Metallurgical Research, Development and Raw Materials Sourcing for the Development of Steel Industries in Nigeria

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Abstract
It has been said that no meaningful industrialisation can take place in a nation without Iron and Steel. In fact, Iron and Steel are the bedrock of Nigeria"s industrialisation and ultimate factor in the realisation of our industrialisation efforts. Most of the Steel industries have been constructed and erected and they have to go into full operation in view of the huge money already sunk into these projects and the relative irreversibility of investment. Metallurgical Research and Development is needed to further discover the use of locally sourced raw materials for the operation of these industries. Apparently, most of the imported raw materials are expensive and some time difficult to import due to bureaucratic process and challenges faced at the present stage of steel development in Nigeria. The need for sustained availability of the raw materials for these steel industries calls for drastic reduction in the imported raw materials. This paper will therefore focus on various Metallurgical Research, Development and Raw materials sourcing for use in metallurgical industries. The paper further highlights the raw materials needs for steel production; processes for metallurgical coke and of refractory clay were reviewed. Local deposits of these materials were mentioned. The future of metallurgical research and development were brought to the fore and finally some suggestions and recommendations were given which will assist Government, stakeholders and those that are involved in the practice of metallurgical engineering with emphasis on the steel industries.

Keywords*: Research, Development, Raw Materials Sourcing and Steel Industries*

Introduction

There can be no national industrial and technological advancement without functional steel sector. It is very strategic for effective technology acquisition. However, steel industries cannot grow sustainably without drawing the bulk of its materials need locally. Thus, import substitution in terms of raw materials and spare parts is an indispensable strategy in developing steel industries. Metallu rgical research and development therefore is a necessity in achieving import substitution as the example of steel development in most of the developed countries. The development of raw materials required for most of the metal-based industries, for iron and steel making in actual fact begin with exploration as shown below.

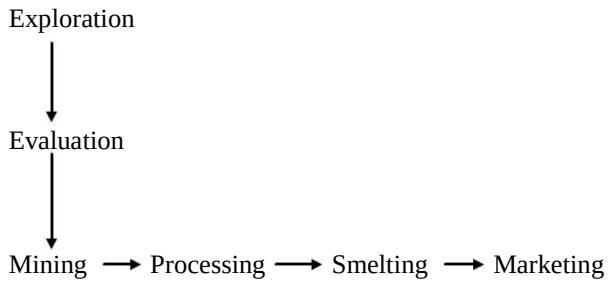

Figure: 1 Activities of the Mineral Industry

Research and development programs of Metallurgical interest have been executed in some institution of higher learning, research centres and industries, especially since independence in Nigeria. The most significant of these projects on record have recounted – the contributions of metallurgical research and development to national economy. It is conclusively advocated that an increased research and development activities in the metallurgical industry is the self – reliant industrialization and economic development of Nigeria as it faces global economy meltdown.

Various mineral resources known to occur in Nigeria (including iron ore, coal, gypsum, clay, salt etc.) could be described as relatively low grade, but they are considered so only in the context of currently commercialized production processes and technologies. With more intensive research and development, it should be possible to develop processing techniques that are peculiarly appropriate to the local resource. A case in point relates to the local iron and steel industry for which iron ore and me tallurgical coals are essential but currently import raw materials.

Unfortunately, Nigeria's largest iron ore reserve on the Agbaja' largest plateau in Kogi State (with over one billion ton of ore) is known to contain unacceptably high levels of phosphorus , an element that is difficult to eliminate in convectional ore beneficiation and iron and steel furnace processes, in addition to being deleterious to the properties of the unfinished steel product. Similarly, the coal resources of Anambra, Beune and Plateau States are new non –coking and therefore unsuitable for direct use in the blast furnaces.

In both of these cases, local research and development efforts geared to the characteristic of these local resources could result in their economical utilization by the local steel industry, thus saving larger sums in foreign exchange that could have been spent on importation, while enhancing Nigeria's security of supplies of critical raw materials (Adigwe, 1983).

Despite the growing competitions from some non – ferrous metal like Aluminum with its alloys, and non- metallic materials, notably plastics, in the country, the supremacy of steel is rather secure. Consequently, the buck of metallurgical research relevant to the current global economic meltdown will provide the necessary impetus to develop the metallurgical industries in Nigeria in the areas of iron and steel making and heat treatment processes with a view of overcoming the present global economic meltdown (Afonja, 1983).

