Considerations for Beneficiation of Low Grade Iron Ore for Steel Making in Kenya

A. K. Bett and S. M. Maranga

Abstract – The iron and steel industry will be prominent in the industrialization process for the country to realize its goals of the vision 2030. There will be great demand of the metal, for example, needed in the manufacture of machines, components and reinforcing rods for the construction. Though quite involving, steel is basically made by smelting iron ore charged with coke is a blast furnace. Kenya has ample iron ore deposits which are yet to be fully utilized for the development and economic growth of the nation. There are iron ore deposits in some counties like Taita Taveta (Manyatta), Tharaka (Marimanti) and Siaya (Samia) which have not been fully exploited. There is need to amass information on the quality of iron ore deposits and the method for pre-processing as a precursor to setting up a steel plant.

The main focus in this paper is on the geology and geographical distribution of iron (Fe) ores and the ways of upgrading them so as to attain better grades to be used in furnaces. Iron ores have different metal (iron) composition ranging between 48-72%, the remainder being impurities/gangue. Very low grade iron ore cannot be used in metallurgical plants and needs to be upgraded to increase the iron content and reduce the gangue. Iron ore is being beneficiated all round the world to meet the quality requirement of iron and steel plant. Use of iron and steel is increasing yearly as a result of upcoming projects all over the world. There are various methods/ways of beneficiating the ores but this paper is focused on two methods; magnetic separation and floatation methods.

The envisaged results of the study will provide relevant information for the prospective investors intending to set up a steel plant in the country using the local ores.

Keywords – beneficiation, geology, iron ore, magnetic separation, froth flotation.

I. INTRODUCTION

A. Iron Ore Characterization

Next to aluminium, iron is the most widely distributed and abundant metallic element in the earth's crust, of which it constitutes about 4.6 per cent. Over 300 minerals contain iron but the chief ores of iron are magnetite, Fe_3O_4, containing 72.4 per cent Fe; hematite, Fe_2O_3 containing 70 per cent Fe; limonite, $2Fe_2O_3.3H_2O$, containing 59.9 per cent Fe; and the carbonate siderite, $FeCO_3$, containing 48.3 per cent Fe. Less important ores are the sulphides, pyrite, FeS_2, and pyrrhotite, $Fe_xS_{(x=0\text{-}0.17)}$ [1].

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Ore deposits must contain at least 25% iron (Fe) to be economically recoverable however this percentage can be lower, however, if the ore exists in a large deposit and can be concentrated and transported inexpensively it can still be economically recoverable.
The main uses of iron ores are for the production of iron and steel accounting for 98% of the ore mined globally.

Iron ore deposits are formed by three geologic processes:

1. Direct sedimentation forming bedded sedimentary deposits

Bedded sedimentary iron ore deposits are thought to occur as a result of mineral precipitation from solutions present during the Precambrian period (2.6 to 1.8 billion years ago).

- Banded Iron-Formations

Banded iron-formations were created when solutions of iron oxides and silica precipitated in alternating layers. The iron oxides form hematite and/or magnetite; the silica forms chert. Iron content in these deposits is in the range of 25 to 40 percent. In some formations, the iron is in the form of carbonates (siderite with manganese, magnesium, and calcium) or silicate (greenolite, minnesotaite, and stilpnomelane) and, rarely, in the form of sulphide (pyrite). Chemically, these iron formations are marked by low contents of alumina (Al), sodium (Na), potassium (K), and other less abundant element.

- Ironstone

Ironstone formed as iron-rich waters permeated shallow, unconsolidated sediments. Iron either occurs with or replaces carbonates in the sediments. The source of the iron is intense weathering of continental crust. Ironstone is much younger (150 to 450 million years) than banded iron deposits, occurs in smaller units, and is not found inter-layered with chert. Ironstones have iron content from 20 to 40 percent. There is a great variety of ironstones, but the most common type of ironstone mined for iron ore is a thick-bedded rock consisting of small pellets (ooliths) of limonite, hematite, or chamosite in a matrix of chamosite, siderite, or calcite.

