Physicochemical Analysis And Mineralogical Composition Of Enugu Coal In Nigeria For Potential Utilization

Nwoko Christopher Ikpeamadi, Nkwoada Amarachi Udoka, Onu Uchenna Lynda

Abstract: The abundance of coal in certain regions of Nigeria had been described as an alternative energy solution. The potential information obtained from the physicochemical and mineralogical characterization of coal samples in such regions has enabled scientist and government to make well informed decisions. Coal samples were obtained from Okpara Mine in Enugu state Nigeria and subjected to proximate, ultimate and mineralogical analyses. The results showed that the coal had uneven particle distribution with higher content of fixed carbon and lower amount of hydrogen and volatile matter. The mineral analyses showed that the coal was rich in silicon and aluminum. The rank was bituminous coal that can be utilized for power generation, steel industry, glass manufacturing and thermite process.

Index Terms: Bituminous coal, Mineralogical composition, Utilization

1 INTRODUCTION

THEsearch for industrial utilizations of coal and its improvement meeting energy demand is integral in coal extraction and characterization. [1]. The gasification process common used for extraction has not been without critical problems [2], while physicochemical analyses had remained paramount in characterizing coal samples and coal mine waste for utilization and hazard assessment [3]. On the other, proposals for treatment of certain industrial effluents using mineral coal ash fly ash had found useful utilization in waste treatment applications [4]. Furthermore, physicochemical analyses of several coal basins have shown that CO_2 affinity in coal is associated with coal rank and increases coal swelling capacity during adsorption of gases [5]. Similarly, pyrolysis activation energy decreases as the volatile content of coal increases on micro fluidized bed reactor [6]. Although many metals are emitted during coal combustion in power generation [7], [8], however, technologies like deashing has been noted as been efficient in reducing ash content under high slurry concentrations producing ultra low ash coal slurries [9]. Additionally, physicochemical analyses have also been applied to the assessment of air pollution around coal mining area [10], [11]. Moreover improved characterization has enabled the identification of mineral matter distribution of coals fit for various utilizations [12]. Like the mineral phases associated to coal samples and the stability of minerals (secondary) in the samples [13]. In some nations, the implementation of cumulative impact assessment of coal mining are been hindered by local or regional policies [14]. For e.g. coal development in Nigeria is moribund due to poor technology but presents capacity of medium to large scale industry [15]. Thus researches have continued to evaluate the chemistry of various coal deposits in Nigeria in order to provide information for policy makers and find various applications of the coal deposits. In the Upper Benue trough, the studies showed that the coal had good coking ability [16] and could be utilized in power generation. In some other deposits, the presence of organic sulphur, pyritic sulphur and sulphate-sulphur constituents presents a possibility of been used to manufacture synthetic chemicals [17]. Consequently, the characterization, determination of proximate and ultimate analyses, rheological properties and mineral determination [18], [19], [20] are being used by researchers as standard procedures for coal samples. Such methodologies had enabled applications of coal deposits and utilization of coal mine wastes [21], [22]. Thus studies of the physicochemical properties and sample characterization of coal sample would continuously provide information on the utilization and application of coal samples [18], [19], [20]. To this end, we would investigate the potential utilization of Enugu coal by determining the physicochemical and mineral composition of coal samples obtained from Okpara Mine in Enugu State Nigeria. Click the forward arrow in the pop-up tool bar to modify the header or footer on subsequent pages.

- *Nwoko C.I.A is a Senior Lecturer at the Department of Chemistry, Federal University of Technology Owerri, Nigeria. E-mail: nwokochristopher@yahoo.com*
- *Nkwoada A.U & Onu Uche are both currently pursuing their Ph.D at the Federal University of Technology Owerri. E-mail: chemistryfrontiers@gmail.com*

2 MATERIALS AND METHODS

1Kg Coal was obtained from Okpara mine in Enugu State Nigeria and was sun dried to remove loose moisture content and afterwards ground to fine particles. The finest size micron for analyses was obtained by passing the powder through sieves of 600, 300, 250, 212, 180 and 150µm. The obtained powder was then analyzed using American Society for Testing and Materials (ASTM) procedure for ultimate and proximate analysis. The chemical composition of the coal sample was determined using Inductively coupled plasma optical emission spectroscopy (ICP-AES. All Analyses were performed using previously published procedures for coal samples. All results reported were average values of analyses performed in triplicates [16], [18], [19], [23], [24]. The American Society for Testing and Materials (ASTM) procedures; ASTM 3286, ASTM 3175, ASTM 3174, ASTM 3173, were used for proximate analysis for determination of volatile matter, ash content and moisture content. The fixed carbon content was obtained by determining the ash percentage and subtracting the value from volatile matter and moisture content from 100 [18], [25], [26]. 1g of the Enugu coal obtained from Okpara Mine in Enugu State was passed through the 180µm sieve for ultimate analysis in an elemental determining device. The Seylers formula was employed to determine the carbon and hydrogen content of the coal sample. The Seylers formula is given below.

