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Metallization of some Nigerian iron ores: Toto-Muro, Itakpe and Koton-Karfe iron concentrates using Obi and Okaba coals

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Abstract
The metallization of beneficiated Toto Muro, Itakpe and Koton Karfe iron concentrates using Okaba and Obi coal samples was investigated. The Toto Muro, Itakpe and Koton Karfe iron ores samples were obtained from the iron ore deposits in Toto, Itakpe and Koton Karfe Local Government Areas of Nasarawa and Kogi States respectively. The iron ore samples in lump sizes were crushed, pulverized and analyzed to obtain their chemical compositions using XRD. The analyses revealed that the head sample of Toto Muro iron ore has 33.5% Fe, 54.14%SiO_2, Itakpe iron ore has 36.88%Fe, 44.80SiO_2 and Koton Karfe iron ore has 43.40%Fe, 10.14%SiO_2 respectively. The pulverized various samples were sieved and concentrated using their established liberation sieves particle sizes fractions and their most suitable adoptable methods of separations. The various concentrates obtained from the various established separation methods established for the respective iron ores samples were assayed for their iron and silica contents respectively. Toto Muro iron concentrate has 57.19% Fe , 8.26% SiO_2 , Itakpe iron concentrate has 64.0%Fe, 31.0%SiO_2 and Koton Karfe iron concentrate has 69.10%Fe, 0.41%SiO_2 respectively. The various concentrates were metalized using up-graded Okaba and Obi coals samples at 1200°C for 2 hours in a muffle electric heating furnace with temperature range of 0-1300°C. The degrees of metallization of the various specimens produced using the various iron concentrates were calculated and found to be 98.79, 70.63 and 62.66% for Toto-Muro, Itakpe and Koton-Karfe using upgraded Okaba, and 88.23, 89.85 and 91.17% on the averages for Toto-Muro, Itakpe and Koton Karfe using as-recieved Obi coking coals samples respectively. The values obtained for the degrees of metallization of the respective iron concentrates using upgraded Okaba and as-received Obi coking coals samples respectively meets the requirements for iron making using direct process route as cited in the literature.

Key words: metallization, iron concentrates Obi and Okaba coals.

Significance of the Research Work: the technology for metallization route for the production of spongy iron from Toto Muro, Itakpe and Koton Karfe iron concentrates will be developed and the utilization of Okaba and Obi coal deposits will be enhanced and through such, job opportunities will be created for the increasing teeming population and also conservation of foreign exchange for the importation of coke will be reduced.

Introduction
Iron and steel industries are the basic foundation for the technological development of any country. A country that neglects iron and steel will ever remain undeveloped and technologically backward in its national development plan. As a result of the realization of the importance of the iron and steel industries and with the intention of laying a formidable foundation for technological take-off of the country, the Government of the Federation in 1971 established the Aladja and Ajaokuta iron and steel projects. Although, the establishment of these projects was laudable, inadequate attention was given to the development of the raw materials to feed the plants even though Nigeria is endowed with large reserves of proven and unproven iron-ore, coal and other raw materials required for the production of iron and steel scattered all over the country (Uwadiale, 1989). As a result, for example the Aladja iron and steel plant on commissioning in early eighties had to depend on foreign sources of iron

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concentrates and coke. Not until recently, with the efforts of the National Ore Mining Project Itakpe, National Metallurgical Development Centre, Jos and individual researchers that a process flow sheet has been developed for the beneficiation of the Itakpe iron ore deposit, estimated at 200 million tonnes to be upgraded and used as feedstock in Ajaokuta and Aladja iron and steel plants (Uwadiale, 1989).

Individuals and other research Institutions have also worked on other locally available iron ore deposits for example Aladja iron ore deposit (Uwadiale, 1989). This is the largest iron ore deposit in the country estimated at over 1 billion tonnes and has been established to possess extremely fine-grained texture and hence has to be ground to -5m in order to achieve substantial degree of liberation. At such extremely fine size, most conventional beneficiation techniques such as froth flotation, magnetic and gravity concentration processes cannot be used to separate the iron oxides from the gangue minerals. Comminuting the ore to that extremely fine particle size, most especially iron ore will be uneconomical because of its market value (Thomas, 2002). In addition, it has a very high phosphorous content, which has discouraged its utilization to date. Attempt has also been made on the beneficiation Agbodo Okudo iron ore deposit (Uwadiale, 1989). The investigation revealed that the ore could be upgraded to a standard concentrate using a combination of gravity and magnetic concentration techniques. The liberation sizes, sieves sizes fractions and most suitable adoptable concentration techniques used in beneficiating the Itakpe, Toto-Muro and Koton –Karfe iron ores samples used for this research work were on the basis of the results findings published by Thomas and Yaro, 2007 in some journals.

