



## Conventional and electrochemical bioleaching of chalcopyrite concentrates by moderately thermophilic bacteria at high pulp density

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### ABSTRACT

Conventional and electrochemical bioleaching were investigated to extract copper from Sarcheshmeh chalcopyrite concentrate at high pulp densities. Experiments were conducted in the presence and absence of a mixed culture of moderately thermophilic iron- and sulphur oxidizing bacteria using a 2-L stirred electro-bioreactor at 20% (w/v) pulp density, an initial pH of 1.4–1.6, a temperature of 50 °C, a stirring rate of 600 rpm and Norris nutrient medium with 0.02% (w/w) yeast extract addition. The results of 10 day leaches showed that, when using electrochemical bioleaching in an ORP range of 400 to 430 mV, copper recovery reaches about 80% which is 3.9, 1.5 and 1.17 times higher than that achieved in abiotic electrochemical leaching, conventional bioleaching, and electrochemical bioleaching at 440–480 mV ORP, respectively. It appears that applying current directly to the slurry optimises both, the biological and chemical subsystems, leading to an increase in both, the dissolution rate and the final recovery of copper from the concentrate. Mineralogical analysis of the solid residues of electrochemical leaching in both, biotic and abiotic media, showed the formation of chalcocite and covellite minerals on the surface of not leached chalcopyrite. It is postulated that the reduction of refractory chalcopyrite to more soluble minerals such as chalcocite and covellite is achieved through both, electron transfer upon electrode contact and by ferrous reduction at the low ORP of the slurry. These secondary minerals are then rapidly dissolved through bioleaching, while at the same time a formation of a passive layer of jarosites is minimised. This process also appears to promote an increased bacteria–solid ratio due to favourable growth conditions.

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### 1. Introduction

Currently, pyrometallurgical processes are the predominant route to treat chalcopyrite flotation concentrates, which from an environmental perspective have some major problems, especially the emission of SO<sub>2</sub> (Dimitrijevic et al., 2009). Over the last 30 years, many researchers in universities and industry have focused their efforts on finding ways to extract copper by bioleaching. However, for chalcopyrite due to the slow dissolution kinetics, caused primarily by passivation of the mineral surface, bioleaching has not been implemented at the full commercial scale as yet.

A number of recent studies have reported that the oxidation reduction potential (ORP) is one of the main parameters governing the chemical and biological leaching rate of chalcopyrite. In this regard, several authors (Hiroyoshi et al., 1997, 2000, 2001; Pinches

et al., 2001; Third et al., 2002; Sandström et al., 2005; Cordoba et al., 2008) have reported that during the chemical leaching of chalcopyrite in ferric sulfate media, both the rate and yield of copper dissolution is at a maximum in a narrow range of ORP around 400–450 mV (vs. Pt, Ag/AgCl), whereas at ORPs above this range, the surface passivation of the mineral could occur. Moreover, it has been found that applying direct current into the bacterial slurry significantly enhances both the activity and growth of microorganisms (Natarajan, 1992; Nakasono et al., 1997; Ahmadi et al., 2010a).

It should be mentioned that in conventional tank bioleaching of chalcopyrite, extremely thermophilic microorganisms (temperatures as high as 70–80 °C) are required to extract copper rapidly whilst maintaining economic viability. The leading process is BioCOP™ which operates at 78 °C and 12% (w/w) pulp density (Batty and Rorke, 2006). At these high temperatures, difficulties such as low solubility of oxygen, high rate of evaporation, high corrosion of reactor construction materials, and high sensitivity of the thermophilic cells to metabolic stress caused by excess turbulence (in the contact of increased pulp density) occur. These are less of a problem at 50 °C or below (Rawlings et al., 2003; Olson et al., 2003; Okibe et al., 2003).

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