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# Optimization of Effective Parameters on Copper Bioleaching from Low-Garde Sulfide Ore from Shahrbabak Copper Complex

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## 1. Introduction

In recent years, attention has been paid to the recovery of metals from low-grade mines, the sustained production processes, used catalysts, slag and dusts from production processes. Due to the relatively low grade of metals in these secondary sources, hydrometallurgy is often used. Microbial leaching processes are particularly suitable for the processing of secondary copper sulfides such as chalcocite ($Cu_2S$), digenite ($Cu_9S_5$), bornite ($Cu_5FeS_4$), and covellite (CuS). Common mesophilic bacteria in copper sulfide leaching are Acidithiobacillus Ferrooxidans (T.f), Acidithiobacillus Thiooxidans (T.t) and Leptospirillum Ferrooxidans (L.f). Several important parameters including temperature, pH, nutrients, pulp density, sulfide minerals, $O_2$ and $CO_2$, and metal toxicity affect bioleaching of copper. These parameters affect the process and ability of bacteria in recovery of metals. On the other hand, the use of the design of experiments (DOE) method with the help of software engineering to examine and model the microbial leaching process will allow the interactions of the effective parameters in the process to achieve the best conditions for achieving the highest level of the copper leaching. It should be noted that in the usual methods, only one parameter is optimized separately, but in this method, the parameters are simultaneously examined and the possibility of evaluate their interactions is possible. In this research, the effective parameters on bioleaching of copper from low grade copper-sulfide ore from Shahrbabak copper complex were investigated using DOE.

## 2. Experimental

Two types of bacteria T.f and T.t were used for microbial leaching experiments. The microorganisms used in this study were prepared from the microorganisms' bank of the Shahrbabak copper complex. To conduct microbial leaching experiments, it is necessary that each microorganism grows in its own culture medium and produces acid. Copper leaching was analyzed by Atomic Absorption Spectrometer (AA spectrometer, UNICAM939). The X-ray Fluorescence (XRF, ARL Optimax) was used to determine and measure the amount of elements in the mineral sample. In order to identify the phases, X-ray diffraction (XRD, Philips-X'pert model) was used. After adaptation, bioleaching process tests were performed in 500 mL Erlenmeyer containing, 250 ml of nutrient and 10% of inoculum bacterial solutions incubated in an orbital shaker incubator at 150 rpm in six different cultures. To investigate the amount of copper dissolution in different days, a 10 mL sample of the solution was isolated and after filtering, the resulting clear solution was analyzed by AAS. Response surface methodology was applied to optimize the leaching of copper. The individual effects and possible interactions of pulp density, percent of T.t bacteria and Fe content on the bioleaching of copper were investigated. The optimum conditions were determined using statistical analysis and analysis of variance (ANOVA). The test parameters and their levels are shown in Table 1.

Table 1. Test parameters and their levels

| Factor | Name | Low level | Central level | High level |
|---|---|---|---|---|
| a | Percentage of bacterial inoculum | 10 | 15 | 20 |
| b | Solid to liquid ratio (g/mL) | 5 | 15 | 25 |
| c | S content (g/mL) | 5 | 12.5 | 20 |
| d | pH | 0.75 | 1.63 | 2.5 |
| e | Fe content (g/mL) | 20 | 45 | 70 |
| f | T.t percentage | 20 | 50 | 80 |

The selection of variables levels was done according to the results of screening tests. Variables and their levels are given in Table 2.

Table 2. Variables and their levels

| Factor | -α | Low level | 0 | High level | +α |
|---|---|---|---|---|---|
| b | 3.3 | 5 | 7.5 | 10 | 11.7 |
| f | 66.59 | 70 | 75 | 80 | 83.14 |
| e | 16.59 | 20 | 25 | 30 | 33.14 |

## 3. Results and Discussion

Figure 1 shows the XRD pattern of mineral ore specimen. The presence of copper in the form of secondary sulfides and low chalcopyrite levels have provided conditions for the use of microbial leaching.

Among the parameters, the bacterial percentage T.t, the solid-to-liquid ratio and the iron content are effective. In fact, the pH parameter is an effective parameter and the expressed pH is related to the start of the experiments. But, pH changes over time as the microbial leaching of copper sulfide ore occurs. According to the results of screening test, the response surface method was used to optimize the process. Parameters of solid-to-liquid ratio, T.t and iron content are effective parameters. Given the Fisher's test value and the percentage of participation, it

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is found that the selected parameters are fitted correctly in the model. Finally, the model obtained for the process is as follows.

