achieved by enterprises producing potassium fertilizers by converting potassium chloride into sulfate salts chenite, langbeinite, glaserite, astrakhanite, etc. Several schemes for the conversion production of potassium sulfate have been proposed, in particular options where iron sulfate, an industrial waste, is used as a sulfate component – inorganic pigments and etching of metals with sulfuric acid. This method as a whole also does not solve the problem of chlorine–free potassium fertilizers (Sedletsky V.I. 1982, Popov B.S., Osichkina R.G., Dep. VINITI. –No. 3232. 1981).

In the Central Asian region, it is possible to organize the production of potassium sulfate on the basis of local raw materials of sulfate salts (thenardite, mirabilite, astrakhanite) from the salt deposits of the Aral Sea region (Akkala, Kushkanataw), located in Karakalpakstan. Reserves of mirabilite at the Akalinskoye deposit alone exceed 2 billion tons (Mirzakulov Kh.Ch., Zhuraeva G.Kh., Kh.Ch. Mirzakulov, G.Kh. Zhuraeva. 2014).

Methods and materials

The density of solutions was determined by the hydrometric method according to GOST (state standard) 18481 for general purpose with a division scale of 1 kg/m^3 (0.001 g/cm^3), the error in the accuracy of the results ranges from 0.0005 to 0.02 g/cm^3 (GOST (state standard) 18995.1–73. 2004). Viscosity was determined using a glass capillary viscometer brand VPZ (hanging level viscometer) in the temperature range 10–40 °C, the maximum deviation of which is ± 0.02 mm (GOST (state standard) 10028–81. 2005).

The sodium and potassium content in the obtained samples was determined according to the GOST (state standard) 20851.3–93 method (GOST 20851.3–93. 1995). To determine the composition of an aqueous solution, sulfate ions were determined according to the GOST (state standard) 8.315 method (GOST 24024.12–81. 1981) and the permissible relative error of the certified value was no more than 1.0%. Chlorine ion was determined according to the GOST (state standard) 4245–72 methods.

Results and discussion

For the purpose of physical and chemical substantiation, development of scientific foundations and technology for processing salt deposits of the Aral region and obtaining potassium sulfate from sulfate deposits with the establishment of optimal process parameters, an analysis of the solubility diagram of the system $2Na^+$, $2K^+$, Mg^{2+}, // SO_4^{2-}, $2Cl^-$ – H_2O was carried out by isothermal method at temperatures 25, 50 and 75 °C (Kucharov B.Kh., Zakirov B.S., A.U. Erkaev, Z.K. Toirov, O.A. Mursaev, N.A. Ulashova. 2016, Kucharov B.Kh., Zakirov B.S., Erkaev A.U., Orakbaev A.A., Reymov, 2019, Kucharov B.Kh., Zakirov B.S., Erkaev A.U. 2019).

From the results of a theoretical analysis of the solubility diagram, it was revealed that the salt deposits of the Aral region mainly consist of sodium or magnesium sulfates and/or their mixtures at certain ratios.

We also investigated the physicochemical properties of sulfate deposits of the Aral region (astrakhanite, glaserite and schenite), which can serve as raw materials for the production of potassium sulfate (N.A. Ulashova, Kucharov B. Kh., Erkaev A. U., Zakirov B. S. 2024).

Based on a theoretical analysis of the solubility diagrams of $2Na^{+}$, $2K^{+}$, $Mg^{2+}//SO_4^{2-}$, $2Cl^{-}$–H_2O at 0; 25 and 75 °C, to provide practical recommendations for the processing of salt deposits, we have proposed a technological scheme. The process of producing glaserite and shenite is carried out using potassium chloride from "Dekhkanabad Potash Fertilizer Plant" JSC and astrakhanite from salt deposits of the Aral region. The technological process includes the following main stages:

– loading a circulating solution, potassium chloride, astrakhanite into the reactor, followed by conversion at 75 °C;

– filtration and separation of glaserite from the solution;

– adding the calculated amount of potassium chloride to the mother solution and dissolving;

– filtration and separation of chenite from the solution at 0 °C;

This article provides data on the study of the rheological properties and filtration ability of the suspension that is formed during the complex processing of astrakhanite, glaserite and schenite with potassium chloride.

When studying the rheological properties of the resulting suspension of glaserite and schenite, the L:S ratio was maintained from 1:1 to 4:1, and the temperature varied from 0 to 45 °C.

