Original Research Article

CONVERTING NIGERIAN COAL DEPOSITS TO SMOKELESS COAL FUEL FOR ENERGY TRANSITION AND SOCIO-ECONOMIC TRANSFORMATION

ABSTRACT

The energy transition is a pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of the present century. Attention is therefore shifting from coal and crude oil to renewable and alternative energies. Although the use of coal for electrical power generation has been on the decline and it is being discouraged world-wide, the Smokeless Coal Research Team at IBB University has been able to differentiate "good" from "bad" coals. Not all coals are environmentally harmful for electrical power generation. And even for the so-called "bad coals the team at the IBBU has identified processes to clean up such coals. Whether generated from dams, gas turbines or thermal sources, Nigeria has been a nation with an acute supply of electricity; yet the country has far more resources of oil, gas and coals than it has the demand for them. The country is currently challenged by series of energy crises with concomitant economic and social implications. Electricity generation and energy availability are in gross shortfall which has resulted in the shutting down of many industries with the attendant job losses and escalating unemployment. Power supply to many homes is very epileptic, covering not more than 10% of the total average domestic daily demand. With these enormous energy challenges, the government of Nigeria is working on reforms at several fronts that will embrace appropriate energy-mix, enabling power generation / energy production from nuclear, coal and renewable sources (solar, wind, biomass) in addition to the conventional hydro and thermal sources. With the use of 30% diluted benzoic and formic acids on some Nigerian coals, smoke emission reduced considerably, thus allowing the use of abundant Nigerian coal deposits as alternative clean energy source for electrical power generation in a physically sustainable environment in an era of energy transition. Furthermore, some coals (in Nigeria and elsewhere) do not need processing (cleansing) based on the inherent chemical and petrological composition as elucidated in this paper. Power (electrical) is the single major factor to social and economic transformation in Nigeria.

Keywords: Coal conversion, Power supply, Defusinization, Industrialization, Job creation

1.0 INTRODUCTION

Whether generated from dams, gas turbines or thermal sources, Nigeria has been a nation with an acute supply of electricity; yet the country has far more resources of oil, gas and coals than it has the demand for them. The country is currently challenged by series of energy crises with concomitant economic and social implications. Electricity generation and energy availability are in gross shortfall which has resulted in the shutting down of many industries with the attendant job losses and escalating unemployment. Power supply to many homes is very epileptic, covering not more than 10% of the total average domestic daily demand. Twenty three (23) out of 26 present power generating stations in Nigeria are gas-dependent. With these enormous energy challenges, the government of Nigeria is working on a reform that will embrace appropriate energy-mix, enabling power generation / energy production from nuclear, coal and renewable sources (solar, wind, biomass) in addition to the conventional hydro and thermal sources. Nigeria is blessed with abundant coal resources deposited widely in 15 states of the federation. Experimental defusinization is a new technique proposed in this investigation as a means for enhancing the performance of coal and thus the production of a new brand of smokeless fuel. Domestic cooking in Nigeria is done through the use of electric-power, kerosene and gas cookers and the use of firewood derived through heavy deforestation. Electric power is in short supply; kerosene emits lots of greenhouse gases while the use of firewood leads to deforestation. In order to curb the alarming rate of deforestation in Nigeria which stands at 400 hectares per annum resulting in erosion and negative climate change effects and in order to contribute to the Nigerian energy mix and energy supply and availability, this research has been conducted to determine the suitability of some Nigerian coal deposits as raw materials for electrical power generation and production of smokeless coal fuels for domestic energy and industrial heating as a substitute to firewood and an augmentation of other energy sources. The study has generated data that will promote the use of Nigerian coal deposits for environmentally friendly electrical power generation and in the production of smokeless coal fuels, thereby further promoting varied energy-mix economy and mitigating deforestation, negative climate change impacts and biodiversity loss.

2.0 SOME REVIEWS

2.1 Nigerian Coal Resources

Coal is found in about 15 federating states of Nigeria, namely, Enugu, Imo, Kogi, Delta, Plateau, Anambra, Abia, Benue, Edo, Bauchi, Adamawa, Gombe, Cross River, Ebonyi and possibly Niger (at Kudu, although not yet properly documented). Geologically, these coal deposits are mainly within the Anambra Basin and the Benue Trough (Fig. 1) outside some minor deposits reported within the Bida and Sokoto Basins (Shekwolo, 2009; Obaje, 2009). Some aspects of these coal deposits have been succinctly discussed by De-Swardtand Cassey (1961), Akande et al. (1992) and Wuyep and Obaje (2010). Coal was first discovered in 1909 near Udi (Eastern Nigeria). In 1950, the Nigerian Coal Corporation (NCC) was formed and given the responsibility for exploration, development and mining the coal resources. The NCC is 100% owned by the Federal Government and is headquartered in Enugu. NCC operated two underground mines, Okpara and Onyeama, and two surface mines, Owukpa and Okaba, located on the eastern edge of the Anambra Coal Basin. Between 1950 and 1959, coal production in the Enugu mines increased annually from 583,487 tonnes to a peak of 905,397 tonnes. After 1959, production decreased significantly each year including the Civil War period of 1966 to 1970 when no coal production was reported. Production in the 1980s was less than 100,000 tonnes annually and decreased further in the 1990s. Much of this production was utilized by the railroad and some smaller tonnages were exported. NCC has not operated any coal mines for several years. The Agency has recently entered into several joint ventures with outside entities to mine coal, but those efforts have met with limited success. Nigeria's only significant coal mine is the Okaba mine (Okaba coal field), which is operated under a production sharing agreement with Nordic Industries Limited. Production of 2,712 tonnes was recorded in 2001.

