Petroleum and Coal

Article **Open Access**

PRODUCTION OF ACTIVATED CARBON FROM A LOW GRADE COAL

B. S. Yahaya[1*], J. O.Akinyeye[2], I. C. Egbuna[1]

[1] Engineering Materials Research Department, Nigerian Building and Road Research Institute
[2] Science Laboratory and Technology Research Department, Nigerian Building and Road Research Institute, Km 10 Idiroko Road, Ota, Ogun State, Nigeria

Received July 18, 2016; Accepted September 30, 2016

Abstract

Nigeria is endowed with a large deposit of non-coking coal; this vast reserve of coal has not been exploited for the production of useful carbon products such as coke, graphite and activated carbon. This research work is therefore designed to obtain process parameters for the production of activated carbon from the large deposit of non-coking coal in Nigeria. The result obtained showed that the ash and sulphur content of the coal were reduced by 32% and 90% respectively. The test conducted on the activated carbon shows that its sulphur and ash content meant the required standard. It has a bulk density of 0.8g/mL^3; making it suitable for purification test. The success of this research has proven that the abundant of non-coking coal reserve in Nigeria can be fully utilized in the production of activated carbon that can be utilized both domestically and industrially.

Keywords: Coal; Activated Carbon; Sulphur; Ash; Purification; Analysis.

1. Introduction

Coal is a fossil fuel. It is a combustible, sedimentary, organic rock, which is composed mainly of carbon, hydrogen and oxygen [1]. It is formed from vegetation, which has been consolidated between other rock strata and altered by the combined effects of pressure and heat over millions of years to form coal seams [2]. It has been estimated that there are over 909 billion tons of proven coal reserve in the world. In Nigeria, coal is found in Enugu, Onyeama, Okaba, Lafia, Ezimo and Akpunje just to mention a few [3], with an approximated estimate of proven reserve of over 257 million tons and inferred reserve of over 820 million tons [4] as shown in Table 1 below.

Table 1. Status of Nigeria coals [4]

Coal location	Proven reserves (mil. Tons)	Inferred reserves (mil. Tons)
Enugu	54	250
Okaba	74	250
Ogboyega	107	320
Lafia-Obi	22	unknown

Coal has found applications in different areas of lives, both domestically and industrially. The most significant uses are in electricity generation, steel production, cement manufacturing, production of activated carbon and other processes, and as a liquid fuel. The variable and heterogenic nature of coal determines its grade, coals are considered to be of low grade when they have a high content of ash, moisture or sulfur. Such coals usually have a heating power below 16 MJ/kg (3822 kcal/kg). Because these coals have a low energy content, their use is limited to the vicinity of their mines in order to minimize transportation costs. Typically they are used in run-of-the mine thermoelectric plants [5].

The importance and relevance of activated carbon to an ever growing society cannot be overemphasized considering its enormous uses. Its uses range from liquid phase to gaseous phase applications. Activated carbons are highly porous and adsorbent materials. Activated carbon is a black carbon material obtained by activating various materials containing high levels of carbon, including coal, wood, coconut shells etc., by heating in the presence of steam or carbon dioxide. Various form of work have been carried out on the production of activated carbon from different forms of carbon rich materials such as coconut shell, coal, oil palm empty fruit bunches, wood and vegetables, grain hulls, corn cobs and nut shells etc. The obtained active-ted carbon from these different sources have been tested in different media such as the removal of zinc from waste water, removal of offensive odour from industrial waste water, removal of odour from drinking water, air treatment, production of cloth for wound treatment *etc*. [5-10]. In the food industry, activated carbon is used in de-colorization, deodorization and taste removal. It is used to remove heavy metals and organic contaminants from liquids. Activated carbon is used in water de-chlorination and processing of foods. It is also used in medicine for adsorption of harmful chemicals and drugs. In gas cleaning applications, activated carbon is extensively used in air filters at industrial level as well as in general air conditioning application [11-15].

Nigeria is blessed with vast coal deposits. Some of these coal deposits are in Enugu, Ezimo, Okaba and Lafia/Obi. None of Nigeria coals have been fully utilized in the production of activated carbon which is a major material in water treatment and other purification processes. The desire to develop an activated carbon was borne out of the need to develop indigenous technological innovations in the production of activated carbon.

