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Beneficiation of Haematite from Fluorspar Tailings by Reverse Flotation

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Abstract **–**Fluorspar tailings produced at Vergenoeg Mine contain a substantial amount of haematite. Reverse flotation of haematite from the tailings has been investigated using a batch, bench –scale mechanical cell. Characterisation of the fluorspar tailings was done and effects of various operating parameters on the recovery of haematite were studied. The results showed that 80% of the tailings particles were - 150µm in size and major mineral phases are haematite, quartz and calcium tecto-dialuminodisilicate. It contains 69.4% haematite. Dodecylamine (DDA) is a better collector than Betacol and a highest grade of 60.8%Fe was achieved using 300g/t DDA, 400-600g/t starch as depressant and at a pH of 8. Si content in the sinks was reduced to 2.83%.

***Keywords*:** reverse flotation, haematite, collector, fluorspar tailings

1. Introduction

The second largest fluorspar (CaF_2) reserves in the world are found in South Africa. However, these reserves are found with high content of haematite which ends up in tailings dam. These tailings can be subjected to beneficiation to yield a haematite concentrate containing 61.5 to 66% Fe and less than 3% SiO_2 (Filippov et al., 2014). In order to increase the efficiency of blast furnace, some of the issues relating to iron ores include chemical composition of iron ore with low Fe content and high Al:Si ratio, low strength, high temperature break down, lower reducibility, low temperature softening and melting behavior of the iron ores, etc. Normally iron ores with Fe content above 65% are desirable to achieve better productivity in blast furnace. Impurities such as silica content should be within permissible limit for better fluidity of slag (Mowla, 2008).

The best method for processing low grade ores and complex ores is flotation. Filippov (2014) showed that flotation has significant advantages when processing low-grade, finely grained iron ores containing iron-bearing silicates. The most common flotation route used for the beneficiation of iron ores is reverse cationic flotation (Lin et al., 2009; Filippov et al., 2014). Flotation is the physic-chemical separation process that utilises the difference in surface properties of valuable minerals and the unwanted gangue minerals (Araujo, 2005). Separation of solid particles is achieved using differences in their affinity for air bubbles (Wills & Napier-Munn, 2006). The main objective of flotation separation process is to achieve the highest recovery of valuable mineral at highest valuable metal grade as possible.

There is literature on a variety of reagents that can be used to alter the surface properties of silica particles in aqueous solution, thus increasing its hydrophobicity making it more available for recovery in the concentrates. Some of these reagents such as C6-C18 fatty acid reagents were investigated extensively by Quast (2005). The effects of pH, dosages of collector, dispersant, depressant, solid concentration and impeller rotation on the performance of the reverse flotation of haematite were studied by Kumar, (2010). It was found that increase in pH and depressant dosage increases % yield and grade of the concentrate. Increase in the collector dosage decreases % yield and increase grade of the concentrate. Effect of different types of depressants was investigated by Bhagyalaxmi Kar (2013). It was found that soluble starch, corn, rice and potato starch have depressing action on hematite. Soluble starch is a better depressant compared to other starches. The effect of particle sizes was investigated and it was found that particles as coarse as 0.297 mm are floatable. (Lima et al., 2013).

In the US, the majority of iron ore concentrates produced in the flotation is preferably palletized. This is done using the bentonite binder to make pellets that are strong enough to form a high grade pig iron when processed in the blast furnace (Kawatra & Halt, 2013).

2. Experimental

2.1. Material

The fluorspar tailings associated with haematite used in this study were obtained from the Vergenoeg Mining Company in Gauteng province, South Africa.

2.2. Experimental Procedure

2. 2. 1. Characterisation

The sample was filtered using pressure filter and oven dried at 100^{o}C for 24 hrs. It was then characterised using Malvern particle size analyser, X-ray fluorescence (XRF) and X-ray diffraction (XRD).

2. 2. 2. Flotation Experiments

Reverse cationic flotation batch tests were conducted using 1kg of fluorspar tailings in 2.5l Denver D12 flotation cell at pulp density of 40% solids, impeller speed of 1000rpm and air flowrate of 60%. Before flotation, the pulp was first conditioned with starch for 4min and then conditioned with collector for 4min. The floats were manually scrapped off every 15 seconds. Soluble starch was used as a depressant and Dowfroth 200 as a frother. The effect of two different collectors was investigated at different concentrations. After which effect of depressant and pH was investigated. In this study, the flotation process is evaluated by recovery of haematite to the sinks.