The obtained data are shown in (tables 1 and 2) and (figures 1–4). The tables and figures show the rheological properties of glaserite and chenite solutions and suspensions. Table 1 shows that the rheological properties of glaserite suspensions with increasing temperature to 25 °C – the viscosity and density of the suspensions gradually increase, a further increase in temperature leads to a decrease in the density and viscosity of the formed suspensions. It was revealed that at L:S = 2:1 and L:S = 4:1, the maximum values of these parameters are observed at low temperatures than at high temperatures. This fact gives us reason to assume that the formation or splitting of double crystalline hydrates with single salts occurs.

Table 1. *Rheological properties of the suspension during the conversion of Na_2SO_4 with potassium chloride*

No.	Ratio	Density, ρ g/cm³, at temperature, °C.			Viscosity, η, mm²/sec at temperature, °C.		
	L:S	10	25	40	10	25	40
1	1:0	1.213	1.210	1.205	1.750	1.642	1.412
2	1:1	1.282	1.271	1.260	2.231	2.091	1.635
3	2:1	1.242	1.282	1.240	2.220	1.932	1.528
4	3:1	1.240	1.243	1.230	2.022	1.851	1.417
5	4:1	1.237	1.288	1.221	1.830	1.733	1.322

Table 2. *Rheological properties of the suspension during the conversion of $MgSO_4$ with potassium chloride*

Sample number corresponds to the table 1	Density, ρ, g/cm³, at temperature, °C				Viscosity, η, mm²/sec, at temperature, °C			
	0	15	30	45	0	15	30	45
1	1.144	1.140	1.138	1.134	1.930	1.8130	1.6769	1.4870
2	1.147	1.149	1.158	1.166	1.990	1.9040	1.8740	1.7060
3	1.155	1.158	1.170	1.170	2.144	2.0377	1.9607	1.4550
4	1.175	1.177	1.170	1.179	2.419	2.3940	2.3500	2.1449
5	1.224	1.235	1.221	1.217	–	–	–	–

Figure 1. *Change in suspension density depending on process parameters*

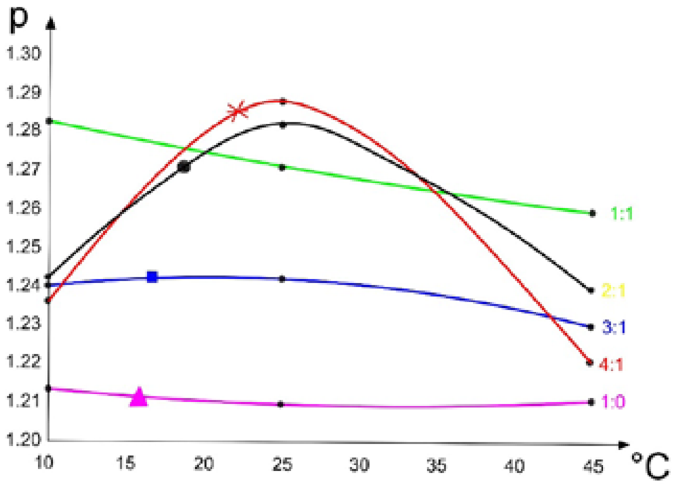
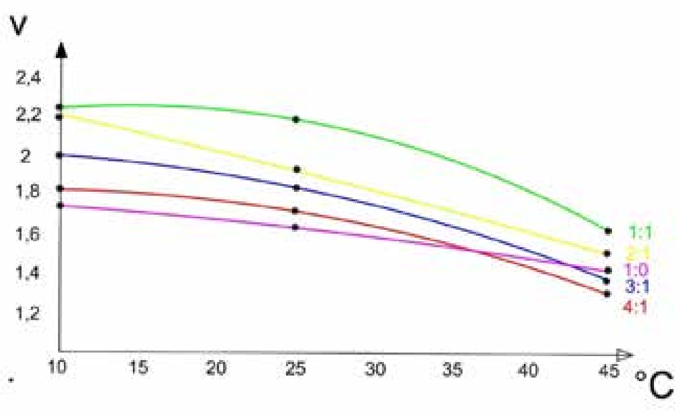


Figure 2. *Change in suspension viscosity depending on process parameters*



From (Table 2) it follows that with an increase in temperature from 0 to 45 °C and with an increase in the S:L ratio from 1:1 to 4:1, the viscosity of the suspension decreases. When the S:L ratio changes from 1:1 to 4:1 and the temperature from 0 to 45 °C, an increase in the density of the formed suspensions is observed, which is in the range of 1.134 – 1.1224 g/sm³. This is probably due to the characteristics of the constituent salts included in this system.

