FUEL QUALITY ANALYSIS OF COAL DEPOSIT SAMPLE OBTAINED FROM CHIKILA, GUYUK LOCAL GOVERNMENT, ADAMAWA STATE.

Musa Runde and Neksumi Musa

*Department of Pure and Applied Chemistry, National Open University of Nigeria
College of Science and Technology, Adamawa State Polytechnic Yola
*Corresponding Author e-mail; rmusa@noun.edu.ng

Abstract

This work examined some physicochemical parameters of fuels in coal deposits found in Chikila village of Guyuk Local Government Area of Adamawa State. The major elements determined were: Carbon, Hydrogen, Nitrogen, Oxygen, and Sulphur while some of properties examined include; moisture content, ash content, volatile matter, fixed carbon, pH and calorific value. The averages are: Moisture content 8.09%, ash content 17.55%, volatile matter 32.67%, fixed carbon 40.975%, pH 5.92 and calorific value 5536.09 Kcal/kg. the coal ash contains heavy metals in form of 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 69.71%, 2.06%, 17.99%, 1.89%, 3.50%, 0.75%, 0.91%, 0.40%, 2.20%, 0.092%, 0.10%, 0.035%, 0.074% and 0.0%**.** The proximate analysis showed that Chikila coal values for moisture and ash are high while the volatile matter, fixed carbon and calorific values are moderate. The ultimate analysis of Chikila coal has higher value of oxygen, nitrogen and less Sulphur. Based on the result of the proximate, coal-ash, calorific value, elemental and ultimate analysis of Chikila coal, it can be concluded that it is high quality source of fuel with less environmental side effects.

KEY WORDS; Calorific value, Ultimate analysis, Proximate analysis, Moisture content and Ash content

INTRODUCTION

The industrial growth and development of a developing country like Nigeria depends on the availability of raw materials resources, exploration and utilization. Most raw materials for industrial development are derived from natural resources (Usman, 2013).

Coal is an organic, combustible sedimentary rock that also contains minerals and inorganic Material, within the organic matter. The compressed organic matter lay down in typically saline inland sea basins or swamps millions of years ago, is interspersed with finely weathered rock material, known as shale (Mahesh *et al* 2016). The heaviest metals accumulate in coal and shale strata because their densities and electronic charge mean they tend to concentrate in depositional environments. Coal and coal shale therefore, concentrate and accumulates heavy metals, amongst other elements, most of which are bio-toxic and some of which are also radioactive (Mahesh *et al* 2016).

This research work is to assess the physicochemical properties and elemental composition of coal mineral for the study area. The specific objectives are;

(i). To carry out proximate analysis of the volatile matter, pH, moisture content and ash content of different samples of coal from the study area; and
(ii). To carry out ultimate analysis and X-ray fluorescence (XRF)

Nigeria is endowed with millions of tons of coals. The knowledge of the quantity of the various constituents of coal will give an idea on how the coal should be processed to enable the utilization within a safe environment. The successful conversion of these coals to smokeless fuel will provide the means to utilize them in national development. The availability of cheap smokeless fuel will reduce the use of fire wood and stem deforestation.

MATERIALS AND METHODS

Sample Collection

Samples were collected in Chikila, 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 top sheet 174 North-East (N.E). It covers a total area of about 7.10km^2. Chikila of Guyuk local government Area, N.E. Nigeria. It can be accessed by roads, which are the major roads linking Numan and Guyuk. This research work will be restricted only to the coal deposits mineral found in the vicinity of Guyuk Local Government Area Chikila villages of Adamawa State.

Sampling and Sample Preparation

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 C_1, C_2, C_3, C_4, and C_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, (2013) 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.

