Coordenação de Processos Metalúrgicos e Ambientais - COPMA

Serviço de Metalurgia Extrativa - SEMEX

Bio-Oxidation of Primary Gold Ore as a Pre-Oxidative Step for Subsequent Extraction of the Gold Content

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Rio de Janeiro
2023

CAC 0035-00-23 – Hydroprocess 2023 – 14th International Conference on Process Hydrometallurgy
07 – 09 de novembro de 2023 – Sheraton Hotel, Santiago, Chile

Hydroprocess2023 | 14th International Conference on Process Hydrometallurgy

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ABSTRACT

The presence of sulphide minerals, such as pyrite, chalcopyrite etc., can pose major challenges in the gold extraction processes, regardless of the downstream extraction route used, including cyanidation and the use of thiosulphate. These sulphides consume the reagents used in gold extraction, leading to operational problems due to the ever-increasing ionic strength during the extraction processes, which impacts the solubility of the oxidizing agent, specifically dissolved oxygen, which is of paramount importance for extracting gold. The presence of sulphide minerals in gold ores represents a major challenge in the gold extraction since they react with leaching agents with their consequent consumption, leading to a reduction in the effectiveness of the gold extraction processes causing operational problems. The pre-oxidative biological process is being investigated as a potential solution to this challenge. This bio-oxidation process aimed at solubilizing the aforementioned sulphide minerals, which took part of the gold ore prospected by the Brazilian gold mine EURO METAL BRASIL, at particle size lower than 0.1mm, using indigenous autotrophic microorganisms, such as Acidithiobacillus thiooxidans, Acidithiobacillus ferrooxidans and Leptospirillum ferrooxidans, and so many other ones, which are commonly found in the natural acid rock drainage generated at that particular gold mine under study, subsequently reducing the consumption of leaching agents used in gold extraction turning this process more efficient and cost-effective. New researches are still in progress, at pilot scale, aiming at improving these gold extraction processes, meeting the aspirations of gold mines.

INTRODUCTION

Bio-oxidation is characterized as being a pre-treatment of refractory ores and concentrates, where microorganisms are used that have the function of oxidizing the present sulphide minerals and, thus, releasing the gold particles, which are encapsulated in the structure of the referred minerals, to be later dissolved by the aforementioned leaching agents (KAKSONEN et al., 2014).

According to Rodrigues (2016), numerous microorganisms species, with the ability to oxidize Fe2+, have already been taxonomically identified, such as, for example, the bacteria Acidithiobacillus

ferrooxidans, Leptospirillum ferrooxidans and Acidithiobacillus thiooxidans etc. These microorganisms are often used in ore bioleaching and bio-oxidation studies. (BRIERLEY, 2010; RODRIGUES, 2015; TAO & DONGWEI, 2014; WATLING, 2006)

In the process of bio-oxidation of sulphide minerals, microorganisms are responsible for generating the oxidizing agent in the reaction system (i.e., Fe3+ ions) from the oxidation of ferrous ions (i.e., Fe2+) that can be added to the system both as a soluble form (FeSO4.7H2O) or insoluble (FeS2). Therefore, this study aimed at bio-oxidizing auriferous ore, as pre-oxidation of sulphide minerals for subsequent extraction of gold by chemical and electrolytic processes.

METHODOLOGY

The bio-oxidation assays were carried out in duplicates, in 12 Erlenmeyer flasks, being two flasks removed every 12 hours for analysing Fe2+ and total iron, which was an indication of the sulphide minerals bio-oxidation. The aforementioned flasks contained a solid: liquid ratio of 10%, and inorganic salts as nutrient source: i) (NH4)2SO4 80.0 mg.L-1; MgSO4.7H2O 80.0 mg.L-1; K2HPO4 8.0 mg.L-1, pH 1.8; ii) Cultures of Leptospirillum ferrooxidans and Acidithiobacillus ferrooxidans, previously acclimatized; and iii) gold ore. The flasks were incubated at a temperature of 35ºC and orbital agitation at 150 rpm. Throughout the process, which was carried out for 72 hours, the redox potential, an indirect way of evaluating the oxidation power of reaction system, and pH were monitored, being this last one adjusted to 1.8 whenever necessary by adding a 5M H2SO4 solution. Sacrifice flasks, two replicate ones, were removed every 12 hours of test, and the supernatant filtered for later analysis of iron and sulphate concentrations, which were not reported in this in progress research study, but will be latter used, in the in progress pilot scale project for evaluating the sulphide . From the availability of sulphate in the solution, the percentage of sulphide oxidation, throughout the process, will be further calculated. At the end, a representative sample of the remaining solid was submitted to an analysis by x-ray diffraction (DRX) to verify, qualitatively, the intensity of the sulphide peaks present in comparison with the same peaks of the original sample. A positive control was prepared, without adding any microorganisms.

