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Adsorption of Crystal Violet Dye from Aqueous Solution Using *Ricinus Communis* Pericarp Carbon as an Adsorbent

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Abstract: Carbon prepared from *Ricinus Communis* Pericarp (RCP) was used to remove a crystal violet dye from aqueous solution by an adsorption technique under varying conditions of agitation time, dye concentration, adsorbent dose and pH. Adsorption is influenced by pH, dye concentration, carbon concentration and contact time. Equilibrium was attained with in 60 min. Adsorption followed both Langmuir and Freundlich isotherm models. The adsorption capacity was found to be 48.0 mg/g at an initial pH of 6.8±0.2 for the particle size of 125–250 μm.

Keywords: *Ricinus communis* Pericarp carbon (RCPC), Dye, Adsorption, Isotherms.

Introduction

Environmental pollution due to industrial effluents is of major concern because of their toxicity and threat for human life and the environment. The discharge of textile effluents to the water bodies has raised much concern because of potential health hazards associated with the entry of toxic components into the food chains of humans and animals. Synthetic dyes are extensively used for dyeing and printing in a variety of industries. Over 10, 000 dyes with an annual production over $7x10^5$ metric tones world wide are commercially available and 5-10% of the dye stuff is lost in the industrial effluents[1]. Therefore there is a need to remove dyes before effluent is discharged into receiving water bodies. The most popular treatment methods for textile wastewater are combinations of biological treatment, chemical coagulation and activated carbon adsorption[2-4]. Adsorption onto activated carbon is proven to be very effective in treating textile wastes. However, in view of the high cost and associated problems of regeneration, there is a constant search for alternate low cost adsorbents. Such types of adsorbents include coir pith[5], parthenium[6], coconut shell[7], peanuthull[8] and rice husk[9].

In the present study removal of crystal violet from aqueous solution using carbon prepared from *Ricinus communis* pericarp (RCP) as an adsorbent was investigated.

Experimental

Adsorbent

In the present study, Pericarp of *Ricinus communis* (RCP) used for the preparation of activated carbon. The dried pericarp was allowed to chemical activation, by the addition of 50% sulfuric acid with constant stirring (w/v). The charred material was kept in hot air oven at 100±5 °C for 12 h. This was washed with double distilled water and soaked in 10% sodium bicarbonate solution and allowed to stand overnight to remove the residual acid from pores of the carbon. The material was washed with distilled water, until the pH of the adsorbent reached 7±0.2. Then it was dried in a hot air oven at 100±5 ºC for 12 h. The dried material was ground and sieved to get the particle size of 125-250 µm. The sieved adsorbent was stored in an airtight container for further experiments. All the chemicals used were of analytical reagent grade obtained from B.D.H and E.Merck. Double distilled water was used for all the experimental studies.

Adsorbate

A stock solution of 1000 mg/L of crystal violet was prepared by dissolving 1 g of the dye in double distilled water. All experiments were carried out in duplicate and the mean values are reported, where the maximum deviation was within 2%.

Batch mode adsorption studies

The stock solution of crystal violet was diluted to required concentration for obtaining a standard solution containing 25–100 mg / L of the dye. Batch mode adsorption studies were carried out with 25 mg adsorbent and 50 mL of dye solution of desired concentration at an initial pH of 6.8±0.2 in 100 mL conical flasks, which were agitated at 120 rpm for predetermined time intervals at room temperature (30±2°C) in a mechanical shaker. Following agitation, the adsorbent and adsorbate were separated through centrifugation and dye concentration in the supernatant solution was determined spectrophotometrically at a wavelength of 540 nm. The effect of carbon dosage on percent removal was studied with carbon dosage varying from 5 to 75 mg/50 mL while maintaining the dye concentrations at 50 and100 mg/L**.** The effect of dye concentration on percent removal was studied with dye concentration from 25 to 100 mg/L at an initial pH of 6.8±0.2. Langmuir and Freundlich isotherm studies were carried out with different initial concentrations of dye from 25 to 100 mg/L, while maintaining the adsorbent dosage at 25 mg/ 50 mL. Effect of pH on the dye removal was studied using 25 mg of carbon dose for the dye concentrations of 25 mg/L. To correct any adsorption of dye on containers, control experiments were carried out in duplicate.