ULTIMATE 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*. (2014) 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 Chikila village were calculated and their standard deviations determined using the equation:

$$S.D = \frac{\sum_{i=1}^{n} xi - \sum_{i=1}^{n} xi^2}{n-1}$$

Where S.D = Standard Deviation

n-1 = Degree of freedom

xi = mean

The results of the standard deviation were used to ascertain the student's t-test 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:

$$C.I = x \pm \frac{ts}{\sqrt{N}}$$

Where C.I = Confidence Interval

X = Mean

S = Standard Deviation

N = Degree of Freedom

The value of t was obtained from the equation:

$$t = \frac{(\bar{x} - \mu)\sqrt{n}}{s}$$

Where $\bar{x}$ = experimentally determined mean

μ = population mean

S = standard deviation

n = number of data set (Mendham *et al.,* 2000)

RESULTS

Moisture Content of Coal Samples

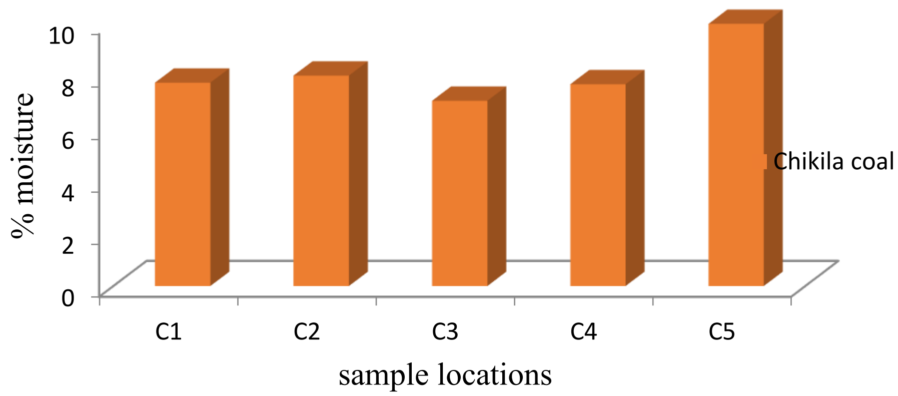

Figure 1: Moisture Content of Chikila Coal at Different Locations

The result of moisture content of the coal sample in figure 1 above shows that sample C_5 retains the highest moisture contents while sample C_3 has the lowest value. All the samples except C5 contain less than 10 % of moisture.

