Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Chemical and Mineralogical Characterization of Ebiya Iron Ore in Kogi State, Nigeria

Abdulkadir, A., Thomas, D.G. and *Asuke, F.

Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Zaria, Nigeria.
*asukef@gmail.com; aabdulkadir344@gmail.com; dungkathomas@gmail.com

ARTICLE INFORMATION

Article history:
Received 02 Mar, 2020
Revised 17 May, 2020
Accepted 17 May, 2020
Available online 30 June, 2020

Keywords:
Chemical composition
Mineralogical characterization
Magnetite
Quartz
Ebiya iron ore

ABSTRACT

The chemical and mineralogical characterization of Ebiya iron ore located in Ajaokuta Local Governmental Area of Kogi State was carried out using X-ray Fluorescence (XRF), X-ray diffractometer (XRD) and optical microscope. The results obtained revealed that Ebiya iron ore has an average content of 61.67% Fe_2O_3, 0.33% MnO, 1.05% TiO_2, 0.86% CaO, 0.02% Cr_2O_3, and 33.9% SiO_2. XRD analysis revealed that the ore contained 53.5% quartz, 35.6% magnetite and 10.9% Ilmenite as major minerals. Petrographic study using polarized light revealed the iron bearing minerals are predominantly magnetite and ilmenite. Ebiya iron ore can be classified as medium grade iron ore.

1. INTRODUCTION

Iron and steel are the most widely used engineering materials for fabrication, construction and manufacture of most items including ships, vehicles, military hardware etc (Olayebi, 2014). The impact of iron and steel in any economy is usually tremendous because its production and consumption are measures of the rates and levels of industrialization (Worrell et al., 1997), This explains why the per capita consumption of steel is an index for assessing development in the economy of any nation. The availability and development of the iron and steel sector is essential for industrial growth, increases engineering capacity and enhancement of technical skills (RMRDC, 2010). Nigeria is blessed with all the raw materials required for steel development including iron ore, coal, natural gas and limestone. Nigeria has the potentials of becoming a regional economic hub in the West African sub-region, but it has been recognized that the growth of Nigeria is slow due to lack of domestic production of iron and steel among others (Ohimain, 2013).

The most widely available iron-bearing minerals are oxides and consist mainly of hematite (Fe_2O_3), which is red, magnetite (Fe_3O_4), which is black; limonite or bog-iron ore ($2Fe_2O_3 \cdot 3H_2O$), which is brown, and siderite ($FeCO_3$), which is pale brown. Hematite and magnetite are by far the most common types of iron ore. Pure magnetite contains 72.4 % Fe, hematite 69.9% Fe, limonite 59.8% Fe and siderite 48.2% Fe but, since these minerals never occur alone, the main iron (Fe) content of the ores is lower due to other impurities (Salawu, 2015).

Based on the % Fe content, the iron ore deposits in Nigeria could be classified as rich ores (> 50 % Fe), medium grade ores (30 – 50 % Fe) and lean ores (25 – 30 % Fe) which respectively constituted 4.5%, 85.4% and 13.1% of the total iron ore reserves (Ohimain, 2013). Medium and low-grade ores require extra technology to process the ores to meet the required standard for iron and steel production (Singh et al., 2015).

The most important economical iron oxides are those occurring within the Okene magnetite complex in North Central Nigeria. The largest of several similar deposits in the district is hematite-magnetite quartz body, which is a ferruginous quartz (Oyedele et. al., 2016). Work to date has outlined mineral reserves of 111,400,000 tonnes grading about 35% Fe which is easily upgraded and is now being developed for open pit mining to provide feed for the Ajoakuta and Delta Steel Companies (Salawu, 2015).

