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ADSORPTION STUDY OF PARTICLE SIZES OF MAIGANGA COAL

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ABSTRACT

The main purpose of this work is to carry out adsorption study of different particle sizes of Activated Maiganga Coal. Activated carbon was produced from five different particle sizes of 63 µm, 300 µm, 425 µm, 600 µm and 2.0 mm from coal using potassium hydroxide as an activating agent. Freundlich and Langmuir adsorption kinetics as well as some quality parameters were studied for the produced activated carbon. These quality parameters were evaluated for the five different samples. With the gradual increase in PH values from 5.7 to 8.3, a corresponding decrease in uptake has been observed as a result of deprotonation of the adsorbent surface. The ash content was found to increases as the particle sizes increases. The n values which reflects the intensity of adsorption decreased from 0.573 to 0.061. The K values (Freundlich constant) present the opposite trend which increased from 69.984 to 163.682. The magnitude of Q^o which indicates the amount of phosphate per unit weight of the adsorbent to form a complete monolayer on the surface also increased from 0.05 to 0.50. This work shows that, the finer the particle size of activated carbon, the greater the adsorption capabilities.

Keywords: Activated Carbon, adsorption, Coal, Freundlich, Langmuir, Maiganga,

INTRODUCTION

Activated carbon is an amorphous form of carbon that has been specially treated to acquire improved adsorptive properties such as surface area, pore volume, pore size and pore size distribution. It is produced from carbonaceous raw materials such as coal, using chemical or physical activation methods. Activated carbons are well-known adsorbents widely used for purification and separation in many industrial processes and for effluent treatment, owing to their ability to adsorb a large variety of compounds from both gaseous and liquid streams. Activated carbons are applied in various shapes, such as powder, granular, pellet, honeycomb etc. and each type has its specific application [1].

The Maiganga Coal field is 140 km from Ashaka Cement plant and some 32 km due south of Gombe, Gombe State, Nigeria**.** It is a Sub-bituminous coal whose properties range from those of lignite to those of bituminous coal [2]**.** 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 [3]. Maiganga Coal mine plant has an estimated proven Coal reserve of 4.5 million tons at the site [4].

Many researches have been carried out on the production of activated carbon from many carbonaceous sources studying different parameters of the produced activated carbon. [1] Studied the effects of activated carbon particle size on adsorption and mechanical properties of semi activated carbon fiber. They reported that, the semi activated carbon fiber coated by the adsorbent mixture with an activated carbon particle size of less than 90µm had the highest adsorption capability and surface area. The extent of adsorption of carotene from palm oil by activated carbon was monitored spectrophotometrically by [5]. It was revealed that, the uptake of carotene from palm oil by activated carbon depends on the PH, Temperature and particles sizes. Similar results were also obtained by [6] where the use of powdered activated carbon and raw coal fly ash in the removal of eosin dye from aqueous solution was highly dependent on various operating parameters, like; contact time, pH and temperature. [7], discovered that, Activated carbon produced with Potassium hydroxide (KOH) as a chemical reagents have total pore volume and Brunauer-Emmett-Teller (BET) surface area which are higher than activated carbon produced by Sodium hydroxide.

There were few studies on the effect of particle sizes and adsorption isotherms of the produced activated Carbon from Maiganga coal. This research has been undertaken, to produce activated carbon from Maiganga coal and to study the adsorption capability of different particle sizes of the produced activated carbon using Freundlich and Langmuir isotherms models.

MATERIALS AND METHODS

Coal, potassium hydroxide (KOH), potassium phosphate, distilled water, hydrochloric acid, filter paper and silver nitrate.

Equipment

Crusher, sieve, beaker, furnace, weighing balance, mortar, crucibles, masking tape, conical flask, UV Spectrometer, magnetic stirrer.

Methods

Sub-Bituminous coal was obtained from Maiganga coal mining site in Akko Local Government of Gombe State Nigeria. The Production of activated carbon involves the following steps: pretreatment of coal, impregnation of coal with an activating agent, carbonization/activation and finally the removal of the activating agent.

Pretreatment

Received coal was first washed thoroughly with distilled water and dried in an oven at a temperature of 110^{o}C. The dried coal was then crushed and sieved to different particle sizes of 63 µm, 300 µm, 425 µm, 600 µm and 2.0 mm.

Impregnation

The sieved particle sizes were weight and mixed with an activating agent (KOH) in five separate beakers. Slurries of the impregnated samples were prepared with distilled water. The prepared slurries were dried in an oven at a temperature of 110^{o}C for 24 hrs.

Carbonization/Activation

The dried prepared samples were then transferred to well label crucibles, weighted and heated in a furnace at temperature of 900^{o}C. Carbonization/Activation time of two hours was measured from the moment the furnace reached the desired temperature (not from the start of heating). After two hours of constant heating, the furnace was then turned off and allowed cooling to ambient temperature. The cooled and activated samples were weighted to determine the weight loss.