Results and Discussion

Adsorbent characterization

Characteristics of carbon prepared from RCP are presented in Table 1. The measured surface area of RCP carbon was 495 m^2/g and was comparable to various adsorbents such as palm pith carbon[10] (188 m^2/g), peanut hull carbon[8] (208 m^2/g), eichhornia[11] (266 m^2/g) and cassava[12] (270 m^2/g). Moisture content of the carbon was 2.50% (Table 1). It has been reported that if the moisture content of the adsorbent is more, it dilutes the action of carbon and necessitates utilizing some extra load of carbon. The phenol adsorption capacity and decolorizing power were 25 mg/g and 21 mg/g, respectively, which indicated that the carbon prepared by the acid activation method had good adsorption capacity and it could be used for adsorption of organic dyes. The surface morphology of RCP carbon visualized via scanning electron microscopy (SEM), being obtained using a JSM-840 JEOL microscope of JEOL Techniques LTD, Japan at 2000X magnification. Examination of SEM micrographs of the RCP carbon particles showed rough areas of the surface of the carbon (Figure 1). The characteristics (Table 1) showed that carbon had a high surface area and more bulk density. The activation process of RCPC by adopting sulphuric acid treatment leads to corrosion of the surface of carbonaceous material and introduce micro-, macro- and meso-pores.

Table 1. Characteristic of RCP carbon.

Parameters	Value
pH 1% solution	6.90
Moisture content, %	2.50
Ash content, %	6.50
Decolorizing power, mg/g	21.00
Ion exchange capacity, equi g	0.80
Determination of surface area, m^2/g	495
Bulk density, gm /L	0.46
Porosity, %	68.27
Specific gravity	1.46
Particle size, µm	125-250
Iodine number, mg/g	468
Yield, %	70
Calcium, mg/g	20.0
Potassium, mg /g	2.3
Water soluble matter, %	1.29
HCl soluble matter 0.25 N, (%)	2.45
Phenol adsorption capacity, mg/g	25.0

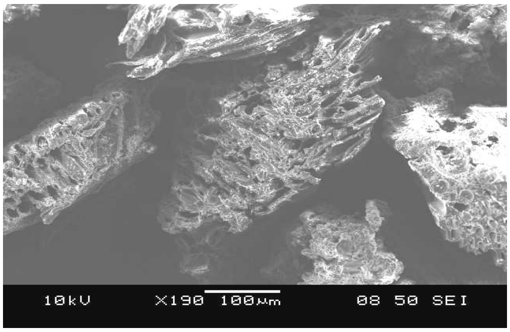

Figure 1. SEM photograph of the RCP carbon.

Effect of agitation time and initial dye concentration on dye adsorption

The effect of agitation time on the removal of crystal violet dye by RCP is shown in Figure 2. The removal increases with time and attains equilibrium with in 50 min for all concentrations studied (25–100 mg/L). The curves were single, smooth and continuous till the saturation of dye on the carbon surface. Similar results were reported for various dye adsorptions by other adsorbents[5,]. Equilibrium time is one of the important considerations in the design of water and wastewater treatment systems because it influences the size of the reactor, thereby the plant economics[13].

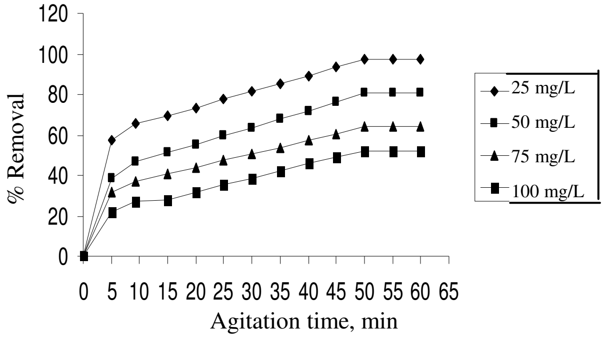

Figure 2. Effect of agitation time on crystal violet adsorption.

