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Д.В. Сокольский атындағы «Жанармай,
катализ және электрохимия институты» АҚ

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
АО «Институт топлива, катализа и
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Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Химия және технология сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Химия және технология сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді химиялық ғылымдар бойынша контентке адалдығымызды білдіреді.

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«ҚР ҰҒА Хабарлары. Химия және технология сериясы».

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STUDY OF GOLD EXTRACTION FROM STALE TAILINGS BY AGITATION LEACHING

Abstract. The object of research is technogenic mineral formations-tailings of the Bestube processing plant located within the Bestube gold field. Analytical and technological studies of stale tailings have been carried out. According to the results of analytical studies, the material composition of stale tails was established. The average gold content in stale tailings according to assay analyses is 0.565 g/t, silver 1.56 g/t. The tailings belong to the category of poor sulfide, oxidized raw materials. The main industrially valuable component in the tailings is gold, silver has a subordinate value, and other metals are not of industrial value. Mineralogical analysis established that stale tails are represented by quartz, muscovite, clinochlore, albite, dolomite. Studies were conducted on agitation leaching of stale tailings of the initial size (64.08% of the class –0.074 mm) and after additional grinding to the size of 90% of the class –0.074 mm. Reducing the size contributes to the dissolution of gold from the tailings: at the initial size, 66.28% of gold is dissolved, after regrinding the degree of dissolution of gold from the tailings increases to 87.23%. The results of research on agitation leaching of gold have shown a high efficiency of hydrometallurgical technology for processing stale tailings of a processing plant.

Key words: stale tailings, stale tailings of the processing plant, leaching, technogenic mineral formations, gold.

Introduction. Given the limited nature of almost all types of natural resources and the significant depletion of the mineral resource base, waste from the extraction and processing of mineral raw materials, stored for a long time, as well as current and replenished, are not only the main environmental pollutants, but also inevitably become a potential raw material base for production ferrous, non-ferrous, precious, rare metals and other by-products [1-3]. Consequently, the development of technologies for the integrated development of tailings storage facilities is an urgent scientific and technical task, the solution of which will significantly expand the raw material base of enterprises, and will increase the effectiveness and rationality of subsoil use. In addition, the need to involve tailing dumps in the secondary development is due to a number of environmental problems, the solution of which will improve the situation in the region and ecology [4,5].

It is known that cyanidation is the most common process for extracting gold from low-grade ores. This process is based on the selective leaching of gold or other precious metal with aqueous solutions of sodium, potassium or calcium cyanides. The resulting solution, containing dissolved gold is sent for processing by various methods to obtain a high-quality commercial product in the form of a Dore alloy in ingots. The resulting alloy is sent to the refining plant for the production of gold of the required degree of purity [6-11].

Leaching gold with alkaline cyanide solutions in the presence of oxygen or air is a widely used process for extracting gold from mineral raw materials. In this case, gold is oxidized and dissolved in the

presence of cyanide with the formation of a complex ion $[Au(CN)_2]^-$ according to the Bodlander's (1) and (2) and Elsner's (3) equation, the latter is the sum of equations (1) and (2) [12,13]:

$$2Au + 4CN^- + O_2 + 2H_2O \rightarrow 2Au(CN)_2^- + 2OH^- + H_2O_2, \quad (1)$$

$$2Au + 4CN^- + H_2O_2 \rightarrow 2Au(CN)_2^- + 2OH^-, \quad (2)$$

$$4Au + 8CN^- + O_2 + 2H_2O \rightarrow 4Au(CN)_2^- + 4OH^-. \quad (3)$$

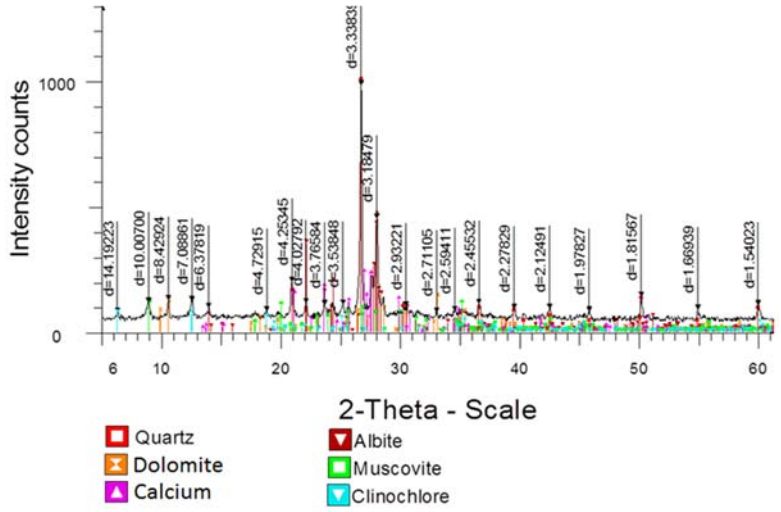
In this work, we studied the indicators of agitation leaching of gold from stale tailings of the processing plant.

