

Study Of Gravity Separation Enrichment And Material Composition Of Stockpiled Technogenic Waste From The Marjanbulak Gold Extraction Plant

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Abstract: Laboratory studies were conducted, the purpose of which was to study the material composition of the lying tailings of the Marjanbulak Gold Extraction Workshop (MZITS). The material composition of the sample was analyzed by spectral, chemical, atomic-absorption, test, mineralogical, rational, granulometric, and other analysis methods. According to the results of chemical analyses, the average gold content in the sample was 0.61 U.U. and silver 11.61 U.U. The technological sample of tailings belongs to the mixed (oxidized and sulfide-quartz) type. Valuable components of tailings are gold and silver. Characteristic features of gold, influencing the technology of enrichment: the form of gold occurrence is native and in the form of electrum in goethite (oxidized part). Perhaps the isolated native gold is found in quartz, and in In sulfides, it is invisible; in terms of reflectivity, gold is medium and low-grade. The main non-metallic minerals are quartz, feldspars, carbonates, sericite, and chlorites. Accessory minerals include apatite, rutile+ilmenite, and epidote. A factor negatively impacting tail enrichment is the high content of micas - sericite (37%) and clay substances (7%). In terms of characteristic properties, quality, as well as the quantity of ore minerals and noble metals, the waste from processing is significantly inferior to the initial ore, which complicates the waste enrichment process and predetermines low technological indicators. According to the results of a rational analysis, the content of "non-extractable" gold in quartz, aluminosilicates, and other acid-insoluble minerals in the initial tailings is 32.79% and bound by sulfides 26.23%.

Keywords: Gold, silver, element, valuable component, technogenic waste, secondary waste, spectral, complete chemical, optical emission spectral, mineral.

Introduction: Entrance: and over the past decades, there has been a steady increase in global gold prices. Especially during periods of political and economic uncertainty, gold is considered a reliable and attractive

investment. For this reason, involving refractory gold-bearing ores, as well as technogenic deposits, in processing is a promising direction for the development of the gold mining industry. In this regard, the need for

the development and industrial implementation of technologies for this type of raw material will remain high. The technology and equipment used must not only ensure high process efficiency and maximum possible extraction indicators of the valuable metal from the raw material, but also exclude exceeding the maximum permissible emissions of harmful substances into the environment, i.e., comply with the requirements and norms for environmental protection, operating at the work site and outside it. [13].

The current interest in technogenic mineral formations and, in particular, in technogenic gold formations as secondary metal concentrators is obvious, but the problems and difficulties of involving technogenic resources in industrial development are also evident. Technogenic gold-bearing objects among other types of mineral extraction and processing waste are the most valuable, in-demand, investment-attractive, and most prepared for recycling.

As a result, the technological properties of technogenic gold will have significant differences compared to the properties of gold in primary ores and placer deposits. Such differences as an increase in the proportion of free gold, an increase in the proportion of gold in isometric-plate, rolled, and semi-rolled forms, the concentration of metal as a result of its deposition from solutions on geochemical barriers, as well as an increase in gold content in the local volumetric areas of the tailings pond, will be favorable factors for the extraction of gold from the lying tailings. However, the combined technological properties of technogenic gold predetermine the low processing rates of waste using traditional gravitational processes, flotation, and cyanidation. [14].

In recent decades, there has been a reduction in geological exploration of deposits in the gold mining industry, a shortage of high-quality raw materials due to a sharp decrease in readily available gold reserves in primary ores and placer deposits, and the depletion of reserve reserves of the ore base as a whole, which negatively affects the volume of gold and silver production. Currently, there is a large amount of technogenic and secondary waste containing gold and silver. Each type of such raw material requires a specific approach to extracting precious metals due to the peculiarities of the material composition and the form in which gold is present.

Интенсивное развитие золотодобывающей промышленности в предыдущие десятилетия привело к накоплению больших объемов техногенных отвалов, в которых содержится 0,5-2,3 у/е золота. Недоизвлечение ценных компонентов объясняется несовершенством технологий извлечения золота из рудного сырья, таких как гравитация, амальгамация, перколяция. Некоторые

хвостохранилища в настоящее время можно рассматривать как отдельные месторождения [1]. Several types of technogenic and secondary raw materials have been identified, which are produced by four main complexes: mining and processing, metallurgical, household, and energy. They are conventionally divided into three large groups: enrichment, hydrometallurgical (chemical action), and pyrometallurgical (thermal action). Hydrometallurgical methods (particularly cyanidation) are most actively used, as they yield high gold recovery rates of 80-99%. In turn, such methods often have a negative impact on the environment, they are quite costly, time-consuming, and have low extraction rates of micro- and ultradisperse gold, the share of which is significant, especially in the waste of mining and metallurgical complexes. Enrichment methods, in turn, show the effectiveness of extracting fine gold from mining and processing complex waste [2].

