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Energy Potential of Nigeria's Natural Bitumen and Coal

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Abstract: **Despite Nigeria being blessed with vast quantities of fossil energy resources, a wide gap still exists between the country's required energy and the generated amount. This shortfall can be met by harnessing Bitumen and Coal which are hitherto not being given adequate attention like Crude Oil and Natural gas.**

The country's Bitumen and Tar sand have a moderately high calorific value; HCV of 27,043.55KJ/kg and 27,759.77KJ/kg respectively which is a great deal of potential energy waiting to be harnessed.

Majority of her Coal reserve deposits is bituminous, but with a class; it has a higher percentage content of Carbon and Hydrogen, and lower percentage content of Sulphur. These properties make it a cleaner and better source of energy generation in comparison to other countries bituminous coal.

Keywords; **Bitumen, Coal, Calorific value, Fossil fuels, Ultimate analysis, Tar sand**

I. INTRODUCTION

Nigeria is blessed with vast number of natural resources, and of immerse importance are fossil fuels because of their commercial worth.

Fossil fuels are non-renewable energy sources that are produced in nature from the remains of plant and animal which decompose under immerse heat and pressure over several millions of years. Crude oil, Natural gas, Bitumen (Tar sand) and Coal are types of fossil fuels, and are available in commercial quantities in Nigeria. Crude oil and Natural gas have continued to be the resources of greater attraction.

With the wide gap that exists between the country's energy generation and requirement, it is imperative to pay closer attention to the country's vast deposit of Bitumen and Coal which can be a cheaper source for energy and hence bridge the existing gap between energy generation and required energy.

Natural Bitumen is a pasty-like fossil energy resource formed from a mixture of hydrocarbons of natural or hydrogenous origin. It is a major source of heavy crude oil and petroleum derivatives, with great prospects as a potential energy source.

Coal is a solid fossil energy resource which is formed in several stages from the remains of plants subjected to intense heat and pressure over millions of years, and can either be hard (bituminous or anthracite) or soft (lignite)

II. LITERATURE REVIEW

Fuels can generally be classified as chemical and nuclear fuels. Fossil fuels are examples of chemical fuels; they liberate heat when combusted in air. They can be solid, liquid or gaseous in nature.

The worldwide distribution of fossil fuels shows that out of a total of 37,880EJ, 17% is Oil, 14% is Natural gas, and the balance of 69% is Coal. [1] These statistics reveals that the worldwide distribution of Coal is more than double the combined distribution of Oil and Natural gas.

Oil has a higher depletion rate than Coal as depicted in fig. 1 below, from which the following estimates were deduced

1) Assume that the rate of fossil fuel energy use remains the same as in 1995 (327.3 EJ/year) for every year thereafter. Then the fossil fuel energy resources known as of Jan. 1, 1996 will be exhausted in year 2111.
2) Assume that the rate of fossil fuel energy use continues to increase linearly, as it has approximately between 1973 and1995, for every year after 1995. Then the world's fossil fuel energy reserves (as estimated on Jan. 1, 1996) will be used up in year 2074. [1].

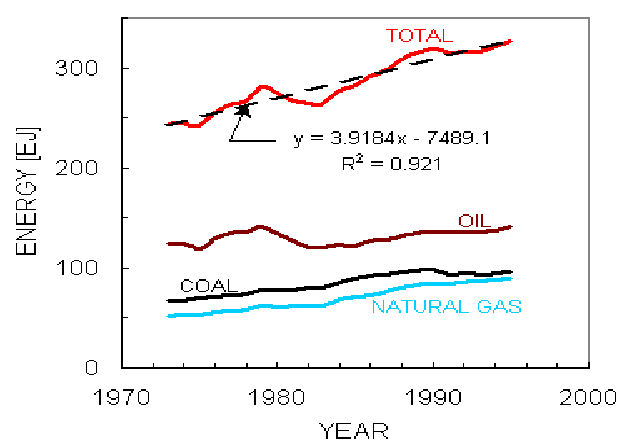

Fig. 1 World annual fossil fuel energy production (1973 – 1995). Data from the U.S. Department of Energy 1996 Annual Energy Review.

Recent studies conducted by Knoema [2] have however shown that the lifespan of fossil energy resources worldwide will extend a little beyond the estimated year 2111 given in assumption 1 above till around year 2128. This is mainly due to the discovery of new reserves. Coal is expected to go into extinction by the year 2128, Oil by 2067 and Natural gas by the year 2069.

Nigeria's Natural gas reserves is ranked 8th in the world with an estimated value of 260 trillion cubic feet, and this is about triple the value of her crude oil reserves[3] The global reserves of Natural gas stand at an estimated value of 186,000 billion cubic metres. [2]

Global crude is estimated to be depleting at the rate of 1.66% annually with sub-Saharan Africa accounting for 2.3% of the worldwide estimated reserve value. [4] Recent global estimated reserve value of Oil stands at 1,688 billion barrels. [2].