Raw Materials for Steel Production

During the short period of production at the Ajaokuta Steel Company Limited and Iron ore mining Corporation at Itakpe both in Kogi State, the Delta Steel Company Limited (DSC) Aladja produced steel which were made into billets (ranging from low to medium carbon steel) for use at Ajaokuta Steel Company Limited, without necessarily depending on imported ores because the vast proven local ore reserves that are largely available have be improved upon and the qualities upgraded. Consequently, the beneficiation of these local ores has attracted a lot of metallurgical research. In the past, the Metallurgical Research and Test Division of the National Steel council had been able to upgrade samples of huge reserve of sedimentary magnetite – hematite ore deposit at Itakpe from 38-40 % as mined to 65 % Fe by the gravity method (Anagbo & Udevi) (Bello, 1986)

This concentrated quality would satisfy the 63% Fe requirement for the production of iron in Ajaokuta Steel company Limited through the use of the bla st furnace. Whenever the furnace is operational, it is also determined that the silicon content could further be minimized. A super concentrate of 68% Fe was produced by a second stage flotation process, providing a possible raw material even for the direct – reduction steel plant (as being practiced at DSC), especially with the intrinsic low sulphur and phosphorus contents of the deposit. The research got to a stage where a pilot plant scale was developed for the beneficiation flow sheet involving Reichert Cone, the Humphrey Spiral and the Magnetic Separator (Bello, 1993)

The Tuto –Buro fine –grained hematite ores have similarly be upgraded from 32% also by the gravity method while the Ajabanoko ores (Kogi State) was improved by magnetite separation from 39 % Fe to 63% Fe –Anagbo (Igwe, 1986). From the research carried out, it implies that the ore from these two deposits could also be processed for the blast furnace feed. The vast deposit of over a billion tonnes of Oolific sedimentary ore at Agbaja is unfortunately associated with very high phosphorus content (John). It has only been possible to upgrade the ores from 52-56% Fe to 60% Fe. In this state it could be blended with richer ores to feed the blast furnace at the Ajaokuta Steel Company Limited, prov ided the phosphorus content could be attenuated.

It was estimated that at full capacity, the Delta Steel Company Limited will require 1.55 million tonnes of iron ore while the first phase of Ajaokuta Steel Company Limited would gulp up to 2 million tonnes per year (Pwajoh, 1989). In the early 80s, the cost of ore per tonne was put at $45, a whooping sum of $159.75 million per year would have been needed for investment in iron ore alone when both industries became fully operational. A substantial part of this sum could be saved if the momentum of local ore beneficiation was maintained to curb importations.

Itakpe Iron Ore

Research and Development work carried out on Itakpe iron ore by NMDC Jos, established that the supply of the required specifications of concentrates to Ajaokuta Steel works is never in doubt. In the research work NMDC Jos collaborated with NIOMP and DSC Warri to prove through research that the handling problems associated with abundant fines in the super- concentrates transported from NIOMP to DSC can be solved.

It is on record that the Itakpe super – concentrates produced by Froth Flotation using feeds of sizes 0- 180µm (> 80% < 90µm) and 0-90µm (> 705 < 63µm) meet the requirements of DSC in terms of physical and chemical characteristics in Fe > 66%, gauge of < 3.5% and sieve size of - 45µm < 30 % (Usman, 2002)

Review of Metallurgical Coke

In the production of steel, the next but important raw material is the metallurgical coking coal. The use of these coking coals is via the blast furnace route. In the 80s, it was established that about 401 million tonnes of coals in Nigeria were intrinsically deficient for the direct application to steel making. The issue of coke-able coals has therefore also attracted considerable metallurgical research, Adigwe discovered that it is possible to reduce the objection of the medium – rank Lafia – Obi (coking coal) high sulphur content, moisture content and ash content from 44 % to only 10% (Tiajopromexport, 1993)

Further work was set in motion to control the sulphur content as being investigated by Afonja; He further showed that Enugu coal estimated at 64.3 million tonnes reserves, characteristically of the low ash content can be upgraded to 30% in convection modern preparation with imported high rank coal. T he drive would be to blend the imported coals with upgraded Lafia coal.

Since its inception in 1979, the Research Centre of NMDC Jos has been conducting applied research to ensure the inclusion of an appreciable percentage of locally available coals in met allurgical coke making at the Ajaokuta Steel Plant. Samples from Enugu, Okaba and Lafia coal deposits were extensively investigated and their results documented.

