Research on modern technologies for processing waste from processing plants

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Abstract: This article examines the challenges and solutions associated with processing technogenic waste generated at mining and beneficiation plants using modern technologies. The study analyzes the significant amount of valuable metals - particularly tungsten - remaining in ore-processing tailings. International experience from the USA, Canada, Portugal, Australia, and other countries is reviewed, focusing on the advantages and limitations of gravity, magnetic, flotation, and combined beneficiation methods. The efficiency of existing technologies is assessed through the example of extracting tungsten from the tailings of the Ingichka processing plant. Based on research findings, scientific and practical recommendations are proposed to improve the technological processes for reprocessing technogenic waste.

Keywords: Tungsten, technogenic waste, beneficiation technology, gravity separation, magnetic separation, flotation, Ingichka mine, reprocessing, ore-processing tailings, environmental safety

In economically developed countries, a significant portion of metals is extracted from production waste, including mining. This share is constantly growing and in some cases exceeds the production of primary raw materials. At the same time, the costs of extracting metals are reduced by 1.5-3 times.

Tailings of mining production, formed during the extraction and processing of ores, lead to the formation of a special class of technogenic formations - a kind of artificial "deposit" created as a result of human activity.

The geological and ecological study of tailings ponds encompasses a wide range of issues related to geology, design and construction, economics, and the technology of their formation. The common solution is to describe and model the processes of formation and interaction of tailings ponds (their constituent elements) with the environment in order to find optimal engineering solutions that have minimal impact on the ecosystem. The choice of such decisions is important both in the regulatory and environmental aspects. [1].

Technological waste from ore beneficiation poses an increased ecological hazard due to its negative impact on the air basin, surface and groundwater, and soil cover across vast territories. However, using them as additional sources of ore-mineral raw materials will significantly reduce the scale of disruption of the geological environment in the region.

Similarly, the storage of ore-enrichment waste and the formation of tailings storage facilities for TMO processing have a negative impact on the environment in several areas: violation and withdrawal of land from economic use; pollution of water sources and disruption of the water balance in the areas where they are created; pollution of the atmosphere and adjacent tailings storage areas with dust particles. [4].

Continuous improvement of mineral raw material processing technology, the application of more progressive methods and techniques, and the selection of optimal technological schemes allow for the economically justified isolation of profitable waste from previously unpromising waste. In addition, technogenic waste occupies vast areas of land, including well-cultivated arable lands, urban areas, and irrigated pastures, altering the natural landscape and forming unique landforms.

Existing methods for extracting tungsten from technogenic waste from the beneficiation of tungsten-containing ores into the scheme usually include the following:

- separation into large and small fractions;
- helical separation followed by obtaining a fine fraction of the tungsten-containing intermediate product;
- release of sulfide-containing material and secondary waste.

In a screw separator, the obtained tungsten-containing intermediate product is purified to obtain a crude tungsten-containing concentrate. At concentration tables, the tungsten-containing concentrate is separated to obtain a tungsten concentrate, which is then subjected to flotation to obtain a high-grade conditional tungsten concentrate and a sulfide-containing product. Further, to obtain secondary waste and a tungsten-containing intermediate product, the tailings of the screw separator and concentrating table are combined and subjected to classification of tungsten-containing ore beneficiation tailings, and the condensed product is subjected to beneficiation in a screw separator. [4].

Further extraction of tungsten from the residual waste is carried out as follows. Gravitational enrichment tails are first finely ground and then degreased in a classifier, and the resulting materials are separated in hydraulic classifiers. After classification, the resulting classes are enriched separately on concentration tables. Then, the coarse-grained tailings are returned to the grinding cycle, and the fine-grained tailings are thickened and re-enriched on concentrating tables to obtain the finished concentrate. After this, the intermediate product, which enters the final grinding stage, and the tailings are sent for flotation. The concentrate of the main flotation is subjected to single purification. The initial material contains from 0.3 to 0.5% WO_3; the extraction of tungsten reaches up to 96%, with about 72% of tungsten extracted by flotation. At the same time, the tungsten content in the flotation concentrate does not exceed 10-12% WO_3 [5].