2.2 Petro-Geochemistry of Coals

Coal is not a homogeneous substance but consists of various basic components comparable with minerals of inorganic rocks. These components which are called macerals are the basic and relatively homogeneous organo-petrographic entities of coal which by their chemical and physical characteristics determine its properties and utilization (Diessel, 1992). In coals, they are normally classified into three groups, namely vitrinite, liptinite and inertinite (Table 1, Fig. 2). This classification is based either on similar origin (e.g. the liptinite group) and / or on the difference in preservation (e.g. the vitrinite and inertinite groups). Chemical and physical properties of the macerals such as elemental composition, moisture contents, hardness, density and petrographic characteristics differ widely and are also subject to changes in the course of diagenesis and coalification (Bustin et al., 1985; Stach et al., 1982).

Besides the parental material and initial decomposition before and during the peat stage, the degree of coalification (rank) is decisive for microscopic appearance of the macerals. Morphology and reflectance under incident light are the main properties in distinguishing macerals and macerals groups under the microscope (Teichmueller, 1989). In low rank coals, relatively hydrogen–rich liptinite show the lowest reflectance, the relatively oxygen–rich vitrinite a medium reflectance, while the relatively carbon–rich inertinite the highest reflectance. Amongst the inertinites, fusinite presents a special problem. High content of inertinite, represented mainly by fusinite and semi-fusinite, reduces the combustibility and smokeless fuel production capability of coals (Schapiro and Gray, 1964; Bustin et al., 1985). Inertinites (fusinite + semi-fusinite) along with the ash content (mineral matter) must greatly be reduced or removed completely to increase the quality of the coals for smokeless fuel production.