Furthermore, with these vast deposits of iron ores, the country could not verily ascertain whether or not her vast coal deposits could be used as reducing agent in the metallization of the country potential iron ores deposits for iron and steel making. Hence, for Nigeria to succeed, in its efforts to develop the indigenous iron and steel industries and hence attain technological development and economic self-reliance, it has thus become necessary to investigate the utilization of some Nigerian coal deposits for iron making.

Currently, new technology for iron making that utilizes coal only as the reducing agent beside the blast furnace route are on the increase and example of these technologies in use are the SL (Stelco-Lurgi process using Rotary Kiln without recycle scrap charge), FASTMELT and HYL (Hojalata Y Lamina) are exploited to produce iron metal. On the basis of the above, prompted this research work with the hope of producing metalized (spongy) iron for steel making.

Metallization is a form of direct reduction applies to processes in which reduction and the resulting metalized spongy iron occurs below melting temperature and the product is in a solid form. This characterized direct reduction from other processes such as a blast furnace route in which melting temperatures are attained and the products are molten pig iron and molten slag usually called hot metal. Metallization of metal is measured by the degree of metallization of the metal, expresses in percentage and defined as the percentage of metal or reduced iron to the total iron content in the concentrate (Obaje and Abba, 2002).

Furthermore, metallization is the science of the production of metals from their concentrates by application of the principles of pyrometallurgy, hydrometallurgy or electrometallurgy. Pyrometallurgy which has found application in the metallization of iron ore concentrates is to be used for the purpose of this research work. It involves the use of heat energy where coke, charcoal or hydro carbon are used as the sources of heat energy and at the same time reducing agents required for metallization process prior to steel making direct method of iron making. Before then, the ore mineral and the reducing agents have to be beneficiated in order to reduce the gangues associated with them.

In metallization process of iron concentrates, iron concentrates or nodules (40-60% Fe_T) is charged with coke, lime, limestone or dolomite, sometimes scraps and blast air into the furnace where the iron concentrates are reduced to spongy or metallic iron(Maigini, 2008).

Metallization reactions using coal (Carbon)

$$3Fe_2O_{3(s)} + C_{(s)} \longrightarrow 2Fe_3O_{4(s)} + CO_{(g)}\uparrow \quad ... 1.0$$

$$Fe_3O_{4(s)} + C_{(s)} \longrightarrow 3FeO_{(s)} + CO_{(g)}\uparrow \quad ... 1.1$$

$$FeO_{(s)} + C_{(s)} \longrightarrow Fe_{(s)} + CO_{(g)}\uparrow \quad ... 1.2$$

(Thomas, 2002)

$$\text{Degree of metallization} = \frac{\text{\% assay of metallized iron}}{\text{\% Assay of concentrate}} \quad ...1.3$$

Directly reduced iron metal is a remarkable new iron source for steel making, there are two main groups of processes for direct reduced iron productions: (i) a gas based process using natural gas as a reducing agent, for example, the MIDREX and the HYL (Hojalata Y Lamina) processes. (ii) a coal-based process which uses coal as a reductant, for example the SL/RN (Stelco-Lurgi process using Rotary Kiln without recycle scrap charge). The gas-based process is already a well-known process, but it is necessary to have easy access to natural gas which for now is difficult to attain. The direct reduced iron process, where carbon composition and iron concentrate pellets are heated rapidly in a rotary hearth furnace, for example the FASTMELT process (Rotary Hearth or Electric Melter) is much better than the process using natural gas or the process operated in a rotary kiln. The advantages of this process seems to be that location of plant is less limited due to the use of coal as reductant and plant investment is low. Hence, make the production of steel economical from the adoption of the latter process as an option (Maigini, 2008).

The country is blessed with up to 3 billion tonnes of iron ores deposits that cut across the Niger and Benue troughs of the country, some investigated fully, while others are partially investigated. Table 2.1 gives the various iron ores deposits in the country and Table 2.2 gives the chemical composition of some major Nigerian iron ore deposits (RMRDC, 2000).

