ХИМИЧЕСКИЕ НАУКИ

UDC 669.334.43

Badamgarav Ch.
Master student

Department of Chemical and Biological Engineering
School of Applied Sciences and Engineering

Yumchmaa B.
Master student

Department of Chemical and Biological Engineering
School of Applied Sciences and Engineering

Zolzaya G.
Master student

Department of Chemical and Biological Engineering
School of Applied Sciences and Engineering

Bujinlham T.
Doctoral student

Department of Chemical and Biological Engineering
School of Applied Sciences and Engineering

Chinzorig R.
Assc. Professor

Department of Chemical and Biological Engineering
School of Applied Sciences and Engineering

Erdenechimeg D.
Professor

Department of Chemical and Biological Engineering
School of Applied Sciences and Engineering

National University of Mongolia
Ulaanbaatar, Mongolia

BIOLEACHING OF LOW GRADE COPPER ORE USING IRON OXIDIZING BACTERIA

The commercial application of copper bioleaching, an environmentally-friendly approach for low-grade and secondary mineral resources recycling, has increased worldwide. In this paper is considered the application of iron oxidizing bacteria in biological treatment of resource from mining of copper. The major bacterial species involved in the bioleaching of sulfide ore were isolated from acid mine drainage. The leaching experiments were carried out in shake flasks in mineral salts media inoculated with iron oxidizing bacteria at 10^{o}C and 30^{o}C. The bioleaching tests yielded Cu recoveries are 19.22 and 56.14 respectively.

Key words: *bioleaching, iron oxidizing bacteria, acid mine drainage.*

Introduction

The copper mine industry is facing with the need to process low-grade ores using low-cost technologies to meet global demand unceasingly [1]. In the last few decades, bioleaching was accepted as a green and economical technology for recovering waste ores [2]. Biohydrometallurgy, which uses microorganisms for the extraction of metals from ores, contributed to 22 % copper production in the 2012 through leaching of cupric oxides, chalcocite, covellite and chalcopyrite [3]. The bioleaching microorganisms are mainly sulfur oxidizing and iron oxidizing microorganisms [10]. Most microbiological researches were developed utilizing known these bacteria, either as single strains or in mixed cultures. Among the most important bacteria in the bio-oxidation of minerals are those responsible for producing ferric iron and sulfuric acid required for the bioleaching reactions [11]. Ferric sulfate, a powerful oxidizing agent, chemically oxidizes Cu-sulfides, and sulfuric acid is responsible for proton attack and dissolution of minerals. The dissolution of sulfide mineral is very complex, which could be attacked by Fe3+ in acid solution presented as Eq. 1 [4; 5; 6; 7].

$$CuFeS_2 + 4Fe^{3+} = Cu^{2+} + 2S^0 + 5Fe^{2+} \qquad \text{(Eq. 1)}$$

The temperature has always remained an important factor for supporting the bioleaching efficiency. Therefore influence of temperature in terms of bioleaching efficiency of copper ore with high pyrite content using iron oxidizing bacteria was examined at the 10^0 C and 30^0 C.

Materials and methods

Ore sample composition and pretreatment

Low-grade sulfide ore sample collected from Erdenet mining industry. The ores were grinded and then sieved to gain a sample with <74um diameter. The main mineralogical composition of the primary ore were chalcopyrite, pyrite, covellite, chalcocite, quartz, feldspar, plagioclase, muscovite, chlorite and kaolinite. Element analysis was carried out with inductively coupled plasma-optic emission spectrometry and X ray fluorescence (XRF). The chemical analyze showed that the copper ore contained 0.164 % Cu, 1.92 % Fe.