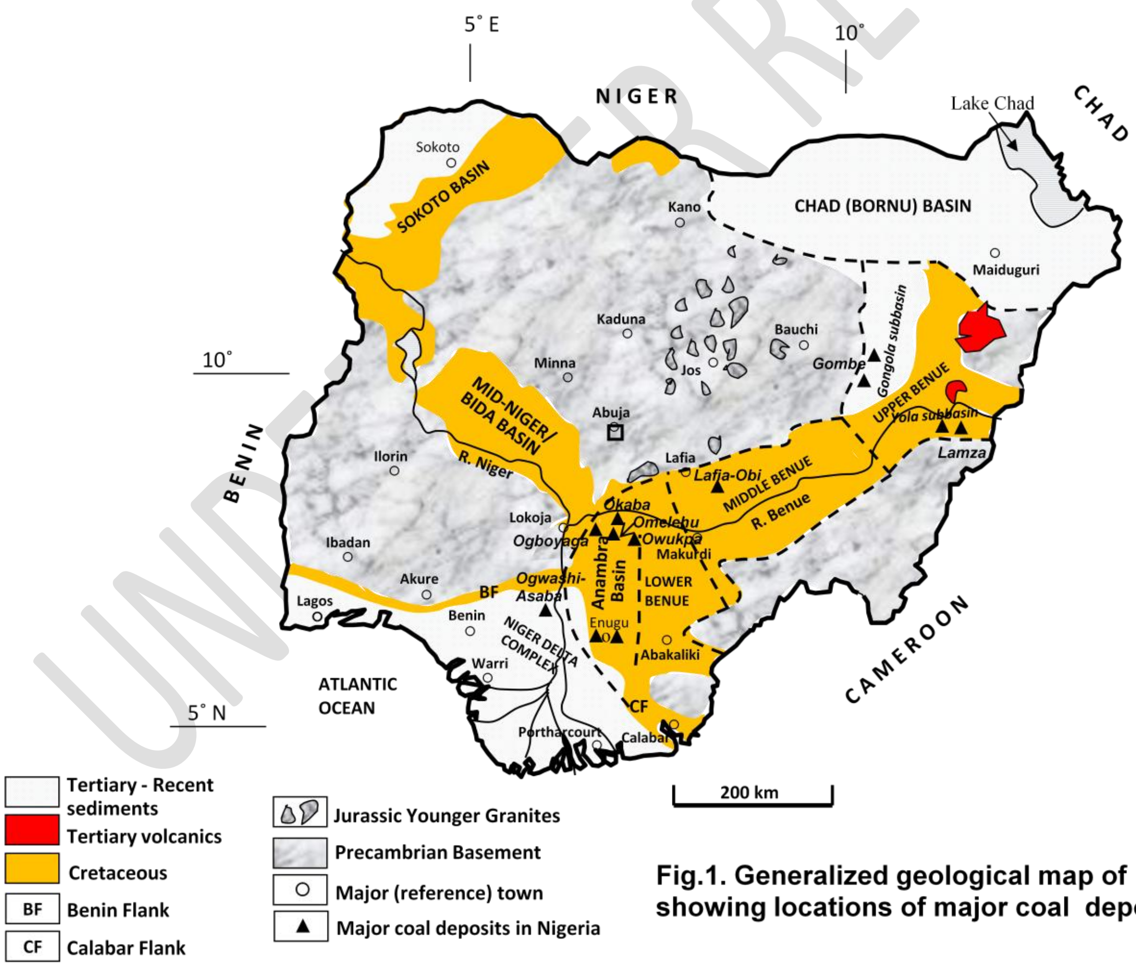

Fig.1. Generalized geological map of Nigeria showing locations of major coal deposits

Maceral Group	Maceral / Submaceral	Source / Origin	Reactivity During Smokeless Fuel Production
Vitrinite	Telinite Collinite - Telocollinite - Desmocollinite - Gellocollinite - Corpocollinite Vitrodetrinite	Woody tissues, bark, leaves, etc	Reactive; promotes smokeless fuel production
Liptinite	Sporinite Cutinite Resinite Flourinite Alginite Liptodetrinite Bituminite Exudatinite	Spores, pollen Cuticules Resins, waxes. Plant oils. Algae Detritus Degradation products of organic matter Secondary products, exudates	Highly reactive when content equals or more than 30%; Essential to smokeless fuel production
Inertinite	Fusinite Semifusinite Macrinite Micrinite Sclerotinite Inertodetrinite	Woody tissues, barks, leaves Degradation product of liptinite Fungal sclerotia, hyphae Detritus	Inert; Demotes smokeless fuel production; Content must be greatly reduced through defusinization processes

Table 1: Coal macerals: Origin, properties and reactivity during smokeless fuel production (After Stach et al., 1982; Bustin et al., 1985; Teichmueller, 1989)

