CARBONIZATION AND CHARACTERIZATION OF NIGERIAN COAL

BY

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DECLARATION

I, Uwakwe Kelechi Francis hereby declare that this project work is solely my work and has

never to my knowledge been submitted elsewhere.
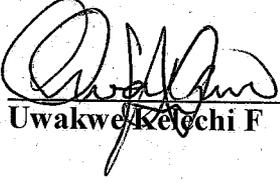
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CERTIFICATION

This is to certify that this project work was originally carried out by Uwakwe Kelechi Francis, Matriculation No. 2001/13878EH of the Department of Chemical Engineering, Federal University of Technology Minna.

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DEDICATION

This project is dedicated to God Almighty for His Protection and provision throughout the course of study.

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To God be the Glory for His guidance and protection throughout what has been a turbulent time. I am grateful to God for the great things He has done.

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ABSTRACT

Owing to the vast availability of coal in Nigeria, the research work – Carbonization of Nigerian coals is aimed at removing the volatile matter content in coal in order to determine the suitability of its products; coke, ash content and volatile matters. The coal samples obtained from three different locations; Lafia-Obi, Okaba and Okpara were heated at $600^{O}C$ in the furnace, until the carbonization process was completed after 5 hours. Proximate analysis method was used in determining the composition of its products. The result of the analysis showed that Lafia-Obi coal (sample C) with high coke content (63.6%) can be considered suitable in most Nigerian Kitchens and in production of metallurgical coke. The coal (sample C) also has low volatile matter content (21.7%) and can be used in installation such as domestic heating system, while Okaba and Okpara coal with low ash contents are suitable for use in combustion where very low ash content is needed. The carbonization carried out on the coal samples showed that Nigerian coals have coking quality in them.

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CHAPTER ONE

1.0. Introduction

The cost involved in purchasing and transporting fossil fuels is becoming increasingly prohibitive and most third world countries are the hardest hit by that reality (Ikoku, 1996).

It is conventional to think of energy resources in terms of two categories; the non-renewable energy resources and the renewable energy resources. Non-renewable energy resources include the fossil fuels- coal, petroleum, natural gas, oil shale, tar sands and nuclear fuels. The renewable energy resources comprises principally hydro-energy, solar energy and fuelwood.

Nigeria is however, lucky to be rich in the fossil fuels and can afford, with proper planning, to integrate its rural areas into its fossil fuel delivery system. Nevertheless, since rural communities requires reliable sources of energy which they can control, decentralized, small scale renewable energy sources, notably solar and bio-energy, are ideal in their setting and should therefore be considered by energy planners in Nigeria (Iwu, 1996).

The most widely used domestic renewable energy resources in Nigeria at the rural areas and even in urban areas by the lower income groups is fuelwood popularly known as firewood. The percentage of fuelwood in the domestic energy consumption is as high as 82%. A survey of 76 developing countries revealed that the amount of wood used domestically as fuel is about eight times the quantity deployed for lumbering and other industrial uses.

The poor ones in the rural areas cannot afford the currently alternative fuels to wood, which thus remains the major fuel with disastrous ecological consequences of desertification in the arid north and erosion in the rain belt of the south both deriving from deforestation. Desert encroachment and erosion also imply that firewood itself will be getting scarce with consequently increase in its price (Ikoku, 1996).

Wood is rather low in calorific value about 13.8MJ/Kg compare to coal which has a heating value of 30MJ/Kg (Okolo etal, 1996). Wood is therefore an inefficient fuel but of course, the rural dweller and those urban citizens who use wood must be provided with alternatives if they are to jettison fuelwood.

Fortunately for Nigeria, fuelwood can be effectively replaced with smokeless coal briquettes which could be readily provided through carbonization of the country's abundant coal reserve. Such fuel is not only of high calorific value, it is also non-polluting. Smokeless coal should also find use as fuel for rural agro-based industries and other cottage manufacturing industries (Ikoku, 1996).

Carbonization of coal is the decomposition by heat without contact with air into a solid residue coke, liquid and gaseous products (Othmer, 1964). When the temperature is in the range 500 – 650°C, it is low temperature carbonization, while high temperature carbonization is in the range 700 – 1170°C (Othmer, 1964)

There are different methods of carbonization of coal to give various types and grade of coke. Coke falls mainly into two types namely metallurgical coke and gas coke. For metallurgical coke, coal is carbonized by blending a strong coking coal with a weak coking one or with non coking coal. This blend of coal gives hard coke under high temperature carbonization with coke oven (Afonja, 1996).

