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Chemistry of Maiganga Coal Deposit, Upper Benue Trough, North Eastern Nigeria

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Abstract Chemical studies have been carried out on coal samples from Maiganga coal mine, Gombe formation, Upper Benue Trough of Nigeria with a view to determine theirchemical characteristics and possible utilization as coking coal or otherwise. The coal samples used for the analyses were sourced from the Maiganga coal mine. Various conventional coal analytical methods were adopted according to the relevant ASTMs. Chemical analysis of the coal samples indicated that, on average, they contain4.8% moisture, 49% ash, 31.11% volatile matter, 0.92% sulphur, 15.64% organic carbon, 0.02% phosphorus, 2283Kj/kg calorific value and 0(zero) Free Swelling Index(FSI). The above analytical results show that the coals show an appreciable property of coking and thus can be employed in the generation of substantial heat for the working of blast furnace.

Keywords: *coal, Maiganga, free swelling index, Gombe, coke*

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1. Introduction

Coal is an organic sedimentary rock that contains varying amounts of carbon, hydrogen, nitrogen, oxygen and sulfur as well as trace amounts of other elements, including mineral matter (James, 2005). Coal is a solid, brittle, combustible, carbonaceous rock formed by the decomposition and alteration of vegetation by compaction, temperature and pressure. It varies in color from brown to black and is usually stratified. Coal deposits, usually called beds or seams, can range from fractions of an inch to hundreds of feet in thickness. Coals are found in all geologic periods from Silurian through Quaternary, but the earliest commercially important coals are found in rocks of Mississippian age (Carboniferous in Europe). Coals generally formed either in basin in fluvial environments or in basins open to marine incursions. Coal is found on every continent and world coal reserves exceed 1 trillion tons.

Coal consists of more than 50% by weight and more than 70% by volume of carbonaceous material (including inherent moisture) (James, 2005). It is used primarily as a solid fuel to produce heat by burning. Coal exists, or is classified, as various types, and each type has distinctly different properties from the other types.

Anthracite, the highest rank of coal, is used primarily for residential and commercial space heating. It is hard, brittle and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter.

Bituminous coal is a dense coal, usually black, sometime dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke.

Subbituminous coal is coal whose properties range from those of lignite to those of bituminous coal, used primarily as fuel for steam-electric power generation. It may be dull, dark brown to black, and soft and crumbly at the lower end of the range, to bright, black, hard, and relatively strong at the upper end.

Lignite is the lowest rank of coal, often referred to as brown coal, used almost exclusively as fuel for steam-electric power generation. It is brownish black and has high inherent moisture content.

Nigeria’s coal reserves are in excess of 1.2 billion tones of proven, indicated and inferred categories (Famuboni, 1996). Despite the above fact, not much of the county’s coal has been useful as a coking coal. Thus, there is need for targeted research on the cokability or otherwise to be carried out on the Nigerian's coal deposit that will indicate which deposit have coking characteristics or otherwise.

This research has been undertaken to examine the chemical characteristics of Maiganga coal deposit in order to elucidate on its best application in terms of cokability.

The study area covers Maiganga Coal deposit, located at Maiganga village in Akko Local Government Area of Gombe state. The Maiganga coal mine is located at 8 km off Gombe-Yola road immediately after Kumo town (Figure 1).

The present study area is located within the Gombe Formation, precisely at Maiganga coal mine, near Kumo in Akko LGA.