2. Igneous activity forming segregation or replacement deposits

Iron ore deposits of igneous origin are formed as a result of magmatic segregation of iron-bearing minerals. These deposits occur as veins and tabular replacement bodies of magnetite and hematite. The iron content is generally about 20 percent, but it can be as high as 60 percent. Most of the iron ore minerals occur as ilmenite, magnetite, or hematite.

3. Enrichment due to surface and near surface weathering

Iron-ore deposits were formed by surface or near surface enrichment as less resistant minerals were removed. Chemical and physical weathering by soil forming processes of pre-existing iron-bearing minerals (such as siderite or glauconite) resulted in progressive concentration of iron oxides to form iron-rich deposits with contents varying between 50 and 60 percent having Fe_2O_3 as the most dominant ore.

B. Iron Ore in Kenya

In certain parts of Kenya and the neighboring countries the smelting of iron ores by the use of charcoal and a forced draught of air from goatskin bellows has been carried out in rural areas for the production of sponge iron. This material has been used to make primitive implements and weapons but the craft has practically died out as the result of increased trade with the industrialized countries, which are able to supply tools and other necessities at comparatively low prices. Iron minerals are of widespread occurrence in western Kenya, chiefly Nyanza as shown in figure 1, where frequently they are associated with the rocks of the goldfields formations [1].

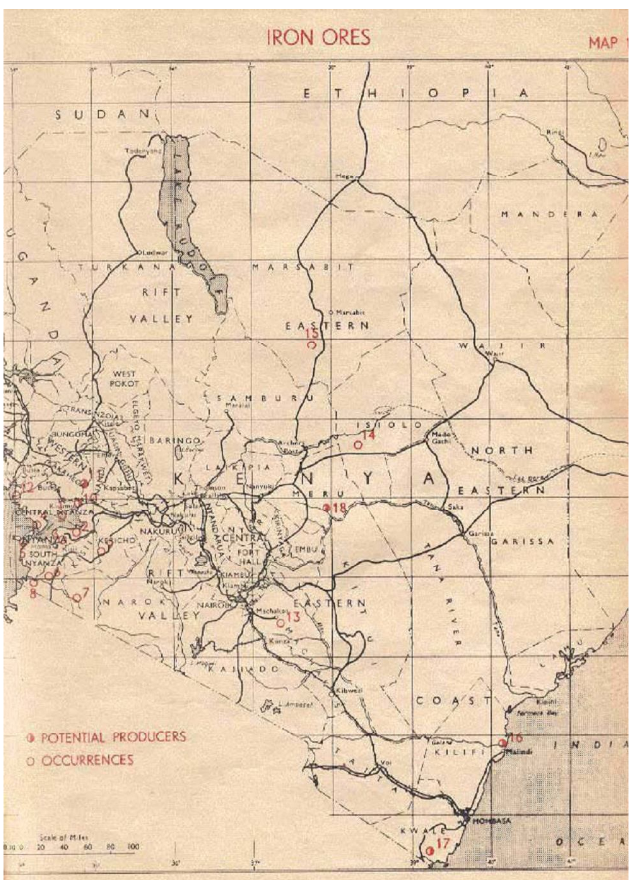

Fig. 1: Iron ore occurrences in Kenya [1]

The ores at present known comprise;

a) Oxide ores including magnetite, haematite, martite, limonite and gothite.
b) Carbonate ores including including siderite and possibly ankerite.
c) Pyritic ore

The rocks in which the ore occurs are schists, pegmatites, banded ironstones,gossans, lateritic iron stones, nodules in shales and iron-ore segregations[6].

Classifications and Geographical Distribution of deposits;

I. Magmatic
   a) Pegmatitic occur in various places within the Basement system rocks of Kenya which occur in the western, central and north-eastern parts of the country.
   b) Associated with carbonatite complexes are known to occur in central Nyanza
   c) Pyritic impregnations which are available in north and south Nyanza.

