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Study of the Adsorption of Anionic Dye onto Activated Bone Char

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ABSTRACT

The adsorption of reactive dye onto activated carbon obtained from cow bones was investigated. The effects of dye concentration and pH on the adsorption of the dye onto the activated carbon were similarly investigated. The optimum adsorption was obtained at dye concentration of 45 mg/L and pH 6 respectively. Langmuir and Freundlich adsorption isotherms were employed to provide qualitative information on the capacity of the adsorbent as well as the nature of the solute-surface interaction. The correlation coefficient obtained for Freundlich isotherm (R^2 = 0.6369) and Langmuir isotherm (R^2 = 0.5823) indicates that Freundlich isothermal model is more fit for the adsorption process. By implication, the adsorption of Reactive Yellow FG onto the activated carbon can be referred to as a multilayer adsorption since the assumption of Freundlich's equation is based on heterogeneous distribution of active sites.

Keywords: Adsorption, Langmuir Isotherm, Freundlich Isotherm, Wastewater, Reactive Yellow FG

INTRODUCTION

The presence of colour and colour-causing compounds has always been undesirable in water for any use. It is therefore, not at all surprising to note that the colour in wastewater has now been considered as a pollutant that needs to be treated before discharge. Thus, colour removal is one of the challenges faced by the textile finish, dye manufacture, pulp and paper industries, among others. Adsorption process is one of the most effective and economically feasible methods for the removal of dyes from aqueous solutions [1].

Adsorption isotherms are mathematical models that describe the distribution of the adsorbate specie among liquid and solid phases, based on a set of assumptions that are related to the heterogeneity/homogeneity of the solid surface, the type of coverage, and the possibility of interaction between the adsorbate specie [2].

There are several isothermal models which includes: Langmuir, Freundlich, Temkin, Sips and Redlich-Peterson isothermal expressions. The studies of adsorption isotherms are carried out on two well-known isotherms, the Langmuir and the Freundlich adsorption isotherm models and the applicability of their isotherm equation is compared by judging from the values of their correlation coefficients (R^2) [3].

Several factors affect the adsorption of dyes onto activated carbon, therefore this research is focused on the investigation of the effect of dye concentration and solution pH on the adsorption efficiency of bone char activated with $CaCl_2$ on Reactive Yellow FG dye.

MATERIALS AND METHOD

Materials

Commercial grade chemicals were utilized all through the research. The NaOH (96.0% purity) and the HCl (37.0% purity) were purchased from Guangdang Guanghua chemical factory China, Reactive Yellow FG dyestuff obtained from African Textile Manufacturers (ATM) Limited, Kano was purchased from PJS products Ltd, Lagos.

Equipment

The major equipment used for this work are: UV-Visible spectrophotometer (Cary 300), pH-meter, electronic weighing balance, thermometer, water bath constant temperature vibrator (SHA-C).

Preparation of Stock Solution of Dye

Stock solution of about 1g/L was prepared by properly dissolving about 1g of the dye in distilled water inside a volumetric flask and filling it up to the 1000ml mark, this is allowed to stand for 24hours [4].

Wavelength of Maximum Absorption (λ_{max}) and Calibration Curve

The stock solution (3ml) was repeatedly diluted with distilled water until its absorbance could be read bythe UV-visible spectrophotometer, after scanning, the λ_{max} of 416nm was obtained for the dye. Using serial dilution formula (equation 1), five standard concentrations were obtained from the stock solution and used in plotting the calibration curve alongside the calibration equation which are used to determine the concentration of the dye solution for subsequent adsorption process.

$$C_1 V_1 = C_2 V_2 \quad (1)$$

where C_1 = original concentration of stock solution, V_1= volume required from the stock solution, C_2= concentration required, V_2= volume of the new concentration required. The removal efficiency (%) and adsorption capacity (Q_e) in mg/g were calculated using equation 2 and 3 respectively.

$$R\iota \qquad e \qquad (\%) = \frac{(C_0 - C_e)}{C_0} \times 100 \quad (2)$$

$$Q_e = \frac{(C_0 - C_e)}{m} \times V \quad (3)$$

where C_0 is the initial concentration of adsorbate, C_e is the equilibrium concentration of adsorbate, V is the volume of adsorbate, m is the mass of the absorbent.

