DOI 10.52209/1609-1825_2023_1_84 UDC 622’17(574)

Study on Effect of Sintering Conditions on Exploration of Barite Raw Materials

[1]***TUREBEKOVA Karakat,** *Doctoral Student, kakosh-94@mail.ru,*
[2]**KATKEEVA Gulnara,** *Cand. of Tech. Sci., Associate Professor, Head of Laboratory, katkeeva@mail.ru,*
[1]**SULTANGAZIYEV Ruslan,** *PhD, Acting Associate Professor, sulrus83@mail.ru,*
[2]**OSKEMBEKOV Ilyas,** *Senior Researcher, ilyasosk@mail.ru,*
[2]**GIZATULLINA Dilara,** *Junior Researcher, dilurin@mail.ru,*
[1]NPJSC «Abylkas Saginov Karaganda Technical University», Kazakhstan, Karaganda, N. Nazarbayev Avenue, 56,
[2]Zh. Abishev Chemical-Metallurgical Institute, Kazakhstan, Karaganda, Ermekov Street, 63,
**corresponding author.*

Abstract. *The object of works has been the barite-bearing technogenic wastes. The wastes include the final tailings of the Karagailinsky mining and processing plant. They are stored in the tailing dumps, and they have been formed during the flotation concentration of the barite-polymetallic ores of the Karagaily deposit [1-2]. These tailing dumps occupy a huge territory. Thus, the dumps are pollution sources of soil, air and water by the heavy metals and barite dust. These wastes have been not recycled yet, i.e. there is no effective technology that would allow the cost-effective production of the quality commercial products. The issue with the barite-bearing waste recycling is its complex mineralogical composition. Thus, it leads to the inefficiency of the traditional recycling methods such as the acid leaching and flotation [3-5]. In order to solve these issues on this raw materialrecycling, some methods should be found to explore the ore mineral aggregateswith the silicon-bearing gangue minerals [6-7]. A promising solution to the issueis to explore the raw materials with the chemical methods, in particular, by a method of ammonium fluorosulfate desiliconization. Studies have been performed to explore the barite raw material by the sintering with ammonium fluorosulfate. As a result, a mathematical model of the exploration has been created and the optimal conditions for this process have been determined. The partial dependences of the raw material exploration on temperature, sintering time and consumption of the exploring reagents have been obtained. Based on the partial dependencies, a mathematical model of the sintering as a generalized multifactor equation has been created. This equation has determined the optimal conditions to explore the barite raw materials. A scheme of ammonium fluorine sulfate exploration of the barite raw materials has been developed.*

Keywords: *technogenic wastes, final tailings, concentration, leaching, desiliconization, barite raw materials, exploration of raw materials, silicon-bearing minerals.*

Introduction

The recycling wastes of the barite-polymetallic ores from the Karagaily deposit have a great economic potential. Their composition includes $BaSO_4$ up to 40%, Cu 0.4%, Zn 0.8% and Pb 0.6%. Thus, these wastes can be classified as the industrial polymetallic barite raw materials.

Their advantage over the mineral raw materials is that they do not require the expenditures connected with extraction from the subsurface resources and grinding. The waste reserves are significant. There are up to two tens of millions of tons.

The problem of processing this type of raw materials is the disclosure of clusters of ore minerals with silicon-containing minerals in the waste rock.

The issue on this raw material recycling is to explore the ore mineral aggregates with the silicon-bearing gangue minerals [6-7]. An innovative solution to the issue is to explore the raw materials with using the chemical methods, namely, by a method of ammonium fluorosulfate desiliconization.

Studies to explore barite raw materials by sintering with ammonium fluorosulfate have been made to create a mathematical model of exploration and to define the optimal conditions for this process.

Experimental part

The studies have been performed with using the probabilistic and deterministic method of an experiment planning [8-9].

The experiments have included the barite raw materials, composition in wt. %: SiO_2 – 40.9; $BaSO_4$ – 32.6; Al_2O_3 – 5.3; Fe – 4.6; S – 6.8; Zn – 0.6; Pb – 0.5 and Cu – 0.2 [1-2].

The effect of four factors on the exploration of the raw materials has been studied such as the sintering temperature (T), sintering time (τ), consumption of ammonium sulfate relative to stoichiometry of reaction with aluminum oxide (C_c) and consumption of ammonium bifluoride relative to stoichiometry of reaction with silicon oxide (C_f).