Gas coke is made in oven in a similar way to hard coke but rather different blend of coal and using rather a lower temperature. The product of low temperature carbonization is smokeless solid fuel (Laditan 1996).

Coal which is a general designation for a great number of solid organic minerals with different composition and properties; all rich in carbon and have dark color, generally black, are found in stratified deposits sometimes at great depth (Othmer, 1964).

Coal may be divided into different types and ranks which are function of carbon content. The following clearly distinguished materials resulting from progressive

metamorphism or increase in rank of coal types; PEAT – LIGNITE – SUB-BITUMINOUS – BITUMINOUS – ANTHRACITE – GRAPHITE

The domestic demand for coal are for power generation, cement manufacturing, cooking and for small scale industries (Othmer, 1964).

When coal is carbonized the volatile matter content is removed and what is left is smokeless solid residue which is used domestically as energy source.

1.1. Aim and Objectives

This research work – carbonization of Nigeria coal is aimed at removing the volatile matter content in coal, in order to determining the suitability of the smokeless fuel as a substitute to fuelwood and also, reduce ecological problems of deforestation and desertification resulting from the use of wood as fuel. This can be actualized through the realization of the following objectives;

- Sample collected from three different locations: Lafia-Obi, Okpara and Okaba

- The use of low temperature carbonization process

- Analysis of carbonization products; ash, volatile matter and smokeless solid (Coke) using proximate method of analysis

- Comparison of the coke content in each coal sample collected.

1.2. Scope of Work

The research is limited to carbonization of coal samples obtained from three different locations in Nigeria, analysis of the coke contents after carbonization and also to make comparison on the coke content of each coal in order to make a suitable recommendation.

CHAPTER TWO

2.0.   Literature Review

2.1.   Energy Resources in Nigeria

There are basically two major types of energy resources; the non-renewable energy resources and the renewable energy resources.

2.1.1. Renewable Energy Resources

Fuelwood

Nigeria has a total land area of about 960,000km^2, about 40% of this is classified as forest land, comprising of high forest zone and savannah woodland. Only about 10% of this forest land is set aside as forest reserve.

Fuelwood available from all the forest areas has been roughly estimated at 11 to 17 million cubic meters. The annual consumption of wood in Nigeria is about 50 to 88 million m^3 of which 80% is consumed as fuelwood, mainly by rural households for cooking. Kerosene and liquefied petroleum gas (LPG) are popular domestic fuels with the semi-urban and urban households, but their supply has so far been inadequate and suffers disruption due to poor transport infrastructure and the frequent operational problems in the country's refineries which prevent them from operating at continuous full capacity. In times of scarcity, Therefore, most users of kerosene and LPG switches to fuelwood.

With the continuous usage and unavailability of cheap alternative fuel for domestic use/cooking, fuelwood has resulted in serious ecological problems of acute deforestation and desertification in the Savannah wood land of the north and erosion in the forest zone of the south (Okolo, 1990).

Hydroelectric Potentials

Hydroelectric power is a renewable energy resources among other world energy resources. The total installed capacity of the Power Holding Company of Nigeria (PHCN) is about 5,000MW. However, available data show that the current available plants capacities Which total about 37% fall drastically below installed capacities (Okolo etal, 1996).

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2.1.2.   Non-Renewable Energy Resources

Oil Products

Kerosene, a product of petroleum refining is widely used by a significant proportion of households in the Urban, Semi Urban and rural areas in Nigeria. The total installed capacity of the four refineries in the country is about 2.8 million metric tonnes per year which is not enough to satisfy the current demand by household and the aviation industry (Ngwu, 1988).

Liquefied Petroleum Gas (LPG) is another product of the petroleum refining and it is used by both the middle and upper income groups in Nigeria as well as in industries as fuel. The installed capacity of the four refineries per year is enough to satisfy the current demand. However, LPG has enjoyed limited patronage in the country because of unreliable supply; inadequate distribution network and high cost of LPG appliances (Ngwu, 1988).

Coal

Coal is a combustible solid, usually stratified which originated from the accumulation and burial of partial decomposed vegetation in previous geologic age.

