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STUDIES ON ELEMENTAL COMPOSITION AND PHYSICO-CHEMICAL PROPERTIES OF COAL DEPOSITS IN LAMZA AND GUYUK LOCAL GOVERNMENT, ADAMAWA STATE, NIGERIA

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ABSTRACT

This work examined some elemental composition and physico-chemical properties of coal deposits found in Lamza Village in Guyuk Local Government Area of Adamawa State. The major elements determined were carbon, hydrogen, nitrogen, oxygen, and sulphur, while some of the physico-chemical properties examined include; moisture content, ash content, volatile matter, fixed carbon, pH and calorific value. Also the elemental composition of the coal ash was determined using XRF. The proximate analysis showed that the moisture content, ash, volatile matter, fixed carbon and Calorific values of the coal are 2.38 %, 14.18%, 38.25%, 44.17% and 5126.74Kcal/Kg respectively. The ultimate analysis shows that the coal has 69.2621% Carbon, 4.7550% Hydrogen, 7.0679% Oxygen, 1.3350% Nitrogen and 0.7200% Sulphur. Based on the result of the proximate and ultimate analysis, the coal is of good quality if power and heat generation is to be considered. Coal-ash elemental analysis of Guyuk (Lamza) coal shows that due to the low heavy metals and ash content of the coal, utilization of the coal within a safe environment is feasible with just a little or no negative environmental impact.

Keywords: Analysis, Coal, Proximate, Oxides and Ultimate

INTRODUCTION

Coal is an organic, combustible sedimentary rock which also contains minerals/inorganic materials (Clark, et al., 2018). Nowadays, coal has been the most important source of energy for heating and lightning, besides uranium in power generating plans. The presence of certain elements in coal makes it difficult and dangerous for utilization. Many of the heavy metals released in the mining and burning of coal are toxic (Zhang et al., 2018).

When bituminous coals are heated, they develop plastic properties at about 3500^0c, and as a result, exhibit fluidity, swelling, and expansion (Tsetu, 2010). Coal accumulates some heavy metals and radio-isotopic elements such as lead, mercury and nickel, antimony, and arsenic, as well as radio isotopes of thorium and strontium (Jeff, 2006). Coal is characterized by a number of chemicals, physical, and petro-graphic properties (Tsetu, 2010). In the proximate analysis, moisture, ash, volatile matter and fixed carbon are determined, and these properties determine and differentiate the different types of coal and their uses (Zhang *et al.*, 2018).

Large deposits of minerals are still yet to be discovered let alone being gainfully exploited in Nigeria. Such is the situation with the coal deposit in Lamza Village, although, it has been peasantry collected majorly for cooking by the local residents. Lamza coal deposit is within the Dadiya-Lau basin (Yola arm), which is one of the two sedimentary basins (the other being Pindiga-Gombe sub-basin), that exists in the Upper Benue Trough (Tsetu, 2010). The large-scale exploitation of the coal from this deposit may be of economic significance in the country, and prior to this, its evaluation is necessary to ensure the nature and safety of its utility in the environment.

This work, therefore, is aimed at the assessment and evaluation of the coal obtained from the virgin deposit in Lamza Village, Guyuk Local Government of Adamawa State, Nigeria. This is to further publish the occurrence of the mineral in this location and to potentially present its applications based on its qualities and properties.

MATERIALS AND METHODS

Sample Collection

The samples were collected from five different locations identified in Lamza village. The area of study is part of Upper Benue Trough that lies within longitude 11^0 50′ East to $11^0$56′ East and latitude 9^0 52′ North to 9^0 52′ North within topo sheet 174 North-East. It covers a total area of about 7.10km^2, Guyuk local government Area, North East Nigeria.

Sampling and Sample Preparation of Coal

Samples of coal were collected using the stratification method described by Samuel and Maina (2010) as follows; five samples per location at several regular meters intervals apart were taken with consideration of possibilities of variations in sample constituents. Pieces of coal were chiseled from the deposit.

About 600 g each of the representative samples from the five locations were collected and labeled L_1, L_2, L_3, L_4, and L_5. The samples were ground using pestle and mortar and sieved through a 150 µm mesh to obtain a consistent particle size. Smaller quantities of the representative samples were obtained by repeated cutting and matching methods (Obaje et al., 2018).

