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Omelewu Coal Characterization for Powering Power Plant at Dangote Cement Factory, Obajana Kogi State, Nigeria.

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ABSTRACT: This aim of this research is to determine the properties of Omelewu coal deposit for electricity generation. Fifteen coal samples were subjected to several analytical tests. These tests were carried out at the Laboratories of Mining Engineering Department, Chemistry Department and Prof. Julius Okojie Central Research at the Federal University of Technology, Akure. The tests carried out on the coal properties include; Density test (1.30kg/m3), proximate analysis which includes, moisture content (14.64%), volatile matter (45.89%), fixed carbon (39.30%), ash content (14.82%) and mineral matter(46.48%) using ASTM D3173, ASTM D5142, ASTM D5142 and INDIAN STANDARD ISO/R/679 standard respectively and calorific value of 21.66MJ/kg using ASTM D5865 standard. Based on the results of tests carried out, it was shown that the coal deposit is a Low rank, sub-bituminous C coal with medium ash coal and suitable for pulverized coal combustion when its calorific value, ash content and moisture content were compared with the coal fuel used for the Genessee Phase 3 power station in Canada. This results indicated that it is a sub-bituminous coal suitable for power generation. We hereby recommend that further analytical research should be done on this coal site for more details such as gravimetric test.

KEYWORDS: *coal, standard, proximate analysis, calorific value, low rank coal, power generation.*

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I. INTRODUCTION

Availability of electricity in a country is a driving force for economic and social development (Sambo *et al.*, 2009). Energy is a key factor in industrial development and in providing vital services that improve the quality of life. Traditionally, energy has been regarded as the engine of economic progress. Limited access to energy is a serious constraint to development in the developing world, where the per capital use of energy is less than one sixth that of the industrialized world (IAEA, 2005). It is widely accepted that there is a strong correlation between socio-economic development and the availability of energy.

Figure 1 presents the map showing the location of the coals in the sedimentary basins of Nigeria (Obaje, 2009). Coal can be defined as a chemically and physically heterogeneous, combustible, sedimentary rock consisting of both organic and inorganic materials. Organically, coal consists primarily of carbon, hydrogen, and oxygen, with lesser amounts of Sulphur and Nitrogen. Coal is considered the cheapest and most widely abundant fossil fuel in the world (Ye *et al.*, 2013). According to the United States Energy Information Administration (EIA), the cost of generating 1 million British Thermal Units (Btu) of energy from coal is $1.69 against $6.94 and $6.23 for natural gas and petroleum, respectively (EIA, 2008). Inorganically, coal consists of a diverse range of ash-forming compounds distributed throughout the coal (Miller, 2005).

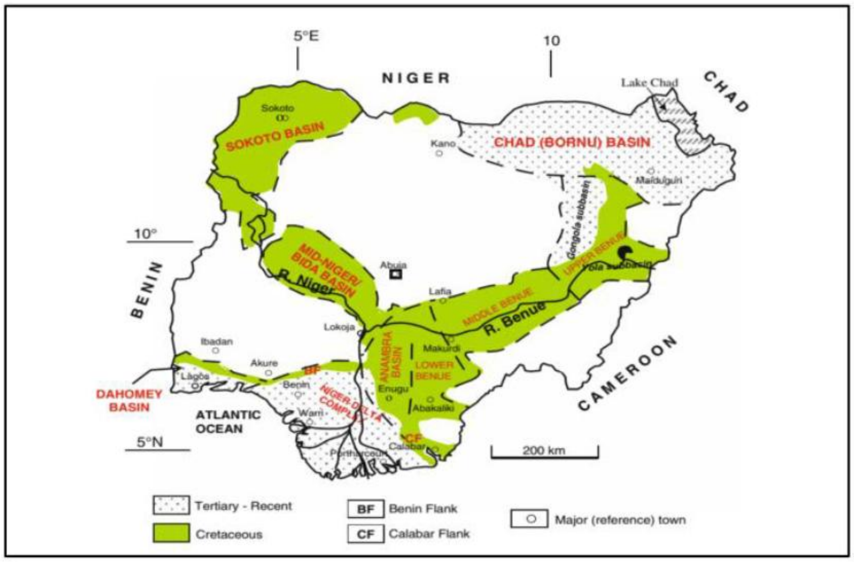

Figure 1: Sedimentary Basins of Nigeria (Obaje, 2009).

