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ADSORPTION OF METHYLENE BLUE BY ACTIVATED CARBON FROM COCONUT SHELL

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Abstract

Powdered activated carbon from coconut shell has been used to adsorb methylene blue. The carbonization was carried out at a temperature of 600°C and activation at 900°C for a residence time of 120 seconds. The chemical activating agents used were, 0.5-2.5M $FeCl_3$ and $CaCl_2$. To create an adsorption equilibrium, $50cm^3$ of $0.1g/dm^3$ of methylene blue solution was shaken with 0.5g of the powdered coconut shell carbon with an electric shaker for an hour. The absorbance of the methylene blue filtrates were compared with that of the stock solution. The results obtained indicated that 0.5M $FeCl_3$ is the best concentration for the activation of the coconut shell raw material in powdered form. The mixture of $FeCl_3$ and $CaCl_2$ at a ratio of 1:4, gave a better carbon than when only $CaCl_2$ was used for activation. Conversely, the mixture of $FeCl_3$ and $CaCl_2$ is less effective when compared with the carbon produced using $FeCl_3$ alone. It was observed that 150μm particle size gave better adsorption than 355μm particle size.

Key words: Coconut shell, Activated carbon, Adsorption, Methylene blue.

Introduction

The use of activated carbon for purification purposes dates back to ancient Egypt, where it was used as medicine to treat ulcer and flatulence and in early Greeks when wood charcoal was used to treat ailments such as diarrhoea and dysentry (Hassler, 1974). Scheeler (1974), reported the use of activated carbon to decolourise sugar and organic solvents.

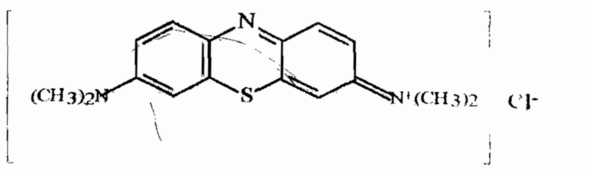
The adsorption of methylene blue in the determination of the surface area of non-porous and porous activated carbon was also reported by Kipling and Wilson (1960). In this report, nitrogen gas was used as the activating reagent and the surface area values obtained for the non- porous and porous carbons indicated that the carbons had very good adsorption capabilities. Similarly, Mkayula and Matumbo (1994), used the adsorption of methylene blue on activated carbon and iodine to study the micropore and surface area properties of activated carbons. The values obtained show the average micropore diameter to range between 0.84 to 1.22nm and the values for surface area were 382 and $1573m^2/g$ respectively.

Nowadays, numerous types of activated carbon are in use and their uses include, sugar, domestic and industrial wastes purification, air purification, adsorption of poisonous gases, water treatment, and organic solvent recovery (Yehaskel, 1978). Cheremisinoff and Ellerbusch (1978) asserted that the application of granular form of coconut shell carbon for water purification had been in use in Germany since 1916.

Child (1974) stated that coconut shell has a high percentage of lignin and cellulosic properties that contribute to making it a good source of raw material for the manufacture of activated carbon. The current laws governing Environmental Protection and the need to reduce the concentration of dyes in drinking water necessitated the use of different materials for their removal (Ekanem, 1996). Similarly, the quality of industrial effluents being discharged into our drainages has also become a cause for concern. This has increased the quest for better ways of reducing the level of pollution caused by these effluents.

The potential of activated carbon from coconut shell as an efficient pretreatment matrix for the adsorption of dyes from textile/tannery effluents before discharge into the environment is obvious and quite promising. Available data on activated carbon from coconut shell offer a lot of industrial attractions because coconut shell material is relatively of very low cost and is easily available.

Methylene blue is an important basic organic dyestuff used by most textile industries. It has an army green colour but turns to deep blue colouration when in solution. It consists of a large organic structure attached to an ionic chloride (Cl) group.



The discharge of any effluent containing methylene blue into the drainage system causes pollution in the environment. It increases the pH of the soil, contaminates river water thus affecting aquatic lives and intensifies colouration of the drainage system. This study is commercially viable because from coconut shell, activated carbon of relatively low cost compared to activated carbon from other sources can be produced and subsequently used to treat effluents from textile/tanning industries.

