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ScienceDirect
Procedia Environmental Sciences 31 (2016) 554 – 559
Procedia Environmental Sciences

The Tenth International Conference on Waste Management and Technology (ICWMT)

Bioleaching of sphalerite by the native mesophilic iron-oxidizing bacteria from a lead-zinc tailing

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Abstract

An isolated native mesophilic iron-oxidizing bacteria, acidithiobacillus ferrooxidans, was used to extract zinc by the bioleaching method from a typical lead-zinc tailing. Experiments were carried out by mixed culture of the mesophilic strain in the shake flasks and the different influencing factors such as pH, temperature, inoculation cell number, as well as slurry concentration on the process of bioleaching were investigated. The results indicated that the extraction efficiency of zinc was relevant with these variables and more than 70% of sphalerite was dissolved on the condition of with pH 2.0, initial ferrous concentration of 10 g/L and slurry concentration of 10wt.% during 25 d, while without bacteria, 22% of Zn was merely extracted.

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Keywords: Acidithiobacillus ferrooxidans; bioleaching; lead-zinc tailing; sphalerite

1. Introduction

As the solid wastes formed by natural dehydrated slurry after mineral separation, lead-zinc tailing usually contains large amount of heavy metals and other toxic substances which will threaten the local environment and impact on the sustainable development of ecosystem[1-2]. Therefore, it is significant to develop simple and environmental-friendly methods to reuse and reducing toxicity of the industrial wastes. Bioleaching is an alternative to traditional physical-chemical methods based on the oxidation of acidophilic bacteria which has the ability to derive the energy from the oxidation to meet with the growth and other metabolic functions of bacteria[3-4], and has gained importance for the extraction of metals particularly from the difficult-to-treat and low grade ores[5-6]. The

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Peer-review under responsibility of Tsinghua University/ Basel Convention Regional Centre for Asia and the Pacific
doi:10.1016/j.proenv.2016.02.085

mechanism can be generally described as follows. During the oxidation of ferrous iron and elemental sulphur with bioleaching process, the reaction energy can be utilized by the acidophilic bacteria which are required for their growth and other metabolic functions (Eq.(1) and(2))[7]. In another word, the bacteria make use of the iron cycle at low pH where the initial ferrous ions were served as electron donor and the ferric irons were used in place of oxygen as an electron acceptor by the sulfur-oxidizing organisms[8]. Meanwhile, the derived products, ferric iron and/or acid, will attack the sphalerite ores and lead to their dissolution (Eq.(3) and(4))[9].

$$2Fe^{2+} + 1/2\ O_2 + 2H^+ \longrightarrow 2Fe^{3+} + H_2O \qquad (1)$$

$$1/8\ S_8 + 3/2\ O_2 + H_2O \longrightarrow 2H^+ + SO_4^{2-} \qquad (2)$$

$$ZnS + 2Fe^{3+} \longrightarrow Zn^{2+} + 2Fe^{2+} + S \qquad (3)$$

$$ZnS + 2H^+ \longrightarrow Zn^{2+} + H_2S \qquad (4)$$

In this study, a native microorganism, acidithiobacillus ferrooxidans, is applied to the bioleaching process of zinc extraction from a local deposit in southern region of Shaanxi province in China containing sphalerite tailings grading nearly 2.3% zinc. The flask tests were done, followed by continuous analytical tests. In addition, some significant factors, such as the effect of residence time, slurry concentration and inoculation cell number on the bioleaching performance were studied under the optimum condition of experiments.

2. Results and discussion

2.1. Mineral characteristics

A representative was obtained from the lead-zinc tailing ore and the cumulative passing fraction of the particles was tested by means of cyclosizer. It found that about 48.2% of core samples was 100 to 80 µm in size (Fig. 1), and was finally ground to particles with size of less than 0.5 µm. Over 80% of the mineral had a particle size of 0.08 µm for the experiment of flask tests.

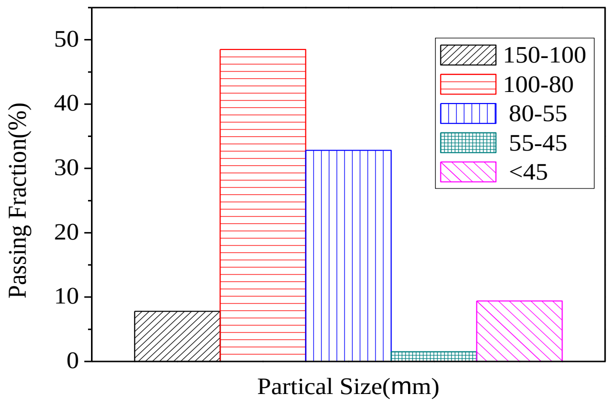

Fig. 1 Size distribution of tailings

Chemical compositions of the sample are presented in Table 1. The X-ray diffraction analysis showed that quartz was the dominate mineral in sample, and chlorite, along with sphalerite as the minor phases.

