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BIOLEACHING OF LITHIUM FROM A LITHIUM-BEARING BORATE CLAY ORE USING ACIDOPHILIC IRON-OXIDIZING MICROORGANISMS

Vesna Conić[1a], Yousef Ghorbani[2a], Cora Dawson-Jones[2b], Dragan Milanović[1b], Miloš Janošević[1c], Ivana Jovanović[1d], Dejan Bugarin[1e]

[1] Mining and Metallurgy Institute Bor, Alberta Ajnštajna 1, 19210 Bor, Serbia
[2] School of Natural Sciences, Joseph Banks Laboratories, University of Lincoln, Green Lane, Lincoln, Lincolnshire, United Kingdom, LN6 7DL

[1a] vesna.conic@irmbor.co.rs, https://orcid.org/0000-0002-4268-3626
[2a] YGhorbani@lincoln.ac.uk, https://orcid.org/0000-0002-5228-3888
[2b] 19702144@students.lincoln.ac.uk, https://orcid.org/0009-0004-2437-8515
[1b] dragan.milanovic@irmbor.co.rs, https://orcid.org/0000-0002-5589-9127
[1c] milos.janosevic@irmbor.co.rs, https://orcid.org/0000-0002-0818-1235
[1d] ivana.jovanovic@irmbor.co.rs, https://orcid.org/0000-0002-7450-6632
[1e] dejan.bugarin@irmbor.co.rs, https://orcid.org/0000-0002-5630-8595

Abstract

This study investigates lithium bioleaching from a lithium-bearing borate clay ore using a mixed culture of acidophilic iron- and sulfur-oxidizing microorganisms. Bioleaching was conducted for 60 days under acidic, agitated conditions. The evolution of pH, oxidation-reduction potential (Eh), biomass and lithium was monitored. Lithium extraction increased progressively and reached 94.43% at day 60, while Eh increased from 380 to 565 mV and pH decreased from 2.07 to 1.08. The results demonstrate effective lithium extraction and the potential of bioleaching for sustainable processing of this ore.

Keywords: *bioleaching, lithium, borate clay ore, Acidithiobacillus, sustainable extraction*

1. INTRODUCTION

Lithium is an important critical raw material for rechargeable batteries and energy-storage technologies. The growing demand for lithium has increased interest in alternative resources and lower-impact extraction technologies. Lithium-bearing clay and other complex mineral resources are therefore receiving increasing attention as potential long-term sources [1].

Conventional processing of clay-type lithium resources can involve thermal treatment and acid leaching, which may require substantial energy and reagents. Bioleaching provides an alternative hydrometallurgical approach in which microorganisms facilitate the dissolution and mobilization of metals from solid materials through their metabolic activities. Depending on the microorganisms and mineral substrate involved, metal solubilization may occur via several biogeochemical mechanisms, including acid production, oxidation–reduction reactions, and the generation of metal-complexing metabolites. Among these, acidophilic iron- and sulfur-oxidizing microorganisms play a particularly important role in acidic mineral systems by modifying the chemical environment through iron and sulfur oxidation. *Acidithiobacillus*

ferrooxidans, *Acidithiobacillus thiooxidans*, and *Leptospirillum spp*. are among the microorganisms most frequently associated with iron- and sulfur-driven bioleaching systems. Recent reviews emphasize the roles of acidolysis and redox reactions and the importance of pH, redox potential, pulp density and microbial activity in bioleaching performance [2–4]. Bioleaching and biomining are established microbial-assisted approaches for metal mobilization [5,6].

The present study evaluates lithium bioleaching from a lithium-bearing borate clay ore using a mixed acidophilic culture. Particular attention was given to the relationships between pH, Eh, biomass and lithium extraction during 60 days of operation. The use of acidophilic microorganisms is consistent with established biomining principles [7].

2. EXPERIMENTAL

2.1. Materials and microorganisms

The tested material was a lithium-bearing borate clay ore from a European deposit. The initial lithium content of the ore was 0.09% Li. Prior to the bioleaching experiments, the bacterial culture was progressively adapted to the mineral substrate through successive subculturing. At each adaptation stage, a portion of the active culture was transferred to fresh 9K medium containing the mineral substrate, while the pulp density was gradually increased. The pH and redox potential (Eh) were monitored during the adaptation process to follow changes in the activity and response of the microbial culture to the increasing solid fase (Li ore). With successive subculturing, the culture was able to reach lower pH and higher Eh values within shorter periods, indicating improved adaptation to the mineral substrate. The culture obtained after the third adaptation stage was subsequently used as the inoculum for the bioleaching experiments. The experimental system contained 100 g of ore, 30 g of pyrite and 35.78 g of $FeSO_4 \cdot 7H_2O$. A 100 mL aliquot of the bacterial culture from the third adaptation stage was introduced into a 1000 mL aqueous system initially adjusted to approximately pH 2. The mixed culture consisted of *Acidithiobacillus ferrooxidans*, *Acidithiobacillus thiooxidans* and Leptospirillum ferrooxidans.

2.2. Bioleaching procedure

Batch experiments were carried out in 1 L glass reactors at a solid-to-liquid ratio of 1:10. According to the experimental protocol, the reactors were incubated at 35 ± 1 °C with continuous agitation at 250 rpm for 60 days. Initial pH adjustment required a total of 6.75 mL of 98% H_2SO_4. Pyrite and ferrous sulfate provide iron and sulfur-bearing substrates for the microbial system. The process conditions and leaching approach are consistent with established leaching practice [8]. The nutrient composition used for one-month periods was 9K solution. The supplied data states that the same substrate concentration was added initially and again after 30 days, substrate consumption was not monitored.

