

# Characterization of Ubo Limestone for Direct Burnt Lime Production.

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## ABSTRACT

The Nigerian Ubo limestone was subjected to physico-chemical characterization to determine its suitability for direct use in burnt lime production. The results of the chemical analysis showed that the limestone contains 52.84, 2.48, 0.40, 1.44, 2.25, 0.03, and 0.02 percents of calcium oxide, magnesium oxide, iron oxide, alumina, silica, phosphorous pentoxide, and sulphur, respectively. Characterization for Loss on Ignition (LOI) and bulk density yielded 39.56% and 2.65g/cm<sup>3</sup>, respectively.

A comparison of the results obtained with the standard obtained showed that the limestone's contents of the main fluxing oxides-calcium and magnesium oxides are sufficiently high for the production of burnt lime making beneficiation treatment unnecessary. In addition, the contents of silica, phosphorous pentoxide, alumina, iron oxide, and sulphur to be fluxed into slag along with those from iron ore input for the iron-making are also sufficiently low. The LOI and the bulk density of the limestone also satisfy the requirements for direct lime production. However, the alkali contents of the limestone need to be determined in subsequent studies as high alkali causes major blast furnace incidents such as frozen hearth.

(Keywords: limestone, characterization, lime, oxides, slag, alkali)

## INTRODUCTION

Limestone is a sedimentary rock type of solid mineral formed by the accumulation of sediments in air or water and composed mainly of calcium or magnesium carbonate. The original material of limestone is calcium carbonate. However, either

before or after its consolidation, dissolved magnesium compounds in water may partly replace the calcium with magnesium forming dolomite (CaMg(CO<sub>3</sub>)<sub>2</sub>). Thus, limestone may be pure calcite, a mixture of calcite and dolomite or pure dolomite (Benton, 1973).

Lime is produced by calcining limestone at about 1,000°C in kilns. It is white or gray in color. Lime is soluble in water forming calcium hydroxide with evolution of heat (Considine, 1974; Wikipedia, 2010a). Lime is used as a fluxing agent in iron and steel-making by the blast furnace/Basic Oxygen Furnace (BOF) route. Several oxides in iron ores or those produced when oxygen is blown into the BOF are highly refractory in nature and if they are not fluxed, the smelting operation would be retarded and the separation of the metal of interest will be interfered with. Lime is added to convert such oxides into readily fusible slags (Considine, 1974; Smith, 2008).

A typical BOF holds 280 tons of molten steel. Burnt lime is fed into the vessel to form slag which absorbs the impurities of the steelmaking process. In the first stage, acid slag is formed from the oxidized silicon, iron and manganese. The lime is only partially dissolved in this stage and part of phosphorous is partially dissolved. In the second stage, lime is progressively dissolved with enrichment in calcium oxide and decrease in iron oxide due to dilution and reduction during full decarburization (in particular, if the lance is too low). The slag is heterogeneous and non-reactive with respect to phosphorus. In the final stage, reactive slag suitable for final de-phosphorization is produced (Wikipedia, 2010b). Slag basicity (S) is defined as:

$$S = \frac{\text{wt\% MgO} + \text{wt\% CaO}}{\text{wt\% SiO}_2} \quad (1)$$

Slag basicity controls the viscosity and melting point of the slag, which in turn affects the hearth temperature and grade of the iron produced (Wikipedia, 2010b).

It has been estimated that that integrated steel plant at Ajaokuta, Nigeria will require about 690,000 tons of lime for annual output of 3 millions tons of steel. Limestone deposits at Ubo, Jakura (both in Kogi state and in proximity of Ajaokuta) and Mfamosing (in Cross River state) have been earmarked as possible sources of the required lime.

The Ubo limestone deposit has been estimated to be about 20 million tons in reserves (IDRC, 1995; Nigerian Embassy, Chile, 2010). In view of the importance of limestone in the successful operation of Ajaokuta steel plant, this research was aimed at determining the physico-chemical properties of Ubo limestone and assess its suitability or otherwise for the production of burnt lime for iron and steel-making.