The sintering of the barite raw materials with ammonium fluorosulfate has been studied with the method described in [10]. The exploration of materials has been estimated with the degree of desiliconization of raw materials. Results of the experiments are demonstrated in Table 1.

Exploration of the barite raw materials relative to the degree of desiliconization has been used as a function of this study. Thus the experimental data on levels of factors under Table 1 have been selected. As a result, the average experimental values of the functions have been found. The experimental values of the partial functions and their average values are presented in Table 2.

Based on data in Table 2, the dot diagrams of the partial dependences to explore raw materials on the studied factors have been plotted. They are illustrated in Figure 1.

Referring to the point data, the approximating functions have been selected to describe the dependences of exploration of raw materials on the sintering factors under study:

$$\alpha_1 = -6.36 \cdot 10^{-4} T^2 + 0.588T - 33.30, \quad (1)$$

$$\alpha_2 = -3.38 \cdot 10^{-4} \tau^2 + 0.103\tau + 81.42, \quad (2)$$

$$\alpha_3 = 8.65 \cdot 10^{-5} C_c^2 - 0.003 C_c + 86.60, \quad (3)$$

$$\alpha_4 = -4.7 \cdot 10^{-3} C_f^2 + 1.287 C_c + 11.34. \quad (4)$$

By these equations, values of the partial functions and their average values have been calculated. Results on calculation are demonstrated in Table 3. The insignificant deviation in the average calculated values of functions from an overall experimental average has proved the close correspondence of equations to the dot diagrams.

Table 1 – Effect of sintering factors on exploration of barite raw materials

Experiment No.	T, °C	τ, min.	C_c, %	C_f, %	Exploration of materials, $\alpha_э$, %
1	2	3	4	5	6
1	350	30	50	50	55.2
2	350	90	100	100	91.69
3	350	60	75	75	75.9
4	350	180	150	150	99.32
5	350	120	125	125	97.99
6	400	30	100	75	80.07
7	400	30	75	150	99.85
8	400	60	150	125	98.40
9	400	180	125	50	67.05
10	400	120	50	100	96.38
11	375	30	75	125	96.38
12	375	90	150	50	65.85
13	375	60	125	100	89.08
14	375	180	50	75	83.03
15	375	120	100	150	98.48
16	450	30	150	100	92.12
17	450	90	125	75	88.10
18	450	60	50	150	99.74
19	450	180	100	125	99.38
20	450	120	75	50	66.38
21	425	30	125	150	99.26
22	425	90	50	125	99.08
23	425	60	100	50	63.59
24	425	180	75	100	96.64
25	425	120	150	75	84.57
				Overall average	87.34

Table 2 – Experimental values of partial functions on exploration of the barite raw materials

Function	Levels					Average value
	1	2	3	4	5	
α_1	84.02	86.56	88.35	88.63	89.14	87.34
α_2	84.606	85.34	88.91	88.76	89.08	87.34
α_3	86.69	87.03	86.64	88.30	88.05	87.34
α_4	63.61	82.33	93.18	98.25	99.33	87.34

