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Flow Behaviour and Mass Transfer Simulation during Bioleaching of Zinc from Sphalerite

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ABSTRACT: Bioleaching is reffered to mobilization of the ions from ores with using biological oxidation reactions. Generally, This method is used to extract valuable metals such as copper, zinc, nickel and gold from complex, resistant, low grade and less pure ores. In these decades, There has been increased attention to bioleaching, because of its less cost and being environmentally friendly. In this study some of the most important researches about bioleaching have been collected. Finally it is propsed to carry out the bioleaching with using Souza's mixed method in column reactors with high air inlet velocity, while there should be a care about safety of the microorganisms.

Keywords: Bioleaching; Simulation; Sphalerite; Zinc extraction

INTRODUCTION

Traditionally, zinc was produced from ZnS or sphalerite using RLE method. During that process SO_2, that is unwanted for the enviroment was produced. Direct Atmospheric Leaching and pressue leaching are two newer methods with a similar approach, except that pressure leaching is caried out under high pressure. In both processes zinc is leached by two reactions, once with ferric ions (Fe^{3+}) and simultaneously during the reaction with H_2SO_4. Required ferric is produced via reaction of ferrous ions (Fe^{2+}) with H_2SO_4 and oxygen (Svens et al.,2003). Using these processes there is no more SO_2 produced and so they are more enviromentally friendly; But they are not still economical, because of oxygen consumption that is relatively an expensive material. Also elemental sulphur produced is impure and so is not easily usable. In order to overcome these limitations bioleaching was proposed. Accually some special bacteria have the ability to oxidize elements such as iron and sulphur. In this process iron is oxidized with these bacteria to produce ferric ion and sulphur is oxidized to produce acid. So sulphur would be used during the process again. Also gasous oxygen is not required because the bacteria would carry out the Fe oxidization and they just need air to respire. However this mechanism is slower than chemical leaching using acid. Equations 1-4 show the reactions (Mousavi et al.,2009).

$$2\ FeSO_4 + 0.5\ O_2 + H_2SO_4 \xrightarrow{bacteria} Fe_2(SO_4)_3 + H_2O \quad (1)$$
$$Fe_2(SO_4)_3 + ZnS \longrightarrow 2FeSO_4 + ZnSO_4 + S^0 \quad (2)$$
$$S^0 + 1.5\ O_2 + H_2O \xrightarrow{bacteria} H_2SO_4 \quad (3)$$
$$ZnS + 0.5\ O_2 + H_2SO_4 \longrightarrow ZnSO_4 + H_2O + S^0 \quad (4)$$

In this paper several important studies about bioleaching of zinc have been gathered and conclusions were proposed.

RESULTS AND DISCUSSION

Proposed a combined technique for bioleaching in two steps: Partial bioleaching of zinc concentrate at the first step followed by chemical leaching of the residue. Using this process less total oxygen was consumed and less elemetal sulphur was produced due to the first step and it took less time to leach the zinc due to the chemical leaching step. It was also found that more zinc was extracted due to the two step process (Souza et al., 2007).

Mousavi et al. developed a CFD model for the flow bihaviour and mass transfer around a single sulphide particle and chose the numerical finite volume method to solve the corresponding conservation equations. They assumed that the sulphide particle is at a fixed point and air flows upward and the bacterial bioleaching solution is fed downward over the sulphide. Because of the two phases involved they also used VOF method to predict the fluid volume fraction in 3D geometry. The results showed that there is significant gradient in the ion concentrations between the surface of the particle and the liquid bulk. Also in high velocity of the inlet air there are symmetric vortices around the particle that could improve heat and mass transfer in the process. figure 1 shows these vortices.

(a) (b)

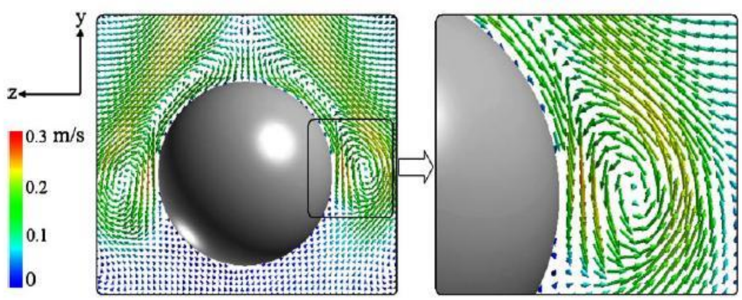

Figure 1. (a) Vector plots of liquid velocity field around single particle in turbulant flow (b) magnified flow field around the particle

Simulated mass transfer and flow behaviour around immobilized microorganism cells with different arrangments. They assumed the cells to be rigid and fixed ellipsoids. The results indicated that turbulency of the liquid flow does not affect the concentration and velocity profile. It was because of sizes of the cells that are in the order of micrometers and so all of the microorganisms are within the laminar viscous layer. Within this sublayer, regardless of the type of the flow the velocity is laminar and the upstream turbulence

does not significantly affect the concentration distribution. They also found that when two cells are arranged behind each other there is more significant concentration profile than the case there are two cells parallel to the fluid flow (Metodiev et al., 2006).

