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Influence of microwave pre-treatment on the flotation of low-grade sulphide ore

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ABSTRACT : *Sulphide ores are always difficult to process because of the complication in their mineralogical associations and the intergrown nature of their constituent minerals. These complexities usually result in a poor liberation of the associated minerals. Hence, full determination of comminution parameters relevant to the crushing and milling of these minerals will enhance higher recovery of the concentrate minerals as well as enable proper plant design to take place. Meanwhile, most high-grade deposits of the world have been depleted which give rise to the need to process low-grade ores. The conventional methods of mineral processing are also no longer effective for the processing of these low-grade ores. This work centres on understanding the effects of microwave pre-treatment on the flotation characteristics of the low grade-sulphide ores. The ore was characterized using JEOL JSM. 7600 SEM-EDX, Qurum150TE XRD-Ultima IV and XRF- ZSX Primus II. Microwave treatment was also carried out using 2.45 GHZ intellowave microwave oven at a power output of 750W. Comminution and particle size analysis of the ore shows that P_{80} for microwave treated sample is equal to -212µm +150µm while for the untreated sample P_{80} corresponds to -250 µm +212µm. Sodium Ethyl Xanthate, SEX was used as the collector, Methyl Isobutyl Carbinol, MIBC as the frother and three different depressants (Starch, sodium silicate and potassium dichromate). Particle sizes 150µm, 106µm, 75µm and 53µm were used for flotation experiment. The trend of the recoveries of both microwave treated and untreated samples shows that recoveries are higher for the microwave treated samples.*

Keywords: *Microwave treatment, flotation, sulphide ore, collectors, depressants*

I. INTRODUCTION

Regardless of the form in which the different minerals occur and are associated in sulphide ores, in which galena-sphalerite are found, they are usually very difficult to process. These complex mineralogy present formidable challenges during processing and thus require that suitable techniques be adopted for optimal recovery of the constituent metals. When valuable minerals are not freed, due to poor liberation, they become very difficult to process in the sense that much more energy will be expended and efficient recovery becomes more difficult to attain. Determination of comminution parameters relevant to the crushing and milling of these minerals will enhance higher recovery of the concentrate minerals. Due to complicated mineralogical characteristics of these ores, it is necessary to properly grind and liberate all the mineral phases, to enable them to be exposed to processing. Meanwhile, most high-grade deposits of the world have been depleted, which gives rise to the need to process low-grade ores, The conventional methods of mineral processing are also no longer effective for the processing of these low-grade ores, as different concentrates obtained are of poor quality.

This work centres on understanding the effects of microwave pre-treatment on flotation characteristics of the low grade-sulphide ores from and Ishiagu 6º 20’00” N 8 º 6’00”E in Nigeria. Microwave technology in mineral processing has been investigated over few decades. Some of its benefits are reported to be low cost, energy and time and also be environmental friendly. The method has been explored for mineral ores processing for which interaction between microwave and minerals, differential heating and reduction in comminution energy following comminution has been reported (Amankwah *et al.*, 2005, Kingman 2006, Kingman and Rowson, 1998, Haque, 1999, Xia and Pickles, 2000). Specifically for sulphide ores, Kingman *et al.*, 2000 reported on the influence of mineralogy on the response of ores to microwave radiation and the reduction in their grinding energy, concluding that microwave radiation may cause surface oxidation of sulphide minerals. Microwave treatment on copper flotation was also investigated and higher recovery for treated samples was reported (Sayhoun *et.al,* 2005). However, no specific work centred on evaluating the capacity of microwave technology in enhancing galena-sphalerite recovery from Ishiagu low grade sulphide deposit in Nigeria was found. The thrust for this work is that the little work available in the literature centres on the influence of microwave irradiation on heating characteristics, breakage response, mineralogy and mechanism of dissolution in sulphuric acid and hydrochloric acid (Olubambi *et. el.*, 2007). Studies reported so far on the influence of microwaves on ore dressing could not provide sufficient information from which industrial systems could be understood, and thus provide basis for its industrial acceptability. Therefore, the aim of this work is to investigate the effectiveness of microwave irradiation for enhancing the processing of low-grade sulphide ore, the interplay of mineralogy and microwave irradiation, and their dual effects on flotation characteristics of the sulphide ore.

