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CHALCOPYRITE: BIOLEACHING VERSUS PRESSURE HYDROMETALLURGY

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ABSTRACT

While bioleaching of pyrite concentrates has been successfully used in industry to liberate gold from the sulfide matrix for subsequent cyanidation, the same technology cannot be recommended for leaching chalcopyrite concentrates for copper recovery. It will be shown to be uneconomical and cannot compete with pressure leaching technology.

INTRODUCTION

Bacterial leaching has been successfully applied for heap leaching of copper ores [1,2]. It was extended to treat auriferous pyrite concentrates to liberate gold and render it amenable to cyanidation by a process known as BIOX [3,4]. BIOX plants currently in operation are the following:

- Ashanti Goldfields Company, Ghana. Designed with an initial capacity of treating 720 tonnes of concentrate per day, the Sansu plant has since been expanded and currently has four modules processing 960 tonnes per day in all. It is by far the largest biooxidation plant in the world. The capital cost of the plant totalled US $ 25 million (1994 terms) and the operating cost is currently US $ 17/tonne milled.
- Fairview, South Africa. The plant at the Fairview mine in Barberton, which was the initial pilot plant, has been fully operational since 1986. It was originally designed to treat of concentrate 10 tonnes/day but with the success of the project this has been increased to 55 tonnes per day. With the purchase of Fairview by Avgold’s Eastern Transvaal Consolidated, Avgold concluded a licensing agreement with Gold Fields, formerly known as Gencor entitling it to use the BIOX technology to treat its concentrate.
- Sào Bento, Brazil. A BIOX plant is in operation in Brazil at the Sao Bento Mine where a pressure oxidation circuit is used to treat the refractory flotation concentrate. This plant has confirmed the viability of combining bio-oxidation with pressure oxidation as a cost-effective method of increasing capacity at an existing oxidation plant.
- Wiluna, Australia. The plant at Wiluna Gold Mine, Western Australia, was commissioned in 1993. Although originally designed to treat 115 tonnes per day of concentrate this has subsequently been increased to 158.
- Other plants at Tamborraque in Peru, Harbour Lights and at Youanami in Australia have been commissioned recently
BIOLEACHING OF CHALCOPYRITE

In the past few years there has been interest to apply bacterial leaching to treat chalcopryite concentrates. For example, according to Paul Miller, Vice President Engineering of BacTech Mining Corporation, a continuous small scale bioleach pilot plant was established to investigate the bioleaching of chalcopryite concentrates in 1998 by BacTech at Mt. Lyell in Tasmania [5]. The plant was integrated with downstream solvent extraction and electrowinning for copper recovery. Treating a few kilograms a day of concentrate over a period of a year, the plant achieved a 96 % extraction of copper. It was found further that the process could be applied successfully on concentrates containing arsenic.

According to the same source, the technology was extended and a demonstration scale plant was constructed in 2001 by the joint technology partnership of BacTech and Mintek in conjunction with Peñoles in Monterrey in Mexico (Figure 1). The plant operated for a year with a capacity of 200 tpa copper cathode production using commercial equipment, and demonstrated well the technical feasibility of a totally integrated process with high levels of copper recovery from arsenic-containing concentrate blend. On completion of the demonstration trial, a feasibility study was conducted for a commercial bioleach plant having a capacity of 25,000 tonnes of copper. However, due to the low price of copper at that time BacTech did not go forward with the project to a commercial scale.

![Figure 1 - Pilot plant for bioleaching of chalcopryite concentrates at Peñoles in Monterrey in Mexico (2001)](image)

It is interesting that in 2002, Alliance Copper, which is a joint venture between BHP Billiton and Codelco in Chile built also a 20,000 tonnes/ year demonstration plant near Chuquicamata (30 km from Calama) in Chile for US $ 50 million. The plant is composed of six large reactors, mechanically agitated, and lined with acid-resisting brick. Since a
thermophilic bacteria is used in the system it is possible to operate at a temperature of about 90°C and this accelerates the reaction.