RESULTS AND DISCUSSION

Figure 1 shows the variation of the redox potential throughout the bio-oxidative process. It can be observed that the potential gradually increases, indicating the evolution of this process. During the experiments, there was an increase in the total iron concentration due to the oxidation of iron-bearing sulphide minerals in their structures, that is, pyrite (FeS2), pyrrhotite (Fe(1-x)S), arsenopyrite (FeAsS) and chalcopyrite (CuFeS2). The fluctuations in the concentrations of the ionic iron species (data not shown) promote the variation of the redox potential throughout the experiments.

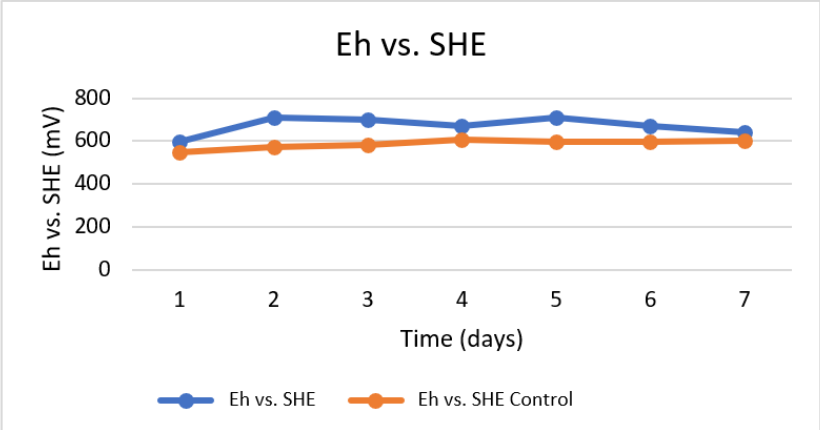

Figure 1 Variation of the redox potential during the pre-oxidative process

Note that there was an increase in pH in the first 24 hours; however, this parameter did not reach a value higher than 3 (Figure 2). This increase in pH is directly related to the reaction of sulphuric acid with the mineralogical species that make up the ore gangue in the concentrate, which easily react with sulphuric acid. The addition of sulphuric acid was done in the first three days, adding the equivalent of 39 kilograms of acid per ton of concentrate.

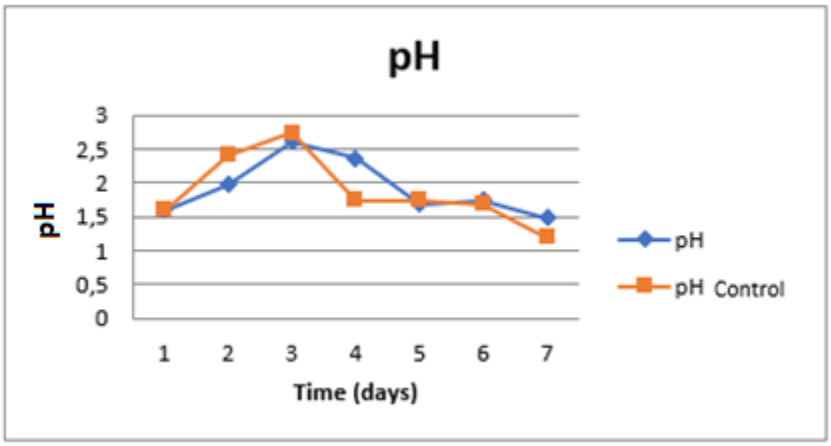

Figure 2 pH variation over time

By carrying out bio-oxidation as a pre-treatment of the ore, before the cyanidation process, aimed at reducing the sulphides content, which are cyanicides, in order to make the cyanidation process more cost-effective. The diffractogram in Figure 3 shows a substantial reduction in the pyrite content, the main sulphide mineral present. However, this reduction in the pyrite content can be even more significant extending of the bio-oxidative process.