Biological changes and subsequent effects of temperature and pressure altered these deposits of coal. There is a wide range in composition and the physical, chemical properties of different types of coal. Variation in the properties of various plant components courses differences in types and rank of the coal (Othmer, 1964).

2.2.   Discovery of Nigerian Coal

Coal in Nigeria was discovered by early British adventures who were group of geologist and who moved into assessing the economic viability in terms of mineral potentials. It was this group of early adventures who discovered coal in 1909 at the streams along the Udi escarpment. Exploration of coal in Nigeria started as far back as 1916. Available data show that coal (mainly sub-bituminous) is available in more than 22 coalfields spread over 13 states in Nigeria. The proven coal reserves are about 639 million metric tonnes, while the inferred reserves are about 2.7 billion metric tonnes (Ngwu, 1988).

Shortly after the Nigeria Civil War set in, and Climax halt with Enugu as the main theatre of the Nigeria Civil War, a number of other industries set up at the point of considering coal as fuel source found a ready excuse and went for alternative energy sources.

At the end of the war in 1970, the abandoned coal mine in Enugu was re-activated when the military government in 1976 decided to mechanize the mines. The contract went to a polish company KOPEX, but the mechanization was a colossal failure as people still preferred to use oil than coal.

The Federal Government estimated in the seventies that there was an excess of about 1.5 billion metric tonnes and out of which only 25 million metric tonnes has been mined from 1916 to date. The present proven reserve of 639 million metric tonnes will last the next 128 years while the 1.5 billion metric tonnes from inferred calculation will last the next 200 years (Ngwu, 1988).

Location and Extent of Nigerian Coal Field

Sub-bituminous coal was first discovered in 1909 near Udi by the then Mineral Survey of Southern Nigeria.

The five economically important seams of coal (bituminous) which have so far been discovered in Nigeria are located in the south east. They occur at the following locations; Enugu and Ezimo in Udi and Nsukka areas respectively, Otukpa in Okpokwu local government of Benue State and at Okaba in Kogi State. The seams which are all of limited lateral extent, outcrop at interval along Enugu escarpment over a distance of recently 144.81km (90miles) from Enugu to Ogboyoga and belongs to the lower coal measure companion. Many other coal seams have been found along this stretch of the country, but are too thin at the outcrop to merit further investigation (Okolo, 1990).

A large number of coal outcrop is present in the country west of the Enugu escarpment in Kabba province and Abiriba in north eastern Owerri province. These belongs to a higher formation, the uppermost cretaceous to Paleocene – some of these coals are

nearly 6 feets (182.88cm) or 1.82m thick but are usually and extremely variable along the strike, both in thickness and quality or are overlain directly by porous water-bearing sandstones.,

Comparatively thick lignite seams are present in the lignite formation or Miocene age in Benin, Onitsha and Owerri provinces (Okolo, 1990)

Table 2.1.   Coal Reserves in Nigeria

Location	Proven Reserve (x 10^6 tones)
Enugu	54
Ezimo	54
Otukpa	57
Okaba	73
Ogboyoga	103
Azagba	250
Lafia-Obi	22

2.2.1. Coal formation

Coal is formed from partial decomposition of plant material whose composition is subsequently changed as a result of the action of various chemical and physical agencies. These changes occur in two distinct stages – biochemical or geochemical (Othmer 1964).

Environment of deposit: Swamps which occur in regions where there is rapid plant growth in water logged conditions, are the only known environment in which complete decay of plant material is prevented. Peat is formed in such swamps from plant debris, such as branches and twigs, bark, leaves, spores, pollen and even entire tree which falls from the plant into the swamp in which they are grown (Othmer, 1964).

Biochemical Stage

The extent of preservation of plant material is dependent on two factors – the inherent resistivity of the different plant materials/substance to decay and the nature of the

swamp water. The decomposition of the plant material by fungi and bacterial is continuous and complete if it is exposed to the atmosphere or deposited in highly aerated water, but is only partial if the material slowly settles into the stagnant swamp water which is the habitant of aerobic bacterial in aerobic conditions, the plant protoplasm, protein and starches, and to a slightly lesser degree, the cellulose are readily decomposed but lignite is much more resistant. The waxy protective layers of plant – the particles and spore and pollen walls and resign are highly resistant to both aerobic and anaerobic attack (Othmer, 1964).

Geochemical Stage

The metamorphism of plant to coal was due to pressure and a comparatively small increase of temperature acting over long period of time. The heat and pressure were the result mainly of the steadily accumulating over burden of younger sediments and acted over a large area.

