Recovery of Aluminium Oxide from Flint Clay through H_2SO_4 Leaching

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***Abstract*—This is a short communication on the work done to recover aluminium oxide from waste produced by a fertilizer manufacturing company in South Africa. Aluminium rich ore (known as flint clay) was subjected to an experimental study in which aluminium oxide (Al_2O_3) was recovered through acid leaching. Sulphuric acid was the leaching agent due to its suitability for leaching aluminium and other base metals. The following phases were present in the sample (Al_2O_3), magnetite (Fe_2O_3), silica (SiO_2) and as well as other metal compounds in concentrations of less than 2%. Parameters investigated were, leaching time, acid concentration, solid to liquid ratio and leaching temperature. The maximum Al recovery was 69%. The optimum conditions found in this study were leaching time of 4 hours, acid ratio of 1:4, leaching temperature of 100^0C and solid to liquid ratio of 1:6.**

***Index Terms*—Acid concentration, aluminium oxide, flint clay, leaching, optimum, phases, recovery**

I. Introduction

Increasing concerns for the environment and it's wildlife as well diminishing ore resources has increased efforts to recover valuable metals from waste. Solid waste from pyro- metallurgical operations is continuously being dumped around the world, posing both environmental and economic challenges due to entrained values of base metals and sulphur. Since 1945 aluminium has been used in high voltage electrical transmission, in place of copper as it is the most cost efficient power line material. Aluminium is used excessively in the modern world, and the uses of the metal are extremely diverse due to its many unusual combinations of properties. Aluminium major uses include cooking equipment, glass manufacturing, packaging material and in the transportation industry. It is used in the transportation industry due to its excellent strength to weight ratio [1]

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In this work, the flint clay contained predominantly aluminium oxide, present as $Al_2O_3.H_2O$. The aluminium oxide (alumina) and iron associated with the alumina react with sulphuric acid forming aluminium sulphate and ferric sulphate according to (1) and (2)

$$Al_2O_3H_2O + 3H_2SO_4 = Al_2\,(SO_4)_3 + 6H_2O \qquad (1)$$

$$Fe_2O_3 + 3H_2SO_4 = Fe_2\,(SO_4) + 3H_2O \qquad (2)$$

The processes which occur during most hydrometallurgical operations are either chemical reactions, mass transport of chemical reagents or combinations of these two. The thermodynamics of a particular reaction will determine its feasibility while reactions kinetics indicates its practical value.

II. Materials and Methods

A. Procedure

A single steel reactor fitted with an agitator with a pitch blade impeller was used in this study. Heating was achieved by using a hot plate to maintain and control the desired temperature. 90% concentrated sulphuric acid was used as the leaching lixiviant. Dilution was achieved using de – ionized water. After flint clay was leached for a specified time, it was filtered using a vacuum filter fitted with a filter paper. ICP-OES was used to measure the concentrations of aluminium and iron in the leach solutions.

B. Effect of Lixiviant Concentration

200 g of 60 mesh flint clay sample was used. Acid corresponding to acid ratio of 1 mole of alumina to 2 moles of acid was diluted to 200 ml, mixed with the flint clay and boiled for 4 h, filtered and the residue washed to make up the leached liquor. Acid ratio was varied from 1:2 to 1:10.

C. Effect of leaching time

A mixture of 1 mol alumina and 4 moles of acid diluted to 200 ml was mixed with 200 g of 60 mesh flint clay and boiled at varying time of 1 to 10 hours.

D. Effect of Temperature

200 g of flint clay was leached at varying temperatures from 40-100^0C. The leaching conditions were flint clay of 60 mesh size, leaching time 4 hours solid to liquid ratio 1:

10 and acid ratio of 1:4.

E. Effect of Solid to Liquid Ratio

The effect of solid to liquid ratio on the leaching was investigated by keeping the amount of the flint clay constant while varying the amount of lixiviant up a dilution ratio of 1:10.

