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Catalytic Effect of Activated Carbon on Bioleaching of Enargite Concentrate

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Abstract

Catalytic effects of activated carbon (AC) on bioleaching of enargite concentrate were evaluated. In bioleaching using moderately thermophilic mixed bacterial cultures at 45ºC, addition of 0.1-0.2% AC positively affected Cu recovery (46-53% at day 60), compared to AC-free mixed cultures (36% Cu recovery). Whilst increasing the AC density to 0.3% reversely affected the final Cu recovery (35%), its chemical leaching effect was noticeable when compared to cell-free control cultures (11% Cu recovery). Increasing the bioleaching temperature to 70ºC using a thermophilic archaeon promoted the baseline Cu recovery (AC-free cultures) to 67% at day 14 and a slightly positive effect of 0.1-0.2% AC addition was seen with 69-77% Cu recovery. What was commonly found with As behavior at both temperatures was that addition of AC facilitates (at least temporarily 45ºC) As immobilization. In order to stabilize As precipitates to prevent their re-solubilization, further condition optimization is ongoing.

1. Introduction

Although enargite (Cu_3AsS_4), one of the low-grade refractory copper sulfides, is considered as an important copper resource, its refractoriness and As content necessitate development of economically feasible and environmentally friendly techniques.

Bioleaching is considered as one of the promising techniques to overcome this problem and previous studies of high-temperature enargite bioleaching have indeed achieved high Cu recoveries over 90% (Takatsugi et al., 2011). On the other hand, under low-temperature conditions (25-30ºC), Cu recovery remained less than 5% (Sasaki et al., 2010). This large difference in Cu recoveries suggests the necessity of a reaction catalyst to realize high Cu recovery from low-temperature bioleaching.

Although its positive catalytic effect is known for bioleaching of chalcopyrite (achieving > 70% Cu recoveries; Zhang et al., 2007), the effect of AC on enargite bioleaching is yet unclear.

Hence, the utility of AC was examined in this study as a possible catalyst for low-temperature bioleaching of enargite.

2. Materials and Methods

2.1. Mineral

The enargite concentrate used for this experiment was from Peru, containing enargite (Cu_3AsS_4; 37.4%) and pyrite (FeS_2; 47.3%). Elemental composition of the concentrate is as follows: S 39%, Fe 22%, Cu 20%, As 7.1%, Zn 0.39%, Sb 0.32%, Al 0.22%.

2.2. Bioleaching Experiments

Mixed cultures of three moderately thermophilic bacteria and pure cultures of the thermophilic archeaon were utilized for bioleaching experiments at 45ºC and 70ºC, respectively. Bioleaching tests were carried out in 500 mL Erlenmeyer flasks containing 200 mL of heterotrophic basal salts media with 2.0% (w/v) enargite concentrate and 5 mM Fe(II) (as $FeSO_4 \cdot 7H_2O$). Different concentrations of AC (0-0.3% (w/v)) were added as a catalyst. The flasks were incubated shaken at 150 rpm (at 45ºC or 70ºC for 60 or 14 days, respectively). Liquid samples were regularly withdrawn to monitor cell density, pH, solution redox potential (vs. SHE), Fe(II) concentration and total soluble Fe, Cu and As concentrations.

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3. Results and Discussion

3.1. Catalytic Effect of AC at 45°C

While Cu recoveries remained 11-23% in abiotic leaching both without and with 0.3% AC, respectively, enargite dissolution was enhanced in AC-free bioleaching cultures to obtain 36% of final Cu recovery at day 60. This was further improved by addition of increasing amount of AC (46% and 53% Cu recoveries at 0.1 and 0.2% AC, respectively), contributed by the galvanic interaction between enargite and AC.

Increasing the AC density also led to lower redox potential levels during bioleaching, consequently hindering pyrite dissolution and preventing jarosite passivation on the enargite surface. The lower redox potential level was likely caused by Fe(III) reduction coupled with As(III) oxidation on the AC surface as an electron mediator. As a result of As(III) oxidation facilitated by AC, As immobilization was promoted up to 77% by day 40). However, As precipitates were later partly re-solubilized accompanied by initiation of Fe dissolution; final As immobilizations were 34% and 37% at 0.1 and 0.2% AC, respectively.

Although it was possible to prevent As re-solubilization by increasing the AC density to 0.3% (90% of dissolved As was still immobilized at day 60), its Cu recovery was only 35% (equivalent to AC-free bioleaching culture). This was caused by excess reduction of Fe(III) coupled with As(III) oxidation, which was faster than microbial Fe(II) re-oxidation, leading to depletion of Fe(III) oxidant for enargite dissolution.

Based on the above results, the catalytic effects of AC can be summarized as follows: (i) chemically facilitated enargite dissolution via galvanic interaction, (ii) suppressed Fe dissolution via Fe(III) reduction coupled with As(III) oxidation on AC surface, and (iii) enhanced As immobilization resulted from promoted As(III) oxidation. However, excess addition of AC shows inhibitory effect on bioleaching system, consequently resulting in lower Cu recovery.

3.1. Catalytic Effect of AC at 70°C

At 70ºC, AC-free bioleaching cultures significantly improved Cu recovery (67% at day 14) compared to the AC-free abiotic condition (11% at day 14). Addition of AC to bioleaching cultures slightly enhanced enargite dissolution: at day 14, 77 and 69% at 0.1 and 0.2% AC, respectively). Arsenic started to solubilize accompanied by Fe dissolution to show final As immobilization of 68 and 65% at 0.1 and 0.2% AC, respectively). The results showed that (i) bioleaching interaction more critically enhances enargite dissolution at 70ºC than galvanic interaction and (ii) As solubilization cannot be prevented solely by a temperature increase. Based on these observation, further condition optimization is ongoing to enhance enargite leaching at the same time to maximize As immobilization.

4. Conclusion

Catalytic effects of AC on bioleaching of enargite concentrate at 45ºC and 70ºC were evaluated. At 45ºC, 0.1-0.2% AC positively affected Cu recovery (46-53% at day 60), compared to AC-free mixed cultures (36% Cu recovery). Bioleaching at 70ºC promoted Cu recovery to 67% (AC-free cultures) at day 14 despite slightly positive effect of 0.1-0.2% AC addition. Common As behavior at both temperatures was that addition of AC facilitates As immobilization. Further condition optimization is required to achieve selective copper leaching with stably leaving arsenic in the solid phase.

Reference

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