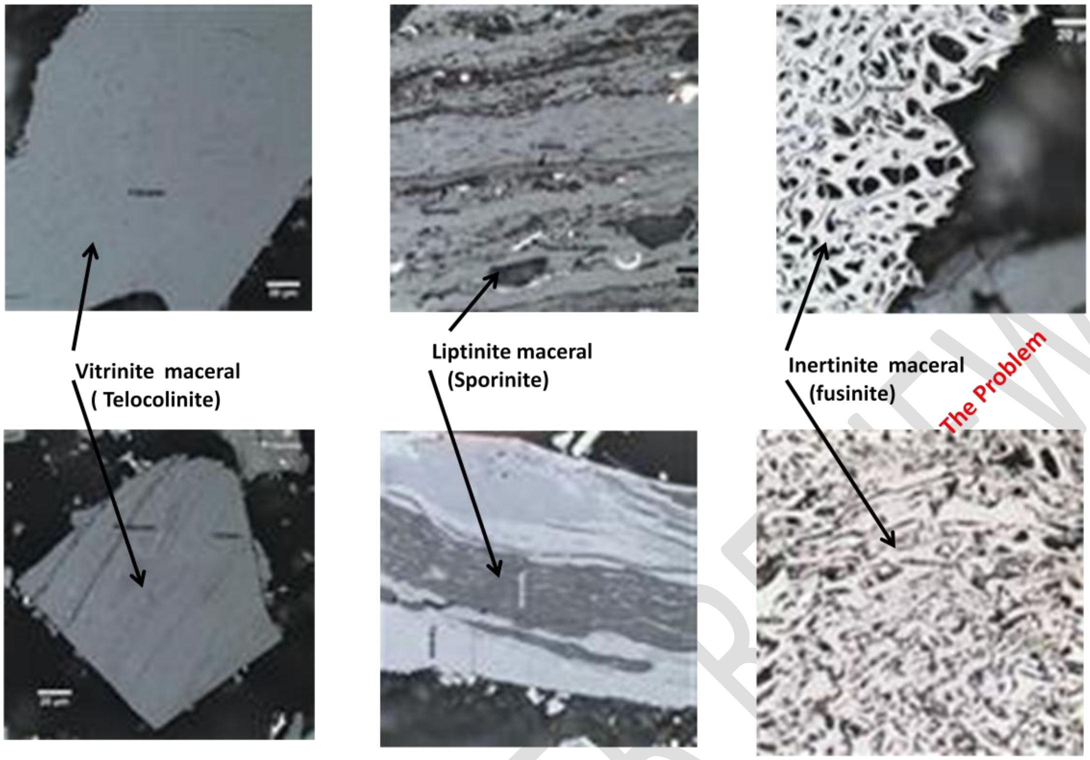

Fig. 2. Photomicrographs of the three maceral groups in coal

2.3 Defusinization

Defusinization is a new concept proposed by researchers at IBBU after some reviews of literature on coal utilization. The concept is based on the very early studies on coal carbonization by Schapiro and Gray (1964) and Davis et al. (1976). The studies discovered that during the carbonization process, coal softens, fuses and resolidifies to form the porous carbon-rich material that is called coke. The capability of a coal to behave in this manner is very essential, and only the bituminous part of the coal series has such a capability, reaffirmed by Bustin et al. (1985). In several previous studies by Obaje et al. (1994), Obaje (1997), Obaje et al. (1999a,b), Jauro et al. (2006), it was discovered that inertinite macerals (fusinites) constitute great obstacle to the performance of coal during carbonization, combustion and liquefaction and would not act differently in its capability for the production of smokeless fuel. In relation to bulk organic geochemistry, the TOC of the coal sample is the <u>burnable organic matter</u> content, the HI is the inherent <u>fuel</u>, the OI depicts the <u>smokability</u>, green house gases content and the amount of retardants. The Tmax is a measure of the coal <u>maturity and rank</u> (see Table 2).

Peak	Usual Interpretation for Hydrocarbons	Measured Indices	For Smokeless Coal
S_1 mg HC/g rock	The free hydrocarbons present in the sample before the analysis. Can be thought of as a residual hydrocarbon phase. When S1 is large relative to S2, an alternative source such as migrated hydrocarbons or contamination should be suspected	Free Hydrocarbon Index: FHC (mgHC/gTOC): = 100xS1/TOC	Not much meaning
S_2 mg HC/g rock	The volume of hydrocarbons that formed during thermal pyrolysis of the sample. Used to estimate the remaining hydrocarbon generating potential of the sample	Hydrogen Index: HI(mgHC/gTOC) = 100xS2/TOC. HI is a parameter used to characterize the origin of organic matter. Marine organisms and algae, in general, are composed of lipid- and protein-rich organic matter, where the ratio of H to C is higher than in the carbohydrate-rich constituents of land plants	Measure of the pyrolyzable organic matter (usually the **FUEL**) in the coal
S_3 mg CO_2/g rock	The CO_2 yield during thermal breakdown of kerogen.	Oxygen Index: OI(mgCO2/gTOC) = 100xS3/TOC. OI correlates with the ratio of O to C, which is high for polysacharride-rich remains of land plants and inert organic material (residual organic matter) encountered as background in marine sediments	Measure of the **smoke elements, green-house gases contents and combustion retardants** in coal
Tmax	Tmax = the temperature at which the maximum release of hydrocarbons from cracking of kerogen occurs during pyrolysis (top of S_2 peak).	Tmax is an indication of the stage of maturation of the organic matter.	Measure of the **coal rank**. Coal rank increases with higher values of Tmax

Table 2: Pyrolysis indices extrapolated from hydrocarbon source evaluation to smokeless coal fuel production assessment (Modified from Hunt, 1991)

3.0 METHODS OF STUDY

Field mapping and sampling in Kudu (Niger State), Okaba, Omelehu, Ogboyaga (Kogi State), Owukpa (Benue State) and Lafia-Obi (Nasarawa State).

Combustibility assessments to determine the combustion efficiencies of the respective coal deposits by burning the same amount of coal and determining the time it takes to bring the same volume of water to boiling point; as well as the combustion pathways though recording of temperature achieved after every 2 minutes of continuous burning.

Bulk organic geochemical evaluation comprising Leco Carbon-Sulfur analysis and Rock-Eval pyrolysis to determine the values of TOC, HI, OI, Tmax as a basis for determining the burnable organic matter, the inherent fuel, the level of retardants and smoke and the maturity/rank of the coals respectively.

Petrological evaluation of the coals through embedding, polishing and maceral analysis of the polished samples to evaluate the relative proportions of individual maceral groups namely, vitrinite, liptinite and inertinite.

Experimental defusinization studies (removal of fusinite and semi-fusinite) through digestion of the coal samples in series of organic acids. Eight organic acids were used; re-measurements after the defusinization will indicate the best organic acids and organic solvents most appropriate for fusinite digestion and removal. The organic used comprised **Benzoic acid** (carboxybenzene or phenylmethanoic acid) C_6H_5COOH; **Butyric acid** (butanoic acid) $CH_3CH_2CH_2COOH$; **Carbolic acid** (phenol or hydroxybenzene) C_6H_5OH; **Carbonic acid** (hydroxymethanoic acid) OHCOOH or H_2CO_3; **Citric acid** (2-hydroxypropane-1,2,3-tricarboxylic acid); **Formic acid** (methanoic acid) HCOOH; **Lactic acid** (2-hydroxypropanoic acid) $CH_3CHOHCOOH$; **Malic acid** (2-hydroxybutanedioic acid); $(COOH)CH_2CHOH(COOH)$; **Oxalic acid** (ethanedioic acid) (COOH)(COOH); **Uric acid** (7,9-Dihydro-1H-purine-2,6,8(3H)-trione) $C_5H_4N_4O_3$.