Coal accounts for 41% of the world's energy source for electricity generation. This is distantly followed by gas (21%), hydro (16%), nuclear (13%), oil (5%) and other renewable (3%). Coal is the key fuel for generating electricity on almost all continents, with almost all developed and developing countries relying on coal for the stable and secure supply of electricity (World Coal Association, 2012). The 2011 Electricity information published by the International Energy Agency (IEA) showing the percentage contribution of coal for electricity generation in some countries is listed in table 1: countries using coal in electricity generation.

Table 1: Countries using Coal in Electricity Generation

Country	Coal usage for Electricity (%)	Country	Coal usage for Electricity (%)
Botswana	100	Zimbabwe	46
Mongolia	93	USA	45
South Africa	93	Germany	42
Poland	88	United Kingdom	29
PR China	78	Turkey	28
Australia	77	Japan	23
Kazakhstan	75	Netherland	21
India	68	Vietnam	18
Czech Republic	56	Russia	16
Morocco	50	Canada	15
Denmark	49	France	5

(Source: World Coal Association, 2012)

Coal also provides an affordable and reliable source of electricity generation. A Comparison of electricity generation costs across international studies (US$/MWh) is shown in Table 1. This proves that coal still remains the cheapest source of electricity in the world today.

II. AIM AND OBJECTIVES OF THIS RESEARCH

This research aimed at determining the physical and chemical characteristics of Omelewu coal deposit for power generation.

The Specific Objectives of this research article are

a. to carry out proximate analyses of the coal samples.
b. to determine the calorific value of the coal samples.
c. to compare results of the above analyses with reference values of coal properties for power generation in order to determine the suitability of the coal deposit for power generation.

2.1 Limitation of the Research

The newly opened coal mine is a fresh mine with limited data concerning the property of the deposit, as regards this, there were no data to be referred to at the beginning of the research. Inability to carryout ultimate analysis due to non - availability of appropriate suitable laboratory equipment at that time. The scope of this research cover the determination of density, proximate analysis (ash content, fixed carbon, moisture content, volatile matter, mineral matter), and calorific value of the coal samples from the mine site.

2.2 Coal Formation

As geological processes apply pressure to peat over time, it is transformed successively into different types of coal.

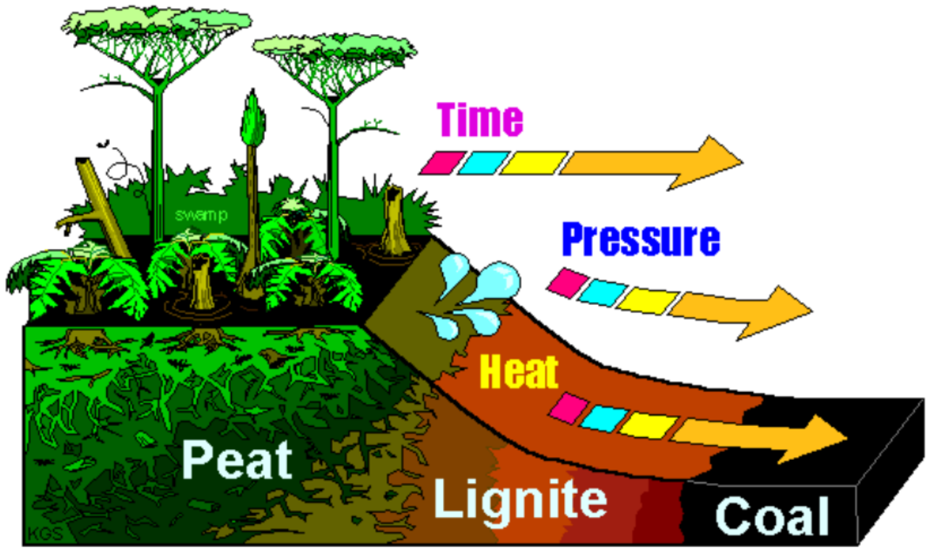

Figure 2: The formation of coal (Brian & Marty, 2008)

Coals are classified according to RANK, TYPE and GRADE.

Brian & Marty (2008) concluded that the degree of 'metamorphism' or coalification undergone by a coal, as it matures from peat to anthracite, has an important bearing on its physical and chemical properties, & is referred to as the 'rank' of the coal.