2. Sedimentary
   a) Archaean schists have been found in the district west of Voi.
   b) Precambrian banded iron stones and lenticles of ironstones associated with them are found in western Kenya and in North Nyanza.
   c) Nodules and shales are known only to occur in the coastal region near Mombasa.

3. Detrital
   a) Black sands which occur at various localities on the coast and also on the shores of Lake Victoria.

4. Residual
   a) Gossans form the caps to pyritic lodes in North and South Nyanza and
   b) Lateritic iron stones are of appreciable extent confined to western Kenya [1-6].

The geology and analysis of the above ores is as shown in the appendix.

II. IRON ORE MINING PRACTICES

Extraction, beneficiation and processing of Fe ore produce iron or steel. “Extraction” is the process of removing ore material from a deposit and encompasses all activities prior beneficiation which is the concentration, removal of unwanted gangue; also regulation of product size, or other steps such as agglomeration to improve its chemical or physical characteristics prior to processing. Processing is beyond the purview of this paper/ research.

At first most of the ores were simply crushed and shipped directly to a blast furnace especially the ores that contained 50% or more Fe without beneficiation. Today most extracted ores undergo beneficiation to upgrade the Fe content and prepare the concentrate for the blast furnace [2].

A. Extraction and Beneficiation Methods

Iron is mined exclusively in surface operations (open pit and open cut methods) which are least expensive.

Beneficiation is milling (crushing and grinding), washing, filtration, sorting, sizing, gravity concentration; magnetic separation; flotation; and agglomeration (pelletizing, sintering, briquetting, or nodulizing). The process result in the production of three materials; a concentrate; a middling or very low-grade concentrate which is either re-processed or stockpiled and a tailing waste which is usually discarded. Beneficiation operation in most cases occur in a liquid medium thus controlling dust emissions and approximately 95% of the water used is recirculated and reused.

B. Milling

Beneficiation begins with the milling of the extracted ore to specified sizes or desired sizes (figure 2) in preparation for further activities to recover the ore values [3].

Fig. 2: Grinding of iron ore

C. Magnetic Separation

Magnetic separation is commonly used to separate natural magnetic iron ore (mostly magnetite) from a variety of less-magnetic or non magnetic materials. The technique is used to beneficiate about 90 % of the ores worldwide and may be carried out either in a dry or a wet environment. It may also be defined as low or high intensity depending on the magnetic field strength, with low magnetic separators using fields between 1000-3000 gauss and mainly used on magnetite ore to capture highly magnetic material. On the other hand high intensity separators employ strong field of 20000 gauss and used to separate weak magnetic iron ores.

Type of magnetic separator is determined by; magnetic intensity, particle size and solid content of the ore slurry feed. The separators involve three stages; cobbing, cleaning/roughing and finishing with each successive stage working on finer particles as a result of removal of oversized particles in the earlier separations. In the first stage, cobbers work on larger particles (3/8 inch) and reject approximately 40 % of the feed as tails while cleaners work on particles in the range of 48 mesh and remove 10-15% feed as tails and finally the finishers work on the ore particles of less than 100 mesh and remove around 5% of the gangue which is as a result of the highly concentrated nature of the feed [2-3]