Nigerian coal available data shows that coal (are mainly sub-bituminous seam coals, except for the Lafia-Obi that is a bituminous coking coal) occurrences in Nigeria have been indicated in more than 22 coal fields spread over 13 states of the Federation. The proven coal reserves so far in Nigeria total about 661 million metric tons while the inferred reserves sum up to 2.75 billion metric tons (Damisa, 2001).

There are five economically important seams of sub-bituminous coal so far recognized in Nigeria of which most are located in the south – east and middle belt of the country. Table 2.3 gives the summary of coal deposits in Nigeria and shows that Nigeria has over 2.5 billion metric tonnes of coal with proven reserves of about 661 million metric tonnes out of which about 25million metric tonnes have been mined.

Metallurgical Requirement for Coke/Coal as Metallization Agent

Coke is a solid carbonaceous residue derived from low ash, low sulphur bituminous coal from which the volatile constituents are driven off by baking in an oven without oxygen at temperatures as high as 1,000^{0}C (1,832^{0}F) so that the fixed carbon and residual ash are fused together. Metallurgical coke is used as a fuel and as a reducing agent in smelting iron ore in blast furnace. Coke from coal is grey, hard and porous and has a heating value of 24.8million btu/ton (29.6mj/kg) (Tastsch, 1980 in Damisa, 2001).

The primary essential in the selection of coking coals is its chemical analysis composition. It is required at frequent intervals in order to ensure maintenance of quality ones the coal has been selected. In the American standard for testing and measurements (ASTM) classification, the ranks of most coking coals are defined by their proximate analysis and the heating value determination. A proximate analysis including moisture, ash, sulphur and sometimes phosphorus also shows the grade of a coal (see Tables 2.4 and 2.5). A good coking coal or blend must possess the correct combination of swelling, coking and plastic properties so that during heating would cause the coal particles to fuse together to form a strong coherent mass, which fractures a long planes of weakness to leave a preponderance of pieces in the 20mm size range on cooling (Damisa, 2001).

Individually, the above coking data serve only to indicate the coals potential for coke manufacture. A confident prediction of coals performance in the coke oven can only be made after more extensive testing. Prime coking coals would exhibit properties in the upper part of the ranges mentioned. The best metallurgical coke would be found from gray king types G4 – G9. The coke pieces must be resistant to further abrasion and size degradation, be un-reactive and contain less than 10% ash, 1% sulphur and only traces of phosphorus or complete elimination of it. Coals outside this range can be blended with high range coking coal (Damisa, 2001).

Caking Power

The behaviour of coal on heating is of special importance and many methods have been suggested for its definition and measurement. One of these is the Gray king method. Coal (20g passing a 72 B.S. sieve) is carbonized under standard conditions to 600^0C. If the carbonized residue is porous with no sign of coherence, the term "non caking type A" is assigned. Coal which gives a hard, compact, non fissured coke of the same volume as the original coal is termed A, while the intermediate letters designated coals whose coke friability decreases within this range, coals of higher caking power are blended with 72 mesh carbon to give a coke corresponding to type a and termed A1 to G10 respectively, the subscript members indicating the corresponding to type G and termed G1 to G10 respectively, the subscript members indicating the number of grains of coke necessary in the 20g blend((Mathias, 2008, Damisa, 2001)).

Types of coke from Gray King Assay

A, B	Non-caking
C, D	Very weakly caking
E, F, G (G_1, G_2, G_3, G_4)	Medium caking
G_5 – G_8	strongly caking
G_9 and over	Very strongly caking

Gray King A B C D E F G G_1 G_2 G_3 G_4 G_5 G_6 G_7 G_8 G_9

Swelling Index 1 ½ 2 3 4 5 6 7 8 8 9

Figure 1.0: Types of coke from Gray-King Assay (Damisa, 2001).

Materials and Method

Materials

The materials used are sodium carbonate, Obi and Okaba coals samples, Itakpe, Koton Karfe and Toto Muro iron concentrates.