Metamorphism of this nature is called normal coalification. It is generally agreed that further increase in temperature and pressure during mounting building processes were necessary for the metamorphism to anthracite (Othmer, 1964).

2.2.2. Types of Coal

Coal may be divided into different types and ranks which are functions of carbon content. Thus coal of similar chemical composition are regarded as percentages of the constituents and grouped together under one rank.

In broad classification, one may say that the older the coal, the higher its rank (quality). Many geologist categorically mentioned that if seam of a single coal field are compared the more deeply buried coals are likely to be of higher rank (Othmer 1964).

Types of coal listed below are in order of increasing rank.

Peat

It is earliest stage of coal formation and act this stage mainly called "primary stage" complete decay of various processes has not taken place to actually qualify it to be coal. It is

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a stage or kind of coaly deposit in which wood is an important constituent. It contains plants tissues somehow embedded at depth.

The accumulation of plant debris may occur in marshy situations apparently under warm and humid conditions. There is a progressively decrease in moisture and an increase in carbon content towards the centre of peat.

Generally, it is a brown fibrous coal mass of partially decayed plant material that has been accumulated instituted under water logged conditions. The agencies causing decay are mainly aerobic bacterial with increasing depth. The peat bogs occurs in many location of coal area in Nigeria (Othmer, 1964).

Lignite

Lignite is a low rank of coal resulting from further transformation of peat and is most commonly found in tertiary mesosonic strata. Lignite is immature coal that has intermediate composition between peat and bituminous coal. Chemically, it has higher oxygen content and high proportion of volatile substance and fixed carbon. They occur in Pakistan and Australia.

Sub-Bituminous

This is generally harder and more matured than lignite and peat. This term is generally used to qualify coal of intermediate chrox between lignite and bituminous coal. They are black in color, when freshly mined has the color like the ordinary bituminous coal (Othmer, 1964).

Bituminous

It is the third stage of variety of coal formed from further chemical and structural transformation of lignite, this include the ordinary household and coking coals. They are generally well jointed (Porter, 1924)

Anthracites

This is the last variety of coal which results from the final stage in the transformation of high variety of bituminous coals. It differs from others in its extremely high carbon

content with a corresponding low proportion of volatile matters accompanied by low percentage of oxygen and hydrogen.

Generally, anthracites have structure bands similar to that of bituminous household coals, the following clearly distinguished materials resulting from progressive metamorphism or increase in rate of coal types: peat – lignite – Sub-bituminous – bituminous – Anthracite – Graphite (Porter, 1924).

2.3. Properties of Coal

The chemical properties of coal depend upon the proportion of chemical component present in the parent plant. It also depends on the nature and extent of the changes in which they have undergone during deposition, the nature and quality of the inorganic matter present in it. Almost only block of bituminous coal can be seen to have a well marked banded stratified structure. The commonest bands are composed of soft bright coal which readily breaks into approximately right angled, pieces with smooth brilliant surfaces.

Many of the bands appears to be quite structure less and appear like thin glass (horizontal bands in coal visible to the naked eye up to 20mm), thick but may be thicker lenticels. It was strong rectangular fracture in one direction, and clean reflection is called "Vitrain" (Horto, 1950).

Other bands appears as thin or very thick bands intrinsically stratified parallel to the bedding plane; most of them has a silky luster and scattered or diffuse reflection of Vitrain under the same illumination. It has no concordat fracture, but splits in irregular directions. Sometimes less friable than Vitrain is called "Clarain".

Many occurring in megascopic band in coal characterized by gray to brownish black color rough surface and finally greasy luster are called "Durain" (Horto, 1950).

Another band of coal material with the appearance and structure of charcoal, friable sooty, and generally high in ash content is 'Fusian'.

All types of coal are intensively opaque, and it is necessary to make thin section ten times as thin as those of ordinary rock before light penetrate them. The variation in

properties depends partly on the proportions in which the types of alteration on the rank of coal.

The first property require of coal for coke making is that the rank and type should lie within close limits i.e. volatile matter (22 – 36%) graying coke type (91 – 96), crucible swelling index 4 – 9. (Horto, 1950).

The four components of banded bituminous coal, Vitrain, Clarain, Durain and Fusian behaves differently on carbonization. Fusian is invariably non-swelling. Durain are usually non-swelling or less swelling than the Vitrain and Clerain. Clerain is usually the highest swelling component of any coal.

