PARTICLE SIZE ANALYSIS AND MINERAL ASSAY OF GUJENI IRON ORE DEPOSIT

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ABSTRACT
Particle size analysis and mineral assay were carried out in the course of this research work. The iron ore deposit is located in Gujeni village, Kagarko Local Government Area, Kaduna State. The Samples were taken from four different pits A, B, C and D at 100 m apart and at 3m depth. The four samples were mixed together to form composite sample. The composite sample was crushed and pulverized. Particle size analysis and mineral assay revealed that the various mineral phases such as hematite, rutiles, goethite etc. are evenly distributed in all the various sieve size fractions(+355 µm to -50 µm).
Keywords: *Iron ore, mineralogy, sieve size fraction, comminution, heamatite, magnetite.*

INTRODUCTION

Particle size analysis/ mineral assay is one of the parameter that are usually determined before the design and development of conceptual flow sheet for the beneficiation of a newly discovered ore deposit after the geological investigation have been carried out (Thomas and Yaro, 2016). Particle size analysis is of great importance in determining the quality of grinding and establishing the degree of liberation of the values from the gangue at various particle sizes. In the separation stage, size analysis of the products used to determine the optimum size of the feed process for maximum efficiency and to determine the size range at which any losses are occurring in the plant, so that they may be reduced. It is essential, therefore, that methods of size analysis must be accurate and reliable, as important changes in plant operation may be made on the small amount of material are used in the sizing test, it is essential that sample is representative of the material and the same care should be taken over sampling for the size analysis as for assay (Usaini *et al.,* 2014).

Sieve analysis is one of the oldest method of size analysis and is accomplished by passing a known weight of sample material successfully through fine sieve weight that amount collected on each sieve to determine the percentage weight in each sieve fraction. Sieving is carried out with wet or dried material and the sieve are usually agitated to expose the particle to openings. When sieving applied to irregular shape particle, is complicated by the fact that a particle with a size near that of nominal aperture of the test sieve may past only when presented in a favourable position. As there is inevitable a variation in the size of sieve aperture, due to irregularity of weaving, prolonged sieving will cause the larger aperture to exert an unduly large effect on the sieve analysis. Given time, every particle small enough could find its way through a few such holes. The procedure is also complicated in many cases by the present of near size-particle which cause blinding, or obstruction of the sieve aperture, and reduce the effective area of the sieving medium. Blinding is most serious with test sieve of very small aperture size (Usaini *et al.,* 2014).

The process of sieving may be divided into two stages: first, the elimination of particle considerable smaller than the screen aperture, which should occur fairly rapidly and the second, the separation of the so-called "near size" particles which is a gradual process rarely reaching final completion. Both stages require the sieve to be manipulated in such a way that all particles have opportunities for passing the aperture and so that any blind aperture may be removed from it. Ideally, each particle should be presented individually to an aperture, as is permitted for the largest aperture sizes, but for most sizes this is impractical (Usaini *et al.,* 2014). Since the particle size of a mineral is an important issue in mineral processing it has become very necessary to carry out particle size analysis on any mineral under processing. On these bases, particle size analysis and mineral assay of gujeni iron ore has to be determined before further processing in order to know how the particles size may be and also to know the mineral phases present in the ore.

TYPES OF IRON ORE

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 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 metal contents of real ores are lower. Deposits with less than 30 % Fe are commercially unattractive, although some ores contain as much as 66% Fe, there are many in the 50–60% range. The quality of iron ore is also influenced by the presence of other constituent which are collectively known as gangue. Silica (SiO_2) and phosphorus-bearing compounds (usually reported as P_2O_5) which caused cold embrittlement in steel and cannot not be removed during the iron making except in steel making process which make the production of steel more expensive. The quality of iron ore is mainly judged based on the Fe content. More specifically, ores with Fe contents above 65% are regarded as high-grade ores; 62–64% as medium- (or average) grade ores and those below 58% Fe are considered

as low-grade ores (Thomas and Yaro, 2007). Table 2.1 is a collection of some of Nigerian iron ores deposits.