III. RESULTS AND DISCUSSION

A. Sample Characterization

The chemical composition of the aluminium rich solid waste was characterized using XRD and XRF and the results are presented in Fig. 1 and Table 1 respectively.

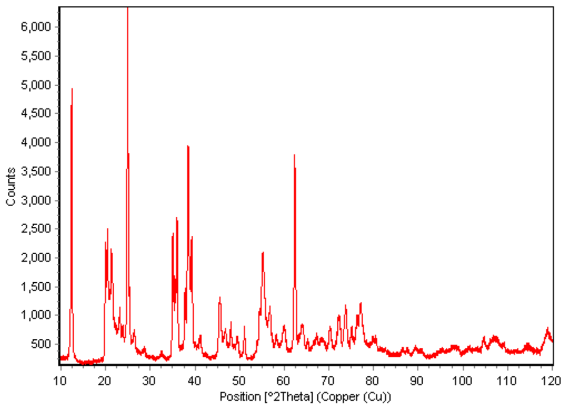

Fig. 1. Aluminium Rich Flint Clay XRF Analysis

TABLE 1
CHEMICAL COMPOSITION OF ALUMINIUM RICH FLINT CLAY

Compound	% Concentration Sample A	Sample B	Concentration (mg/l)
Al_2O_3	45	10	2750000
SiO_2	51	79	650000
Fe_2O_3	1.6	0.31	11100
TiO_2	1.5	2	17500
CaO	0.11	0.017	635

B. Effect of Leaching Time

As shown in Fig. 2, the optimum leaching time for Al_2O_3 with a corresponding low Fe_2O_3 was found to be 4 h. However, the highest Al_2O_3 recovery was obtained after leaching for 3 h, but this was undesirably accompanied with high extractions of Fe_2O_3.

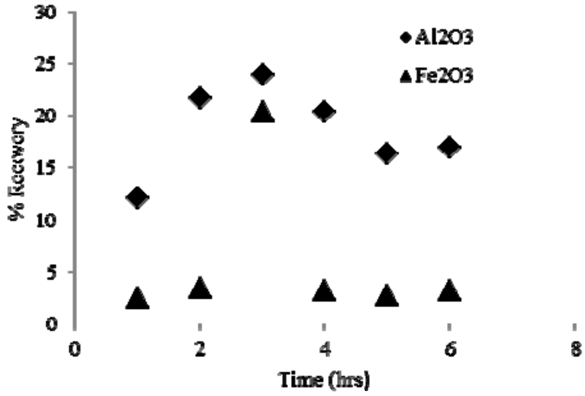

Fig. 2. Variation of recovery with time

C. Effect of Lixiviant Concentration

The amount of aluminium oxide and iron oxide extracted increased gradually from acid ratio 1:1 to 1:4. However, acid concentrations greater than 1:4 (1:8 to 1:10), resulted in a high recovery of Al_2O_3 but simultaneously contaminated the mother liquor with high iron concentrations as shown in Fig. 3. Acquah (1999) studied the production of aluminium from bauxite at acid ratio of 1.4 and the findings support the results of this work [2]. Therefore, acid ratios above 1:4 are quite unfavourable for pure recovery of Al_2O_3. An optimum acid ratio of 1:4 is recommended because it gives the best alumina ratio (% recovered Al_2O_3 / % recovered Fe_2O_3) of 9.5 compared to other acid ratios, say 1:8 and 1:10 which give alumina ratios of 1.97 and 1.74 respectively.

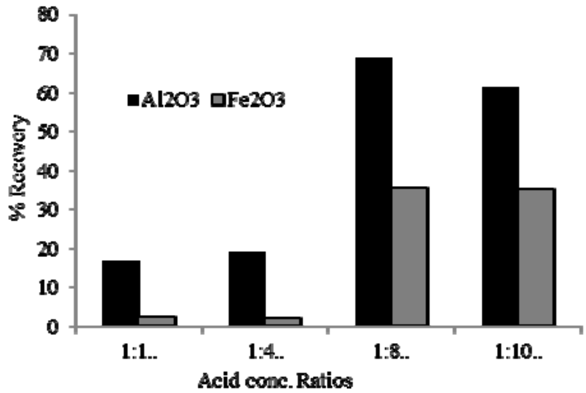

Fig. 3. Effect of leaching acid ratios on recovery

D. Effect of solid to liquid ratio

As presented in Figs 4 and 5, a solid to liquid ratio of 1:2 gave the highest recovery of Al_2O_3 with a corresponding unfavourable high extraction of Fe_2O_3. A solid – liquid ratio of 1.6 gave the best case scenario.