## EXPERIMENTAL PROCEDURE

### Materials and Preparation

The limestone sample for this work was obtained from Ubo deposit found in the vicinity of Okene, Kogi state, Nigeria. The sample was collected randomly and about 1 kg of the field sample was ground to size fractions required for the various tests conducted.

### Methods

The oxide composition of the limestone with respect to alumina, silica, calcium and magnesium oxide, iron oxide, titanium oxide, phosphorous oxide and sulphur was determined by the classical chemical analysis (Ray, 1979; Jeffrey *et al*, 1978). The physical properties such as loss on ignition, bulk density, porosity, reactivity and specific gravity were also determined according to standard procedures.

### Determination of Alumina Content

About 0.1 g of the sample was weighed into a nickel crucible and 10 pellets of sodium hydroxide and a pinch of sodium carbonate was added. The mixture was melted over hot plate and finally

fused over a low flame at 700°C for 15 minutes. The crucible was set aside and allowed to cool in air. When cooled, the crucible along with the content was dropped in a 250 ml beaker and 100 ml of hot distilled water was slowly added and boiled for 10 minutes. The crucible was removed with a glass rod and washed thoroughly with water into the beaker. The hot solution was filtered with No. 40 filter paper into a 500 ml conical flask.

The precipitate was washed with hot water for 6 times to ensure that no sodium aluminate remains trapped in the precipitate. The filtrate was acidified with hydrochloric acid and 25 ml standard EDTA was also added. The pH was adjusted to 5.5 with ammonium hydroxide and hydrochloric acid and the solution boiled for 15 minutes. The solution was allowed to cool and 25 ml acetic acid ammonium acetate buffer solution was added. The pH was checked and adjusted to 5.5 and drops of xylenol orange indicator were added and a lemon color developed. Standard zinc acetate was used to titrate the solution. The color changed from lemon yellow to purple indicating the end point. From the titre value the  $Al_2O_3$  percentage was calculated with the formula:

$$\% Al_2O_3 = \frac{(A-T) \times X \times 100}{W_s} \quad (2)$$

Where:

A = volume of zinc acetate equivalent to 25 ml EDTA solution

T = the titre value of zinc acetate with the sample

B= volume of zinc acetate solution required for titration after adding 25 ml EDTA solution to the 5 ml standard  $Al_2O_3$  solution

### Determination of Silica Content

About 0.2 g of the sample was weighed into a platinum crucible and mixed thoroughly with the fusion mixture and then covered up with some of the fusion mixture. It was fused at a temperature of 950°C in a muffle furnace and allowed to cool. The fused mass was extracted into a 400 ml beaker using 50 ml of 1:1 hydrochloric acid (HCl).

The extract was dehydrated on the hot plate using asbestos pad, after which it was cooled and

10 ml concentrated HCl was added. Distilled water was used to make up the volume to the 50 ml mark in the beaker. It was allowed to boil and filtered through No 541 filter paper. The residue was washed with 1:4 HCl three times and with hot water several times until the residue was free from HCl. The filter paper was folded into the platinum crucible and ignited at a temperature of 950°C to constant weight in 20 minutes.

The crucible was then cooled in the desiccators and weighed as W1. Eight drops of 1:1 sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) and 15 ml hydrogen fluoride (HF) were added to the residue in the crucible and it was heated in a sand bath placed on a hot plate to ensure slow evaporation. At the end, a copious fume was observed leaving the dried mass. The residue was then ignited in a muffle furnace at 950°C for 20 minutes. It was cooled in a desiccators and the crucible weighed as W2. The percent weight of silica was calculated with the formula:

$$\% \text{ SiO}_2 = \frac{(W1 - W2) \times 100}{W_s} \quad (3)$$

Where:

W1 =weight of the platinum crucible with the material before hydroflourisation

W<sub>s</sub>=weight of the sample

#### **Determination of Calcium and Magnesium Oxide Contents**

About 0.2 g of the sample was weighed into a 25 ml beaker. Twenty (20) ml of 1:1 HCl was added and digested on the hot plate. The solution was then filtered into a 250 ml volumetric flask using filter paper No 541. The filter paper was washed several times with hot water and the solution was cooled and made up to mark.