Proximate Analysis of Coal

Determination of Moisture Content

The moisture content of coal samples preserved in polythene bags (Krumins et al., 2017), determined by adopting the method described by Usman, (2014) as follows; an empty crucible was weighed with its lid to obtain W1, 20 g of coal was weighed together with the crucible and this was recorded W2. The unit was then heated at 120°C for 2hrs, after which it was cooled in the desiccator before it was weighed again to obtain W3. Triple determinations were carried out and the average was calculated using the formula below:

The percentage moisture content (M %) = $\frac{WB-WA}{W2-W1} X \frac{100\%}{1}$

Where;

W1 = weight of empty crucible and lid

W2 = weight of crucible and sample before drying

W3 = weight of crucible and sample after drying

Then, W2 – W1 = WB (weight of the sample after drying)

W3 – W1 = WA (weight of the sample after drying)

Determination of Ash content

Coal sample (20 g) was weighed into a crucible and heated in a muffle furnace. The residue was dissolved in aqua regia (HNO_3 and HCl in ratio 3:1), to remove organic substances from the sample. Care was taken to ensure that volatile elements such as mercury, arsenic and even lead were not removed in the ashing process (Nkafamiya, et al., 2017).

Determination of Fixed Carbon

Determination of fixed carbon contents was calculated based on the modified Dulong's formula, i.e. Seyler's formulae (Ryemshak and Jauro, 2013):

$$\% \text{ Carbon} = 0.59 \left[\frac{Q}{2.3} - \frac{1.1 \times VM}{3}\right] + 43.4$$

Where Q is the gross calorific value (MJ/Kg) and VM is the percentage of volatile matter

Determination of pH Values of Coal

Coal sample (5g) was soaked in 100cm^3 of distilled water at room temperature and allowed to stay overnight, after which the pH was taken using the pH meter (phywe pH meter model 18 195.04) (Tiza, 2010).

Determination of the Calorific Value of Coal

The calorific value of coal was carried out using the bomb calorimeter (6400 Parr isoperibol). The finely powdered sample of coal (sieved through the 90µm mesh) was weighed (1g) and pressed into pellets and placed into a bomb calorimeter. The machine was run for 8 minutes.

Elemental Analysis

The ultimate analysis includes the determination of the amount of carbon, hydrogen, oxygen, nitrogen and sulphur. All these except sulphur were determined by measuring the weight percent (wt. %) and were calculated using the empirical formula given below:

$\% C = 0.97c + 0.7 (Vm + 0.1A) – M (0.6 – 0.01M)$

$\% H_2 = 0.036c + 0.086 (Vm – 0.1A) – 0.0035M^2 (1- 0.02M)$

$\% N_2 = 2.10 – 0.020Vm$

Where C = % of fixed carbon

A = % of ash

Vm = % of volatile matter

M = % of moisture (Ritz and Klika, 2010).

Determination of Sulphur was carried out using carbon/Sulphur analyzer (CS2000). Coal sample (0.25g) was accurately weighed into the analyzer's sample compartment. The machine was then operated at 1335^{0}C.

Elemental Analysis of Coal Ash Using X-ray Fluorescence Spectroscopy (XRF)

X-ray fluorescence method was adopted for the determination of the coal ash elemental oxides as reported by Magili, et al. (2010) as follows; 2.0g of coal ash mixed with 0.4g stearic acid which acts as a binder so as not to allow the sample to disperse or scatter and pressed with a hydraulic press. This fused tablet was X-rayed and counted to determine the major and minor elements present in the ash sample.

Statistical Analysis of Data

The mean values of the five main coal samples from Lamza village were calculated and their standard deviations and student's t-test was used for the purpose of comparing some standard values and also to express some level of confidence in the significant of the comparison at 95% confidence Interval.

RESULTS AND DISCUSSION

Moisture Content of Coal Samples

Figure 1 comparatively presents the moisture content of coal samples collected from the locations. L_3 retains the highest moisture content (4.26%) while L_2 and L_5 both exhibited the lowest (3.38%). Variation in moisture content among the samples can be attributed to variation in their morphology, hence the void spaces in their crystals (Tsetu, 2010). The highest moisture content (4.26%) obtained in this work is relatively lower compared to coal samples reportedly obtained from India (5.98%), Indonesia (9.43%) and South Africa (8.5%) (Nwoko et al., 2016). Low moisture content coal will require less drying prior to final use (Chittatosh *et al.*, 2013).