Table 2 shows the rheological properties of the schenite suspension.

Figure 3. *Change in suspension viscosity depending on process parameters*

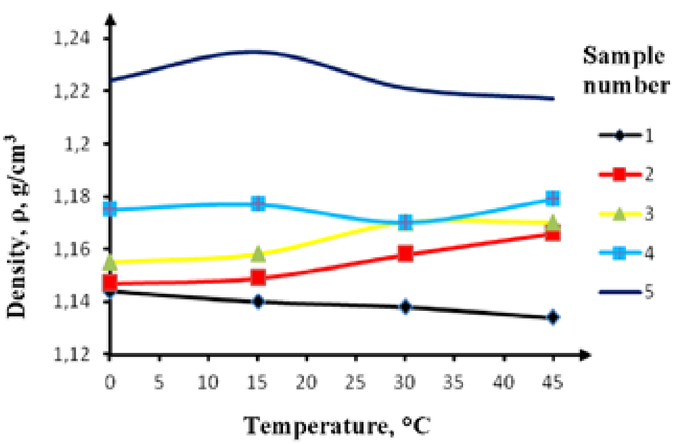


Figure 4. *Change in suspension viscosity depending on process parameters*

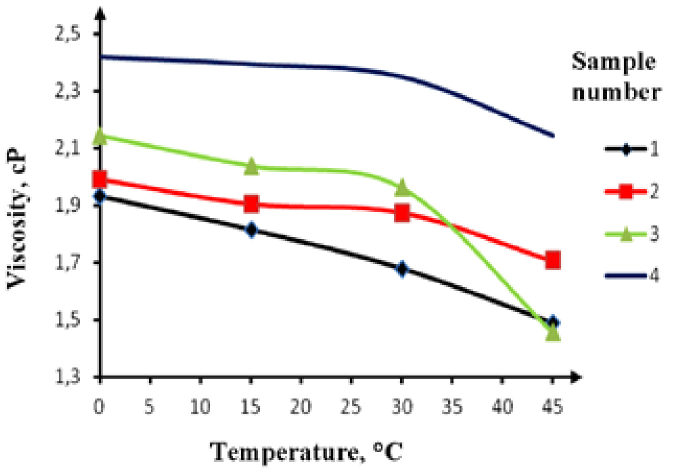


Table 3. *Filtration rate of glaserite and shenite suspensions, kg/(m² . hour)*

Sample numbers correspond to numbers table 1	When using Na_2SO_4.			When using $MgSO_4$.		
	By liquid phase	According to the solid phase	Solids moisture, %	By liquid phase	According to the solid phase	Solids moisture, %.
2	1953.35	404.98	14.690	1940.10	580.81	11.72
3	2056.33	545.43	10.790	2037.51	802.65	12.61
4	1984.40	1021.16	16.601	2234.90	1186.20	10.56
5	1937.10	2165.80	7.720	2134.90	1969.25	7.23

Table 3 presents data on the filterability of glaserite and chenite suspensions.

As follows from the data obtained, within the studied limits of L:S variation, the filtration rate of glaserite suspensions in the liquid phase fluctuates in the ranges of 1937.10÷2056.33 kg/h · m², and in the solid phase, with an increase in the L:S ratio, an increase in the rate is observed filtration, ranging from 404.98–2165.80 kg/h · m². Precipitation humidity ranges from 7.72–16.60%.

When using chenite suspensions, the filterability in the liquid phase is in the range of 1940.10÷2234.90 kg/h · m². A similar pattern is observed in the solid phase: the filtration rate fluctuates in the ranges of 550.81÷1996.25 kg/h · m², the sediment moisture is on average 2.5–2.6% lower, and the filtration rate is on average 100–200 kg/h · m² more than in glaserite sediments.

Conclusion

Thus, in order to provide practical recommendations for the production of potassium sulfate from sulfate salt deposits, we studied the rheological properties and filtration rate of suspensions that are formed during the complex processing of astrakhanite, glaserite and schenite with potassium chloride. It was established that changes in the density and viscosity of the formed suspensions depend on the L:S and the characteristics of the constituent salts of the system.

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Contact: doniyor_obidjonov94@mail.ru