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ANIONIC REVERSE FLOTATION OF LOW-GRADE IRON ORE ON WEST OF THE KHARTOUM, SUDAN

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ABSTRACT

In this study, the anionic reverse flotation method was used to improve the quality and reduce impurities of iron ore concentrate.

The research on iron ore using the anionic reverse flotation technology in the flotation was conducted. Low-grade iron ore samples were obtained from west of Khartoum iron ore deposits (Markhyat area) to beneficiate these ores. This thesis aimed to investigate the reverse anionic flotation of low-grade iron ore which is containing 31.5% Fe and 46.21% SiO_2 to increase the iron contained in the ore. The mineralogical characterization indicated that the iron ore sample should be ground to -150 μm (-100 mesh) for the liberation of iron ore, the size below -28 μm was removed. The effect of varying dosage of collector concentration (Oleic acid), the dosage of a depressant (Potato starch), the dosage of activator (Calcium chloride), and pH of pulp was studied in the flotation test. Under the optimum conditions, a concentrate with an iron grade of 52.08% Fe and 82.5% iron recovery. The target of the froth flotation process is to upgrade the iron ore content and minimize the silica content.

Keywords: *Anionic reverse flotation; Iron ore; Low grade; Liberation; upgrade the iron ore.*

INTRODUCTION

The physical properties of iron ore phases determine the suitable beneficiation method to upgrade the quality of the iron ore material. There is a rapidly increasing demand for iron ore resources with the fast-paced development of the iron and steel industry. For this reason, the iron and steel industry is facing the risk of a raw material shortage. Froth flotation is one of the most efficient techniques for upgrading iron ore. The anionic reverse flotation is the most effective technology in processing poor, fine, and hard-to-select hematite, in that the reagent of anionic reverse flotation has the highly effective action mechanism [1].

The study area where the ore is concentrated appears in the Khartoum sheet (ND36B), west of theNile. It is bounded by coordinates *15º-16º* and from the Nile to the east up to longitude *31º 30*'. The area covered is approximately 12487 sq. km. The area under investigation is accessible through two main asphaltic roads. Khartoum-Dongla (Shirian Al Shamal) road and to the western area via the White Nile road. Seasonal motorable tracks connect Omdurman to areas in North Kordofan [2]. The oolitic iron in the area is generally could be of high economic value as it covered a very vast terrain.

EXPERIMENTAL

The sample was collected about 100 kg from the Iron ore deposit west of the Khartoum area at Khartoum state, Sudan. This area considered is as one of the promising (areas) for iron ore in Sudan. The sample was taken from different pits in the deposit area to represent the actual deposit.The comminution of iron ore sample took place in a sequence of crushing processes including large and mini jaw crushers followed by roll crusher then screened (by sieve 2mm), the crushed sample over 2 mm return into the closed circuit with the roll crusher. The obtained product was found to be finer than 2 mm. The sample is divided after the crushing stage by rotary table riffle or splitter for the accurate division of bulk laboratory samples. The representative sample was sent to XRD, XRF, and AAS to obtain a full chemical analysis and mineral composition of the ore sample. Moreover, bulk samples were directed to prepare polish and thin sections for microscope studies.

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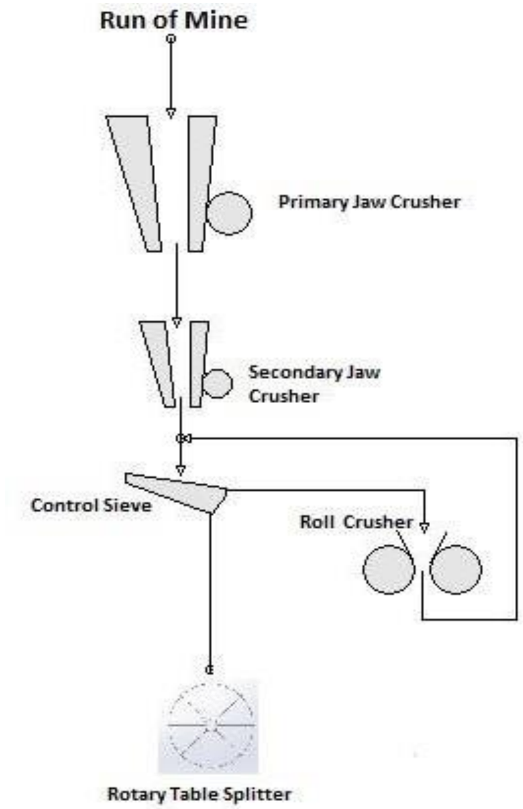