For calcium, 25 ml of the aliquot was pipetted into a 250 ml conical flask and 100 ml of distilled water added. About 30 mg of MgCl<sub>2</sub> + 4 ml 8M potassium hydroxide (KOH) was added to the solution to precipitate the magnesium hydroxide. After two minutes, 30 mg of potassium cyanide and hydroxylamine hydrochloride were added and allowed to dissolve by constant stirring. The 0.01M EDTA was titrated against the solution using calcon indicator until the color changes from pink to blue. The percent calcium oxide was

calculated with the formula:

$$\% \text{ CaO} = \frac{V_{EDTA} \times 0.5608}{W_s} \quad (4)$$

Where:

W<sub>s</sub> =weight of sample

V<sub>EDTA</sub> = volume of EDTA

For magnesium, 25 ml of the aliquot was pipetted into a 250 ml conical flask. One hundred (100) ml distilled water and 5 ml buffer solution was added. About 30 mg each of potassium cyanide and hydroxylamine hydrochloride were added and allowed to dissolve by constant stirring. 0.01M EDTA was titrated against the solution using Erichrome Black T indicator until the colour changes from wine red to blue. The percentage magnesium oxide was calculated with the formula:

$$\% \text{ MgO} = \frac{V_{EDTA} \times 0.4032}{W_s} \quad (5)$$

#### **Determination of Iron Oxide Content**

About 0.2 g of the sample was weighed into a dry 250 ml conical flask and about 3 drops of distilled water was added to moisten it. Twenty five (25) ml of concentrated HCl was added and swirled for proper mixture. Two drops of HF was added and the flask placed on a hot plate. 5% SnCl<sub>2</sub> was added until the solution turned colorless.

The flask was covered with a silica crucible lid and boiled on a hot plate until dissolution was completed. The flask was removed from the hot plate and the crucible lid and the inside wall of the conical flask was rinsed into the solution. 5% KMnO<sub>4</sub> solution was added until the yellow color of ferric ion appeared. The solution was heated to boiling and 15% stannous chloride solution was added to reduce the ferric ion. This was evident with the disappearance of the yellow color.

Fifteen (15) ml of (1:3) H<sub>2</sub>SO<sub>4</sub> was added and the solution was mixed by shaking and distilled water was added until the total volume was approximately 100 ml. The flask was cooled properly in a water bath. Then, 10 ml of 2% mercuric chloride solution was added, mixed and the solution mixture was allowed to stand for 5 minutes. 10 ml of 0.02% Fe indicator in H<sub>3</sub>PO<sub>4</sub>

(1:4) was added. The solution was then titrated against 0.1N  $K_2Cr_2O_7$ . The percent Fe was calculated with the formula:

$$\% Fe = \frac{V_1 \times V_2 \times 100}{W_s} \quad (6)$$

Where:

$V_1$  = titre of  $K_2Cr_2O_7$

$V_2$  = volume of  $K_2Cr_2O_7$

### Determination of Sulphur Content

About 0.2 g of the pulverized limestone was weighed in a nickel crucible. About 2 g of sodium peroxide was added and thoroughly mixed, after which the surface was covered with a thin layer of the peroxide. The mixture in the crucible was then transferred into muffle furnace and gently heated at a low temperature (60°C) for 15 minutes. The crucible was removed from the furnace and allowed to cool in the air. The crucible was now placed in a 500 ml beaker; 100ml of distilled water was poured into the beaker and the fused mass was extracted with water and boiled for a few minutes. The supernatant liquid was filtered with Whatman filter paper No. 40 into a 500 ml beaker and washed six times.