The development of mining led to the formation of large volumes of extraction and processing, followed by the accumulation of waste: waste rock, poor ores, tailings, etc. The storage of production waste in mining enterprises, the volume of which is increasing every year, occupies vast territories. This leads not only to the disappearance of landscapes, but also to the pollution of the environment. The basis of modern gold hydrometallurgy is the cyanide process, which is extremely widespread in domestic and foreign industry. In practice, there is not a single enterprise in the world that operates on the production of commercial metal and does not undergo the stage of cyanidation of ore or its processed products [3]. Due to the depletion of placer gold and silver deposits, modern and highly efficient extraction technologies are necessary for processing raw materials with low content of valuable components and complex composition [10].

Developing and mastering the technology for extracting gold from accumulated technogenic mineral objects, primarily from tailings, waste, and water of gold extraction plants and production facilities, is becoming increasingly relevant for many gold mining enterprises where the raw material reserves of conditioned ores are close to depletion. [15].

Currently, the reserves of gold-bearing ores in the Marjanbulak ore field are practically depleted, with the volume of lying tailings in the No. 1 MGEP tailings storage facility, accumulated between 1980 and 2017, amounting to about 20 million tons. These technogenic wastes can be considered as a raw material resource for the Marjanbulak gold extraction plant in the near future. To involve MSIC waste in processing, it is necessary to develop a rational and comprehensive technology for extracting gold for its processing under

MGEP conditions.

Ore preparation is the initial and important stage in the technology of processing gold-bearing raw materials and gold-bearing technogenic waste. Ore preparation includes sieving, crushing, grinding, and classification operations. In laboratory studies, the mixing operation, necessary for obtaining a representative sample of the studied material, is added to the above-mentioned operations, which is not insignificant, since gold is unevenly distributed in the ore raw material.

The material composition of the MGEP waste sample was studied using spectral, chemical, test, rational, opto-emission spectral, mineralogical, and other types of analyses. When conducting research, the processes of selection, sampling, processing, and preparation of samples, as well as the setting and interpretation of the conducted experiments, are among the important moments from which further research results depend.

The preparation of a representative sample of technogenic gold-containing tailings from MGEP s was carried out using the manual sampling method, which consists of the following stages: sampling, averaging it using the "ring and cone" method, and quartzization [4]. Despite significant research on increasing the efficiency of gold extraction, the flotation extraction of finely dispersed gold associated with sulfides and quartz does not exceed 60-80%, and in some cases 30-40%. Thus, research on increasing the extraction of noble metals from mineral raw materials is a pressing task.

Spectral analysis

The semi-quantitative spectral analysis was performed in the laboratory of the Ministry of Health of the Republic of Uzbekistan, the results of which are presented in Table. 1.

Table 1
Results of spectral analysis of the average tail sample

Name of elements	Quantity, 10 ⁻³ %	Name of elements	Quantity, 10 ⁻³ %	Name of elements	Quantity, 10 ⁻³ %
Ba	30	Ni	2	Mn	100
Be	0,7	Sn	0,7	Cu	20
V	100	Pb	100	Mo	5
Bi	<0,2	Ag	10	As	<1,1
W	7	Sb	30	Nb	5
Ga	3	Ti	700	Ta	10
Ge	1	Cr	100	Li	<3
Cd	<0,1	Zn	100	Au	0,07
Co	5				

Complete chemical analysis

Complete chemical analysis was performed in the laboratory of the Ministry of Higher and Secondary Specialized Education of the Republic of Uzbekistan. The results of which are presented in the State Unitary Enterprise "IMR" Table. 2.

