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Heap bioleaching of chalcopyrite: A review

N. Pradhan *, K.C. Nathsarma, K. Srinivasa Rao, L.B. Sukla, B.K. Mishra

Institute of Minerals and Materials Technology, Bhubaneswar 751013, Orissa, India

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Abstract

Bioleaching is an emerging technology with significant potentials to add value to the mining industries so as to deliver attractive environmental and social benefits to all the associates. Chalcopyrite, $CuFeS_2$, is the most important copper-bearing mineral in the world and unlike many other ores it is known to be recalcitrant to hydrometallurgical processing. The main hindrance to the commercial application of biohydrometallurgical processing of chalcopyrite is its slow rate of dissolution.

In this piece of review work, the microbiological and other important aspects of chalcopyrite heap bioleaching processes are discussed. The modest nutritional requirements of bioleaching organisms may be provided with the aeration of iron- and/or sulfur-containing mineral suspensions in water or the irrigation of a heap, while working in a large scale. This chemolithotrophic metabolism makes the organisms industrially important. The emphasis is given on the biodiversity of microbial community and the factors affecting heap bioleaching. The cost of bio heap leaching in respect of some existing commercially operating heap bioleaching plants is also included. Application of chalcopyrite bioleaching in heap/dump leach processes can potentially result in lower cost and reduced environmental impact in copper production.

Keywords: Heap bioleaching; Chemolithotrophic microorganisms; Chalcopyrite; Copper bioleaching; Thermophilic bioleaching bacteria/archea

Contents

* Corresponding author. Tel.: +91 0674 2584091; fax: +91 0674 2581637.
E-mail address: nilotpala_pradhan@yahoo.co.in (N. Pradhan).

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1. Introduction

Heap and dump leaching offer a number of advantages embracing simple equipment, low investment and operation cost, and reasonable yields over a period of recirculation. The earliest engineering technology used in dump leaching was very basic in nature involving dumping a low-grade (otherwise waste) copper-bearing ore in the form of large rock/boulder into vast mounds and irrigating it with dilute H_2SO_4 to enhance the growth and activities of mineral-oxidizing acidophiles, i.e., primarily iron-oxidizing microorganisms. Copper was precipitated from the metal-rich streams draining out of the dumps by cementation with scrap iron. Later developments on the engineering and hydrometallurgical aspects of biomining have involved the use of thin layer heaps of refractory sulfidic ores (mostly copper, but gold-bearing material) stacked on to water-proof membranes, and the solubilized copper recovered using solvent extraction and electrowinning (SX/EW).

The process permits recovery of copper, zinc and other metals using the catalytic activity of several strains bearing ferrous iron and sulfur-oxidizing chemolithotrophic bacteria (Norris, 1990). Generally speaking, industrial-leaching processes operate with the naturally occurring microorganisms in mine waters and in the ore body. Most of experiments carried out on bioleaching of chalcopyrite are so far carried out in shake flask level. Scale up of such studies to an industrial level requires process development through engineering and process modeling. The ore grade and particle size are the controlling factors while making a choice of leaching process. Rawling et al. (2003) categorized the engineering approaches used in biomining in two broad categories as follows:

1.1. Irrigation-based leaching processes

It can again be categorized depending on the type of resources to be processed as dump leaching, heap leaching and in situ leaching. In dump leaching, waste rock, low-grade ore or concentrator tailings (low grade oxides and secondary sulfides) are leached at the place of disposal. This is a mature and widely used technology. Heap leaching deals with the newly mined/run-off-the-mine (ROM) materials (intermediate grade oxides and secondary sulfides) deposited in the form of a heap on an impervious natural surface or a synthetically prepared pad leached with circulation, percolation, and irrigation of the leaching medium. Primary sulfides like chalcopyrite are suitable for this type of leaching. In situ leaching is employed with abandoned and/or underground mines where the ore deposits cannot be mined by the conventional methods since they are either low grade or of small deposits or both.

1.2. Agitation based leaching processes

This is a stirred tank process involving stirred tank bioreactors. The types of resources or raw materials suitable for this kind of leaching range from intermediate to high-grade ore. Chalcopyrite concentrates are taken in a tank and leached using mechanical agitation. In stirred tank processes, highly aerated and continuous-flow reactors placed in series are used to treat the minerals. From a process-engineering standpoint, the complex network of biochemical reactions encompassed in bioleaching would best be performed in reactors that would allow a good control of the pertinent variables resulting in a better performance.

2. General description of heap bioleaching operations

Heap reactors are cheaper to construct and operate and are therefore more suited to the treatment of lower grade ores. Commercial bioleaching involving the irrigation of waste ore dumps can take place economically, for which it is considered as a low technology process. The metal extraction process may be made much more efficient by the construction and irrigation of especially designed heaps rather than by the irrigation of an existing dump that has not been designed as per the optimized leaching process. While building a heap, ore is piled onto an impermeable base supplied with an efficient leach liquor distribution and collection system. Acidic leach solution is percolated through the crushed ore, and the microbes growing on the mineral surfaces of the heap produce the ferric iron and acid that result in mineral dissolution and metal solubilization. The microbial population operating in natural leaching processes does not really have the characteristics of a pure culture, although environmental conditions