Figure 1. Flowsheet of Three-Stage Crushing and Preparation of Head Sample

The crushing product was sent to a laboratory ball mill with the close circuit to obtain a size range -150+28 μm that is suitable for following the flotation test. The minus 28 μm fines were discarded (de-sliming). The grinding product was subjected to the flotation cell. Flotation tests were performed to investigate the effect of starch Dosage, the effect of oleic acid dosage, the effect of calcium chloride, and the effect of pH. The solid-liquid ratio was 20% for all experiments. The ore was conditioned without any reagents for 3 min into a 1-L flotation cell, then depressant was added and the pulp was conditioned for 5 minutes, the calcium chloride was added and conditioned for 3 minutes and the collector was added and conditioned for 3 min. All reagents were conditioned for 3 minutes before aeration and the pH also was adjusted before aeration and monitored during the process. Flotation reagents were dissolved in distilled water and added into flotation cell in dilute solutions.

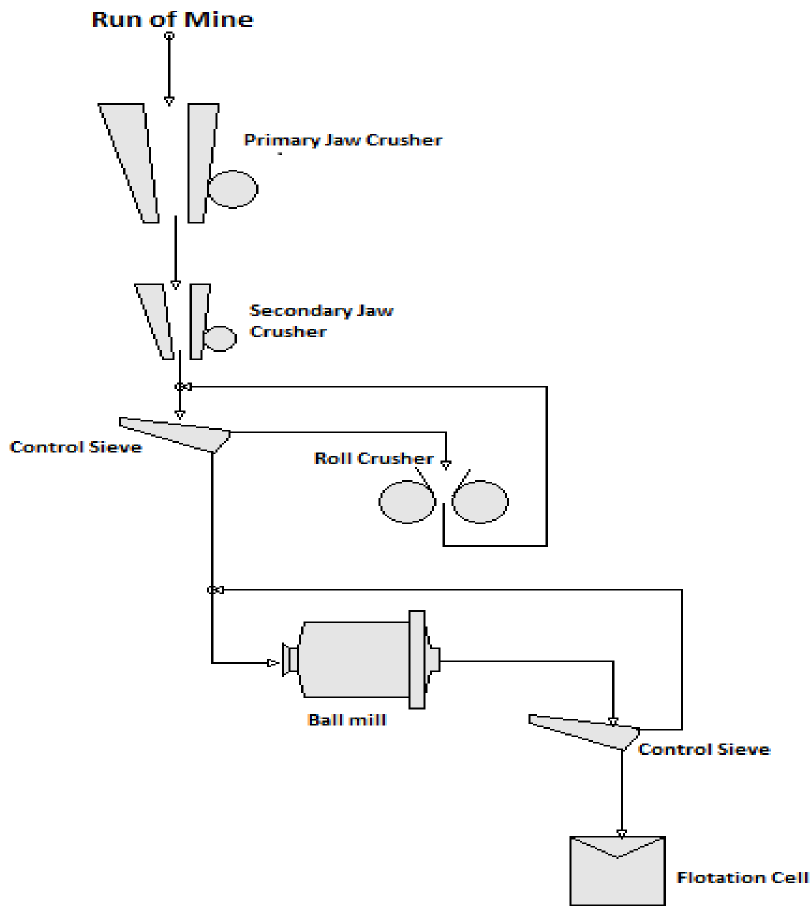

Figure 2. Flowsheet of Flotation Experiment

RESULTS AND DISCUSSION

A. *Chemical Characterization*

According to the X-ray diffraction pattern shown in Fig. 3, hematite is the iron-bearing mineral phase, quartz is the silica mineral and kaolinite is the aluminum bearing silicate gangue phase.