Asuke *et al.* (2019), studied the chemical and mineralogical properties of Gidan Jaja iron ore, Zamfara State and reported that the XRF analysis of the ore revealed Fe_2O_3, TiO_2, CaO, SiO_2 and Al_2O_3. XRD analysis revealed that the ore contained Ilmenite, Magnetite and Spinel minerals. The results obtained from SEM analysis showed that the iron bearing minerals are separated from other minerals in the ore by smooth grain boundaries. Khoso *et al.* (2017) studied the mineralogy of Zard Koh and Kulli Koh Iron Ore Deposits of Pakistan. Results indicated that the Zard Koh ore is mainly composed of maghemite, pyrite, chlorite, grossular and admontite minerals. The chemical analysis revealed that Zard Koh iron ore contains an average of 54.27% Fe, 12.73% S, 8.70% Si, 3.07% Al, 4.07% Ca, and 2.16% Mg. Similarly, the mineralogical study of the Kulli Koh iron ore indicated that the ore also contains hematite, quartz, dravite, and kaolinite minerals. Elemental analysis of different samples indicated that Kulli Koh iron ore contains an average composition of 40.23% Fe, 20.67% Si, 3.44% Ca, 3.81% Al and 3.25% Mg. Agava *et al.* (2016) determined the chemical, mineralogical and liberation size of Ochokochoko iron ore. They reported that the ore is predominantly magnetite, hematite, calcite, alumina, and silica. They also reported that the ore can be classified as medium grade and liberated at -180+125 µm sieve size. Salawu (2015) investigated the chemical and mineralogical characterization of Gujeni iron ore deposit Kaduna State, Nigeria and the findings showed that the ore contained majorly hematite, goethite, rutile while, manganese oxide, zincite, zirconium and silicate minerals were present in minor quantities. Agava, (2006) studied Agbado Okudu iron ore deposit Kogi state, Nigeria and reported that the iron ore contained on the average 38.82%Fe, 49.10%SiO_2, 0.05%%P_2O_5 and 0.03%S. Mineralogical analysis revealed that the iron bearing minerals are predominantly magnetite and hematite.

Based on the above literatures, no previous work has been carried out on Ebiya iron ore. The primary objective in this research work is to determine the chemical and mineralogical characteristics of Ebiya iron ore.

2. MATERIALS AND METHODS

2.1. The Ebiya Iron Ore Deposit

The iron ore deposit is located in Ebiya, Ajaokuta Local Government Area of Kogi State, Nigeria. It is close to the rail line to Ajaokuta steel plant. The deposit is bounded by latitudes 6^{o} 21’ 42”-N’ and longitudes 7^{o} 25’58”E, and its preliminary estimated deposit is 10 million tonnes with 34%Fe (MMSD, 2012).

2.2. Materials and Equipment

The materials and equipment used include the Ebiya Iron ore sample, global positioning system (GPS), laboratory sledge hammer, laboratory jaw crusher, ball mill, X-ray florescence (XRF) machine, X-ray diffractometer (XRD) machine and petrological microscope.

2.3. Sample Collection and Preparation

Samples of the iron ore were collected from various points at the deposit site, 60 kg of the samples were collected at interval of 100 m apart at 3 m depth in order to have a representative sample of the ore deposit. The ore samples were crushed and ball milled. Samples from the different locations were mixed and homogenized. Coning and quartering method of sampling was used to have a true representative sample for analyses. The representative sample was used for this investigation.

2.4. Chemical Composition Analysis

The representative sample was analyzed using X ray Florescence (XRF) machine to determine the chemical composition of the ore. The standard procedure for preparation and analysis of sample were used as reported in Asuke et al. (2018).

2.5. Mineralogical Analysis of the Ore

The mineralogy of the ore was determined using X-ray diffraction (XRD), and optical microscope (petrographic). This was carried out in order to identify the individual mineral, mode of occurrence and the degree of association of the minerals.

3. RESULTS AND DISCUSSION

3.1. Chemical Analysis of Ebiya Iron Ore

XRF analysis of the head sample is presented in Table 1. It shows that the ore contain 61.67% Fe_2O_3, with high amount of silica, 33.9% and 1.05% TiO_2 as major elements, while 0.864% CaO, 0.33% MnO, 0.31% BaO, 0.24% PbO, and 0.46% Eu_2O_3 were present as minor elements while the other elements are in traces. The quality of iron ore and its viability for commercial exploitation is mainly determined by its chemical composition (Abraham *et a*l., 2012). Therefore, iron ores should preferably have high Fe contents and low impurity element contents in order to justify investment during exploitation (Kiptarus *et al.*, 2015). Deposits with greater than 50 %Fe could be classified as rich ores, 30 – 50 % Fe as medium grade ores and 25 – 30 % Fe as lean ores (Ohimain, 2013). Thus, the Ebiya iron ore is a medium grade deposit.

Table 1: Chemical composition of Ebiya iron ore

Oxides	% composition
SiO_2	33.9
In_2O_3	0.96
CaO	0.864
Cr_2O_3	0.021
TiO_2	1.05
Fe_2O_3	61.67
CuO	0.029
BaO	0.31
MnO	0.33
PbO	0.24
ZnO	0.11
Rb_2O	0.01
Eu_2O_3	0.46

3.2. Mineralogical Analysis of Ebiya Iron Ore

The result of X-ray diffraction analysis of the iron ore head sample is shown in Figure 1 while Table 2 gives the percentage composition.