Five drops of methyl red indicator and few drops of HCl were added to the filtrate. The solution was then heated to boiling, after which 15 ml of 10% barium chloride solution was slowly added. The beaker and its content were then removed from the hot plate and the precipitate was filtered with Whatman filter paper No. 42. The precipitate was then washed eight times with hot water. The residue was transferred in weighed platinum crucible and ignited at a temperature of 1,000°C for 20 minutes. The crucible and the ash were removed, cooled in the desiccators and weighed. A blank determination was also carried out. The percentage of sulphur (S) in the limestone was then calculated with the formula:

$$\% S = \frac{W_{BaSO_4} \times 0.1374 \times 100}{W_{Sample}} \quad (7)$$

Where:

$W_{BaSO_4}$  = weight of barium sulphate

$W_{Sample}$  = weight of sample

### Calorimetric Determination of Titanium Oxide

About 0.2 g of the pulverized sample was weighed into the platinum crucible and fused with about 1 g of potassium hydrogen sulphate ( $KHSO_4$ ) at 950°C for one hour. The fused mass was then extracted into 25 ml beaker with 10% sulphuric acid and digested on a hot plate. The digested solution was filtered into 250 ml volumetric flask using Whatman No. 40 paper and then washed with 10%  $H_2SO_4$ . Five (5) ml of orthophosphoric acid and 10 ml hydrogen peroxide was added to the content of the flask and the solution was made up to mark with 10% sulphuric acid. For the calibration curve, a standard solution of titanium dioxide with concentrations 10 ppm, 20 ppm, 30 ppm, 40 ppm, and 50 ppm were prepared from a 1000 ppm stock solution by first pipetting 10 ml out of the stock solution.

Using 1 cm<sup>3</sup> cuvette, the absorbance of the various solutions was read at a wavelength 410 nm using pye unicam spectrophotometer and the percentage of titanium oxide was calculated with the standard formula (Jeffrey *et al.*, 1978).

### Spectrophotometric Determination Phosphorous as Phosphorous Pentoxide

About 0.1 g of the sample was weighed into 250 ml beaker and 5 ml of concentrated nitric acid and few drops of hydrogen fluoride were added. The content of the beaker was then slowly evaporated to dryness over a hot plate. The beaker was removed and allowed to cool and 5 ml nitric acid and 50 ml distilled water were added. The solution was boiled and filtered into a 100 ml flask and washed with hot water. The volume was made up to mark and thoroughly mixed up. The color was then developed by adding 10 ml of ammonium vanadate solution, making up the volume to mark with distilled water followed by thorough mixing.

For the calibration curve, 0.5 ppm, 1 ppm, 1.5 ppm, and 2.0 ppm solutions of the standard phosphorous pentoxide was prepared and color were developed as described earlier. The

absorbance of the solutions was read at 400 nm using PYE unicam u/v spectrophotometer. The percentage phosphorous pentoxide was calculated with the standard formula (Jeffrey *et al.*, 1978).

### **Determination of Loss on Ignition (LOI)**

One gram of the limestone sample was weighed and transferred into a weighed platinum crucible. The sample was then taken into muffle furnace and ignited at a temperature of 1,000°C for 30 minutes. The crucible was brought out and allowed to cool in desiccators. It was then weighed and the percentage loss was calculated as:

$$\% \text{ Loss} = \frac{W_2 - W_1}{W_s} \times 100 \quad (8)$$

Where:

$W_2$  = weight of crucible + ash after firing

$W_1$  = weight of empty crucible

### **Determination of Bulk Density**

The limestone sample was shaped smoothly into a sphere about 2 cm diameter. It was then weighed on a top-loaded balance ( $W_1$ ). Clean mercury was poured into a 1,000 ml beaker and placed centrally on the balance pan under the saddle. The gram-scale was then tared zero. The saddle was lowered into and locked with the bridge locking screw. The micrometer was adjusted until the pointer just touched the surface of the mercury. The balance was again tared back to zero. The saddle was now raised by means of the hand wheel and the sample was immersed in the mercury and the bridge locking screw was locked. The micrometer was adjusted until the pointer just touched the surface of the mercury. The weight was read as  $W_2$ . The volume of the specimen is given by:

$$\text{Volume} = \frac{W_2}{D} \quad (9)$$

Where

D=density of mercury at the temperature the analysis was carried out

The bulk density was calculated with the formula:

$$\text{Bulk Density} = \frac{W_1 \times D}{W_2} \quad (10)$$

### **Determination of Porosity**

The test sample of about 1.5 cm diameter was dried in an oven for about one hour after which it was cooled to room temperature and weighed (D). The dried sample was suspended in distilled water, such that it did not touch the bottom or sides of the Pyrex beaker. It was after boiled on the hot plate for two hours while suspended in water after which it was cooled to room temperature and its weight was noted while still in water (S). The sample was then removed from the water and the water on its surface was wiped off by lightly blotting with a wet towel and then weighed in the air (W). The apparent porosity was calculated with the formula:

$$\% \text{ Porosity} = \frac{W - D}{W - S} \times 100 \quad (11)$$

### **Determination of Reactivity**

About 150 g of the limestone was calcined at 900°C, after which it was removed and ground to less than 5 mm diameter size. The room temperature  $T_r$  and 150 g of lime was poured into a 600 ml beaker. The stop watch was put on and the thermometer was inserted in the mixture at the same time. The time taken by the lime to reach 60°C was noted (t). The reactivity, R, was calculated with the formula:

$$R = \frac{60 - T_r}{t} \quad (12)$$

### **Determination of Specific Gravity**

The limestone sample was pulverized into very fine particles. About 10 g of the sample was then weighed and gradually introduced into the density flask (with the aid of a funnel) filled with distilled water. The volume displaced by the sample charged into the density flask was noted. The specific gravity (SG) was calculated with the formula:

$$SG = \frac{W_s}{V_d} \quad (13)$$

Where:

$W_s$  =weight of sample

$V_d$  =volume displaced by the sample

The results of the analyses are presented in Tables 1 and 2, while Table 3 shows the standard specification of limestone for lime production (Plumpton, 1984).

**Table 1:** Chemical Composition of Ubo Limestone.

S/No	Chemical parameters	Percentage (%)
1.	Calcium oxide (CaO)	52.84
2.	Magnesium oxide (MgO)	2.48
3.	Iron oxide (Fe <sub>2</sub> O <sub>3</sub> )	0.40
4.	Alumina (Al <sub>2</sub> O <sub>3</sub> )	1.44
5.	Silica (SiO <sub>2</sub> )	2.25
6.	Phosphorous pentoxide (P <sub>2</sub> O <sub>5</sub> )	0.03
7.	Titanium oxide (TiO <sub>2</sub> )	Trace
8.	Sulphur (S)	0.02

**Table 2:** Physical Properties of Ubo Limestone.

S/No	Physical parameters	Percentage (%)
1.	Loss on Ignition (LOI)	39.56
2.	Bulk density	2.65g/cm <sup>3</sup>
3.	Porosity	1.20%
4.	Reactivity	22.6°C/min
5.	Specific gravity	2.67

**Table 3:** Standard Limestone Specifications for Lime Production.

S/No	Chemical parameters	Percentage (%)
1.	Calcium Oxide (CaO)	50.0-65.0
2.	Magnesium Oxide (MgO)	2.3-5.5
3.	Iron Oxide (Fe <sub>2</sub> O <sub>3</sub> )	0.2-0.5
4.	Alumina (Al <sub>2</sub> O <sub>3</sub> )	1.0-2.8
5.	Silica(SiO <sub>2</sub> )	0.8-2.5
6.	Phosphorous Pentoxide (P <sub>2</sub> O <sub>5</sub> )	0.01-0.10
7.	Potassium Oxide (K <sub>2</sub> O)	1.0-1.50
8.	Sodium Oxide (Na <sub>2</sub> O)	1.0-1.30
9.	Sulphur (S)	0.01-0.10
10.	Loss on Ignition (LOI)	30-45

(Source: Plumpton, 1984)

## RESULTS

The chemical composition and physical properties of Ubo limestone, are presented in Tables 1 and 2, while the standard specifications for a limestone to produce burnt lime suitable for direct use in iron-making is shown in Table 3.

