Beneficiation of Iron in Thermal-Reduced Ilmenite by Magnetic Separation

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Abstract: Increasing demands for Iron in countries development, and lack of conventional reducing agents has resulted into sourcing of alternative ways of beneficiating the iron ore. This paper reports on the study that was done to concentrate low grade iron ores. Raw biomass / low grade iron ore mixed in the ratio of 1:10 in a reducing environment was heated in a controlled air condition to increase the magnetic susceptibility of iron in the ore. The magnetic portion of the resulting product was separated using a horse shoe-magnet. This resulted into concentrating the ore from 45.6% - 53.1 % to 76.3%- 82.2%. This gave an ore that could be fed to a blast furnace for extraction of iron.

Keywords: Key Words: Ilmenite, Maghemite, beneficiation, iron, magnetic.

1. Introduction

Iron ores occur in deposits of all geological ages. Most of the world supply is obtained from Precambrian and Jurassic rocks [1]. Principal types of deposits yielding iron are bedded ores, igneous segregation, contact metamorphic deposits, vein deposits and superficial residues. The bedded ores are the most important and constitute a large proportion of world iron ore reserves[2].

In Kenya, Iron ore deposits have been documented to exist in laterites, in various parts of Kenya [3-5]. Previous studies have shown that iron in laterites is fairly widely spread all over the country and contain 15 to 45% iron depending on source. Iron in these laterites are mainly in the form of ilmenite, haematite and goethite [6]. The average deposits of a typical iron ore contains 25 – 68% [6]. Geological survey of Kenya [7], reports that laterites containing iron ore deposits are mainly used for surfacing the roads. Research studies recently established that iron in laterites can be used as a source of iron [3-5].

From the studies, researchers used charcoal as a source of reducing agents and heat. This would result to deforestation of locally available tree cover and hence reduce rapidly the tree cover which is less than 10 % of the total land available [8, 9]. In this paper, raw biomass can be used as a source of syngas, such as, hydrogen, carbon monoxide and methane [10, 11], which can be used as reducing agent and source of heat in the reduction process. The biomass-ore are heated in the temperature range of 500 – 800 $^{\circ}$C in a controlled air-current flow. The iron ore was mixed with raw biomass in clay crucibles, and were heated to a temperature range of 500 – 800 $^{\circ}$C, in a controlled current of air through the mix. On cooling the mixture in a desiccator, horse shoe magnet was used to separate maghemite.

2. Methodology

A. Sampling of the sample
Laterites samples were collected from Kaharate in Murang'a County from four quarries and Gitong'o and Gitara-Kianderi in Tharaka Nithi County from three sites. Within a given site, the samples were collected at a depth of 30 cm, 50 cm and 100cm in depth that denotes level A, B and C respectively.

B. Treatment of the sample
The samples were dried in an oven at 105 $^{\circ}$C for eight and a half hours. The samples were then removed and placed in a desiccator for two hours to cool. The dried samples was ground to 300 microns using a Pulverizer then mixed with raw biomass and heated to a temperature of between 500 – 800 $^{\circ}$C for 2.5 – 3 hours in clay crucibles, in a controlled current of air. The crucibles with heat treated sample are then placed in a desiccator. The heat treated samples was separated by a strong magnet. The magnetically separated substance was analyzed for major elements and mineral present.

C. Optimization of Raw Biomass to Sample Ratio
Raw ground samples were separately mixed with ground charcoal and raw biomass at ratios of 1:1 to 1:10 in increments of one in clay crucibles. The crucible were carefully placed on the burner and charcoal added carefully. The mixture was then heated in controlled current of air for 3 hours using a charcoal burner. The temperature was recorded using an electronic thermocouple. The roasted sample was then cooled to room temperature in a desiccator. The magnetic material was separated from the heat-treated sample using a horse shoe magnet (*about 92milliteslas*). Raw biomass was added carefully when temperatures reduced to 500 $^{\circ}$C.

3. Results and Discussion

The chemical and mineralogical analysis on the raw and concentrated samples was done using AAS. Table 1 and 2 shows the percentage composition of iron by mass in raw samples and concentrated samples.

The XRD shown in figure 1 and 2 shown a decrease of peaks of goethite, ilmenite and haematite and a sharp peak rise of maghemite
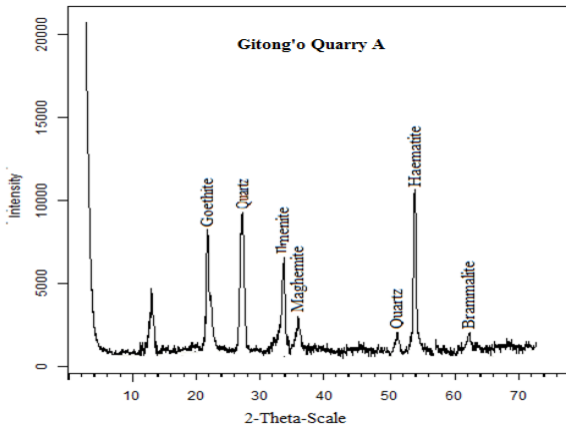