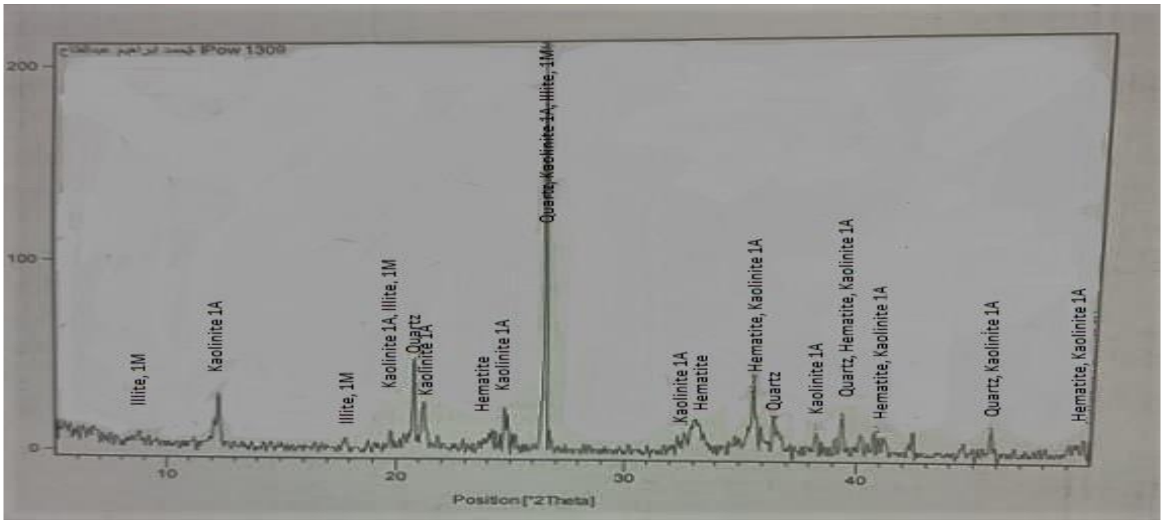

Figure 3. XRD pattern of iron sample

The chemical analysis of the iron ore sample using XRF is shown in table 1. The sample consists of 31.5 of Fe with SiO_2 and Al_2O_3 as main impurities.

Table 1. XRF Analysis of west of the Khartoum Iron Ore Sample

Element	**Fe_2O_3**	**Fe**	**SiO_2**	**Si**	**Al_2O_3**	**P_2O_5**	**SO_3**	**TiO_2**	**ZnO**	**Mn_3O_4**	**Others**
Assay %	**45**	**31.5**	**46.21**	**14.063**	**7.03**	**0.09**	**0.075**	**0.365**	**0.097**	**0.487**	**0.646**

B. *Characterization studies*

From the Optical Microscope, the iron oxide filling-pore the spaces between rounded to sub- rounded quartz grains and brown clayey fragments which means the iron oxide is the sedimentary origin.

Cement material occurs between the grains are composed mainly of iron oxide (Hematite) it has brown color and is amorphous, as in Fig. 4.

The rock matrix is composed of ore minerals which are mainly hematite sometimes occurring as very fine grains which show deep red internal reflection, the rock is composed of small crystals of silicate and the quartz mineral is the most mineral in the rock matrix, as in Fig. 5.

