Bioleaching to reprocess sulfidic polymetallic mining residues: Two case studies from the H2020 NEMO project

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BIOLEACHING TO REPROCESS SULFIDIC POLYMETALLIC MINING RESIDUES: TWO CASE STUDIES FROM THE H2020 NEMO PROJECT

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1. Keywords
Bioleaching, mining residues, sulfides, reprocessing, metals

2. Highlights

- Mining residues can be considered as a metal resource that could be reprocessed.
- Bioleaching processes recover metals by microorganism-catalysed dissolution.
- In H2020 NEMO project bioleaching was applied to Aïtik and Sotkamo mining residues.
- The residues composition highly influences the efficiency of bioleaching.

3. Purpose

In Europe, most of metallic high- or moderate-grade primary sources that are reasonably accessible and easy to process are exhausted. In today's context of resource scarcity, complex low-grade ores and extractive wastes are receiving increasing attention. In particular, mining waste may be evaluated as a metal resource while their reprocessing might mitigate environmental impacts related to mining waste disposal [1]. Many efforts are being made to develop recycling or reuse options at reduced costs, with low environmental impacts and economic benefits. Conventional processes and technologies are often not profitable, sometimes due to the complexity of composition [2]. In this context, bio-hydrometallurgy, i.e. the use of microorganisms in hydrometallurgical operations, is increasingly being recognised as an ecologically acceptable and yet economic alternative for the recovery of metals in low-grade sulfide materials. The European research project NEMO (Near-zero-waste recycling of low-grade sulfidic mining waste for critical-metal, mineral and construction raw-material production in a circular economy) aims to valorise sulfidic mine waste by combining innovative hydrometallurgical processes for the recovery of valuable metals and critical raw materials with the transformation of the residue in clean mineral to be used for mass production of cement, concrete and construction products [3]. In the framework of this project, this study focuses on the development of enhanced bioleaching methods (i.e. the dissolution of metals catalysed by microorganisms) on two mining residues from Sotkamo mine (Terrafame, Finland) and Aïtik mine (Boliden, Sweden).

4. Materials and methods

In the Sotkamo mine, bio-heap leaching is applied to process a pyrrhotite-rich pentlandite-containing black schist ore to extract Ni (and Zn and Cu to a lesser extent). The residues still contain 3.2%(w/w) sulfides, 1310 ppm Ni, 1370 ppm Cu and 3460 ppm Zn [4]. In the Aïtik mine, Cu concentrates containing Au and Ag are produced by flotation. The process also produces low and high sulphur tailings, the latter being targeted in our study. They contain 41.6%(w/w) pyrite, 900 ppm Co and 2240 ppm Cu.
For both materials, bioleaching kinetics were first evaluated in 2 L stirred tank reactors (STR) to define basic operational parameters (pH, temperature, nutrients media…) before scaling up the process to 114 L-continuous stirred tank reactor (CSTR). The solid load was maintained at 20%(w/w) for both materials, while the nutritive medium was identical (0Km medium). The microbial consortia, mainly

composed by the genera *Leptospirillum*, *Acidithiobacillus*, *Sulfobacillus* and *Acidithiomicrobium*, which are either iron or sulfur-oxidizers or both, were slightly different for the two case studies. Two different temperatures were used (55°C for Sotkamo material and 40°C for Aïtik material).

5. Results and discussion

Both materials have highly different sulfidic contents (2.6% and 22.2% of sulfur as sulfides respectively) and thus highly different bioleaching amenability. The bioleaching of Sotkamo material demonstrated that reprocessing mining residues should be carefully studied, due to the complexity of composition of this material. Part of the metals are still contained in sulfidic minerals, while some of them were precipitated in SO_4-phases during primary metallurgy activities. The presence of remaining minerals as pyrrhotite and other soluble sulfides consumes acid and oxygen, thus playing a role in the dissolution of metals. The microbial activity promoted the dissolution of Co. Due to the simultaneity of all these mechanisms, the fine monitoring of the hydraulic residence time in the bioreactors is of primary importance to ensure a good efficiency of the bioleaching of Sotkamo residues. Pilot operation allowed gathering fundamental information regarding the material balance of the process, including metal and sulphide dissolution yields, reagent and gas consumption and process kinetics, which will serve as input data for the economic, environmental and social assessment of the process.

The bioleaching of Aïtik material, which is more favourable due to the high content of pyrite, revealed the importance of heat balance during the process, as the dissolution of pyrite is exothermic. The use of different temperatures during bioleaching process influences the microbial communities composition, which then highly affects the metal dissolution yield and rates. In particular, the predominance of *Leptospirillum* species (an iron-oxidizer micro-organism) increased the Co recovery from the material, up to more than 90% in STR. Controlling the temperature during pilot operation is required to ensure high efficiency of the process. The high efficiency of mass transfers in bioreactors is also necessary, as the oxygen demand is high. The development of new process designs should include all these requirements, in addition to the economic, environmental and social constraints.

6. Conclusions and perspectives

Bioleaching efficiency was evaluated on two mining residues in the framework of H2020 NEMO project. The materials composition was highly different, with sulfidic content varying from 2.6 to 22.2%(w/w). Consequently, the operating conditions that should be optimised were physico-chemical parameters (pH and nutrients medium composition, to prevent excessive precipitation as an example) in the case of Sotkamo material and operating parameters (heat and mass transfers) in the case of Aïtik material. High metal dissolution efficiency was demonstrated in both cases. The results of the pilot demonstration were used to perform a Life Cycle Analysis and to identify the main environmental impacts of the process. The reprocessing of such materials should be carefully studied to ensure that all parameters are taken into account when developing new bioreactor designs and assessing the economic, environmental and social feasibility of these activities.

7. References

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