Table 2.2. below shows the chemical components of mid-rank bituminous coal.

Table 2.2: Chemical Component of Mid-Rank Bituminous Coal.

ANALYSIS	VITRAIN	CLARAIN	DURAIN	FUSIAN
Proximate				
Moisture	1.7	1.4	1.2	0.9
Volatile	34.6	37.6	32.2	19.1
Ash	0.6	3.5	4.6	9.6
Ultimate				
Carbon	84.4	82.2	85.8	88.7
Sulphur	1.0	2.3	0.9	1.0
Hydrogen	5.4	5.7	5.3	4.0
Nitrogen	1.5	1.9	1.4	0.7
Oxygen	7.7	7.9	6.6	5.6

2.4.   Economic Importance of Nigerian Coal

Within the country, coal is used presently as an energy fuel in cement production, brick factories, foundries, and laundry and bakery industries. Other factories for which it

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forms an important raw material base are in tyre and battery manufacture as well as substitute for fuel wood in domestic cooking (N.C.C 2000)

A survey of coal utilization in the country revealed a great potential in the following industries:

2.4.1. Metallurgical Industries

Nigeria coal is suitable as a component blend with foreign coking coals to produce coke of acceptable strength and character for the country's steel plants. In this regard, up to 200,000 metric tonnes of Nigeria coal will be required annually when Ajeokuta steel plant goes into full production. Okpara and Onyeama coal in Enugu state have been earmarked to provide a source of future coal supply for the steel sector (N.C.C, 2000)

2.4.2. Household Use

Coal and its derivatives, smokeless coal briquettes have been demonstrated as the cheapest, safest and therefore the most suitable substitute to fuel wood, the continued use of which in Nigeria is causing deforestation with the attendant environmental degradation of decertification in the north, soil and coastal erosion in the south. The production of smokeless coal briquettes involves setting up of coal carbonization/briquette plant. In addition, the by-products of carbonization which include gases, ammonical liquor, tar oils and many aromatics will serve as feed-stock to downstream chemical industries in the same manner as the petrochemicals.

2.4.3. Power Generation

Nigeria coal are suitable as energy fuel for electricity generation for the abandoned Oji power station in Enugu state and other proposed power station at Kogi, Benue, Anambra and Delta states. With the current deregulation of power generation in the country, which was facilitated by the lack of sufficient power generating capacity, Nigeria is a fertile ground for the independent Power producers. (Ikoku, 1978).

The potential levels of coal utilization in the country are as follows.

Cement Manufacture: Only the Nigeria cement company (Nigercem) at Nkalagu uses coal for firing its kilns. At their present limited production capacity, consume about 20,000 tonnes per annum for 1 kiln. Other industry like Ashaka Cement Company, Gombe requires about 300,000 tonnes per annum (installed coal capacity utilization), usually uses for prospecting and as an alternative to fuel.

(i)   Oji Power Station (120 – 240MW) using coal from Enugu and Inyi deposit; which will require about 120,000 tonnes per annum.

(ii)   Proposed Onitsha/Asaba Power station in Anambra and Delta states respectively requires about 300,000 tonnes per annum.

(iii)   Proposed Makurdi/Abagina Power Stations in Benue and Kogi states respectively requires about 300,000 tonnes per annum.

(iv)   Numan Power Station (150MW) using coal from Gombe and Lamja

2.4.4. Chemical Industries

Large amount of coal is used for the production of Soda ash, battery casing and cosmetics. Coals are also used in the manufacture of synthetic rubbers, rubber seals, polymers and casing.

2.4.5. Agriculture

Coal is used as a source of ammonia for the production of fertilizer which would largely save foreign exchange through import substitution. (N.C.C 2000).

2.5.   Carbonization

Carbonization refers to the heating of bituminous coal (or mixture of different ranks of bituminous coal) in oven, sealed from the air, to form coke (Othmer 1964). The process involves thermal decomposition of the coal together with distillation. When the temperature to which the coal is heated is in the range $500 – 650^{O}C$, the process is known as low temperature carbonization, if the temperature is in the range of $700 – 850^{O}C$, it is known as medium temperature carbonization, and from $900 – 1175^{O}C$, high temperature carbonization. (Othmer, 1964)

Coke from the high temperature carbonization process, being principally carbon, has a form value that is particularly suitable for use in the iron blast furnace and for other industrial uses.

