BIOLEACHING OF COPPER SULPHIDES FLOTATION CONCENTRATE USING CONSORPTIUM OF MESOPHILES AND TERMOPHILES MICROORGANISMS: A PILOT SCALE APPROACH

Renata De B. Lima, Carlos Gomes De Souza, Luis Sobral & Débora Monteiro de Oliveira
Centre for Mineral Technology – CETEM, Brazil

Selma Leite
UFRJ – Federal University of Rio De Janeiro, Brazil

Paulo Medeiros
Caraíba Mining Company S/A, Brazil

ABSTRACT
The use of mixed cultures of acidophilus microorganisms that act in different temperature ranges, aims at speeding up the digestion of chalcopyrite, highly refractory sulphide mineral, the major mineral in the flotation concentrate of Caraíba Mining Co., with an attractive processing cost. The concentrate under consideration contains mainly chalcopyrite (CuFeS₂) and bornite (Cu₅FeS₄) with nearly 70 and 30% contents, respectively. It was observed in this study, the performance of consortium of mesophiles, moderate and extreme thermophile microorganisms, in the oxidation of the aforementioned sulphides minerals, evaluating operational parameters such as pH of the leaching solution, the reaction temperature and redox potential, with consequent extraction of 77.4% of the concentrate copper content within 60 days of bioleaching. Such high copper extraction was achieved in a pilot scale column bioleaching tests.

INTRODUCTION
The present technical contribution aimed at releasing the copper from its sulphide minerals in the flotation concentrate, more specifically chalcopyrite and bornite, through pilot scale column bioleaching. Seeking to accelerate, in particular, the oxidation of chalcopyrite, so as to reach the expectations of the copper mining, that needs to extract copper out of the flotation concentrate, as quick as possible at an attractive processing cost, consortia of microorganisms mesophile, moderate and extreme thermophile will be used.
OBJECTIVE

To extract in an optimized way the copper from a copper sulphides flotation concentrate containing mainly chalcopyrite and bornite, among other mineralogical species, from which the copper is released, as copper sulphate, by Column bioleaching.

LITERATURE SURVEY

The solubilisation of metals by using microorganisms from ores for the subsequent recovery of metals from solution are referred to as bioleaching [1]. This is an economical method for the recovery of metals from minerals; especially low-grade ores, overburden, and waste from current mining operations which requires moderate capital investment with operating cost [2].

Heap and dump leaching offer a number of advantages embracing simple equipment, low investment and operation cost, and reasonable yields over a period of recirculation [7].

In the absence of sulphur oxidizing microorganisms, more than 90% of sulphide–sulphur is transformed into elemental sulphur [5]. The role of sulphur oxidising microorganisms in the oxidation of sulphide minerals at low pH is, therefore, very important.

Chalcopyrite (CuFeS₂) is the most abundant and refractory copper sulphide, and the bioleaching of such sulphide mineral is the key industry target. The main problem hindering commercial application of chalcopyrite bioleaching is the slow dissolution rate [3, 4].

Recent studies [6] have shown that precipitation and nucleation of jarosites on chalcopyrite particles is the main cause of chalcopyrite passivation in ferric sulphate medium. The formation of jarosite depends on the redox potential of the leaching solution and speeds up when the potential is above a critical value, near 450mV vs. Ag/AgCl; this relates to the tendency of Fe³⁺/Fe²⁺ solutions towards a chemical equilibrium in which the activities of both ions are equal [6].

EXPERIMENTAL

GEOCOAT™ Process

Is the coverage of a support rock (in the size range of 6 to 25mm) with the flotation concentrate (layer of 0.5 to 1.0 mm). The support rocks, properly covered are accumulated in a heap, which a representative scheme can be seen in Figure 1.

The coating operation is accomplished by spraying the concentrate slurry onto the support rock as it discharges from the end of a stacking conveyor onto the biooxidation heap [8].
Then, this heap is irrigated on its upper part with an acid solution (H\textsubscript{2}SO\textsubscript{4}) containing basic chemicals, biomass and nutrients.

**Concentrate Coating Operation Onto Inert Support Rocks**

The mass of concentrate coating the surface of the mineral substrate can reach 10% of the total mass of material that feeds the heap. The Figure 2, as follows, shows in detail the mechanical system used for coating the support rock.
In the Figure 3A, can be observed how the concentrate is dispensed during the coating operation, and in Figure 3 B, the support rock completely coated with flotation concentrate.