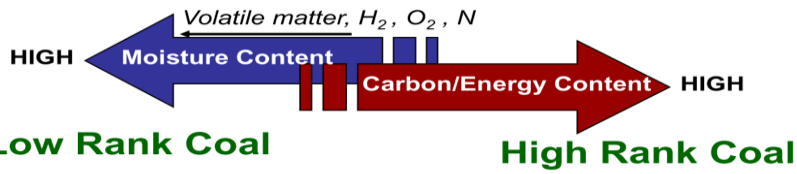

Figure 3: Coal ranking (Brian & Marty, 2008)

The rank of coal is its degree of maturation and is an indication of the extent of metamorphism the coal has undergone. Rank is also a measure of carbon content as the percentage of fixed carbon increases with the extent of metamorphism. Lignites and sub-bituminous coals are referred to as being low in rank, while bituminous coals and anthracites are classified as high-rank coals. The heating value of coals increases with increasing rank but begins to decrease in higher rank coals due to significant increase in volatile matter (Brian & Marty, 2008).

The American Standard for Testing and Materials (ASTM) classification system (ASTM D388) is popular in the industry. The ASTM D388 distinguishes among four coal classes, each of which is subdivided into several groups shown in Table 3 (Miller, 2005).

Table 2: ASTM Coal Classification by Rank

Class/ Group	Fixed Carbon (%)	Volatile Matter (%)	Heating Value (Btu/Ib)
Anthracite			
Meta- anthracite	> 98	< 2	-
Semi- anthracite	92- 98	2- 8	-
Bituminous			
Low- volatile	78-86	14- 22	-
Medium –volatile	69-78	22 – 31	-
High- volatile A	<69	>31	>14,000

High- volatile B	-	-	13,000- 14,000
High- volatile C	-	-	10,500- 13,500
Sub-bituminous			
Sub-bituminous A	-	-	10,500- 13,500
Sub-bituminous B	-	-	9,500- 10,500
Sub-bituminous C	-	-	8,300- 9,500
Lignite			
Lignite A			6300- 8300
Lignite B	-	-	<6300

Calculated on dry, mineral-matter-free coal. Correction from ash to mineral matter is made by means of the Parr formula: mineral matter=1.08[percent ash + 0.55(percent sulfur). Ash and sulfur are on a dry basis. *Calculated on mineral-matter-free coal with bed moisture content. *Coals with heating values between 10,500 and 11,500 Bru/lb are classified as high volatile C bituminous if they possess caking properties or as subbituminous A if they do not.* (Source: Miller, 2005**).

III. MATERIALS AND METHODOLOGY

Materials: Materials used for the research include; coal samples, diggers, polythene nylon, paper tape, metre tape, distilled water and permanent marker. Equipment used for this research include; fabricated pulverizer, automatic sieve shacker, measuring cylinder, and e2k combustion bomb calorimeter.

3.1 Study Area

The study area is located between 7°11'N, 7°34' E and 7°18'3''N and 7° 56'7''E in the southeast region of Nigeria, bordering Enugu State and Benue State with an area of 1,132km^2, (Wikipedia, 2016). Omelewu Coal mine site is the study location, located at Imane town in Olamaboro Local Government Area in Kogi State.