Assessment of Effect of Dye Concentration on the Adsorption of the Dye

The activated carbon used for the adsorption was produced using the method of [5]. By adopting [4], a predetermined weight of the adsorbent (0.5g) was constantly agitated with 25ml of the dyes solutions for 100 min for each batch experiment with an initial dye concentration of 35, 45, 55, 65 and 75mg/L respectively.

Assessment of Effect of pH on the Adsorption of the Dye

The effect of pH was studied by agitating 0.5g of the adsorbent with 25 ml of the dye solutions for 100 min with a pH of 5, 6, 7, 8and 9respectively. Variation of pH was accomplished by drop-wise addition of HCl or NaOH (0.1M in each case) with the aid of a dropping pipette until required pH is indicated by the pH meter.

RESULTS AND DISCUSSION

Effect of Dye Concentration on the Adsorption of the Dye

Fig. 1 shows the effect of dye concentration. It was observed from Fig. 1 that at an initial concentration of 35mg/L a removal capacity of 56.28% was recorded at equilibrium and by increasing the concentration to 45mg/L, the highest adsorption (62.30%) was recorded, thus an increase in concentration has led to an increase in removal capacity.

This phenomenon may be attributed to the driving forces that needed to be overcome for the resistance of mass transfer between the aqueous and solid phases as observed by [6].

However, upon further increase in dye concentration from 45 - 65mg/L, there was a drop in the removal capacity. The reduction may be either due to the saturation of the active binding sites on the adsorbent surface at higher concentrations [7] or due to increase in repulsive force between dye molecules in the solution thus reducing the removal efficiency [8].

Effect of pH on the Adsorption of the Dye

The pH is the most important factors affecting adsorption as it contributes not only to surface charge of adsorbent and the degree of ionization of the material present in the solution but also to the dissociation of functional groups on the active sites of the adsorbent [3, 9, 10].

In Figure 2, the removal capacity was seen to be higher at acidic pH (5 -6.5) with the optimum colour removal capacity (63.07%) recorded at pH 6. In the basic region (pH above 7), removal capacity was observed to decrease with increasing pH with minimum colour removal capacity (56.03%) recorded at pH 9. It is worth noting that the hydroxyl apatite structure of bone char presents it with a negatively charged surface, however activation with $CaCl_2$ essentially confers positive charge to its surface.

According to the explanation offered by [6], it can be deduced that decrease in pH of aqueous solution can lead to the decrease in negative charge density on the adsorbent surface. This view will yield positive results for adsorption of anionic dyes (reactive dye in this case). Therefore, the increase in dye adsorption observed at acidic pH may be related to the electrostatic interactions between the positively charged absorbent surface and negatively charged reactive dye anions. On the other hand, at basic pH (above 7), the repulsive electrostatic forces between the dye anions and the negatively charged adsorbent surface (due to increased pH) may be responsible for the consequent decrease in adsorption observed.

