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# XVI International Mineral Processing & Recycling Conference

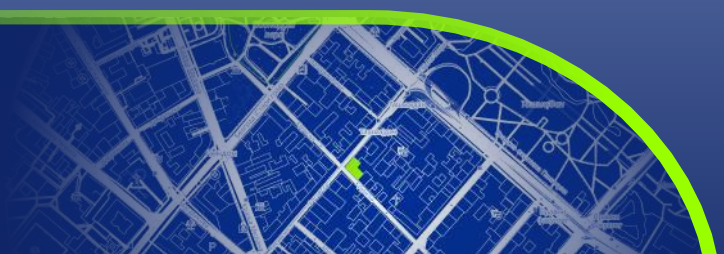
# 2025 IMPRC

INTERNATIONAL MINERAL PROCESSING & RECYCLING CONFERENCE

# Proceedings

Editors:
Zoran ŠTIRBANOVIĆ
Milan TRUMIĆ

28-30 May 2025
Belgrade, Serbia



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XVI International Mineral Processing and Recycling Conference
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# EFFECT OF TEMPERATURE ON THE LEACHING COPPER FROM FLOTATION TAILINGS WITH IONIC LIQUID

**Dragana Marilović,** 0000-0001-8301-750X,
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**ABSTRACT** – Flotation tailings of copper ore contain a high concentration of valuable metals such as copper, gold and silver. Minerals are mainly found in the form of oxides and less in the form of sulfides that have not been separated by flotation concentration. Recovering these valuable resources would reduce the environmental impact and increase the economic benefits. Compared to sulphide ores and minerals, the presence of oxidising agents is generally not required for the leaching of raw materials rich in oxides. This paper presents the results of the study the influence of temperature on the copper leaching degree from flotation tailings by ionic liquid solutions of different concentrations. Based on the results obtained, it was found that increasing the leaching temperature significantly affects the leaching efficiency. After 120 minutes of leaching at 70°C, a copper leaching degree of 99.7% was achieved at lower ionic liquid concentration than at ambient temperature.

**Keywords:** Leaching, Flotation Tailings, Ionic Liquid, Copper, High Temperature.

## INTRODUCTION

Copper is produced mainly from sulfide ores and usually occurs together with iron in a variety of minerals. Flotation tailings is a raw material consisting mainly of oxides and less of sulfides. Considering the fact that natural resources of rich sulphide ores are becoming increasingly depleted, the processing of secondary raw materials is becoming more important [1]. These particular raw materials are known for their low copper content, quick oxidation, an extremely fine particle size and complex copper phase composition [2]. The complexity creates challenges in their extraction, turning them into a difficult resource to process. Due to its composition, flotation waste, when disposed of in nature, contributes to the formation of acid mine drainage (AMD), which can pose a risk to the environment. In recent years, handling complex copper oxide raw materials has become as a significant and challenging issue for researchers in mining and metallurgy. The studies of flotation tailing leaching indicate that these raw materials have many impurities including silicate, iron and calcium which influence the quality of the product [3-5]. The hydrometallurgical method is an eco-friendly option, which includes processes like sulfuric acid leaching and chloride leaching with oxidants or ammonia

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leaching with oxidants. Leaching with acid leaching agents, the impurities, especially iron can easily be dissolved [6].

Sulphuric acid leaching has advantages such as a higher copper extraction rate, lower environmental impact and lower energy requirements.

Newer generation reagents, such as ionic liquids (ILs), are increasingly taking the leading position in the leaching of mineral raw materials. Their application has been reported for mineral leaching, solvent extraction and electrochemical processes, showing that these compounds can play an important role in the recovery and purification of high-value metals from raw materials [7, 8].

Ionic liquid 1-butyl-3-methylimidazolium hydrogen sulfate ([bmim]$HSO_4$) was used as a leaching agent due to its advantages such as water solubility, low cost, environmentally safe and easy availability. Previous research has reported that [bmim]$HSO_4$ acts as an acid in the aqueous solutions [9-11].

Hydrogen ions, released from ionic liquid, along with dissolved oxygen, are important for the oxidative leaching of sulfide minerals. Compared with traditional acid solutions, [bmim]$HSO_4$ and its aqueous solutions showed higher efficiency at higher temperatures, which was attributed to increased oxygen solubility and improved transport of dissolved oxygen, accelerating the oxidation reaction [12].

This paper was focused on copper leaching with different concentration of ionic liquid [bmim]$HSO_4$ from a low-grade flotation tailing at a high temperature.

## EXPERIMENTAL AND METHODS

For the experiments flotation tailings samples with the chemical composition showed in Table 1 were used.

**Table 1** Chemical composition of copper flotation

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

Based on the obtained qualitative mineralogical analysis, the following mineral composition was determined: Pyrite, Covellite, Chalcopyrite, Limonite, Rutile, Silicates, Quartz and Carbonates.