II. METHODOLOGY

Ore sample

The Sample for this study is a low-grade complex consisting of Sphalerite, Galena, Anglesite, Pyrite, Hematite and Silica. The sample was taken from Abakaliki south of Ebonyi Nigeria on a coordinate's 12º6'30"N 5º 58'00"E and 6º 20'00" N 8 º 6'00"E). The sample was divided into three portions, for mineralogical studies, pre-microwave treatment and microwave treatment respectively. The portion for characterization was crushed ground screened to sizes and were prepared for the analyses while the other two portions were taken for treatment and processing without treatment respectively.

Microwave treatment

The 3500g of the bulk sample was placed on a glass revolving tray inside a 2.45GHz microwave oven with multi-modal cavity. The Exterior dimension of the microwave was 455x281x325mm and the interior was 310x196x294mm, it was ensure that the samples were placed on a central position of the microwave in other to minimize effect of field pattern variations as the glass rotates within the oven. The heating was carried out for 5mins at 750W power rating even though there were arcing within the ores.

Particle size analysis and ore characterization

Both microwave treated and untreated samples were subjected to crushing and milling and particle size analysis. 1500g of each portion was crushed in a Chipmunk VD67 jaw crusher and milled in a rod Mill using 17 steel rods of 1.5cm by 30cm dimension. Pulverized sample were screened separately on a King Test VB 200/300 Model 51V520125 with Endecott's set of sieves 2000µm, 1700 µm, 1180 µm, 850 µm, 600 µm, 425 µm, 300 µm, 212 µm, 150 µm, 106 µm, 75 µm and 53 µm. Thereafter, the samples were characterized using JEOL JSM. 7600 SEM-EDX, Qurum150TE XRD-Ultima IV and XRF- ZSX Primus II.

Froth Flotation

Selective froth flotation experiments were conducted in a standard Denver D-12 laboratory flotation cell to obtain concentrates of Lead and Zinc from both microwave treated and untreated samples. Particle sizes 53µm sizes 75µm, 106µm and 150µm were used for the flotation experiment. The pulp was prepared to 40% solid with initial pH of 6.53. Quick lime was added to raise the pH to 10.00, 400g/t of sodium ethyl xanthate, SEX was used as collector three times for each of the particle sizes, 125g/t of $ZnSnO_4$ was employed as depressant for zinc in the lead-zinc circuit as lead was floated without activation and three different depressants (10% starch solution, potassium heptaoxodichromate (VI) and sodium silicate) were also used to depress lead.in each of the experiments Other parameters; pH, concentration, speed, etc. were kept constant. 80g/t of $CuSO_4$ was used to reactivate zinc in zinc-lead circuit

III. RESULTS AND DISCUSSION

Ore characterization

Figures 1a indicates the mineral phases revealed by XRD prior to microwave treatment. Identified phases were galena, and quartz. It was difficult to identify sphalerite phase or that of other compounds due to low concentrations or overlapping peaks. The quantitative analysis results show about 77% of quartz and 23% of lead while an unidentified phase is suggested to be zinc (Figure 1b). Hence, further mineralogical examinations via SEM confirmed the presence of the identified minerals.

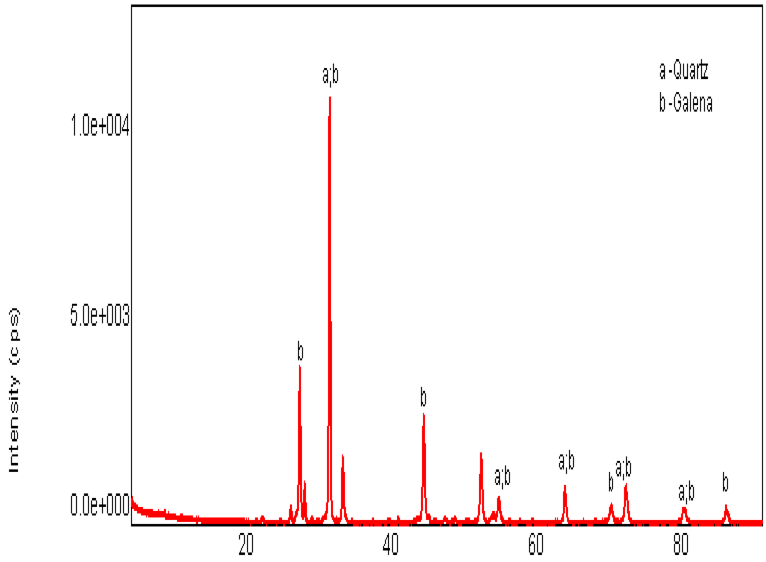

Figure 1a: XRD pattern of Ishiagu sulphide ore deposit.