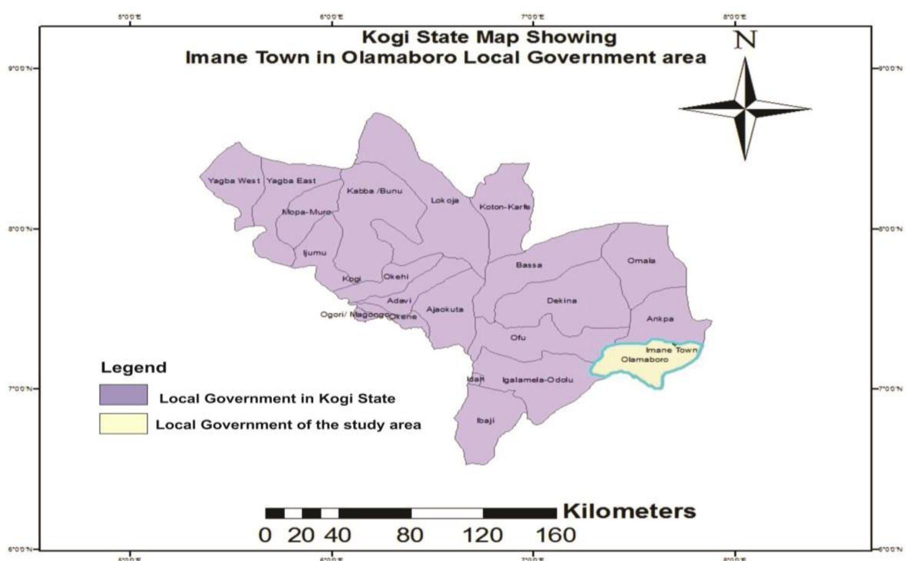

Figure 4: Map of Olamaboro Local Government Area In Kogi State.

Field Materials/ Equipment used are global positioning system (GPS), polythene bag, paper tape, measuring tape, permanent maker, hammer, digger and chisel. A total of 15 different coal samples were collected from the mine site and were tested in the laboratories.

3.1 Coal Samples Preparation

The coal sample is prepared using both the mechanical and manual methods so as to meet the desired analytical specifications using an array of sample preparation equipment. Crushing of the samples from a top-size of about 500 - 600mm as shown in plate 1, to a suitable size distribution range of 30.5 – 100mm was carried out manually through the use of hammer. A pulveriser shown in Plate 3.3 was then used to prepare samples from a top

size of 6mm down to a suitable size distribution range of 150 – 250µm as shown in plate 3.4. An automatic sieve shaker, shown in Plate 3.5, was used for sieving the samples to the desired size distribution required for each test.
The breaking down of the sample to required size was carried out in the laboratory of the department of Materials and Metallurgical Engineering (Federal University of Technology, Akure) and 600g of 250-microns size of representative sample of coal was used to carry out analysis at the laboratory of the department of Industrial Chemistry of Federal University of Technology, Akure for proximate analyses, and calorific values was carried out in Professor Julius Okojie Central Research Laboratory of the Federal University of Technology, Akure. The tests conducted on the coal samples includes; coal density determination, Proximate analysis (Volatile matter, Moisture content, Mineral matter, Fixed carbon, Ash content) and Calorific value determination.

Plate 1. 250µm coal sample

3.2 Determination of Density of the Coal Samples: The density was determined by weighing the mass (mg) of each coal samples on the weighing balance to know the weight of each coal sample. A 250ml measuring cylinder was filled to with distilled water (initial volume, Vi). Grain Coal sample was gently and carefully put into the measuring cylinder containing distilled water and change in volume was recorded (Final volume, Vf). Then the density is being determined using the equation below.

$$Density = \frac{mass}{Change\,in\,volume} = \frac{mass}{Vf - Vi}\ x\ 100 \qquad (1)$$

3.3 Proximate Analysis:

3.3.1 Moisture Measurement

(ASTM D3173, ISO 11722, ASO1038.3) standards was used for the moisture content determination.

$$moisture\ \ content = \frac{Weight\ of\ sample - weight\ of\ dried\ sample}{Weight\ of\ sample} x100 \qquad (2)$$

3.3.2 Measurement of Ash Content

(ASTM D5142, ISO 172, 46) standard was used to determine ash content.

$$ash\ \ content = \frac{Weight\ of\ sample - weight\ of\ dried\ sample}{Weight\ of\ sample} x100 \qquad (3)$$

3.3.3 Measurement of Volatile Matter

ASTM D3175, ISO 562, ASO1038.3 specification was used to determine the volatile matter.

$$Volatile\ matter = \frac{Weight\ of\ sample - weight\ of\ dried\ sample}{Weight\ of\ sample} x100 \qquad (4)$$

3.3.4 Measurement of Fixed Carbon

Determination of fixed carbon is carried out using the equation below:

$$Fixed\,Carbon = 100 - (volatile\,matter + ash\,content)\% \qquad (5)$$

3.3.5 Determination of Mineral Matter

INDIAN STANDARD, ISO/R/679, ISO/TC.27 specification was used to determine Mineral Matter.