Table 2
Chemical analysis results of the average waste sample

Name of elements	Quantity, %	Name of elements	Quantity, %	Name of elements	Quantity, %
SiO ₂	65,7	Na ₂ O	0,46	Al ₂ O ₃	14,2
Fe ₂ O ₃	9	K ₂ O	2,96	CaO	1,95
FeO	2,27	S _{COM.}	2,04	MgO	1,60
TiO ₂	0,59	SO ₃	2,32	H ₂ O	0,16
MnO	0,09	S	1,11	M.L.P.	4,58
CO ₂	3,74				

Optical emission spectral analysis

Table 3
Results of optical emission spectral analysis of the initial tailings

№	Elements	Quantity, u/c	№	Elements	Quantity, u/c	№	Elements	Quantity, u/c
1	Ag	3,42	21	Na	8290	31	Fe	48300
2	Al	65600	22	Nb	14,1	32	Gd	19,9
3	As	546	23	Nd	26,4	33	Ga	19,9
4	Au	0,663	24	Ni	51,2	34	Hf	1,85
5	Ba	914	25	P	503	35	Ho	0,527
6	Be	2,39	26	Pb	13,3	36	In	0,221
7	Bi	1,64	27	Pr	6,15	37	K	28700
8	Ca	5090	28	Rb	63,5	38	La	28,8
9	Cd	0,1	29	S	19900	39	Li	15,5
10	Ce	62,5	30	Sb	0,674	40	Lu	0,323
11	Co	17,2	31	Sc	12,5	41	Mg	6550
12	Cr	178	32	Se	12,5	42	Mn	743
13	Cs	7,95	33	Sm	4,19	43	Mo	22,9
14	Cu	24,3	34	Sn	4,96	44	Te	0,129
15	Dy	3,44	35	Sr	152	45	Th	9,2
16	Er	2,61	36	Ta	0,375	46	Ti	3220
17	Eu	1,04	37	Tb	0,1	47	Tl	0,469
18	Tm	0,292	38	W	3,1	48	Zn	265
19	U	3,68	39	Y	18,4	49	Zr	86,2
20	V	148	40	Yb	2,1	50	ΣREE	169,2

According to the results of the optical emission spectral analysis of the initial tailings, the content of rare earth elements (RZE) was 169.2 units/ha, the main part of which belongs to the light RZE group. Industry requirements for rare earth raw materials have fundamentally changed over the past 10 years. If until the beginning of the 90s, more than 90% of CMRs were used as mixed compounds, then in the last decade, the demand for individual CMRs and their oxides grew most intensively. Currently, the share of individual RZ products is about 30% in volume and more than 70% in value. At the same time, global demand for SMEs increased 1.7 times in the 1990s, reaching 79 thousand tons of SMEs in 2000, while demand for individual rare earth elements increased from 5 to 9 times during the same period [9].

Rational analysis of gold and silver

The forms of precious metals in the ore sample were studied using a rational analysis, which was carried out according to the standard methodology based on the sequential leaching of the ground sample (size 85% cl. - 0.074 mm) with a cyanide solution after preliminary freeing of gold and silver from association with other ore and rock-forming components. The analysis scheme included the following operations: sample cyanidation, alkaline treatment of the I cyanidation tailings followed by another cyanidation, hydrochloric acid treatment of the II cyanidation tailings followed by III cyanidation, nitric acid treatment of the III

cyanidation tailings followed by cyanidation of the insoluble residue. As can be seen from the data in the rational analysis, the content of cyanidated free gold in the tailings sample is 27.87% and silver 32.64%; with minerals and chemical compounds of antimony and arsenic, 0.17% of silver is associated; with carbonates, hydroxides.

iron and manganese are associated with 13.11% gold, 15.16% silver; sulfides (pyrite, arsenopyrite) are associated with 26.23% gold and 26.54% silver; 32.79% of gold and 30.49% of silver are found in quartz, aluminosilicates, and other acid-insoluble minerals. Currently, cyanide leaching is used to extract gold and silver from mineral raw materials after beneficiation. The intensive cyanidation process is based on the use of high concentrations of cyanide, oxidizer (oxygen), and alkali [7].

Mineralogical studies of the lying tailings of the MISC Mineralogical analysis of the initial waste and processed products was carried out using chemical atomic absorption, spectral, rational, and test analyses, based on which a list of minerals from the above-mentioned samples was compiled.

To determine the material composition of the initial tailings and processing products, the behavior of gold and gold-containing sulfides, as well as the main negative factors affecting tailings enrichment, in addition to microscopic observation, the following auxiliary types of research were required. Изучение

минерального состава (рудных и нерудных минералов) продуктов переработки, в том числе:

- изучение продуктов переработки под бинокулярным микроскопом (увеличение 16-56 раз);
- production of polished briquettes;
- study of ore minerals under the "ORTOLUX" ore microscope at a magnification of 100-1250 times. Finding gold nuggets using immersion fluids.

b) Conversion of the silicate chemical analysis of waste processing products into mineral composition, taking into account all the study materials.

c) Photographing polished briquettes of processed products with a digital camera (morphology of minerals and their associations) and obtaining color images. The content of valuable components and harmful impurities in the initial sample of MSIM waste is presented in Table. 7).