Washing

The activated products were thoroughly washed with 5 molar HCl to remove the activator from the products. After that, washing with distilled water was continued until the washed water is free of chloride ions as indicated by silver nitrate test. Finally, the washed products were then dried in an oven at 110^{o}C for two hours.

Characterization

The activated carbon produced was characterized by the following parameters: Ash contents, Bulk densities, PH values and percentage removal.

Adsorption isotherm studies

Adsorption of solute involves the establishment of equilibrium between the amount adsorbed on the surface and concentration of substance in solution [8]. A standard phosphate solution was prepared by dissolving 500 mg/l of anhydrous potassium phosphate in 1 litre of water. 75 ml of this solution was placed in each of the five different Erlenmeyer flask with an activated carbon doses of 0.5 g, 1.0 g, 1.5 g, 2.0 g and 2.5 g for 63 µm particle size. The contents were shaken in a vertical shaker with the aid of magnetic stirrer for three hours to attain equilibrium. After that, the content were filtered through a filter paper and analyzed for residual phosphate concentration using UV spectrophotometer. The above set experiment was repeated for the other particle sizes.

RESULTS AND DISCUSSION

Table 1: shows the results for the characterization of the produced activated carbon for the five different particle sizes.

Table 1: Characterization of activated carbon

Particle size	**Ash Content (wt %)**	**Bulk density (g/ml)**	**%Removal of Adsorbate**	**PH Value**
63 **µm**	50.5	1.00	78.0	5.7
300 µm	58.9	0.83	64.0	6.3
425 µm	62.6	0.50	53.6	6.8
600 µm	67.9	0.67	25.2	7.4

2.0 mm	70.6	0.71	17.4	8.3

From Table 1, it can be seen that, the percentage removal of the Adsorbate decreased from 78.0 to 17.4 % with an increased in PH of the adsorbent from 5.7 to 8.3, which means that, percentage removal of the Adsorbate was higher in the acidic than the alkaline PH range. With the gradual increase in PH values, a decrease in uptake has been observed as a result of deprotonation of the adsorbent surface. This was also shown by [9]. The ash content increases as the particle size increases. Low ash content is necessary because the percentage of mineral matter during activation is increase thereby decreasing adsorptive capacity of the activated carbon [8].

Adsorption isotherm studies

The variation of extent of adsorption of phosphate by activated carbon with an initial concentration of 500 mg/liter is presented in Table 2.

Table 2: Freundlich and Langmuir adsorption isotherm data for 63 µm particle size.

Equilibrium concentration of adsorbate Ce (mg/l)	Quantity absorbed x=(Co-Ce) (mg/l)	Mass of adsorbate (g)	x/M (mg/lg)	Log (x/M)	Log Ce	(1/x/M)	1/Ce
58	442	0.5	884	2.95	1.76	0.0011	0.0172
30	470	1.0	470	2.67	1.48	0.0021	0.0333
23	477	1.5	318	2.50	1.36	0.0031	0.0439
9	491	2.0	246	2.39	0.95	0.0041	0.1111
5	495	2.5	198	2.30	0.70	0.0051	0.2000

Table 3: Freundlich and Langmuir adsorption isotherm data for 2.0 mm particle size

Equilibrium concentration of adsorbate Ce (mg/l)	Quantity absorbed x=(Co-Ce) (mg/l)	Mass of adsorbate (g)	x/M (mg/lg)	Log (x/M)	Log Ce	(1/x/M)	1/Ce
289	211	0.5	422	2.63	2.46	0.0024	0.0035
326	174	1.0	174	2.24	2.51	0.0057	0.0031
119	381	1.5	254	2.40	2.08	0.0039	0.0084
210	290	2.0	145	2.16	2.32	0.0069	0.0048
18	482	2.5	193	2.29	1.26	0.0052	0.0556

Table 4: Parameters of Freundlich isotherm model

Particle size	Freundlich constants		
	K	**1/n**	**R^2**
63 µm	69.984	0.573	0.893
300 µm	45.920	1.709	0.783
425 µm	2013.724	0.468	0.577
600 µm	139.637	0.620	0.119
2.0 mm	163.682	0.061	0.029

Table 5: Parameters of Langmuir isotherm model

Particle size	Freundlich constants		
	Q^o	**b**	**R^2**
63 µm	0.0526	1000	0.861

300 µm	0.0018	1000	0.832
425 µm	0.1852	200	0.446
600 µm	0.1250	500	0.070
2.0 mm	0.5000	250	0.012