## DISCUSSION

The 52.84% calcium oxide content of Ubo limestone falls within the range of 50% to 65% required for limestone for burnt lime production (Plumpton, 1984). The CaO content is also very close to 54.1% determined for limestone to be used for pilot scale iron-making in India. The CaO content of the raw Ubo limestone is higher than 43.05% for Indian Salem Madras deposit and is only slightly lower than the flotation concentrate of Salem limestone with 52.9% CaO. The Ubo CaO content is also far higher than 43.44% and 38.68% for low grade raw limestone under consideration for upgrading by Indian Tata Iron and Steel Ltd. and Rhotas Industries, respectively. The flotation concentrates obtained in both cases contained 50.50% and 47.43% CaO, respectively (Ghandy, 1966).

Calcium oxide is one of the two oxides that play the most important role in the removal of oxide impurities during iron and steel-making. Calcium oxide, for example, will react with silica to produce calcium silicate that has a much lower melting point than the two oxides (Cottrel, 1980). These results showed that the Ubo limestone as received is a high grade limestone that meets the specification for direct use for production of burnt lime for iron and steel-making.

The MgO content of 2.48% in the raw Ubo limestone falls within the range of 2.30% to 5.50% standard specified for limestone for direct lime production (Plumpton, 1984). The MgO content of Ubo limestone is higher than 1.0% MgO content for a limestone for pilot scale iron-making in India (Ghandy, 1966). MgO forms the low melting point magnesium silicate with silica during iron-making. These results strongly suggest that the Ubo limestone is a high grade limestone suitable for use in blast furnace iron-making.

The iron oxide content of 0.40% in Ubo limestone also falls within the range of 0.2% to 0.5% specified for a high grade limestone for lime making. It is far lower than the 1.54% determined

for the Indian Rhotas industries limestone (Plumpton, 1984; Ghandy, 1966). The content of iron oxide also helps in enriching the iron ore sample in a blast furnace. These results further indicate that Ubo limestone is suitable for burnt lime production.

The 1.44% alumina content for Ubo limestone falls in the range of 1.0% to 2.8% for alumina content of limestone suitable for direct production of lime (Plumpton, 1984). It is only slightly higher than 1.2% for the Indian limestone for pilot scale iron-making and much lower than the 4.03% for the poor grade Rhotas limestone (Ghandy, 1966). Since alumina is a highly refractory oxide, its low content in Ubo limestone strongly indicate Ubo limestone as a high grade limestone. Alumina acts as a base or as an acid depending on the conditions imposed. For example, in highly siliceous slags, it may form alumina silicates, while in the presence of a strong base like lime it may form calcium aluminate.

The silica content of 2.25% for Ubo limestone falls within the range of 0.80% to 2.50% standard specified for high grade limestone (Plumpton, 1984). It is however higher than 0.88% silica for limestone used in India pilot scale iron-making (Ghandy, 1966). Silica is not very harmful in iron-making, being the source of the important Si. However, high quantity of silica will lead to the formation of large volume of calcium silicate slag with the associated high energy requirements for fluxing (Moitra *et al*, 1972). The low content of silica in Ubo limestone further shows it as being suitable for direct lime production since acid impurities will reduce the potency of a basic slag.

The 0.03% content of phosphorous pentoxide in Ubo limestone is much lower than 0.19% for Indian Salem limestone and 0.065% in the low grade Indian Rhotas limestone. The phosphorous pentoxide content in Ubo limestone also falls within the range of 0.01% to 0.10% for high grade limestone. Furthermore, the sulphur content of 0.02% for Ubo limestone falls within the range of 0.01% to 0.10% for a high grade limestone. For the Indian practice, sulphur and phosphorous were not considered in the analysis of limestone for iron-making (Plumpton, 1984; Ghandy, 1966).

The low content of sulphur in Ubo limestone is significant since part of the sulphur in the fluxing lime will get into the molten iron to form iron sulphide that embrittles the iron. The low content of phosphorous pentoxide in the limestone is also

advantageous as phosphorous pentoxide is acidic and will need to be fluxed along with silica. In addition, it also serves as a source of the difficult to remove phosphorous into the molten iron. Titanium was found to be in trace quantity in the limestone. It is a harmless impurity and serves as a source of titanium that improves steel strength. The percentage content of the alkali oxides was not determined.

