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Technical note

Comparison of bioleaching ability of two native mesophilic and thermophilic bacteria on copper recovery from chalcopyrite concentrate in an airlift bioreactor

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Abstract

A mesophilic iron oxidizing bacterium, *Acidithiobacillus ferrooxidans*, has been isolated (33 °C) from a typical chalcopyrite copper concentrate of the Sarcheshmeh copper mine in the region of Kerman located in the south of Iran. In addition, a thermophilic iron oxidizing bacterium, *Sulfobacillus*, has been isolated (60 °C) from the Kooshk lead and zinc mine near the city of Yazd in central Iran. Effects of some variable parameters such as solids concentration, temperature and pH on the bioleaching of chalcopyrite obtained from Sarcheshmeh copper mine were investigated. Bioleaching experiments were carried out in two batch airlift bioreactors with a recycling stream. The results indicate that the efficiency of copper extraction is dependent on all the variables studied for both microorganisms. Maximum copper recovery was achieved using a thermophilic culture. Copper dissolution reached 85% with *Sulfobacillus* and 70% with *Acidithiobacillus ferrooxidans* at 10% w/v pulp density, after 10 days.

Keywords: Bioleaching; *Acidithiobacillus ferrooxidans*; *Sulfobacillus*; Airlift bioreactor; Chalcopyrite; Copper extraction

1. Introduction

Much effort has been directed towards developing a hydrometallurgical process suitable for the treatment of complex sulfide ores. Bio-hydrometallurgical techniques seem to offer one of the better alternatives for treatment of these types of ores (Rubio and Garcia Frutos, 2002). These methods, which have been applied industrially to copper and uranium production, use bio-assisted heap, dump and in-situ technologies, and have been applied successfully to the extraction of gold from refractory sulfide-bearing ores and concentrates (Jordan et al., 1996; Brierley, 2001; Lizama, 2001; Gerike et al., 2001). However, for other metal concentrates, this technology remains a promising alternative against conventional pyrometallurgical extraction processes. This is the case for the treatment of chalcopyrite concentrates, which repre-

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sent a more complex situation, due to the natural refractivity of chalcopyrite.

Several studies with mesophilic microorganisms such as *Acidithiobacillus ferrooxidans* and *Leptospirillum ferrooxidans* have showed very slow copper leaching rates (Mehta and Murr, 1982; Sand et al., 1992; Howard and Crundwell, 1999). However, when thermophilic microorganisms are used, leaching rates are considerably enhanced due to high temperatures, higher metal tolerance capacity and the metabolic characteristics of these type of microorganisms (Brierley, 1993; Clark and Norris, 1996).

Initially, chalcopyrite can be oxidized by dissolved oxygen according to Eq. (1) in acidic solution. According to Eq. (3), the role of the bacteria is to regenerate the oxidant ferric ion from the ferrous iron, which results from the chemical oxidation of the metal sulfide in the ore by ferric iron (Eq. (2)).

$$CuFeS_2 + O_2 + 4H^+ = Cu^{2+} + Fe^{2+} + 2S^0 + 2H_2O \quad (1)$$

$$CuFeS_2 + 4Fe^{3+} = Cu^{2+} + 5Fe^{2+} + 2S^0 \quad (2)$$

$$4Fe^{2+} + 4H^+ + O_2 = 4Fe^{3+} + 2H_2O. \quad (3)$$

Most of the studies on bacterial dissolution of sulfide have been carried out using mesophilic microorganisms, especially *Acidithiobacillus ferrooxidans*. Copper bioleaching of sulfide ores at ambient temperature has been practiced. However, recently, the effect of thermophilic bacteria on the sulfide dissolution has taken more importance since, in the presence of thermophilic bacteria, chalcopyrite is oxidized more rapidly and to a greater extent (Konishi et al., 1999; Third et al., 2000; Rodriguez et al., 2003).

The possibility of recovering copper from a sulfide concentrate by bacterial oxidation with mesophilic and thermophilic microorganisms in an airlift bioreactor has been evaluated in the present research.

2. Material and methods

2.1. Ore concentrate

A copper sulfide concentrate supplied by Sarcheshmeh Copper Mine (Kerman, Iran) was used. Chemical analysis of the sample revealed 24.74% Cu; 26.39% Fe; 0.68% Mo; and 35% S. X-ray diffraction analysis of the ore showed chalcopyrite ($CuFeS_2$) as the major component (57.1%) and pyrite (FeS_2)(19.3%) as the minor one together with small amounts of chalcocite (Cu_2S), covellite (CuS) and molybdenite (MoS_2). Over 90% of the ore had a particle size less than 45 μm.

2.2. Microorganisms and media

The mesophilic and thermophilic iron oxidizing bacteria used in this work were isolated from the Sarcheshmeh copper mine and Kooshk lead and zinc mine. These strains were identified by the Department of Microbiology in IROST (Iranian Research Organization of Science and Technology). According to the report of IROST, the strains were identified as *Acidithiobacillus ferrooxidans* and *Sulfobacillus* respectively.

Acidithiobacillus ferrooxidans was grown on a medium containing $FeSO_4.7H_2O$: 33.4 g/l, $(NH_4)_2SO_4$: 0.4 g/L, $MgSO_4.7H_2O$: 0.4 g/L and K_2HPO_4: 0.4 g/L; whilst *Sulfobacillus* was cultured on a medium con-

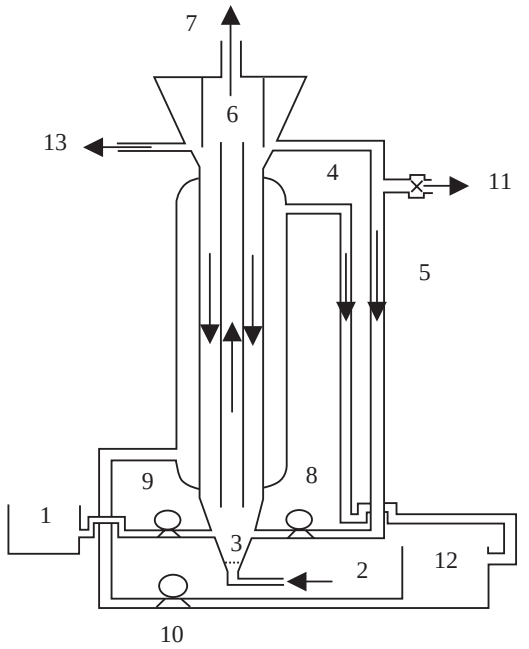

Fig. 1. Schematic diagram of airlift bioreactor (1: fresh feed; 2: input air; 3: air sparger; 4: circulation of water in jacket; 5: recycling stream; 6: draft tube; 7: output air; 8,9,10: peristaltic pump; 11: sampling port; 12: thermostatic bath; 13: effluent solution).