Nigeria's Bitumen (Tar sand) deposits reserve spans within a belt extending from Lagos State through Ogun State to Ondo State, and its estimated value is about 31 billion barrels. [5] [6]. The country boasts of having the second largest deposit of Bitumen worldwide after that of Alberta, in Canada [7], giving an implication of abundant amount of potential energy source that can be harnessed for meeting the country's energy requirement.

Wellmer et al [8] gave the global reserves estimate of Coal to be 558 Gt (558 Giga tones) with hard Coal being the bulk of this figure. Coal is distributed in ninety six (96) countries but with concentration in fourteen (14). New discoveries of Coal deposits reserves however puts its estimated value based on the studies carried out in the year 2015 at 892 Gt [2] as against 558 Gt quoted by Wellmer et al.

Data from Nigeria's ministry of solid minerals development puts the estimated value of Coal deposits in the country's reserves at 2.75 billion tones, out of which 0.639 billion tones have be proven. [9].

Fossil fuels contain Hydrogen as one of its constituents, thus making them to posses two calorific values; the lower calorific value (LCV) and the higher calorific value (HCV). The reason for the difference arising from the heat of vaporization due to the condensation of the vaporized steam formed from Hydrogen.

Researchers have carried out ultimate analysis of some coal types and the results documented in text. Table 1 gives the values as documented in text. [10]

Table 1. Ultimate Analyses of Coal (Dry Coal)

Coal	C	H	O	N + S	Ash
Anthracite	90.27	3.00	2.32	1.44	2.97
Bituminous	74.00	5.98	13.01	2.26	4.75
Lignite	56.52	5.72	31.89	1.62	4.25

Sourced from Rogers and Mayhew (1999)

III. MATERIALS AND METHODS

Fossil fuels contain Hydrogen as one of its constituents, thus making them to posses two calorific values; the lower calorific value (LCV) and the higher calorific value (HCV). The two calorific values are related by the equation;

$$LCV = HCV - 2465Mw \qquad 1$$

Where Mw is the mass of water vapour liberated per combustion of 1kg of the fuel

The higher calorific value (HCV) of the fuel was derived by the application of the Dulong's formula to the results obtained from the ultimate analysis on the energy resource. The Dulong's formula is;

$$HCV = \frac{(33800\,C + 144000\,(H - \frac{O}{8}) + 9270\,S)}{100} \qquad 2$$

Where C is the percentage by mass of carbon, H is the percentage by mass of Hydrogen

O is the percentage by mass of Oxygen, and S is the percentage by mass of Sulphur

The ultimate analysis was used to determine the percentage by mass of carbon, Hydrogen, Oxygen and Sulphur for three (3) samples labeled A, B and C.

Plain Bitumen was labeled as Sample A, it was collected from mile 2, via Ilubinrin in Odigbo Local government area of Ondo State.

Tar sand which was collected from Ode Aye in Okitipupa Local government area of Ondo State was labeled as Sample B, while Sample C was Bituminous Coal from the Enugu mines in Enugu State.

A. Carbon and Hydrogen percentage by mass determination

The following apparatus were utilized in the determination of the percentage by mass of Carbon and hydrogen; oxygen gas Cylinder, Pre-heater, Bubble counter, U-tube, Combustion tube, Absorption tubes, Flow meter, Furnace, Digital scale and constant temperature mortar.

CO_2 and H_2O were trapped in the absorption tubes after the experiment. The percentage by mass of Carbon was derived after weighing the absorption tube containing the trapped CO_2 using the relationship;

$$\%C = \frac{\text{Weight of trapped CO2} * 0.2729 * 100}{\text{Weight of Sample}} \qquad 3$$

Likewise the percentage by mass of Hydrogen was derived by weighing the absorption tube which contained the trapped H_2O with the relation;

$$\%H = \frac{\text{Weight of trapped H2O}*0.1119*100}{\text{Weight of Sample}} \quad 4$$

B. Oxygen percentage by mass determination

The apparatus utilized in the determination of the percentage by mass of Oxygen are; Furnaces (Long stationary furnace maintained at 675^0C, long stationary furnace maintained at 1120^0C and a short movable furnace maintained at 1120^0C), Nitrogen purification train, Bubble counter, U-tube, Quartz tube, By-pass stop cocks, Scrubber tube, Drying tube, Oxidation tube, Safety trap, Digital scale and Nitrogen tank.