The use of the coke obtained from high temperature carbonization in the blast furnace to convert iron ore to iron is represented in the chemical equations below

At the bottom; $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

At the Middle; $CO_{2(g)} + C_{(g)} \longrightarrow 2CO_{(g)}$

At the top; $Fe_2O_{3(g)} + 3CO_{(g)} \longrightarrow 2Fe_{(s)} + 3CO_{2(g)}$
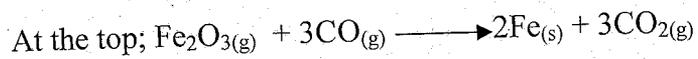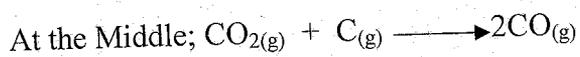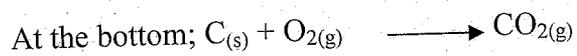
Iron is then converted to steel.

Low Temperature Carbonization

In the low temperature carbonization process coal is heated in the absence of air to temperature in the range $500 - 650^{O}C$. Because of this relatively low temperature and the resulting low rate of heat transfer, this process is not confined to refractory ovens, as in the case for high temperature carbonization, but may also be carried out in metal apparatus such as rotary kilns, fluidized bed, and continuous or intermittent metal retorts. (Othmer, 1964). The coke produced by the low temperature process may be in lump form or it may be in the form of small particles, depending on whether or not the coal used is a coking coal or a non-coking coal. Coke in the form of small particles is generally called Char (Othmer, 1964).

Both coking coal and non-coking coals are used as raw materials for low temperature carbonization. In fact, the low temperature carbonization is most widely applied to the non-coking coals or brown coals. Coking coals soften and become sticky during heating, causing difficulty, especially in the apparatus in which the charge moves. In some of the recently development processes, however, coking coals are first oxidized to destroy their coking properties.

Carbonization Processes

The main processes of carbonization are the low, medium and high temperature processes. Table 2.0 shows a simple classification of the carbonization processes according to the temperature employed.

Table 2.3: Classification of Carbonization Processes

Processes	Final Temperature (^{O}C)	Aim and Benefits
Low temperature Carbonization	500 – 650	Reactive Coke and tar yield
Medium temperature Carbonization	700 – 900	Reactive cake with gas yield
High temperature Carbonization	900 – 1175	Hard, un-reactive coke for metallurgical uses

Source :(Okolo etal, 1990)

2.5.1 Mechanism of Carbonization

The formation of coke depends upon the softening of bituminous coals when they are heated in the absence of air and the fusing together of the particles. Softening first occurs between 300 and 440°C depending upon the type of coal; the softened coal becomes more and more fluid as the temperature rises, reaching a maximum fluidity after which it decreases, and the mass finally becomes rigid at about 500°C. (Othmer, 1964) At or near the temperature of softening, the coal decomposes, forming tar vapors and gaseous products; a porous solid residue, coke, is left behind. Further increase in temperature causes continued decomposition and finally, when the temperature reaches about 1000°C, decomposition is substantially completed (Othmer, 1964).

2.5.2. Coal Composition

The composition of coal is generally reported in two different ways. The PROXIMATE and ULTIMATE ANALYSIS both expressed in weight percent (Perry etal, 1998).

Proximate Analysis

The proximate analysis is the determination of moisture, volatile matter, fixed carbon (coke) and ash. The fixed carbon and heating values increase with an increase in rank but the moisture and volatile matter decreases.

The total moisture in coal consists of inherent moisture and bed moisture. Inherent moisture exists as a quality of a coal seam in its natural state of deposition. Free moisture also referred to as surface moisture that is lost when coal is air dried under standard conditions.

The volatile matter is the portion of the coal which, when heated in the absence of air under prescribed conditions, is liberated as gases and vapors. Volatile matter does not exist by itself in coal, except for a little absorbed methane, but results from thermal decomposition of the coal substance.

Fixed carbon is the residue left after the volatile matter is driven off and is calculated by subtracting from 100 the percentage of moisture, volatile matter and ash of the proximate analysis.

Ash is the inorganic residue that remains after the coal has been burned under specified conditions, and it is composed largely of compounds of silicon, aluminum, iron and calcium and of minimum amounts of compounds of magnesium, sodium and potassium (Perry etal, 1998).