3. Results and Discussion

3.1. Characterisation

3.1.1. Chemical Analysis

The chemical analysis of the fluorspar tailings is shown in table 1.

Table. 1. Chemical analysis of Vergenoeg fluorspar tailings

Element	F	Fe	Si	Ca	O	Al	Ce	K	Mn	Na	P	S	Y
%	2.54	48.54	9.02	2.99	34.09	0.95	0.20	0.17	0.15	0.15	0.17	0.21	0.23

The sample has an iron grade of 48.54% and contains 9.02% Si, 2.99% Ca and 2.54% F as the main gangue elements. All other elements are <1%.

3. 1. 2. Mineralogy

The X-ray diffraction (XRD) pattern of the flotation tailings is shown in Fig. 1.

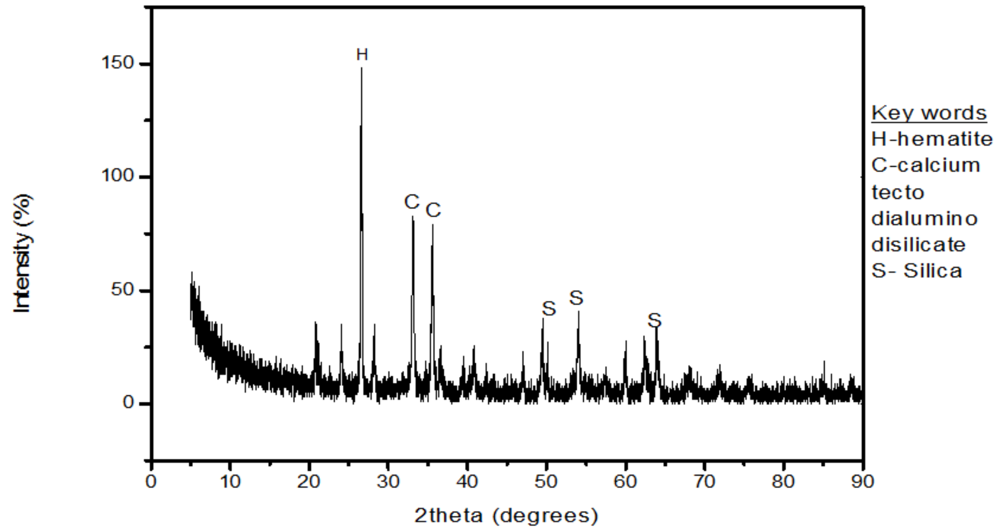

Fig. 1. XRD pattern of the fluorspar tailings

From Fig. 1, it can be seen that major mineralogical phases in the tailings are haematite, calcium tecto dialumino disilicate and Silica. There are other minor phases present which are represented by smaller peaks. From XRF and XRD results, Si content is high and there is need to reduce its content to <3% and increase Fe content to between 61.5 - 66% (Filippov et al., 2014). Since content of SiO_2 is not very high, reverse flotation was carried out.

3. 1. 3. Particle Size Distribution

The particle size distribution of the fluorspar tailings was studied and the results are shown in Fig. 2. Fig. 2 shows that 80% of the material is -150µm. This result proves that the sample is from a flotation process and no milling is required for the subsequent test work.