Low moisture content may also indicate better the concentration of some functional constituents, increase plant capacity, improve calorific value and decrease the operating cost, hence the superiority of Lamza coal (Nigeria) compared to the aforementioned.

Ash Content of Coal Samples

Figure 2 comparatively presents the ash content of the coal samples. L_3 leaves the highest ash content (17.21%) while sample L_1 leaves the lowest (12.05%). Variation in the amount of ash left of the coal samples can be attributed to the variation in the occurrence and abundance of minerals in the samples (Usman, 2013).

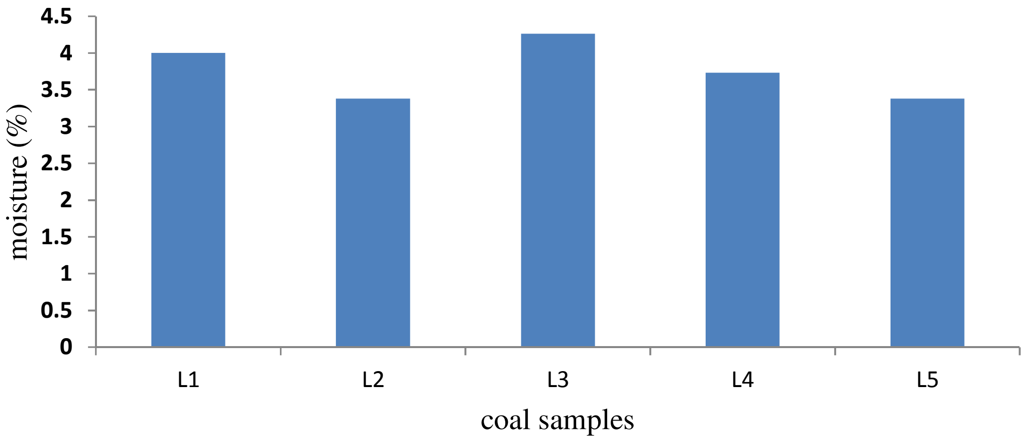

Figure 1: moisture content of Guyuk (Lamza) coal at different locations

The highest composite ash content (17.21%) obtained in this research is comparable with the South African (13.99%) and Indonesian (17.00%) coal, while it is significantly lower compared to the Indian coal (38.99%) (Nwoko et al., 2016). For optimum use, the limit 5 – 40% ash has been reported for coal (Nwoko et al., 2016). This, therefore, keeps Lamza coal within the range of optimum utility coal. Low ash content is an essential requirement in the production of coke from coals (Naveed et al., 2018). This because low ash content increase handling and burning capacity, decrease handling costs, improves combustion and boiler efficiency and prevent/minimize clinkering and slagging (Ryemshak and Jauro, 2013). Lamza coal, therefore, will be considerably better in coke production.

