A. K. KOIZHANOVA, B. K. KENZHALIYEV, D. R. MAGOMEDOV, E. M. KAMALOV, M. B. ERDENOVA, N. N. ABDYLDAEV

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A STUDY OF THE BIOHYDROMETALLURGICAL METHOD FOR EXTRACTING GOLD FROM FLOTATION TAILINGS

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This paper shows the results of the comparative study of efficiency of gold extraction methods from technogenic flotation tails by agitation cyanidation and biooxidation followed by leaching. A representative sample of flotation tails was taken at gold extraction plant of Altyntau Kokshetau LLP.

Experimentally, an increase in the efficiency of leaching gold from flotation tails during preliminary bacterial oxidation was found. By biochemical leaching, 72 % was extracted, which is 7 % more than using expensive sodium peroxide and 10 % more than using the traditional method of cyanidation.

Key words: gold hydrometallurgy, flotation tails, extraction, bio-leaching, research

INTRODUCTION

One of the most important areas of overcoming the technical and economic problems of the gold mining industry is the abandonment of outdated technology, designed for the practically disappeared category of large gold. It is necessary to move to new high-tech processes and devices, a new environmentally friendly technology that ensures the extraction of very thin classes of precious metals [1–4].

In recent years, researchers have paid attention to the development of new methods that can be competitive and effective in terms of mining precious metals. Currently, the use of achievements in the field of biotechnology, methods of bioleaching and bio-opening, in the process of which industrially valuable strains of microorganisms are used for bio-extraction of gold and associated metals from technogenic raw materials, it is the most acceptable and less expensive [5-8].

Therefore, research aimed at improving the efficiency of gold extraction from technogenic mineral raw materials is not only of scientific and practical, but also of social and environmental importance.

In concerning with this depletion of gold ore deposits in Kazakhstan, the extraction of gold from the tailings and dumps of gold recovery factories becomes relevant. The technology for processing ore raw materials with a low content of precious metals should be inexpensive, ensure a sufficiently high degree and complexity of their extraction, and provide for effective measures to protect the environment.

A characteristic feature of the sample under study, as gold-bearing raw materials, is the low content in them of the main valuable component. Extraction of gold in industry is carried out in the ore preparation cycle (crushing, grinding), during the enrichment processes (gravity, flotation). Often, even ultra-fine grinding of the material does not allow to achieve the necessary degree of opening, since the gold-bearing raw materials are very diverse in their material composition and gold content forms, it is needed an individual technology for each specific case in their processing.

TEST AND ANALYSIS

The phase and chemical composition of the content of the main components of the sample was studied using a complex of modern physico-chemical methods of analysis, including the following types: atomic absorption spectrophotometric analysis, X-ray phase, X-ray fluorescence (elemental, semi-quantitative), electron microscopic. To perform assay, chemical, X-ray fluorescence, mineralogical, X-ray spectral analyzes, private samples with a particle size of 90% of -0,074 mm were selected.

The estimated gold content in the sample according to chemical analysis is given in Table 1.

It has been established that the sample of flotation tailings that was get averaged and crushed to a particle size of 0,074 mm contains Au — 0,65 g/t and Ag — 1,02 g/t.

Currently, the study of the mineral composition of gold-bearing ores, as well as the forms in which are found precious metals, is not without mineralogical

B. K. Kenzhaliyev, A. K. Koizhanova, D. R. Magomedov, E. M. Kamalov, M. B. Erdenova, N. N. Abdyldaev, Satbayev University, JSC "Institute of Metallurgy and Ore Beneficiation", Almaty, Republic of Kazakhstan, E-mail: bagdaulet_k@satbayev.university, a.koizhanova@satbayev.university, d.magomedov@stud.satbayev.university.

Table 1 **The chemical composition of samples flotation tailings**

Components	Content
Gold (Au) fire assay (tigel smelting)	0,65 g/t
Gold (Au) atomic absorption analysis	0,63 g/t
Silver (Ag) atomic absorption analysis	1,02 g/t
Iron (Fe) atomic absorption analysis	2,16 %
Zinc (Zn) atomic absorption analysis	0,003 %
Lead (Pb) atomic absorption analysis	0,003 %
Copper (Cu) atomic absorption analysis	0,002 %
Arsenic (As) atomic absorption analysis	0,15 %

analysis based on modern research methods. Of the rock-forming minerals, quartz, feldspars, less often mica are noted. Associated ore components are presented in Table 2.

