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Mineralogical and Physicochemical Assessment of Ihioma Coal in Imo State of Nigeria

Nwoko C.I.A, Onyedika G.O, Nkwoada A.U, Anyanwu G.C
(Department of Chemistry,School of Physical Sciences/ Federal University of Technology Owerri, Nigeria.

Abstract: *The physicochemical characterization of coal samples from deposits provides mineral distribution and composition data for utilization by scientists and policy makers. The characterization of coal samples of Ihioma coal deposits in Imo state, Nigeria was performed using proximate and ultimate analyses. XRD and ICP-AES were used to characterize the coal samples for potential energy utilization. Proximate analyse determined fixed carbon content and volatile matter to be 51.5% and 38.5% respectively, an indication of a good coking material. The carbon % in the ultimate analyses was at 64.6% while O_2, H_2, N_2 and S were all below 5% which showed the coal potential to emit lower emissions. ICP-AES chemical composition determined SiO_2 to be the most abundant followed by Na_2O. The XRD peaks classified Ihioma coal as having Quartz, Albite and Haematite. Material mapping by XRD showed that Al and Si were evenly distributed while S, Co and Fe were unevenly distributed. Thus Ihioma coal has features of ignition and can undergo spontaneous combustion, hence a good source of thermal energy. Results also confirmed Ihioma coal as a potential material for pigments and can be utilized for ceramics, pottery and ornamentals.*

Keywords: *Coal, characterization, mineral composition, physicochemical properties*

I. Introduction

The characterization and physicochemical assessment of coal has remained an integral part of sustainable management of coal basins and its cumulative impact [1, 2]. The physical and chemical characterization of coal samples from such deposits provides mineral distribution and composition data for scientists and policy makers [3, 4, 5] and efforts are constantly being made to forecast and optimize mineral compositions [6, 7]. Sometimes, accuracies of up to 96% have been achieved [8]. The results obtained, can then be used to advice scientists and policy makers accordingly [9, 10]. On the other hand, interpretation of the analyses would evaluate the suitability of such coal mines for proposed mining activities and determine the environmental impact [11]. For example, the waste from coal mines can cause acid drainages; release of abundant bio-accumulative metals that contaminate water bodies, and promote the transformation of air pollutants into a more aggressive pollutants like methane [12]. In addition, certain trace metals (As, Mn, Ni, V, Zn) that are potentially hazardous are often emitted into the atmosphere during coal mining activities [13]. Moreover, these named trace metals significantly increase the temperature of waste fire from coal mines [14]. Consequently, the production and proper disposal of coal ash is inevitable [15], which may lead to expensive reclamation of waste dump if abandoned for a long time [16]. Thus the physical and chemical assessment of coal deposits should be performed in order to characterize and utilize them in a way to reduce waste mines from coal deposits [14, 15, 16]. In Nigeria, coal development is a potential alternative energy mix for improved electricity grid, but the nation lacks the technological capacity for large scale production. However, local mining activities seem to revive the industry on a low key in areas where there are large deposits [17, 18, 19]. Moreover several authors have characterized different coal samples for its economic and energy value, giving us reason for further research. Thus investigating the physical and chemical properties of coal, and sample characterization would continuously elucidate the characteristics of deposits and possible utilization of such coal deposits [20, 21, 22, 23]. With this in mind, we would determine the mineral composition of coal samples from Ihioma coal in Imo state; a south-east geopolitical zone of Nigeria. Proximate and ultimate analyses were also performed to characterize the coal samples for utilization.

II. Materials And Method

2Kg of Ihioma Coal were obtained from Orlu in Imo state Nigeria and were air dried to remove loose moisture content and was ground to a fine powder. The powder was then sieved through a 600, 300, 250, 212, 180 and 150µm test sieves to obtain the finest size micron for analysis. The powdery coal was then analyzed using ASTM approach for proximate and ultimate analysis. Statistical evaluation was also performed. The chemical composition was determined using XRF and mineral distribution using XRD. All Analyses were based on previously reported procedures for coal analyses [3, 19, 20, 21, 23]. Further accuracy was obtained by performing each analysis in triplicates and only average values were reported.

Proximate analysis

The proximate analysis was determined using American Society for testing and Materials; ASTM 3286, ASTM 3175, ASTM 3174, ASTM 3173 for volatile matter, ash content and moisture content. The fixed carbon content was determined by calculating the ash percentage and subtracting it from volatile matter and moisture content from 100 [24, 25].