2. Methodology

The coal that was employed for this research work was sources locally from Okaba in Kogi State, Nigeria at the Nigerian Mining Corporation (NMC) open pit mine at seams number 2 and 3 from a depth of 10m to 15m down the threshold. 15kg of the bulk sample was used for this research.

The size reduction of the as-received Okaba coal lumps was accomplished using a pulverizing machine which was made use of machine action involving impact, compression, splitting, shearing, and attrition usually in a combination of two or three forces and in several stages. The crushed coal, which was carried out in two different stages i.e. primary crushing which involve the use of the grinder and the secondary crushing that involve the use of pulveriser, was then collected and taken for sieve analysis.

2.1. Particle size distribution analysis

Particle size distribution analysis was carried out on the sample collected; the coal sample was crushed and pulverized for further processing. The sizing of the crushed coal sample was carried out by using an automated sieve shaker. The sieve surface was made up of parallel bars. The sieves were arranged in the order of decreasing mesh sizes with the sieve with largest mesh size at the top. The mesh sizes employed were 1.4mm, 1mm, 850, 600, 500, 300, 250, 125, 106 and 63 µm. A representative sample of 172g was measured from the crushed coal sample and was poured into the sieves. The stack of sieves was subjected to the vibratory action of the sieve shaker for about an hour. The coal sample retained on each sieve was then weighed in order to determine the particle size distribution of the coal and the result recorded.

2.2. Determination of the physical properties

The physical properties of the coal sample was determined and recorded. The equilibrium moisture content and the total moisture content, ash content, sulphur content, volatile matter and the fixed carbon content were all determined according to [5].

2.3. Froth flotation upgrading of the coal

The upgrading of the coal sample is required in other to improve the performance of the properties of the coal sample and makes it more suitable for the production of activated carbon. The upgrading is achieved by employing froth flotation principle as described by [5]. The properties of the upgraded coal were also recorded.

2.4. Activation of Okaba coal

The activation of Okaba coal was achieved by mixing 2g of the upgraded coal sample with 7.5g of potassium chloride (KCl). 5.0g of the activating agent was thoroughly mixed with the coal (upgraded coal) sample and the remaining 2.5g was added to cover the surface of the coal. The mixture was introduced into a furnace at 800^{0}C for 5mins after which they were quenched with cold water, washed with distilled water and allowed to dry at room temperature. The activated carbon (AC) sample was stored in a sealed air tight polythene bags. The KCl helps to activate the coal sample by increasing the pore size for adsorption purpose also prevent/reduce the rate of oxidation of Okaba Coal in the furnace at the activating temperature of 800^{0}C.

2.5. Purification test

The purification test was carried out to determine the effectiveness of the produced activeted carbon in the water treatment and most especially, its ability to remove heavy metals such as zinc, lead, mercury, etc., from water. 1g of the heavy metal of interest (zinc and lead) was dissolved in 500mL of distill water. The mixture was passed through untreated Okaba coal and treated (activated) Okaba coal, the collected treated water was taken for further analysis.

3. Results and discussion

Figure 1 shows the particle size distribution analysis of Okaba coal at A to K size ranges corresponding to +1.4, -1.4+1 mm, -850+600, -600+500, -500+300, -300+250, -250+125, -125+106, -106+63 and -63 µm, respectively. The results obtained shows that after primary and secondary crushing the mesh size H (-250+125 µm) has the highest weight fraction of 28.8% of the total fraction, followed by the mesh size F (-500+300) with 22.4% of the total weight. The results thus show that about half of the coal material is contained in the two relatively coarse size ranges. The results suggest that Okaba coal has a low grindability being somewhat resistant to crushing and grinding due to the geology of its formation [5].

