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Bioleaching of copper-zinc concentrates under different conditions

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Motivation and Aim: Substandard copper concentrates do not meet quality standards for pyrometallurgical processing due to the high content of impurities such as zinc, arsenic, and other metals and metalloids. For the processing of this type of raw material, hydrometallurgical technologies are promising, including biohydrometallurgical technologies, which make it possible to process raw materials with a low content of target components and a high content of harmful impurities. Substandard copper concentrates include concentrates with high arsenic content in copper minerals such as tennantite and enargite. Currently, the possibility of processing concentrates with a high content of tennantite and enargite using various hydrometallurgical technologies (autoclave leaching, biohydrometallurgy, etc.) is actively studied. An analysis of works on the bioleaching of tennantite and enragite minerals, as well as concentrates containing these minerals, showed that bioleaching is a promising method for processing such concentrates, however, the information available in the literature on the dependence of the rate of bioleaching of arsenic-containing copper minerals on various factors is incomplete and even contradictory. Therefore, the purpose of this work was to study the process of bioleaching of arsenic-containing polymetallic concentrates containing tennantite, chalcopyrite and sphalerite under different conditions. The dependence of non-ferrous metal leaching on process temperature (in the range of 40–60 °C) and the use of CO_2 and molasses bioreactors as carbon sources for the microbial population was studied. Previously, our works showed that various carbon sources can affect the biooxidation of pyrite-arsenopyrite concentrates at elevated temperatures [1]. Therefore, in this work, we investigated the influence of carbon sources on the bioleaching of copper concentrates, since they can also increase the rates of bioleaching of copper.

Methods and Algorithms: For experiments, sulfide concentrates, the main minerals of which were chalcopyrite ($CuFeS_2$), tennantite ($Cu_{12}As_4S_{13}$), sphalerite (ZnS), pyrite (FeS_2), and quartz (SiO_2) were used. The first concentrate contained 6.2 % copper, 7.3 % zinc, 1.7 % arsenic, 24.4 % iron, 31.9 % sulfide sulfur, the second concentrate contained 16.0 % copper, 5.3 % zinc, 1.7 % arsenic, 28.0 % iron, 33.2 % sulfide sulfur. Thus, in the first concentrate a large proportion of copper was contained in tennantite, while in the second concentrate the main part of copper was contained in chalcopyrite. Bioleaching was carried out in laboratory scale reactors in a continuous The residence time was 10 days, the pulp density was 1 : 10 (S : L). For the concentrate 1, bioleaching was performed at 40, 45, 50, 55, and 60 °C. For the concentrate 2, bioleaching was performed at 45 and 55 °C. The influence of carbon sources on the biooxidation process

was investigated by adding 0.02 % molasses to the pulp or by supplying CO_2. Microbial populations were analyzed by metabarcoding of V3-V4 fragments of 16S rRNA genes.

Results: Bioleaching of concentrate 1 in the temperature range of 40–60 °C showed that the highest rate of copper recovery was achieved at a temperature of 45–50 °C (23–27 %), and increasing the temperature to 55 and 60 °C led to a decrease in copper leaching to 20–22 and 10–20 %, respectively. In the temperature range of 45–50 °C, the degree of copper leaching was weakly dependent on the use of additional carbon sources, while at 60 °C, leaching increased when using carbon dioxide (up to 20 %), while in variant with molasses and in the control experiment (without additional source carbon), copper leaching reached about 10 %.

When bioleaching concentrate 2, increasing the temperature from 45 to 55 °C led to an increase in the degree of copper leaching from 25–28 to 36–52 %. At the same time, the degree of leaching at 45°C depended to a small extent on the carbon source, while at 55 °C the highest degree of copper leaching was when molasses was used.

The composition of microbial populations differed during bioleaching of concentrates 1 and 2, as well as when process conditions changed. During the bioleaching of concentrate 1 at lower temperatures, archaea of the genus *Ferroplasma* and bacteria of the genera *Acidithiobacillus* and *Sulfobacillus* predominated. An increase in temperature led to the predominance of archaea of the genus *Acidiplasma*. During bioleaching of the concentrate 2, archaea of the genus *Ferroplasma*, and bacteria of the genera *Acidithiobacillus* and *Sulfobacillus* were predominant. Bacteria of the genus *Sulfobacillus* in this case were dominant at a temperature of 55 °C.

Conclusion: Thus, in this work, when studying the process of bioleaching of arsenic-containing polymetallic concentrates containing chalcopyrite, tennantite and sphalerite, at different temperatures and using different carbon sources, it was shown that the use of different carbon sources and an increase in temperature makes it possible to intensify the process of copper bioleaching. Moreover, a comparison of the results obtained with the results obtained in previous works [2, 3] shows that such effects can be determined by the ratio of sulfide minerals in the concentrate. The observed effect of the studied factors on the bioleaching process is largely determined by their impact on the microbial population that carries out the bioleaching process, since changes in the composition of the microbial populations of bioreactors were observed when the process conditions changed.

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