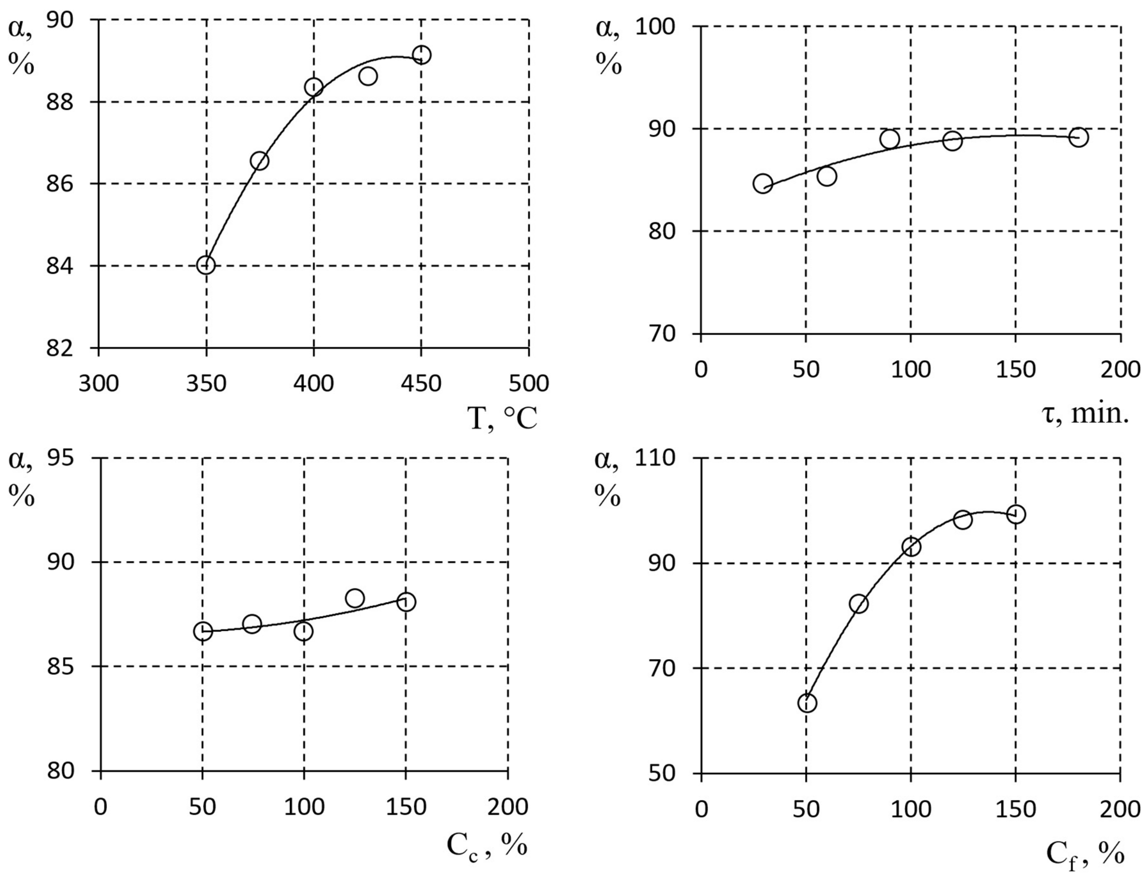

Figure 1 – Dependences of exploration of barite raw materials on sintering factors

Table 3 –The calculated values of partial functions on exploration of barite raw materials

Function	Levels					Average value
	1	2	3	4	5	
α_1	84.09	86.51	88.14	88.97	89.01	87.34
α_2	84.21	86.38	87.95	88.91	89.01	87.29
α_3	86.67	86.86	87.16	87.58	88.10	87.27
α_4	63.94	81.43	93.04	98.78	98.64	87.17

By equation 5, a coefficient of the nonlinear multivariable correlation has been determined. Thus, by equation 6, the signification of the obtained partial dependencies has been calculated. Results are presented in Table 4.

$$R = \left(1 - \frac{(N-1)\sum_{1}^{N}(\alpha_{\exp} - \alpha_{cal})^2}{(N-K-1)\sum_{1}^{N}(\alpha_{\exp} - \alpha_{av.})^2} \right)^{0.5}, \quad (5)$$

Table 4 – Correlation coefficient and its signification for private functions on exploration of barite raw materials			
Function	R	t_R	Significationof function
α_1	0.99	122.48	significant
α_2	0.92	10.35	significant
α_3	0.74	4.93	significant
α_4	0.999	576.76	significant

$$t_R = \frac{R(N-K-1)^{0.5}}{1-R^2}. \qquad (6)$$

Analysis of the partial dependencies has demonstrated that in the matrix experiments, the high effect on degree of exploration of barite raw materials relative to silicon has been made by consumption of ammonium bifluoride. Thus, desiliconization of raw materials has scaled upaverage by 35% during the increase in consumption of ammonium bifluoride from 50% to 125%. Moreover the increase in exploration has been observed in the entire studied interval.

All dependencies have been significant.

The generalized multifactor equation (8) to explore barite raw materials has been made under (7) on the basis of the significant partial dependences, and it is presented as

$$\alpha_P = \frac{P_{i=1}^{n}\alpha_i}{\alpha_{av.}^{n-1}}, \qquad (7)$$

$$\alpha = 1.5\cdot10^{-6}(-6.36\cdot10^{-4}T^2 + 0.558T - 33.30)\times$$
$$\times(-3.38\cdot10^{-4}\tau^2 + 0.103\tau + 81.42)\cdot(8.65\cdot10^{-5}C_c^2 - \qquad (8)$$
$$-0.003C_c + 86.60)\cdot(-4.7\cdot10^{-3}C_f^2 + 1.287C_c + 11.34).$$

This equation is a mathematical model of the sintering of the barite raw materials with ammonium fluorosulfate in relation to the exploration in terms of silicon. Thus, it has significantly correlated with the experimental data ($R = 0.989$, $t_R = 195.95$).