Table 2 **Characteristics of the dimensions and prevalence of the main components**

List of main components	Formula of mineral	% of the studied minerals	Sizes, mkm/ mkm^2
Quartz	SiO_2	46	5-150
Magnetite Mgt	$FeFe_2O_4$	35	8-10
Marcasite	FeS_2	10	10-30
Pyrite Py	FeS_2	9	5 -20
Arsenopyrite Ars	FeAsS	rare	20-27
Hematite Hem	αFe_2O_3	rare	18-27
Bismuthin	Bi_2S_3	rare	2 -5
Gold Au	Au	rare	1,2-8,2
Total:		100	

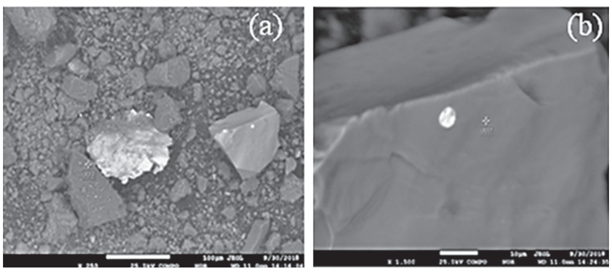
The elemental composition and presence of gold has been studied using scanning electron microscope - roentgen spectral micro analyzer (SEM-RSMA). It is known that scanning electron microscopy allows one to study directly the surface of materials and to obtain, with comparatively high resolution, both qualitative and quantitative information on the chemical composition of the object in conjunction with the surface topography. An electron probe microscope with energy dispersive (EDX) and wave dispersive (WDX) analyzers is used to analyze the elemental composition. The results of topographic images of the scanning microscope are shown in Figure 1.

In the sample under study, elements such as silicon, oxygen are largely present, and when focused on individual fragments, iron, sulfur, and gold are noted. Thus, with an increase in resolution of 1500 times in the residual fragments of sulfide minerals, the spectra of gold associated with pyrite were recorded.

Based on data from analytical studies, it can be seen that gold in the sample under study is in associations with both quartz and pyrite, and is present in a generally finely dispersed form in intergrowths, which requires a careful approach when choosing a method of extracting gold. The presence of sulphide minerals of marcasite and pyrite is due to the fact that these tailings were obtained in the process of selective flotation, with the use of depressant reagents that reduce the transfer of these minerals to concentrate. In a number of scientific works, the authors considered similar types of raw materials and methods for their processing [9-10].

Determination of the technological parameters of the opening of flotation tailings by biochemical method

Waste of flotation benefication differs from ores and concentrates both in the content of the main components, and in the content of mineral components and nutrient substrates necessary for the full development of the natural microbiocenosis. In this regard, the next stage of research was the study of flotation tails microflora, identifying the main groups of microorganisms among native cultures, isolating individual bacterial cells, isolating active strains for further use in the process of bioleaching gold. When conducting microbiological studies one of the most important tasks is the selection and optimization of nutrient media. When selecting media, it is necessary to take into account not only the components (sources of nitrogen, carbohydrate, protein, amino acids, vitamins) necessary for the growth and accumulation of biomass, but also include the compounds necessary for the optimum growth of some difficultly identifiable groups of microorganisms. Thus, for the isolation of chemolithotrophic and heterotrophic microorganisms, nutrient media were selected from the sample under study, which positively influ-



(a) gold particles in quartz (b) gold particles in pyrite

Figure 1 Energy dispersive spectrometry analysis of the quartz and sulphide parts of the original sample of flotation tailings at SEM-RSMA

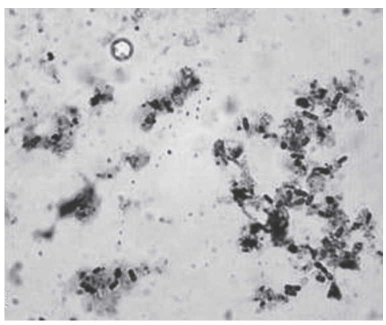


Figure 2 Microflora of flotation tails: photo from leicadmled optical microscope, gram-stained

enced the optimal growth and development of the native microbiota. As can be seen from the Figure 2, the microflora is mainly represented by rod-shaped forms of gram-negative cells, which are arranged in pairs or singly.