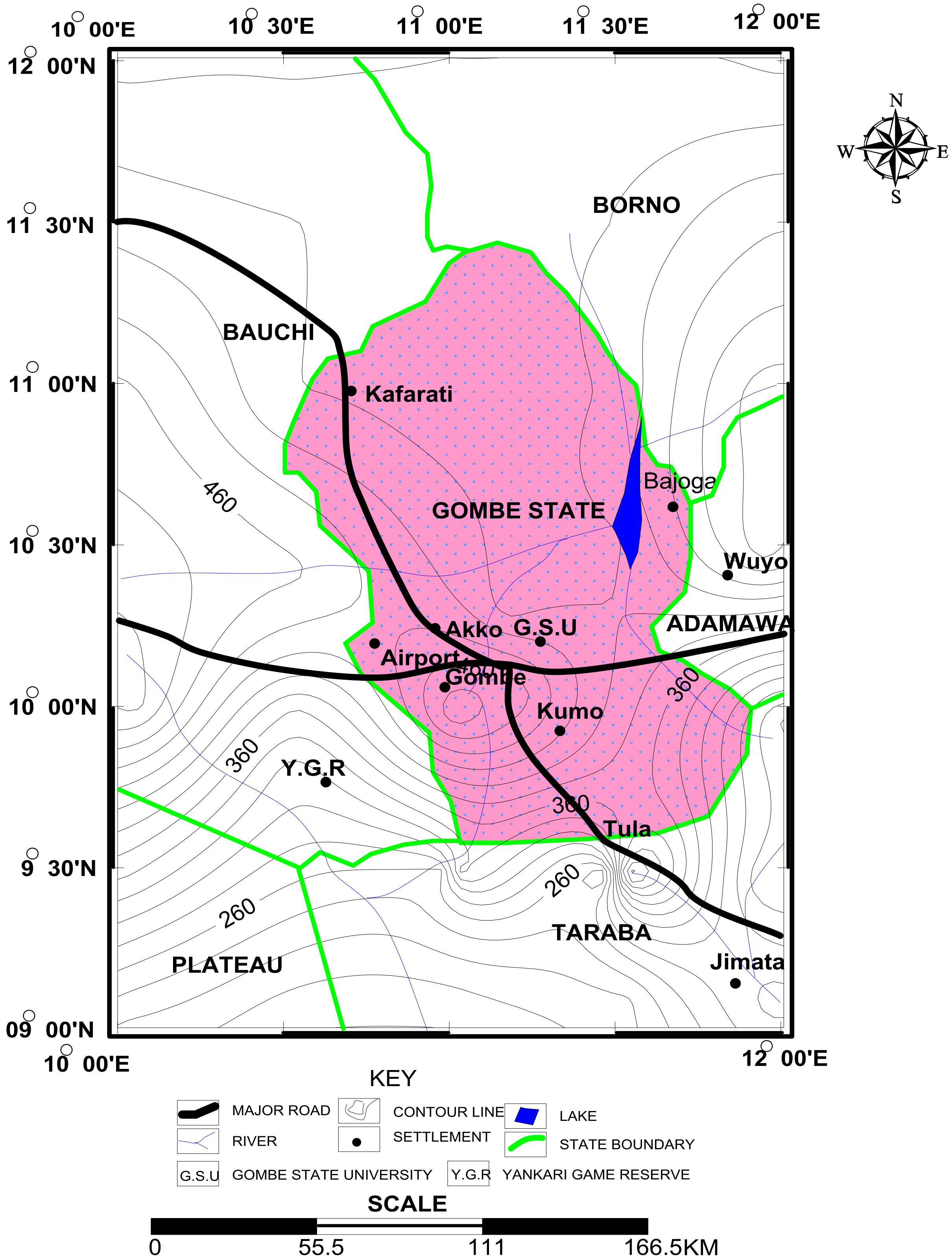

Figure 1. Location map of Maiganga coal mine

2. Materials and Methods

The methodology employed in this study included fieldworkfor samples collection and the various analytical methods involved in the coal analysis according to the relevant ASTMs which constitute the laboratory work.

The equipment used for the field work included a geological hammer, geological map, compass clinometers, sample bags and field note book.

The coal samples used for the various chemical tests were obtained from Maiganga coal mine. A total of 10 samples were taken from the mine for the various analyses. The samples were carefully labeled and bagged after some detailed macroscopical examinations were carried out on them and appropriately recorded in a field notebook. The carefully bagged samples were then taken for various chemical analyses, including proximate and ultimate analyses. The chemical analyses were carried out at the

National Metallurgical Development Council (NMDC), Jos, Nigeria.

A 1kg weight of each sample of the coal was grounded to pass a 210 micron test sieve and the powdery coal used for various analyses according the various American Standards for Testing Materials (ASTM) adopted from Afonja, 1974.

2.1. Fixed Carbon Determination

A 1gm sample taken from the coal ground to pass a 0.2mm test sieve was burnt in a three-stage Lieberg furnace in a current of oxygen. The carbon dioxide and water formed were absorbed by soda asbestos and magnesium per chlorate respectively, and determined gravimetrically to ascertain the level of carbon contents.