2.3. Analytical methods

The pH and oxidation-reduction potential were measured using electrochemical probes. Dissolved lithium and iron were determined by ICP-OES, while microbial biomass was monitored by direct cell counting using a Neubauer counting chamber. Lithium extraction efficiency was calculated from dissolved lithium relative to the initial lithium content. Experiments were conducted in triplicate with abiotic control. The results are presented in section 3 results and discussion.

3. RESULTS AND DISCUSSION

3.1. Evolution of pH and Eh

The experimental data show a continuous shift toward more acidic and more oxidizing conditions. pH decreased from 2.07 at the beginning of monitoring to 1.08 on day 60, whereas Eh increased from 380 to 565 mV. These simultaneous changes are consistent with increasing microbial oxidation activity and establishment of a strongly acidic oxidative leaching environment. The results of the pH and Eh changes during the bioleaching process are shown in Fig.1 and Fig.2, respectively.

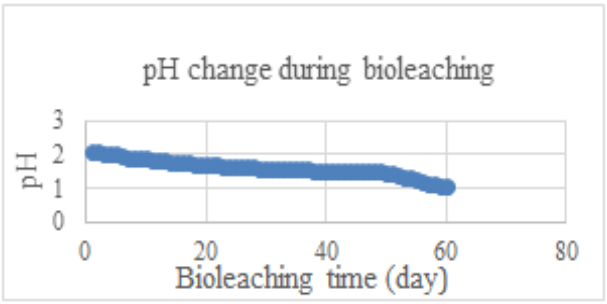


Figure 1. *pH change during Li ore bioleaching*

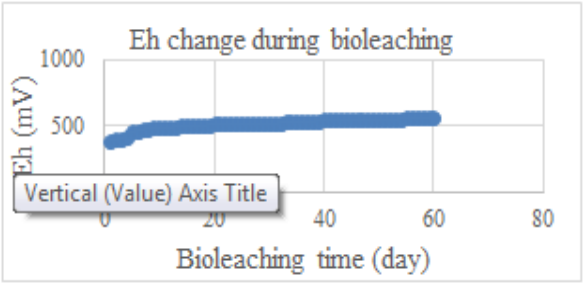


Figure 2. *Eh change during Li ore bioleaching*

3.2. Microbial biomass

Biomass concentration increased progressively throughout the experiment, reaching 4.5 × 10^8 cells/mL by day 60 and presented in Fig.3. This increase coincided with rising Eh and lithium extraction, indicating enhanced microbial activity and intensification of the leaching environment.

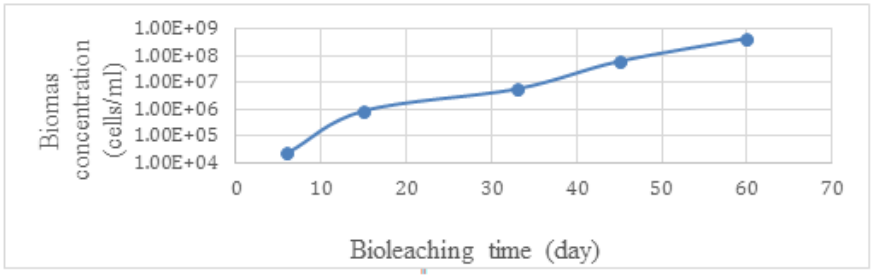


Figure 3. *Biomass concentration during lithium ore bioleaching*

3.3. Lithium extraction

Lithium dissolution increased throughout the monitored period. The final value recovery of Li was 94.43% at day 60. The results of Li recovery during bioleaching process are presented in Fig.4.

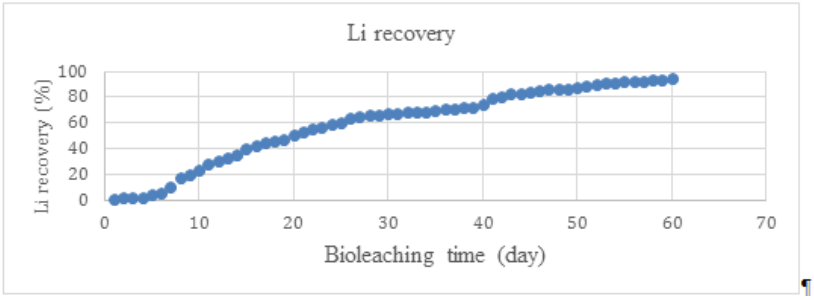


Figure 4. *Lithium extraction efficiency during bioleaching*

The concentration of dissolved iron was also monitored during the bioleaching process, and it was found that the concentration also increased from 21.12% on day 6 to 31.00% on day 60, while the recorded concentration of H_2SO_4 increased from 0.55 to 4.90 g/L. The evolution of iron, acidity, Eh and lithium indicates a progressive development of the leaching system.

4. CONCLUSION

The 60-day bioleaching experiment demonstrated effective lithium mobilization from the investigated lithium-bearing borate clay ore. Lithium extraction increased progressively to 94.43%, while Eh increased from 380 to 565 mV and pH decreased from 2.07 to 1.08. Biomass increased from 2.3 × 10^4 cells/mL at the beginning to 4.5 ×

10^8 cells/mL at day 60. The results support the potential of the mixed acidophilic culture for lithium extraction under strongly acidic and oxidative conditions. Further work will focus on process optimization, kinetic modelling and systematic monitoring of substrate consumption.

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