Experimental

Materials

Coconut shell was collected from different locations in

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Zaria, Nigeria. They were washed, dried, ground and sieved into two different particle sizes (150 and 355μm).

Iron (III) chloride ($FeCl_3$) and calcium chloride ($CaCl_2$) were from British Drug House (BDH) Ltd., England and were all reagent grade. Methylene blue was obtained from a textile manufacturing company in Kano.

Methods

Carbonization

The muffle furnace (model GLM 3 + PD/IND manufactured by Cabolite, Bamford, Sheffield, England) was set to 600°C. A nickel crucible was cleaned and heated to constant weight. 2g each of the 150 and 355μm particle sizes of the coconut shell raw material were carbonized at this temperature in an enclosed environment for a period of 120 seconds.

Activation

Two grams of the carbonized coconut shell was weighed and mixed thoroughly with 4cm^3 each of solutions of $CaCl_2$ and $FeCl_3$ separately at concentration levels between 0.5 and 2.5M. Each was separately activated at 900°C for 120 seconds. The activated samples were washed three times with distilled water and dried. The same procedure was carried out with the mixture of $FeCl_3$ and $CaCl_2$ in the mole ratios of 0.5 : 1.0M, 1.0 : 1.5M, 1.5 : 1.0M, 2.0 : 0.5M and 1.0 : 1.0M.

Adsorption of Methylene Blue

About 0.5g each of the raw coconut shell material, the carbonized sample and the different activated carbons were dispersed into 250cm^3 capacity conical flasks and 50cm^3 of the methylene blue stock solution (0.1g/dm^3) was added and shaken thoroughly with an electric shaker for 1 hour. The samples were filtered by suction through a sintered glass crucible.

The different filtrates obtained were collected and the concentrations of methylene blue determined photometrically by comparing the absorbance of the samples with that of a reference solution, using colorimeter "CORNING 253" (manufactured by Corning Ltd., Halstead, Essex, England) at 661nm and the results are as shown in Table I – IV.

Results and Discussion

Table I show the percent adsorption of methylene blue on the powdered activated carbons from coconut shell with particle sizes of 150 and 355μm. It was observed that there was an inverse relationship between the molar concentration of $FeCl_3$ used for activation and the percentage of methylene blue adsorbed. The lower the concentration of $FeCl_3$ used for activation the higher the activity of the carbon produced and consequently the higher the percentage of the methylene blue adsorbed. From the results, there is a leveling off of percentage methylene blue adsorbed with concentration of either $FeCl_3$ or $CaCl_2$. Thus, 0.5M $FeCl_3$ is the best concentration for activation of the carbonized coconut shell to improve the adsorption capacity of the material, at least for the concentration range used in this work. Table I also indicate that the percentage of methylene blue adsorbed was higher for the 150μm particle size when the same mole concentration of $FeCl_3$ was used for the activation. This is because the material with particle size 150μm provides more surface area for activation/adsorption than the one with particle size 355μm.

Table I: Adsorption of methylene blue onto powdered activated carbon using $FeCl_3$ as the activating agent

Concentration of $FeCl_3$ (moles/dm^3)	% Methylene blue adsorbed	
	150μm	355μm
0.1	87	76
0.2	90	80
0.5	95	84
1.0	88	78
1.5	85	75
2.0	78	73
2.5	72	71

Table II: Adsorption of methylene onto powdered activated carbon using $CaCl_2$ as the activating agent

Concentration of $CaCl_2$ (moles/dm^3)	% Methylene blue adsorbed	
	150μm	355μm
0.1	41	40
0.2	50	48
0.5	56	50
1.0	53	49
1.5	48	47
2.0	45	43
2.5	42	40

Table II shows percentage of methylene blue adsorbed using varying concentrations of $CaCl_2$ for activating the carbonized coconut shell material. Similarly, it was observed that the efficiency of each activated carbon for the adsorption of methylene was higher when lower concentrations of $CaCl_2$ were used for activation. Thus 0.5M of $CaCl_2$ was the best molar concentration for the activation of the carbon to improve the adsorption capacity of the carbonized carbon. In addition, the colour adsorption capacity in Table II is less as compared to that of Table I. That is, $CaCl_2$ is less effective as an activating agent when compared to $FeCl_3$. Also the percentage colour adsorbed by 155μm particle size is higher than that of 355μm. The other interesting observation is that 0.5M of either $FeCl_3$ or $CaCl_2$ is the best molar concentration to be used for activation.

