

Magnetic Concentration of Iron in Lateritic Soils from Kamahuha, Murang'a County, in Kenya using Carbon Monoxide Generated *In-Situ*

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Abstract: *Chemical and Mineral Analyses of laterites from selected sites in Kamahuha area of Murang'a County, in the Republic of Kenya, have been carried out with particular interest in the levels of iron and the type of minerals the iron is present in. A laterite/charcoal mixture was heated in the temperature range 500-700°C as a slow current of air was passed through the hot mixture, the material cooled and the iron-containing mineral picked with a permanent magnet. Elemental Analysis, which was done on both the raw and concentrated samples was carried out using, Atomic Absorption Spectroscopy (AAS). The Analyses also showed that whereas the level of iron in the raw laterites was in the range 28-35, in the magnet-separated product, the level had increased to 55-62% depending on several factors such as how efficiently the laterite-charcoal mixture had been mixed and the length of time of heating. The nature of the minerals present was determined using a Bruker D2 Phaser Diffractometer. In the raw laterites, iron was present as the minerals goethite, FeO.OH and haematite, Fe₂O₃. These minerals have diffraction peaks at angles $2\theta=21.51^\circ$ and $2\theta = 54.11$, respectively. On the other hand, iron in the magnet-picked product was present predominantly as the mineral magnetite, Fe₃O₄, as shown by presence of a characteristic peak at $2\theta = 36^\circ$. The results of this study show that iron in laterites can be concentrated by magnetic separation after passing compressed air over hot charcoal laterite mixture.*

Key Words: Hematite, Laterites, magnetic concentration, Magnetite

INTRODUCTION

Kenya has several geologically-documented iron ore deposits, many of them known even during the period the country was a British colony [1]. For example, there is a large lateritic deposit in Lela, West of Kisumu which is estimated to contain at least 2.7×10^7 million cubic metres of laterites [1]. In a previous study, it has been shown that laterites are fairly widely spread all over the country and that they contain 15-45% iron depending on source. In these laterites, iron is present predominantly as the minerals goethite and haematite [2]. During that study, a laterite sample collected from Lela showed that it contained an average of 32% iron. It is, therefore, reasonable, to treat the Lela deposit as a typical iron ore deposit since materials containing 25-68% iron are treated as iron ores [2]. In his Geological Report published in 1952, reference [1], reported that laterites from Lela were being used for surfacing roads. We note that, well over

sixty years later, this situation has not changed. At the same time, we note that furthermore, the country has been spending a lot of money annually to import iron and iron-made products. Thus, according to data published by United Nations Commodity Trade Statistics Database, during the years 2008, 2009 and 2010, the country imported iron-made products valued at, US dollars 102,283,716, 136,512,664 and 148,992,169 respectively [6]. These products do not include imports of items such as vehicles and Heavy machinery [7]. Ironically, some of the iron-made products imported to Kenya have been manufactured using ores with much lower percentage of iron than the Kenyan Ores. A specific example of such ores is the iron from Frodingham, UK, which contains only 18-25% iron [4]. This example has been cited because, when Kenya was a British Colony, practically all iron-made imports came from Britain.

Previously, iron in the minerals goethite and haematite has been concentrated using froth flotation with the aid of suitable frothing agents [5], [3]. More recently, Reference [6] have shown that iron in the two minerals can be concentrated by magnetic separation after heating the laterites in the temperature range 400-700°C at a current of CO/CO₂ in a molar ratio of 1:3. In this paper, we wish to report the results of a study undertaken to find out whether similar results can be obtained by generating the CO in situ. Thus, instead of using separate gas cylinders, one with CO and another one with CO₂, the laterites were mixed with charcoal, heated in the temperature range 500-700°C as a current of air is passed through the hot mixture, cooling the material and using a permanent magnet to separate magnetite from the cooled mixture. Whereas positive results in our study will definitely impact positively towards achieving Kenya's Vision 2030, it should definitely have universal application. It is simple and cost effective.

METHODOLOGY

Laterite samples were collected from Kamahuha Area in Murang'a County, in the Republic of Kenya in an area enclosed by latitudes of $1^\circ 12' 26''$ S and $1^\circ 13' 52''$ S and longitudes $37^\circ 40' 40''$ E and $37^\circ 40' 12''$ E from four quarries marked as K₁, K₂, K₃ and K₄ in an area shown in the attached map of Kenya. Within a given quarry, the top soil was removed (since it contained a lot of organic matter) and samples of about 1kg collected from three different depths of 10cm, 50cm and one meter on profiles already cut by the road construction

companies. We have confirmed the material the Ministry of Roads recommends as high quality for road construction contains well of 25% iron. The material was dried in an oven at 105°C for two hours, ground to 300 microns (150 meshes) using a pulverizer, Lab Disc Mill Machine. The accuracy of elemental Analysis using AAS was confirmed using Rock Standards, Syenite (SY-3) and Mount Royal Gabbro (MRG) from Canada, obtained through the Ministry of Mines, Kenya. The AAS Instrument used was Spectr AA.10 model from SEANAC Company while the weighing was done using the analytical balance Model Mettler AJ150, X-ray fluorescence analysis was done using Minipal-2 version 4 PanAnalytical Model available at Ministry of Mines, Kenya. The nature of Minerals present was determined using a Bruker Model D2 Phaser X-ray Diffractometer available at International Centre for Research in Agro-Forestry (ICRAF), Nairobi, Kenya.