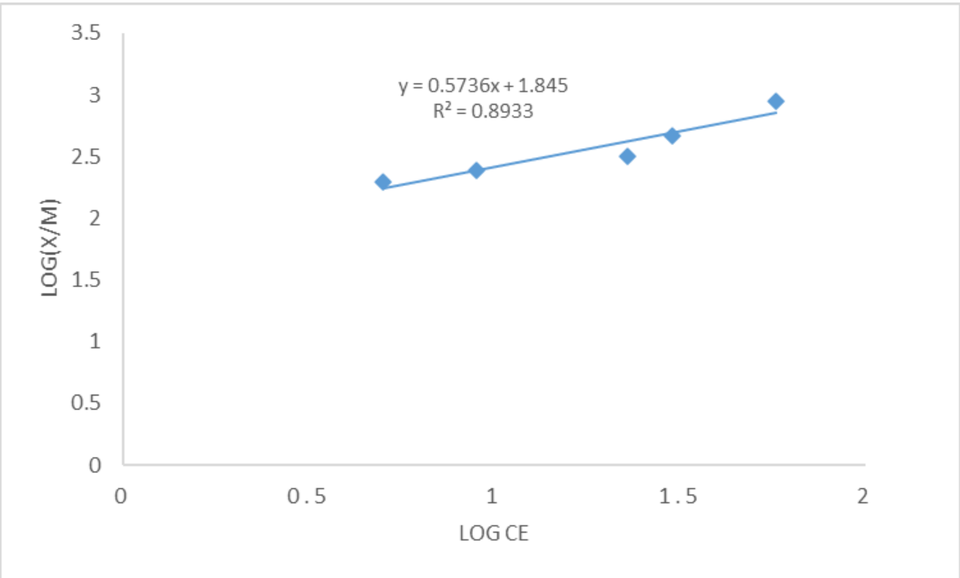

Figure 1: Freundlich adsorption isotherm for 63 µm particle size

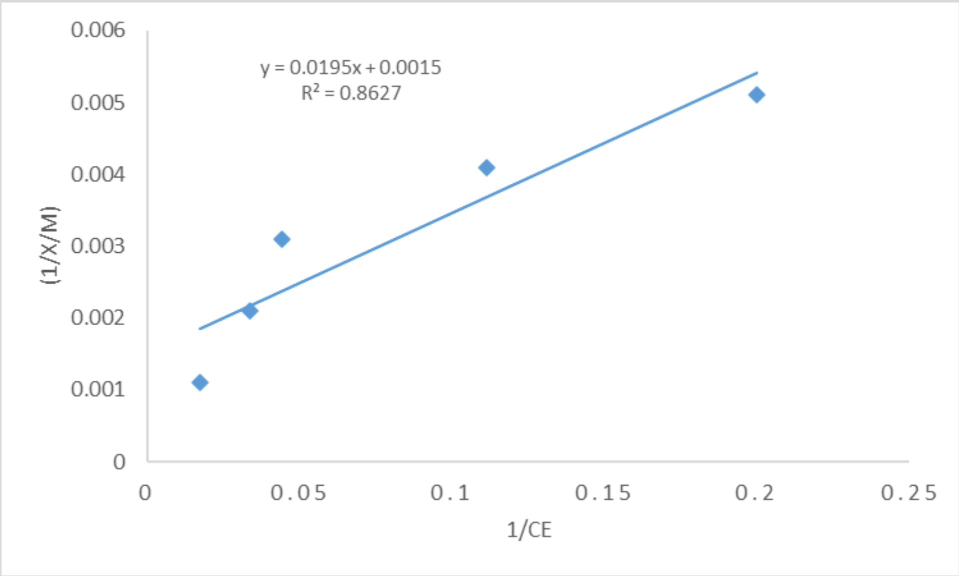

Figure 2: Langmuir adsorption isotherm for 63 µm particle size

The linearized Freundlich and Langmuir adsorption isotherms of particle size of activated carbon are shown in figures 1 and 2, Table 1 and 2.

The Figures 1 and 2 gave a better fit with R^2 values of 0.893 and 0.861 respectively. In general R^2 values are the measure of good fitness. Tables 4 and 5 revealed that both the Freundlich and Langmuir isotherm models can adequately described the adsorption data for 63 µm particle size of activated carbon. The n Values, which reflects the intensity of sorption decreased from 0.573 to 0.0061, the K values (Freundlich constant), present the opposite trend which increased from 69.984 to 163.682. The magnitude of Q^o indicates that the amount of phosphate per unit weight of adsorbent to form a complete monolayer on the surface appears to be significantly increased from 0.052 to 0.500.

Comparism with literature

The smallest particle size of 63 µm in this study gives a better adsorption capability than the larger ones. This was also demonstrated by [10], who reported that, adsorption capacity of activated carbon decreased with increased in particle size. In this work, The ash content (see Table 1) of the smallest particle size (63 µm) have the least value, this was also demonstrated by [8] that the smallest particle size of activated carbon have a low ash content value, because, the percentage of mineral matter during activation is increased thereby decreasing the adsorptive capability of activated carbon.

CONCLUSIONS

The adsorption study of particle sizes of Maiganga coal was carried out. Activated carbon was produced from coal using KOH as an activating agent. The activated carbon produced was characterized for some quality parameters. From the results obtained, it was shown that, the smallest particle size 63 µm was found to have the best quality parameters, with a lowest PH value of 5.7, highest percentage removal of 78 %, lowest ash content of 50%, and with the most effective for the adsorption of phosphate in both Freundlich and Langmuir models, gave a better fit with R^2 values of 0.893 and 0.861 respectively.

This study leads to the conclusion that, the finer the particle size of activated carbon, the greater the adsorption capabilities.

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