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Investigation of Copper Recovery rate from Copper Oxide Ore Occurring as Coarse Grains Locked in a Porphyritic Fine Grain Alumina and Silica

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Abstract

An investigation was carried out on a high grade copper oxide ore to determine the optimum recovery rate of copper from the pregnant leached solution obtained from leaching the ore in a sulfuric acid lixiviant. The copper oxide ore occur in coarse grains locked in a porphyritic fine grain alumina and silica. 800 g of copper oxide ore was obtained at the deposit; the samples were chemically and mineralogically analyzed. The analysis shows that the copper oxide ore contain 19.52 % copper extraction. The ore samples were crushed to sizes within 5 cm and 12 cm. The crushed samples were then grinded to a mesh size of -150 µm. This size was used to conduct the leaching process and sulfuric acid was used as the lixiviant. Parameters varied in this study include: the concentration of acid, temperature and time. The pregnant leach solution obtained was analyzed and the results showed an increase in the % recovery of copper as the molar concentration of H_2SO_4 increases from 0.25M to 1M and the % copper extraction decreases as the acid concentration increases from 1 M to 3 M. Higher copper recovery of 32.13 % was observed at elevated temperature of up to 80°C. These findings suggest the possibility of effectively producing copper from the Pingel-Bauchi Deposit through hydrometallurgical extraction process; optimum recovery can be obtained at an elevated temperature using acid concentration of 1 M.

Keywords: ***Leaching; Copper oxide; Temperature; Acid Concentration; Pingel Copper***

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1. Introduction

Pyrometallurgy and hydrometallurgy are the two common processes employed in the extraction of copper from its ore. Pyrometallurgy has more application in the extraction of copper from copper-iron-sulphide while hydrometallurgical method of extraction has bulk of its application in extracting copper from oxidized copper ores which includes carbonates, hydro-silicates, oxides and sulphates). Hydrometallurgical method of extraction accounts for 20% of copper production. Sulfuric acid is the most popular lixiviant used in the leaching of copper ores before which solvent extraction and electrowinning is applied to obtain the pure copper from the leacheate [1].

Copper ore is reported to occur mainly in the Northern Part of Nigeria because of the unique geology of the area and they are been mined in Nassarawa, Plateau, Zamfara, Bauchi and Gombe State. The exploration of copper in Bauchi state revealed the presence of mineralization around Rishi, Dawa, Kulfana and Pingel villages. Typical occurrences in Pingel consist of disseminated copper oxide and azurite ores hosted in coarse grained to porphyritic granite [2].

Most of the research published on copper has been conducted on copper oxide ores - malachite and chrysocolla – a copper silicate ore. However, [3] identified chrysocolla as the most available copper ore but also the most complicated of all the major copper minerals [4].

Copper occurs finely disseminated and intimately associated with gangues just as the case of most minerals, hence, they must be initially "unlocked" or "liberated" before separation can be undertaken [5]. This process of liberation can be achieved by comminution. The particle size of the ore is progressively reduced by crushing and grinding the ore until the liberated minerals can be separated by any chosen method [6].

Hydrometallurgical processes are carried out by the dissolution of ore into a leaching agent. In one of his research in Nchanga, [6] stated that oxidized copper flotation has proven to be inefficient; he stated this as the reason why flotation is not a suitable method for the processing of copper carbonate and oxide ores of copper. This consequentially informs the reason for the selection of hydrometallurgical method in this study.

Different researchers had shown the behavior of copper oxide when leached in sulfuric acid solution. [7] studied the different conditions for the dissolution of malachite in sulfuric acid. 100 % malachite was dissolved in the sulfuric acid at 40 ^{0}C, 1/3 gcm^{-3} solid to liquid ratio, also, acid concentration of 10 % was used at a stirring speed of 480 rpm in 45 minutes of reaction. This shows the ability of sulfuric acid to dissolve malachite at varying condition. [8] also employed the use of sulfuric acid to leach malachite in which he obtained 99.95 % dissolution at 14 minutes, 0.5 M and 25 ^{0}C leaching conditions.

[9] also demonstrated the effect of varying the leaching condition in obtaining the optimum conditions from the dissolution of malachite in sulfuric acid solution. [10] noted the effect of iron in the leaching of malachite ore, this plays a major role in designing the methodology for this study. The decision to select sulfuric acid as the lixiviant can be traced to it efficacy in previous studies as demonstrated by [8] and [9]. Furthermore, [11] also applied sulfuric acid lixiviant in a comparative study of two low grade copper ores; the result further proved the effectiveness of sulfuric acid in leaching copper oxide ores. The ability of sulfuric acid to leach malachite ore rapidly was demonstrated by [12]. He studied the rate of increase of the dissolution of malachite in sulfuric acid; by slight increase in the activation energy, he obtained a dissolution rate of 53.6 kJ mol^{-1}.