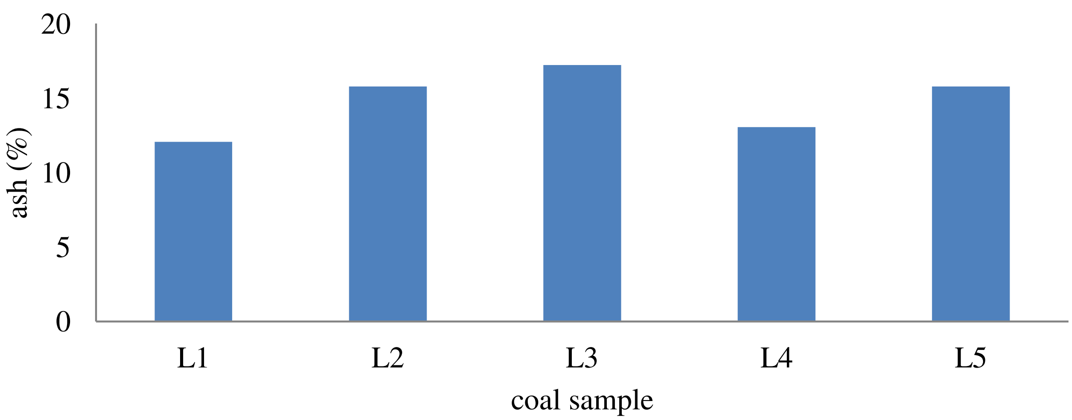

Figure 2: ash content Guyuk (Lamza) coal at different locations

Volatile Matter of Coal Samples

Figure 3 shows and compares the result of the volatile matter of the coal samples obtained from Lamza. Sample L_4 exhibited the highest volatile matter composition (40.38%), while the lowest was recorded for L_2 (39.81%). Volatile matter is majorly organic and/or polymeric materials (Mahato et al., 2016). Variation in these constituents of the coal samples may be responsible from the fashion presents in Figure 3. The volatile matter value obtained for all the Lamza coals fall out of the utility coal range (20 to 35%), and are also higher compared to Indian (20.70%), Indonesian (29.79%) and South African (23.28%) coals (Nwoko et al., 2016). High volatile matter proportionately increase flame length, help in the easier ignition of the coal, set minimum limit on the furnace height and volume, influence secondary air requirement and distribution aspects and influence secondary oil support as compared to the other coals. However, too high volatile content may induce very rapid and wasteful combustion of coal.

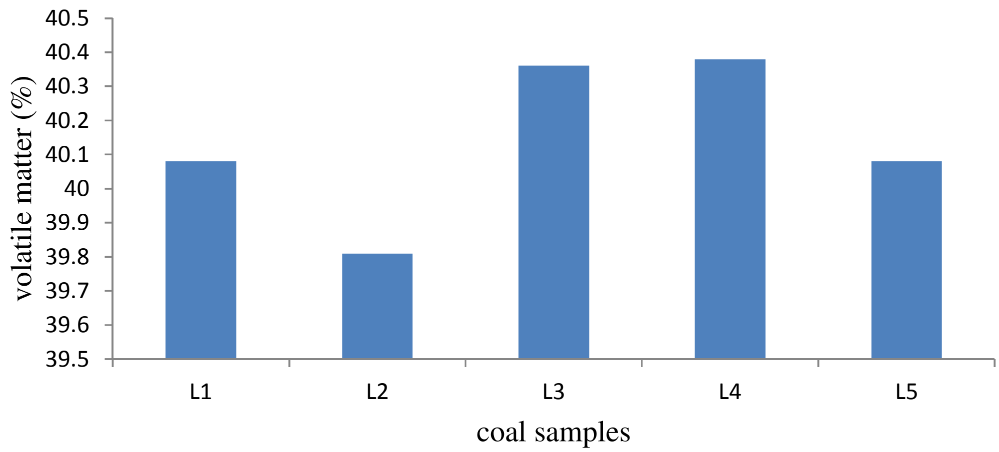

Figure 3: volatile matter of Guyuk (Lamza) coal at different locations

Calorific Values of Guyuk (Lamza) Coal Samples

Figure 4 shows and compares the calorific values of the coal samples. L_3 has the highest calorific value (5409.37 Kcal/Kg), while L_1 has the least (5682.3 Kcal/Kg). Calorific value of coal indicates its heat generation and retention capacity (Nwoko et al., 2016). The reported limit for the calorific value of coal used in generating electricity from power plants is 2700 - 9500 Kcal/Kg (Nwoko et al., 2016). The calorific value of all the Lamza coal samples fall with this range, therefore, the coal samples are considered suitable as fuel for electricity generation in power plants. The average calorific value of Lamza coal samples has also brought them within the lignite coal range (ASTM, 1999), hence their suitability in coke formation (Nasirudeen and Jauro, 2011).