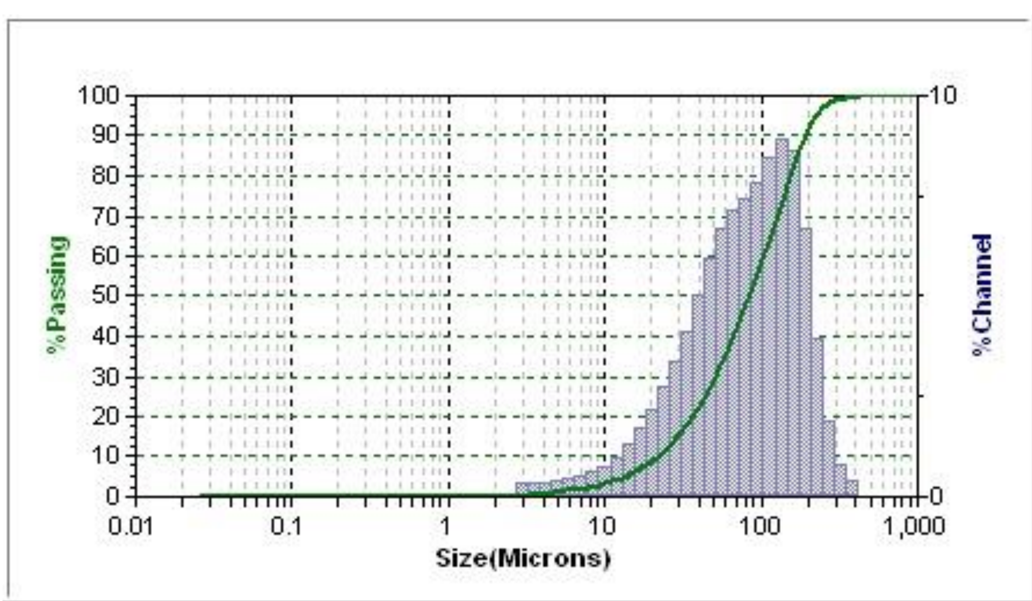

Fig. 2. Cumulative percent passing size distributions of the sample

3. 2. Flotation Tests

3. 2. 1. Choice of Collector

The response of the tailings to flotation using Dodecylamine (DDA) and Betacol was investigated and the results are illustrated in Fig. 3.The results show that as the collector concentration increases, the silicon grade in the floats also increases. DDA shows better selectivity in terms of silicon grade compared to Betacol at all concentrations. Hence DDA was used for all subsequent flotation test work.

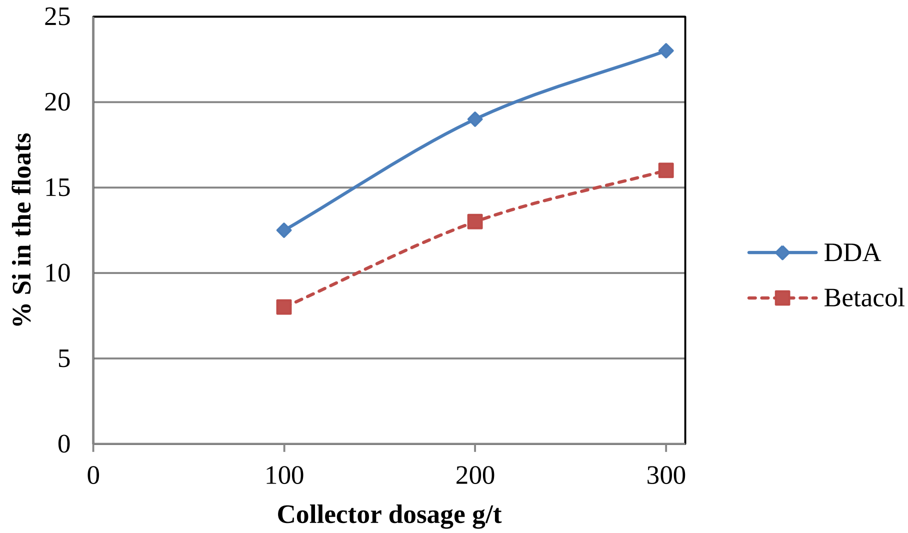

Fig. 3. Effect of collector concentration on Si distribution in the floats

3. 2. 2. Effect of DDA Dosage

Effect of DDA dosage on the recovery and grade of haematite in the sinks was investigated and the results are shown in Fig. 4. The results show that as the collector dosage increase the Fe grade increases and the recovery decreases. This is explained by the fact that at high dosages there is no reagent starvation and most of the Si will be floated. The highest grade of 60.8% Fe at a recovery of 52% was obtained using 300g/t of DDA. Si grade in the sinks decreased from 9.02% to 2.83%.