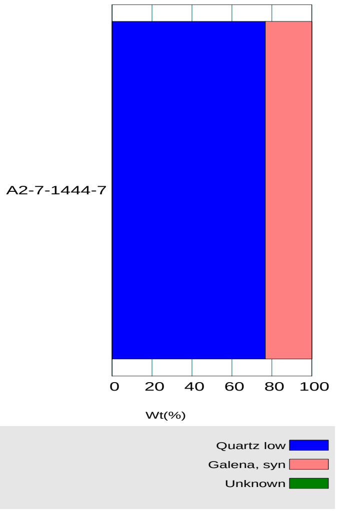

Figure 1b: XRD Quantitative analysis Result of low grade sulphide from Ishiagu deposit

Figure 2 shows SEM/EDS micrographs which further established the mineralogical composition of the ore. The morphologies of the constituent minerals within ores are show the presence of galena, sphalerite, quartz and other minerals in low concentrations.

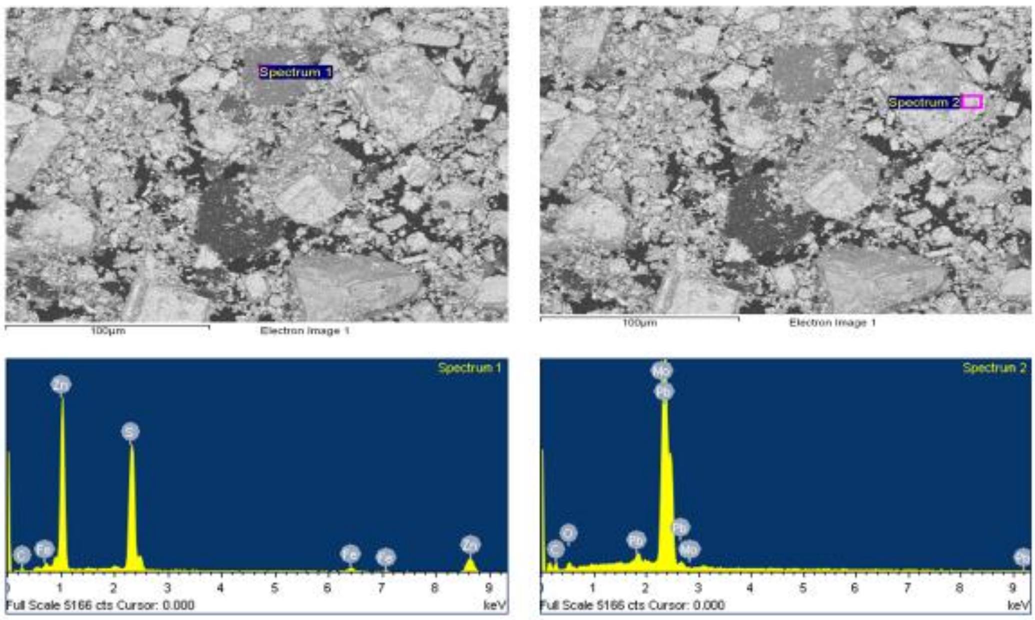

Figure 2: SEM/EDS Micrograph of "As mined" sulphide ore

Table 1: XRF Analysis of Ishiagu sulphide ore

Compound	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	Cr_2O_3	MnO	Fe_2O_3	CuO	ZnO	PbO
Weight %	0.000	0.546	0.813	4.22	0.0355	16.4	0.152	1.11	0.0635	1.33	15.6	0.640	0.91	53.86

It was discovered that the low grade ore contains 0.91% zinc and 53.86% lead as seen in table 1. There are other unwanted minerals in various percentages.

