Quality of Iron ores in Kenya; TharakaNithi and Samia

Alvin Kiprono Bett, Joan A. Onyango, S. M. Maranga, B. K. Rop

Abstract—Iron ores have been identified in various parts of the country. These regions include Eastern region, Tharaka-Nithi County, and Western/Nyanza region, Busia County. Kenya has had various challenges in the iron and steel sectors which include unavailability of data on iron ore. This paper focuses on chemical analysis of iron (Fe) ores. Chemical analysis was carried out at the Ministry of Mining at Mines and Geology Department Laboratories using XRF machine. The iron ore sampled had Fe₂O₃ composition ranging from 41-57% for the ores from Marimante and 18-25% for Samia samples. It was found that the common gangue in the ores from both sites were silica and alumina with traces of other elements. The Marimante ore was found to be ilmenite.

Keywords – iron ore, grade, gangue, ilmenite

I. INTRODUCTION
Iron ores are minerals from which metallic iron can be economically extracted [1, 2]. The main iron ores are magnetite (Fe₃O₄) and hematite (Fe₂O₃). Magnetite contains 72.4% Fe and usually black while hematite has 70% Fe and red in colour. Other ore include limonite (2 Fe₂O₃ -3H₂O) containing 59.9% Fe and brownish; and the carbonate siderite, FeCO₃, containing 48.3% Fe, brown [3]. The composition are in pure state but in the case of ores they are at lower levels [4]. Iron ores are majorly used for the production of iron and steel accounting for 98% of the ore mined globally [5].

Iron ores have different metal(iron) composition ranging between 48-72%, the remainder being impurities. Impurities/gangue mostly contain silica, alumina, lime and magnesia as well as very small amount (usually under 1 %) of other compounds like Zn, Cu, Ti, Cr, Mn, Ni, S, P [6]. Iron ores are normally classified as high grade (more than 64% Fe), medium grade (62 to 64% Fe) and low grade (less than 62% Fe) [7].

A. Iron Production
The following raw materials are used in production of molten/pig iron in the blast furnace [8]:

a. iron ore e.g. hematite ore, or magnetite ore: source of iron
b. coke (carbon, C), used as fuel and reducing agent
c. hot air for the oxygen (O₂), in it to burn the coke
d. limestone (calcium carbonate, CaCO₃) used to remove impurities like silica in form of slag

For better productivity in the blast furnace, silica should be less than 2%, sulphur less than 0.3% and alumina less than 2% [9-10]. The alumina and silica ratio should be 1:1 [11]. High alumina content increases slag volumes and thus coke consumption [12]. Low gangue in iron ore reduces the rate of fuel/coke consumption in the furnace [13].

B. Mining in Kenya
Mining in Kenya is primarily for production of non-metallic minerals encompassing industrial minerals such as soda ash (trona), fluorspar, diatomite, natural CO₂, kaolin, gemstone and limestone [14].

Iron ores are mined from small localized deposits that have not been fully developed/explored and are largely sold to cement industries where they are used as additives in the manufacture of cement [15].

II. METHODOLOGY
The samples were sampled from two regions in Kenya, Tharaka-Nithi County and Bungoma County. Random method of sample collection was applied in both cases. In Marimante area the ores were collected from residents carrying out small scale mining with the aim of selling the iron ore to the cement industries in Kenya. Sampling was done on the surface. Some of the ores collected were from a mine of approximately 6 m deep.

In Samia iron ores samples were collected from a mine of approximately 0.5 m deep and from the surface. Residents assisted to identify old mines in the area. The samples were then labeled as, M1, M2 and M3 (Marimante) and S1, S2 and S3 (Samia). The first experimental work was grinding of the samples using laboratory jaw crusher. All the samples were crushed to less than 30 mm. Crushed specimens were then pulverized to fine powder of mesh 16 for chemical analysis.

A. Chemical Analysis
The pulverized samples were subjected to chemical analysis in laboratories at Mines and Geology Department, Ministry of Mining, to determine the iron oxide content and other
compounds. X-ray fluorescence (XRF) machine, Bruker model was used to scan the specimens. The results of the analysis were as tabulated below for the two sites under the study.

Table 1: Chemical Composition of Iron ores from Marimante and Samiascanned using XRFMachine