With the increase in copper prices in 2006 Paul Miller believes that the situation is now ready to exploit this technology. In spite of this enthusiasm for bioleaching technology, one cannot recommend its use for leaching chalcopryite concentrates because it cannot be economical for the following reasons. The leaching reaction for chalcopryite is as follows:

$$\text{CuFeS}_2 + 4 \text{O}_2 \rightarrow \text{CuSO}_4 + \text{FeSO}_4$$

From this it can be seen that a large amount of oxygen will be consumed, a large amount of lime will be needed to precipitate ferrous sulfate, and there will be an excessive disposal and material handling problem of ferrous hydroxide—gypsum mixture:

$$\text{FeSO}_4 + \text{Ca(OH)}_2 + 2 \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_2 + \text{CaSO}_4 \cdot 2\text{H}_2\text{O}$$

The reaction is slow—it is complete in 4–5 days when conducted and in addition, some bacterial nutrients such as phosphate and ammonium ions must be supplied to the reaction mixture. In the recovery step by electrolysis, acid will be generated and must be disposed of.

**PRESSURE LEACHING OF CHALCOPYRITE**

When bioleaching technology is compared with pressure leaching, the reaction that takes place in one autoclave at 150°C and 4000 kPa oxygen partial pressure is as follows:

$$2 \text{CuFeS}_2 + 4 \text{H}^+ + 5/2\text{O}_2 \rightarrow 2 \text{Cu}^{2+} + \text{Fe}_2\text{O}_3 + 4 \text{S} + 2 \text{H}_2\text{O}$$

The advantages of this route are the following:

- The reaction is fast—complete in 20–30 minutes
- Oxygen consumption is $1^{1/4}$ moles per mole chalcopryite as compared to 4 moles in the case of bioleaching, that is less than one third that required for bacterial leaching
- One reactor is enough
- Cu$^{2+}$ is already separated from Fe$^{2+}$ since Fe$_2$O$_3$ is precipitated during the reaction
- All the sulfur in the concentrate can be obtained in the elemental form
- When copper is recovered from solution by electrowinning, the acid generated at the anode is equal to that required for leaching hence no acid disposal problem
- There is no material handling and disposal problem involving lime addition
- Any arsenic present in the concentrate will remain in the residue as ferric arsenate

Pressure leaching has been successful for treating pyrite and arsenopyrite concentrates to liberate the gold in the matrix (Table 1). Figure 2 shows a typical autoclave for treating concentrates while Figure 3 shows a schematic flowsheet for handling the concentrate.
<table>
<thead>
<tr>
<th>Start up</th>
<th>Plant Location</th>
<th>Owner</th>
<th>Feed</th>
<th>Medium</th>
<th>Capacity t/d</th>
<th>Number of autoclaves</th>
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<tr>
<td>1985</td>
<td>McLaughlin USA</td>
<td>Homestake USA</td>
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<td>acid</td>
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<td>American Barrick Canada</td>
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<td>alkaline</td>
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<td>Getchell USA</td>
<td>First Miss Gold</td>
<td>ore</td>
<td>acid</td>
<td>2,730</td>
<td>3</td>
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<td>acid</td>
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<td>Placer Dome Canada</td>
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<td>acid</td>
<td>1,350</td>
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<td>2,700</td>
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<tr>
<td>1997</td>
<td>Lihir, Papua New Guinea</td>
<td>Rio Tinto</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>3</td>
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<td>Macraes Mining</td>
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<td>acid</td>
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Figure 2- An autoclave for pressure leaching of pyrite concentrates

Figure 3- Typical flowsheet for pressure leaching of sulfide concentrates where an efficient heat recovery system is in place.

CONCLUSIONS

Beside application in heap leaching, it is believed that bacterial leaching can be applied only and effectively to liberate gold from auriferous pyrite concentrate since there is no economic way to get elemental sulfur from pyrite, but it cannot be
recommended for chalcopyrite concentrates.

References