Sample collection and Preparation

10 kg each of the sample of Toto Muro, Itakpe and Koton Karfi iron ores and coals samples were sourced from their various deposits located in Nasarawa and Kogi states respectively. The iron ore samples were pulverized, sieved to their required liberation size and beneficiated using their established published most suitable adoptable concentration techniques. The various iron concentrates obtained and the beneficiated various coals samples were assayed for iron and silica contents using XRF; fixed carbon, ash, moisture and volatile maters contents using proximate analysis respectively. The results are presented in Tables 2.8 and 2.9 of this paper.

Equipment

Electric heating furnace with control temperature ranges, platinum crucible, electrical weighing balance, Denver magnetic separation, Denver pulverizing machine, Denver laboratory shaking and XRF analytical machines.

Method

Metallization of Toto-Muro, Itakpe and Koton-Karfe Iron Concentrates using Okaba and Obi Coal Samples Respectively 2 grams of Toto-Muro iron concentrate was mixed with the upgraded Okaba coal and lime to form a paste (Table 2.11). The paste was placed into crucibles and inserted into an electric furnace. The electric furnace was switched on and allowed to reach the temperature of 1200°C after which the crucibles containing the paste were inserted into the electric furnace and heated for one hour. After one hour, the crucibles were removed from the furnace and cooled at room temperature. The molten paste specimens were taken for chemical analyses using XRF and the result of the degree of metallization was computed using equation 1.3. The same procedures were repeated for Itakpe and Koton Karfe iron concentrates respectively and also with Obi coal respectively. The results of the metallization tests are given in Table 2.10 of this paper.

Discussion of Results

The chemical analyses of Toto-Muro, Itakpe and Koton-Karfe iron ores samples.

The chemical analyses of Toto-Muro, Itakpe and Koton-Karfe iron ores samples are given in Table 2.9. The Toto-Muro iron ore has 33.60%Fe and 54.14%SiO_2, Itakpe has 36.88%Fe and 44.80%SiO_2 and Koton-Karfe has 43.40%Fe and 10.14%SiO_2 on the average. Comparing the chemical compositions of the head samples of the various iron ores used for this research work to other four (4) major iron ores given in Table 2.2 revealed that the percentage of phosphorous peroxide (P_2O_5) in Toto-Muro(0.3%), Itakpe (0.18%) and Katon-Karfe (2.14%) are less and moderately compared favourably with that of Agbado-Okudo (2.08%) and Bassa-Nge (1.45%) respectively. Also, the percentage of sulphur of the Toto-Muro, Itakpe and Koton-Karfe iron ore samples are moderately less and lies closely to that of the four (4) major iron ore deposits. The sulphur contents of Toto-Muro, Itakpe and Koton-Karfe iron ores are within the acceptable limit of 0.20% required for iron making. Also, the proportion of 54.14%SiO_2 of the Toto-Muro iron ore is high compared to that of Bassa-Nge (8.28%), Katon-Karfe (10.14%), Itakpe (44.80%) and Agbado Okudo (10.89%). The silica contents of the iron ores samples could be drastically reduced during beneficiation and slag formation (Wills, 1985; Kudrin, 1985). Therefore, the low and moderate phosphorus, low and high percentages of silica contents of some of the iron ore samples do not pose any threat to their utilization in iron and steel plants. The proportions of the chemical compounds in Toto Muro, Itakpe and Koton Karfe iron ores are within the acceptable limit required for iron and steel making (Kudrin, 1985).

Proximate analyses of the Okaba and Obi coals samples.

The tests of the qualities of the coals are given in Tables 2.7 and 2.8. The results compared favourably with the literature values cited in Tables 2.4 and 2.5. From results, the selectively leached and inoculated Okaba coal has high percentage of fixed carbon compared to that of Obi coal as indicated in Tables 2.7 and 2.8; this could be attributed to the absorption of the fossil fuels into the matrix of the Okaba coal during treatment before being used as a reducing agent. Hence, this action increased the proportion of the fixed carbon content in the Okaba coal sample compared to the untreated Obi coking coal sample used also in the metallization process. See also Table 2.10.

Metallization of Toto Muro Iron Concentrate using Okaba Coal.