Adsorption kinetics

The rate constant for adsorption of Crystal Violet by *Ricinus communis* pericarp carbon was studied using Lagergren rate equation. The equation is

$$\log_{10} (q_e - q) = \log_{10} q_e - K_{ad}\, t / 2.303 \quad (1)$$

where,

q_e – The amount of crystal violet dye adsorbed (mg/g) at equilibrium.

q – The amount of crystal violet dye adsorbed (mg) at time t.

K_{ad} - The rate constant of adsorption of crystal violet by *Ricinus communis* pericarp carbon.

Linear plots of $\log_{10} (q_e\text{-}q)$ *vs.* t were obtained for different dye concentrations (25, 50, 75 and 100 mg/L) which indicate that the adsorption process follow the first order rate expression (Figure 3). Adsorption rate constants (K_{ad}) are presented in Table 2. The rate constants of adsorption of the basic dye found to be 4.85×10^{-2} to 5.25×10^{-2} (1/min).

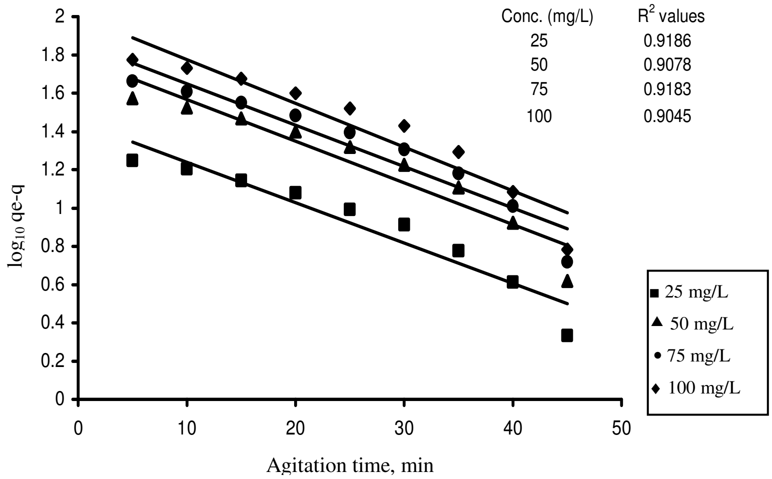

Figure 3. Lagregren plots for crystal violet adsorption.

Effect of carbon dosage on crystal violet removal

Figure 4 shows the effect of carbon dosage on crystal violet dye adsorption. The removal of dye increased with increasing carbon dosage and attained a maximum (100%) at a particular carbon dosage. It can be seen from the results that the complete removal of dye from aqueous solution required 35 mg and 60 mg of activated carbon for 50 mg/L and 100 mg/L of dye respectively. The increase in the percent removal of dye with the increasing carbon dosage is due to the increase in the surface area consequent to the number of carbon particles with more number of active surface sites for the adsorption and the saturation occurs as a result of non-availability of dye molecules for adsorption.

Table 2. Lagergren rate constant for crystal violet adsorption.

S.No	Dye concentration, mg/L	K_{ad} , 1/min
1	25	0.0485
2	50	0.0502
3	75	0.0497
4	100	0.0525

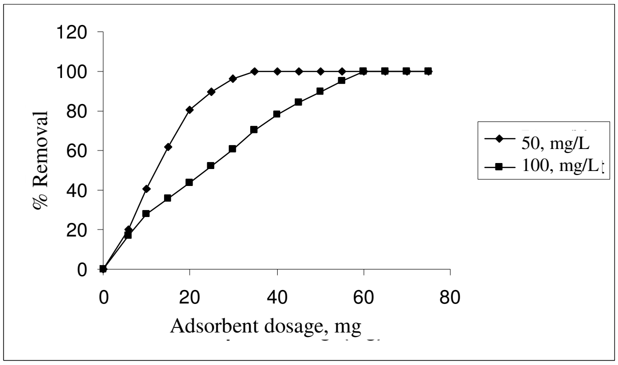

Figure 4. Effect of adsorbent dosage on crystal violet adsorption.