Ash Content of Chikila Coal Samples

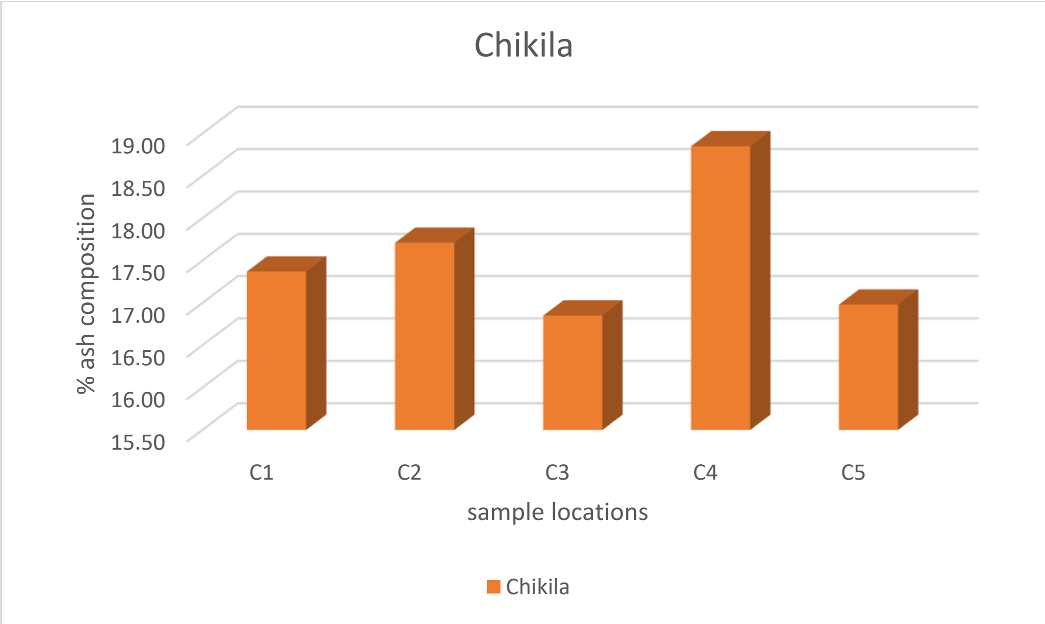

Figure 2: Ash Content of Sample Coal at Different Locations

The result of dry ashing process of five coal samples from the study area is shown in figure 2 above. Sample C_4 has the highest ash content of 18.85%, while samples C_5, C_1 and C_2 have lower ash content ranging from 16.98 to 17.71%. Sample C_3 has the lowest ash content of 16.85%.

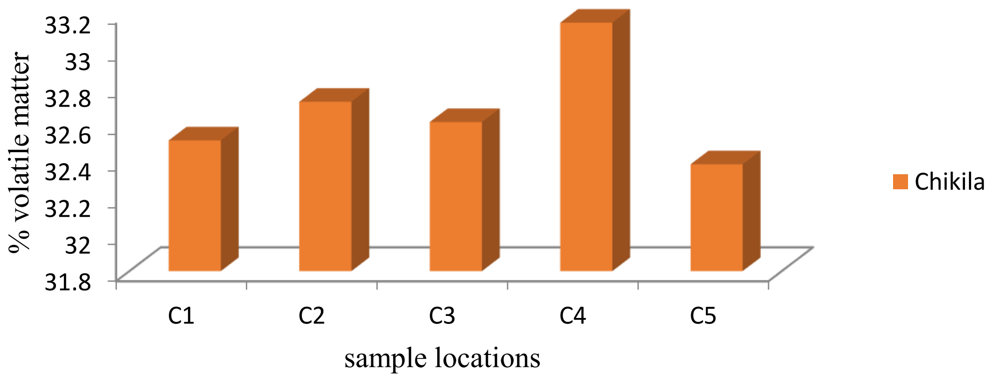

Figure 3: Volatile Matter of Coal at Different Locations

The result of volatile matter of Chikila village coal samples is shown in Figure 3. Sample C_4 has the highest volatile matter (33.2 %) while sample C_5 has the lowest volatile matter (32.4 %). The result also showed that, sample C_2 is next in percentage value with 32.8 % total volatile matter, C_3 contained 32.7 % and C_1 has 32.6 % of volatile matter.

