Journal of Hazardous Materials 241–242 (2012) 197–206

Contents lists available at SciVerse ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Bio-processing of copper from combined smelter dust and flotation concentrate: A comparative study on the stirred tank and airlift reactors

Ali Behrad Vakylabad[a,e,*], Mahin Schaffie[b,c], Mohammad Ranjbar[a,c], Zahra Manafi[d], Esmaeel Darezereshki[c,f]

[a] *Department of Mining Engineering, Shahid Bahonar University, Kerman, Iran*
[b] *Department of Chemical Engineering, Shahid Bahonar University of Kerman, Kerman, Iran*
[c] *Mineral Industries Research Centre (MIRC), Shahid Bahonar University of Kerman, Kerman, Iran*
[d] *Sarcheshmeh Copper Complex, National Iranian Copper Industry Company, Iran*
[e] *Engineers of Nano and Bio Advanced Sciences Company (ENBASCo.), ATIC, Mohaghegh University, Iran*
[f] *Energy and Environmental Engineering Research Center (EERC), Shahid Bahonar University of Kerman, Kerman, Iran*

HIGHLIGHTS

- ► Flotation concentrate and smelter dust were sampled and combined.
- ► Copper bioleaching from the combined was investigated.
- ► Two bio-reactors were investigated and optimized: stirred and airlift.
- ► STRs had better technical conditions and situations for bacterial leaching.

ARTICLE INFO

Article history:
Received 14 May 2012
Received in revised form
13 September 2012
Accepted 14 September 2012
Available online 23 September 2012

Keywords:
Bioleaching
Mesophiles
Moderate thermophiles
Stirred tank reactor
Airlift reactor

ABSTRACT

To scrutinize the influence of the design and type of the bioreactors on the bioleaching efficiency, the bioleaching were evaluated in a batch airlift and a batch stirred tank bioreactors with mixed mesophilic and mixed moderately thermophilic bacteria. According to the results, maximum copper recoveries were achieved using the cultures in the stirred tank bioreactors. It is worth noting that the main phase of the flotation concentrate was chalcopyrite (as a primary sulphide), but the smelter dust mainly contained secondary copper sulphides such as Cu_2S, CuS, and Cu_5FeS_4.Under optimum conditions, copper dissolution from the combined flotation concentrate and smelter dust (as an environmental hazard) reached 94.50% in the STR, and 88.02% in the airlift reactor with moderately thermophilic, after 23 days. Also, copper extractions calculated for the bioleaching using mesophilic bacteria were 48.73% and 37.19% in the STR (stirred tank reactor) and the airlift bioreactor, respectively. In addition, the SEM/EDS, XRD, chemical, and mineralogical analyses and studies confirmed the above results.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

The production of solid waste streams such as dust, slag, etc. is usual in metallurgy and recycling industries. As such, owing to the harmful effects of the wastes to the environment if released, environmental-friendly methods are extremely of high importance [1].

The environmental lead pollution particularly around mining and smelting operations has become a global problem, and quite a few countries seriously have investigated and presented methods to control the pollution [2]. Arsenic compounds (As (V), arsenate; As (III), arsenite; As (0), and As (−III), arsine) discharged into atmosphere during copper smelting operation is classified as a very hazardous materials in the US Environmental Protection Agency (EPA) [3].

Two reverberatory and converter furnaces in the Sarcheshmeh copper complex (south-east of Iran) produce nearly 50 tpd copper dust with about 30% copper content. According to our investigations at the complex, the hazardous dust contains about 8.63% As, and 3.14% Pb. At present, recycling the dust to the furnaces results in the reduction of their efficiencies, increases the required energy

* Corresponding author. Tel.: +98 9149536049/9302932233; fax: +98 451 774 22 91.
E-mail addresses: alibehzad86@yahoo.co.uk, alibehrad788@yahoo.com.au, enbasco@yahoo.com.au (A.B. Vakylabad).

0304-3894/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jhazmat.2012.09.031

for their smelting, damages the refractory bricks, and imposes a circular load on the furnaces. Also, in this copper complex about 1500 tpd chalcopyrite concentrate is produced with about 27% copper content [4].

Therefore, the primary aim of the study was to find a safer and cleaner technology to treat the hazardous materials. In spite of the reports in this regard [4,5], two questions are central to the debate here: firstly, which is the best option for the bioleaching operation, stirred tank or airlift reactors?

The advantages of using tank bioreactors, the higher costs of which restrict their use to the bio-oxidation of high-grade ores and concentrates [6] are: more homogenous reacting mass, better control of the main process variables such as pH and temperature, resulting in the high rate bioleaching of minerals, a better performance, and much shorter turnover times (the times required for mineral processing to be effectively completed). As a result, parameters such as volumetric productivity and degree of extraction can be significantly increased [7–10]. Stirred tank reactors (STRs) are also favorable mass transfer devices providing a large gas–liquid interfacial area and high shear stress to enhance the mass transfer [11].

On the other hand, in the STRs, high pulp densities negatively affect both extraction rate and final recovery of metals. Some downsides of the STRs are as follows: oxygen and carbon dioxide availability, low bacteria–solids ratio, metabolic stress by high shear stress and abrasive conditions, inhibition of bacterial attachment, and the build-up of toxic leach products or other detrimental substances (such as some flotation reagents) [12]. However drawbacks the reactors have, they can be greatly compensated by adaptation to high pulp densities and the STR conditions.

