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Original Research Paper

Studies on the Removal of Acid Blue 25 from Wastewater Using Activated Carbon and Turmeric (*Curcuma longa* L.) as Adsorbent

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ABSTRACT

Activated carbon has been widely used as an adsorbent. *Curcuma longa* (Linn.) may be an alternative of activated carbon. In the present investigation the study on removal of dye Acid blue 25 using *Curcuma longa* waste activated carbon as an adsorbent following the down-flow column adsorption technique with a view to assess the stability of the chosen adsorbent for design purpose. Batch kinetic and isotherm studies were carried out at different conditions like contact time, Acid blue 25 concentration and bed height of the adsorbent. The Bohart-Adams and Thomas models were employed for the mathematical description of adsorption equilibrium, and finally it has been observed that the experimental data fitted more accurately to the Thomas model for both the cases.

INTRODUCTION

The major cause of environmental water pollution is industrial effluents. The effluents discharged from dyeing industries are highly coloured with a large amount of suspended organic solids. Presently, more than 12,000 different commercial dyes and pigments exist and about 7×10^5 tonnes are produced annually worldwide. Raw disposal of the dyed wastewater into the receiving water body causes much damage to aquatic life (Kanawade & Gaikwad 2011). Dyes are widely used in industries such as textile, rubber, paper, plastic, cosmetic, etc. Among these various industries, textile ranks first in usage of dyes for coloration of fibres. In fact, the proper discharge of such effluent is necessary for both toxicological and environmental reasons (Kanawade & Gaikwad 2011). The conventional wastewater treatment, which rely on aerobic biodegradation has low removal efficiency for reactive and other anionic soluble dyes. Due to low biodegradation of dyes, the conventional biological treatment process is not very effective in treating dye wastewater. It is usually treated with either physical or chemical processes. Also these processes are very costly and cannot effectively be used to treat the wastewater widely. The adsorption process is one of the effective methods for removal of dye from wastewater. The process of adsorption has an advantage over the other methods due to its sludge free clean operation and complete removal of dyes, even from the diluted solution (Alothman et al. 2011).

The commercially available activated carbon is much expensive, and moreover, regeneration using solution produces small additional effluent, while regeneration by refractory technique results in a 10-15% loss of adsorbents and its uptake capacity (Hairul & Kelly 2011).

Nowadays, there are many low cost adsorbents used for removal of dyes. Also there has been much interest in finding cheap and effective alternatives of activated carbon, such as clay minerals, lignin, fly ash, wood powder, coir pith and peat, etc., Therefore, the new adsorption technique that is economically viable, easily available and more effective is need of the hour (Dhir & Kumar 2010).

MATERIALS AND METHODS

Acid blue 25: Acid blue 25 supplied by Sterling Pigments and Chemicals, Mumbai, India was used as an adsorbate (Table 1). Double distilled water was used for preparing all the solutions and reagents.

***Curcuma longa* (Linn.):** It is a rhizomatous herbaceous perennial plant of the ginger family, Zingiberaceae. It needs a temperature between 20°C and 30°C and a considerable amount of annual rainfall to thrive.

Preparation of activated carbon and dye solutions: Agricultural waste used for this study was *Curcuma longa* collected from rural areas in and around the City Erode, Tamil Nadu. The dried material was used for the preparation of

Table 1: Summary data on Acid blue 25.

Classification	Anionic
Colour index	62055
Molecular weight	416.38
Molecular formula	$C_{20}H_{13}N_2Na0_5S$
Appearance	Purple blue
Phase	Solid
λmax (nm)	600

Table 2: Summary of data from batch studies (Acid blue 25).

Name	Effective Biomass pretreatment	Effect initial pH	Equilibrium time (h)	Effective effluent
Acid blue 25	H_2SO_4 + Auto clave	4.0	24	0.1 M NaOH

activated carbon using physical and chemical methods. All dyes and chemicals used were of AR grade. The dye solution was prepared by dissolving accurately weighed Acid blue 25 in distilled water at respective concentrations. The pH of Acid blue 25 solutions of various concentrations was adjusted to its effective pH obtained from result of the batch studies as given in Table 2. The concentration of the Acid blue 25 solution was determined using a spectrophotometer (Rangaraj et al. 1999).

