University of Belgrade
Technical Faculty in Bor,
Mining and Metallurgy
Institute Bor

54th International October Conference on Mining and Metallurgy

PROCEEDINGS

Editors:
Ljubiša Balanović
Dejan Tanikić

18-21 October 2023, Bor Lake, Serbia

PROCEEDINGS,

54th INTERNATIONAL OCTOBER CONFERNCE

on Mining and Metallurgy

Editors:

Prof. dr Ljubiša Balanović

Prof. dr Dejan Tanikić

University of Belgrade, Technical Faculty in Bor

Technical Editor:

M. Sc. Miljan Marković

University of Belgrade, Technical Faculty in Bor

Publisher: University of Belgrade, Technical Faculty in Bor

For the publisher: Dean Prof. dr Dejan Tanikić

Circulation: 200 copies

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

622(082)(0.034.2)
669(082)(0.034.2)

INTERNATIONAL October Conference on Mining and Metallurgy (54 ; 2023 ; Borsko jezero)
Proceedings [Elektronski izvor] / 54th International October Conference on Mining and Metallurgy - IOC 2023, 18-21 October 2023, Bor Lake, Serbia ; [organized by] University of Belgrade, Technical Faculty in Bor and Mining and Metallurgy Institute Bor ; editors Ljubiša Balanović, Dejan Tanikić. - Bor : University of Belgrade, Technical Faculty, 2023 (Niš : Grafika Galeb). - 1 USB fleš memorija ; 1 x 1 x 5 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 200. - Preface / Ljubiša Balanović. - Bibliografija uz svaki rad.

ISBN 978-86-6305-140-9

a) Рударство -- Зборници b) Металургија -- Зборници

COBISS.SR-ID 126659849

Bor Lake, Serbia, October 18-21, 2023

Conference is financially supported by
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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

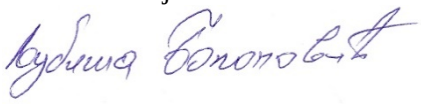
We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,

Prof. dr Ljubiša Balanović



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LEACHING OF FLOTATION TAILINGS WITH A SOLUTION OF SULFURIC ACID AND IONIC LIQUID

Dragana Marilovic[1], Grozdanka Bogdanovic[1], Sanja Petrovic[2]

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Abstract

This paper presents the results of leaching flotation tailings containing 0.13% of copper and 4.22 % of iron. The experiments were carried out in a sulfuric acid solution (H_2SO_4) and an ionic liquid solution 1-butyl-3-methyl-imidazolium hydrogen sulfate ([bmim]HSO_4). Concentrations of the reagents of 0.01 mol/dm^3 and 0.05 mol/dm^3 were tested. When leaching with sulfuric acid, the leaching degree of copper was 71.05% at the lower concentration of solution and 76.59% at the higher concentration of solution. When flotation tailings was leached in an ionic liquid solution with the same concentrations, the leaching degree of copper was 72.57% (for 0.01 mol/dm^3) and 77.10% (for 0.05 mol/dm^3), respectively. The results showed that the leaching rate of copper increased in the first 5-10 minutes of the reaction due to the presence of oxide minerals and then slightly increased with time. The dissolution of iron was <3% under the tested conditions. These results indicate that the ionic liquid 1-butyl-3-methyl-imidazolium hydrogen sulfate ([bmim]HSO_4) can be used as agent for the leaching process of flotation tailings.

***Keywords**: leaching, flotation tailings, sulfuric acid, ionic liquids.*

1. INTRODUCTION

Flotation tailings are a common solid waste in mining production. Most often, they are disposed of in tailings ponds that occur in nature. In this way, undesirable reactions of atmospheric precipitation with pyrite occur, resulting in acid mine drainage that are potentially hazardous to the environment [1,2,3].

Technologies for recovering useful components from such raw materials are used to obtain copper, but also other elements such as iron, zinc, aluminum, chromium, silver or gold [1]. The old flotation tailings pond in Bor has accumulated about 26 Mt of solid waste during the 70 years of operation of the RTB Bor plant [2]. Considering that the copper content in the processed ores varied from 4% at the beginning of the plant operation to 0.6% at the end of the old flotation plant, the copper content in the tailings also varied from 0.5 to 0.1% [3]. In this way, the flotation tailings became a potential raw material for copper recycling.