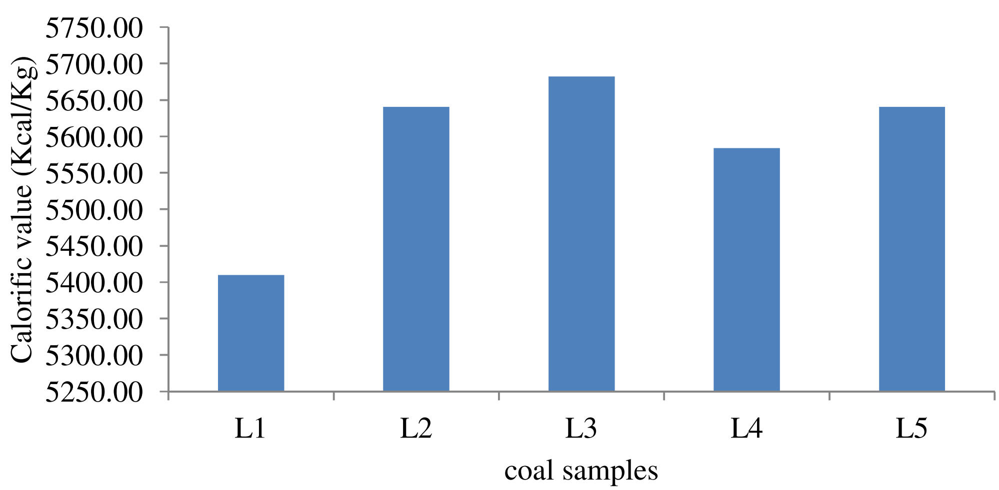

Figure 4: calorific values of Guyuk (Lamza) coal at different locations

Fixed Carbon Content of Coal Samples

Figure 5 comparatively presents the fixed carbon content of the coal samples. L_4 has the highest fixed carbon content value (42.25%), while sample L_3 has the lowest (38.07%). Variation in the amount of fixed carbon content of the coal samples can be attributed to the variation in the difference in a soil profile. The highest fixed carbon content (42.25%) obtained in this research is higher compared to Indian coal (34.69%) but lower compared to the Indonesian (46.79%) and South African (51.22%) coals (Nwoko et al., 2016), hence can be regarded as moderate. The fixed carbon content is a factor in heat generation capacity of coal and its suitability in coke formation (Obaje et al., 2018). The fixed carbon content of a coal sample is the carbon found in the material which is left after volatile materials are driven off (Nyakuma & Jauro, 2016).

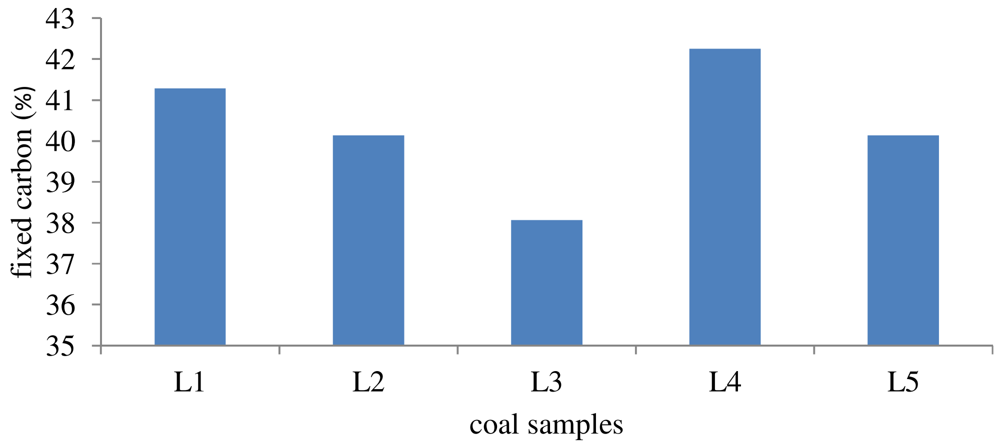

Figure 5: fixed carbon values of Guyuk (Lamza) coal at different locations

pH of Coal Samples

Figure 6 comparatively presents the pH of the coal samples. There are slight variations in the pH of the coal samples and all are slightly acidic with L_3 being the least acidic (pH = 5.7), while sample L_1 is the most acidic (5.35). The acidic nature of these samples can be attributed to the presence and abundance of non-metallic oxides (e.g. sulphur) which on contact with water molecules can form various types of acids (Tiza, 2010) The slight or weak acidity implies that utilization of Lamza coal within a safe environment is feasible with just a little or no negative environmental impact due to acid mine drainage (AMD) (Usman, 2013).