Effect of microwave treatment on the particle size

There were no particles retained on the 2000µm sieve for microwave treated sample unlike the untreated sample during sieve analysis. Figure 3 represents the cumulative % passing of microwave treated and untreated Ishiagu sulphide ore and figure 4 represents the size distribution patterns of the ore samples after Gate-Gaudin-Schuhmann law.

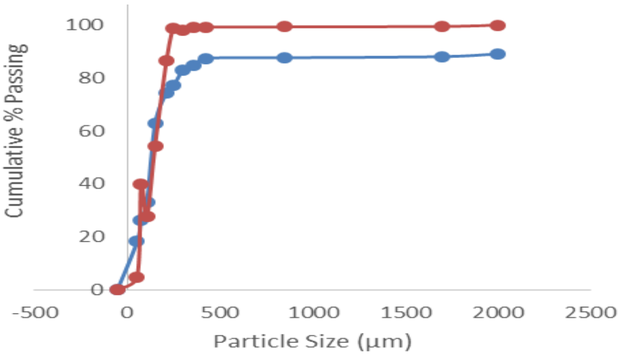

Figure 3: Graph of cumulative % passing of microwave treated ore

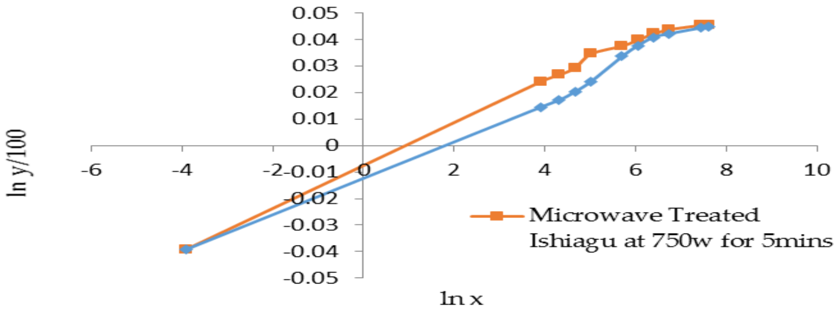

Figure 4**:** Gates-Gaudin-Schuhmann plot of particle size analysis

Cumulative % passing for 2000µm is equal to 89.13% while cumulative% passing for 2000µm of the microwave treated sample is equal to 100% no particles were retained on the 2000µm sieve. Hence, P_{80} for microwave treated sample is equal to -212µm +150µm while for the untreated sample P_{80} corresponds to -250µm +212µm. The implication of the results of particle size analysis as shown in figure 3 is that as a result of microwave treatment, enough required fine were produce and less energy is required to produce enough particle sizes because there will not be need to regrind and re-crush the ore, that mean less energy is required to produce enough particle sizes. Both microwave treated and untreated sample were comminuted under the same parameters. The energy expended on microwave is 17.85kwh/t because 3.5kg of the ore was microwaved for 5 minutes. If intensive grinding was to be done so as to get the same output as that of the microwave sample, more energy would be expended and too much fines would be generated. Intensive fine grinding reduces particles to fine sizes which make separation inefficient though froth flotation requires as much of the valuable mineral surface to be exposed.

Effect of microwave treatment on the recovery of lead and zinc

Figure 5, 6,7and 8 show the effect of microwave treatment on the recovery of lead and zinc concentrates at various particle sizes and a power rating of 750W. Figures 5 shows that 88.48% of lead concentrate was recovered using SEX as collector and potassium dichromate as depressant. That of zinc was 17.9% (figure 6) with potassium dichromate as depressant and particle size 106µm. Meanwhile the untreated sample gave a recovery of 73.47% (figure 7) of lead and 11.72% (figure 8) of zinc. Microwave treatment has allowed most of the valuable minerals to be freed from the associated gangues. Recoveries are higher for all particle sizes of the microwave than for their unmicrowaved counterparts. For example, the values of lead recovery for microwave treated samples are higher in figure 5 when compare to the values of lead recovery in figure 7 of the unmicrowaved samples. Similarly, figure 6 and 8 followed the same trend of recovery of zinc. Potassium dichromate was the depressant which gave the best result though with higher particle size in each case, it may be because higher particle sizes are easily depressed because they are heavier than the finer sizes. Meanwhile, improvement in the recovery of zinc shows that using potassium dichromate to depress lead is the best out of the collectors.