The Koton-Karfe, Itakpe and Toto-Muro iron concentrates were metalized using the beneficiated Okaba and Obi coals as reducing agents. Table 2.10 gives the % assays of the spongy (metalized) iron of the various specimens A, B, C, D and E and the corresponding degrees of their respective metallization of the various iron concentrates used in this research work. From the result, the % assays of iron in the metalized specimens E and F of the Toto-Muro iron concentrate sample was found to be 56.60% Fe with corresponding degrees of metallization of 98.79% on the average for the specimens E and F respectively using Okaba coal as the metalizing agent. 50.45%Fe was found as the assayed of iron on the average in the metalized specimens E and F with 88.23% on the average as the corresponding degree of metallization for the same iron concentrate using Obi coal sample as the metalizing agent respectively. The values obtained for using Okaba coal sample as a metalizing agent are higher compared to that of Obi coal and the metalized values of 90 to 91% cited in the literature. This phenomenon could be attributed to the improved properties of the Okaba coal by selective leaching and inoculation using fossil fuels (Kerosene and diesel oils as inoculants) to increase its carbon content before being used as a reducing agent. This action enhanced the prompt response of the Toto Muro iron concentrate to the reactive characteristic of the inoculated Okaba coal compared to that of Obi coal. Since carbon is the principal source of energy and the reducing agent that aid metallization in iron ore reduction. The higher the percentage of associated combustible carbon alongside fixed carbon in coal, the better its reducibility property as stated in the literature (Mathias, 2008). The degrees of metallization obtained for Koton Karfe and Itakpe specimens A and B, C and D are found to be 91.17 and 89.85% on the average respectively. These values are higher compared to those obtained using Okaba coal as a metalizing agent for the same Itakpe and Koton Karfe specimens. This phenomenon could be attributed to the high percentage of the fixed carbon contained in the Obi coal compared to that of Okaba coal, hence, its high reducibility potential compared to Okaba coal. The results also obtained compared favourably with those cited in Table 2.6.

Conclusion

On the basis of the results obtained in this research work, it can be concluded that high degree of metallization was achieved for using the selective leached and inoculated Okaba coal than the as-received Obi coking in the reduction of Toto Muro iron concentrate while high degrees of metallization was achieved using the as-received Obi coking coal for the reduction of Itakpe and Koton Karfe iron concentrates than the selectively leached and inoculated Okaba coal. Though both coals degrees of metallization compared favourably with those values of degrees of metallization cited in the literature. Hence, both coals have to be upgraded before utilization in metallization process for iron and steel making.

Recommendation

(i) It is recommended that Okaba coal should be blended with other coals to determine the degree of their metallization using local iron concentrates.

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Table 2.1: Estimated reserves and quality in terms of iron content of some iron ore deposits in Nigeria are given in table below

Location of Deposit	Quality in terms of Fe content (% Fe)	Estimated Reserves in Million tonnes	Distance from Ajaokuta steel complex (km)
Itakpe	40.45	200	66
Ajabanoko	40.00	60	70
Agbaja	44.50	98	100
Enugu	32.00	20	400

Source: Ajaokuta Steel Company Limited published Report (1985)

Table 2.2: Chemical Composition of some Nigerian iron ore deposits

Deposit	K_2O	CaO	TiO_2	MnO	FeT	Mg0	Al_2O_3	SiO_2	P_2O_5	S
Chokochoko	0.53	0.15	0.16	0.08	34.45	0.18	9.67	51.07	0.02	0.007
Agbado-Okudu	0.04	0.72	0.37	0.14	47.80	0.38	9.60	10.89	2.08	0.12
Ajagbaoko	0.26	0.21	Trace	0.01	37.22	0.15	3.39	46.50	0.01	0.03
Bassa Nge	0.02	0.17	0.17	0.13	46.90	0.40	8.28	8.28	1.45	0.05

Source: RMRDC (2000)

Table 2.3: Coal deposits in Nigeria and their reserves

State	Location	Indicated in-situ (million tonnes)	Inferred reserves (million tonnes)	Overall reserve (million tonnes)
Enugu	Enugu Ezimo Inyi	54 56 20	200 60 Unknown	254 116 20
Kogi	Okaba Ogboyoga	73 107	250 320	323 427
Benue	Otukpo Ogboyoga	57 107	75 320	132 427
Delta Nassarawa Gombe	Asaba Obi Maiganga	250 22 22	Unknown Unknown Unknown	250 22 -
		661	905	1544

.Source: (Aderibigbe, 1989, Damisa ,2001)

