Optimizing The Gold Bearing Material Roasting for Artisanal and Small Scale Mining for an Efficient Leaching in Thiosulfate Solution: Microwave Roasting; Conventional Roasting

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***Abstract*—**This paper discusses the environmentally friendly microwave processing of gold bearing ores material as it impacts the produced calcine. Multimode microwave cavity was used. It was observed that the microwaving of the gold bearing ore enhanced roasting behavior of gold. The calcine produced was dissolved into a thiosulphate aqueous solution. It was observed that the green solution dissolved a higher amount of gold bearing calcine.

***Keywords*—** Microwave pre-treatment, recovery roasting, thiosulphate.

I.INTRODUCTION

Conventional techniques and processes used for the extraction of gold often come with environmental impacts and health risks, and recovery challenges, in particularly artisanal small-scale operations (ASSO). The need for environmentally friendly ways to recover gold has led to development of recent methods such as the use of green lixiviants such as thiosulphate solution. Thiosulphate solution is an innovative eco-friendly lixiviant than cyanide. In addition, it is also cheap and does not get polluted by dissolution of undesirable ions as it is highly selective which is the opposite of cyanide [1]. Gold can often be challenging in terms of being liberated from its ore. Its occurrence of being disseminated makes it interlocked within its host rocks. More recently, microwave treatment has emerged as the most effective way to enhance the extraction of gold from its bearing ores. Microwave treatment uses the irradiation of microwaves to the surface of the minerals to interact with them, altering their morphology and bods between grain boundaries and improve the leaching rates, which leads to improved leaching rates, and result in a more efficient process that reduces the environmental impacts and operation costs [2]. Microwave pre-treatment also contributes as a roasting process. This is due to the high temperatures generated when it is used. Roasting is the transformation of a sulfide into an oxide. Oxides tend to be more reactive during a leaching process. One of the reasons is because they contain high amount of oxygen. Oxygen necessary in oxidative leaching environments promoting the formation of soluble complexes. On the other hand, sulfides contain sulfur. Sulfur promotes stable compounds which are less reactive and resistant to dissolution [3].

Fig 1: A multimode microwave cavity .

Thiosulphate solution is one of the environmentally friendly lixiviants for gold extraction. It has attracted a lot of interests over a lot of researchers and metallurgists due to its fast kinetics and its adaptability to gold ores over the last decades [4]. Thiosulfate leaching of gold has a high potential of reducing environmental effect. It also offers potential to other countries where cyanide leaching is banned [5]. The main chemical components of thiosulphate leaching are ammonium thiosulfate and ammonium sulphate. The process consists of various different oxidants including oxygen, Cu(II) ammine complexes, Co(III) ammine complexes, and various Fe(III) complexes. They react with the thiosulphate ions to form a cupric thiosulphate complex. This thiosulphate complex oxidizes gold to form a gold thiosulfate complex.

II. METHODS AND MATERIALS

The run of mine sample was obtained and taken through comminution for size reduction. After comminution, the crushed sample was weighed and portion was collected for SEM analysis, XRF and FTIR analysis. Portions from the

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sample was also obtained for determination of the present gold grade using fire assay. During fire assay, borax, sodium carbonate, litharge and carbon were mixed with the sample and put in the furnace. After heating, buttons were obtained and hammered into cubes and loaded back to the furnace for cupellation. 4 out of the total 10 buttons contained prill while the others did not. This could be due to errors encountered during sampling.

The remaining mass was weighed and prepared for milling. In the milling process, 4 runs were carried out at different time frames 5 minutes, 15 minutes, 30 minutes, and 60 minutes respectively. This was done to identify the optimum time frame to meet 80% passing 75 microns for preparation of the leaching process. After milling, the sample was collected, and a milling curve was obtained.

The preceding step was floatation. The aim of floating was to concentrate the sulfide before it could be carried on into microwave roasting and leaching. SIBX and copper sulphate reagents were prepared for the leaching circuit. The mixed reagents were allowed time of 5 minutes for conditioning. After 5 minutes, the sample was poured into the leaching circuit of mixed water and reagents which made up to 1L. The sample was floated for 10- minutes up until little to no froth was obtained. This was to avoid losses at all costs. The floated sample was dried separately with the tailings. After drying, the tailings were stored in a cool dry place while the concentrates were taken and prepared for microwaving.

The concentrate was microwaved at high power and low power. For 5-10minutes This was to be able to determine the optimum conditions that would cause a significant impact. After microwaving the sample, it was allowed to cool and weighed to equal mass fractions for leaching. The solution preparations were prepared where thiosulfate concentration was ranged between 0.5M, 1.25M and 2M. Temperature was also varied for 30, 45 and 60 degree Celsius for each concentration together with leaching time at 30, 105 and 180 minutes. Proper inspection was done to minimize errors during the leaching process.