Object and method of research. The object of research is technogenic mineral formations-tailings of the Bestube processing plant located within the Bestube gold field. The technogenic mineral formations of the Bestube processing plant began to form in 1935. The tailings of ore processing using amalgamation and gravity technology were sent to storage, then the tailings of ore processing using gravity-flotation technology were sent to storage. The reserves of the old tailing dump are about 500 thousand tons. There were no detailed studies on the data of stale tails. According to the results of assay-gravimetric analysis, the average gold content in stale tailings is 0.565 g/t, silver 1.56 g/t [14,15].

The chemical composition of stale tailings, %: Cu – 0.004, Ni – 0.01, Co – 0.001, Zn – 0.008, Pb – 0.02, Fe – 3.77, CaO – 4.06, MnO – 3.20, Na_2O – 0.72, K_2O – 2.80, SiO_2 – 57.88, Al_2O_3 – 11.52, As – 0.17, C(total) – 2.59, C(organic) – 0.61, C(carbonate) – 1.98, S(total) – 0.80, S(sulfate) – 0.04, S(sulfide) – 0.76. The tailings belong to the category of poor sulfide, oxidized raw materials [15].

X-ray diffractometric analysis of average samples was performed using a DRON-4 diffractometer with Cu - radiation, β - filter. Conditions for recording diffraction patterns: U = 35 kV; I = 20 mA; shooting θ-2θ; detector 2 degree/min.

The identification of mineral phases according to the data of X-ray diffractometric analysis is shown in the diffractogram in figure. The results of the mineralogical analysis of stale tailings are presented in table 1.



Diffraction pattern of stale tails

Table 1 – Results of mineralogical analysis of stale tailings

Components	Formula	Percentage, %
Quartz	SiO_2	33.4
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_{20,5}$	32.9
Albite	$Na\ Al_2\ Si_3O_8$	2.2
Clinochlore	$(Mg,Fe)_6(Si,Al)_4O_{10}(OH)_8$	8.8
Calcium	$CaCO_3$	1.5
Dolomite	$CaMg(CO_3)_2$	4.2
X-ray amorphous phase	–	16.9

From in table 1 it is seen that stale tails is represented by quartz, muscovite, clinochlore, albite, dolomite.

The sieve characteristics of the tailings sample and the distribution of gold by size class are shown in table 2.

Table 2 – The sieve characteristics of the tailings sample and the distribution of gold by size classes

Tailings size class, mm	Yield		Gold content, g/t	Gold amount, g/t	Gold distribution, %
	g	%			
+0.074	1760	35.92	0.84	0.302	48.02
–0.074+0.036	810	16.53	0.48	0.079	12.63
–0.036	2330	47.55	0.52	0.247	39.35
Tailings	4900	100.00	0.628	0.628	100.00

From the data in table 2 it follows that the yield of the granular fraction (+0.074 mm) is 35.92%, and the yield of the sludge fraction (–0.036 mm) in the tailings is 47.55%. There is an increased gold content (0.84 g/t) in the size class +0.074 mm. In the size class –0.074+0.036 mm and in the size class –0.036 mm, the gold content is approximately the same (0.48 g/t and 0.52 g/t, respectively) [15].

The average estimated gold content in the tailings is 0.628 g/t and is in good agreement with the results of direct assay analyzes.

The four tests were conducted for agitation leaching of stale tailings of the initial size and crushed to a size of 90% of the class –0.074 mm. Modes of carrying out the leaching was as follows: Solid:Liquid =1:2, the pH of the pulp due to the addition of lime is 10-11, the initial concentration of NaCN is 0.1 %, the speed of rotation of the agitator is 30 rpm, the leaching time is 24 hours. The mass of stale tails for each experiment is 300 g. During the leaching process, the concentration of sodium cyanide and the pH of the medium were monitored, and reagents were added if necessary.

At the end of leaching, the solution was separated and analyzed for the content of gold and the main accompanying elements-silver, copper and zinc by atomic absorption method. The solid phase was washed with water, dried, and analyzed for gold content.

Results and discussion. According to the results of assay, chemical and mineralogical analyses, only gold is an industrially valuable component. Other metals, due to their low content, are not of industrial value.

The results of agitation leaching of gold from stale tailings are presented in table 3.