Based on this equation, the optimal conditions can be determined to explore the studied barite raw material in terms of silicon. In particular, to make 100% desiliconization of raw materials at the specified sintering conditions such as temperature 400°C, time 90 min, consumption of ammonium bifluoride 100%, the optimum rate of ammonium sulfate should be 277%.

The recommended technological scheme of the ammonium fluorosulfate exploration of barite raw materials is illustrated in Figure 2.

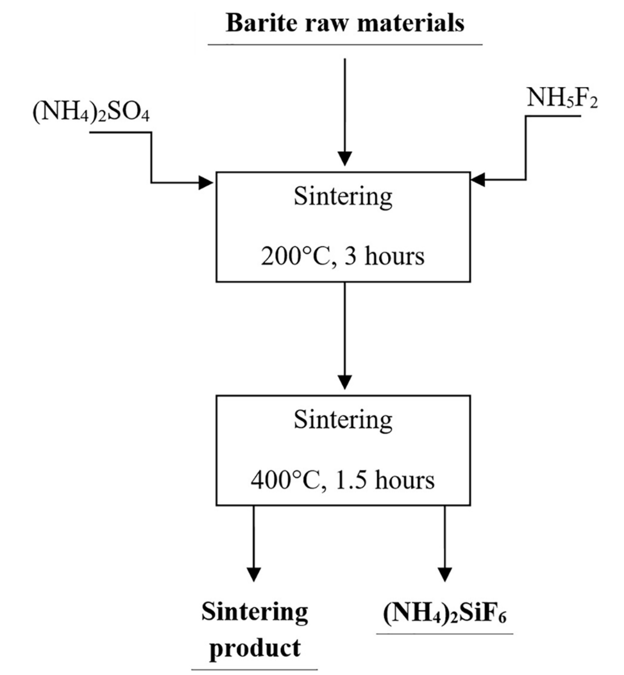

Figure 2 – Technological scheme of exploration of barite raw materials

As a result, the study on sintering of the barite raw materials with the exploring reagents such as bifluoride and ammonium sulfate has determined the essential effect of the sintering conditions on exploration of the raw materials in terms of silicon.

Conclusion

The partial dependences of exploration of the raw materials on temperature, sintering time and consumption of the exploring reagents have been obtained. Based on the partial dependencies, a mathematical model of the sintering as a generalized multifactor equation has been created. This equation has calculated the optimal conditions to explore the barite raw materials. The scheme of ammonium fluorine sulfate exploration of the barite raw materials has been developed.

REFERENCES

1. Мирошниченко Л.А. О скарнах Центрального Казахстана // Изв. АН КазССР. Сер.геол. – 1955. – № 20. – С. 75-79.
2. Янулова М.К. О лемонтите Карагайлинского месторождения в Казахстане // Зап. Всесоюз. минерал.об-ва. Вторая серия. – 1956. – Ч. 85. – С. 424-428.
3. Янулова М.К. Минералогия скарново-барито-полиметаллического месторождения Карагайлы. – Алма-Ата: АН КазССР, 1962. – Т.1. – 243 с.
4. Еникеева Г.Н. Гипогенная минерализация полиметаллических месторождений Центрального Казахстана // Тр. ВСЕГЕИ. – 1959. – Т.23. – С. 345-359.
5. Фурсова М.З. Минералогия зоны окисления скарново-барито-полиметаллического месторождения Карагайлы // Тр. ИГН АН КазССР. – 1966. – Т. 15. – С. 196-201.
6. Копылова Н.В., Шкетова Л.Е., Селезнев А.Н. Разработка технологии цветных металлов из отходов обогатительных фабрик с использованием приемов био- и геотехнологии // Материалы международного совещания «Прогрессивные методы обогащения и комплексной переработки природного и минерального сырья». Плаксинские чтения, 16-19 сентября 2014 года. – Алматы, 2014. – С. 384-385.
7. Селезнев С.Г., Светлов А.В., Макаров Д.В., Маслобоев В.А. Возможности извлечения цветных металлов из техногенных месторождений Мурманской области // Там же. – Алматы, 2014. – С. 370-372.
8. Малышев В.П. Вероятностно-детерминированное планирование эксперимента. – Алма-Ата: Наука, 1981. – 116 с.
9. Малышев В.П. Математическое планирование металлургического и химического эксперимента. – Алма-Ата: Наука, 1977. – 37 с.
10. Туребекова К.С., Султангазиев Р.Б., Морозов Ю.П. Разработка схемы фторо-сульфатоаммонийного вскрытия сырья // Труды Международной научно-практической online конференции «Интеграция науки, образования и производства – основа реализации Плана нации» (Сагиновские чтения №12) // 18-19 июня 2020 г. – Караганда, 2020. – С. 135-138.