$$\text{Mineral Matter} = \frac{M_1 + M_2 + P + HCL + 1.1A +}{M_1} \, x \, 100\,\% \qquad (6)$$

$$F = \frac{MM}{A_1} \qquad (7)$$

Where, Where M1 = mass in grams of sample taken; M_2= mass in grams of sample after extraction; P= mass in grams of pyrites in the extracted coal; H C l= mass in grams of hydrochloric acid in the extracted coal; A= mass in grams of ash, less iron oxide from the pyrites in the extracted coal; F= mineral matter factor; A1= percentage of ash in the original coal and MM= Mineral Matter

3.4 Determination of Calorific Values of Coal samples

ASTM D5865, ISO 1928:ASO1058.5 specification was used to determine gross calorific value. In determining the calorific value, coal samples of aperture size of 250µm were used for this analysis. The calorific value of the samples is determined using the e2k combustion bomb calorimeter. The heat released is proportional to the calorific value of the substance (Michael, 2015).

IV. RESULTS AND DISCUSSION

Table 3: Proximate Analysis Result and Density value

samples	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Density (ℓ)(kg/m3)
A	13.64	12.33	49.36	38.31	1.28
B	14.39	21.94	49.38	28.68	1.33
C	15.15	11.32	45.38	43.10	1.27
D	12.96	12.46	45.97	41.57	1.30
E	15.44	23.96	39.71	36.33	1.29
F	13.69	16.80	49.60	33.60	1.33
G	13.18	11.04	45.66	43.30	1.32
H	16.10	7.61	40.14	52.25	1.30
I	13.68	20.82	46.53	32.65	1.27
J	16.19	8.51	42.76	48.73	1.35
K	15.13	10.89	41.34	47.77	1.29
L	15.94	17.50	44.90	37.60	1.27
M	14.94	19.51	50.34	30.15	1.29
N	15.92	15.92	48.96	39.28	1.35
O	13.23	13.23	48.05	36.04	1.31
Average	**14.82**	**14.82**	**45.89**	**39.30**	**1.30**
Standard deviation	**5.07**	**5.07**	**3.54**	**6.87**	**0.02**
Mean	**14.82±5.06**	**14.82±5.06**	**45.89±3.54**	**39.30±6.87**	**1.30±0.02**

V. RESULT OF THE CALORIFIC VALUES OF COAL SAMPLES

Table 4: Shows the Calorific Value of the Coal Samples

Sample	Calorific value (MJ/kg)
A	23.101
B	20.760
C	22.627
D	20.760
E	17.931
F	21.396
G	23.375
H	21.895
I	20.241
J	22.665
K	23.134
L	21.183
M	20.054
N	21.898
O	21.578
Average	**21.66**
Standard Deviation	**1.48**
Mean	**21.66±1.48**

4.1 The Proximate Analysis

The proximate analysis (percent by weight) gives information on coal behaviour when it is heated, (how much coal goes off as gas, tar, and vapor, and how much remains as fixed carbon). Volatile matter, fixed carbon, and ash were determined. The quantity of volatile matter indicated ease of ignition of a coal and whether supplemental flame stabilization is needed. The ASTM D388 classification system uses volatile matter and fixed carbon content in the proximate analysis along with the heating value of the coal to establish the coal rank. This ranking system provides basic information that assists in making judgments about the combustion properties and the commercial uses of the various types of coal.Table 5 shows Coal properties comparison of Shankodi-Jangwa coal seam and Omelewu.

Table 5: Comparison of proximate analysis of Shankodi-Jangwa coal seam in Obi, Nasarawa State (Bemgba, 2015) with Omelewu coal in Kogi State.

Property	Shankodi-Jangwa coal (Bemgba B. N, 2015)	Omelewu coal
Fixed carbon	39.8 %	39.29 %
Ash content	14.94 %	14.82 %
Moisture content	5.14 %	14.54 %
Volatile matter	40.73 %	45.88 %
Mineral matter	17.25 %	46.85 %

The results indicate that lowest moisture content was observed in Shankodi coal when compare to Omelewu coal. Consequently, the results for the Moisture content corroborate the order of maturity of the coals; Shankodi - Omelewu. The Moisture content and Volatile Matter content of coals is an index for evaluating the maturity, quality and potential application of different coals. Furthermore, the classification of coals as either agglomerating or non-agglomerating is based on the determined volatile matter values (Speight, 2012). The highest volatile matter content was observed for Omelewu, with the values 45.88%. In addition, the results also indicate that Shankodi is agglomerating coals as against Omelewu which is non-agglomerating. Overall, the lower the Volatile Matter content, the higher the ranking or maturity of the coal. Based on the Volatile Matter criteria, Shankodi can be considered to be a matured of the coals (Bemgba, 2015) as well as Omelewu Coal. Considering the coals‟ moisture contents, Shankodi coal and Omelewu coal is higher in quality, because of their low moisture. High moisture leads to a decrease plant capacity and an increase in its operating costs. This is by affecting the calorific value and the concentration of other constituents (IEA/OECD 2002).