$$\%\,\text{Hydrogen} = 0.069\left(\frac{\text{Q}}{2.3} + \text{VM}\right)$$

$$\%\,\text{Carbon} = 0.59\left(\frac{\text{Q}}{2.3} - \frac{1.1\ \text{X VM}}{3}\right) + 43.4$$

VM and Q are the gross calorific value (MJ/Kg) and the percentage of volatile matter respectively [18], [25], [26]. Using the air-dried mass bases, the oxygen and nitrogen contents were calculated as shown below.

$$\%\,\text{Oxygen} = 100 - (\text{Carbon} + \text{Hydrogen} + \text{Nitrogen} + \text{Sulphur})\%$$

All The elemental analysis was performed using ICP-AES conducted on the parent samples after digestion. The ICP-AES analysis was used for determination of major inorganic elements present in Enugu coal samples, including the major oxides and elements present in the coal sample. A weighed sample amount of 0.2g was digested in about 12ml of 20% HCl and afterwards 4ml of 20% HNO_3. The mixture was subjected to heat at 4100C for 35mins in a controlled furnace. The samples were allowed to equilibrate and then about 50ml of de-ionized water was added. The analyses were performed at Institute of Materials, Research, Michigan Technological University, Michigan United States of America [27], [28].

3Results and Discussions

1g of coal sample was sieved through the provided six different mesh sizes. At maximum of 600µm, 0.985g fraction passed through while 0.00148 was retained. At minimum of 150um, 5g of coal was sieved. 4.485g fraction passed through while 0.500 was retained. This observation showed that decrease in mesh size would not decrease the fraction of coal powder that passed through and simultaneously affecting the cumulative weight retained. They results showed the summed values for each mesh were not approximate to initial value. Thus the coal may not ignite easily because its particle size distribution is more than 1g [29].The proximate analysis showed that the moisture content was 3.5 wt% while the ash content was 4.5 wt%. Although the lower ash content and moisture content indicated a prime coking coal, however, this coking ability can be improved by blending with some other coals to improve ignition temperature and then utilized in industries. Also the moisture content showed that the coal is at maturity level. The higher wt % of fixed carbon at 70% was compensated by % lower volatile matter at 22 %. Again depicting a coal with good coking property but carbonizes at lower pressure during carbonization leaving behind large mass of carbon after combustion [16], [19]. The results obtained from ultimate analyses showed that wt % of Nitrogen and Oxygen was determined to be 1.2 % each. It can be deduced that the coal would emit lower levels of NOx pollutants during combustion. In addition, the low oxygen amount indicated that high calorific value and low moisture content, a pointer of a good quality coal. The sulphur amount was 0.5%. Thus, depicts characteristic of a coal that would emit low concentrations of SO_2 and SO_3 gases. The hydrogen content was determined to be 2.5% while the carbon was as high as 77.2%. The higher carbon indicated high calorific value while a combination of high carbon and low oxygen as was obtained showed that the coal was a fine quality coal (rank) that would easily form coke residue [16], [19].Different groups of elements with their oxides were identified using ICP-AES. The percentage of silicon oxide was highest at 61.0%. Next to it was aluminum oxide at 32.0%. The sodium oxide percentage was 7.2%, iron oxide was 4.2%, while magnesium was 1.2%. The amount of calcium oxide was 0.8%, potassium oxide 1.0%, and sulphur oxide 0.8% while phosphorus was not detected. The result of sodium, iron and aluminum indicated that the level of maturity of the coal was still in sub-bituminous form. Moreover at this development stage, some of its mineral can be extracted because of their volume by weight percent.

4Conclusions

As In conclusion, the results showed that the hard black coal obtained from Okpara Mine in Enugu state, Nigeria would be placed around medium volatile bituminous coal and low volatile bituminous coal. It would be confirmed that in such coal samples, the calorific value simultaneously increases along with the carbon content and volatile matter. Thus we concluded that our coal sample was a high rank coal (low moisture content and high fixed carbon) that can be utilized in gasification for power generation and steel industry uses. The coal can also serve other synthetic industries for production of silicon and aluminum for thermite process and glass manufacturing.

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