The leaching experiments were performed with an ionic liquid, 1-butyl-3-methylimidazolium hydrogen sulfate solution ([bmim]$HSO_4$) without oxidising agent at ambient temperature and at 70 °C. A 600 $cm^3$ glass reactor with a magnetic stirrer was used for the experiments. Once the operating conditions were established, 10 g of tailings were added to 200 ml of a solution with a specific concentration. The stirring speed was set to 400 rpm. At predetermined time intervals (5, 10, 15, 30, 60, 90 and 120 minutes), samples of 1 ml were taken and filtered. The concentration of copper and iron in the diluted samples was determined using optical emission spectrometer with inductively coupled plasma (ICP-OES Optima 8300; Perkin Elmer) and a multiparameter photometer Hanna HI 83200. This paper was focused on copper leaching with different concentration of ionic liquid from a flotation tailings at a high temperature.

## RESULTS AND DISCUSSION

### Influence of [bmim]$HSO_4$ concentration on the copper leaching degree at ambient temperature

The effect of [bmim][$HSO_4$] concentration on the copper leaching degree is shown on Figure 1. The leaching experiments at ambient temperature were done using three ionic liquid concentration 0.001, 0.1 and 1 mol/dm$^3$.

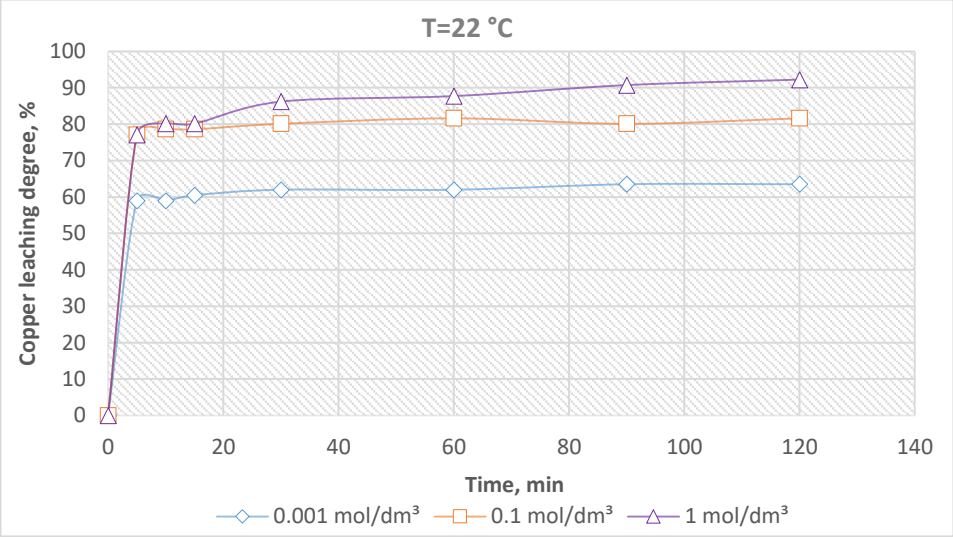


**Figure 1** Effect of [bmim][$HSO_4$] concentration on copper leaching degree at ambient temperature, agitation speed 400 rpm, S:L ratio 1:20

The results show that the copper leaching rate is very rapid at ambient temperature in the initial leaching time for all concentrations of ionic liquids. The observed is probably due to the fact that the copper is predominantly in the oxide form. After the initial leaching of easily soluble copper oxide minerals, leaching of copper sulphide minerals begins, which can be observed during leaching with 0.1 mol/dm$^3$ and 1 mol/dm$^3$ [bmim][$HSO_4$]. With increasing duration of leaching, dissolution of copper minerals occurs at a lower rate for all concentrations of ILs studied.

The leaching of flotation tailings at ambient temperature using the lowest reagent concentration of 0.001 mol/dm$^3$ resulted in a copper leaching degree of 63.4% after 120 minutes of process time. Increasing the concentration of the ionic liquid to 0.1 mol/dm$^3$ increased the copper leaching degree up to 80%, while the highest concentration examined of 1 mol/dm$^3$ achieved a copper leaching degree of 90% in the same period. For all concentrations, no significant changes in copper leaching degree were observed after 90 minutes.

These results suggest that higher reagent concentrations are required to achieve higher copper recovery from flotation tailings at ambient temperature. Other authors [9] conducted experiments with a sample containing copper mainly in metallic form under conditions similar to those used in this work. The copper leaching degree they achieved without oxidants was less than 30%.

**Influence of [bmim]$HSO_4$ concentration on the copper leaching degree at 70 °C**

The effect of ionic liquid [bmim][$HSO_4$] concentration (0.001, 0.01 and 0.1 mol/$dm^3$) on the copper leaching degree at 70 °C is shown in Figure 2.