Gold leaching experiments

For comparison, the following leaching variants were carried out:

Variant No. 1 - agitation leaching using NaCN 1 g/dm^3, Solid : Liquid ratio = 1:4, t 25 °C, without prior acid washing and bacterial dissection (control variant);

Variant No. 2 - agitation leaching - cyanidation with preliminary acid washing for 3 hours and bacterial dissection with a duration of 120 hours, Solid : Liquid ratio = 1:4, t 25 °C, concentration of cyanide solution 1 g/dm^3, concentration of sulfuric acid wash solution 20 g/dm^3;

Variant No. 3 - agitation leaching with using sodium peroxide 10 g/dm^3 and solution sodium cyanide with a concentration of 1 g/dm^3, Solid : Liquid ratio = 1:4, t 25 °C, with a preliminary acidic washing without bacterial opening;

Variant No. 4 - agitation leaching using NaCN 1 g/dm^3, Solid : Liquid ratio = 1:4, t 25 °C, with prior acid washing.

After filtration, the resulting solution was submitted for chemical analysis to determine the gold content, the cake was subjected to drying and further bacterial dissection (variants No. 1 and No. 2). The experimental results are shown in Table 3.

From the data it can be seen that during normal cyanidation without prior acid washing and bacterial dissection, part of the cyanide is spent on the extraction of accompanying elements, such as copper, iron, arsenic, zinc. It also leads to a decrease in the extraction of the main valuable component - gold. Preliminary acid washing of the sample with subsequent neutralization allows to transfer a significant part of the interfering impurities in the acid solution, which increases the efficiency of further cyanidation. Thus, with conventional cyanidation, gold recovery amounted to 55,1 %, and during cyanidation with preliminary acid washing, it was 60,7 %. The use of sodium peroxide as an additional oxidizing agent, in combination with a preliminary acid washing, made it possible to extract 63,9 %. The use of the bacterial culture of A. Ferrooxidans in the preliminary oxidation of the raw material under study, later on during cyanidation, made it possible to achieve the maximum, compared to other options, gold recovery rate – 73,4 %. As a result of the experiments, a method was developed for the extraction of gold from the flotation tailings, including pretreatment of flotation tailings with sulfuric acid and A. Ferrooxidans bacterial solution for 120 hours, followed by neutralization of the acidic medium and cyanidation.

Table 3 **Extraction of gold and impurities of other elements into solutions with different variants**

Options	Extraction of elements into solution, %				
	Cu	Zn	Fe	As	Au
Solute after acid washing	78,02	5,53	18,43	2,16	0,0
Solute after bacterial dissection	67,39	5,70	92,49	4,68	0,0
Variant 1 (Final productive solute)	82,94	1,73	66,70	14,04	55,1
Variant 2 (Final productive solute)	3,11	0,23	8,84	1,44	73,4
Variant 3 (Final productive solute)	1,06	0,16	6,26	1,33	63,9
Variant 4 (Final productive solute)	1,61	0,28	13,63	0,25	60,7

CONCLUSIONS

In the process of research, the most acceptable biochemical method for treating flotation tailings was established - including preliminary acid washing, subsequent bacterial oxidation, neutralization, and cyanidation. The degree of extraction of gold from the flotation tailings during biochemical leaching reached 73,4 %, which is 9,5 % more than with the use of a chemical oxidant sodium peroxide. In addition, the bacterial solution is less expensive and non-toxic in comparison with the oxidizing agent - sodium peroxide. Spent biochemical solutions, after measuring the residual living cells of bacteria and their nutrients, can be regenerated and reused. Also, with the accumulation of sufficient concentrations of non-ferrous metals in waste solutions after acid washing, their further processing by hydrometallurgical technologies for producing copper and zinc is possible.

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