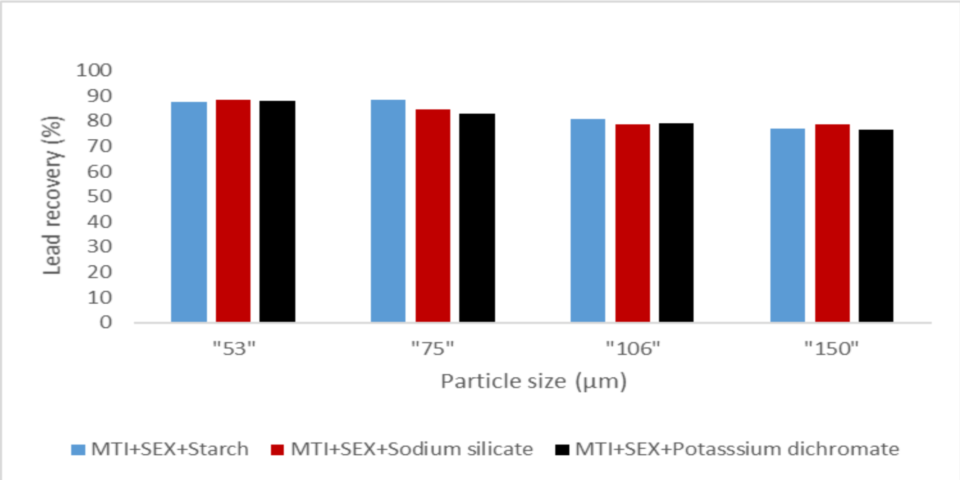

Figure 5**:** Recovery of lead microwave treated (MTI) Ishiagu sulphide ore using SEX as collector and varying depressants.

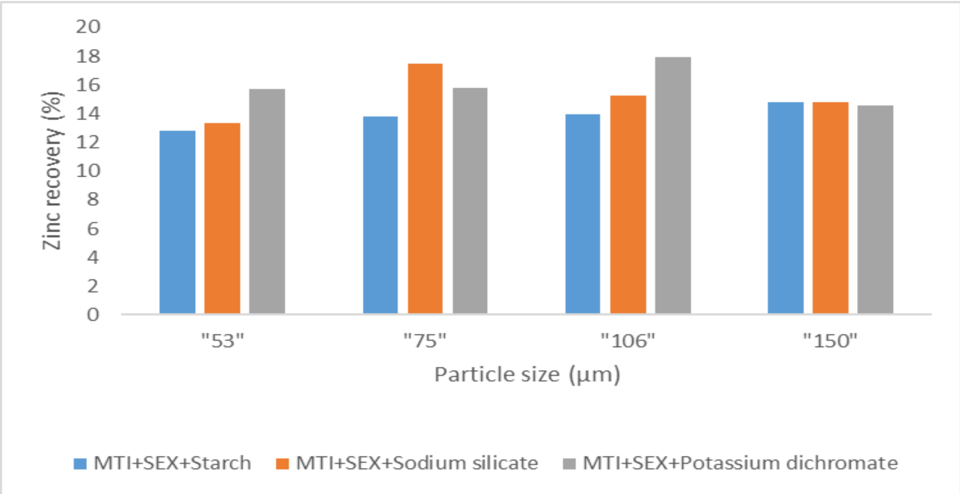

Figure 6: Recovery of zinc microwave treated (MTI) Ishiagu sulphide ore using SEX as collector and varying depressants.