The ash content, and mineral matter, is used to determine the fouling or slagging potential of coals during thermal conversion (Speight, 2012). Ash content reportedly affects the composition, volume and performance of blast furnace coke (Ryemshak and Jauro, 2013). The results of ash analysis indicate that both shankodi and Omelewu have low ash content as required for a good coal.

The Fixed Carbon of Shankodi coal was considered to be high which means Omelewu coal also can be considered to be high comparing both values. Since, Fixed Carbon is the solid residue leftover after devolatization and can be used to estimate the amount of coke obtainable from coal carbonization. Shankodi has high coke potential so as Omelewu coals. Similar observations have been reported in literature (Ryemshak and Jauro, 2013).

4.2 Calorific Value

The average value of the calorific value of the fifteen sample (21.66MJ/Kg) represents the calorific value of the whole deposit. The calorific value gives the heating value or the heat of combustion of a substance. It has been suggested that the calorific value of power plant coals are in the range of 9.5 MJ/kg to 27 MJ/kg (Zactruba, 2009). Thus, considering the average calorific values of all the coal samples, it can be deduced that all the coal deposit would be suitable for power generation.

MINERAL MATTER RESULT

Table 6: The Analysed Result of Mineral Matter of the Coal Samples

samples	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Density (f)(kg/m3)
A	13.64	12.33	49.36	38.31	1.28
B	14.39	21.94	49.38	28.68	1.33
C	15.15	11.32	45.38	43.10	1.27
D	12.96	12.46	45.97	41.57	1.30
E	15.44	23.96	39.71	36.33	1.29
F	13.69	16.80	49.60	33.60	1.33
G	13.18	11.04	45.66	43.30	1.32
H	16.10	7.61	40.14	52.25	1.30
I	13.68	20.82	46.53	32.65	1.27
J	16.19	8.51	42.76	48.73	1.35
K	15.13	10.89	41.34	47.77	1.29
L	15.94	17.50	44.90	37.60	1.27
M	14.94	19.51	50.34	30.15	1.29
N	15.92	15.92	48.96	39.28	1.35
O	13.23	13.23	48.05	36.04	1.31
Average	**14.82**	**14.82**	**45.89**	**39.30**	**1.30**
Standard deviation	**5.07**	**5.07**	**3.54**	**6.87**	**0.02**
Mean	**14.82±5.06**	**14.82±5.06**	**45.89±3.54**	**39.30±6.87**	**1.30±0.02**

4.3 Correlation of Some Properties with the Calorific Value of the Sampled Coals

Calorific values were obtained using the average value of each coal property and the results are as shown in table 8.

Table 7: Correlation between Some Coal Properties and Calorific Value

Coal Property	Calorific Values	Correlation Coefficient, r	Equations
Fixed Carbon	Calorific Value	0.5930	$y = 2.744x - 20.15$
Volatile Matter	Calorific Value	0.0695	$y = 0.165x + 42.29$
Moisture Content	Calorific Value	-0.2655	$y = -0.264x + 25.52$
Ash Content	Calorific Value	-0.85249	$y = -2.909x + 77.85$

There is a positive correlation between the fixed carbon and calorific value, (r= 0.6) and negative correlation between ash content and calorific value (r=-0.86) this means that the fixed carbon content of the coal samples contributes to the calorific value of the coals.