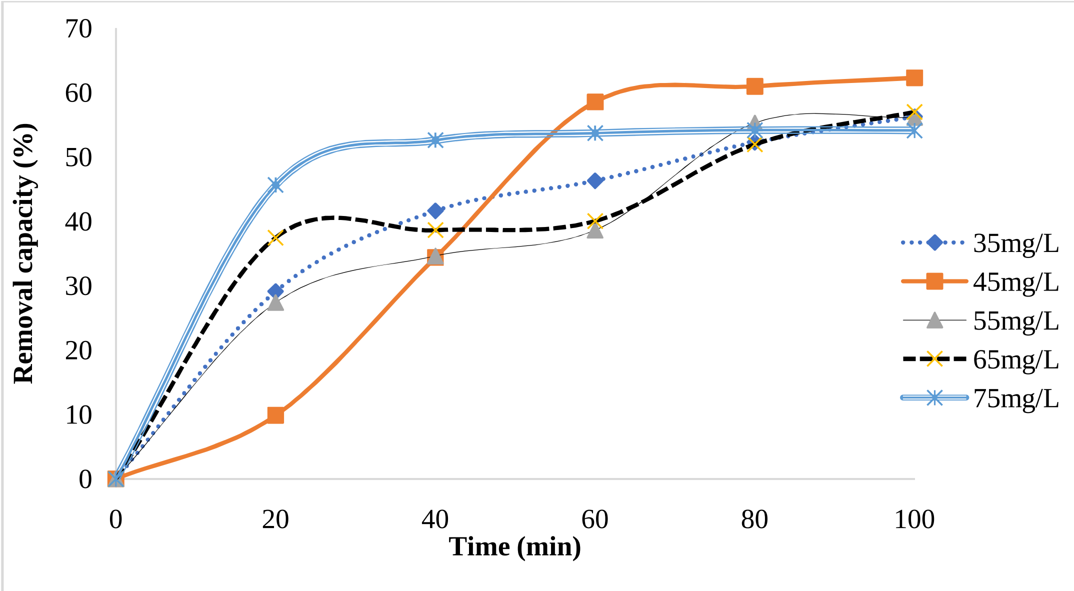

Figure 1. Effect of Initial Dye Concentration on the Adsorption of the Dye

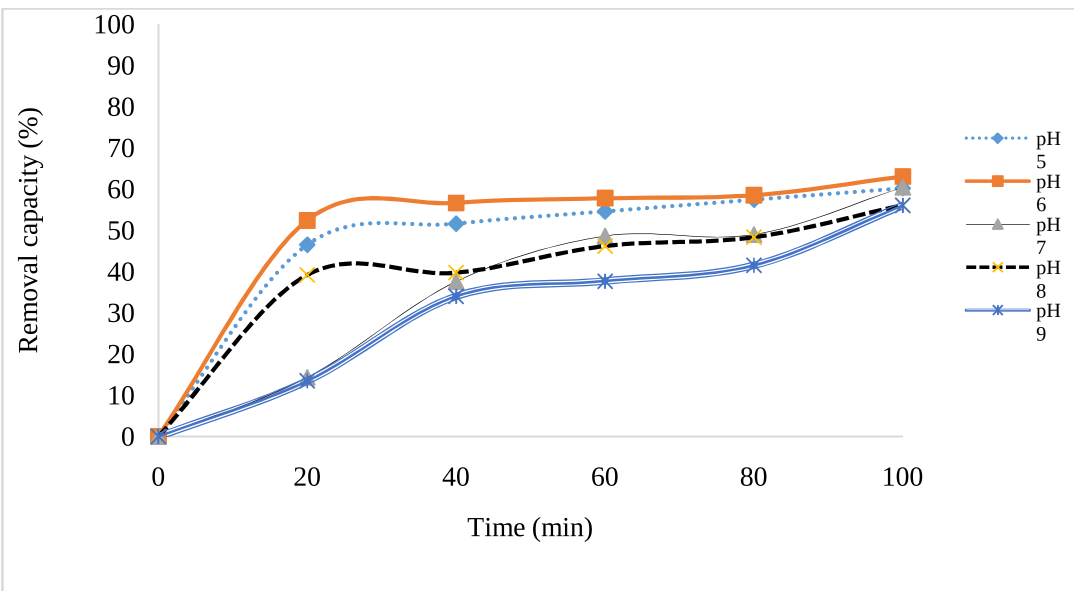

Figure 2. Effect of pH on the Adsorption the Dye

Adsorption Isotherm

Adsorption isotherms provide qualitative information on the capacity of the adsorbent as well as the nature of the solute-surface interaction [11]. To describe the equilibrium adsorption process, the two theoretical models used in comparing the experimental results are Langmuir and Freundlich isotherms and all the parametric values calculated from their respective curves are shown in Table 1.

Table 1. The Values Obtained of Respective Isotherm Parameters for the Adsorption of the Dye

Isothermal Model	Parameters	Values
Langmuir Isotherm	Q_m(mg/g)	94.34
	K_L (L/mg)	105.99
	R_L	0.0003
	R^2	0.5823
Freundlich Isotherm	K_F (mg/g)	4.915
	1/n	0.8025
	N	1.2461
	R^2	0.6369

Figures 3 and 4 respectively represent the Langmuir and Freundlich isothermal models for adsorption of the dye. The Langmuir constants K_L and R_L were obtained from the slope and intercept of the linear plot of $1/Q_e$ versus $1/C_e$ while the Freundlich constants K_F and n were also obtained from the intercept and the slope of the linear plot of $\ln Q_e$ versus $\ln C_e$. The value of separation factor obtained (R_L=0.0003) reflects that the experimental data agrees with the Langmuir model ($0 < R_L < 1$) according to [12] and [13]. Similarly, the value of the adsorption intensity (n=1.2461) obtained for the Freundlich model being greater than unity reflects that the ex perimental data agrees with the Freundlich model. This is because the Freundlich constant 'n' gives an idea of the favorability of the adsorption process, so the value of n should be less than 10 and higher than unity for a favorable adsorption condition [11].