Ultimate analysis

2g of the sample was passed through the 180um sieve for ultimate analysis in an elemental determining device. The determination of carbon and hydrogen contents was done using Seylers formulae. The Seylers formulae are expressed below in equation 1 and 2.

$$\%\, Hydrogen = 0.069\left(\frac{Q}{2.3} + VM\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\%\, Carbon = 0.59\left(\frac{Q}{2.3} - \frac{1.1\, X\, VM}{3}\right) + 43.4 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Q and VM are the gross calorific value (MJ/Kg) and percentage of volatile matter respectively. The oxygen and nitrogen contents were calculated on air-dried mass bases using equation 3 below.[24, 25].

$$\%\, Oxygen = 100 - (Carbon + Hydrogen + Nitrogen + Sulphur)\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

ICP-AES Analyses

The determination of chemical composition was performed using ICP-AES studies conducted on the parent samples after ashing. The ICP-AES technique used for determination of major inorganic elements present in coal was employed [3]. The analyses were to determine the major oxides present and the results are reported in Table 4

XRD Analysis

The powdered coal obtained from 180µm was fired at 1000oC for 2 hours and the ash obtained was analyzed using XRD at Step 0.020, Cnt Time was 0.600 Seconds, Range at 5.00-60 (degree) and scan rate was 2.00 Deg/Min.

III. Results And Discussions

The 6 different mesh sizes chosen were used to filter 1 gram of coal (powder) sample. The Table 1 below showed that as the mesh size decreased the fraction of coal powder that passed through the sieve reduced considerably. On the other hand, the cumulative weight retained increased.

Table 1: Particle size distribution of Ihioma Coal

MESH SIZE (µm)	WEIGHT FRACTION RETAINED (g)	WEIGHT FRACTION PASSED (g)
600	0.161	0.839
300	0.563	0.437
250	0.70	0.299
212	0.767	0.233
180	0.767	0.233
150	0.832	0.168

Particle size distribution of Ihioma coal shows that the summed values were approximately 1%. Similar work had identified such property as having good ignition value and easily combustible [26]. Thus the particle distribution within the coal samples suggests that oxidation reaction (combustion) would experience faster kinetics; an indication of good thermal energy potential

Proximate analysis

The Ihioma coal exhibited low ash content of 4.0% as shown in Table 2 below. This puts the coal in the class of prime coking coals and thus research has confirmed that enhancement of cokability of such coal samples by blending with some other Nigeria coal like Enugu and Lafia-Obi coal [21]. Thus the lower ash content confirmed that Ihioma coal would find more usefulness as a fossil fuel example in the steel industry. This tied a correlation as having good ignition temperature due to its fine particle size.

Table 2: Proximate analysis of Ihioma Coal.

Coal Sample (%)	Moisture content	Ash content	Volatile Matter	Fixed carbon
Ihioma Coal	6.0	4.0	38.5	51.5

The moisture content was determined to be very low at 6.0%, an indication that the coal is of high rank and a good coking coal. This puts the Ihioma coal as high energy generating ore due to low moisture content. The volatile matter was 38.5%, a near optimum value for coking characteristics. Thus volatile organic matters are they portions lost during carbonization and mainly consist of gases (H_2, N_2, O_2, N_2 and S). They would normally escape as tar or oxides during carbonization. Hence Ihioma coal is a high volatile coal sample and would generate high pressure during carbonization; thus a high rank coal. The fixed carbon content was the highest at 51%. The fixed carbon content also determines the rank and quality of coal. The high value depicts good coking properties since it is the mass left behind after volatile materials had escaped (after carbonization), therefore more carbon will be available after carbonization and Ihioma coal is a good coking material [21, 23].

Ultimate Analyses

Carbon and hydrogen proximate determination gave high percentage content as depicted in table 3 below. While nitrogen and oxygen had low values during this elemental analysis. The values of 64.6% and 4.0% values obtained for carbon and hydrogen respectively and are significantly related to the maturity (rank). The carbon and hydrogen content are used in classification of coal. Thus higher carbon content depicts corresponding high calorific value and fine quality of the coal while hydrogen can be related to its volatile matter

Table 3: Ultimate analyses of Ihioma coal

Parameter (%)	Oxygen	Hydrogen	Nitrogen	Carbon	Sulphur
Ihioma Coal	2.0	4.0	1.1	64.6	0.3

The 1.1% value of Nitrogen indicated the environmental friendliness of this coal (fuel) because it is relative to potential emission of NOx pollutants. Sulphur content was very low at 0.3% showing a reduced percentage quantity. Thus low SO_2 and SO_3 will be emitted during combustion, an indication of potential less corrosion damaging effect. The low oxygen content depicts that the coal is of good quality because on the contrary, high oxygen content would indicate low coking power, high moisture content and low calorific value. The carbon content was high and that showed that it could easily form coke residue [21, 23].

