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Adsorption-based Cationic Dyes using the Carbon Active Sugarcane Bagasse

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Abstract

The use of activated carbon made of sugarcane bagasse, to eliminate cationic dyes present in waste water was studied in this research. It investigates the potential use of activated carbon made of sugarcane bagasse. Increase in the PH of the dye solution caused an equivalent increment in its adsorption efficiency. This study demonstrates that activated carbon made from sugarcane bagasse is an efficient and cheap adsorbing agent and very effective at removing dyes present in solutions and the possibility of using it for a simple and inexpensive method of dye removal from waste waters in either stirred tank reactors or in batch reactors. The data obtained could be utilised to design an optimally productive system that uses either stirred tank reactors or batch reactors remove of cationic dyes from effluents industrial. This study predicts effect of activated carbon made from sugarcane bagasse on adsorption of cationic dyes.

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Keyword: Adsorption; Cationic dyes, Sugercane bagasse, Surface acidity/basicity; Point zero charge.

1. Introduction

The presence of cationic dyes in effluent water is harmful to human beings. It reduces the diffusion of light and eventually constraints the process of photosynthesis [1-2]. A lot of methods have been used to

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remove dyes from effluent water. Because of the extremely low biodegradable value of dyes, the common biological treatment techniques are not potent enough to give desirable results [3-4].

Physical and chemical processes are used most times to treat effluent water containing dyes. The extent of operation, total costs and potential for removing colour for these methods are not the same. Of all these methods and techniques, adsorption is known to have the highest potential of effective dye removal from wastewater due to its low cost of production, unambiguous design, easy operational procedure and unresponsiveness to substances that are toxic in nature. Due to its very high capability for adsorption, activated carbonis adjudged as the most widely used adsorbing agent with very high level of success [5-6]. Its use is a very effective and efficient and can also reduce the inorganic and organic toxic chemical contents and other elements of unwanted odors and tastes present in certain media [7-9].

The elimination of color in industrial effluents through adsorption process has been identified as an emerging phenomenon worthy of vigilance in the recent times [10]. The process of adsorption remains the preferred removal method above others because of its ability to destabilise dyestuffs chemically and biologically and the rising demand for improved treatment techniques which is inherent in the method [11]. However, despite its high effectiveness as an adsorbent, industrial activated carbon is very expensive, subsequently, re-searchers are trying to find cheaper adsorbents to substitute industrial activated carbon [12-14].

In this research we used activated carbon made from sugarcane bagasse we used to predict its efficiency on cationic dye removal. Therefore, the primary objectives of this study were:

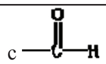
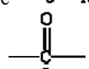
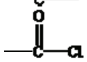
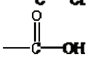
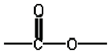
- To find point zero charge and thereafter determine the range of optimum pH.
- To find surface acidity/ basicity which will assist in investigating the possibility of utilising activate

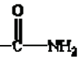
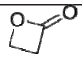
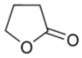
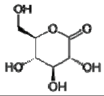
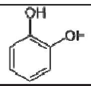
Carbon made by sugarcane bagasse as an adsorbing agent that could be used to eliminate cationic dyes.

2. Removal of Cationic (Basic) Dyes

Cationic dyes easily dissolve in water and they earn their general name from their ability to form colored positively charged ions in solution. There are different categories of cationic dyes but the major ones are cyaninediazahemicyanine, triarylmethane, cyanine, hemicyanine, thiazine, oxazine and acridine. They have diverse uses cutting across many fields such as in pulp industry, nylon making industry and even in the medical practice. Initially, their use was limited to textile industry [15].

Table1. Some common functional groups including carbonyls, lacton and phenolic. [15].

Functional groups	Chemical Name	Example
	Carbonyl Groups	
	Aldehyde	CH3CHO(acetaldehyde)
	Ketone	CH3COCH3 (acetone)
	Acyl chloride	CH3COCl(acetyl chloride)
	Carboxylic acid	CH3CO2H (acetic acid)
	Ester	CH3CO2CH3 (methyl acetate)

	Amide	CH3NH2 (acetamide)
	Lacton Groups	
	β-propiolactone	C3H4O2
	γ-butyrolactone (GBL)	C4H6O2
	D-glucono-δ-lactone (E575)	C6H10O6
	Phenolic Groups	
	1,2-benzenediol o-benzenediol	C6H6O2

3. Determination of Point Zero Charge

The point zero charge (pH_{pzc}) of activated carbon made from sugarcane bagasse was determined by the solid addition method. The net charge of surface is zero on the adsorbent surface at pH_{pzc}, therefore, no activation of acidic or basic functional groups are detected on the solution pH. Batch equilibrium method was used for the determination of point of zero charge. To each of the flask 0.1 g of respective adsorbents was added including 100 ml solution KNO_3 (0.01 N) in the pH range between 2 to 10.

The initial pH of solutions were adjusted by adding drops of 0.5 N NaOH and 0.5 N HCl solutions and. Each flask was sealed and shaken thoroughly for 48 hr at room temperature and the final pH of the solution was measured and recorded. The total charge adsorbed on bagasse surface was determined by ΔpH (the difference in the value of pH of the solution before and after 48 hr). The intersection of obtained curve with pH_0 axis indicated the pH_{pzc} value.

4. Performance of Surface Acidity/Basicity

The Boehm titration procedure was used to calculate the amount of surface acidic and basic functional. All experimental was carried out in a batch mode. The surface chemistry was determined with the use of four independent solutions of 0.1N HCl, 0.1N $NaHCO_3$, 0.1N Na_2CO_3 and 0.1 N NaOH.