COMMINUTION PROCESS

Comminution is a process in which the particle size of the ore is progressively reduced until the clean particles or valuable minerals are liberated from the gangue and can be separated by such methods are available. Crushing and grinding are the two primary comminution processes. Crushing is normally carried out on "run-of-mine" ore, while grinding normally carried out after crushing. In comminution, the size reduction of particles is done by three types of forces: compression, impact and attrition. Compression and impact forces are extensively used in crushing operations while attrition is the dominant force in grinding. The primary equipment used in crushing are-jaw crushers, gyratory crushers and cone crushers Crushing is a dry process whereas grinding is generally performed wet. (Gupty, 2003).

MINERAL PROCESSING CONCEPTUAL PARAMETERS

Ores are usually subjected to some concentration processes in order to separate the various minerals in the ore into two or more products. This is done for the purpose of beneficiating the ore for its desired mineral or metallic value (Sirajo, 2008). Beneficiation of minerals is a physical, chemical and physico-chemical process of using the inherent properties of the minerals in order to maximize its quality (Olokesusi, 2010). Separation is achieved by utilizing some specific difference in physical or chemical properties between the valuable and the gangue minerals in the ore. After the geological survey has been carried out, the standard procedures usually followed in the development of the conceptual flow sheet for the beneficiation of a newly discovered ore deposit and are as follows (Thomas and Yaro, 2007).

Determination of Chemical Composition of a Representative Sample of the ore

This is to establish the chemical composition of the ore and also to confirm the result of the geological investigation and probably Mining Engineers who had already worked on the ore deposit. Chemical analysis is used to detect and estimate quantities of elements or compounds present in the ores. The present of the dominant element or compound determined the name of the mineral ore.

Mineralogical Analysis

Evaluation of the ore in order to reveal the major and minor compounds making up the ore under characterization process, grain size of each mineral in the ore, allocation of each element to each mineral present in the ore and the degree of association of valuable minerals to the gangue minerals.

Generally the study of these properties can be achieved by chemical, mineralogy, physical and crystallography analyses and studies. These involved uses of petrography microscope, X-Ray Diffractometer (XRD), X-Ray Florescence (XRF) and Scanning Electronic Microscope/ Energy Dispersive Spectrometer (SEM/EDS).

Petrography analysis is the study of rocks using a microscope. In this study, cross section is useful for the identification of rocks minerals of the ores, their characteristics, and properties such as cleavage, twining, reflectance and shape. The thin section is observed with a transmitted polarized Microscope (Beuler, 2009).

The petrography microscope is a type of microscope used in the study of thin section of minerals and rocks by examining the mineral fragment, grained crystal or aggregate and in the interpretation of texture, structure, growth pattern and various relationship of natural or artificial substance (Arogundade, 1999).

Carrying out Size Analysis

This is use to establish the distribution of both the valuable and gangue minerals in the various size fractions. Particle size analysis is of great importance in determining the quality of grinding and in establishing the degree of liberation of the valuable mineral from the gangue mineral at various particle size in the separation stage.

Conducting of Liberation Studies

This is used to establish the liberation size of the individual mineral in the ore; here emphasis is placed on the grain size of the valuable minerals and probably the gangue which may likely affect the subsequent separation process. Liberation size of an ore is very significant component in any process design as it gives the operators a clear view of the sieve size. It avoid over grinding and hence save a cost.

MATERIALS AND METHODS
Materials and Equipment

(i)Iron ore sample (ii) Sledge hammer (iii) Jaw crusher (iv) Cone crusher (v) Ball mill (vi) Set of sieves (vii) Laboratory sieve shaking machine (viii) Weighing machine (ix) X-ray florescence (XRF) Machine (x) X-ray diffractometer (XRD) Machine

Location and accessibility of Gujeni iron ore deposit

The Gujeni iron ore deposit is located in a village called Gujeni. The Gujeni village is along Kaduna/Abuja express way. It is about 20 km away from Jere village towards Abuja and about 50 km to Zuba town. The Gujeni village can be accessed through Zuba or Kaduna town. The deposit covers a distance of about 2.3 kilometres square and its reserve has not yet been quantified by any of the agencies responsible for mineral resources development in the country.

Methods
Sample collection

Samples of the iron ore were collected from various points of deposit site located at Gujeni village, in Kagarko Local Government Area of Kaduna State. GPS was used to measure the exact location at which samples were taken. Grab method of sampling was adopted in collecting the sample. 60kg of the sample was collected from (4) four points at interval of 100m apart at 3m depth. The reference ore sample (granite) was sourced from Kujama area of Kaduna State. Table 3.1 shows the GPS coordinates of where the iron ore samples were sourced.