4.4 Ranking of Analysed Coal Samples Using ASTM Classification Criteria

Results of proximate analyses and calorific value showing the classification of the coal sample based on ASTM D388 specifications. Based on the results above, the Fixed Carbon (<69%) and Volatile Matter (>31%) values obtained imply that the coals may only be ranked using the Heating Value (Btu/lb) parameter (table 8 shows coal ranking)

Table 8: Ranking of Five Coal Samples using the ASTM Classification

Coal Rank	Heating Value Criteria (Btu/lb) (Miller, 2005)	Coal Samples (Heating Value, Btu/lb)
Bituminous (high-volatile B)	13,000 – 14,000	
Bituminous (high-volatile C)	10,500 – 13,000	
Sub-bituminous A	10,500 – 11,500	
Sub-bituminous B	9,500 – 10,500	
Sub-bituminous C	**8,300 – 9,500**	□ □ □ □ □ □ □
Lignite A	6,300 – 8,300	
Lignite A	>6,300	

From the table above, the calorific value which is 21.66 MJ/kg (9312.124Btu/lb) shows that the coal is a Sub-bituminous C coals which indicate that it is a low rank coal.

4.5 Ash Classification of Analyzed Coal Samples

From results of proximate analysis the average ash content of the samples was used to deduce the ash content of the whole reserve which is 14.82%, Table 9 show the ash classifications of the coal samples.

Table 9 Ash Classification of the Coal Samples

Classification	Composition Range	Average Coal Sample
High Ash	> 15.0	
Medium Ash	**8.0 – 15.0**	□ □ □ □ □
Low Ash	< 8.0	

(Source: Tavoulareas *et al.*, 1995

Omelewu coal deposit contains medium-ash that ranges between High ash content and Low Ash content. The medium ash coal can also be said to be suitable for electricity generation.

4.6 Suitability of Analyzed Coal Samples for Pulverized Coal-Fired Power Generation

Pulverized Coal Combustion is the most commonly used method in coal-fired power plants. This technology is well developed, and there are thousands of units around the world, accounting for well over 90% of coal-fired capacity. Pulverized Coal Combustion can be used to fire a wide variety of coals, although it is not always appropriate for those with a high ash content (IEA, 2010). Omelewu coal is a sub-bituminous coal. Comparison of Coal Samples were drawn with Characteristics of Sub-bituminous Coal used by the Genessee Phase 3 Power Station in Canada to determine its suitability with typically published requirements for pulverized sub-bituminous coal-fired power generation.

Table 10: Comparison of Omelewu Coal Samples with Characteristics of Sub-bituminous Coal used by the Genessee Phase 3 Power Station in Canada

Parameters	Unit	Genesee Phase 3, Canada	Omelewu Coal
Coal type		Sub-bituminous	Sub- bituminous
Heating value	Mj/kg	17.9	21.66
Moisture content	%	19.4	14.64
Ash, % mf	%	19.4	14.82

The result shows that the coal is suitability with typically published requirements for pulverised sub-bituminous coal-fired power generation

VI. CONCLUSION

The properties of Omelewu coal were characterized to determine their proximate analysis, mineral matter and calorific values. The properties of this coal shows that it is suitable for applications such as domestic heating and power generation and high coking potential of which is useful for steel manufacture, based on result of tests carried out, the coal have been classified in terms of rank, grade and type which shows that it is a matured coal considering the moisture content, and it is a low rank, sub-bituminous with medium ash coal.

RECOMMENDATIONS

In order to obtain more detailed information on the study area, it is highly recommended that further research should be done on Ultimate Analysis (chemical composition of coal), Petrographic Analysis (PGA) and Thermo-gravimetric analyses (TGA).

REFERENCES:

[1]. ASTM D3173 / D3173M - 17 :Standard Test Method for Moisture in the Analysis Sample of Coal and Coke. ASTM
[2]. International, West Conshohocken, PA, 2017, www.astm.org
[3]. ASTM D5142 – Test Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures.
[4]. Bemgba B, N. (2015). Centre for Hydrogen Energy, Institute of Future Energy, University Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia, pp. 2 – 5 Brian H. B and Marty W. I. (2008) Coal Characteristics. The Energy Center at Discovery Park Purdue University. Indiana Centre for Coal Technology Research. Pp. 13 – 15. EIA (2008) https://www.eia.gov/ accessed date 6 March, 2016.
[5]. International Energy Agency. (2010) “Pulverized coal combustion,” http://www.iea-coal.org.uk/site/2010/database- section/clean-coal-technologies.
[6]. IEA/OECD (2002). World Energy Outlook Report. http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2002_part1.pdf accessed 30 April, 2016. Pp. 366-369.
[7]. IAEA (2005). Annual Report. Safety standards series, ISSN 1020-525X ; no. NS-R-4). STI/PUB/1220. ISBN 92-0- 115804-1.
[8]. International Atomic Energy Agency. (2005). Energy indicators for sustainable development: guidelines and
[9]. methodologies.www:pub.iaea.org/MTCD/publications/PDF/Pub1222_web.pdf.
[10]. International Atomic Energy Agency (2010). Report. http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.
[11]. ISO 11722:2013: Solid mineral fuels - Hard coal - Determination of moisture in the general analysis test sample by drying in nitrogen.