Sulfuric acid is used as one of the most common reagents for leaching copper from flotation tailings [2,6,7,8,9]. During the leaching process, sulfuric acid is consumed due to unwanted reactions with oxides and carbonates of alkaline earth metals [10]. Although other leaching agents are used in addition to sulfuric acid, as well as bacterial leaching with microorganisms [11], new environmentally friendly reagents are still being tested. Recently, ionic liquids have begun to be applied in this field to obtain metal ions. Ionic liquids are considered a new branch of chemical compounds and a suitable alternative for organic and inorganic solvents. Ionic liquids are recognized as green reagents due to their characteristics such as viscosity, thermal stability, negligible volatility, non-toxicity and high conductivity [12].

Research has shown that ionic liquids with the sulfate group HSO_4^- are most often used for copper leaching from chalcopyrite [13, 14, 15, 16], where the leaching degree is up to 75%, but also from waste PCB boards [12], where the leaching degree is almost 100%.

This paper presents the comparative results of flotation tailings leaching with sulfuric acid and the ionic liquid 1-butyl-3-methyl imidazolium hydrogen sulfate ([bmim]HSO_4).

2. EXPERIMENTAL

Flotation tailings taken from the old flotation tailings pond in Bor was used for the experiments. The chemical composition of the initial sample is shown in Table 1.

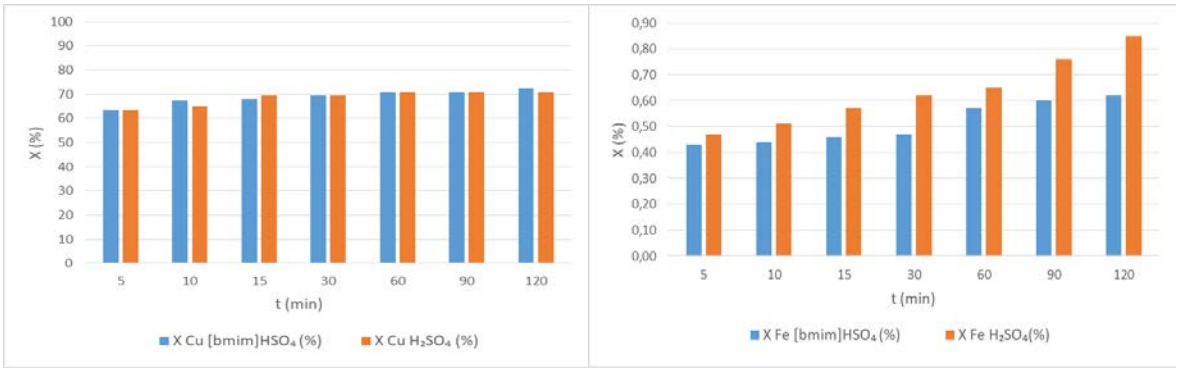
Table 1 - Chemical composition of the flotation tailings

Element	Cu	Cu_{ox}	Fe	Zn	As_{ppm}	Pb	S	SiO_2	Fe_3O_4	MgO	CaO
%	0.13	0.09	4.22	0.01	13.24	0.01	4.70	60.02	0.03	0.48	3.50

All experiments were performed in a 600 cm^3 glass reactor with a magnetic stirrer and adjustable speed. Solutions were prepared with analytical grade chemicals and distilled water. After setting the working parameters, 10 g of raw material was taken and added to 200 ml of a solution of a certain concentration. The stirring speed was 400 rpm. At regular time intervals (5, 10, 15, 30, 60, 90 and 120 minutes) 1 ml of the solution was taken and filtered. The diluted solution was analyzed for copper and iron using a UV-VIS spectrophotometer.

3. RESULTS AND DISCUSSION

Figure 1 shows the results of flotation tailings leaching at a concentration of 0.01 mol/dm^3 of sulfuric acid and the ionic liquid [bmim]HSO_4 as reagents.