However, the results obtained from different researchers shows varying dissolution rate which shows the peculiarity of the leaching behavior of copper oxide to the location of the ore and the nature of occurrence. The Pingel-Bauchi copper oxide ore occurrence is a peculiar one and the dissolution of copper oxide ore of this kind of occurrence in sulfuric acid has not been recorded in literature. The aim of this present study is to determine and discuss the copper concentration in the pregnant leach solution obtained from the leaching of the Pingel-Bauchi copper oxide ore. For this purpose, the concentration of acid was varied, the temperature was also varied; and the stirring speed of the leaching was also varied in this study.

2. Experimental

Copper oxide ore was obtained from Pingel village of Toro Local Government area of Bauchi state, Nigeria. Sulfuric acid was used as the lixiviant. Large chisels and jack hammers were used to collect copper oxide sample from the ore body at an interval of 5 feet between the pits towards the North East of the deposit as opened by the existing artisanal miners at the study area. The ore was chipped off the wall of the pits and collected in different sample bags. The pits were made to align parallel to the width of the deposit. The obtained ore samples were weighed; 800 g of copper oxide was obtained.

Mineral Assemblage was carried out using the X-ray Diffractometer. Chemical analysis of the ore was carried out using the Atomic Absorption Spectrometer (AAS) to determine the element present in the ore. The result obtained from this analysis is presented in Table 1. Sample preparation was carried out by crushing the ore, grinding and determination of the liberation size before been weighed into different sample containers. Leaching was carried out in transparent plastic containers while some samples were leached in a water bath controlled thermostatically. The leaching experiments were performed in six different containers. 100 g each of -150 µm +75 µm copper oxide samples were weighed into different containers.

400 mL of H_2SO_4 was added at different concentration of 0.25 M, 0.5 M, 1 M, 2 M and 3 M. In some other containers, temperature was varied from 25 °C, 40 °C, 55 °C and 80 °C. The default time of leaching used was 2 hours. The resulting solvent from each of the containers were filtered. AAS equipment was used in determining the copper concentration in each of the PLS and the results are represented by Figure 1.

3. Results and Discussion

3.1. Elemental Analysis

The result of the elemental analysis carried out on the Pingel copper oxide ore sample is presented in Table 1.

Table 1: Elemental Analysis of the Bauchi Copper oxide Ore.

Sample	Cd (%)	Cu (%)	Pb (%)	Fe (%)	Mn (%)	Na (%)
Copper oxide	0.0038	19.52	0.0248	3.64	0.0114	0.00046

Table 1 which shows the result of the elemental analysis carried out on the copper oxide ore sample shows an appreciable concentration of copper with 19.54 % (19.52 g/L), it is above the 0 – 2.9 % which Escarate et al. [10] prescribed for an economically worthwhile extraction. The other elements such as cadmium, lead, manganese and sodium occur in traces in the ore, this shows the ability of copper to combine with virtually all elements as stated by Escarate [10], this particularly contribute to the reason for the formation of different associated complex minerals. The presence of these elements determines the leaching behaviour and that of the resulting pregnant leach solution from the leaching of the copper oxide. Also, some of the associate minerals as detected by the XRD equipment include Osbornite, Zincite, Tenorite and Quartz.

3.2. Ore Microscopy

The results of ore microscopy carried out on the Pingel-Bauchi Copper Oxide ore is presented in Plate 1a and Plate 1b. The result shows the occurrence of the copper oxide ore in a coarse grains locked in a porphyritic fine grain alumina and silica.

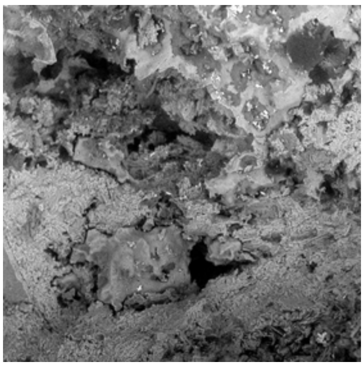

Plate 1 (a): Scanning Electron Micrograph of the Pingel-Bauchi copper oxide ore

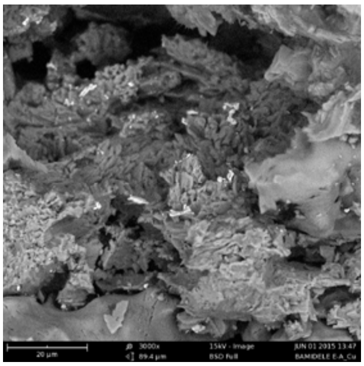

Plate1(b): Scanning Electron Micrograph of the Pingel-Bauchi copper oxide ore at 1000X magnification and 20um spatial resolution.

3.3. Effect of the Concentration of Acid

Figure 1 shows high concentration of copper in the copper oxide at the different molar concentrations of sulfuric acid. Direct proportionality is observed from 0.25 M to 1 M. The maximum concentration of copper was observed at 1 M. However, inverse proportionality is observed from 1 M to the point where 3 molar concentration of sulfuric acid was used. The result obtained from the analysis of the pregnant leach solution obtained from the leaching process is shown in Figure 1.