In each adsorption experiment, 0.1 g adsorbent was added to 50 mL of the solutions with known concentration in a 250 mL round bottom flask under room temperature and the mixture was subjected to continuous stirring for 96 Hr using a shaker with a speed of 150 rpm. The suspension was then centrifuged at 5000 rpm for 5 minute. 10 mL from each solution was taken and the excess of base and acid was titrated against 0.1 N HCl first and then later against 0.1N NaOH. The amount of HCl that reacted with the absorbent was then used to calculate the number of surface basic sites while the amount of NaOH, Na_2CO_3 and $NaHCO_3$ reacted with the absorbent was used to calculate the number of surface acidic sites.

The calculation of surface chemistry is based on the consumed volumes of HCl and NaOH for titration. Groups of carboxyls, lactones and phenolics are acidic groups. Carboxyl groups were calculated by the consumed volume of 0.1 N HCl for titration of $NaHCO_3$ solution. Lactone groups were estimated by difference between the consumed volume of 0.1 N HCl. Phenolic groups were determined by difference between the consumed volume of HCl(0.1 N) for titration of NaOH and Na_2CO_3 solutions. The basictiy groups were obtained by calculation of the consumed volume NaOH(0.1N) for titration of HCl(0.1N). The amount of functional group is calculated as following:

$$functional \quad group\,(mmol\,/\,g) = \frac{(Normality \times Volume_{consumed})}{Molecular \quad weight} \times \frac{(initial \quad volume)}{(selected \quad volume \quad for \quad titration)} \quad (1)$$

5. Result of Point Zero Charge

Point zero charge can be estimated using KNO_3(0.01 N) solution. The point zero charge of activated carbon made from sugarcane bagasse was determined and the results shown in Figure 1. Since KNO_3 solution was used, it is desirable to have a fixed background electrolyte concentration that is high enough to minimize the total salt concentration changes during the titration and no clear effect of KNO_3 was found on the mobility.

The pH_{pzc} values were known by determining the position where the resulting curves cut through the pH_0 axis as shown in Figure 1. The pH_{pzc} was found to be 7.4, for activated carbon made from sugarcane bagasse sample. Cation adsorption becomes enhanced at pH higher than the pH_{pzc}, while adsorption of anions is equally enhanced at pH less than pH_{pzc}. Increase in the pH above the point zero charge tends to increase the adsorption of cationic dyes on the adsorbents. The result of point zero charge shows in Fig. 1.

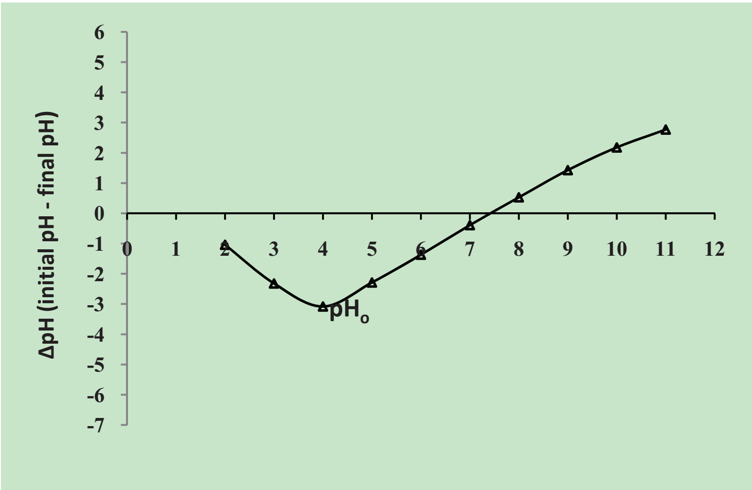


Fig. 1. Point Zero charge of Activated carbon made from sugarcane bagasse.

6. Discussion of Surface Acidity/Basicity

The Boehm's technique was used to characterize the surface chemical property of the adsorbent. Several assumptions were made before the surface acidity and basicity could however be calculated. It was assumed that acidic group generally, could only be neutralised by NaOH, Na_2CO_3 and $NaHCO_3$while all basic groups would be neutralised by HCl.

Table 2 shows the summary of the properties of the surface functional groups through the Boehm titration. The concentration of acidic sites for the Activated carbon made from sugarcane bagasse is

0.38125 mmol.g^{-1}, while the basicity group is very low. The basicity groups value is correspond to 0.0260. The significant increase of acidity groups in compared to the basicity groups, suggesting that the majority of functional groups on the adsorbent surface are acidic. The more acidic groups, indicating more oxygenated functional groups, gave rise to higher adsorption of cationic dyes.

Table 2. The Bohem titration data for Activated carbon made from sugarcane bagasse.

Adsorbed	Carboxyl groups	Bohem Titration method		Acidity	Basictiy
		Lactone	Phenolic		
Activated Carbon made from sugarcane bagasse	0.20285	0.0143	0.16401	0.38125	0.0260

7. Conclusion

To find surface acidity/basicity we used Boehm titration method and we found 0.202849 for carboxyl groups and 0.014387 for lacton and 0.164013957 for phenolic and 0.0260274 for basicity and 0.38125 for acidity. For cationic dyes we need acidity to be high and this acidity is acceptable.Also we found point zero charge for carbon active made by sugarcane bagasse by using KNO_3 0.01 N solution. The zero point charge is at pH 7.4 then as our dyes are cationic dyes optimum pH should be over 7.4. It means as pH increases the adsorption will increase too. In the future work, we determine to research in adsorption of some cationic dyes on activated carbon made from sugarcane bagasse.

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