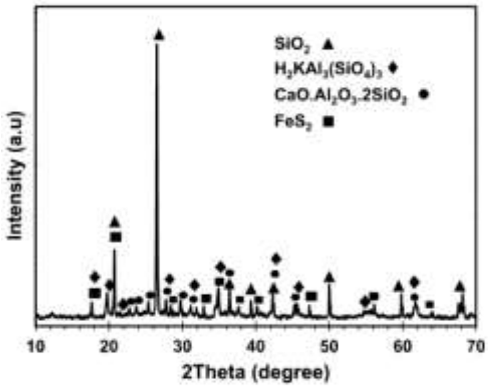

Figure 1. XRD pattern of mineral ore specimen

$$\text{Copper leaching }(\%) = 97.36 - 0.47 \times \frac{\text{S}}{\text{L}} + 1.07 \times \%\text{T.t} - 0.68 \times \text{Fe content} + 0.51 \times \frac{\text{S}}{\text{L}} \times \%\text{T.t} - 1.17 \times \%\text{T.t} \times \text{Fe content} - 1.06 \times (\text{S/L})^2 - 0.88 \times (\text{Fe content})^2$$

For the interpretation of the results, the perturbation plots of the model is presented in Figure 2 It showes the effect of different factors of the solid-to-liquid ratio (b), the iron content (e), and the percentage of bacteria T.t (f) in the constant value of the other parameters. The ratio of solid to liquid and the iron content has a negative effect and the percentage of bacteria T.t has a positive effect on the percentage of copper leaching.

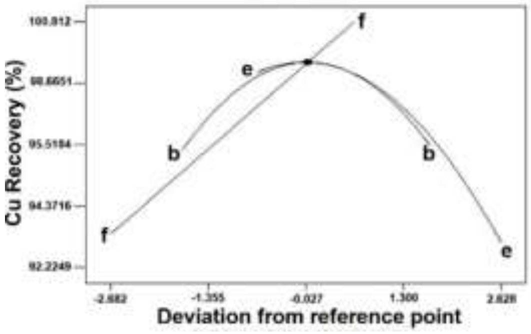

Figure 2. Perturbation plots

Figure 3 shows the three-dimensional interaction between the two parameters of the solid-to-liquid ratio and the percentage of bacteria T.t. In fact, these interactions indicate that the effect created by a parameter depends on the level of other parameters. As can be seen, the high percentage of bacteria T.t has a negative effect on the increase of solids content, while in the lower percentage of this bacterium, increasing the amount of solid-to-liquid ratio results in a further decrease in the Cu recovery.

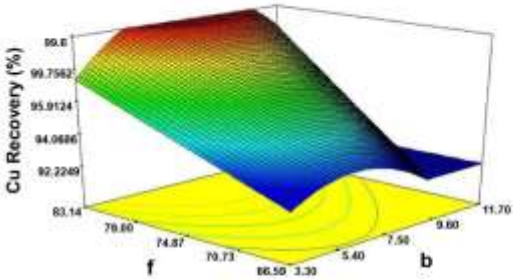

Figure 3. Three-dimensional plot of Cu recovery for solid-to-liquid ratio (b) and percentage of bacteria T.t (f)

The interaction between the percentage of bacteria T.t and the amount of iron in a solid to liquid ratio of 7.5 is shown in Figure 4. The interaction between the amount of iron and the percentage of bacteria T.t indicates that the percentage of bacteria for high and low levels of iron content has a very low and very high effect on the Cu recovery, respectively.

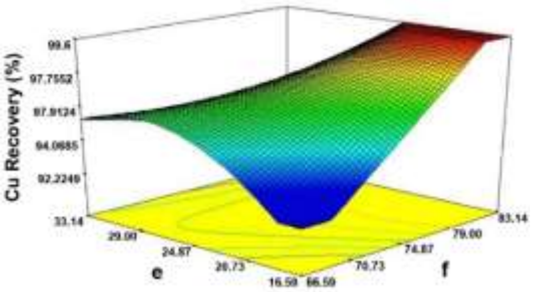

Figure 4. Three-dimensional plot of Cu recovery for iron content (e) and the percentage of bacteria T.t (f)

The optimum conditions were as a solid-to-liquid ratio of 55.7 g/ml, 80% T.t., iron content of 20 g/ml and copper extraction of 99.4% by the model. In order to ensure this, a practical leaching test was conducted under the proposed optimum conditions and the dissolution rate reached about 98.8.

## 4. Conclusion

The optimum conditions were determined using statistical analysis and analysis of variance (ANOVA). The optimum conditions for the copper recovery of 99.4% were pulp density of 7.55 g/mL, 80% of T.t bacteria and 20 g/L of Fe. Also, the most effective factor for the copper recovery was the percent of T.t bacteria. Furthermore, the statistical analysis indicates that the model fits the experimental data well.