Table 1. Chemical compositions of the tailings

Zn	Fe	Pb	Cu	SiO_2
2.27	14.92	0.95	0.04	44.54
Al_2O_3	CaO	MgO	MnO	SO_3
12.56	4.18	3.59	1.23	5.04

2.2. Bacterial adaptation and bioleaching

A mesophilic bacterium, iron-sulphur oxidizing bacteria, isolated from the acidic water drainage of the local copper mine, located in Shaanxi province. Biooxidation of ferrous iron ($FeSO_4$•$7H_2O$) was carried out in 250mL Erlenmeyer flasks each containing 100 mL of the medium in a rotary shaker maintained at 150 r/min. The liquid phase was 9 K medium (3.0g/L $(NH_4)_2SO_4$, 0.5g/L K_2HPO_4, 0.1g/L KCl, 0.5g/L $MgSO_4$ • $7H_2O$, and 0.01g/L $Ca(NO_3)_2$)[9]. The bacteria were then incubated at 30℃ and cells were harvested by centrifugation and washed three times in distilled water adjusted to pH 2.0. The bacterial adaptation started by adding 1 g of sample to 90 mL fresh medium and 10 mL cell culture. In each stage of adaptation, cells from the previous stage were used to the next stage, and the process continued until 20 g of tailings sample was added to 100 mL of solution. Bioleaching tests were conducted with 10% inoculum in a rotary shaker at 150 r/min and 30 °C. The progress of the leaching was followed by daily measurement of pH value.

In the preliminary experiment, it was found that more than 40-50% of zinc would be dissolved with initial ferrous concentrations from 10 g/L to 15 g/L in the solution, after 10 d. And it seems that the extraction rate of zinc will not fluctuate with the improvement of initial ferrous concentration in the selected levels. Therefore, the following test was accordingly carried out with the initial ferrous concentration of 10 g/L. Three other key factors, such as pH, slurry concentration and the effect of inoculation cell number, were discussed.

2.3. Effect of pH on bacterial leaching

Effect of pH on the Zn extraction with initial ferrous concentration of 10 g/L was shown in Fig. 2.

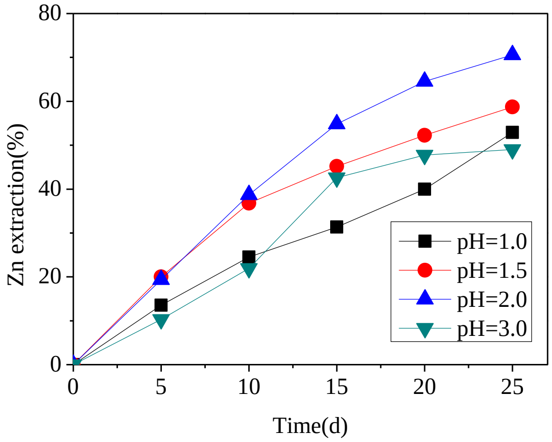

Fig. 2 Effect of pH on bacterial leaching

From the result, it can be seen that with changing of pH from 1.5 to 2.0, Zn extraction efficiency increases from about 54% to 70% significantly, which is expected to get the complete dissolution with pH 2.0 during 25 d. Since the ferrous iron oxidized by acidithiobacillus ferrooxidans will be decreased rapidly when the pH increase, and the formation of ferric iron precipitates is regarded to have an inhibiting influence in the range of pH， therefore the optimum pH for Zn extraction from sphalerite tailings is at pH 2.0.

2.4. Effect of slurry concentration

According to the literature, slurry concentration is the parameter which could dramatically change the metal concentration in the bioleaching solution. If the slurry concentration is too large, accumulations of some metal ions in the solution may exceed the limit of bacterial resistance and affect the growth of bacterial activity in adverse, which will reduce the number of bacteria per unit area, resulting in a decline in leaching efficiency.

The effect of slurry concentration on the Zn extraction for the experiment with initial ferrous concentration of 10 g/L and pH 2.0 was shown in Fig. 3.