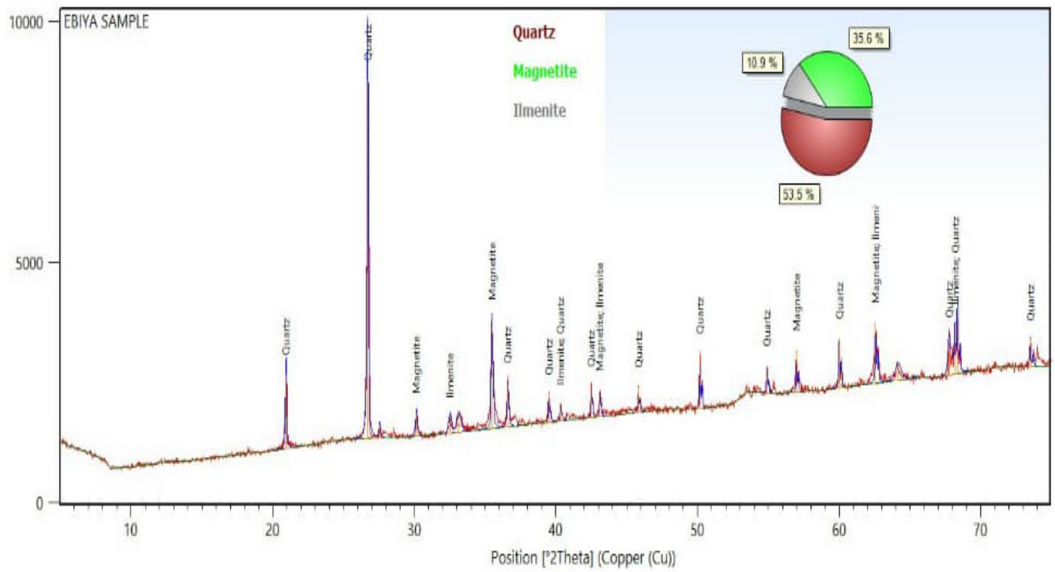

Figure 1: XRD pattern for Ebiya iron ore

Table 2: XRD analysis result of the representative sample

Mineral name	Chemical formula	% Composition
Ilmenite	$FeTiO_3$	10.9
Magnetite	Fe_3O_4	35.6
Quartz	SiO_2	53.5

From the result, it is clear that the predominant crystalline minerals in the ore sample is magnetite (Fe_2O_3) and quartz (SiO_2) which showed a high phase of 35.6% and 53.5% respectively with subordinate amount of ilmenite ($FeTiO_3$) with 10.9%. This is in line with the XRF result presented and similar to results presented by Asuke et al. (2019).

3.3. Petrographic Microscopy of Ebiya Iron Ore

The petrographic analysis was carried out under cross polarized light (XPL). The results of petrographic microscopy from three different points of the iron ore sample are shown in Figures 2a, 2b and 2c.

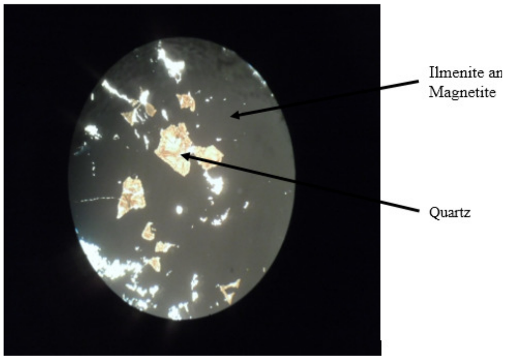

Figure 2a: Micrograph of head sample at point 1 (X10)

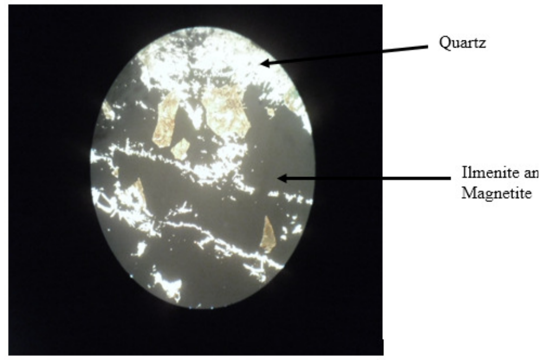

Figure 2b: Micrograph of head sample at point 2 (X10)

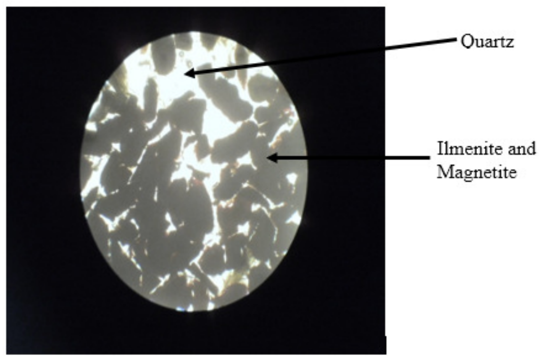

Figure 2c: Micrograph of head sample at point 3 (X10)

Figure 2 show the petrological micrographs of the iron ore sample at three different points. From the results, three mineral phases were recognized under plane and cross polarized light and the phases are Ilminite and Magnetite (opaque) and Quartz (colourless). This result confirmed the result of XRD analysis, which indicated that the predominant mineral present is magnetite with subordinate amounts of ilmenite and quartz.