Microorganisms and growth conditions

Iron oxidizing bacteria was isolated from the leachate of an industrial bio-heap. For the enrichment of the bacterial species from acid mine drainage were used 250 mL Erlenmeyer flasks with

100 mL of the 9K culture medium which contained 3 g $(NH_4)_2SO_4$, K_2HPO_4 0.50 g, KCl 0.10 g, $Ca(NO_3)_2$ 0.01 g, and 44.22 g $FeSO_4 \cdot 7H_2O$ per liter. The pH value was adjusted to 1.80 with 0.1M H_2SO_4. The media with AMD incubated at 150 rpm, 30^oC for 15 days and control was run in parallel. Culture broth of 10 ml was re-inoculated to fresh 9K medium and re-incubated. The most frequently observed colony was semi-spheroidal and smooth-surfaced, Gram negative, rod-shaped, very small (1-2 µm in length), seen in singles or pairs. The obtained concentrate containing more than $1*10^9$ cells/ml bacteria was then used for inoculation in bioleaching experiment.

Bioleaching experiment

Bioleaching experiments were carried out in 250 ml shaker flasks containing 100 ml sterile medium, 2.5 ml inoculated concentrate bacteria and 10 gr low grade copper ore at 10^oC and 30^oC for 30 days. Then the shake flasks were placed into an shaker with rotating speed 170 rpm. The bioleaching experiment were conducted with initial cell density of $6*10^8$ cells/ml and pulp density 10 % (w/v). 5 ml of solution were taken every three days to determine pH, ORP, Fe^{2+}, Cu, Fe in the dissolution systems were measured. The concentrations of dissolved copper ion, ferrous iron and total iron were analyzed by using ICP-OES, phenanthroline spectrophotometry respectively. The ORP, pH was measured using a platinum electrode with a Ag/AgCl reference electrode.

At day 30, the experiment was terminated and the pulp filtered. The residue was washed and then dried.

Result and discussion

Bioleaching experiment carried out to investigate the effect of temperature to dissolution of low grade copper ore by iron oxidizing bacteria. Fig1 shows the variations of pH, ORP, copper and iron dissolution during bioleaching for 30 days. It should be noted that, during the bioleaching experiment, the leaching parameters including total iron, ORP, pH and copper dissolution showed similar trends at 10^oC and 30^oC.

Oxidation reduction potential control

It was well known that the ORP was partially correlated to the proportion of Fe^{3+}/Fe^{2+} species, and had a close connection with the efficiency of low grade copper ore bioleaching. In this work ferrous concentration 10^oC and 30^oC decreased from 8.39 and 6.31g/l at day 6 to 0.02g/l at day 18, during which, ORP in 10^oC and 30^oC increased from 426 and 480mV to 720 and 674mV respectively. The ORP in 10^oC and 30^oC continuously increased to 721 and 769mV in the SIC phase, indicating that iron started to precipitate and inhibit the copper dissolution (Fig 1 a).

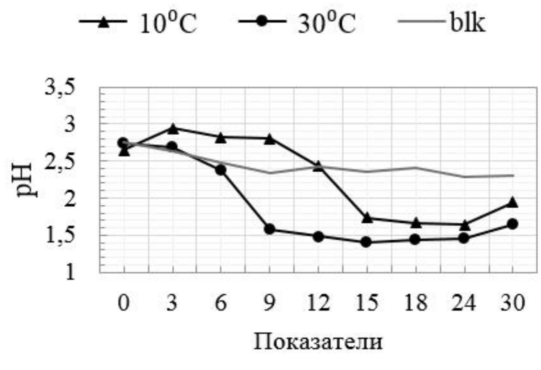
Copper recoveries

Copper recovery was calculated based on the daily Cu production during the 30 days bioleaching period. The effect of temperature on copper recoveries is shown Fig 1 c. Higher temperature increased the Cu leaching efficiency. The final copper recoveries were 19.22 and 56.34 % in the 10^oC and 30^oC.