Calorific Values of Coal Samples

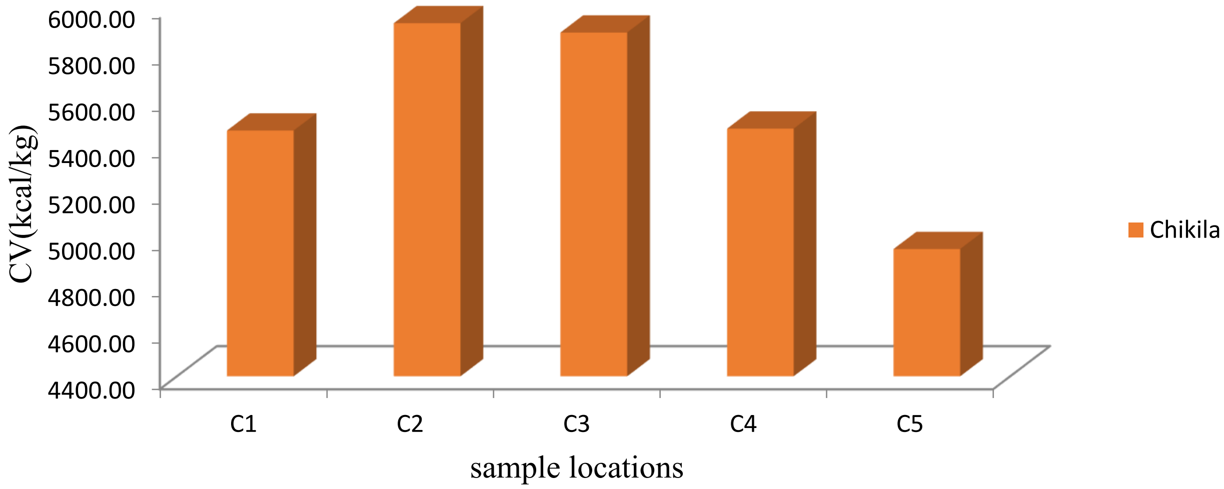

Figure 3: Calorific Values of Coal at Different Locations

Figure 3 shows clear view of calorific value of coal which is the suitability of heat capacity retention and generation of viable coal to produce heat and light. It indicated that sample C_2 has the highest calorific value of 6000 Kcal/Kg while C_5 recorded the lowest calorific value of 5200. Other calorific values are those presented by sample C_3 5800 Kcal/Kg whereas samples C_1 and C_4 has the same calorific value of 5600 Kcal/Kg.

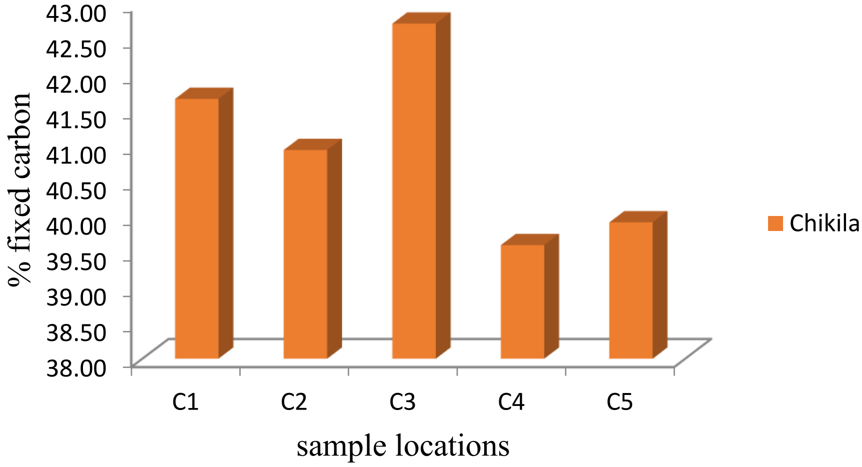

Figure 4: Fixed Carbon Values of Chikila Coal at Different Location

Sample C_3 has the highest fixed carbon content of 43 % while sample C_4 has the lowest fixed carbon content of 39.50 % as shown in figure 4 above. Sample C_1 has a total of 42 % fixed carbon value exceeding sample C_2 and C_5 which have 41 and 40 % fixed carbon respectively.

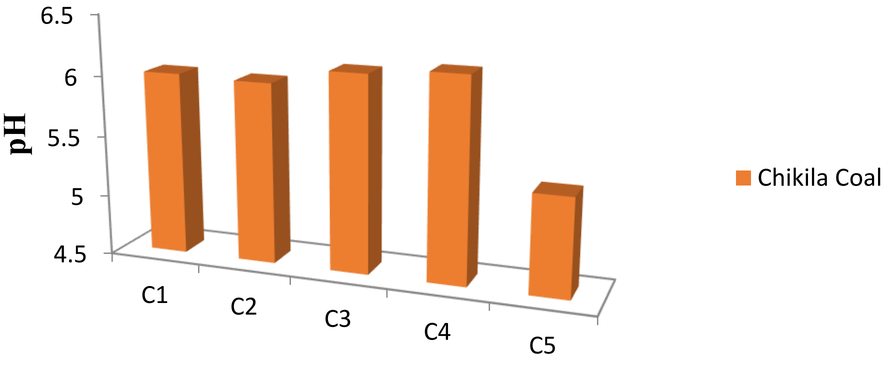

Figure 5: pH Values of Chikila Coal at Different Location

pH levels of coal samples using pH meter as shown in Figure 5, revealed that sample C_4 has the highest pH of 6.3 and C_5 has the lowest pH of 5. Other pH values are for C_1 6.05, C_2 6.0 and C_3 6.10.