Adsorption isotherm

Langmuir isotherm can be applied for the adsorption of crystal violet onto RCP[6].

$$\frac{C_e}{q_e} = \frac{1}{Q_0\, b} + \frac{C_e}{Q_0} \qquad (2)$$

Where, C_e is the equilibrium concentration (mg/L), q_e is the amount of the dye adsorbed (mg/g), Q_0 and b are Langmuir constants related to adsorption capacity and energy of adsorption, respectively. The linear plot of C_e/q_e *vs*. C_e shows that the adsorption follows Langmuir isotherm models (Figure 5). The value of Q_0 and b were calculated from the slope and intercept of the plot, respectively. The values obtained were Q_0=106.95 mg/g and b = 0.4770 L/min.

The essential characteristic of Langmuir isotherm can be expressed in terms of dimensionless separation factor of equilibrium parameters R_L. It can be defined by,

$$R_L = \frac{1}{1+bC_0} \qquad (3)$$

Where, C_0 is the initial dye concentration (mg/L) and b is the Langmuir constant (L/mg). The R_L values indicate the type of isotherm as follows,

R_L Value	Type of isotherm
$R_L>1$	Unfavorable
$R_L=1$	Linear
$0< R_L<1$	Favorable
$R_L=1$	Irreversible

The R_L values were found in the range 0.0205 - 0.0773 for different dye concentrations of 25 -100 mg/L, which indicates favourable adsorption of crystal VIOLET dye onto *Ricinus communis* pericarp carbon.

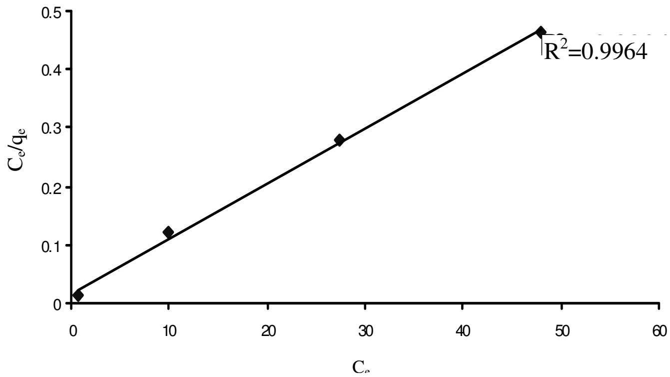

Figure 5. Langmuir plots for crystal violet adsorption

The Freundlich equation is widely used in the environmental engineering practice to model adsorption of pollutants from an aqueous medium[14]. The expression for Freundlich equation is given as,

$$q_e = K_f C_e^{1/n} \tag{4}$$

The linear form of Freundlich equation is given by the following expression.

$$\log_{10}\left(x/m\right) = \log_{10} K_f + \frac{1}{n}\log_{10} C_e \tag{5}$$

Where, x is the amount of the dye adsorbed at equilibrium (mg), m is the weight of adsorbent used (mg), and C_e is the equilibrium concentration of the dye in solution (mg/L) .kf and n are the constants incorporating all factors affecting the adsorption process. Linear plot of log x/m *vs.* log C_e show that the adsorption follows Freundlich isotherm (Figure 6). The Freundlich constants were K_f = 53.3676 and n=5.6980 for 25 mg/L of the dye. The mathematical calculations of n values between 1 to 10 represent the best adsorption[15].