The percentage loss on ignition of 39.56% falls within the range of 30% to 45% specified for high grade limestone. The LOI may be due to the presence of water and some adsorbed gaseous impurities in the limestone which escape on ignition. The bulk density of 2.65g/cm<sup>3</sup> for Ubo limestone is higher than 1.0g/cm<sup>3</sup> specified for a prime grade limestone. However, the essence of determining the bulk density is to ensure that the limestone is within the acceptable charge standard during calcinations. The other physical properties (e.g., porosity) determined will only be critical in the assessment of mineral oxides for refractory applications.

## CONCLUSIONS

The Ubo limestone was subjected to chemical and physical analyses to investigate its suitability or otherwise for direct lime production. Chemical analysis showed that the raw Ubo limestone contains sufficiently high percentages of the main fluxing oxides i.e. calcium and magnesium oxides. The percentage contents of silica and phosphorous pentoxide, the main acidic oxides to be fluxed into a fusible slag along with those from iron ore is also within the allowable limit for the production of burnt lime for iron and steel-making. However the contents of the alkali oxides-potassium and sodium oxides were not determined. On the basis of the chemical analysis conducted, Ubo limestone is suitable for direct burnt lime production provided its alkali contents are sufficiently low.

## REFERENCES

1. Benton, W. 1973. *Encyclopedia Britannica*. 15<sup>th</sup> Edition. 10: 980-982.
2. Considine, D.M. 1974. *Chemical and Process Technology Encyclopedia*. McGraw-Hill: New York, NY. 685-689.

3. Cottrel, A. 1980. *Introduction to Metallurgy. ELBS Edition*. Edward Arnold: London, UK.
4. Ghandy, J.J. 1966. "Annual Report". National Metallurgical Laboratory: Delhi, India. 1965-1966. 32-33, 152-153.
5. International Development Research Centre (IDRC). 1995. "Technological Change and Project Execution in Nigeria: The Case of Ajaokuta Steel Plant". Banji Oyelaran-Oyeyinka and Adeloje, O.(eds.). [http://www.idrc.ca/en/ev-30807-201-1-DO\\_TOPIC.html](http://www.idrc.ca/en/ev-30807-201-1-DO_TOPIC.html). 10/26/10.
6. Jeffery, G.H., J. Bassett, J. Mendham, and R.C. Denney. 1978. *VOGEL's Textbook of Quantitative Chemical Analysis. Fourth Edition*. Longman Scientific & Technical: New York. NY. 756
7. Moitra, A.K., N.G. Banerjee, K.Y. Shrinkhande, K. Sing, K. Raja, and S. Banerjee. 1972. *Studies on Coal Carbonisation in India. First Edition*. Central Fuel Research: Calcutta, India.
8. Plumpton, A.J. 1984. *Production and Processing of Fine Particles. Third Edition*. Pergamon Press: New York, NY. 605.
9. Ray, A.K. 1979. *Manual for Chemical and Instrumental Analysis of Ores*. Minerals and Industrial Products: Controller, Indian Bureau. New Delhi, India. 41.
10. Smith, A.W. 2008. *Materials of Machines*. Biblio Bazaar, LLC.: London, UK. 42.
11. The Nigerian Embassy. 2010. "Steel Development". <http://nigerianembassy-chile.org/nigeria/xsteel.shtml>. 10/26/10.
12. University of Texas. 2008. <http://www.utexas.edu/courses/asdon/blasts.htm>. 2/18/08.
13. Wikipedia. 2010a. [http://www.en.wikipedia.org/wiki/Lime\\_material](http://www.en.wikipedia.org/wiki/Lime_material). 10/26/10.
14. Wikipedia. 2010b. [http://en.wikipedia.org/wiki/Basic\\_Oxygen\\_Process](http://en.wikipedia.org/wiki/Basic_Oxygen_Process). 2/18/08.

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