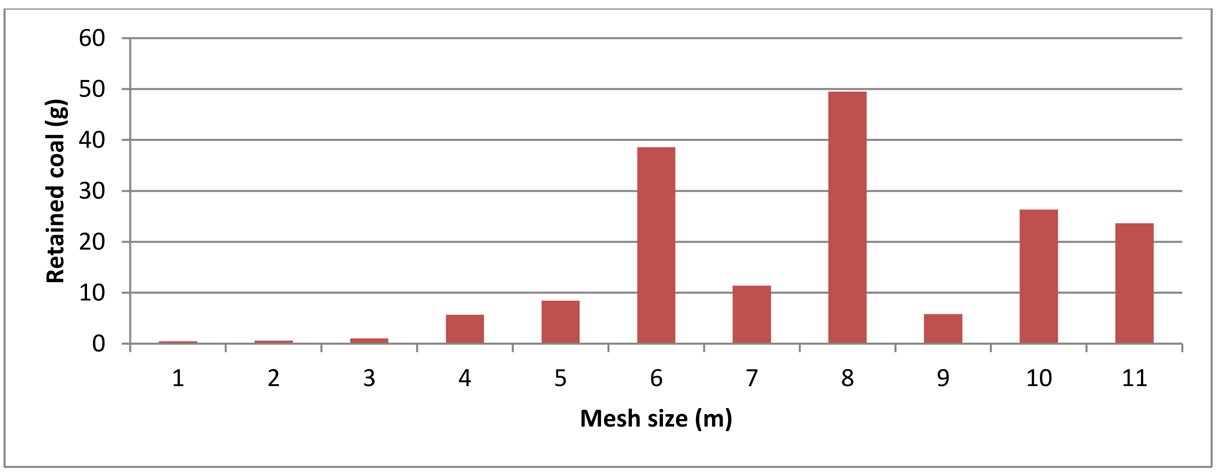

Fig. 1. Particle size distribution of Okaba coal

The reduction in the sulphur content and ash content of the upgraded coal by 90% and 43.25% respectively shows the effectiveness of froth flotation in upgrading low grade coal as it can be seen in Table 2. It can also be proven from the pore size of the activated carbon that there was great increase in the pore size compare to the untreated coal which will help in the adsorption process. The physiochemical properties of the activated carbon show a great improvement in the properties and met the required property of an effective activated carbon with a bulk density of 0.8g/mL3.