This technological scheme of gravitational enrichment for processing technogenic waste has several disadvantages - high load at the initial stage of the process on the enrichment operation on concentration tables, multi-operation nature, and low quality of the resulting concentrate.

As noted by the authors Bert P.O. and K. Mills, the following beneficiation methods are used to extract tungsten from tungsten-containing ores and tailings: flotation methods; gravitational methods; electrostatic methods; as well as magnetic, hydrometallurgical, and other methods. For example, for the preliminary concentration of mineral raw materials at the “Mount Carbine” and “King Island” (USA) processing plants, lumometric and photometric sorting are used, at the “Panascuera” (Portugal) and “Hemerdan” (England) plants, heavy medium enrichment, sedimentation, magnetic separation in a weak magnetic field, or high-intensity magnetic separation are employed.

For the processing of tungsten-containing sludge, their flotation is used, in particular, tungstate in the PRC and at the Canadian “Mount Plysad” factory, and at some “Yokberg” (Sweden) and “Mittersil” (Austria) factories, flotation has been completely replaced by gravitational enrichment. However, this technology has not found widespread application in global practice.

Screw separators are widely used in practice to enrich tungsten-containing ores, waste, and sludge.

For example, to extract tungsten from technogenic waste of tungsten ore, the initial waste material, after crushing and grinding to a size of 2-3 mm at the Kazakhstani “Cherdoyak” plant, was enriched in MOD-type sedimentation machines and the lattice product was transferred to a concentration table. According to this scheme, they were also enriched on screw separators, on which the extraction was 76.9% WO_3 with a yield of 25-30% of the enrichment products. When using a screw separator, WO_3 extraction increased from 3 to 4% [4].

Such technological schemes for extracting tungsten from technogenic waste have the following disadvantages, such as high sedimentation load and insignificant yield of beneficiation products due to low WO extraction$_3$.

At the Canadian “Climax Molybdenum” factory, by extracting molybdenum from molybdenite flotation tailings, volfram concentrate is also obtained along the way. Tungsten-containing tailings are divided into two parts - dump slags and cassiterite concentrate using screw separation. The sludge discharge is directed to the dump tailings, and the fraction in the form of sand is directed for the flotation separation of pyrite concentrate containing 55% sulfides (S) and its subsequent discharge into the dump tailings. Using screw separation and cones, the chamber product is cleaned to obtain pyrite-containing tailings and wolframite-cassiterite concentrate, and then they are processed on concentrating tables. As a result, wolframite-cassiterite concentrate and tailings are obtained. The raw concentrate, after dehydration, is sent for purification. After magnetic separation and flotation of phosphates (float removal of monazite from it), the concentrate is dried. The resulting dry concentrate is classified and, after the first stage, separated by stage magnetic separation into concentrate with a WO3 content of 65% and after the second stage, concentrate with a WO3 68%. In addition, a tin (cassiterite) concentrate with a tin content of 35% is obtained, which is a non-magnetic product.

The disadvantages of this method are the complexity and multistage nature of this method, as well as its high energy intensity.

A method for processing scheelite-containing tailings using an improved separation process to remove harmful materials and process ore minerals is also known. The method includes, for the purpose of removing various foreign materials, the stages of homogenizing mixing of scheelite-containing waste, introducing pulp into the reactor, and "filtering" the pulp. In addition, subsequent separation of the pulp by screw separation, condensation, and dehydration of non-metallic minerals to obtain a cake occur. After this, the cake is dried and the dry cake is crushed using a hammer crusher operating in a closed-loop sieve, the crushed minerals are separated using a "micron" separator into fine and coarse grain fractions (granules), and the coarse-grained fraction is magnetically separated to obtain magnetic minerals and a non-magnetic fraction containing scheelite. The multi-operation nature and the use of energy-intensive wet cake drying are the main disadvantages of this method.

On the debris tails of the Ingichka mine, a method for extracting tungsten from them has been applied [4].