However, the correlation coefficient for Freundlich isotherm (R^2 = 0.6369) being greater than that of Langmuir model (R^2 = 0.5823) indicates that Freundlich model fits the adsorption process better. Therefore, the adsorption of Reactive Yellow FG can be referred to as a multilayer adsorption since the assumption of Freundlich's equation is based on heterogeneous distribution of active sites [3].

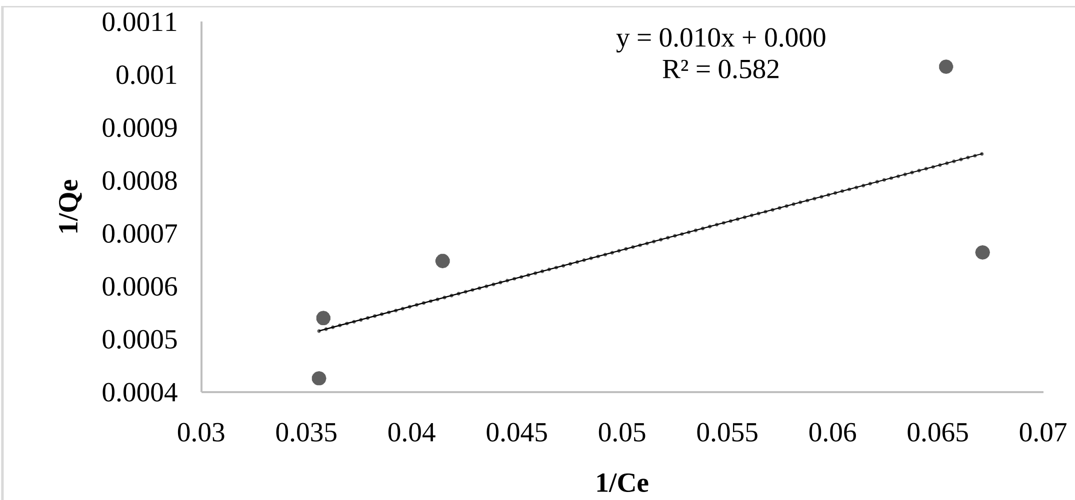

Figure 3. Langmuir Isotherm Model for the Adsorption of the Dye

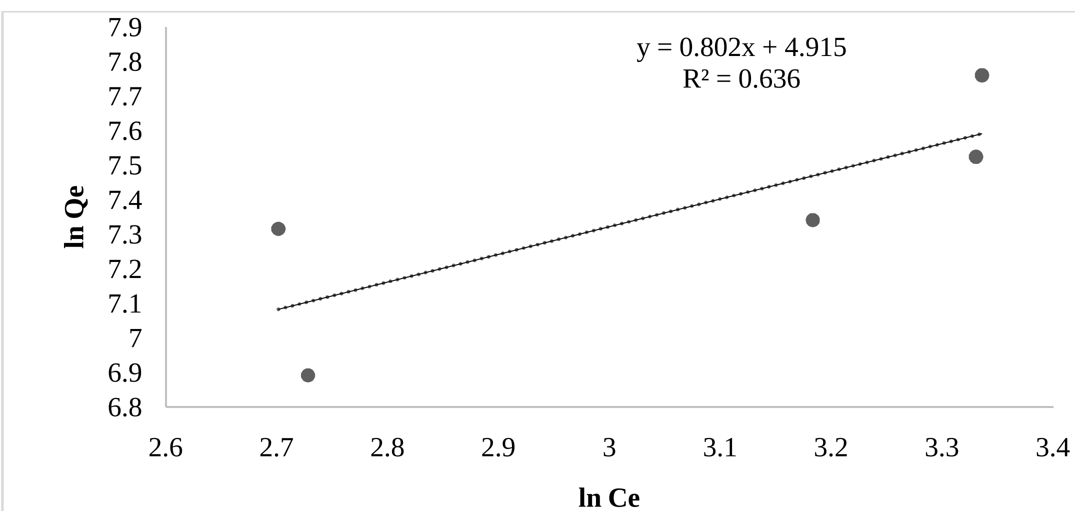

Figure 4. Freundlich Isotherm Model for the Adsorption of the Dye

3.7 CONCLUSION

The two variables investigated viz. dye concentration and solution pH have been found to have direct influence on the adsorption process and an optimum adsorption of62.30% was recorded at 45mg/L while pH 6 recorded an optimum adsorption of 63.07%.

Freundlich's model is best fit for the adsorption of the dye, consequently, the adsorption is said to be multilayer adsorption process.

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