Барит шикізатының ашылуына бірігу жағдайларының әсерін зерттеу

*[1]***ТУРЕБЕКОВА Каракат Сериковна,** докторант, kakosh-94@mail.ru,*
*[2]**КАТКЕЕВА Гульнара Летаевна,** т.ғ.к., доцент, зертхана меңгерушісі, katkeeva@mail.ru,*
*[1]**СУЛТАНГАЗИЕВ Руслан Бауржанович,** PhD, доцент м.а., sulrus83@mail.ru,*
*[2]**ОСКЕМБЕКОВ Ильяс Маликович,** аға ғылыми қызметкер, ilyasosk@mail.ru,*
*[2]**ГИЗАТУЛЛИНА Дилара Рафаиловна,** кіші ғылыми қызметкер, dilurin@mail.ru,*
[1]«Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КеАҚ, Қазақстан, Қарағанды, Н. Назарбаев даңғылы, 56,
[2]Ж. Әбішев атындағы Химия-металлургия институты, Қазақстан, Қарағанды, Ермеков көшесі, 63,
**автор-корреспондент.*

Аңдатпа. *Жұмыс объектісі – Қарағайлы кен орнының барит-полиметалл рудаларын флотациялық байыту кезінде қалыптасқан және үйінді қалдық қоймаларында сақталған Қарағайлы байыту фабрикасының қалдық қалдықтарын қамтитын құрамында барит бар техногендік қалдықтар [1-2]. Бұл қалдықтар үлкен аумақты алып жатыр және топырақты, ауаны және суды ауыр металдармен және барит шаңымен ластаушы көздер болып табылады. Жоғары сапалы коммерциялық өнімді үнемді түрде алуға мүмкіндік беретін тиімді технологияның жоқтығынан бұл қалдықтар әлі де қайта өңделмеген. Құрамында бариті бар қалдықтарды өңдеу мәселесі күрделі минералогиялық құрамда жатыр, бұл өңдеудің дәстүрлі әдістерін – қышқылмен шаймалау және флотациялауды қолданудың тиімсіздігін тудырады [3-5]. Шикізаттың бұл түрін өңдеу мәселесін шешу үшін бос жыныстардың кремнийі бар минералдарымен кенді минералдардың аралық өсінділерін ашу жолдарын табу қажет [6-7]. Мәселені шешудің перспективалы жолы – шикізатты химиялық әдістермен ашу және, атап айтқанда, аммоний фторсульфатты кремнийсіздендіру әдісі. Ашудың математикалық моделін құру және процестің оңтайлы шарттарын анықтау мақсатында фторидпен және аммоний сульфатымен біріктіру арқылы барит шикізатын ашу бойынша зерттеулер жүргізілді. Шикізатты ашудың температураға, агломерация уақытына және ашу реагенттерінің шығынына ерекше тәуелділіктері алынған. Жартылай тәуелділіктер негізінде жалпыланған көпфакторлы теңдеу түріндегі агломерация процесінің математикалық моделі алынды, оған сәйкес барит шикізатын ашудың оңтайлы шарттары анықталды. Барит шикізатын фторсульфат аммонийді ашу схемасы әзірленді.*

Кілт сөздер: *техногендік қалдықтар, үйінділік қалдықтар, байыту, сілтісіздендіру, кремнийсіздендіру, бариттік шикізат, шикізатты ашу, кремнийлі минералдар.*

Исследование влияния условий спекания на вскрытие баритового сырья

[1]****ТУРЕБЕКОВА Каракат Сериковна,** докторант, kakosh-94@mail.ru,*
[2]***КАТКЕЕВА Гульнара Летаевна,** к.т.н., доцент, зав. лабораторией, katkeeva@mail.ru,*
[1]***СУЛТАНГАЗИЕВ Руслан Бауржанович,** PhD, и.о. доцента, sulrus83@mail.ru,*
[2]***ОСКЕМБЕКОВ Ильяс Маликович,** старший научный сотрудник, ilyasosk@mail.ru,*
[2]***ГИЗАТУЛЛИНА Дилара Рафаиловна,** младший научный сотрудник, dilurin@mail.ru,*
[1]НАО «Карагандинский технический университет имени Абылкаса Сагинова», Казахстан, Караганда, пр. Н. Назарбаева, 56,
[2]Химико-металлургический институт имени Ж. Абишева, Казахстан, Караганда, ул. Ермекова, 63,
**автор-корреспондент.*