Pelletization of the defusinized coals (already ground to fine aggregates or to "coal marsh") at the Pilot Production stage using the Coal Miller/Mixer machine to convert the coal marsh into uniformed sized smokeless coal fuels (1cm and 5cm diameters) that can be fed into industrial furnaces and/or domestic smokeless fuel cooking stoves. Epoxy-resin with some hardner and sub-ordinate bentonite will be used as the binder.

4.0 RESULTS

4.1 Field Mapping and Sample Collection / Core Driiling

Field mapping and surveys have been carried out on the coal fields at Okaba, Omelehu, Owukpa, Lafia-Obi and Kudu-Makera and coal deposits encountered are shown in next following figures with explanatory captions. Drilling for subsurface sample collections were undertaken at Okaba and Owukpa.

Fig. 3. Logging and sample collection at the Okaba coal field. Note the heavy acid mine waters within the mines

Fig. 3b. Logging and sample collection at the Okaba coal field (underground) (2nd visit)

Fig. 4. Direct sample collection of coal in-situ at the Omelehu coal field

Fig. 5. Logging and sampling at the Owukpa coal field

Fig. 6. Logging and sampling (in different views) at the Lafia-Obi coal outcrop site at Shankodi near Jangwa, Nasarawa State

Fig. 7. In the absence of any coal exposure in Niger State, the team relied on the shaley coal samples collected during the earlier study on Bida Basin hydrocarbons. These shaley coals are more suitable for oil and gas generation than for the production of smokeless fuel

4.2 Combustibility Studies

Combustibility studies were carried on coal deposits from Okaba, Omelehu, Owukpa and Lafia-Obi (Fig. 8). The combustibility studies comprised combustion efficiency based on the time it took same weight of coal from each of the deposits to bring same volume of water to boiling point and combustion pathway based on temperature for every 2 minutes of continuous boiling with same volume of water. The results are shown in the next following tables figures and tables.

Fig. 8. Combustibility studies for the determination of the coal energy efficiencies and coal combustion pathways by measuring the time it takes same quantity of each of the coal deposits to bring same volume of water to boiling point as well as the temperature achieved at every 2 minutes using local cooking stove

Coal Deposit	**Time to Boiling (Minutes)**
Okaba	10.00
Omelehu	11.37
Owukpa-1	13.22
Owukpa-2	25.02
Lafia-Obi	Did not bring to boiling
Ogboyaga	Not used
Kudu-Makera	Too shaley. Suitable for oil/gas generation ony

Table 3: Time to bring water to boiling using same quantity of coal and same volume of water on a local cooking stove (combustion efficiency).

Coal Deposit						
	2	4	6	8	10	**Time (mins)**
Okaba	50	62	77	88	95	**Temperature (^{o}C)**
Omelehu	28	62	74	86	93	
Owukpa-1	46	50	68	78	87	
Lafia-Obi	27	28	28	27	27	
Ogboyaga	Not used					
Kudu-Makera	Too shaley. Suitable for shale gas					

Table 4. Progressive boiling of same volume of water on same quantity of coal using local cooking stove for the evaluation of the combustion pathways for the coals