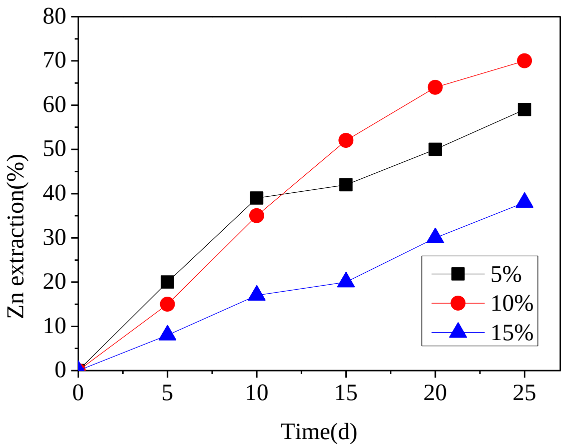

Fig.3 Effect of slurry concentration on bacterial leaching

From the result, it can be seen that the dissolution of zinc was influenced markedly by slurry concentration when inoculating 10% acidithiobacillus ferrooxidans. It showed that the maximum zinc dissolution extraction was achieved to nearly 70% when the slurry concentration is of 10% at pH 2.0, initial ferrous concentration of 10 g/L, after 25 d.

2.5. Bioleaching in presence and absence of the bacteria

Bioleaching curve of zinc extraction in the presence and the absence of acidithiobacillus ferrooxidans (30°C, 10% slurry concentration) were shown in Fig.4.

From the result, it can be seen that in the control test (in the absence of bacteria), 22% of Zn was merely extracted, whereas in bacterial leaching zinc extraction reached 70% after 25 d, which means that the addition of bacteria in the leaching process improved Zn extraction efficiency by up to 48%.

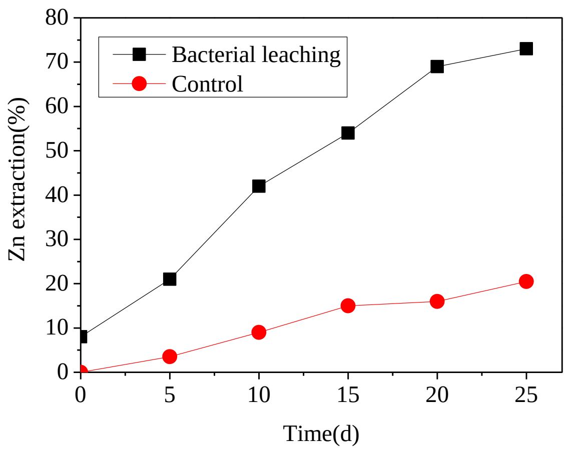

Fig.4 Bioleaching in presence (or absence) of bacteria

2.6. Effect of inoculation cell number on bacterial leaching

The effect of inoculation cell number on the Zn extraction for the experiment with slurry concentration of 10% and pH 2.0 were shown in Fig. 5.

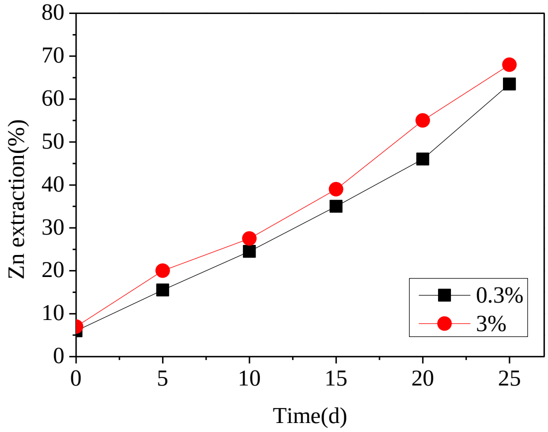

Fig. 5 Effect of inoculation cell number

From Fig.5, it can be seen that the dissolution of zinc was marginally influenced by inoculation cell number and the maximum zinc extraction was achieved when the inoculation cell amount is 3%. However, it should be mentioned that during the last several days of leaching, Fe extraction rate was improved obviously. The results showed that after 20 d of bacterial leaching, about 67% sphalerite was leached out, and with increasing the leaching time to 25 d, Zn extraction rate was improved only 3%, while within the last 5 d of leaching the Fe extraction rate was nearly from 3% up to 7%. Therefore, the tailing solution was dissolved in mixture of bacteria and lasted for less than 25 d of bacterial leaching, and about 70% of Zn was extracted in the bioleaching of tailings.

Meanwhile, other parameters such as redox potential and bacterial medium were discussed in the bioleaching process and did not show significant effect on the Zn dissolution in the selected levels.

3. Conclusion

Bioleaching results showed that the maximum zinc recovery was achieved using a mesophilic culture. Zinc extraction reached 70% for sphalerite in the bioleaching of tailings when the optimum condition was at pH 2.0, initial ferrous concentration 10 g/L, inoculation cell amount 3% and slurry concentration 10%, after 25 d, respectively.

Acknowledgements

This work is supported by the Shaanxi Key Laboratory of Comprehensive Utilization of Tailings Resources, China (Grant No. 2014SKY-WK005 & 2014SKY-WK008) and the Science and Technology Planning Project of Shangluo City, Shaanxi Province, China (Grant No. SK-2013-5).

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