Figure 1: Spectra of Raw Samples

The untreated sample contained 45.6 – 47.7 % of iron. The results shown that it contained iron that can cannot be fed in a blast furnace since it is below 55% *[12]*. Thus need to undergo pre-concentration process.
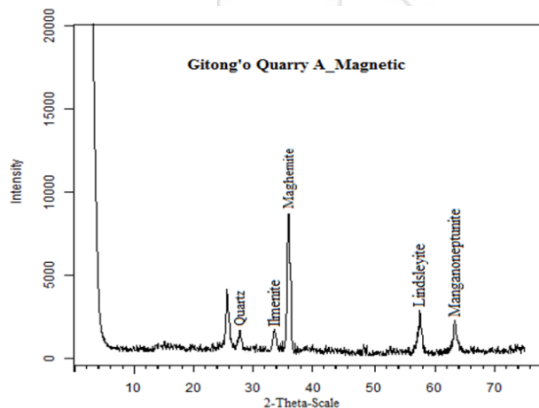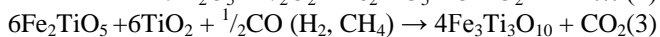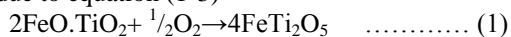

Figure 2: Spectra of concentrated Samples

Similar results were obtained [3-5] though used charcoal as a source of reducing agents. Increased magnetic susceptibility of iron ore is due to equation (1-3)

$$2FeO.TiO_2 + {}^1/_2O_2 \rightarrow 4FeTi_2O_5 \qquad \ldots\ldots\ldots (1)$$
$$2FeTi_2O_5 + {}^1/_2O_2 \rightarrow Fe_2TiO_5 + 3TiO_2 \qquad \ldots (2)$$
$$6Fe_2TiO_5 + 6TiO_2 + {}^1/_2CO\ (H_2, CH_4) \rightarrow 4Fe_3Ti_3O_{10} + CO_2 (3)$$

Due to antiferromagnetic nature of the iron in oxidation state Fe^{2+}, the ore has low magnetic susceptibility [13]. Syngas produced from raw-biomass lead to the formation of Fe^{3+} which is highly magnetic susceptible.

Chemical analysis of heat-treated ores had shown an increase in iron by up to 36.6%.

4. Conclusion

Iron content in laterites from Kaharate in Murang'a county, Gitong'o and Gitara-Kianderi in Tharaka Nithi County was more than 45.6 percent. Results show that raw biomass can be used to increase the magnetic susceptibility of iron bearing ores, thus use of a strong magnet. This will help greatly in bio-waste management.

5. Acknowledgement

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Table 1: The AAS of raw samples

Level A	SiO_2Mean ±SE	Al_2O_3Mean ±SE	CaOMean ±SE	MgOMean ±SE	Na_2OMean ±SE	K_2O Mean ±SE	TiO_2 Mean±SE	MnO Mean ±SE	Fe_2O_3 Mean ±SE	LOI Mean ±SE
KAHARATE 3	16.72±0.04	9.87±0.03	0.07±0.01	0.28±0.00	0.32±0.01	0.00±0.00	3.50±0.04	1.86±0.01	**53.10±0.26**	15.19±0.29
KAHARATE 4	19.20±0.03	6.85±0.03	0.16±0.01	0.30±0.01	0.23±0.01	0.10±0.00	4.15±0.01	2.01±0.03	**50.33±0.14**	13.95±0.14
GITONG'O A	18.42±0.06	19.02±0.08	0.07±0.01	0.03±0.00	0.68±0.68	0.00±0.01	1.77±0.04	0.39±0.01	**45.61±0.06**	13.95±0.04
GITONGO B	16.24±0.06	18.64±0.06	0.09±0.01	0.27±0.02	0.12±0.01	0.00±0.00	1.61±0.03	0.43±0.04	**47.70±0.14**	14.31±0.19
GITARA KIANDERI	17.53±0.06	15.95±0.05	0.13±0.01	0.30±0.02	0.14±0.01	0.00±0.01	1.60±0.04	1.02±0.02	**46.87±0.07**	15.52±0.43

Table 2: the percentage composition of the concentrated sample of the same sample

Level A	SiO_2Mean ±SE	Al_2O_3Mean ±SE	CaOMean ±SE	MgOMean ±SE	Na_2O Mean ±SE	K_2O Mean ±SE	TiO_2 Mean±SE	MnO Mean ±SE	Fe_2O_3 Mean ±SE	LOI Mean ±SE
KAHARATE 3	6.35± 0.13	7.68±0.06	0.06±0.02	0.15±0.03	0.19±0.12	0.06±0.01	5.93±0.05	1.19±0.04	74.53±0.04	5.26±0.09
KAHARATE 4	7.71±0.14	5.32±0.07	0.12±0.03	0.22±0.04	0.23±0.05	0.08±0.01	5.45±0.10	1.27±0.04	78.18±0.04	3.36±0.11
GITONG'O A	6.68±0.03	8.77±0.06	0.15±0.02	0.06±0.01	0.16±0.02	0.06±0.01	7.43±0.09	0.47±0.06	75.28±0.12	3.61±0.03
GITONGO B	5.22±0.04	7.60±0.04	0.24±0.05	0.35±0.05	0.09±0.02	0.06±0.01	8.49±0.13	0.73±0.06	77.58±0.13	2.74±0.41
GITARA KIANDERI	4.37±0.06	6.17±0.05	0.25±0.05	0.72±0.11	0.07±0.01	0.17±0.01	4.43±0.09	1.30±0.10	82.20±0.12	3.13±0.05