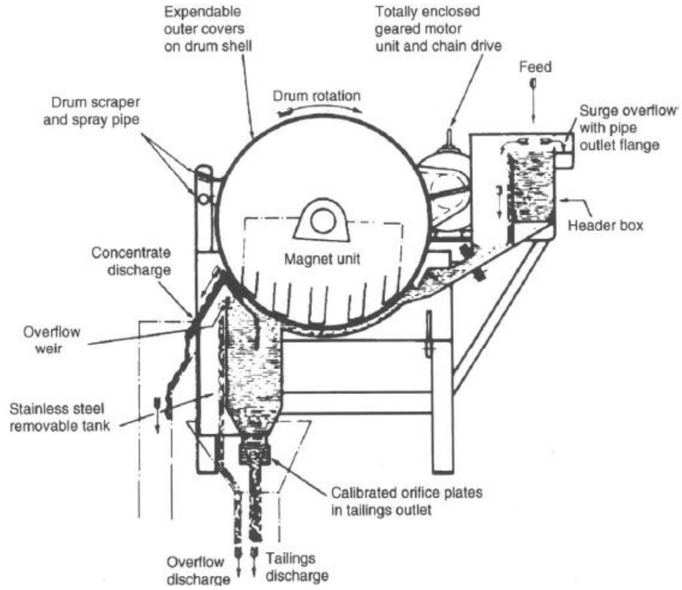

Fig. 3: Magnetic drum separator.

Fig. 4: Typical dense media magnetic separator.

D. Flotation

It is a technique where particles of the ore mineral or group of minerals are made to adhere preferentially to air bubbles in the presence of a chemical reagent [4]. For the floatation process to be successful there are important factors and they include; uniformity of particle size, use of reagents compatible with the mineral, and water conditions that will not interfere with the

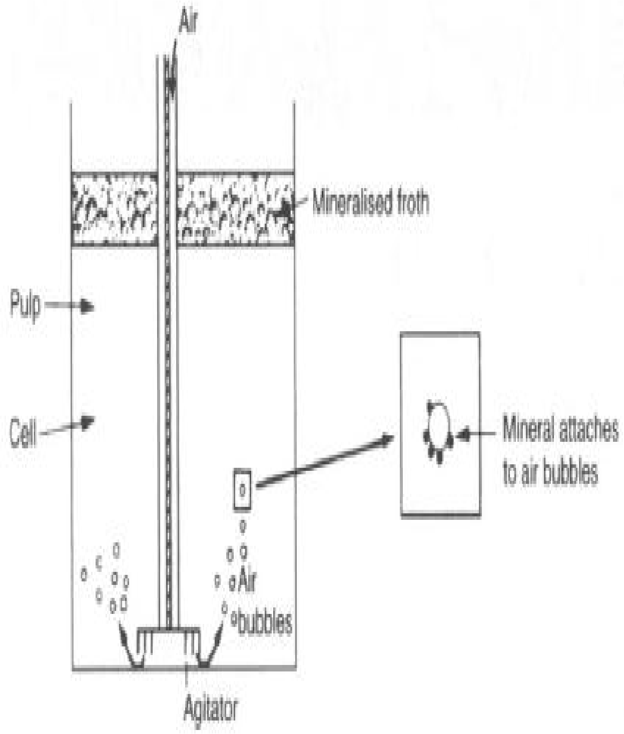

Fig. 5: Principle of flotation.

attachment of the reagents to the mineral or air bubbles. Reagents used are of three main groups:

- Collectors/amines which cause adherence between solid particles and air bubbles in a floatation cell.
- Frothers whose role is to stabilize air bubbles by reducing surface tension thus collection of valuable material by skimming from the top of the cell, and
- Antifoams which react with particle surfaces in the floatation cell to keep materials from remaining in the froth, instead materials fall to the bottom as tailings.

When conditioning ore for floatation with chemical reagents several factors are important and they are; thorough mixing and dispersal of reagents through the pulp, repeated contact between the reagents and all relevant ore particles and time for development of the contacts with the reagents and ore particles to produce the desired reactions[3-4].