A. Treatment of Laterites

A laterite sample, usually between 150 and 300 gm was weighed and mixed with some finely ground charcoal in different ratios, eg 1:20 charcoal : laterite, put in a glass tube and the latter put on a heat exchanger. (locally called Jiko in Kenya , see Figure 1). The Temperature of the heat exchanger was controlled by increasing or reducing the air opening on the side of the heat exchanger and the temperature attained checked occasionally with a Thermocouple. The mixture was heated to the temperature range 500-700°C as a slow current of air was passed through. After heating the mixture for 2-3hours, the tube was removed from the heat exchanger, cooled and the contents spread on a cardboard or newspaper. Flat plywood was placed on top of the cool mixture and a permanent horse shoe magnet placed on top. When the horse shoe magnet was lifted together with the cardboard, it was found that on removing the magnet from the cardboard, the black material dropped. Finally, the material was analyzed for the major elements and the mineral present, as shown in figure 1.

B. Determination of Loss on Ignition (LOI)

About 1.00 gram each of pulverized samples were weighed into crucible boats and transferred into the furnace. The samples were heated to 1,000 °C for about 6 hours to burn all organic materials. The samples were then cooled in a desiccator, re-weighed and the percentage difference determined [8],[9].

RESULTS AND DISCUSSION

The results of Elemental Analysis on the raw laterites and concentrated laterites samples using AAS are summarized in Tables 1 and 2 respectively. A comparison of results in the two tables shows that, the level of iron in most raw samples was in the range 31.5 – 39.2%. On the other hand, the level of iron in the magnet separated product was in the range 54 – 62.7%. Since it is recommended that for an iron ore to be suitable for putting in a blast furnace, it should contain at least 55% iron [10], it can be concluded that this very simple ore treatment converts very low quality iron ore to ore grade. These results show that when charcoal is used as the source of the carbon monoxide that converts haematite to magnetite, the concentration of iron in the laterites was readily increased from about 30% in the raw laterites to well over 55% in some samples and over 62% in a number of samples using an extremely simple set –up whereby perhaps the most complex set up is the compressed air cylinder. Fig 2 is a spectrum of Raw Laterite Sample showing Haematite and Goethite peaks while Fig 3 is the spectrum of Magnetite-Separated laterite showing disappearance of Haematite and Goethite peaks and well pronounced peaks for magnetite. XRD spectrum for KI showed that the laterite had the minerals, Quartz which and a peak at $2\theta = 26.2^\circ$, Goethite was also present and had a broad peak at 21.51° , Rutile was also present and gave a peak at 24.8° .

The minerals that gave peaks in the raw laterites include Quartz (SiO_2), Goethite ($\text{FeO}(\text{OH})$), and Rutile (TiO_2). When concentration was carried out the peak for goethite disappeared and several peaks associated with magnetite appeared. The main peaks observed in the concentrated portion were for the minerals Quartz (SiO_2), Rutile (TiO_2) and Magnetite (Fe_3O_4).