Ultimate Analysis

The ultimate analysis is the determination of ash, carbon, hydrogen, nitrogen, oxygen and sulphur. Along with this analysis, the heating value expressed as joules per kilogram is also determined (Perry etal, 1998).

CHAPTER THREE

3.0. Methodology

3.1. Equipment and Material Used

In this research work the equipments and materials used are

3.1.1. List of Equipments

- Laboratory Muffle Furnace
- Crucibles
- Digital Weighing Balance

Description of Equipment

The laboratory muffle furnace is a rectangular metal oven with a digital thermo controller. It is designed to hold about half a kilogram of charge per batch. The carbonization chamber is an adapted muffle furnace fitted with a pulling handle to either slide down the cover or pushes it to close. The temperature and residence time of carbonization are effectively monitored via the digital thermo controller and a stop watch. The temperature range of the muffle furnace is between $0 - 1100^{O}C$

3.1.2. List of Materials

- 100g of Okpara coal
- 100g of Okaba Coal
- 100g of Lafia-Obi Coal

3.2. Experimental Procedure

100g of each coal samples were weighed, placed on crucibles labeled A, B and C. The weight of each sample was taken and recorded.

The three samples were placed in the muffle furnace, shortly after; the furnace was switched on and allowed to heat the samples to about $600^{O}C$ for 5 hours.

After the heating of the samples at $600^{O}C$ for 5 hours, there was no smoke of any kind present in the furnace, an indication that the coal samples had been carbonized. After

which, the furnace was switched off and the three coal samples were allowed to cool in the furnace before been removed.

The crucibles together with their contents were weighed immediately in order to determine their respective loss in weight. Then, the resulting products on the crucibles were separated and weighed respectively.

CHAPTER FOUR

4.0. Result and Discussion of Result

4.1. Results

Table 4.1. Samples Weight before Carbonization

Sample	Sample Name	Weight of Sample (g)	Weight of Crucible (g)	Weight of sample + crucible (g)
A	OKPARA	100	31.00	131.00
B	OKABA	100	31.00	131.00
C	LAFIA-OBI	100	32.5	132.50

Table 4.2: Samples weight after carbonization

Sample	Sample Name	Sample Product + Crucible (g)	Sample Products Only (g)	Volatile Matter Content (g)	Ash Content (g)	Coke (g)
A	OKPARA	95.74	64.74	35.26	8.20	56.54
B	OKABA	89.70	58.70	41.30	7.22	51.48
C	LAFIA OBI	110.80	78.30	21.70	14.70	63.60

Table 4.3. Samples Percentage Composition

Sample	Sample Name	Volatile %	Ash Content (%)	Coke (%)
A	Okpara	35.3	8.2	56.5
B	Okaba	41.3	7.2	51.5
C	Lafia-Obi	21.7	14.7	63.6

4.2.   Discussion of Result

From the results of the proximate analysis obtained as shown in table 4.2. it was observed that Lafia-Obi coal has the highest parentage of coke (63.6%) followed by Okpara Coal with 56.5% and then Okaba coal with the least percentage of coke (51.5%).

The high coke observed in Lafia-Obi coal could be as a result of Lafia-Obi coal been higher in coal ranking (Lignite coal) compared to Okpara and Okaba which are both bituminous coal types.

Table 4.3. clearly shows that the ash content obtained (a part of residual product obtained after carbonization) from sample C (Lafia-Obi coal) was observed to have the highest percentage of ash content (14.7%), followed by sample A (Okpara Coal) with 8.2% of ash content and the least percentage was that of sample B (Okaba Coal) with 7.2% of ash content.

On the same table 4.3, it was observed clearly that sample B (Okaba Coal) gives off the highest percentage of volatile matters about (41.3%) as a result of loss in weight observed, followed by sample A (Okpara coal) with 35.3% of volatile matters and sample C (Lafia-Obi Coal) gives off the least volatile matters of 21.7% during carbonization. The high volatile matters content observed in sample B could be attributed to high moisture content in coal sample B when compared to moisture content in samples A and C respectively.

CHAPTER FIVE

5.0. Conclusion and Recommendation

5.1. Conclusion

From the proximate analysis it was obvious that the carbonization of Lafia-Obi coal gives off high yield of coke which makes it suitable in most Nigerian Kitchens and as a component in coking blend for the production of metallurgical coke. Therefore, it is most preferred.