Table 1. Coal Reserves and Resources in Nigeria

State	Location	Indicated in Site Reserve Million T	Inferred Resources Million T	Overall Resources Million T
Benue	Orukpa	57	73	
	Okaba	73	250	
	Ogboyoga	107	320	
Delta	Asaba (lignite)	250	Unknown	
Enugu	Enugu Area Ezimo	54	200	
		56	60	
Plateau	Inyi Lafia – Obi	20	Unknown	
	(Coking Coal)	15	Unknown	

Source: Selection of coals for making High Quality Metallurgical Coke at Ajaokuta

Table 2. Results of Proximate Analysis and Coking Properties Determination of Nigerian Coals

S/N	Origin of the Coal Sample	Proximate Analysis Mad	Aad	Vad	Vdat	Sulphur slot a.d	Crusible Swelling Numble (CSN)	Gray King Coke type
1	Enugu (washed)	8.2	12.54	34.5	42.5	0.7	0	A
2	Onyeama	3.4	13.80	40.40	48.9	0.5	0	A
3	Okaba	9.4	11.60	35.30	44.70	0.50	0	A
4	Akpunuje	8.5	7.0	26.90	31.90	0.60	0	A
5	Lafia (original)	1.5	25.60	22.60	32.20	2.30	6	G
6	Lafia after beneficiation H.M.S. of 1.4g/CM^3	1.6	11.30	22.10	30.0	Sulphur intact	8	G3

Note: ad – as determined, daf – dried ash free, tot – total

Source: The Development of Steel Industry from Nigerian Raw Materials

Table 3. Petrographic Composition of Nigerian Coals

Coal	Maceral Analysis					Maceral Composition
Sample	V	E	M	F	MS	
Enugu	58.6	18.1	1.0	16	5.7	Vitrinite: Collinite Exinite: Spores and cuticles Fascinate: 50% F + 50 % SF Pyrite in mineral substance
Okaba	55.5	19.5	1.5	18.5	5.0	Vitrinite: Collinite and telinite Exinite: Spores and cuticles Fusinite: Fusinite and semi-Fusinite, Scleronite
Lafia	47.5	25.0	1.0	7.5	19	Vitrinite: Collinite Exinite: Spores, cuticles, Low-eflectance. Fusinite: Fusinite (60%) and Semi-fusinitie (40%) Pyrite in mineral sub-Stance

(V – Vitrinite, E – Exinite, M – Micrinite, F – Fusinite, MS – Mineral Substance)
Note: The Leitz photometer then used is now broken down and obsolete.
Source: The Development of Steel Industry from Nigerian Raw Materials

Coal Chemical Composition (Coal Grade)

Coals are selected by grade, which takes cognizance of the chemical quality in respect of ash, sulphur, phosphorus, alkali and chloride contents. If any chemical parameter of a particular coal exceeds limits specified at a coke plant, the coal may still be satisfactory for specific use if is possible to formulate a blend with other coals or materials such that the final charge lies with the limits sp ecified. It should be noted that alkalis cause coke breakdown, scabs and other operating problems in the blast furnace. Consequently, the alkali content in a coal charge for coke making is always kept as low as possible. It is restricted to a maximum of 1.95% in the case of Ajaokuta Steel Company Limited (Adigwe, 1983). Also chlorides pass into by –product section and require considerable water to remove from the tar recovered in the By-product plant. Because of its corrosive nature, chlorides also cause maintenance problems in the coal handling and coke oven plant

In April 1993, at Vukhim pilot plant Russia, a number of coals were used to compose coking coal blend for the operation of Ajaokuta Coke Oven Plant. Six coals from Australia, United State of America and Great Britain were subjected to a series of tests after which eight -charge variants were shot listed. In 1993, direct blending test of imported and Enugu coal was carried out on a 250 Kg pilot Oven at NMDC, Jos.

Coal Blend Studies

Lafia and Enugu coals have been co-carbonized and also co-carbonized with a prime coking foreign coal – Ogmore coal from U.K. The effects of coking modifiers such as pitch have also been determined for the carbonization of Lafia and Enugu coals. Ashland A240 petroleum pit ch was used. The resulting coke products were subjected to optical microscopy, micro strength tests and reactivity tests.