ICP-AES Analyses

The groups of mineral obtained in the coal samples are listed in Table 4. The results of these analyses are shown in no particular order: It indicated that silicon and sodium have 20.5% and 6.6% values respectively higher than the other minerals obtained from the coal sample. The other minerals were in trace amount. It depicts that Ihioma Coal had not reached maturation the other mineral constituents are not evenly distributed.

Table 4: Chemical compositions of the studied sample by ICP-AES

Chemical Compositions	CaO	Na_2O	K_2O	Fe_2O_3	SO_2	Al_2O_3	MgO	SiO_2	P_2O_4
Wt (%)									
Ihioma Coal	0.08	6.6	0.05	0.85	0.3	0.43	0.08	20.5	0.0007

XRD Analysis

The scans of XRD results are shown in fig 1. The sub figure A showed the absorption spectra of x-ray radiation by Ihioma coal. Four major peaks were identified and labeled as A, H, Q and X in sub figure B. Instrumental analyses showed that the A consist of Albite fragments, H consist of Hematite, Q showed Quartz and X is the suspect phase. The sub figure C revealed the presence of Fe, S, and Al detected at those peaks. Sub figure D showed the x-ray mapping and distribution of elements present in the sample. Al, Si atomic distributions were observed along the x-ray mapping with dark strips while S, Co, Fe were not evenly distributed

IV. Conclusion

The fineness of the particle size of Ihioma coal showed that the particle size are well distributed and such coal samples are often characterized by good ignition property and easily undergo oxidation (combustion). Fixed carbon had the highest percentage in proximate analyses an indication of coking material while the ultimate analyses showed the potential to form less oxidized pollutants and large proportion of coke residue. ICP-AES analysis confirmed a larger proportion of SiO_2 to more abundant than other oxides. The XRD layered coal structure confirmed that coalification of Ihioma coal was not complete hence the predominant lignite stage. The XRD analyses further identified Hematite as its major mineral which is mostly reddish and brown in colour

and slight amount of iron used as pigmentation for paints, glazes, facial and body decoration. Quartz which is colorless with black brownish parts was also determined. It provides resistance to weathering, enhances energy amplification and signal transmissions. While Albite present in the coal and shown as sodium aluminum silicate appears white or colorless, cream or light yellow, light brown used in manufacture of ceramics, pottery, and manufacture of ornamental stones. Furthermore, in order to achieve clean coal technology devoid of sulphur dioxide emission, the sulphur content can be apparently removed from the coal by adopting the method advanced by Nwoko et al [27] in their recent work.

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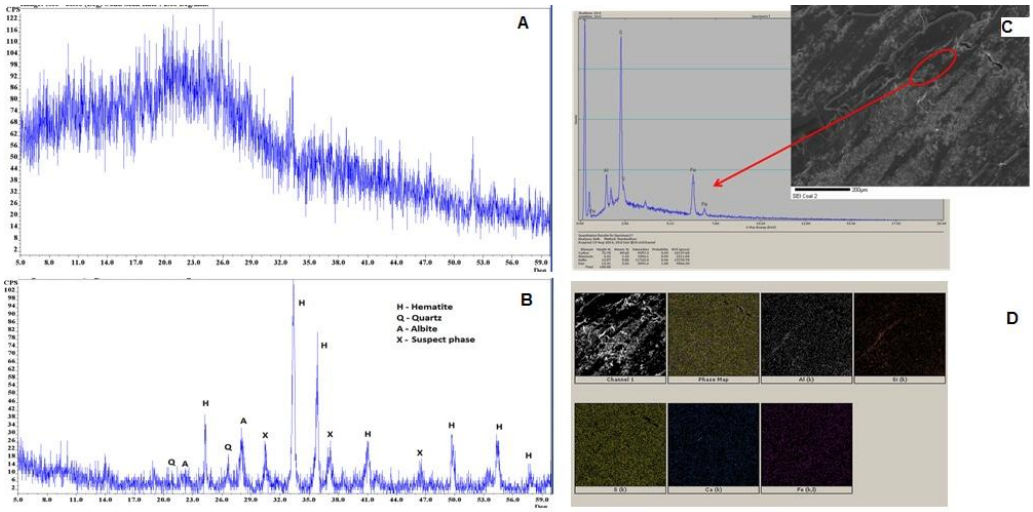

Fig1: *XRD Scans of Ihioma coal. (A) XRD image of sample. (B) XRD scan showing elemental chemical composition of coal. (C) Dark strip composition of sample showing metals and non metals. (D) X-Ray Mapping Of Coal Showing: Al, Si Distributed Along With The Dark Strips, But S, Ca, and Fe was not distribute*