<table>
<thead>
<tr>
<th>S/No</th>
<th>Sample code</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>K₂O</th>
<th>TiO₂</th>
<th>MnO</th>
<th>P₂O₅</th>
<th>S</th>
<th>Fe₂O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M1</td>
<td>7.302</td>
<td>9.108</td>
<td>0.067</td>
<td>0</td>
<td>0.102</td>
<td>24.217</td>
<td>0.288</td>
<td>0</td>
<td>57.267</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>M2</td>
<td>23.07</td>
<td>8.504</td>
<td>4.37</td>
<td>6.221</td>
<td>0.038</td>
<td>14.977</td>
<td>0.277</td>
<td>0.037</td>
<td>41.779</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>M3</td>
<td>41.642</td>
<td>1.844</td>
<td>0.046</td>
<td>0</td>
<td>0.108</td>
<td>0.094</td>
<td>0.125</td>
<td>0.028</td>
<td>55.391</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>M average</td>
<td>24.005</td>
<td>6.485</td>
<td>1.494</td>
<td>2.073</td>
<td>0.0827</td>
<td>13.096</td>
<td>0.23</td>
<td>0.0217</td>
<td>0.002</td>
<td>51.479</td>
</tr>
<tr>
<td>5</td>
<td>S1</td>
<td>80.266</td>
<td>0.69</td>
<td>0.031</td>
<td>0</td>
<td>0.072</td>
<td>0.026</td>
<td>0.105</td>
<td>0.128</td>
<td>0.099</td>
<td>18.457</td>
</tr>
<tr>
<td>6</td>
<td>S2</td>
<td>70.977</td>
<td>4.125</td>
<td>0.045</td>
<td>0</td>
<td>0.126</td>
<td>0.046</td>
<td>0.111</td>
<td>0.05</td>
<td>0.095</td>
<td>24.264</td>
</tr>
<tr>
<td>7</td>
<td>S3</td>
<td>69.009</td>
<td>4.637</td>
<td>0.1</td>
<td>0</td>
<td>0.559</td>
<td>0.083</td>
<td>0</td>
<td>0.159</td>
<td>0.068</td>
<td>25.099</td>
</tr>
<tr>
<td>8</td>
<td>S average</td>
<td>73.417</td>
<td>3.152</td>
<td>0.059</td>
<td>0</td>
<td>0.252</td>
<td>0.052</td>
<td>0.072</td>
<td>0.112</td>
<td>0.087</td>
<td>22.577</td>
</tr>
</tbody>
</table>

Figure 1: Pie Charts showing the composition of Marimante Iron Ores
Figure 2: Pie charts showing the composition of Samia Iron ore

Table 2: Ratio of Silica to Alumina in the samples

<table>
<thead>
<tr>
<th>S/No</th>
<th>Sample code</th>
<th>SiO2</th>
<th>AL₂O₃</th>
<th>Ratio(SiO₂ : AL₂O₃)</th>
<th>Fe₂O₃</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>M1</td>
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<td>4.</td>
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<td>3.701619121</td>
<td>51.479</td>
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<td>5.</td>
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<td>80.266</td>
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<td>116.3275362</td>
<td>18.457</td>
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<tr>
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<td>S2</td>
<td>70.977</td>
<td>4.125</td>
<td>17.20654545</td>
<td>24.264</td>
</tr>
<tr>
<td>7.</td>
<td>S3</td>
<td>69.009</td>
<td>4.637</td>
<td>14.88225146</td>
<td>25.009</td>
</tr>
<tr>
<td>8.</td>
<td>S average</td>
<td>73.417</td>
<td>3.152</td>
<td>23.29219543</td>
<td>22.577</td>
</tr>
</tbody>
</table>
III. DISCUSSION

A. Chemical Analysis

From Table 1 above the compounds contain in the ores were noted. From the Marimante area the iron ore composition ranges from 41 – 57 %. For M1 and M2 samples the unique gangue compound was titanium oxide. Titanium has a higher melting point of about 1800°C as compared to iron thus the iron ore of about 1590°C. Blast furnace route will not be applicable for the Marimante ores. Other gangue in the Marimante iron ores are alumina, silica, magnesia and calcium oxide. The sample M2 also has various compounds; this includes calcium oxide (CaO) and magnesium oxide. M3 samples has only three major compounds of iron ore, alumina and silica. From Figure 1 above the average percentage of iron ore is 52% of Fe₂O₃.

The Samia iron ore have the least iron ore of between 18-25% with an average of 23% for the three samples studied. S samples mainly consists of three compounds; silica, alumina and Fe₂O₃ with silica having an average of 74% SiO₂, AL₂O₃ at 3%.

In both cases as the silica content increases the iron value decreases.

B. Silica: Alumina Ratio

The ratio of silica to alumina for M1 is approximately 1:1 but for other Marimante samples its 2.7 and 22.5 for M2 and M3 respectively. For Samia site this ratio varies from 14-116. S1 has the highest ratio of 116 and it has 80% silica and 0.69% alumina with the least iron ore content of 18% Fe₂O₃.
IV. CONCLUSION

Iron ores in Kenya are of lower grade and have to be upgraded for them to be suitable for blast furnace. Marimante iron ore is of ilmenite type because of the titanium oxide. The Samia iron ore have the lowest grade and for it to be economical in iron processing it shall require intensive startup capital only on condition that the quantity of deposit is large enough.

Further research work should be done on the beneficiation methods of the ores. Exploration work has to be carried out on the areas identified to be having iron ore deposits to ascertain the quantity of the deposits.

Silica:alumina ratios clearly indicates that the Kenyan iron ores have high content of silica gangue.

REFERENCES

[3] A. J. B. Muwanguzi, “Characterisation of Muko iron ores (Uganda) for the different routes of iron production,” 2010
[14] www.ipckeny.org