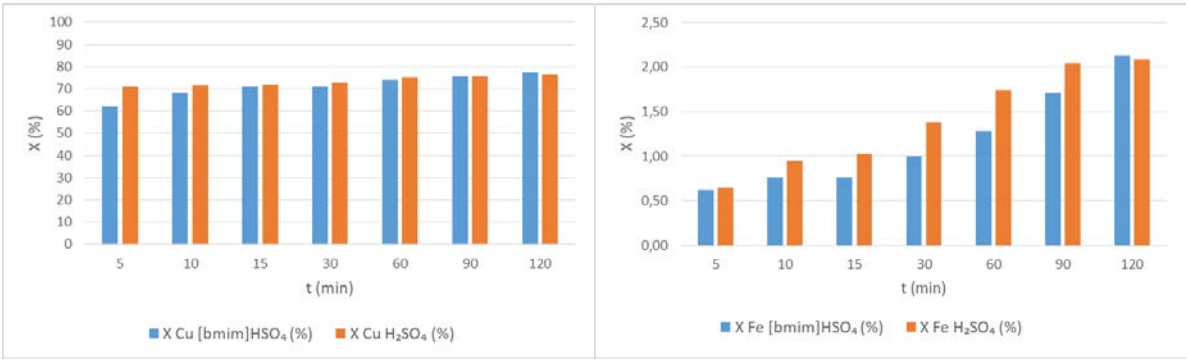


a) **b)**

Figure 1 - Leaching degree of copper (a) and iron (b) in 0.01 mol/dm^3 solution of sulfuric acid H_2SO_4 and 0.01 mol/dm^3 solution of ionic liquid [bmim]HSO_4

The results show that in the presence of 0.01 mol/dm^3 H_2SO_4 solution, the leaching degree of copper after 120 minutes was 71.05%, while the leaching of iron was 0.85%. When flotation tailings was leached in [bmim]HSO_4 solution of the same concentration, the copper leaching degree was 72.57%, while the iron leaching degree was lower compared to leaching with a sulfuric acid solution (0.61%).

The leaching degree of copper in the solution of 0.05 mol/dm^3 H_2SO_4 was 76.59%, while in the solution of 0.05 mol/dm^3 [bmim]HSO_4 it was 77.10% during the leaching time of 120 minutes (Figure 2a). The results obtained clearly demonstrate the rapid leaching kinetics of copper minerals. Approximately 70 % of copper is efficiently leached within the initial 5-10 minutes. This can be attributed to the high presence of copper oxides in the initial sample, which readily undergo leaching. Furthermore, it is evident that under all tested conditions, the dissolution decreases after the initial leaching period.



a) **b)**

Figure 2 - Leaching degree of copper (a) and iron (b) in 0.05 mol/dm^3 solution of sulfuric acid H_2SO_4 and 0.05 mol/dm^3 solution of ionic liquid [bmim]HSO_4

With increasing reagent concentration, the leaching of iron in the sulfuric acid solution was 2.09%, while it was 2.13% in the ionic liquid solution (Figure 2b).

Based on the results, it can be said that [bmim]HSO_4 shows similar behavior as H_2SO_4 in the leaching of flotation tailings. The dissolution of copper under tested conditions is slightly affected by the concentration of leaching agents, since the difference in the leaching degree at five times higher acid concentration is approximately 5%. However, it can be assumed that a higher concentration of reagents is necessary to enhance the dissolution of copper. It can also be concluded that ionic liquids can replace sulfuric acid as an environmentally friendly reagent and be used in the process of copper leaching from flotation tailings when economically justified.

Similar results were obtained by Carlesi et al. [14]. The authors studied the leaching efficiency of chalcopyrite concentrate with a solution of the ionic liquids [bmim]HSO_4 and [hmim]HSO_4 (1-hexyl-3-methyl imidazolium hydrogen sulphate) and H_2SO_4 solution at room temperature. The difference in copper concentration in the solution was negligible. Better results were obtained when leaching with [bmim]HSO_4 and [hmim]HSO_4 solutions at a higher temperature (60 °C). This temperature effect may be related to physicochemical properties that affect mass transfer and the rate of chemical reaction. The mechanism of copper dissolution with ionic liquids proposed by authors [17,18] is based on dissociation of hydrogen sulfate anions from the ionic liquid, so that the leaching results are consistent with those obtained when leaching in a sulfuric acid solution.

4. CONCLUSION

In the paper, the leaching of copper and iron in aqueous solutions of sulfuric acid and the ionic liquid [bmim]HSO_4 by the agitation leaching process was studied. Although there is a difference in the copper leaching degree in sulfuric acid solution and in ionic liquid solution, the difference is negligible. At a reagent concentration of 0.01 mol/dm^3, the copper leaching degree was 71.05 and 72.57% for sulfuric acid and ionic liquid, respectively. At the higher tested concentration of 0.05 mol/dm^3, the copper leaching degree was 76.59 % for the sulfuric acid solution and 77.10% for the ionic liquid solution. The obtained results suggest that ionic liquids can replace sulfuric acid as an environmentally friendly reagent and can be used in copper leaching from flotation tailings.

ACKNOWLEDGMENTS

The research presented in this paper was done with the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, within the funding of the scientific research work at the University of Belgrade, Technical Faculty in Bor, Grant No. 451-

03-47/2023-01/200131 and Mining and Metallurgy Institute Bor, Grant No. 451-03-47/2023-01/200052.

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