[12]. ISO 172, 46. Information and Documentation

[13]. ISO1038.3 INDIAN STANDARD, ISO 1928:ASO1058. (1928-2009). Solid Mineral Fuels - Determination of Gross Calorific Value by the Bomb

[14]. Calorimetric Method and Calculation of Net Calorific Value. Ndubuisi, I., Mbada., Pethuel, O., Atanda., Ola. A., Abiodun, A., Abioye., Michael, I., Ugbaja., Ayo S., Alabi. (2016).

[15]. Performance Evaluation of Suitability of Carbonized Palm Kernel Shell (PKS) as a Veritable Alternative to Coal and Charcoal in Solid Fuel Fired Furnaces. International Journal of Metallurgical Engineering, 5(1). pp. 15-20. Michael C, (2015) Characterisation of Some Nigerian Coals For Power Generation. (Unpublished masters thesis).

[16]. Ahmadu Bello University, Zaria, Nigeria pp. 1 – 20. Miller, B. G. (2005). "Coal Energy Systems," Elsevier Academic Press, Burlington, p. 1.

[17]. Miller, B. G. (2015) "Coal Energy Systems," Elsevier Academic Press, Burlington Massachusetts, USA, pp. 6 – 9. Minchener, A. J. (2005). Coal Gasification for Advanced Power Generation. Fuel, 84(17), pp. 2222-2235.

[18]. Obaje, N. G. (2009). Geology and Mineral Resources of Nigeria. Springer Dordrecht Heidelberg London New York, p. 221.

[19]. Ryemshak, S. A., and Jauro, A. (2013). Proximate Analysis, Rheological Properties and Technological Applications of

[20]. Some Nigerian Coals. International Journal of Industrial Chemistry,4(1) pp. 1 - 7. Sambo, A. S., Garba, B., Zarma,I. H., and Gaji, M. M. (2009). Electricity generation and the present challenges in the Nigerian power sector. Retrieved April 4, 2010, from, http://www.energy.gov.ng/. Speight, G. J. (2005). Handbook of Coal Analysis. John Wiley and Sons, Inc., Hoboken, New Jersey, USA, pp. 41 – 102.Speight, J. G. (2012). The Chemistry and Technology of Coal. CRC Press. <http://www.ket.org/Trips/Coal/AGSMM/agsmmtypes.html>

[21]. Tavoulareas, E. S., and Charpentier, J. P. (1995).Clean coal technologies for developing countries. In World Bank

[22]. Technical Paper No. 286. Retrieved from ttp://documents.worldbank.org/curated/en/1995/07/5186832/clean-coal-technologies developing-countries.

[23]. World Coal Association. (2012). Coal matters 3/coal and electricity generation. Retrieved from < http:// www.worldcoal.org/resources/wca-publications>.

[24]. World Energy Outlook (2010). www.iea.org, www.worldenergyoutlook.org, pp. 2-18 World Energy Outlook (2012). www.iea.org, www.worldenergyoutlook.org, pp. 45-55

[25]. Ye, R., Xiang, C., Lin, J., Peng, Z., Huang, K., Yan, Z., Cook, N. P., Samuel, E. L., Hwang, C. C., and Ruan, G. (2013). Coal as an Abundant Source of Graphene Quantum Dots. Nature communications, pp. 1-4. Zactruba, J. (2009) Burning Coals in Power Plants—Calorific Value and Moisture.

Afu, D.J.“ Omelewu Coal Characterization for Powering Power Plant at Dangote Cement Factory, Obajana Kogi State, Nigeria.” American Journal of Engineering Research (AJER), vol. 7, no. 3, 2018, pp.143-152.