Figure 4. Polish Section

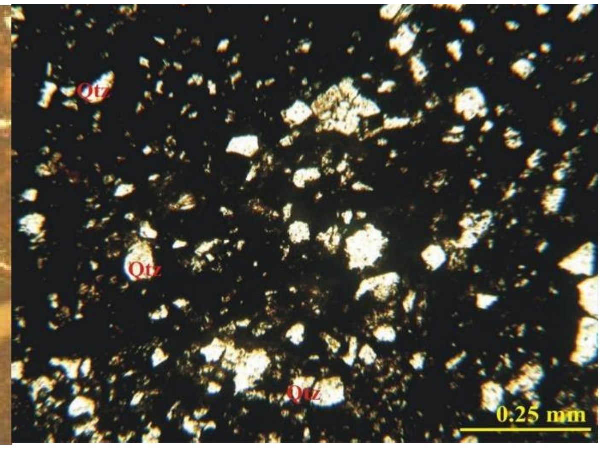

Figure 5. Thin Section

C. *Flotation Tests*

The anionic reverse flotation is the most effective technology in processing poor, fine, and hard- to-select hematite, in that the reagent of anionic reverse flotation has the highly effective action mechanism [1].

Tests were performed to investigate the effect of starch Dosage, the effect of oleic acid dosage, the effect of calcium chloride, and the effect of pH.

EFFECT OF STARCH

The effect of starch on iron ore grade, recovery is illustrated in Fig. 6. In an alkaline medium, adsorbed starch maintains hematite depression [3]. This resulted in hydrophilic surfaces that allow for the selective flotation of quartz. In this experiment, Soluble potato starch has been used as a depressant of iron oxide. From the test, it was observed the grade of iron increased with increasing in starch dosage. The reason for that is the more addition of starch means more iron oxides depressed. In these investigations, better concentrate results using Soluble potato starch indicate a higher adsorption or coating activity of Soluble potato starch.

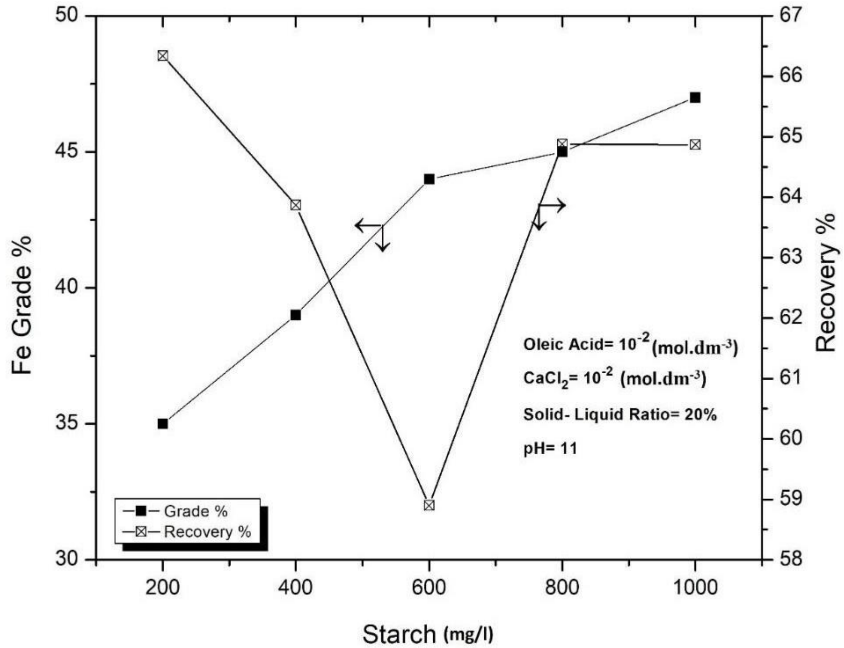

Figure 6. Effect of Starch Dosages on Flotation Recovery and Grade

EFFECT OF OLEIC ACID

Results the effect of oleic acid dosage on iron ore with different reagents demonstrated in Fig. 7. With increasing in oleic acid dosage, the recovery and grade of hematite improved. That means, the cover around silica particles increases with increasing the collector dosage and adsorbed strongly on quartz surface until dropping the flotation performance. It is observed the grade of iron ore decreased due to an increase in collector concentration. In this case, other minerals tend to floatand selectivity is reduced. Over-dosing with collector can lead also to froth stability issues, ringing from immobility to collapse, and can induce bubble clustering in the pulp, that is arrays of bubblesbridged by particles, which can potentially entrap gangue [4].