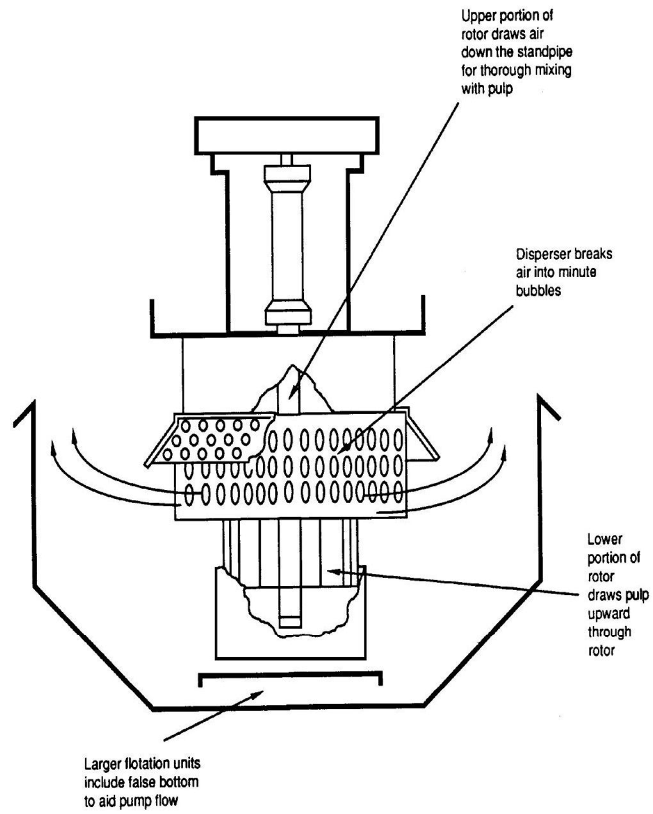

Fig. 6: Cross-section of a floatation cell.

III. DISCUSSION

The country has ore deposits identified in the following locations: Taita Taveta (Manyatta), Tharaka (Marimanti) and Siaya (Samia) and in various parts of the country as shown in the appendix where geological studies have been carried out.. Compared to the ore found in other countries, the quality is of acceptable standards and moreover there are ores which can be fed directly into the blast furnace without upgrading.The estimated tonnage is what the country needs to embark on to verify if it can sustain the operations of a blast furnace. Other requirement is the local coal and its suitability for coking.

The technology exists for pre-processing the iron ore before smelting. The most widely used are: magnetic separation methods which accounts for approximately 80% of the beneficiation methods worldwide because they are easy to operate energy-saving and high efficiency and flatation methods are also widely used and in most cases they are used to upgrade fine ores which have undergone the magnetic sepation. The equipment including the floatation cell and magnetic separator at Mines and Geology will be handy in assessing the most appropriate method for the prospective investors. So far magnetic separating methods are being used in quarries in Wanjala which is the major site of the research and Marimante where the locals have been selling the ore to the cement making companies.

IV. CONCLUSION

Most of the steel industries in Kenya rely heavily on imports as their raw material and partly on recycling of scrap. Research on the extent and quality of the iron deposits and documenting the range of methods for upgrading the ores will speed up establishment of a steel making plant.

APPENDIX

Geology of iron ore deposits

TABLE 1:
ANALYSIS IS PYRITE BODY AT BUKURA SOUTH-WEST OF KAKAMEGA[5]

Sample	1	2	3
	Percent (%)		
SiO_2	6.19	5.67	5.22
Al_2O_3	1.24	0.80	0.16
Fe_2O_3	53.69	43.22	47.83
S	34.65	46.18	37.15

TABLE 2:
ANALYSIS OF ORES FROM THE KISUMU DISTRICT [5]

Sample	1	2	3
	Percent (%)		
SiO_2	39.10	62.10	21.00
Fe_2O_3	55.31	33.36	64.72
P_2O_5	0.28	0.12	0.17
TiO_2	0.09	0.12	Tr.
S	0.10	0.08	0.09

TABLE 3 (A):
CHEMICAL ANALYSIS OF SAMPLES FROM WANJALA (ATACA & CO.) [6]

Fe	SiO_2	AlO_3	TiO_2	P	S	As	Sn	in %
61.19	10.84	.031	.02	.009	.008	nil	.004	
63.79	18.12	.082	.07	.005	.011	nil	.022	

TABLE 3(B):
CHEMICAL ANALYSIS OF SAMPLES FROM WANJALA (MINES AND GEOLOGY DEPARTMENT)[6]

Fe_2O_3	P_2O_5	TiO_2	S
65.89	3.91	.02	Nil
82.26	Nil	.08	Nil
84.66	Nil	.08	Nil

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