2.2. Moisture Determination

The moisture content was determined by drying a 1gm coal sample in a minimum free space oven at 110℃ for four hours in an atmosphere of nitrogen. The sample was then cooled in a desicator in an atmosphere of nitrogen and weighed. This process was repeated until a consistent weight of the coal sample was achieved. The difference in the original weight of the coal sample and the weight of the dry coal sample gave the weight of the moisture content and usually expressed in percentage.

2.3. Ash Content Determination

The ash content was determined by incinerating a 1gm coal sample in a special furnace at 815^oC, the heating program being in accordance with BS 1016 Part 3 specifications. The sample was then cooled in a desicator, weighed and re-incinerated until the weight became consistent. The difference in the initial weight and the final weight of the coal sample gave the ash content.

2.4. Determination of Volatile Matter

1gm of the crushed coal sample was heated in minimum air at 900℃ for seven (7) minutes. The heated sample was then cooled in a desicator and weighed. This process was repeated until a consistent weight of the sample was achieved.

2.5. Sulphur Determination

The sulphur content was determined by mixing a 1gm sample of coal of 0.2mm particle size with Eschka mixture and heated until all the sulphur was converted to sulphate. The resultant sulphate solution was then extracted and determined gravimetrically by precipitation with barium chloride. Eschka mixture refers to a mixture of either K_2CO_3 or Na_2CO_3 and magnesia but in this study Na_2CO_3 (sodium carbonate) was used. The nature of the sulphur analysed in the coal was determined by boiling a 5gm sample of coal with dilute hydrochloric acid to bring the sulphate sulphur and non-pyritic iron into solution and filtered. The filtrate was then made alkaline to precipitate the non-pyritic iron which was then removed by filtration. The sulphate sulphur was precipitated from the filtrate as barium sulphate and determined gravimetrically. The difference between the total sulphur and sum of the pyretic sulphur and sulphate sulphur was computed as the organic sulphur. This is illustrated in the formular: $S_{org} = S_{total} - (S_{sulphate} + S_{pyrite})$.

2.6. Determination of Free Swelling Index (FSI)

To determine the FSI, a 1gm finely crushed sample of the coal was placed in a crucible without appreciable packaging, and heated under carefully controlled conditions of temperature and pressure. This made the coal to soften and the particles fused. The coal mass then swell and re-solidified to resemble a very porous mass of coke, which is light and much larger in volume than the original coal sample. The swelling index was then analyzed by simply comparing the shape of the residue of the swollen coal with a series of standard samples provided in the analytical laboratory.

2.7. Phosphorus Determination

Phosphorus was determined by treating 1gm of the coal ash with a hot mixture of HNO_3, H_2SO_4 and HF acids. This volatilized the silica and dissolved the phosphorus to precipitate a complex phospho-molybdate from which the phosphorus content was estimated.

3. Results and Discussion

The results of the analyses are shown in Table 1 and Table 2 below.

Table 1. proximate characteristics of Maiganga coal

Sample nos	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9	MC10	AVERAGE
Moisture content(%)	4.00	4.10	4.60	4.50	4.20	4.00	4.60	4.50	3.90	3.92	4.18
Ash content(%)	49.21	48.23	48.87	48.80	49.80	49.21	49.25	48.91	49.55	48.89	49.00
Volatile matter(%)	31.04	30.12	31.12	31.15	31.22	31.04	33.11	30.58	31.84	30.00	31.11

Table 2. Ultimate characteristics of Maiganga coal

Sample nos	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9	MC10	AVERAGE
Fixed carbon content(%)	15.74	15.72	16.00	15.15	15.69	15.55	15.89	15.66	15.34	15.33	15.64
Sulphur	0.94	0.94	0.87	0.92	0.91	0.87	0.88	0.99	0.94	0.30	0.92
Phosphorous	0.02	0.02	0.87	0.92	0.91	0.87	0.88	0.99	0.94	0.30	0.92
Calorific value(ThU/g	2282	2295	2151	2252	2451	2252	2211	2202	2283	2449	2283
Free Swelling Index(FSI)	0	0	0	0	0	0	0	0	0	0	0

3.1. Physical Properties of the Coals

Maiganga coal in hand specimen is dark,massive, hard, dull-black to grayish black. It possesses perfect basal cleavage, concoidal fracture and shows elements of brittleness.