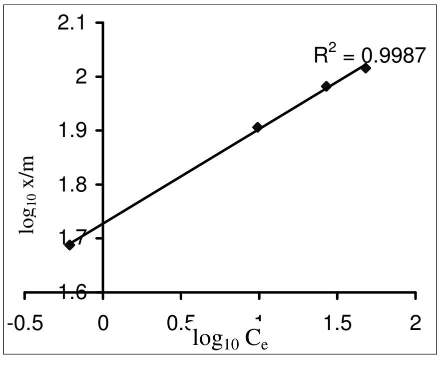

Figure 6. Freundlich plot for crystal violet adsorption.

Effect of pH on crystal violet removal

Figure 7 shows the effect of pH ranging from 3.0 to 9.0 on crystal violet dye removal by adsorption. Adsorption of dye increases with increasing pH. Lower adsorption of crystal violet at acidic pH was probably due to the presence of excess of OH ions competing with the dye anions for the adsorption sites.

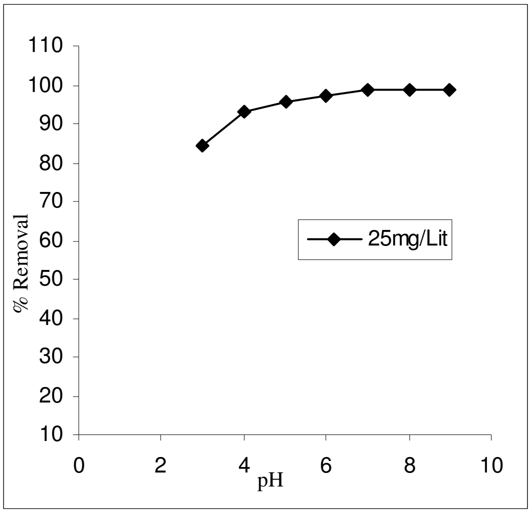

Figure 7. Effect of pH on Crystal violet adsorption.

Desorption studies

Regeneration of the adsorbent may make the treatment more economical. Attempts were made to degenerate colour from the dye-laden carbon using various strengths of CH_3COOH (0.1–1N). The percent desorption increased with increasing CH_3COOH concentration in the aqueous medium (Figure 8) and attained a maximum desorption at 0.8 N CH_3COOH solution. The effect of percentage desorption was inversely correlated to pH effect, indicating that ion exchange was probably the major mode of adsorption process. Similar results were observed for the adsorption of Congo red by coir pith carbon[5].

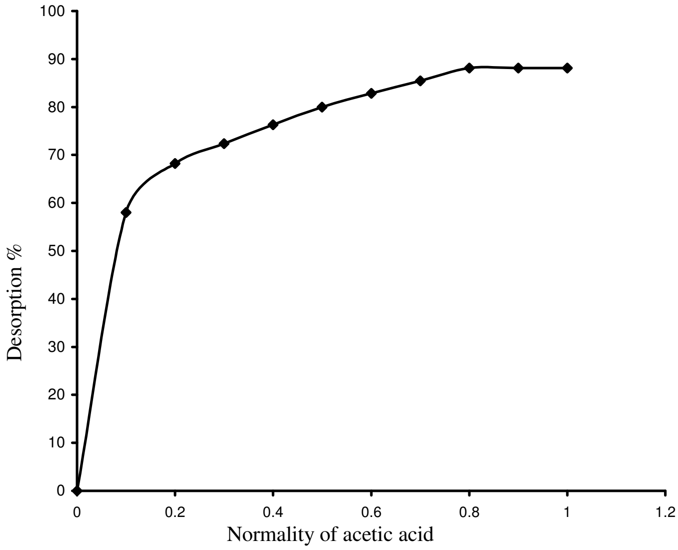

Figure 8. Desorption on crystal violet.

Conclusions

Based on results it was concluded that *Ricinus communis* pericarp carbon was an effective adsorbent for the removal of the crystal violet dye from aqueous solution. In batch mode adsorption studies, the adsorption was dependen**t** on the solution pH, carbon dosage and initial dye concentration. Adsorption followed both Langmuir and Freundlich isotherm models. Desorption studies reveals that recovery of dye from adsorbent was possible.

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