Table 1: Coordinates of the area of the deposit

S/No.	Coordinates
Pit 1	N 09° 27' 03.3", E 007° 22' 36.3"
Pit 2	N 09° 27' 05.4", E 007° 22' 38.4"
Pit 3	N 09° 27' 06.6", E 007° 22' 31.3"
Pit 4	N 09° 27' 05.5", E 007° 22' 28.5"

Sample preparation
Sample preparation involves comminution which consists of crushing and grinding processes. The lump sizes of the ore sample were reduced to the sizes that could be accepted by the crusher using sledge hammer. The sample was crushed using jaw crusher and pulverized using ball mill.

Sampling for the purpose of tests and analyses
Coning and quartering sampling method was used to divide the pulverized sample into smaller portions that were used for other tests and analyses conducted.

Chemical composition analysis
After communication processes and proper sampling, a composite sample was taken and analysed using X ray Florescence machine to determine the elemental Composition of the ore. The results of the chemical analysis are presented in Table 2.

Particle size / mineral assay analyses of the iron ore
Particle size and mineral assay analyses were carried out to establish the distribution and determination of minerals phases present in the various sieve size fractions. 600 g of the pulverized sample was placed on the set of sieves arranged on the basis of $\sqrt{2}$ and placed on the sieve shaking machine. The sieves were vibrated for 30 minutes to enhance proper sieving. The minerals on each sieve were weighed, packed in cellophane leather and properly labelled for analyses. The result of the test is presented in Table 3.

RESULTS AND DISCUSSION

Table 2: Result of chemical analysis of Gujeni iron ore deposit

Oxide	Percentage
SiO_2	29.36
Fe_2O_3	58.26
Al_2O_3	9.60
MgO	0.02
Na_2O	0.59
CaO	0.07
MnO	0.099
K_2O	0.004
Loi	1.99

Table 2 presents the result of chemical analysis which shows that SiO_2 is 29.36%, Fe_2O_3 is 58.26%, Al_2O_3 is 9.60%, MgO

is 0.02%, Na_2O is 0.59%, CaO is 0.07, MnO is 0.099, K_2O is 0.004 and loss of ignition (LOI) is 1.99. The particle size and minerals assay analysis are presented in Tables 3 to 10 and Table 3 presents the result of particle size analysis reveals that +355 µm retains 195 g, -355+250 µm (81.4 g), -259+180 µm (34.8 g), -180+125 µm (54.5 g), -125+90 µm (47.1 g), -90+50 µm (49.0 g) and -50 µm (138 g) of the minerals. This trend shows that the minerals in the ore sample are uniformly distributed and the particle size of the minerals in the ore can enhance the degree of liberation of the various minerals as the particle size reduces (Wills, 2006; Weiss, 1985).

Table 4 presents the mineral phases contained in -50 µm size fraction. The mineral phases are rutile (TiO_2), zirconium oxide (ZrO), zincite (ZnO), rhodochrosite ($MnCO_3$), ferro-magnesite ($Fe,MgCO_3$),haematite (Fe_3O_3) and potassium-magnesium-aluminum-silicate (KMg_3AlSiO_3).

Table 5 presents the mineral phases contained in -90+50µm size fractions. The minerals phases are zirconium oxide (ZrO_2), rutile (TiO_2), magnetite (Fe_3O_4), manganese oxide (MnO_2), calcium- aluminum-iron-silicate (Ca, Al, $FeSiO_3$).

Table 6 presents the mineral phases contained in -125+90 µm size fractions. The mineral phases are goethite ($Fe_2O_3.H_2O$), zincite (ZnO), potassium-magnesium-aluminum-silicate (KMg_3AlSiO_3), rutile (TiO_2) and hematite (Fe_2O_3).

Table 7 presents the mineral phases contained in -180+125µm size fractions. The mineral phases are hematite (Fe_2O_3), sodium-aluminum-silicate ($NaAlSiO_3$), magnetite (Fe_3O_4), lead sulphate ($PbSO_4$), calcium carbide (CaC_2), hematite (Fe_2O_3), iron chromate ($FeCrO_4$) and manganese oxide (MnO_2).