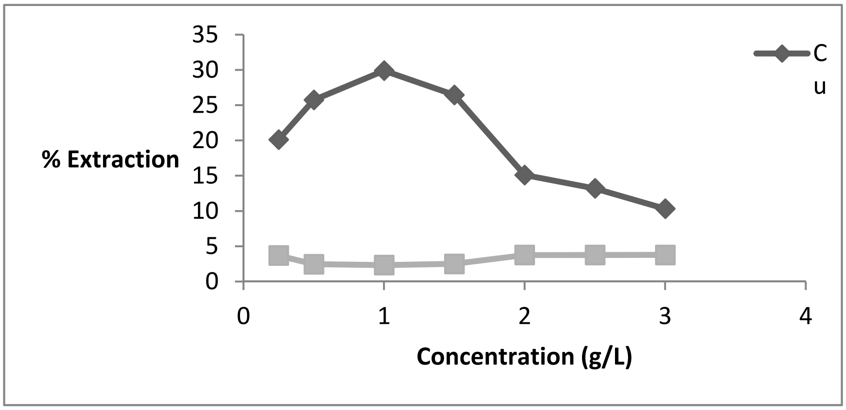

Fig. 1. Percentage Concentration of Copper at Different Molar Concentration of Acid for the Pregnant Solution for each of the Copper oxide Ore.

The result obtained from the variation of sulfuric acid concentration shows that the maximum dissolution of the Pingel-Bauchi copper oxide ore in the sulfuric acid lixiviant occurs at 1 M concentration of H_2SO_4 while the dissolution rate begins to decrease thereafter with the increase in acidic concentration. The maximum concentration of copper obtained was 29.89 g/L at 1 M concentration while the lowest was obtained when leaching was carried out using 3 M of H_2SO_4. Percentage extraction of iron increases slowly with increasing concentration of the sulfuric acid lixiviant.

The result obtained from the leaching of Pingel-Bauchi copper oxide ore also correlate with the results obtained by Bingol [9] in which the copper concentration obtained increases from 0.2 M of H_2SO_4 to 1.02 M of H_2SO_4 and thereafter decreases as the molar concentration increases from 1.02 M.

3.4. Effect of Temperature

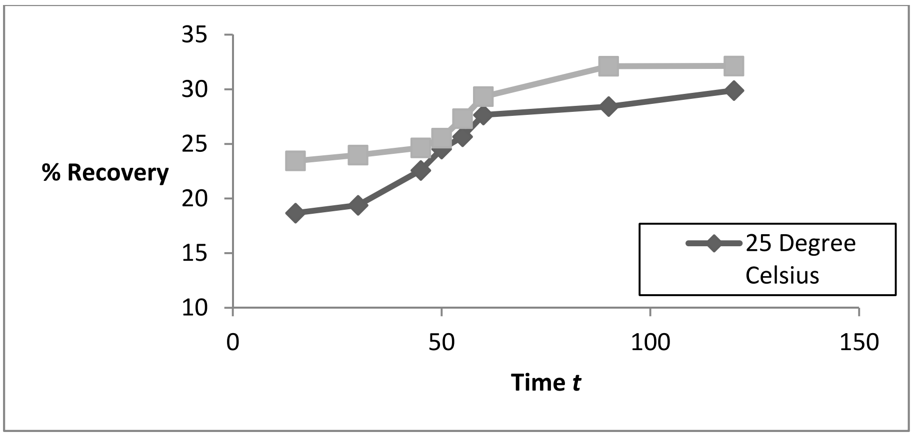

Fig. 2. Plot of Temperature against Copper Concentration

Another major observation obtained from the experiment is that the copper concentration at elevated temperature is higher than that obtained at room temperature, at equal molar concentration of H_2SO_4 (1 M). Recovery rate of 32.13 g/L was obtained for the pregnant leach solution of copper oxide leaching at an elevated temperature of 80 ^oC while 29.89 g/L of copper was obtained at room temperature.

4. Conclusion

The general objective of the study is to determine and discuss the copper concentration in the pregnant leach solution obtained from the leaching of the Pingel-Bauchi copper oxide ore. The study which was carried out on the Pingel-Bauchi copper oxide ore shows that the ore contain 19.52 wt% Cu which is higher than the established 0 - 2.6 %, this shows a highly rich deposit especially when ore sorting is carried out appropriately. The study which varied different concentrations of sulfuric acid liviviant obtained the maximum copper recovery at 1 M from which the leaching yielded 29.89 g/L copper. The increase in copper recovery was observed as sulfuric acid concentration was varied from 0.25 M to 1 M and copper recovery began to decrease from 2 M to 3M. In addition, another major observation from the study is the relationship of the copper recovery and the temperature. The higher the temperature of the leaching environment, the higher the copper recovered from the Pregnant Leach Solution. The optimum recovery was obtained at 80 ^oC. At this temperature, 36.74 g/L of copper was recovered from the leacheate. Also, the density of the pregnant leach solution increases with the concentration of the acid.

Finally, the results obtained from this study shows that Pingel-Bauchi copper oxide ore deposit is a good prospect from which copper oxide ores can be obtained for processing, leaching and extraction without causing environmental problems. The massive reserve of the deposit as reported by the Federal Ministry of Mines and Steel Development indicate Pingel-Bauchi copper oxide ore deposit as a prospective abundance source of copper production in Nigeria.

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