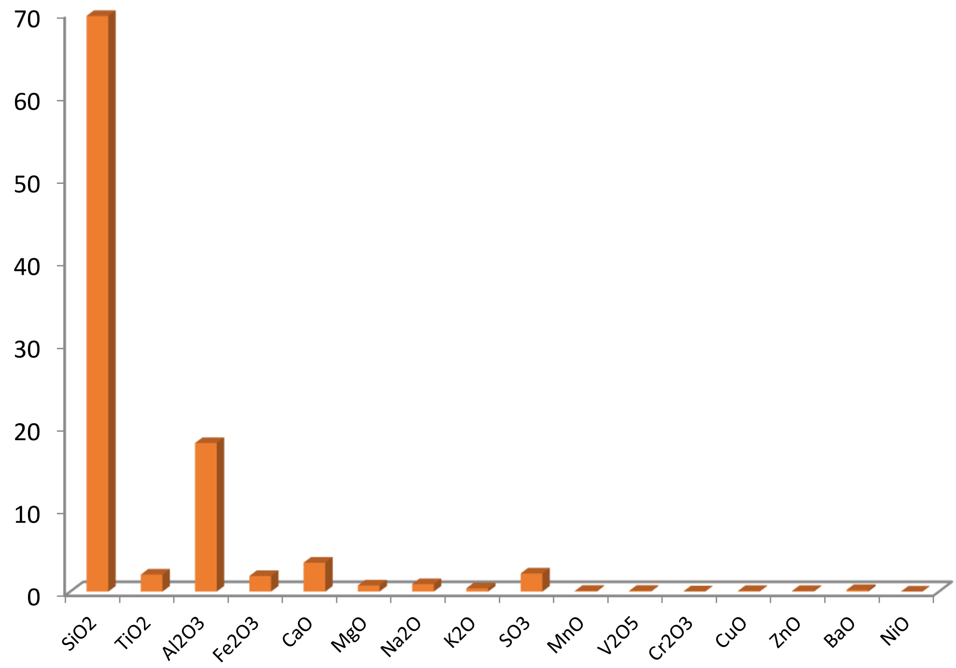

Figure 6: Average Percentage Mineral Compositions in Coal Samples

The result of X-ray Fluorescence analysis as indicated in figures 6 of Guyuk coal 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 70 %, 2.06%, 17.99%, 1.89%, 3.50%, 0.75%, 0.91%, 0.40%, 2.20%, 0.092%, 0.10%, 0.035%, 0.074% and 0.0% for coal samples from Chikila village.

DISCUSSIONS

Moisture Content of Chikila Coal Samples

Generally, High moisture content would result in a decrease plant capacity and an increase in operating cost and it also affects calorific value and concentration of other constituents (Chittatosh *et al.*, 2013). Due to the fact that when coal burns, the moisture in coal evaporates taking away some heat of combustion which is not available for use vis-à-vis the amount of moisture determines how much of heating is to be done to dry coal before it is burned in the boiler (Chittatosh *et al.*, 2013).

Ash Content of Chikila Coal Samples

Since typical range for coal ash is 5 to 40% (Nasirudeen and Jauro, 2011), a high ash percentage reduces handling and burning capacity, increases handling costs, affects combustion efficiency and boiler efficiency and Causes clinkering and slagging (Nwoko, *et al*, 2016). Thus, all the coal samples are very good for making coke for heating in industries. Since low ash content is an essential requirement for making coals. In addition to the rich ability for coke making, Chikila village coal will influence slag volume and composition in blast furnace with poor in coke making as stated by (Ryemshak and Jauro, 2013).

Volatile Matter of Chikila Coal Samples

Since the typical range for volatile matter is 20 to 35% (Andrés and Juan 2013), therefore, the high volatile matter obtained in Chikila coal will proportionately increase flame length, help in 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.