The method consists of the following operations:

- pulp preparation and its subsequent deslamation in a hydrocyclone, i.e., removal of the class - 0.052 mm;
- separation of the sludge-free pulp in a cone separator;
- two-stage purification of the cone separator concentrate to obtain a concentrate containing 20.6% $_{WO3}$, with an average extraction of 29.06% $_{WO3}$ on concentrating tables.

The main disadvantages of this method are the low quality of the resulting concentrate and the low extraction of WO_3.

We are familiar with the results of research using gravity enrichment of Ingichka processing plant tailings [24; p.80-83]. The method described by O.S. Artemova in her dissertation "Development of a technology for extracting tungsten from the residual tailings of the Jidin MMC" for extracting tungsten from the residual tailings of the enrichment of tungsten-containing ores is closest to the object under study [5].

The technology for extracting tungsten from old stale tailings includes the following operations:

- operation for obtaining crude tungsten concentrate,
- the operation of obtaining the intermediate product,
- operation for obtaining gold-bearing products and secondary waste.

These operations are carried out using gravitational wet enrichment methods and subsequent refinement of the obtained crude concentrate and intermediate product using gravitational (centrifugal) enrichment and magnetic separation to obtain a conditional tungsten concentrate containing 63% WO_3, with 50% WO_3.

Under this technology, residual waste is subjected to primary classification, releasing 44.5% of its total mass as a +3 mm fraction into secondary waste. Tailings of the -3 mm fraction are separated into -0.5 mm and +0.5 mm classes, and coarse concentrate and tailings are obtained from the +0.5 fraction using screw separation. The remaining tails are divided into -0.1 and +0.1 mm classes. The separated coarse concentrate from the +0.1 mm class using centrifugal separation, like the coarse concentrate from screw separation, is subjected to centrifugal separation, and crude tungsten concentrate and gold-containing product are obtained. The tailings of the screw and centrifugal separation are finely ground to a fraction of -0.1 mm and then divided into classes from -0.1 to +0.02 and -0.02 mm. The -0.02 mm class is removed from the process for secondary waste. The -0.1+0.02 mm class is enriched by centrifugal separation to obtain secondary waste and tungsten intermediate product, and the tungsten intermediate product is sent for finishing by magnetic separation together with finely ground -0.1 mm centrifugal separation concentrate. The resulting magnetic fraction is a tungsten concentrate, while the non-magnetic fraction is an intermediate product. The intermediate product undergoes the II stage of magnetic separation, separating the non-magnetic fraction into secondary waste and tungsten concentrate (magnetic fraction). Subsequently, the tungsten concentrate is enriched by centrifugal and magnetic separation. After this, by centrifugal separation, a conditioned tungsten concentrate with a WO_3 62.7% content is obtained, with a yield of 0.14% and an extraction of 49.9%. Waste from centrifugal separation and the non-magnetic fraction are directed to the secondary dump tailings, and the total yield of the raw tungsten concentrate at the finishing stage, with a WO content of $_3$ - 2.1%, will be 3.28%.

The main disadvantages of this method are the multi-operational nature of the technological process, which includes six classification operations, two finishing operations, as well as five centrifugal operations and three magnetic separation operations using relatively expensive apparatuses. At the same time, the completion of the raw tungsten concentrate is associated with its loss to secondary tailings with a relatively high content of WO_3 - up to 2.1%.

When enriching tungsten ores with WO_3 up to 45%, a scheelite concentrate is obtained, with an extraction rate not exceeding 70-75%. When such concentrates are subsequently processed into calcium volframate products, oxides, or ammonium salts, the extraction yield is not higher than 95%. With existing ore processing technologies, the maximum possible through extraction of tungsten from ores into final products is no more than 70%, and actually 60-65% [26; p. 24-27]. Additionally, their cost and tungsten losses in tailings increase sharply when used to obtain conventional scheelite concentrates before enriching industrial products by steaming and numerous flotation refinings.

Analysis of the conducted research on existing methods for processing trapped waste from the tungsten ore processing and the experience of leading global mining and processing companies shows the reality and relevance of conducting research on improving and developing the technology for processing waste from the mining and processing plants, including the multi-tonnage trapped waste of the Ingichka Mining and Processing Plant.

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