Table 2.4: Summary of characteristics of good coking coal/coke

Parameter	Desire	Typical limit	Comments
Total moisture %	5 – 10	12	Limited for easy handling and grinding
Volatile matter (%)	Various	16 – 21 21 – 26 26 – 31	Low volatile coals Medium volatile coals High volatile coals
Total sulphur (air dry)	Low %	0.6 – 0.8	Sulphur content of coke should be low to limit take- Zip of sulphur by pig iron in blast furnace.
Free swelling index	7.9	Min. 6	
Roga index	60 – 90	Min. 50	
Gray king coke	G6 – G14	Min. G4 – G5	
Dilatometry	25 – 70 80 – 140 150 – 350	Min. 20 Min. 60 Min. 100	Low volatile coals Medium volatile coals High volatile coals
Plastometry Fluidity range	Min. 80 Min. 100 Min. 130	Min. 70 Min 80 Min. 100	Low volatile coals Medium volatile coals High volatile coals

Source: Aderibigbe, (1989) in Damisa, (2001); Eugene, (2008)

Table 2.5: Specifications for blast furnace coke/coa

Volatile matter	0.75 – 2% by weight
Ash	7.0 – 9.0% by weight
Sulphur	0.65 – 1% by weight
Shatter test (on 5cm)	70 – 78% by weight
Drop number	4
Drop resistance	4
Porosity	7-10%
Size	7 – 12cm
Fixed carbon	48.91 – 90%
Moisture content	Below 5%
Calorific value kcal/kg	7,652
Phosphorus	0.007%
Total Reactive	97.6%

Source: Weiss, (1985); Eugene, (2008).

Table 2.6: Chemical composition of metalized iron metal requirement

	Percentage (%)	Lumps	Fines
Fe (total)`	90-92	91.50	92.00
Fe (metallic)	81 – 84	80.00	82.00
Metallization	90.00	88.00	90.00
Sulphur	0.03	0.04	0.04
P_20_5	0.05	0.45	0.45
Carbon	0.10	0.20	0.25
Gangue	6.80	5.00	5.00

Source: WWW.Trimilaspongy Iron.Org. (2008).

Table2.7: Proximate analysis of Okaba coal.

Proximate Analysis	Unwashed (%)	Selective Leaching /Inoculation (%)
Moisture (%)	9.56	1.22
Ash (%)	10.12	1.56
Volatile matter (%)	13.59	5.46
Fixed carbon (%)	65.97	80.35
Phosphorus	0.034	0.034
Sulphur (%)	0.72	0.045

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Table 2.8: Result of the chemical analysis carried out on as-received Obi coal using proximate method of analysis.

Item	Percentage
Fixed Carbon	52.64%
Sulphur	4.01%
Phosphorus	0.0081%
Moisture	7.99%
Volatile matter	24.62%
Ash	10.73%

Table 2.9: Chemical analysis of head sample

Ore	Fe_T	SiO_2	CaO	Na_2O	P_2O_5	S	Al_2O_3	V_2O
Toto Muro	33.6	54.14	2.39	0.28	0.3	0.20	0.12	0.08
Koton Karfe	43.40	10.14	1.23	-	2.14	-	-	-
Itakpe	36.88	44.80	0.30	-	0.18	0.05	1.00	-

Table 2.10: Degrees of metallization of the various types of iron concentrates reduced using Obi and Okaba coals samples

Type of Concentrate	Specimen	Period of Reduction (hr.)	% Assay of Conc.	Wt. of Conc.	Type of Coal: Obi Coking Wt (g)	Obi Coking % Fe in Spongy metal	Obi Coking % Degree of Metallization	Okaba Wt (g)	Okaba % Fe in Spongy metal	Okaba % Degree of Metallization
Koton Karfe	A	1.0	69.1	20	2.0	62.80	90.88	2.0	43.30	62.66
	B	1.0	69.1	20	2.0	63.20	91.46	2.0	43.30	62.66
Itakpe	C	1.0	64.0	20	2.0	57.00	89.10	2.0	45.20	70.63
	D	1.0	64.0	20	2.0	58.00	90.60	2.0	45.20	70.63
Toto Muro	E	1.0	57.1	20	2.0	50.60	88.48	2.0	56.50	98.79
	F	1.0	57.1	20	2.0	50.30	87.95	2.0	56.50	98.79

Table 2.11: Weight of charge materials required on the basis of material balance

Sample	Coal (g)	Iron ore (g)	Sodium carbonate as flux (g)
1	2.0	20	11.5