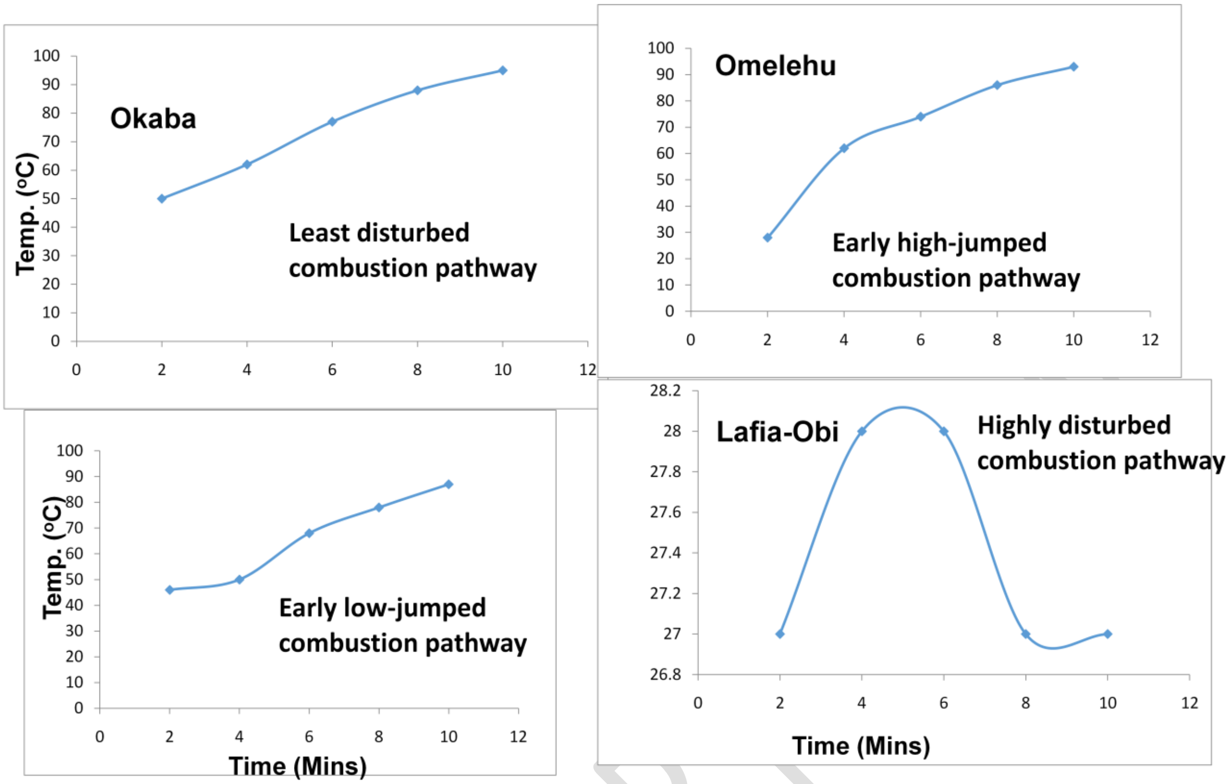

Fig. 9. Results of combustion pathway studies on four of the coal deposits showing the Okaba coals as having the best predictable (least disturbed) combustion pathway and the Lafia-Obi as the most unsuitable for combustion.

4.3 Bulk Organic Geochemistry

Leco CS and Rock-Eval pyrolysis analyses were carried out on five coal samples from each of the studied coal deposits as a basis for the determination of the TOC (burnable carbon), HI (inherent fuel, OI (smokes and retardants) and Tmax (coal maturity and rank). The results are shown in the table and figure below.

Sample ID	Coal Deposit	S2 mg/g	S3 mg/g	Tmax °C	TOC	S	HI	OI
LBI-001	Lafia-Obi	20.72	11.36	451	36.075	0.54	57.4	31.49
LBI-002	Lafia-Obi	19.54	10.85	451	36.05	0.493	54.2	30.10
LBI-003	Lafia-Obi	19.76	11.04	452	36.2	0.508	54.6	30.50
LBI-004	Lafia-Obi	20.56	10.71	451	34.9	0.498	58.9	30.69
LBI-005	Lafia-Obi	20.16	10.99	450	36.3	0.543	55.5	30.28
OGB-001	Ogboyaga	150.06	23.8	425	63.4	0.62	236.7	37.54
OGB-002	Ogboyaga	133.89	25.65	423	62.1	0.713	215.6	41.30
OGB-003	Ogboyaga	153.36	24.12	424	63.7	0.638	240.8	37.86
OGB-004	Ogboyaga	154.59	24.05	424	64	0.663	241.5	37.58
OGB-005	Ogboyaga	153.44	24.28	424	63.8	0.636	240.5	38.06
OKB-001	Okaba	170.92	12.14	421	62.9	1.28	271.7	19.30

OKB-002	Okaba	174.84	12.11	420	62.8	1.08	278.4	19.28
OKB-003	Okaba	178.08	12.05	423	62.9	1.18	283.1	19.16
OKB-004	Okaba	177.36	12.14	419	63.1	1.08	281.1	19.24
OKB-005	Okaba	174.95	12.22	419	63.2	1.1	276.8	19.34
OML-001	Omelehu	92.73	13.47	421	45	0.639	206.1	29.93
OML-002	Omelehu	123.78	14.11	420	52.5	0.794	235.8	26.88
OML-003	Omelehu	111.62	13.49	423	48.9	0.753	228.3	27.59
OML-004	Omelehu	103.76	13.71	423	46.6	0.713	222.7	29.42
OML-005	Omelehu	112.42	13.63	422	48.7	0.736	230.8	27.99
OWU-001	Owukpa	93.23	8.03	426	39.55	0.374	235.7	20.30
OWU-002	Owukpa	92.12	8.13	427	38.85	0.363	237.1	20.93
OWU-003	Owukpa	90.01	7.77	427	39.1	0.378	230.2	19.87
OWU-004	Owukpa	91.32	8.14	427	39	0.348	234.2	20.87
OWU-005	Owukpa	89.76	8.01	428	38.4	0.357	233.8	20.86

Table 5. Rock-Eval pyrolysis raw data (courtesy Federal Institute for Geosciences and Natural Resources – BGR, Hannover, Germany)