As present research conducted by NMDC, Jos, the state of test, research and development of relevant local materials and their preparedness for use in the steel industry was brought to the limelight. Apart from the fact that Lafia / Obi coals would be blended with other imported coals, the Atito Akpuneje coal (Nasarawa state) shows promising characteristics (Ash 14.9, Fixed carbon 53.5) (Bello, 1986)

Improved quality of coke was produced at a pilot scale from blend of Okaba and an imported coal (Agro- allied, supplied by ASP 1993), employing the pre-heating coking improvement technique. The pre- heated blend between Agro-allied coal (medium coking) an 5% Okaba coal almost satisfy ASP‘s M10 (≤9% as against obtained value of 9.5%) and M40 (≥ 78% as against obtained value of 76.2%) requirements despite that Agro- allied low Free Swelling Index (FSI) of only 2.5 Consequently, primer coking coal with an FSI of 6, blended with Okaba coal and an additive of bitumen, would no doubt result in a far more than 5% Okaba blend in the imported coal˙.

The execution of these would bring savings for the country to about $632 million per years as estimated for use in the first phase of Ajaokuta Steel Company Limited. Other basic raw materials that is important to steel making which has drawn the attention of researchers in the metallurgical / metal based industries is clay.

Review of Refractory Clay and Deposits

A research was carried out, where a pilot plant was designed to upgrade the products of a Nigeria industry based in Ukpor / Ozubulu belt (Anambra) and offshore, to determine and find out the requirements of refractory as needed in making iron and steel in terms of plasticity.

Among the clay, vast deposits of identified Kaolinite exist in Oza- Nogogo, Ukwuazu, Okhuo and Iguoriaski (Edo state). Refractory clays have also been reported in abundance In onibode and Oshiele

(Ogun) , Ogbete and Ekulu (Enugu) as well as Giru (Sokoto), Nsu (Imo) and Barkin Ladi (Plateau). High quality bricks clays occurs in many parts of the country including Umuahia (Imo), Abeokuta (Ogun) and Abakaliki (Ebonyi).

A good number of studies were carried out on local clay depo sit in Nigeria, the result oriented showed that they satisfy the chemical and physical requirements for manufacture of refractory brick. Critical parameter with alumina (Al_2O_3) that ranges between 31.24 % and 38.50 % and their refractoriness are from 1660ºC to 1750ºC. However, initial investigation into Oza- Nogogo clay deposit show that it is plastic with Alumina content of 31.08% and a refractoriness of over 1600ºC

A laboratory test was carried on Jakura limestone and the result indicated that it has pure chemical composition of about 55% CaO and low silica value of 0.80%. The Osara dolomite which is about the best so far studied gave a 54 .80% CaO, 42.82 MgO (Calcined) and a refractoriness of 1710ºC. Table 4: shows clay deposit in Nigeria.

Table 4. Data Bank of Some Clay Deposits in Nigeria

S/N	DEPOSIT	CHEMICAL COMPOSITION (%)								PHYSICAL PROPERTIES	
		Al_2O_3	S_iO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	L.O.I	Plasticity Index	Refractoriness
1	GIRU (Kebbi State)	38.50	43.63	0.67	0.02	0.10	0.03	0.04	14.16	0.42	1750
2	KANKARA (Katsina State)	36.40	46.48	1.09	0.79	0.87	0.08	0.10	14.31	3.19	1700
3	NSU (Imo State)	31.24	49.57	1.72	0.61	0.43	0.06	0.09	11.79	6.03	1710
4	KWI (Plateau State)	31.69	37.63	14.48	0.025	0.12	0.06	0.12	12.40	0.68	1660
5	ONIBODE (Ogun State)	35.00	48.00	1.70	0.2	0.3	0.12	0.05	13.1	6.5	1730
6	OZUBULU (Anambra State)	34.10	47.21	1.85	0.61	0.48	0.07	0.12	11.03	5.71	1727

Source: The Development of Steel Industry from Nigerian Raw Materials

The Future of Metallurgical Research and Development

Two distinct patterns are readily identified from the few metallurgical research and development projects enumerated above. Firstly, we notice that the bulk of result –oriented research and development projects are associated with the premier steel industry. It is clearly indicative of an urge, perhaps borne out of necessity, to indigenize what is essentially an imported technology. It is for this reason that some of us have contended that no transfer of technology is possible which side tracks the _Philosophical approach‘. In ensuring that any imported technology process is adequately matched with _indigenizing‘ research, development and raw materials sourcing, in this present time a fundamental pattern, must be adopted which will drive the desired technology and development.