After leaching, the solutions were filtered, and the pregnant leach liquor was extracted from the residue and stored in separate sample holders with appropriate labelling. The samples were then taken for AAS/ICP. Grades were calculated from the AAS results.

III. Results and discussion

A. Characterization

The XRF results showed Si occurring in high abundances of 27% compared to the other elements. The high percentage of silicon suggests the presence of silicon-containing minerals within the sample. This is expected as various natural minerals contain silicon. Simillar gold deposits from Hamze-Qarnein in Iran and Barberton mine in Mpumalanga were also associated with similar elemental composition. Natural occurring oxides such as MgO, CaO, Fe_2O_3, Al_2O_3 and SiO_2 are the commonly found tailings associated with gold minerals. Consequently, these oxides were found to occur in high percentages within the composition of the ore with SiO_2 being the most dominant oxide at 58% and Fe_2O_3 at 37%. Similarly, the gold mined in kibali mine situated near Dri where the sample is from is associated with silica which classifies as gangue. Fe, As, and Zn occurring at 23% 0,9% and 0,04% respectively. These elements mostly occur within sulphide minerals. The SEM results confirmed the presence of gold within the mineral. The particle size of the detected gold within the mineral ranges between 6-7 microns. This indicates a very fine particle size [1]. The fine particle size may also be an indication of a refractory gold. Fine sized gold particles can often be challenging when it comes to processing using conventional methods. This is where newly advanced technology gets involved. Pre-treatment can efficiently liberate the fine particles and maximize its recovery [2].

B. Roasting and leaching

These leaching results obtained are highly linked to the microwave pre-treatment roasting. According to Batchela (2017), microwave pre-treatment used as roasting enhances the amenability of gold particles during leaching. In the experiments, microwave treatment was executed at low power and at high power, it was found out that the microwave treatment usually becomes more effective at high power. High power means that microwaves get to effectively interact with the particles and cause sufficient strain leading to microcracks. To determine the effectiveness of microwave pre-treatment, XRF analysis was conducted after microwaving. The XRF results showed that their sulfur content present was way lower than the sulfur content before microwaving. Some sulfur compounds have relatively low boiling points, and microwaving could lead to their volatilization. The sulfur compounds may turn into gaseous forms and escape from the material, effectively reducing the sulfur content. Its loss on the sample may be a representation that effective heating was obtained [3].

The decrease in sulfur content may also result in a reduction in other impurities or contaminants that were associated with the sulfur compounds. This could lead to a cleaner and more valuable gold concentrate. Microwave heating is often considered more energy-efficient compared to traditional heating methods like conventional ovens or furnaces. This can reduce the overall energy consumption during the extraction process [4].

The SEM image obtained after roasting was clearly released from the matrix. The presence of released gold grain boundaries suggests that the microwave-assisted treatment and subsequent leaching process were effective in liberating gold particles from their host minerals. This liberation is crucial for efficient gold recovery because it allows the gold to be separated from the surrounding ore matrix.

Released gold grain boundaries indicate that gold grains are more accessible to leaching agents. The exposed grain boundaries provide a larger surface area for the leaching solution to interact with the gold, increasing the chances of successful dissolution and recovery.

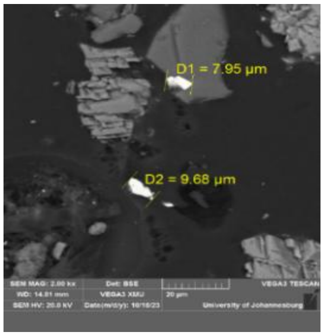

Fig.2. Before microwaving

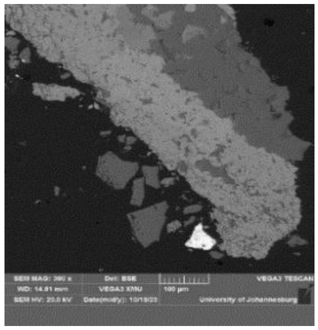
Fig.3. After microwaving

IV. Conclusion

It was observed that the microwaving improved the reactivity of the calcine and its dissolution rate into thiosulfate aqueous solution. The longer the dissolution contact time, the more gold was dissolved in the aqueous solution. A similar trend was observed on the increase of the lixiviant concentration..

Appendix

TABLE 1: LEACHING RESULTS

Temperature	Time	0,5M	1,25M	2M
30	30	0,013225	1,523987	1,625204
45	105	1,505042	3,254463	7,400367
60	180	2,304474	4,842443	9,141341

TABLE II: XRF RESULTS

Elements	Metal results
Mg	0,58242
Al	0,58604
Si	27,251
S	0,29514
Ca	2,27832
Cr	0,1027
Mn	0,09766
Fe	23,4408
As	0,99834
Ni	0,01906
Cu	0,00858
Zn	0,04426

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