Tmax = Temperature of S2 pyrolysis → Maturity / Rank of Coal; TOC = Total Organic Carbon (Burnable Organic Matter); HI = Hydrogen Index (Inherent Fuel), OI = Oxygen Index (Smoke, Retardants); S = Sulfur Content

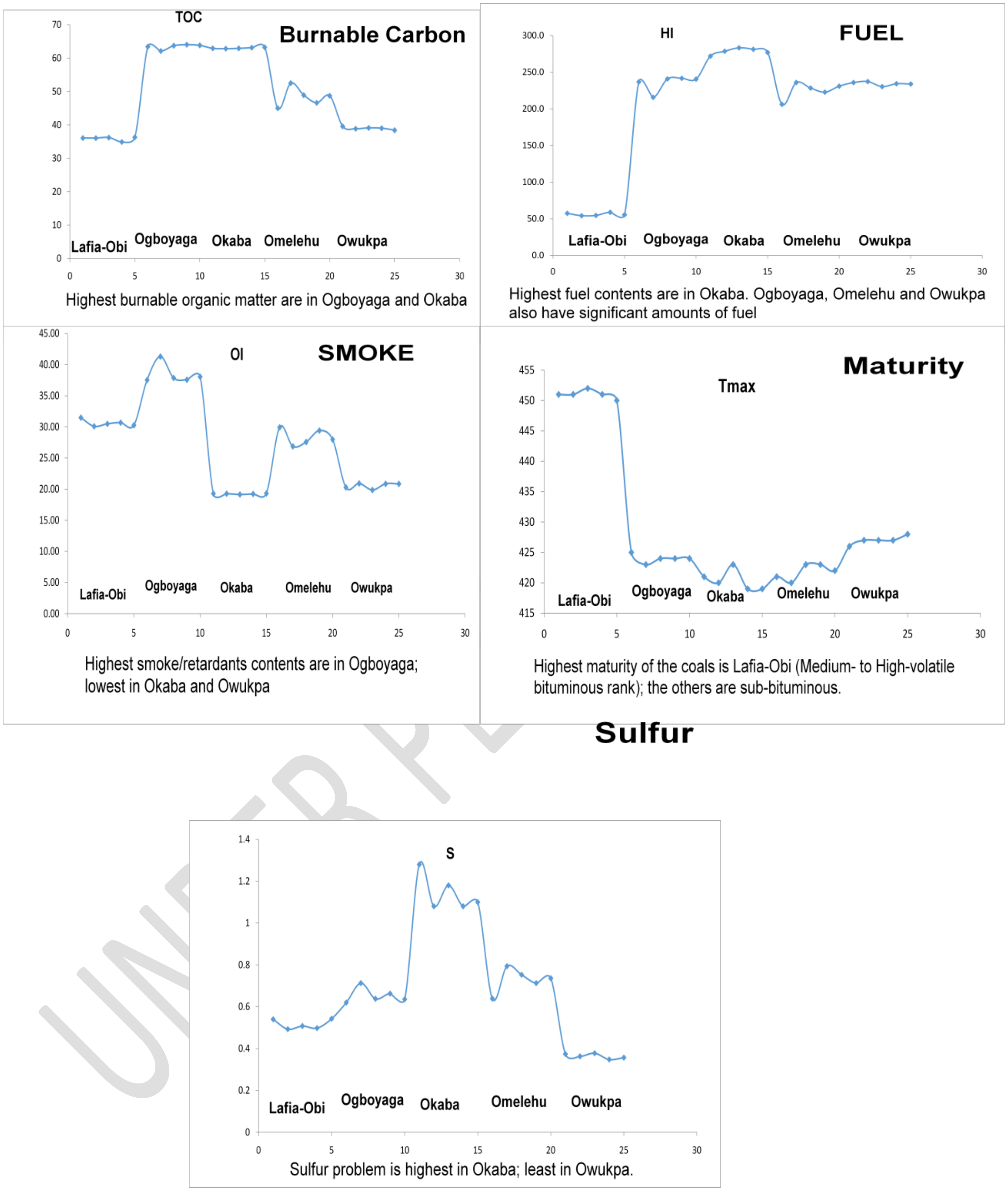

Fig. 10. Interpretation of Rock-Eval pyrolysis data shows that the Okaba coal deposit with the highest burnable organic matter, highest inherent fuel and least amounts of smoke is most suitable

for smokeless coal fuel production and electricity generation in its present form. However, sulfur content presents some problems. The Ogbayaga and Omelehu coals will need defusinization.