Secondly it must be admitted that most of the local result – oriented metallurgical research have been unduly restricted by infrastructure and definitely funds. Yet it has been demonstrated that a reasonable investment in research investment and development can bring rewarding returns and is in any case mandatory for speedy technological and economic empowerment and development. The often quoted rapid technological growth of Japan since World War II is a case in point. For instance, in 1973, Japan invested an equivalent of N1Billion (by first tier rate of N1= Y180.272) in technological research and development and 200 out of every 10000 Japanese were involved in research work, spending at an average rate of 40 % per annum to sustain what was observed from a far as the Japanese feat.

The point being made here is that Nigeria should plan for accelerated economic empowerment and development program by deliberatively encouraging research and development, since the steel industry is a spring determinant of our economic stability by way of producing the essential industrial raw materials, the funding of Metallurgical Research and Development must receive priority consideration.

From the National Metallurgical Development Centre (NMDC) Jos, Nigerian‘s point o f view and experience, it is very obvious that a lot of result –oriented metallurgical research would be necessary to all metallurgical industries, like the Ajaokuta Steel Company Limited, Delta Steel company Limited and other related industries. This will also assist to indigenize the imported technology as much as possible and therefore improve the chance of these metal-based industries for surviving.

Conclusion

The economic impact of Research and Development (R&D) on local raw materials to develop the steel industry and later for expansion and improvement cannot be over-emphasized. As a security in case of international supply problems in the future, R&D on all types of relevant deposits has to be conducted continuously ahead of production.

Consequently, all the Metallurgical base industries requires adequate funding to provide consumables, replace obsolete equipment and other specialized equipment to facilitate aggressive research. Material Society of Nigerian and other material / Metallurgical Societies should join in this crusade; they should therefore work in conjunction with the steel industries, so that they could jointly proffer solutions to importation problem of raw materials, expatriates skill and technology by substituting them with locally sourced raw materials.

Finally, Today‘s neglect of Research and Development is tomorrow‘s regret of technological breakthrough for Nigeria Government to meet up with the vision 20, 2020 and realize the aims and objectives of the of steel and materials development. We must therefore join hands to develop R&D and show concern to developing the steel and material industries. The only way out of this quagmire is to have effective policy and legislative laws that will enforce the principle and practice ass ociated to Research and Development there by overcoming the effect of materials and steel development at the epileptic status in Nigeria.

Recommendations

Finally, as a way of funding research in Nigeria, it is suggested that metallurgical industries and government should do the followings:

(a)That now declare huge profits by selling scarce and essential commodities at inflated prices, should be made to contribute 15- 20% compulsorily to a Research and Development Fund (RDF).

(b) The Research and Development Fund should be organized along the lines of the Industrial Training Fund (ITF). This would help in the development of raw materials sourcing for the industries to increase their productivities.

(c) Proper utilization of resources by research centres shou ld be enforced by the Government, in order to achieve optimal performance.

(d) The Government should consider establishing Research and Development centres in each Geo – political Zones in Nigeria, where newly graduated Nigerians could be involved in rese arch and developmental works rather than roaming the street in search of employment.

(e) Government should encourage the participation of private investors in building centres and funding research works / programs.

(f) Most of the metallurgical -based industries should make it as a point of duty to develop a research centre in their industries, where research work could be carried out.

(g) The Management of Ajaokuta Steel Company Limited and Delta Steel Company Limited should update and upgrade their equipment and pay more attention in funding their researches for effective and optimal utilization of the centres.

(h) The concept and ideology of an industrialized nation like Nigeria, which has been based on the policy of import substitutions, needs must be reversed. Researches in the steel industry with the use of these locally sourced raw materials should be the major focus.

(i) An industrialized nation should not be structured in such a way that it has to depend on foreign raw materials, imported components, spare parts and expatriate skill for sustained development.

(j) To achieve the desirable object of substituting imported raw materials with locally sourced ones, a lot of funds will be spent on research and development.

(k) The Metallurgical Training Institute in Onitsha should be encouraged to develop a research centre, where findings from these works are documented and use same as aiding teaching tool for students.

(l) A Nation that wants to be self – reliant, self sufficient and strong economically should not build on mass importation of raw materials but rather source for these raw materials locally.

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