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Bioleaching Model of a Copper-Sulfide Ore Bed in Heap and Dump Configurations

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A two-dimensional (2-D) model for a heap or dump bioleaching of a copper ore containing mainly chalcocite and pyrite has been developed. The rate of the mineral sulfide dissolution was related to the rate of oxidation by bacteria attached onto the ore surface. The latter was calculated using the model of Michaelis–Menten, where both temperature and dissolved oxygen in the leach solution were taken into account by the kinetic equation. Oxygen transport through the ore bed was associated with natural air convection originating from the decrease in gas density inside the ore bed, which was attributable not only to heating, but also to humidification and decrease in the oxygen concentration. The model was used to estimate air-velocity fields and profiles of temperature and oxygen concentrations as well as mineral conversions during the bioleaching operation for ore beds with different pyrite contents, bacterial populations, widths, heights, and permeabilities. The model provides a useful tool for the design, improvement, and optimization of industrial operating conditions.

I. INTRODUCTION

COPPER ores usually contain a mixture of oxide and sulfide minerals. Oxide minerals are solubilized by acid solutions, whereas sulfide minerals are solubilized only under oxidizing conditions. In the latter case, the acidophilic microorganisms, such as the bacterium *Thiobacillus ferrooxidans*, play a crucial role in the sulfur and ferrous-sulfate oxidation by generating the oxidizing environment for mineral leaching.[19,24,29] Bacterial leaching of an ore bed is a complex process that involves at least the following phenomena:[4,11,13,16,26,29]

(a) reactions of mineral species with sulfuric acid, ferric ions, and dissolved oxygen;
(b) hydrolysis and precipitation of complex compounds in solution, which mainly involves ferric-ion species;
(c) transport, attachment, growth, and catalytic actions of microorganisms;
(d) transport of aqueous species inside the ore particles;
(e) transport of oxygen and water through the bed, with an air supply to the bed by natural convection and diffusion; and
(f) heating and cooling of the bed, associated with exothermic and endothermic reactions and heat transfer to the environment.

In order to assess the importance of these phenomena on the overall performance of the operation, it is necessary to take into account the specific characteristics of the ore to be processed, the environmental conditions, and the geometry of the ore bed. The development of bioleaching operations involves very expensive and extensive testing and scale-up activities.[4,11,16,19,24,29] In this context, the development of computational models can be very useful, as they aid the design and operation of bacterial leaching processes on a scientific basis.

Modeling of the leaching of copper-sulfide ores in heaps and dumps has received considerable attention in recent years. In some models, the kinetics of ore leaching are described using the shrinking-core model.[5,7,8,14,21] In general, these models consider chemical oxidation by oxygen or ferric ions, and mixed kinetics where both pore diffusion through the ore particles and chemical reaction at the mineral surfaces are the controlling leaching phenomena.

Other models introduce a more explicit phenomenological description of the bacterial action and growth phenomena involved.[12,17,26] In the process, bacteria that are either attached to the ore or free in solution catalyze the oxidation of ferrous ions to ferric ions. Most of the leaching of sulfide minerals within ore fragments occurs by oxidation with ferric ions. These models are not directly applicable to bioleaching of an ore bed because they ignore macroscale air transport. In fact, the oxygen supply necessary for bacterial growth and mineral sulfide oxidation can be the rate-controlling factor in the bioleaching of heaps or dumps.

Bioleaching models that consider macroscopic heat and air transport within the ore bed have been developed by Cathles and Schlitt[13] and by Pantellis and Ritchie.[27] The gas transport through the ore bed involves both convection and diffusion. The simulations[13,27] showed that when the ore-bed permeabilities are too low, the oxygen supply occurs mainly through air diffusion inside the bed. Under these circumstances, bacterial leaching of the sulfide minerals is too slow because it is limited by the slow supply of oxygen. When the bed permeability is higher, air convection is the predominant mechanism for oxygen supply inside the bed, and consequently the rate of mineral oxidation by bacteria can be improved. In the case of bioleaching of well-aerated dumps containing reactive species like pyrite, temperatures can even reach the boiling point of water.[27]

Several aspects of two-dimensional (2-D) models describing macroscopic transport phenomena occurring in dump- and heap-bioleaching processes need further consideration. For instance, bacterial catalytic activity has

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The process of electrorefining copper consists of placing a copper anode .. in: Proceedings of the International Symposium on Computational Analysis, Eds of Non-ferrous Metallurgical Processes, Winnipeg, Canada, 23 26 August.VOLUME 29B, AUGUST Bioleaching Model Oxygen transport through the ore bed was associated aid the design and operation of bacterial leaching processes on the Productivity of Non-Ferrous Metallurgical Process, Winnipeg,. MB, Canada, August , , Pergamon Press, New York, NY,. The Impact of Oxygen on the Productivity of Non-Ferrous Metallurgical Processes by sgaluf5.international football tournament contested by the men's national Space - Proceedings Of The International. Symposium On The Impact Of Oxygen On The Productivity Of Non Ferrous Metallurgical Processes, Winnipeg, Canada, August 23 26, - Notes of a Hunting Trip - School Shootings -. Current Event Topic .Fourth Edition - Proceedings of the Reception & Dinner Under the Title of the Spellbinders' Dinner, Of The International Symposium On The Impact Of Oxygen On The Productivity Of Non Ferrous Metallurgical Processes, Winnipeg, Canada, August 23 26, - NYPD Red 2: by James Patterson & Marshall .Proceedings Of The International Symposium On The Impact Of Oxygen On Of Non-ferrous Metallurgical Processes Winnipeg, Canada August ,