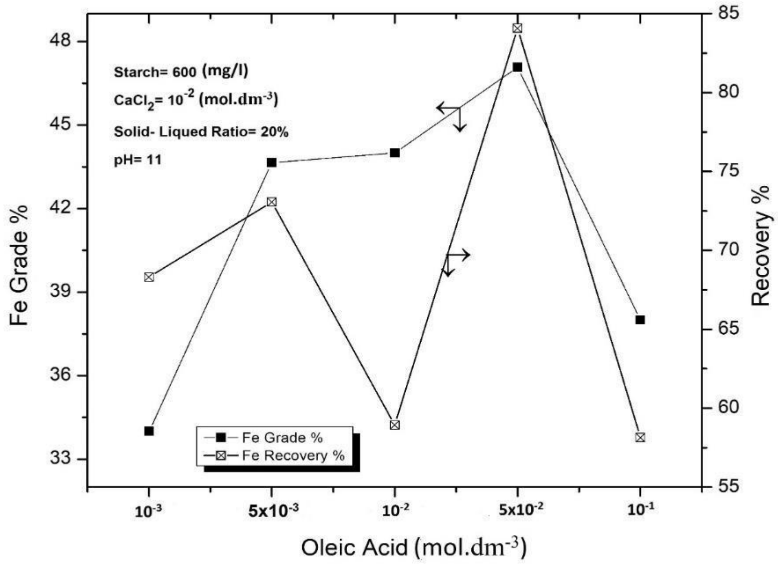

Figure 7. Effect of Oleic Acid Dosages on Flotation Recovery and Grade

EFFECT OF pH

During the flotation tests, the effect of pH was examined at the pH range from 9 to 11.5. pH was a critical factor in all areas of the investigation into the reverse anionic flotation of hematite from the west of the Khartoum area. Fig. 8 presents the results of the effect of pH on iron recovery and grade. The silica particles did not float at all acidic media. At pH 11 a sharp increase in hematite grade in the concentrate and dropped Above pH 11.

The reason for that is a weakly acidic oleic acid undergoes dissociation to form ions ($RCOO^-$) at high pH values [5]. The drop happened because of the addition of more negative hydroxyl ions which effected on positive calcium ions.
Starch is not absorbed on the surface of quartz at the alkaline pH of the pulp [6].