3.2. Effect of Ash Content

The Maiganga coal contains a relatively high ash (49.00%) as compared to the low ash value required for prime coking coals. Some imported coking coals (e.g. Bellview and Agro-Allied), which are to be blended with some Nigerian coals (e.g. Enugu and Lafia-Obi) for their cokability enhancement, contain 6.13% and 9.62% ash respectively (Wessiepe, 1992). This puts Maiganga coal at a disadvantage in terms of usage as a coking coal even on blending with some other coking coal since ash content is undesirable as far as coal utilization is concerned.

High ash content in coals give rises to a high slag volume and low blast furnace efficiency. High ash also results in high coke rate, which is a consequence of accelerated oxidation of coke by carbon dioxide and oxygen due to the catalytic activities of the metallic oxides in the ash. The high ash content is also an indication of low degree of coalification and hence immaturity of the coal.

The lower the ash content of a coal, the better is its application as a source of fossil fuel especially in the steel industry (Wessiepe, 1992). However, coking coal with ash content up to 20% are being used for smelting iron in some parts of the world (Afonja, 1974). In such cases, coke and flux consumption per ton of pig iron produced is relatively high. It is possible and advisable that the ash content of Maiganga coal be reduced considerably by washing.

3.3. Effect of Moisture Content

The Maiganga coal contains an average of 4.18% moisture and this is considered to be optimum for a coking coal. The low moisture content is an indication that the coal is of high rank, possibly the rank of bituminous grade. It can also be inferred that the coal has experienced sufficiently deep burial to warrant enough transformation at the phase of catagenesis during which an appreciable part of the moisture would have been lost. In terms of usage, the coal may be suitable for high-energy generation or the blast furnace due to its low moisture content. When compared with some imported coking coal e.g. Bellview and Agro-Allied coals, its moisture value is high. Bellview has a moisture content of 0.58% while Agro-Allied has 1.62% and both coals are good coking coals intended to be blended with Enugu and Lafia-Obi coals, to enhance their cokability (Adebayo, 2002 – Personal Communication).

3.4. Volatile Matter

Maiganga coal has an average of37.11% volatile matter which is considered near optimum value and this is an indication of the maturity of the coaland will likely have an appreciable coking characteristics. Coking coals normally have a volatile matter content of between 20 and 32 percent (Afonja, 1974).

Volatile matters are components of coal that are lost in the form of gases and vapor on carbonization. These include hydrogen, oxygen, nitrogen, sulphur, phosphorus and carbon. The percentage of the volatile matter given off by a coal on carbonization is directly related to the amount of the above mentioned elements contained in a coal.The elements that constitute the volatile matters are given off in the form of HO_2, CO, CHO_4, and NO_2 etc.

3.5. Effect of Sulphur Content

The sulphur content of Maiganga coal is relatively low (average value of 0.92%). This puts the coal at an advantage in this regard both in terms of usage as a fossil fuel and environmental consideration. High sulphur contents is undesirable in steel and coking coal because it promotes the formation of insoluble iron sulphides during iron making causing brittleness of the iron produced. The formation of di- and tri- sulphur oxide during coal carbonization which gives rise to sulphuric acid that causes industrial fumes will be highly minimal due to the low content of sulphur in the coal.

3.6. Implication of Carbon Content

The average carbon content of the Maiganga coal was found to be15.64% and this was considered low. The swelling index of 0 shows that Maiganga coal has very low agglomerating characteristics. The phosphorus contentis relatively low (0.02%). This places the coal at an advantage in terms of usage either as coking or non-coking coal since the environment will be less polluted as consequence of burning the coal.

3.7. Possible Uses of Maiganga Coal

Based on the analyzed properties of the coal, the coal is considered suitable for coking coal. The coal can however be used as fossils fuels in rail locomotives, steam boat and for electric generation.

The coal can equally be processed to smokeless briquette for domestic purposes e.g. home warming, cooking, etc. This will reduce the desertification problem caused by deforestation by firewood sourcing. It can also be used in the production of calcium carbide a raw material for the manufacture of acetylene.

4. Conclusion

The study has shown that Maiganga coal, in the light of the analyzed chemical parameters, is a low volatile, low ash, bituminouscoking coal. This means that the coal can be employed in the firing of blast furnaces for the generation of heat.

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