Table 8 presents the mineral phases contained in -250+180 µm size fractions. The mineral phases are ferro-magnesite Fe,MgCO3), potassium-magnesium-aluminum-silicate (KMg3AlSiO3), goethite Fe2O3.H2O), rhodochrosite (MnCO3), hematite (Fe2O3), zincite (ZnO), rutile (TiO2) and manganese oxide (MnO2)

Table 9 presents the mineral phases contained in -355+250 µm size fractions. The predominant mineral phases are zincite (ZnO), rhodochrosite ($MnCO_3$), hematite (Fe_2O_3), rutile (TiO_2), potassium-magnesium-aluminum-silicate (KMg_3AlSiO_3) and Table 10 presents the mineral phases contained in +355 µm size faction. The mineral phases are hematite (Fe_2O_3), manganese oxide (MnO_2), Calcium-Iron-Titanium -Silicate (Ca, Fe, Ti, and SiO3) and zirconium oxide (ZrO_2).

Table 3: Result of particle size analysis of the composite sample

Sieve size (µm)	Weight (g) retained	Weight (%) retained	Nominal aperture	Cumulative (%)	
				Weight (%) retained	Weight (%) passing
+355	195.00	32.50	355	32.50	67.50
-355+250	81.4	13.57	250	46.07	53.93
-250+180	34.8	05.80	180	51.87	48.13
-180+125	54.5	09.08	125	60.95	39.05
-125+90	47.10	07.85	90	68.80	31.20
-90+50	49.00	08.17	50	76.97	23.03
-50	138.00	23.00	Pan	100	0.00
Total	599.8				

Table 4: Mineral assay analysis result of the composite sample (-50 µm)

Card No.	Mineral Name	Chemical Name	Chemical Formula
21-1276	Rutile, syn	Titanium oxide	TiO_2
34-1084		Zirconium oxide	ZrO_2
36-1451	Zincite	Zinc oxide	ZnO
21-1272	Anatase, syn	Titanium oxide	TiO_2
36-0383	Magnesite, ferr	Iron Magnesium carbonate	$(Mg, Fe) CO_3$
33-0664	Hematite, syn	Iron oxide	Fe_2O_3
44-0141		Maganese oxide	MnO_2
44-1472	Rhodchrosite	Manganese Carbonate	$MnCO_3$
10-0492		Potassium Magnesium Aluminum Silicate Hydrate	$KMg_3(Al SiO_3) (OH)_2$
10-0495		Potassium Magnesium Aluminum Silicate Hydrate	$KMg_3(Al SiO_3) (OH)_2$

Table 5: Mineral assay result of the composite sample (-90+50 µm)

Card No.	Mineral Name	Chemical Name	Chemical Formula
20-0684		Zirconium oxide	ZrO
26-1136	Magnetite	Iron oxide	Fe_3O_4
24-0735	Pyrolusite	Manganese oxide	MnO_2
19-0629	Magnetite	Iron oxide	Fe_3O_4
6-0395	Romarchite	Tin oxide	SnO
34-0842		Calcium Aluminum Iron Silicate Hydroxide	$Ca,Al, FeSiO_3,).4H_2O$
21-1276	Rutile	Titanium oxide	TiO_2

Table 6: Mineral assay result of the composite sample (-125+90 µm)

Card No.	Mineral Name	Chemical Name	Chemical Formula
13-0092	Goethite	Iron oxide hydrate	$Fe_2O_3 .H_2O$
36-1451	Zincite	Zinc oxide	ZnO
46-1045	Quartz,	Silicon oxide	SiO_2
44-0141		Manganese oxide	MnO_2
10-0492		Potassium Magnesium Aluminum Silicate Hydrate	$KMg_3 (Al SiO_3) (OH)_2$
10-0495		Potassium Magnesium Aluminum Silicate Hydrate	$KMg_3 (Al SiO_3) (OH)_2$
21-1276	Rutile	Titanium oxide	TiO_2
33-0664	Hematite	Iron oxide	Fe_2O_3

Table 7: Mineral assay result of composite sample (-180+125 µm)