Low volatile matter burns with short flame which is used in installation such as domestic heating system, as such Lafia-Obi coal will be considered suitable for this due to its low volatile matter content (21.7%), while in Kilns, long flame is needed which could be obtained from a high volatile matter so, Okaba coal is suitable for this, also high volatile content from Okaba coal could be used to produce raw materials or intermediates required in other chemical industries.

In combustion where a very low ash content is needed, the Okaba and Okpara coals can be recommended suitable for use, hence the coals have low ash content values. Okaba (7.2%) and Okapra (8.2%). When high ash content is used, the heat obtainable from a given quality of coal is reduced.

5.2. Recommendation

The carbonization carried out on Lafia-Obi, Okpara and Okaba coal samples shows that Nigerian coals have coking quality in them, and therefore the following recommendations are made.

During carbonization, the furnace should be covered very well to exclude oxygen completely which could lead to combustion of the coal sample.

A more research work should also be carried out to determine the effect of temperature, time and weight on carbonization processes.

More emphasis should be made on setting up coal carbonization plant near the mines to produce the much needed smokeless solid residue for domestic use, by removing the smoky properties so that it will be suitable for use, thereby, saving us from exhausting our other energy resources.

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APPENDIX

The weight and percentage composition of each coal sample is calculated as follows:

Basic: 100g of coal sample

Weight of Coal Samples

Sample A (Okpara Coal) = 100.00g

Sample B (Okaba Coal) = 100.00g

Sample C (Lafia-Obi Coal) = 100.00g

Weight of Crucibles

Crucible A = 31.00g

Crucible B = 31.00g

Crucible C = 32.50g

Volatile matters (g) + Ash content (g) + Coke (g) = 100.00g Coal

Samples Weight before Carbonization

Sample A + Crucible = (100.00 + 31.00)g = 131.00g

Sample B + Crucible = (100.00 + 31.00)g = 131.00g

Sample C + Crucible = (100.00 + 32.50) = 132.50g

Samples Weight after Carbonization

Sample A + Crucible = 95.74g

Sample B + Crucible = 89.70g

Sample C + Crucible = 110.80g

Weight of Products of Carbonization (g)

= Weight after carbonization (g) – Weight of Crucible (g)

Sample A = (95.74 – 31)g = 64.74(g)

Sample B = (89.70 – 31)g = 58.70g

Sample C = (110.80 – 32.5)g = 78.30g

Volatile matter (g) = Weight before carbonization (g) – Weight after carbonization (g)

Sample A = (131.00 – 95.74)g = 35.26g

Sample B = (131.00 – 89.70)g = 41.30g

Sample C = (132.50 – 110.8)g = 21.70g

Ash Content (g) = Weight of products of carbonization (g) – Coke (g)

Sample A = (64.74 – 56.54) g =- 8.20g

Sample B = (58.7 – 51.48)g = 7.22g

Sample C = (78.3 – 63.6)g = 14.70g

Coke Content (g) = 100g coal – (Ash Content + volatile matter)g

Sample A = 100g – (35.26 + 8.20)g = 56.54g

Sample B = 100g – (41.30 + 7.22)g = 51.48g

Sample C = 100g – (21.70 + 14.70)g = 63.60g

Sample Percentage Composition (%)

$$= \frac{\text{Weight of Composition (g)}}{\text{Total weight of coal samples (G)}} \times 100$$

Volatile Matter

Sample A = $\frac{35.26}{100} \times \frac{100}{1}$ = 35.26%

Sample B = $\frac{41.30}{100} \times \frac{100}{1}$ = 41.30%

Sample C = $\frac{21.70}{100} \times \frac{100}{1}$ = 21.70%

Ash Content

Sample A = $\frac{8.20}{100} \times \frac{100}{1}$ = 8.20%

Sample B = $\frac{7.22}{100} \times \frac{100}{1}$ = 7.22%

Sample C = $\frac{14.70}{100} \times \frac{100}{1}$ = 14.70%

Coke Content

Sample A = $\frac{56.54}{100} \times \frac{100}{1}$ = 56.50%

Sample B $\quad = \quad \dfrac{51.48}{100} \times \dfrac{100}{1} = \quad$ 51.50%

Sample C $\quad = \quad \dfrac{63.60}{100} \times \dfrac{100}{1} = \quad$ 63.60%