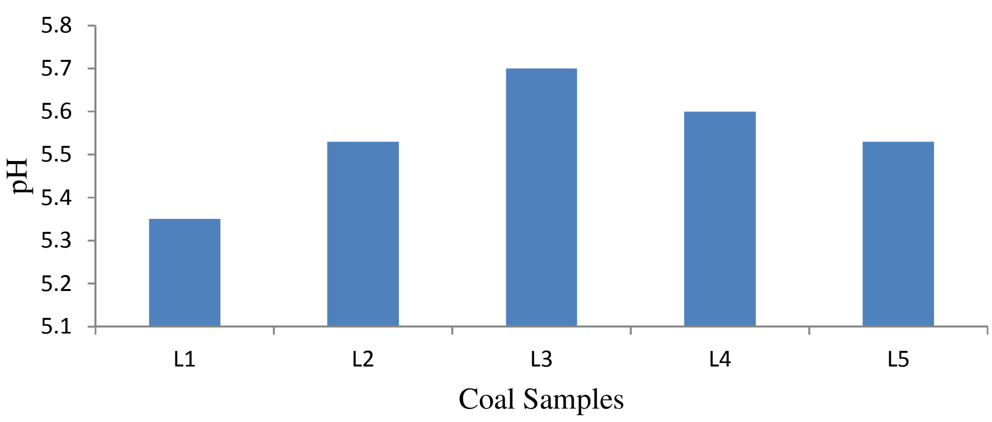

Figure 6: pH values of Guyuk (Lamza) coal at different locations

Ultimate Analysis of Coal Samples

Figure 7 shows the ultimate analysis of five major elements found in coal samples from Lamza and village of Guyuk Local Government. The elements are; Carbon, Hydrogen, Oxygen, Nitrogen, and Sulphur. The percentage composition of sulphur is small. Therefore, the outflow of acidic water or acid mine drainage from coal will be of a lesser concern due to the low sulphur content of the coal. This implies that the depletion of the buffering ability of streams located close to the coal mining site will be very minimal (Adebisi et al., 2017). Notwithstanding, the sulphur can still affect clinkering and slagging tendencies, corrodes chimney and other equipment such as air heaters and economiers and limit exit flue gas temperature.

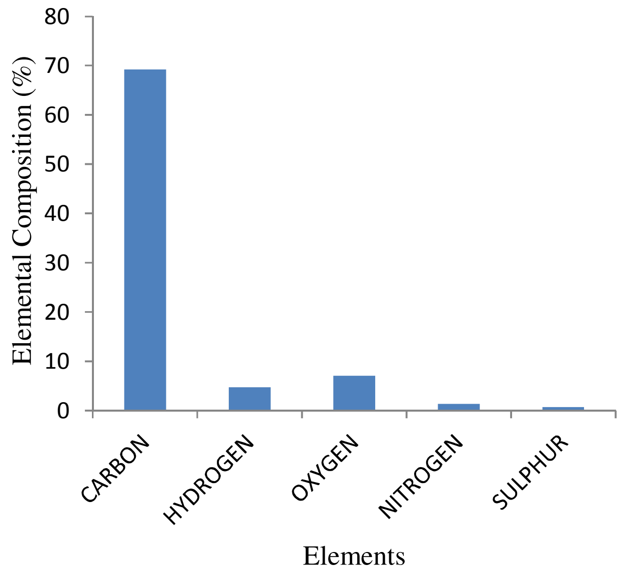

Figure 7: Percentage Elemental Composition of Guyuk (Lamza) Coal

Coal Sample Ash Elemental analysis
The result of X-ray Fluorescence analysis as indicated in Table 1 has shown that the coal contains heavy metals in form of compounds or oxides of; Fe_2O_3, CaO, MgO, Na_2O, K_2O, SO_3, MnO, V_2O_5, Cr_2O_3, CuO, ZnO, BaO and NiO, with average compositions of 69.590%, 2.620%, 18.130%, 1.770%, 3.130%, 0.520%, 1.230%, 0.620%, 1.800%, 0.082%, 0.099%, 0.026%, 0.052%, 0.062%, 0.230%, and 0.040% respectively.

Table 1: Percentage Mineral Compositions of Coal Samples

Elemental oxides	Amount in ash (%)
SiO_2	69.59
TiO_2	2.62
Al_2O_3	18.13
Fe_2O_3	1.77
CaO	3.13
MgO	0.52
Na_2O	1.23
K_2O	0.62
SO_3	1.80
MnO	0.082
V_2O_5	0.099
Cr_2O_3	0.026
CuO	0.052
ZnO	0.062
BaO	0.23
NiO	0.040

CONCLUSION
This work significantly contributes to the exploration of minerals in Nigeria. Based on the result of the Proximate (high calorific value that can be compared with any coal in the world), Coal-ash elemental which shows that the heavy metal levels are also low, and the Ultimate analysis of Guyuk coal which shows a high Carbon content; it shows that coal is of good quality if power and heat generation is to be considered. Also, due to the low sulphur and ash content of the coal, utilization of the coal within a safe environment is feasible with just a little or no negative environmental impact. Guyuk coal if well harnessed can be a means of heat/electricity generation to Adamawa State.

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