Table 4

Content of valuable components in the initial tailings

Sampling Name	Quantity				
	u.c.		%		
	Au	Ag	As	Sb	S _{com.}
Initial tails	0,61	11,61	0,16	0,002	2,04

Mineralogical analysis of initial tailings

Based on the results of mineralogical analysis, ore and non-ore minerals were identified in the initial sample. Ore minerals consist mainly of sulfides, which are replaced by secondary minerals of the oxidation zone, from partial to complete pseudomorphism. It is also the most common mineral containing gold. Gold is often closely related to pyrite as a persistent gold ore, which cannot be extracted by traditional cyanidation. Therefore, to extract gold from pyrite, effective oxidation is necessary. Before leaching, the oxidation of sulfides can expose the packaged gold, increasing the contact area of gold with the gold leaching agent and thus increasing the efficiency of gold leaching [11].

Research on the technological sample for separating particles from the tailings of the Marjanbulak gold extraction plant was conducted on the Knelson MD3 concentrator with different rotor rotations, creating centrifugal force: 50%, 60% and at 60 G (maximum rotor rotation 2340 rpm). The remaining gravity regimes (weight of the sample 10 kg, fluidization water flow rate 2.8-3.0 l/min.) did not change. Three enlarged laboratory experiments with the above parameters were set up.

From the research results, it can be seen that with an increase in rotor speed from 50% to 60G of the maximum rotor speed, gold extraction in a straight-line state increases from 35.3% to 50.1%, and silver extraction decreases from 14.9% to 12.8%. The optimal rotor rotation, at a grinding rate of 70% -0.074mm for gold extraction, is 60G. At this rate, a concentrate with a mass of 764 g (7.64%) was obtained, containing 4 units/l of gold at 50.1% extraction and 19.5 units/l of silver at 12.8% extraction.

To study the form of gold and silver occurrence, the concentrate obtained during enrichment in the concentrator under optimal conditions was subjected to a rational analysis.

Based on the results of a rational analysis of the graviocentrate, the distribution of gold and silver by and the nature of their relationship with ore components were established:

- free cyanide: gold - 51.37%, silver - 58.48%;
- related to minerals and chemical compounds of antimony and arsenic: gold - not found, silver - 8.76%;
- associated with carbonates, iron and manganese hydroxides: gold - 8.23%, silver - 20.62%;
- associated with sulfides (pyrite, arsenopyrite): gold - 35.69%, silver - 9.93%;
- found in quartz, aluminosilicates, and other acid-insoluble minerals (not extracted): gold - 4.71%, silver - 2.21%.

The technological sample of MSIC tailings belongs to the mixed (oxidized and sulfide-quartz) type. Valuable components of tailings are gold and silver.

Characteristic features of gold influencing the beneficiation technology:

gold's occurrence form is native and in the form of electrum in goethite (oxidized part). Perhaps isolated native gold is found in quartz, and in sulfides it is invisible;

- excretory form - isometric, rounded, oval, elongated, lens-shaped, etc.;
- by size, gold belongs mainly to finely dispersed and dust-like classes with a particle size of 0.001-0.05 mm;
- in terms of reflectivity, gold is medium and low-grade.
- no visible gold was found in the initial tail sample.

The main non-metallic minerals are quartz, feldspars, carbonates, sericites, and chlorites. Accessory minerals include apatite, rutile-ilmenite, and epidite.

A factor negatively affecting the enrichment of tailings is the high content of micas - sericite (37%) and clay substances (7%).

In terms of characteristic properties, quality, as well as the amount of ore minerals and noble metals in the waste, processing is significantly inferior to the initial

ore, which complicates the waste enrichment process and predetermines low technological indicators.

According to the results of a rational analysis, the content of "non-extractable" gold in quartz, aluminosilicates, and other acid-insoluble minerals in the initial tailings is 32.79% and bound by sulfides 26.23%.

According to the results of mineralogical analysis, the frequency of occurrence of native gold in tailings is significantly higher than in other processed products. Released gold particles from sulfides, as well as gold particles bound by non-metallic minerals, undergo a cupulation process at high temperatures. In this regard, secondary gold becomes visible and high-quality.

Based on the results of mineralogical studies of MGEP waste processing products, it is recommended to conduct oxidative roasting with air supply to detect "closed" gold in sulfides.

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