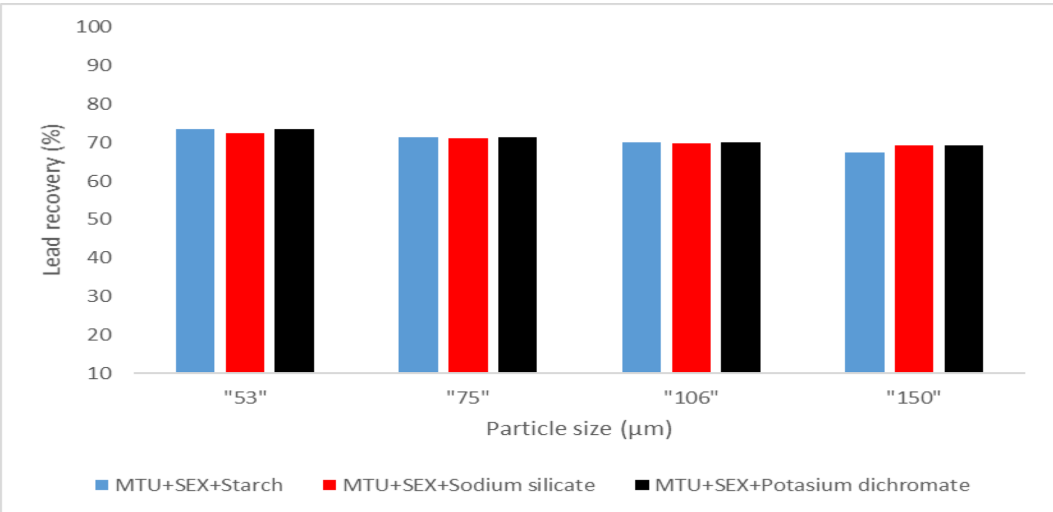

Figure 7**:** Recovery of lead from untreated (MTU) Ishiagu sulphide ore using SEX as collector and varying depressants.

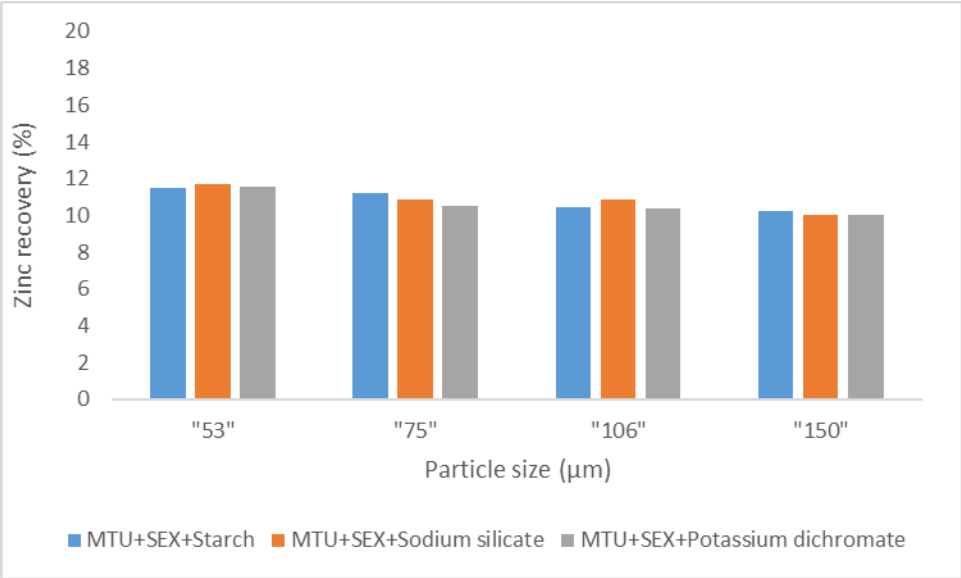

Figure 8: Recovery of zinc from untreated (MTU) Ishiagu sulphide ore using SEX as collector and varying depressants.

IV. CONCLUSION

Influence of microwave pre-treatment on the flotation of low-grade sulphide ore have been studied. From the results of sieve analysis for microwave treated and untreated samples it can be concluded that since more smaller particles were obtained from lower particle sizes microwave processing of minerals, especially sulphides, is beneficial for the recovery of the metals, since higher recoveries were obtained from fine particles sizes. Also, the results have shown that microwave pre-treatment has a significant effect on the recovery of lead and zinc concentrates from the sulphide ores. It can be concluded that with microwave treatment 53µm of Ishiagu galena-sphalerite ore gave a recovery of 88.48% using sodium ethyl xanthate as collector. The results have shown that microwave pre-treatment has a significant effect on the recovery of lead and zinc concentrates from the sulphide ores.

V. ACKNOWLEDGEMENT

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