Table III: Percentage of methylene blue adsorbed using the mixture of $FeCl_3$ and $CaCl_2$.

Concentration of $FeCl_3$ to $CaCl_2$ (moles/dm^3)	% Methylene blue adsorbed	
	150μm	355μm
0.5 : 2.0 (1 : 4)	57	55
1.0 : 1.5 (2 : 3)	54	51
1.5 : 1.0 (3 : 2)	49	47
2.0 : 0.5 (4 : 1)	48	44
1.0 : 1.0 (1 : 1)	55	46

Table III indicate the mixtures of $FeCl_3$ and $CaCl_2$ in different mole ratio that were used to activate the material with particle sizes 150μm and 355μm respectively. The percentage of methylene blue adsorbed was observed to be directly proportional to the concentration of $CaCl_2$ and inversely proportional to the concentration of $FeCl_3$ in the mixture. That also indicated that using the mixture of $FeCl_3$ and $CaCl_2$, for activation $FeCl_3$ is the determining activating agent.

Table IV:Percentage of methylene blue adsorbed using the raw and carbonized coconut shell material

	% Methylene blue adsorbed	
	150μm	355μm
Raw (uncarbonized) material	29	22
Carbonized material	49	47

Table IV shows the carbonized (i.e. unactivated) material used for the adsorption of methylene blue. It was observed that though, the material carbonized at 900°C can be used for the adsorption of methylene blue, the percentage adsorbed is relatively low in comparison with the carbons produced using $FeCl_3$ as the activating agent. Similarly, the uncarbonized (raw) coconut shell material showed extremely low adsorption capability when compared with the carbonized and/or activated samples. This is expected because the raw coconut shell material has no porous structure necessary for adsorption.

The higher the viscosity of a substance the less the rate of its adsorption and/or diffusion into the structure of the carbon. Since $FeCl_3$ is less viscous than $CaCl_2$, $FeCl_3$ diffuses faster into the porous carbon and activates better than $CaCl_2$. This implies that $FeCl_3$ is relatively more adsorbable than $CaCl_2$. Also, since Fe^{3+} ion has more stable and available empty orbitals than Ca^{2+}, the empty orbitals of Fe^{3+} in addition to the porous nature of the carbon, can effectively adsorb the methylene blue significantly, forming Fe^{3+} - methylene blue complex.

Conclusion

Coconut shell in powdered form can be a good source of a raw material that may be carbonized and activated and used as a treatment matrix for the removal of colour emanating from dyes especially methylene blue. The study also shows that activation done with $FeCl_3$ gave the best activated carbon, with very high percentage of methylene adsorption. This implies that $FeCl_3$ is a very good activating agent for this purpose.

Likewise, the result obtained with the mixture of the two activating reagents (i.e. $FeCl_3$ and $CaCl_2$) gave a better adsorption than when $CaCl_2$ was used alone. However, the mixture was less effective than when $FeCl_3$ was used alone. Activation done with 0.5M each of $FeCl_3$ and $CaCl_2$ indicated that this concentration of the reagents gave the best result in each case. The activated coconut shell carbon with the particle size of 150μm gave a higher percentage of methylene blue adsorbed than the 355μm particle size.

Conclusively, the particle size 150μm, which was activated with 0.5M of $FeCl_3$ as the activating reagent is a good material for the adsorption of methylene blue and activated carbon produced in this work can be used to remove colour from textile/tannery effluents and other industrial wastes containing dyes.

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