Card No.	Mineral Name	Chemical Name	Chemical Formula
27-0997		Zirconium oxide	ZrO_2
44-0103		Sodium Aluminum silicate hydrate	$NaAlSiO_3.H_2O$
19-0629	Magnetite	Iron oxide	Fe_3O_4
19-0629	Magnetite	Iron oxide	Fe_3O_4
8-0454		Barium sulfide	BaS
34-0140	Chromate	Iron chromium oxide	$FeCrO_2O_4$
34-0977		Tantalum oxide	TaO
12-0104		Manganese oxide	MnO_2
4-0712		Calcium carbide	CaC_2
18-1304		Tantalum oxide	Ta_2O_5
30-1836		Nickel iodide Triethylamine oxide	Ni_2IO_3
33-0285		Calcium Iron Titanium Silicate	$Ca_,Fe, TiSiO_3$
6-0408		Neodymium oxide	Nd_2O_3
5-0390		Cassiterite	SnO
5-0592	Galena	Lead sulphate	Pbs
4-0326		Manganese oxide	MnO
19-1297		Tantalum oxide	TaO_2
26-1399		Zirconium oxide	ZrO
6-0399		Barium Zironium oxide	$BaZrO_3$
6-0695		Aluminum Iron	Fe_3Al

Table 8: Mineral assay result of the composite sample (-250+180 µm)

Card No.	Mineral name	Chemical name	Chemical formula
21-1276	Rutile	Titanium oxide	TiO_2
36-0383	Magnesite	Iron Magnesium Carbonate	$(Mg, Fe) CO_3$
36-1451	Zincite	Zinc oxide	ZnO
21-1272	Anatase	Titanium oxide	TiO_2
13-0092	Goethite	Iron oxide hydrate	$Fe_2O_3 . H_2O$
44-0141		Manganese oxide	MnO_2
10-0492		Potassium Magnesium Aluminum Silicate hydrate	$KMg_3(Al SiO_3)(OH)_2$
44-1472	Rhodochrosite , syn	Manganese Carbonate	$MnCO_3$

Table 9: Mineral assay result of the composite sample (-355+250 µm)

Card No.	Mineral name	Chemical name	Chemical formula
36-1451	Zincite	Zinc oxide	ZnO
33-0664	Hematite	Iron oxide	Fe_2O_3
21-1276	Rutile	Titanium oxide	TiO_2
44-0142	Ramsdellite	manganese oxide	MnO_2
44-1472	Rhodochrosite	Manganese carbonate	$MnCO_3$
21-1272	Anatase	Titanium oxide	TiO_2
46-1045	Quartz	Silicon oxide	SiO_2
10-0492		Potassium Magnesium Aluminum Silicate hydrate	$KMg_3(Al SiO_3) (OH)_2$

Table 10: Mineral Assay Result of the Composite Sample (+355µm)

Card No.	Mineral Name	Chemical Name	Chemical Formula
22-1025		Zirconium oxide	ZrO
33-0285		Calcium Iron Titanium Silicate	Ca, Fe, $TiSiO_3$
12-0141		Manganese oxide	MnO_2
39-0238	Hematite	Iron oxide	Fe_2O_3
5-0390		Cassiterite	SnO
27-1402		Silica	SiO_2

From the results of the analyses, majority of the mineral phases contained in the ore sample are distributed in all the sieve size fractions and this could be attributed to the allocation of the mineral constituent to the particle size that formed the mineral grain of the ore. This phenomenon has also been observed and reported by Thomas and Yaro, (2007), Weiss, (1985) and Wills, (2006). The petrological analysis carried out on Gujeni iron ore deposit by (Salawu *et al.,* 2016) also revealed that the structure of iron bearing minerals are in form of plates and river lines, which are characteristic of haematite and goethite

CONCLUSIONS

Based on the result of this research work, the chemical composition of the iron ore contained the following; SiO_2 was 29.36%, Fe_2O_3 was 58.26%, Al_2O_3 was 9.60%, MgO was 0.02%, Na_2O was 0.59%, CaO was 0.07, MnO was 0.099, K_2O is 0.004 and loss of ignition (LOI) was 1.99. The result of particle size analysis revealed that +355 µm retains 195 g, -355+250 µm (81.4 g), -259+180 µm (34.8 g), -180+125 µm (54.5 g), -125+90 µm (47.1 g), -90+50 µm (49.0 g) and -50µm (138 g). It can be concluded that the minerals phases contained in the ore are uniformly distributed in all the sieve size fractions which were majorly heamatite, rutile, magnesite, goethite which have been confirm by petrological analysis carried out by other researchers and the minor minerals were zincite, potassium-magnesium-aluminum-silicate (KMg_3AlSiO_3),rhodochrosite ($MnCO_3$), etc.

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