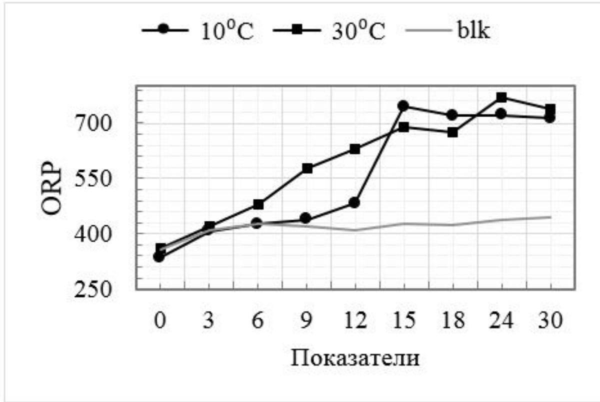
Iron and acid production

The decrease in pH values during bioleaching may mainly result from the oxidation of S^0 [8]. The pH showed a similar decreasing tendency to 1.45 at both temperatures.

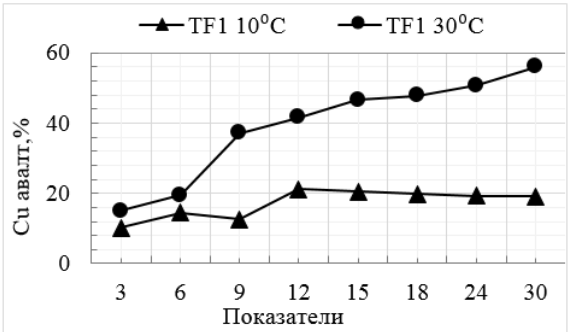
$$2S^0+2H_2O+3O_2=2SO_4^{2-}+4H^+ \qquad \text{(Eq. 2)}$$



a)



b)



c)

Fig. 1. Leaching parameters of low grade ores at 10^0 C and 30^0 C.
Where (a) pH, (b) ORP, (c) copper recovery time curves

For bioleaching the low ORP value can enhance the leaching rate with high amount of ferric ion, while the high ORP value can promote the jarosite precipitation to hinder dissolution.

Conclusion

Bioleaching experiments of low grade copper ore showed that the copper extraction rate at 10^0C and 30^0C were 19.22 % and 56.14 % respectively, indicating that higher temperature can significantly promote bioleaching efficiency.

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Бадамгарав Ч.
магистрант

Кафедра химической и биологической инженерии
Школа прикладных наук и инженерии

Юмчмаа Б.
магистрант

Кафедра химической и биологической инженерии
Школа прикладных наук и инженерии

Золзая Г.
магистрант

Кафедра химической и биологической инженерии
Школа прикладных наук и инженерии

Буйинлхам Т.
докторант

Кафедра химической и биологической инженерии
Школа прикладных наук и инженерии

Чинзориг Р.
доцент

Кафедра химической и биологической инженерии
Школа прикладных наук и инженерии

Эрденечимег Д.
профессор

Кафедра химической и биологической инженерии
Школа прикладных наук и инженерии

Национальный университет Монголии
Улан-Батор, Монголия

БИОЛОГИЧЕСКОЕ ВЫЩЕЛАЧИВАНИЕ НИЗКОСОРТНОЙ МЕДНОЙ РУДЫ С ИСПОЛЬЗОВАНИЕМ БАКТЕРИЙ, ОКИСЛЯЮЩИХ ЖЕЛЕЗО

Коммерческое применение биологического выщелачивания меди, экологически чистого подхода к переработке низкосортных и вторичных минеральных ресурсов, получило распространение во всем мире. В данной статье рассматривается применение бактерий, окисляющих железо, для биологической очистки ресурсов, образующихся при добыче меди. Основные виды бактерий, участвующих в биологическом выщелачивании сульфидной руды, были выделены из дренажа кислых шахт. Эксперименты по выщелачиванию проводились в колбах для встряхивания в среде с минеральными солями, инокулированной бактериями, окисляющими железо, при температуре 10 °C и 30° C. Испытания биологического выщелачивания показали, что извлечение Cu составляет 19,22 и 56,14 соответственно.

Ключевые слова: *биологическое выщелачивание, железоокисляющие бактерии, кислотный шахтный дренаж.*