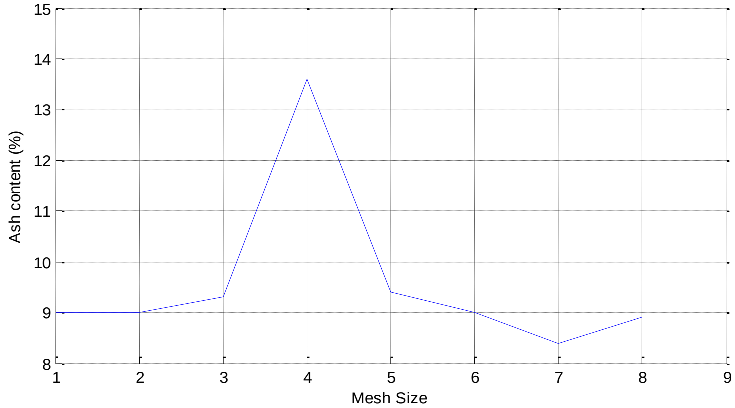

Fig. 2. Ash content distribution

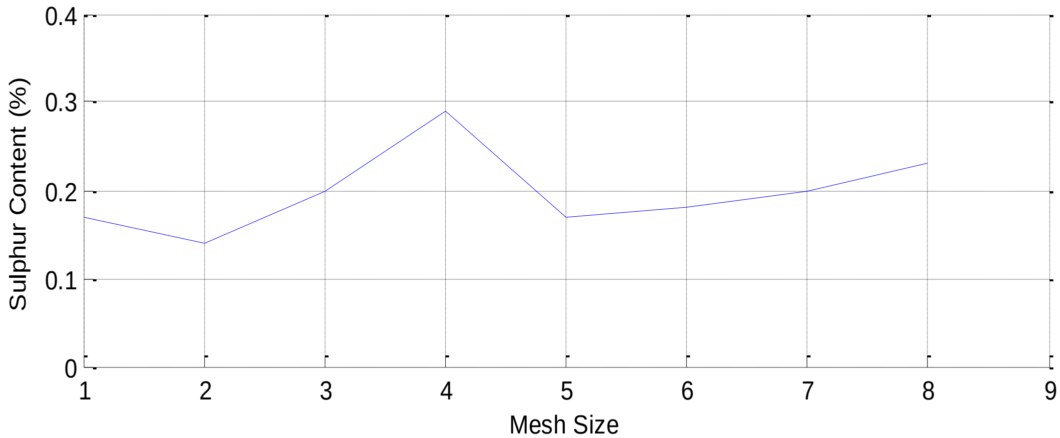

Fig. 3. Sulphur content distribution

Table 2. The physico-chemical properties of crude and upgraded Okaba coal

Properties	Crude coal	Upgraded coal
Free moisture content (%)	11.9	11.9
Total moisture content (%)	1.0	1.0
Ash content (%)	9.6	5.85
Sulphur content (%)	0.2	0.02
Bulk density gml^{-1}	1.04	0.80
Volatile matter (%)	58.4	58.4
Carbon content (%)	25.35	29.28

4. Conclusion

The production of activated carbon from a low grade coal was based on the need to develop an indigenous process parameter for useful utilization of the vast deposit of non-coking coal in the country. The upgrading of the coal sample was achieved using froth flotation techniques with the ash and sulphur content of the as-received coal sample been reduced by 43.25% and 90% respectively. The produced activated carbon was able to removed heavy metals from waste water and it has a bulk density of 0.8g/mL^3.

References

[1] Francis W and Peters MC. Fuels and Fuels Technology. Pergamon Press, Oxford 1980, ISBN 0-08-02524-8.

[2] World Coal Institute, The Coal Resources 2nd Ed. http://www.coal.org 15 November, 2015

[3] Adeleke AO. Numerical Computations for coal blend optimization. M.Sc Mathematics Thesis, 1997, University of Jos, Nigeria.

[4] Task force on the maximum utilization of Nigerian coals at the Ajaokuta Steel Plant, 1987, Lagos, Nigeria.

[5] Yahaya BS and Adeleke AA. Froth Flotation Upgrading of a Low Grade Coal, Pet Coal. 2014; 56 (1): 29-34.

[6] Wills. BA. Minerals processing Technology, An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery, Seven Edition, Butterworth-Heinemann, 2006, ISBN:9780080479477.

[7] Zahangir A, Suleyman AM, and Noraini K. Production of Activated Carbon From Oil Palm Empty Bunches for Removal of Zinc. Twelfth International Water Technology Conference, IWTC12 2008 Alexandria, Egypt, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.416.8521&rep=rep1&type=pdf.

[8] Budavari S. The Development of a Fluidized Bed Technology for the Regeneration of Powdered Activated Carbon, Merck Index, Whitehouse Station, 1996, NJ: Merck Washington.

[9] Ahmedna M, Marshal WE, Rao RM. Surface properties of Granular Carbons from Agricultural By-product and their Effects on Raw Sugar Decolorization. Bioresource Technology, 2000; 71(2): 103-112.

[10] Sullivan PD. Organic Vapor Recovery Using Activated Carbon Fiber Cloth and Electrothermal Desorption. Environmental Engineer, Air Force Research Laboratory, Tyndall Air Force Base, Florida, (2003).

[11] Gimba, CE, Olayemi JY, Okunnu ST and Kagbu JA. Adsorption of methylene blue by activated carbon from coconut shell, Global Journal of Pure and Applied Sciences, 2001; 7(2):265-267.

[12] Peters WJ and Pekerh BK. Column froth flotation result at Powell mountain coal company, CAER, University of Kentucky, Center for Applied Energy Research, 1992;3(2): 1-6.

[13] Akpabio IO, Chagga MM and Jauro A. Assessment of Some Nigerian Coals for Metallurgical Application, Journal of Minerals & Materials Characterization & Engineering, 2008; 7(4): 301-306.

[14] Usaini MNS and Ndanusa IAA., Determination of Optimal Conditions for the flotation of Lafia-Obi coal using locally demand reagents. Nigerian Mining Journal, 2010; 8(1): 11-16.

[15] Adeleke AA, Ibitoye SA, Afonja AA and Chagga MM. Multistage caustic leaching deashing of Nigerian Lafia-Obi coal. *Pet Coal*, 2011; 53(4): 259-265.

**Corresponding author: *ybabatunde@gmail.com*