Biooxidation of ferrous ions in a bubble column bioreactor was investigated by Mousavi et al. A CFD simulation was developed assuming the liquid is stationary within entire of the reactor, containing ferrous and bacteria medium and air is injected through the spargers into the liquid. The suggested kinetic model by Nemati and Webb was used to predicti the ferrous biooxidation rate in the bioreactor (Nemati et al., 1998). The inlet air velocity had an optimum value in which the maximum biooxidation rate was obtained. Because lower than this value the gas-liquid interfacial area was low and higher than that, microorganisms damaged and their activity decreased, so biooxidation reaction rate was decreased. It was also observed that at any time the maximum bioxidation rate can be obtained in the center region of the column, because of higher air volume fraction and at top of the reactor, because of coalescence of the bubbles and domination of gas–liquid mass transfer. figures 2 and 3 indicate air velocity and volume fraction profile vs. radial distance and ferrous concentration distribution from bottom to top, respectively through the reactor (Mousavi et al., 2009).

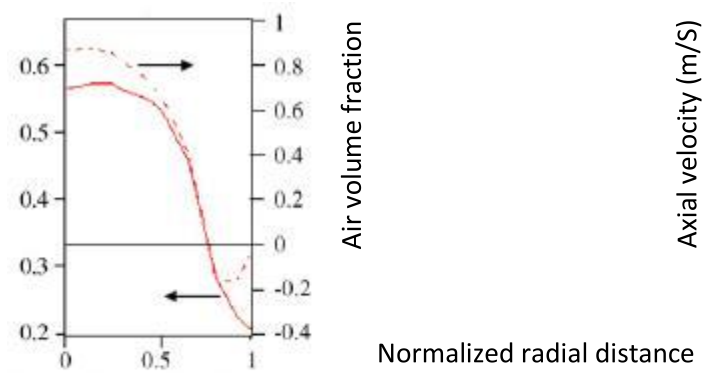

Figure 2. 2D plots of velocity and air volume fraction vs. normalized radial distance in 15 cm from the bottom of the column at t = 120 s

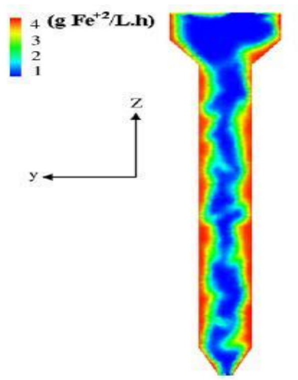

Figure 3. A snapshot of ferrous bioxidation rate in the bioreactor at 120 s and inlet air velocity of 0.1 m/s

Figures

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Figure 2	2D plots of velocity and air volume fraction vs. normalized radial distance in 15 cm from the bottom of the column at t = 120 s
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Abbreviations

CFD	Computational fluid dynamics
RLE	Roasting, Leaching and Electrolysis
VOF	Volume Of Fluid

CONCULSION

Several important studies about bioleaching of zinc from sphalerite were investigated. Bioleaching because of using bacteria is a slow process and a mixed bioleaching- chemical leaching can be carried out faster than just bioleaching, while it will take the bioleaching advantages. Also more zinc recovery has been observed. So far CFD simulation has allowed engineers to have insights in the biological phenomena such as bioleaching. Simulations showed that in bioleaching with flowing air within the reactor, high inlet velocity can improve mass transfer and heat transfer in the case temprature gradient involved, because of turbulancy and better flow mixing. However in very high velocity of the air bacteria can be damaged and biooxidation reaction rate will be decreased. The ferrous biological oxidation depends strongly on the gas–liquid interfacial area, as it was observed in bubble column reactors.

It is proposed to apply Souza's combined biolaching technique in the industry to produce more zinc in optimum condition and in the bioleaching step, to inject the air with high inlet velocity. It should be considered that the velocity not to be that much high to damage the bacteria. The optimum velocity can be obtained by a CFD simulation in the condition of the reactor.

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