***Аннотация.** Объектом работ являются баритсодержащие техногенные отходы, к которым относятся отвальные хвосты Карагайлинской обогатительной фабрики, складированные в хвостохранилищах и образованные при флотационном обогащении барито-полиметаллических руд Карагайлинского месторождения [1-2]. Эти хвостохранилища занимают огромную территорию и являются источниками загрязнения почвы, воздушного и водного бассейнов тяжелыми металлами, баритовой пылью. Данные отходы до сих пор не перерабатывают ввиду отсутствия эффективной технологии, позволяющей рентабельно получать качественные товарные продукты. Проблема переработки баритсодержащих отходов состоит в сложном минералогическом составе, что обусловливает неэффективность применения традиционных методов переработки – кислотного выщелачивания и флотации [3-5]. Для решения проблемы переработки данного вида сырья необходимо изыскание способов раскрытия сростков рудных минералов с кремнийсодержащими минералами пустой породы [6-7]. Перспективным решением проблемы является вскрытие сырья химическими методами и, в частности, методом фторо-сульфатоаммонийного обескремнивания. Проведены исследования вскрытия баритового сырья спеканием с фторидом и сульфатом аммония с целью построения математической модели вскрытия и определения оптимальных условий проведения процесса. Получены частные зависимости вскрытия сырья от температуры, времени спекания и расхода вскрывающих реагентов. На основании частных зависимостей получена математическая модель процесса спекания в виде обобщенного многофакторного уравнения, по которому определены оптимальные условия вскрытия баритового сырья. Разработана схема фторо-сульфатоаммонийного вскрытия баритового сырья.*

***Ключевые слова:** техногенное отходы, отвальные хвосты, обогащение, выщелачивание, обескремнивание, баритовое сырье, вскрытие сырья, кремнийсодержащие минералы.*

REFERENCES

1. Miroshnichenko L.A. On the skarns of Central Kazakhstan // Izv. AN KazSSR. Ser. geol. – 1955. – No. 20. – Pp. 75-79.
2. Yanulova M.K. About lemontite of the Karagaily deposit in Kazakhstan // Zap. All-Union. mineral. ob-va. Second series. – 1956. – Ch. 85. – Pp. 424-428.
3. Yanulova M.K. Mineralogy of the skarn-barite-polymetallic deposit of Karagaily. – Alma-Ata: ANKazSSR, 1962. – V. 1. – 243 p.
4. Enikeeva G.N. Hypogenic mineralization of polymetallic deposits in Central Kazakhstan // Tr. VSEGEI. – 1959. – T. 23. – Pp. 345-359.
5. Fursova M.Z. Mineralogy of the oxidation zone of the skarn-barite-polymetallic deposit Karagaily // Tr. IGN AN KazSSR. – 1966. – T. 15. – Pp. 196-201.
6. Kopylova N.V., Shketova L.E., Seleznev A.N. Development of technology for non-ferrous metals from the waste of concentrating factories using bio- and geotechnology methods // Proceedings of the international meeting «Progressive methods of enrichment and complex processing of natural and mineral raw materials». Plaksinsky readings, September 16-19, 2014. – Almaty, 2014. – Pp. 384-385.
7. S.G. Seleznev, A.V. Svetlov, D.V. Makarov, and V.A. Masloboev, Tech. Possibilities of extracting non-ferrous metals from technogenic deposits of the Murmansk region // Ibid. – Almaty, 2014. – Pp. 370-372.
8. Malyshev V.P. Probabilistic-deterministic planning of experiment. – Alma-Ata: Science, 1981. – 116 p.
9. Malyshev V.P. Mathematical planning of metallurgical and chemical experiment. – Alma-Ata: Science, 1977. – 37 p.
10. Turebekova K.S., Sultangaziyev R.B., Morozov Yu.P. Development of a scheme for fluoro-ammonium sulphate opening of raw materials // Proceedings of the International scientific and practical online conference «Integration of science, education and production – the basis for the implementation of the Plan of the Nation» (Saginovsky Readings No. 12) // June 18-19, 2020. – Karaganda, 2020. – Pp. 135-138.