Table 3 – Indicators of agitation leaching of gold from stale tailings

Name of leaching parameters and indicators	Original particle size of tailings		Particle size of 90% of class –0,074 mm	
	Test №1	Test №2	Test №1	Test №2
Content in the liquid phase of the pulp after 24 hours, mg/L:				
Au	0.29	0.28	0.38	0.37
Ag	0.26	0.12	0.16	0.11
Cu	3.76	3.78	7.48	6.64
Zn	4.89	5.45	5.01	4.30
pH (units)	10.68	10.68	10.59	10.72
Gold content in the solid phase of cyanidation tailings, g/t	0.28	0.30	0.12	0.10
Estimated gold content in the initial stale tailings, g/t	0.86	0.86	0.88	0.84
Degree of dissolution of gold from stale tailings, %	67.44	65.12	86.36	88.10

From the data in table 3, it follows that the degree of dissolution of gold from stale tailings of the initial size is 65.12-67.44%, from regrinding (particle size of 90% of class –0,074 mm) stale tailings 86.36-88.10%. The gold content in the solid phase after cyanidation is 0.28-0.30 g/t and 0.10-0.12 g/t, respectively. Thus, additional grinding of stale tailings has a positive effect on leaching.

Conclusion. Studies on agitation leaching of stale tailings have shown that a decrease in size contributes to the dissolution of gold from the tailings: with the initial size, on average 66.28% of gold dissolves, after regrinding the degree of dissolution of gold from the tailings increases to 87.23%. The results of research on agitation leaching of gold have shown a high efficiency of hydrometallurgical technology for processing stale tailings of a processing plant.

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АГИТАЦИЯЛЫҚ ШАЙМАЛАУ ӘДІСІ АРҚЫЛЫ ЕСКІ ҚАЛДЫҚТАН АЛТЫН АЛУДЫ ЗЕРТТЕУ

Аннотация. Зерттеу нысаны ретінде техногенді минералдық түзілімдер – Бестөбе алтын кен орны шегінде орналас-қан Бестөбе байыту фабрикасының қалдықтары алынды. Ескі қалдықтарға аналитикалық және технологиялық зерттеулер жүргізілді. Аналитикалық зерттеу нәтижелері бойынша ескі қалдықтардың материалдық құрамы анықталды. Талдау бойынша ескі қалдықтардағы алтынның орташа мөлшері 0,565 г/т, күміс 1,56 г/т құрайды. Қалдықтар аз сульфидті, тотыққан шикізат болып жіктеледі. Химиялық және минералогиялық анализ нәтижелері бойынша құрамындағы өнеркәсіптік құнды компонент алтын ғана болып саналады. Қалған металдардың өндірістік маңызы жоқ. Минералогиялық талдау нәтижесінде ескі қалдықтар кварц, мусковит, кинохлор, альбит, доломит минералдары негізінде ұсынылған. Зерттеулер бастапқы мөлшердегі (64,08% -0,074 ММ кластан) ескірген қалдықтарды үгіту арқылы және 90% -0,074 мм кластан кейін жүргізілді. Мөлшердің азаюы алтынның қалдықтардан еруіне ықпал етеді: бастапқы мөлшерде алтынның 66,28% ериді, қайта өңдеуден кейін алтынның құйрықтардан еру дәрежесі 87,23% дейін артады. Алтынды үгіттік шаймалау жөніндегі зерттеулердің нәтижелері байыту фабрикасының ескірген қалдықтарын қайта өңдеудің гидрометаллургиялық технологиясының жоғары тиімділігін көрсетті.

Түйін сөздер: ескі қалдықтар, байыту фабрикасының ескі қалдықтары, шаймалау, техногенді минералдық түзілімдер, алтын.

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ИЗУЧЕНИЕ ИЗВЛЕЧЕНИЯ ЗОЛОТА ИЗ ЛЕЖАЛЫХ ХВОСТОВ МЕТОДОМ АГИТАЦИОННОГО ВЫЩЕЛАЧИВАНИЯ

Аннотация. Объектом исследования являются техногенные минеральные образования-хвосты обогатительной фабрики "Бестубе", расположенные в пределах золоторудного месторождения "Бестубе". Проведены аналитические и технологические исследования залежных хвостов. По результатам аналитических исследований установлен вещественный состав несвежих хвостов. Среднее содержание золота в несвежих хвостах по данным пробирных анализов составляет 0,565 г/т, серебра - 1,56 г/т. Хвосты относятся к кате-

гории бедного сульфидного, окисленного сырья. Основным промышленно ценным компонентом в хвостах является золото, серебро имеет второстепенное значение, а другие металлы не имеют промышленной ценности. Минералогическим анализом установлено, что несвежие хвосты представлены кварцем, мусковитом, клинохлором, альбитом, доломитом. Исследования проводились на агитационном выщелачивании несвежих хвостов исходного размера (64,08% от класса -0,074 мм) и после дополнительного измельчения до размера 90% от класса -0,074 мм. Уменьшение размера способствует растворению золота из хвостов: при первоначальном размере растворяется 66,28% золота, после перешлифовки степень растворения золота из хвостов возрастает до 87,23%. Результаты исследований по агитационному выщелачиванию золота показали высокую эффективность гидрометаллургической технологии переработки несвежих хвостов обогатительной фабрики.

Ключевые слова: лежалые хвосты, лежалые хвосты обогатительной фабрики, выщелачивание, техногенные минеральные образования, золото.

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