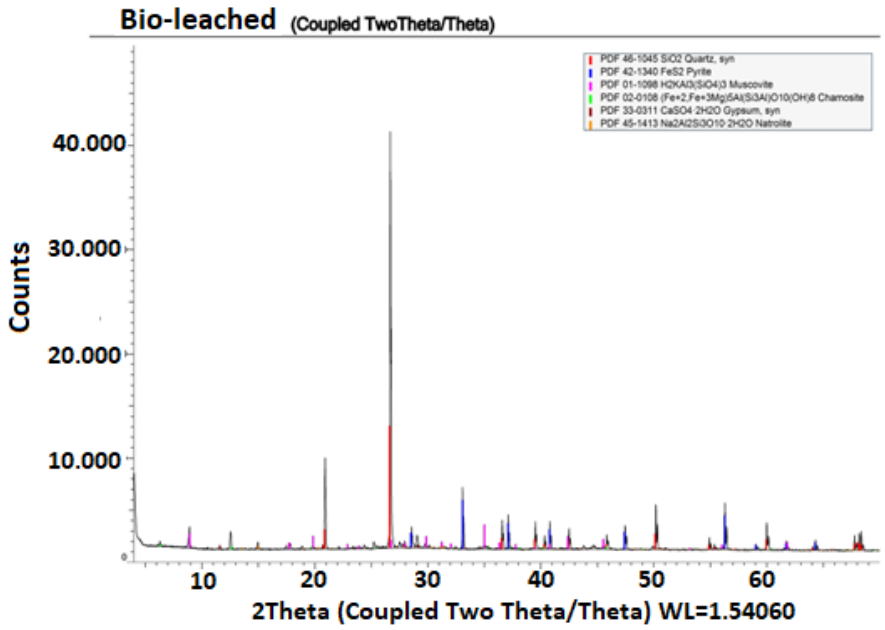

Figure 3 XRD analysis for the identification of sulphide minerals after accomplishing the pre-oxidative process

CONCLUSION

By accomplishing the in vitro Bio-oxidation experiments, with Fe3+ biologically generated in the reaction system, it is concluded that there is the possibility of its application as a previous step that precedes the gold extraction, mainly with finely ground ore samples. However, this biotechnological route needs further studies, considering, among other parameters, the use of other bacterial strains and the conduction of continuous experiments. In addition, the pilot scale tests are being run using, this time, coarser ore particles (i.e., between 3 and 6mm) being produced by different ore processing operations, such as jaw crusher, HPGR – High pressure grinding rolls, and high voltage pulse fragmentation, so as to verify the influence of such operations on the bio-oxidation of gold ores.

REFERENCES

BRIERLEY, CL. Biohydrometallurgical prospects. Hydrometallurgy 2010; v.104, p.324-8.

CAPONERO, J. Reciclagem de Pneus. Tese de Doutorado – Escola Politécnica, Universidade de São Paulo, SP, 2002.

KAKSONEN AH, MUDUNURU BM, HACKL R. The role of microorganisms in gold processing and recovery - a review. Hydrometallurgy. 2014; acesso em 18 de dezembro de 2022.

RODRIGUES MLM, LOPES KCS, LEÔNCIO HC, SILVA LAM, LEÃO VA. Bioleaching of fluoride-bearing secondary copper sulphides: Column experiments with Acidithiobacillus ferrooxidans. Chemical Engineering Journal. 2016

RODRIGUES,MLM. Biolixiviação de cobre com Micro-Organismos Mesófilos e Termófilos Moderados: Sulfetos Secundários Contendo Flúor e Placas de Circuito Impresso. REDEMAT, ufop, 2015. 116p.

TAO, H; DONGWEI, L. Presentation on Mechanisms and Applications of Chalcopyrite and Pyrite Bioleaching in biohydrometallurgy- A Presentation. Biotechnology Reports 2014.

WATLING, H.R. The bioleaching of sulphide minerals with emphasis on copper sulphides – A review. Hydrometallurgy, v.84, p81-108, 2006.