Because of simple design and construction, low power input, low shear, good mixing characteristics and high heat and mass transfer, many chemical, petrochemical, mineral processing and biotechnological industries are using the airlift reactors [13–15]. In these reactors, owing to a pressure gradient due to gas retaining in the riser and the down-comer, the fluid flows from the bottom of the down-comer towards the riser, creating liquid velocity and mixing. In the airlift bioreactors, there is a complex connection between solids loading and mechanical stress for three-phase (solid–gas–aqueous) systems. Low solids loadings of about 2% seem to reduce particle stress whereas high solids loadings of up to 10% cause higher mechanical stress compared to two-phase mode [14].

Practically speaking, selection and design of a bioleaching reactor is driven by the physical, chemical and biological properties of the leaching system. Design is further complicated by the multiphase nature of the pulp, consisting of an aqueous solution with cells adhering to the mineral in suspension, and also a suspended solid and air bubbles [7,16].

Two important parameters that significantly affect a bioleaching process are: type of culture used in the process and mineralogical properties of copper sulphides [4]. Copper extraction from combined flotation concentrate and smelter dust has been studied [5]. The results of the study revealed that it is possible to efficiently extract copper from the combined using STRs at 50 °C inoculated by moderately thermophilic bacteria [5].

Most secondary copper sulphides, such as chalcocite, digenite, bornite and covellite, can be bioleached successfully at 35–45 °C, using mesophilic bacterial cultures [17]. However, the bioleaching of chalcopyrite is still a major challenge due to relatively slow kinetics and poor extractions [4,5,12], which have mainly been attributed to passivity [18–22].

Thus, the second question is: can mesophilic microorganisms enhance the rate of dissolution of the combined as moderately thermophilic bacteria do?

All in all, the present study was conducted to comparatively evaluate bioleaching process for copper recovery from mixed samples containing 50% metallurgical dusts and 50% flotation concentrate using mixed mesophilic and mixed moderately thermophilic bacteria in both stirred and airlift tank reactors.

2. Materials and methods

2.1. Bacterial cultures

Two types of mixed cultures were used in the bioleaching tests. The first one contained strains of *Acidithiobacillus ferrooxidans*, *Acidithiobacillus thiooxidans*, and *Leptospirillum ferrooxidans*. This culture was previously isolated from the Sarcheshmeh Copper Mine (Iran). The second culture mainly contained strains of *Sulfobacillus (S.) thermotolerans*, *Sulfobacillus. thermosulfidooxidans*, *Acidithiobacillus (At.) caldus*, and *Leptospirillum (L.) ferriphilum* and was originally obtained from the Mintek Company (South Africa).

2.2. Adaptation of the consortia to the combined

Two types of mixed cultures were adapted to the combined flotation concentrate and smelter dust as follows: The mixed culture firstly inoculated to the reactor with 0.01 g/mL of the flotation concentrate and during the next 3 months the solid concentrations was gradually reached up to 0.1 g/mL (final bacterial population $\equiv 8.6 \times 10^8$).

2.3. Bacterial enumeration

Having been taken a fresh sample from the reactors, the sample was directly sent to enumerate free cells in the solution by direct counting using a Thoma chamber of 0.1 mm depth and 0.0025 mm^2 area with an optical microscope (×1500, model: Zeiss-Axioskop 40) (phase contrast microscopy). All analytical measurements were carried out in triplicate for each sample to ensure the reliability of the process. And, every reported point in the figures was averaged over the triplicates of each sample (measurement).

2.4. Reactors

2.4.1. STR

In the STR, the bio-leaching experiments were performed in a batch-operated 3.0 L glass bioreactor (2.0 L worked volume) with a variable speed mixer (SS30 Stuart scientific overhead stirrer, BIBBY, UK), 4 baffles, stainless steel shaft, and two pitched-blade impellers, providing a constant stirring at approximately 300 rpm. The bioreactor thermostated at the desired temperature (for mesophilic and moderately thermophilic tests) by circulating water from a constant temperature bath through the double-wall jacket. Also, air was injected directly to the bottom of each reactor just below the impellers at 1.5 L/min without extra CO_2. A flow-meter was located at the inlet airflow to the reactors (Fig. 1A).

2.4.2. Airlift

In an internal loop airlift reactor, the bio-leaching experiments were accomplished in a 6.2 L glass bioreactor with internal loop. The bio-reactor consisted of two concentric tubes, where the inner tube as a gas-sparged riser was removable draft tube (540 mm × 100 mm), the external tube as a down-comer had dimensions of (800 mm × 102 mm). To maintain the desired temperature, water circulated from a constant temperature bath through the double wall jacket of the reactor. The top and bottom of the reactor was also sealed with a flange made of stainless steel. In addition to a double-wall condenser, the volume of the evaporated liquid (not returned by the condenser) was daily compensated by adding acidified distilled water (pH 1.5). Throughout all the experiments, compressed air from a compressor was fed at 1 L/min per

Download English Version:

https://daneshyari.com/en/article/577644

Download Persian Version:

https://daneshyari.com/article/577644

Daneshyari.com