Figure 2 shows that the copper leaching degree increases with the increase in [bmim][$HSO_4$] concentration. The copper leaching rate from the tailings is highest during the leaching time of about 10 minutes due to the dissolution of the copper oxide minerals. The copper leaching degree ranges from 61% (0.001 mol/$dm^3$) to 79% (0.01 mol/$dm^3$ [bmim][$HSO_4$]). With a further increase in leaching time, leaching of the tailings occurs at a slower rate at [bmim][$HSO_4$] concentrations of 0.001 and 0.01 mol/$dm^3$. A greater influence of the ionic liquid at higher temperatures is observed in the leaching of tailings with 0.1 mol/$dm^3$ [bmim][$HSO_4$]).

At the lower reagent concentration (0.001 mol/$dm^3$) temperature does not significantly affect the leaching process and the copper leaching degree remained the same (63.49%). It can be because of the low ionic liquid concentration which shows that there may not be enough leaching agents to significantly affect the mineral dissolution kinetics even at high temperature.

When flotation tailings was leached with an ionic liquid solution concentration 0.01 mol/$dm^3$ a copper leaching degree of 78% was achieved. At the highest examined reagent concentration of 0.1 mol/$dm^3$, a copper leaching degree of 99.7% was achieved which indicates that copper sulphide minerals are also leaching. The final concentration of copper in pregnant leaching solution was 64.8 mg/$dm^3$. Comparing these results with those obtained at ambient temperature, it can be concluded that temperature has a significant impact on copper leaching. Higher recovery was achieved at a lower reagent concentration under high temperature conditions than at a higher concentration at ambient temperature.

Temperature significantly affects the process of copper leaching from primary and secondary raw materials, as an increase in temperature can improve the kinetics of mineral dissolution, increase the solubility of minerals and reduce the viscosity of the solution, which facilitates the diffusion of ions [13]. When studying the leaching of chalcopyrite by ionic liquids at higher temperatures, the authors found that the rate of chemical reaction almost doubles with every 10°C increase in temperature. It is assumed that this is due to the fact that sufficient activation energy is supplied to the molecules in this way to increase the kinetics of the reaction [14].

Research has shown that higher temperatures accelerate the leaching of copper from certain minerals. Earlier research concluded that the leaching of copper from minerals

with sulfuric acid is most affected by temperature, then particle size, concentration of reagents, leaching time and at the end agitation speed [2].

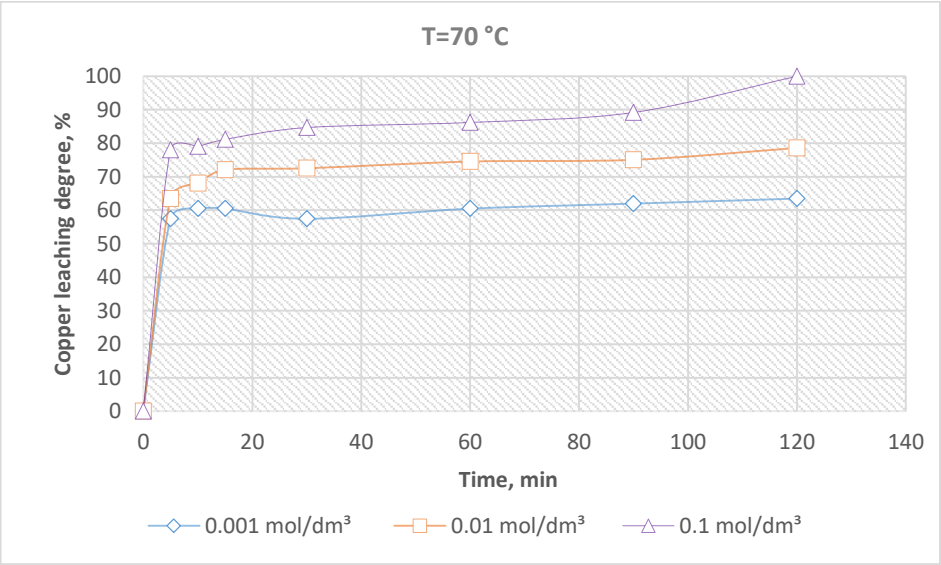


**Figure 2** Effect of ionic liquid concentration on copper leaching degree at 70°C, agitation speed 400 rpm, S:L ratio 1:20

## CONCLUSION

This paper shows the influence of temperature on the copper leaching degree from flotation tailings. Leaching experiments were done with ionic liquid different concentration at ambient temperature and high temperature without the presence of oxidizing agents. Based on the obtained results, it was found that the temperature has a significant influence on the leaching of copper from the flotation tailings.

The highest copper leaching degree of at room temperature was achieved at 1 mol/dm$^3$ [bmim][$HSO_4$] and was 92.2% after 120 minutes of leaching. When leaching at a temperature of 70°C, a lower concentration of leaching agent (0.1 mol/dm$^3$) is required to transfer the copper present almost quantitatively into the solution.

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