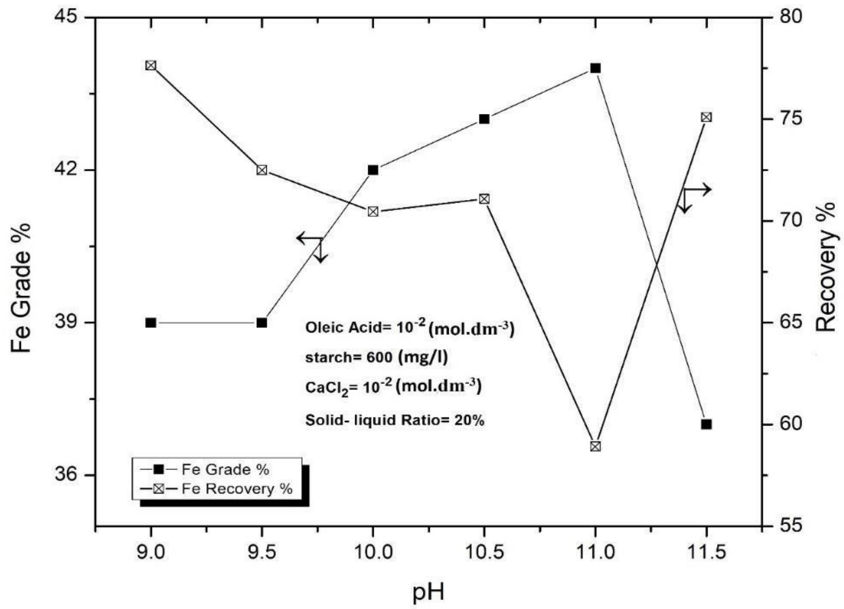

Figure 8. Effect of pH on Flotation Recovery and Grade

EFFECT OF CALCIUM CHLORIDE

The effect of calcium chloride on iron grade, iron recovery was examined in Fig. 9. At dosage 10^{-2} mol/l, it was found that calcium chloride effectively activated the silica which reflects at iron grade. With more addition of calcium ions, the flotation lost its selectivity [7]. Excess Ca^{++} also had an adverse effect on the frothing ability of MIBC [8]. In an investigation with increasing in Ca^{++}, the froth volumes were small and very unstable. This arises from an increase in the hardness of water that is associated with the increase in Ca^{++}.

The adsorption of starch on iron oxides was shown to be strongly dependent on the presence of calcium ions, but it is not well understood [6].

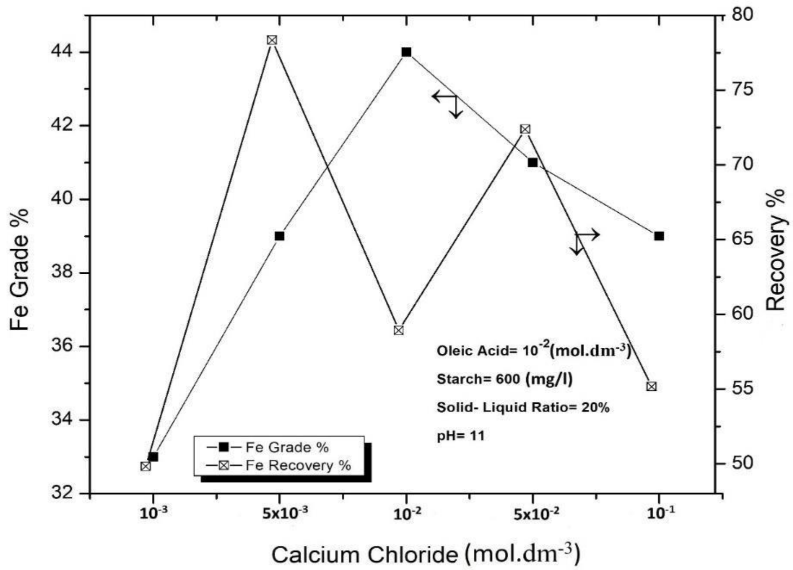

Figure 9. Effect of Calcium Chloride Dosages on Flotation Recovery and Grade

The optimum variables were obtained at collector dosage $5x10^{-2}$ mol.dm^{-3}, potato starch dosage 1000 mg/l, calcium chloride $5x10^{-2}$ mol.dm^{-3}, and pH 10.5. The best result obtained was 52.08% Fe grade with 82.5% Fe recovery.

CONCLUSION

The low-grade iron ore on the west of the Khartoum area can be upgraded by reverse flotation using oleic acid, starch soluble (potato starch), calcium chloride, and alkaline pH. The raw iron ore sample contains around 31.5% Fe, 46.21% SiO_2, and 7.03% Al_2O_3. Mineralogical analysis indicated that the sample was composed mainly of hematite and quartz as main gangue minerals. Microscopic investigation indicated that the sample has an oolitic iron ore structure.

The flowsheet includes crushing using large and mini jaw crushers and roll crusher, then grinding with ball mill in close circuit. The fraction -150+28 was subjected to flotation cell. The optimum variables were obtained at collector dosage $5x10^{-2}$ mol.dm^{-3}, potato starch dosage 1000 mg/l, calcium chloride $5x10^{-2}$ mol.dm^{-3}, and pH 10.5. The best result obtained was 52.08% Fe grade with 82.5% Fe recovery, and suitable for the blast furnace and steel Company.

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