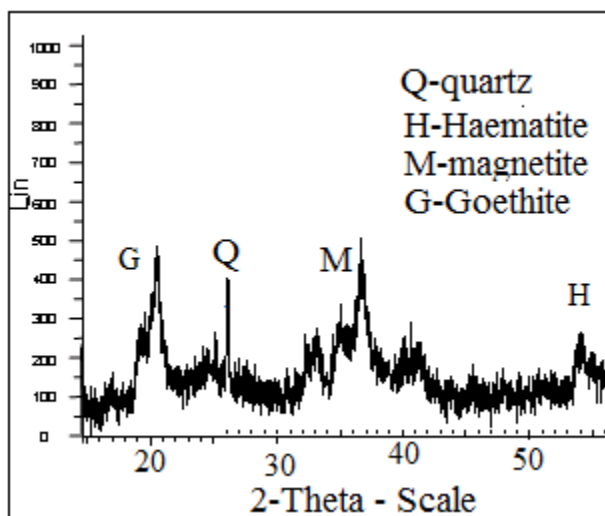


Fig 2: XRD Spectrum of raw Sample K₁

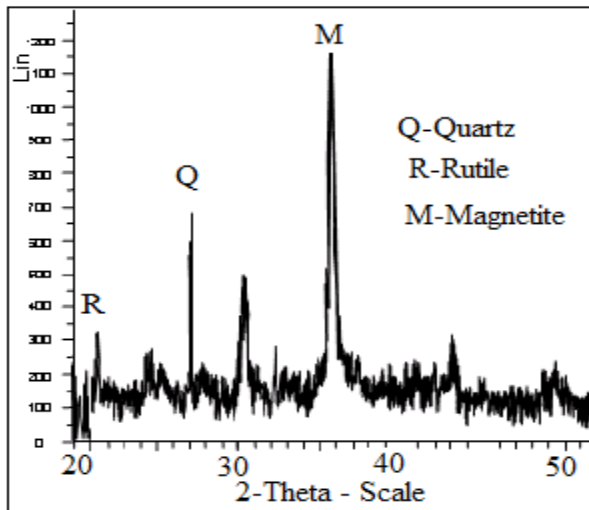


Fig3:XRD Spectrum for concentration Sample K₁

CONCLUSION

Iron content in laterite from kamahuha in Murang'a County is in the range between 31.5 to 39.2 percent, iron in this laterites is found in the form of minerals goethite and hematite. The levels of iron in the laterites are high enough for them to be termed as iron ore. Charcoal has been used used to reduce hematite to magnetite. Upon reduction magnetic separation has been used to concentrate the iron to well over 62%. These laterites can therefore be used as a source of iron.

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Table 1. Analysis of Raw Laterites from Different Sites using AAS (Values in %).

	SiO ₂	Al ₂ O ₃	K ₂ O	Na ₂ O	CaO	TiO ₂	MnO ₄	Fe ₂ O ₃	Fe	LOI
	Mean± SE	Mean± SE	Mean± SE	Mean± SE	Mean± SE	Mean± SE	Mean± SE	Mean± SE		Mean± SE
K1A	18.34±0.07	18.07±0.04	0.25±0.17	0.09±0.01	0.09±0.01	7.93±0.04	0.41±0.00	52.83±0.17	36.90	4.19±0.01
K1B	18.88±0.06	18.67±0.16	0.05±0.03	0.10±0.01	0.08±0.01	6.78±0.01	0.28±0.12	51.67±0.17	36.12	5.19±0.01
K2A	22.28±0.04	18.21±0.10	0.31±0.01	0.21±0.01	0.12±0.01	7.12±0.01	1.62±0.01	49.37±0.19	34.55	3.65±0.02
K2B	22.35±0.01	17.32±0.01	0.31±0.01	0.21±0.01	0.12±0.01	7.22±0.01	1.64±0.01	48.51±0.01	33.95	6.36±3.32
K3A	21.44±0.01	20.89±0.33	0.29±0.01	0.53±0.34	0.11±0.02	7.77±0.01	1.28±0.00	45.49±0.01	31.84	5.68±0.01
K3B	20.44±0.01	22.50±0.30	0.30±0.01	0.20±0.01	0.11±0.02	7.81±0.01	1.28±0.01	46.47±0.00	32.5	4.68±0.01
K4A	21.69±0.34	15.81±0.01	0.17±0.01	0.14±0.01	0.12±0.01	5.79±0.01	0.58±0.01	56.03±0.33	39.22	2.14±0.01
K4B	21.39±0.02	15.61±0.01	0.14±0.02	0.15±0.01	0.21±0.01	5.96±0.01	0.38±0.01	55.39±0.02	38.71	2.31±0.01

Tables 2: Levels of Iron after Concentration using Charcoal (Values in %).

	SiO ₂	Al ₂ O ₃	K ₂ O	Na ₂ O	CaO	TiO ₂	MnO ₄	Fe ₂ O ₃	Fe	LOI
	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean± SE		Mean±SE
K1A	4.14±0.02	6.09±0.24	0.20±0.12	0.19±0.11	0.13±0.31	8.63±0.04	0.21±0.00	76.13±0.17	53.65	4.19±0.21
K1B	4.8±0.16	8.67±0.32	0.15±0.00	0.20±0.21	0.14±0.04	7.75±0.01	0.18±0.12	76.68±0.17	54.05	3.19±0.16
K2A	5.24±0.02	8.67±0.11	0.11±0.05	0.31±0.21	0.22±0.00	7.32±0.06	0.56±0.01	79.09±0.19	55.72	3.65±0.00
K2B	6.34±0.04	7.82±0.00	0.34±0.31	0.41±0.31	0.42±0.31	7.62±0.03	0.84±0.01	80.71±0.01	56.83	1.36±0.32
K3A	5.46±0.01	7.99±0.21	0.21±0.11	0.33±0.32	0.21±0.22	8.73±0.05	0.98±0.08	78.05±0.01	54.97	1.18±0.03
K3B	6.24±0.02	8.59±0.23	0.19±0.11	0.30±0.03	0.31±0.01	8.01±0.00	.98±0.71	78.77±0.00	55.47	0.98±0.05
K4A	3.69±0.32	5.46±0.12	0.32±0.05	0.24±0.02	0.42±0.00	6.99±0.01	0.38±0.02	86.55±0.33	60.95	0.11±0.05
K4B	3.39±0.22	3.69±0.00	0.16±0.14	0.05±0.24	0.11±0.41	6.23±0.03	0.28±0.05	89.19±0.02	62.75	0.21±0.02