4.4 Defusinization Experiments

Defusinization experiments using eight types of organic acids to digest the fusinite (inertinite) contents as basis for reducing the OI which is the major cause of smoke, greenhouse gas emission and retardation in coal combustion for electricity generation and smokeless coal fuel production were carried on twenty coal samples (exempting the Okaba coals) (Fig. 11). The defusinized samples were subjected to another round of Leco CS and Rock-Eval analyses. The organic acids used attacked all the macerals in the coal and hence affected both the Hydrogen Index (Fuel) and the Oxygen Index (Smoke). The concept was not perfectly successful as none of the acids was able to diminish the Oxygen Index considerably. However, Benzoic and Formic acids at 30% concentration showed significant promises to reduce the smoke content.

Fig. 11. Defusinization experiment involved digestion of the pulverized coals with different types of organic acid and kept to react for 48 hours.

5.0 INTERPRETATION AND DISCUSSION OF THE RESULTS

The results achieved so far have been used to evaluate the energy conversion efficiencies of the respective coal deposits while defusinization experiments to convert the coals to smokeless fuels have been conducted. This is an innovation achieved, subject to series of validation to become an invention. Field data, local combustion, organic geochemical Leco CS and Rock-Eval data were generated on the coals. Field mapping and core drilling to 50m depth at Okaba and Owukpa show that the Okaba coal field has a surface area exposure of 5,408 sq m measuring 52m x 104m. Drilling shows that there are 9 seams of average 3m thick from the present surface into the subsurface. It has an operating mine. Omelehu coals are exposed sparingly only along a stream channel but geophysical surveys indicate 6 seams of average 5m thick in the subsurface. Omelehu does not have an operating mine at present but some companies have acquired licenses for exploration works. The Owukpa field with exposed coals measures 50m x 20m (1,000 sq m). Core drilling to 50m depth proved 9 coal seams of average 3.5m in the subsurface. The Ogboyaga coal deposits are also exposed along a stream channel in the village of Odu Okpakili in Kogi State with1.7m thick coal seam. No core drilling was undertaken and subsurface information is not available. There are also no operating mines. Coal deposits of the Lafia-Obi are also sparingly exposed along the bank of River Dep in the village of Shankodi near Jangwa in Nasarawa State. The thickest seam is ca 0.5m. Core drillings by the National Steel Raw Materials Exploration Agency indicate several subsurface seams with thicknesses of up to 5m for a seam. The earlier reported coal exposures at Kudu (Shekwolo, 2009) were not found anywhere in the reported Kudu-Makera areas. However, earlier drillings and other subsurface information indicate some shaley coal occurrences with the shallowest at about 30m beneath the surface.

Combustion studies recording the time it takes same quantities of water to attain boiling point using same quantities of coal show that the Okaba coal is the most efficient with 10.0 minutes; followed by Omelehu (11.4 minutes), Owukpa (13.2 minutes and 25.0 minutess) while the Lafia-Obi coal never brought the water to boiling point (Fig. 12). The Kudu coals were too shaley for this experiment. Leco CS shows that higher Corg (TOC) values equivalent to burnable carbon are recorded in the Okaba and Ogboyaga coals. Rock-Eval data show that highest Hydrogen Index (HI) values equivalent to fuel contents are recorded in the Okaba coals followed successively by Ogboyaga, Omelehu, Owukpa and the least in Lafia-Obi coals. High Oxygen Index (OI) values equivalent to smoke or retardants are recorded in the Ogboyaga coals, followed successively by the Lafia-Obi, Omelehu, Owukpa and the least in Okaba coals. Maceral (petrological) studies support the high HI contents in the Okaba coals which have equally highest content of liptinite and high relative abundance of C_{28} sterane biomarkers. Rock Eval Tmax values indicate that the Lafia-Obi coals have higher rank/maturity than the deposits in the Anambra Basin.

Integrating and combining the results, the coals from Okaba have the best energy conversion efficiency and therefore most efficient for use in smokeless fuel production and electricity generation, in the present form, with little negative impacts on man and the environment. The Ogboyaga, Lafia-Obi and Omelehu coals have too much of retardants and will produce too much smoke. Although the Ogboyaga coals were not used during the combustion experiments, a test-run conducted based on the results of the Rock-Eval pyrolysis (relatively high Oxygen indices) corroborates the envisaged high smoke emission compared to the Okaba coals with least smoke emission. The Owukpa coals, though low on retardants and with appreciable inherent fuel, have low burnable organic matter (TOC). The Lafia-Obi coals are deficient in fuel and have high retardants in addition to being poorly combustible. The Kudu-Makera coals are too shaley and suitable only for the generation of gaseous hydrocarbons. For the ranking of their use in the present forms for smokeless coal fuel production, the order will be Okaba, Owukpa, Omelehu, Ogboyaga, Lafia-Obi, Kudu-Makera in descending order.

Nigeria as a country is currently challenged by series of energy crises with concomitant economic and social implications. Deficit power supply is the single major culprit for the social and economic downturns in Nigeria. The conversion of Nigeria's coal deposits into smokeless coal fuel will provide alternative clean energy to power industrialization that will create employment, grow the economy and thus will transform the socio-economic environment positively in addition to encouraging mining of coals and diversification of the economy.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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