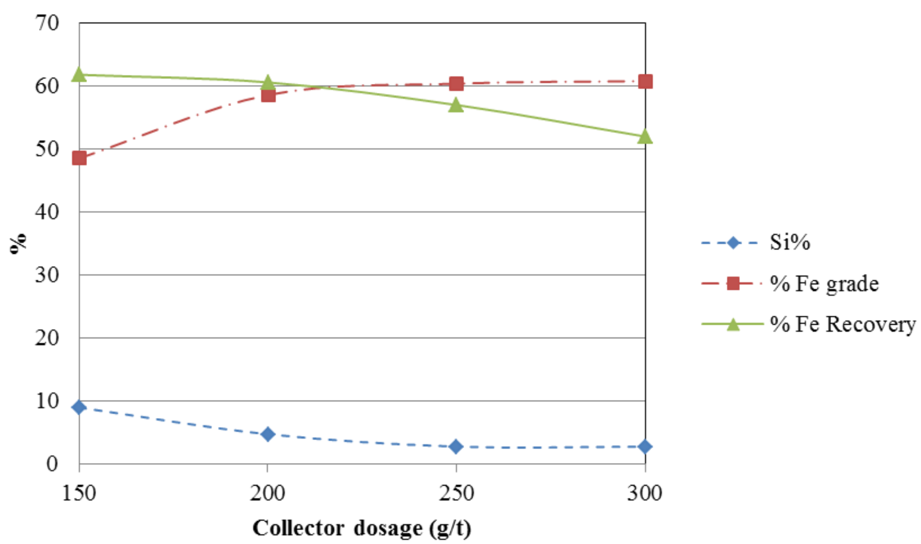

Fig. 4. Effect of DDA dosage on Fe and Si grade of the sinks and Fe recovery

3. 2. 3. Effect of Depressant

The effect of depressant on the Fe grade is shown in Fig. 5. This figure shows that as the concentration of the depressant is increased the Fe grade in the sinks decreases. This is because at higher dosages of depressant most of the material is rendered hydrophilic, thus some of the silica remain trapped in the sinks. Depressant dosages in the range of 400 - 600g/t gave optimum conditions.

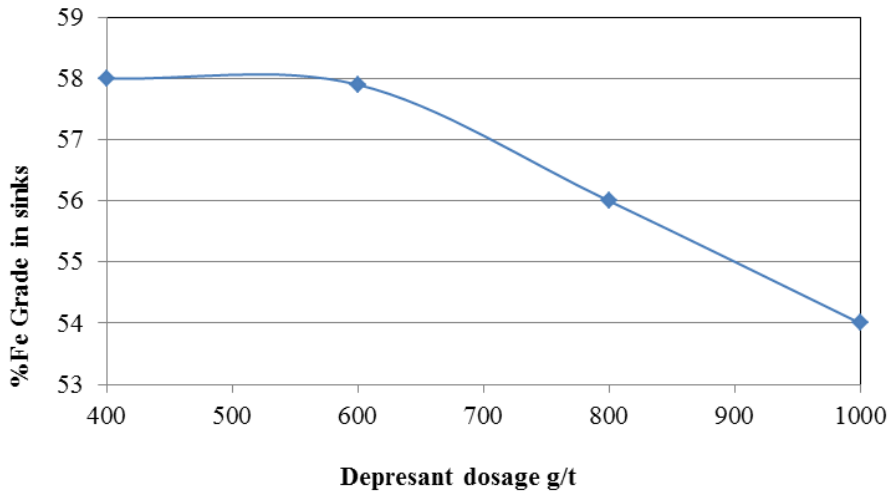

Fig. 5. Effect of depressant dosage on Fe grade in sinks

3. 2. 4. Effect of PH

Fig. 6 shows the effect of pH on the grade of Iron. As evident from this figure, the pH of 8-9 is optimum for this process. This is the natural pH of the material and thus the material is best processed at its natural pH.

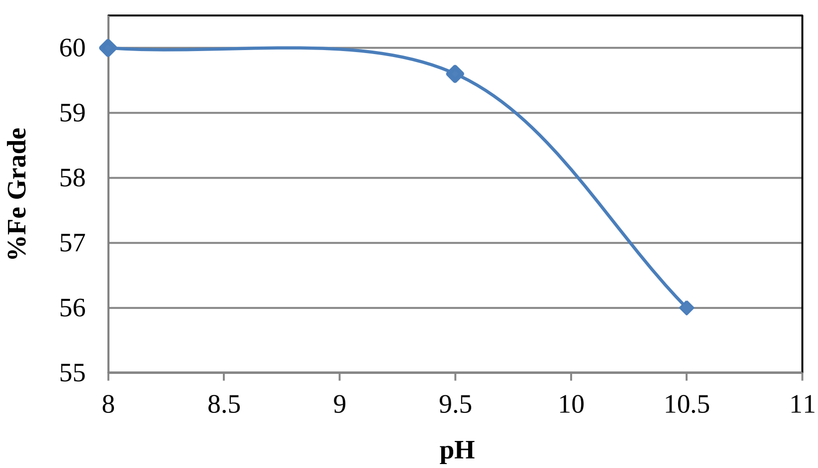

Fig. 6. Effect of pH on Fe grade in sinks

4. Conclusion

Reverse flotation of haematite from a local fluorspar tailings has been investigated using a batch, bench-scale mechanical flotation cell. The following conclusions can be made from the experimental results.

- Haematite can be beneficiated from the fluorspar tailings using reverse flotation
- DDA is a more selective collector for silicon as compared to Betacol.

- 300g/t of DDA, 400-500g/t of starch and natural pH of 8 – 9 gave the best results of 60.8% Fe and 2.83%Si in the sinks.

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