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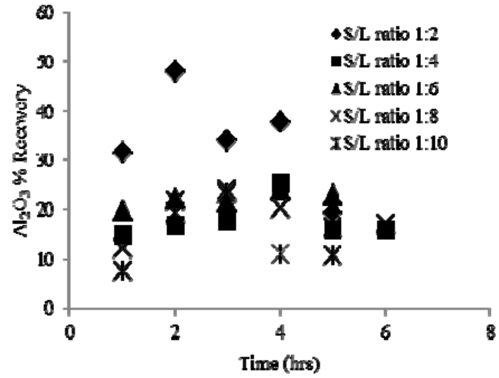

Fig. 4. Effect of solid to liquid ratio on Al_2O_3 recovery

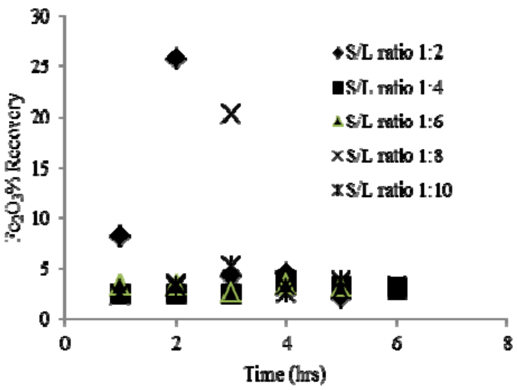

Fig. 5. Effect of solid to liquid ratio on Fe_2O_3 recovery

E. Effect of Temperature

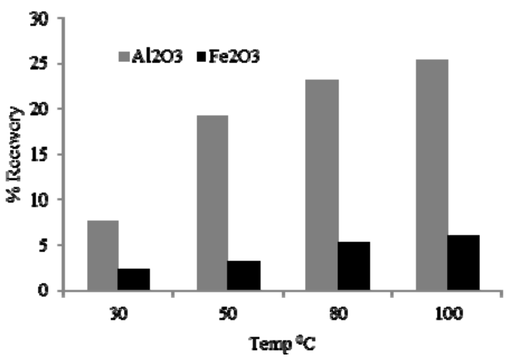

Fig. 6. Influence of temperature on recovery

Recovery for both Al_2O_3 and Fe_2O_3 was found to increase with increase in temperature. A range of 80^0C-100^0C is recommended as a high extraction of Al_2O_3 is achieved with a comparable small amount of iron dissolution (Fig. 6). Similar trends on the effect of temperature on leaching were also observed by [3] – [6]. The rate of leaching increased with increase in temperature because the diffusion coefficient of aluminium ions in solution increased and the solution became less viscous. At 100^0C, 25% of alumina was extracted; commercial leaching is reported to be in the range 100- 120^0C.

IV. Conclusion

The leaching of alumina from flint clay was studied in this work. The study aimed to determine the optimum Al_2O_3 leaching conditions while minimizing that of Fe_2O_3. Optimum conditions were a leaching time of 4 h, acid dilution ratio of 1:4, leaching temperature of about 100^0C and solid to liquid ratio of 1:6. The flint clay containing about 28% Al_2O_3 and 1% Fe_2O_3 on average is suitable for the production of aluminium. The flint clay had a high silica content resulting in low Al_2O_3 grade. This could have led to the formation of unfavourable phases. The effect of the nature of the phases present in the flint clay on the extent of extraction will form part of our future investigations.

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