The different samples were analyzed separately for Oxygen using the above listed apparatus and the necessary chemical reagents. The weight of the CO_2 released in each case was taken and recorded. Percentage by mass of Oxygen was then derived using the relation;

$$\%O = \frac{\text{Weight of CO2}*0.3635*100}{\text{Weight of sample}} \quad 5$$

C. Sulphur percentage by mass determination

Mechanical shaker and Oxygen flask combustion apparatus were used in conducting the analyses. The Sulphur percentage by mass in the samples was derived from the expression;

$$\%S = \frac{(\text{Titre value} - \text{blank})*0.1582*100}{\text{Weight of Sample}} \quad 6$$

The blank value was 0.001ml and the titre values gotten from the analyses.

IV. RESULTS AND DISCUSSION

The percentage composition by mass of Carbon, Hydrogen, Oxygen and Sulphur for the samples A, B and C were determined using ultimate analyses.

Tables 2, 3, 4 and 5 give the results for the analyses for percentage compositing by mass of Carbon, Hydrogen, Oxygen and Sulphur for the three samples.

The calorific values for the individual samples were then calculated based on their percentage compositions by mass.

For Sample A (plain Bitumen); using the Dulong's formula quoted in equation 2,

$$HCV = \frac{(33800\,C + 144000\,(H - \frac{O}{8}) + 9270\,S)}{100}$$

$$HCV = \frac{(33800*73.62 + 144000\,(2.13 - \frac{7.27}{8}) + 9270*4.33)}{100}$$

= 27,043.55KJ/kg

Using the relation in equation 1, the lower calorific value (LCV) was determined.

LCV = HCV – 2465Mw

Mw is the product of the fraction of Hydrogen in the sample and 9kg.

$$LCV = 27{,}043.55 - 2465\,(\frac{2.13}{100}*9) = 26{,}571\text{KJ/kg}$$

For Sample B (Tar sand);

$$HCV = \frac{(33800*80.57 + 144000\,(1.64 - \frac{10.39}{8}) + 9270*4.31)}{100}$$

= 28,123.6KJ/kg

Likewise, LCV = HCV – 2465Mw

$$= 28{,}123.6 - 2465\,(\frac{1.64}{100}*9) = 27{,}759.77\text{KJ/kg}$$

Sample C (Bituminous Coal)

$$HCV = \frac{(33800*81.87 + 144000\,(6.10 - \frac{10.61}{8}) + 9270*1.77)}{100}$$

34,710.34KJ/kg

LCV = HCV – 2465Mw

$$= 34{,}710.34 - 2465\,(\frac{6.10}{100}*9) = 33{,}357.01\text{KJ/kg}$$

The derived percentage composition by mass of Carbon, Hydrogen, Oxygen and Sulphur as depicted in Tables; 2, 3, 4 and 5 for samples A and B shows a sort of correlation with the range of values provided in literature for Bitumen by Adedimila [6]; Carbon (70 - 80)%, Hydrogen (7 – 12)%, Oxygen (1 – 5)% and Sulphur (1 – 7)%.

The calculated calorific values of Sample A and Sample B indicate that they possess a great deal of energy which can be harnessed to meet the country's energy requirement.

The higher and lower calorific values (HCV and LCV) of Sample C as calculated was 34,710.34KJ/kg and 33,357.01KJ/kg, and these are a bit higher for values derived from Table 1; (HCV = 31,480KJ/kg and LCV = 30,153.3KJ/kg) and that quoted in text by Eastop and mcConkey [11] (HCV = 33,500KJ/kg and LCV = 32,450KJ/kg), mainly because of the higher Carbon and Hydrogen content in the country's bituminous coal. The result also shows that the country's bituminous coal have a lower Sulphur content in comparison to that quoted in literature making it a potential cleaner source of energy in terms of emission of compounds of Sulphur.

Table 2. Carbon percentage by mass

Sample	Weight of Sample (g)	Weight of CO_2 (g)	%
A	0.022	0.058	73.62

B	0.021	0.062	80.57
C	0.021	0.065	81.87

Table 3. Hydrogen percentage by mass

Sample	Weight of Sample (g)	H2O Absolute	%
A	0.021	0.004	2.13
B	0.020	0.003	1.64
C	0.022	0.012	6.10

Table 4. Oxygen percentage by mass

Sample	Weight of Sample (g)	Titre Value	%
A	0.013	0.003	7.27
B	0.014	0.004	10.39
C	0.013	0.0037	10.61

Table 5. Sulphur percentage by mass

Sample	Weight of Sample (g)	Titre Value	%
A	0.064	0.019	4.33
B	0.060	0.017	4.31
C	0.063	0.008	1.77

V. CONCLUSION

Bitumen is available in large quantities in Nigeria, and its moderately high calorific value makes it a potential source for energy generation.

The result of this study showed that the Sulphur content of country's bituminous coal is low, making it a cleaner potential source of energy when compared to that of other nations, asides its higher calorific value which makes it to be a better potential energy source.

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