Calorific Values of Chikila Coal at Different Locations

the coal samples have high potentials in coke formations and heat generation capability. Since coal is the primary fuel for producing electricity in industries, therefore, the calorific value of coal has a profound influence on the day to day working and economics of the power plant. Power plant coals have a general calorific value in the range of 2700 kJ/kg to 9500 kJ/kg (Mahapatra, 2016). Therefore, Chikila coal has a very suitable calorific value for utilization in power plants. The calorific value is also related to the fixed carbon contents in terms of heat generation capacity (Ayhan, 2003).

Fixed Carbon Content of Coal Samples at Different Locations

The values of percentage carbon content (40 to 43) of Chikila coal indicate that the coal will be suitable for generation of electricity and also show that the coal type is sub-bituminous. Sub-bituminous coal has carbon content percentage range of 35 to 45 (Brian and Marty, 2008). Sub-bituminous coal contain low Calorific value compare to Anthracite and Bituminous coal. It is a clean source of fuel which is valued above lignite coal which contains high pollutants (Chibuisi and Maduabuchi, 2017). Another quality of the coal sample under study is effective coke formation due to its relative carbon content since this parameter is responsible for coke formation as reported by (Nasirudeen and Jauro, 2011).

pH of Coal from Chikila

The distribution of pH in Chikila coal which ranges from 5 pH to 6.3 pH is an indication that the coal contains low acidic oxide. This reality is possible due to the very low sulphur content (0.88 %) in the coal as revealed earlier in this work (see Figure 6). Another study on bimodal pH distribution in coal shows that pH is controlled by iron disulfide and calcareous minerals found in coal-bearing rock (Charles, *et al*, 2004). These acidic enhancers and neutralizers are readily reactive as such contribute to the bimodal pH distribution in coal. Going by this, it is also evident that the near neutral values observed in all the coal samples as presented above, could be attributed to the presence of substantive amount of carbonate buffering (Charles, *et al,* 2004).

Ultimate Analysis of Sample Coal

The ultimate analysis of five major elements found were; Carbon, hydrogen, oxygen, nitrogen and sulphur. The percentage composition of sulphur is small, 0.88%. The ultimate carbon composition of the coal sample is 60.2%, Hydrogen, 4.1% whereas Oxygen and nitrogen have 8.1% and 1.4% respectively. Since the cause of acid mine drainage is sulphide mineral (Sangita and Bably, 2010 and Clark, *et al* 2018), the outflow of acidic water or acid mine drainage from Chikila coal will be of a lesser concern due the low sulphur content of Chikila coal. This implies that the depletion of the buffer ability of streams located close to the coal mining site will be very minimal as presented by (James and Kevin, 2000). Notwithstanding, the sulphur can still affect clinkering and slagging tendencies, corrodes chimney and other equipment such as air heaters and economisers and limit exit flue gas temperature. This side effect is also observed in other equipment use in oil industries (Alexander, *et al*, 2015).

Conclusion

This work significantly contributes to the exploration of fuels in Nigeria based on the result of the Proximate (high calorific value). Result of Coal-ash element shows that the heavy metal levels are also low whereas, the Ultimate analysis of the coal shows a high Carbon content; this confers that the coal obtained from Chikila is of good quality for power and heat generation. Also, due to the low sulphur and ash content of the coal, the mining and utilization of the coal will pois no harm to the environment, underground and surface water as well safe for life existence within the proximity of the mining site.

Recommendations

1. The coal deposits found in Chikila village will have a tremendous importance due to its high energy capacity. The Government and other firms should put some effort to utilize the deposits of this coal for heat and energy generation. This will help substitute the shortage of power supply and possibly, provide the energy needed to explore the vast amount of minerals such as limestone deposit located in the same vicinity.
2. Further geological studies of Chikila in Guyuk Local Government Area coal should be made to determining the extent and size of the coal deposit.

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