![Figure 3: (A) Coating operation; (B) Support rock coated with flotation concentrate](image)

The coating of a support rock with the flotation concentrate can be made 24 hours before beginning the activities in the bioleaching column, for better adhesion of the flotation concentrate on the rock. The coating solids density is highly dependent on the slurry viscosity and densities of 50–65% of solids have been successfully coated at scale. The support rock is relatively uniformly sized, in the range of 6–25 mm in diameter and the concentrate coating is relatively thin, less than 1 mm in thickness [8].

**Reaction System**

The reaction system for running the column bioleaching process, as practiced in the GEOCOAT™ process can be seen in Figure 4:

![Figure 4: Schematic drawing of the column bioleaching apparatus](image)
The column was filled with the support rock, covered with the flotation concentrate and the microbial consortium (mesophilic, moderate thermophilic and extreme thermophilic) in a concentration of $10^6$ cells/g of flotation concentrate. The mineral bed was percolated with leaching solution in a flow rate of 24.5 L/h/m².

**MKM Culture Medium**

The MKM Culture Medium was used to make the cultivation and maintenance of the microbial consortium (mesophilic microorganisms, moderate thermophilic and extreme thermophilic), acting as a leaching solution during bioleaching process. The composition of this medium is described in Table 1, below:

<table>
<thead>
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<th>MKM</th>
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<tbody>
<tr>
<td>(NH₄)SO₄</td>
<td>0.4 g/L</td>
<td></td>
</tr>
<tr>
<td>MgSO₄. 7H₂O</td>
<td>0.4 g/L</td>
<td></td>
</tr>
<tr>
<td>KH₂PO₄</td>
<td>0.04 g/L</td>
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For the maintenance of microbial cultures, using the MKM Culture Medium in dual concentration and as leaching solution, was used a concentration of 0.2 times that of this culture medium.

**Microbial Culture**

It was used 33.3 g/L of FeSO₄·7H₂O and 1% of $S^0$ for the mesophilic consortium cultivation. For cultivating of thermophilic consortium, it was used FeSO₄·7H₂O and $S^0$, and, additionally, more 1% of the flotation concentrate, 1% pyrite and 0.2 g/L of yeast extract.

**Analytical Determinations of Control Parameters**

Parameters such as pH, was constantly adjusted to a value equal to 1.5, the redox potential was monitored and the iron ionic species concentration ($Fe^{2+}$ and $Fe^{3+}$) analyzed by spectrophotometry and the copper concentration by atomic absorption spectrometry so as to evaluate the copper extraction.

**RESULTS DISCUSSION**

The Figure 5 shows the PLS copper analysis in the samples taken during bioleaching process. Taking into account to growing copper extraction, that has reached 77.4%, approximately in 60 days of test, it is possible to observe a higher extraction rate in the first twenty days (50%) due to the digestion of bornite (Cu₅FeS₄), copper sulphide minerals more prone to be oxidized, which contribute as 30% of the concentrate composition used in this experiment.
When accomplishing the comparison between the ferric and ferrous ions concentrations, as show the figure 6, it is possible to observe, by superimposing the curves, a fluctuation in the Fe$^{3+}$ and Fe$^{2+}$ concentrations. However, those concentrations remain high, evidencing the high efficiency of the biological concentrate oxidation process. However, as the ferric ions concentration goes down, with a consequent increase in the ferrous ions concentration, starting from the 50th day of reaction, the oxidation rate also decreases.

The redox potential corroborates with the analyses of the iron species, which could also be used as an indicative of the copper sulphides oxidation rate. In figure 6, it is noticed the aforementioned redox potential fluctuation (~650 mV vs. EPH) up to the 50th day of reaction.
CONCLUSIONS

The use of a microbial consortium in a column bioleaching process was quite effective regarding the digestion of refractory sulphides, where a copper extraction near to 77% was reached within 60 days of test.

The ferrous and ferric ions concentrations, during the test, are directly related to the redox potential values, as it was possible to observe that in the moment where the Fe$^{3+}$ concentration tended to an increase, reaching concentration around 4 g/L, the redox potential also increased, providing a higher leaching rate.

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REFERENCES