4. CONCLUSION

From the results obtained the following conclusions were drawn:

i. The chemical analysis revealed that the iron ore contains 61.67% Fe_2O_3, 33.90% SiO_2 as major constituents and MnO, TiO_2, CaO, Cr_2O_3, CuO, ZnO, PbO, Eu_2O_3, BaO, Rb_2O and V_2O_5 as minor constituents. The result indicates that the ore contains 43.17% Fe and thus can be regarded as medium-grade iron ore.
ii. The mineralogical analysis of the ore revealed that the iron bearing minerals are predominantly Magnetite and ilmenite.
iii. Ebiya iron ore is another potential deposit that can be explored and exploited for usage in iron and steel production.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Abraham, J.B., Adrey, V.K., Joseph, K.B. and Par, G.J. (2012). Characterization of Chemical Composition and Microstructure of Natural Iron Ore from Muko Deposits. *ISRN Materials science*, 174803, pp. 1-9.

Agava, A.A. (2006). Upgrading of Agbado-Okudu iron ore using magnetic separation and shaking table techniques. M.Sc Thesis submitted to the Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Zaria.

Agava, A.A., Murina, R.A., Abdurrahman, A.S., Egbe, E.A.P. and Thomas, D.G. (2016). Determination of Chemical, Mineralogical Composition and Liberation Size of Ochokochoko Iron Ore, Kogi State, Nigeria. *Nigerian Journal of Engineering*, 23(1), pp. 77-86.

Asuke, F., Bello, K.A., Muzzammil, M.A., Thomas, D.G., Auwal, K. and Yaro, S.A. (2019). Chemical and Mineralogical Characterization of Gidan Jaja Iron Ore Zamfara State Nigeria. *Nigerian Journal of Technology*, 38(1), pp. 93 – 98.

Asuke, F., Yaro, S. A., Popoola, A.P.I. and Aponbiede, O. (2018). Chemical and Mineralogical characteristics of Phosphorus distribution in the Koton-karfe iron. Proceedings of the National Engineering Conference. Faculty of Engineering, Ahmadu Bello University, Zaria. pp. 130 - 135.

Khoso, S. A., Abro, M. I. and Agheem, M. H. (2017). Mineralogical Study of Zard Koh and Kulli Koh Iron Ore Deposits of Pakistan. *Mehran University Research Journal of Engineering and Technology*, *36*(4), pp. 1017 - 1024

Kiptarus, J. J., Muumbo, A. M., Makokha, A. B. and Kimutai, S. K. (2015). Characterization of selected mineral ores in the Eastern Zone of Kenya: Case study of Mwingi North Constituency in Kitui County. *International Journal of Mining Engineering and Mineral Processing*, *4*(1), pp. 8-17.

Ministry of Mines and Steel Development, (MMSD) (2012). Nigeria Mineral Projects, p. 12

Ohimain, E. I. (2013). The challenge of domestic iron and steel production in Nigeria. *Greener Journal of Business and Management Studies*, *3*(5), pp. 231-240.

Olayebi, O.O. (2014). Steel making experience in the use of Nigerian iron ore at the Delta steel company, Nigeria. *Journal of Chemical Engineering and Materials Science*, 5(5), pp. 47-62.

Oyedele, K., Oladele, S. and Salami, A. (2016). Geophysical investigation of banded iron ore mineralization at Ero, North–Central Nigeria. *Materials and Geoenvironment*, *63*(2), 109-118.

Raw Materials Research and Development Council (RMRDC) (2010). Annual report on steel raw materials in Nigeria.

Salawu, A.O. (2015). Characterization of Gujeni iron ore deposit, Kaduna state, Nigeria. M.Sc Thesis, Department of Metallurgical and Materials Engineering. Ahmadu Bello University, Zaria.

Singh, G. P., Choudhary, R. P., Vardhan, H., Aruna, M. and Akolkar, A. B. (2015). Iron ore pelletization technology and its environmental impact assessment in eastern region of India-a case study. *Procedia Earth Planetary Science*, *11*, pp. 582-97.

Worrell, E., Price, L., Martin, N., Farla, J. and Schaeffer, R. (1997). Energy intensity in the iron and steel industry: a comparison of physical and economic indicators. *Energy policy*, *25*(7-9), pp. 727-744.