Laboratory work/batch experiment: Aqueous solutions (20ppm, 40ppm and 60ppm) of Acid blue 25 were prepared by adding known amount of dye in de-ionized water. To study the adsorption capacity of the adsorbent, batch experiments were carried out. These experiments are effective to evaluate the basic parameters affecting adsorption (Tabrez et al. 2004).

During these experiments, the effects of bed depth, dye flow rate and carbon particle size, for the adsorption of Acid blue 25, have been correlated with this design procedure. The removal of adsorbent was by the process of centrifugation and the concentration of dye in the supernatant liquid was measured using spectrometer and by the calibration curves. The values obtained from the batch adsorption experiments are given in Table 3.

Instruments: Spectrophotometer-169 (Systronics model) was used for the measurement of colour. Absorbance values were recorded at the wavelength for maximum absorbance (λ max). A calibration curve has been prepared for the dye using known concentration of dye and measuring absorbance in each case. The wavelength for maximum absorbance of Acid blue 25 solution has been found to be 600nm.

RESULTS AND DISCUSSION

The experimental adsorption data from the column studies were analysed using the Thomas equation. Application of the Thomas model to the data at C_t/C_o ratios higher than 0.05 and lower than 0.90 with respect to the adsorption conditions such as flow rate, dye concentration, particle size and mass of adsorbent, enable determination of the adsorption parameters of the system (Liakou et al. 1997). The description of the column performance has also been based on bed depth-service time (BDST) model of Bohart and Adams.

The slope and intercept of the Thomas equation is dependent on the three parameters, the initial dye concentration, mass of adsorbent used and the volumetric flow rate. Moreover, the slope of the BDST equation is dependent on the initial dye concentration, flow rate and adsorption capacity. However, as the cross-section area of the column is constant throughout all experiments and the flow rate is also constant, the only cause for the change in slope is due to the bed capacity (Klong & Yuen 1996).

Effect of initial dye concentration: The effect of initial dye concentration on the shape of the breakthrough curves and the column adsorption parameters was investigated. Figs.

Table 3: The parameters of the column studied.

				Parameters				
Column	Initial dye concentration (mg/L) ppm	Internal Diameter (mm)	Particle size (μm)	Mass of adsorbent (g)	Flow rate, Q(mL/min)	Bed height (cm)	Retention time, t(min)	% of Removal colour
A	20	3.35	106.25	2	10	3.0	115	81.8571
	40	3.35	106.25	2	10	3.0	129	72.4286
	60	3.35	106.25	2	10	3.0	142	60.8571
B	20	3.35	106.25	3	20	4.5	59	83.6868
	40	3.35	106.25	3	20	4.5	73	71.7143
	60	3.35	106.25	3	20	4.5	85	61.4281
C	20	3.35	106.25	4	30	6.0	38	90.7624
	40	3.35	106.25	4	30	6.0	52	75.7143
	60	3.35	106.25	4	30	6.0	64	62.3051

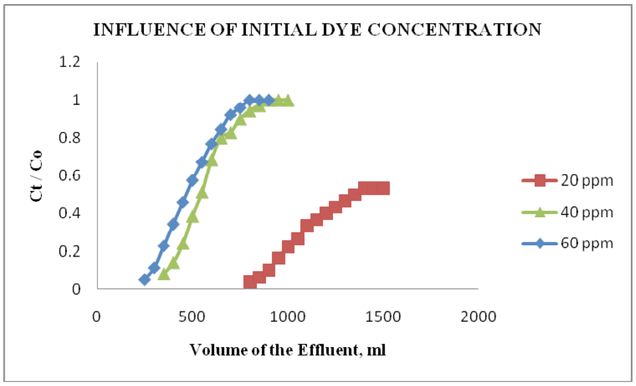

Fig. 1: Volume of the effluent Vs C_t/C_o

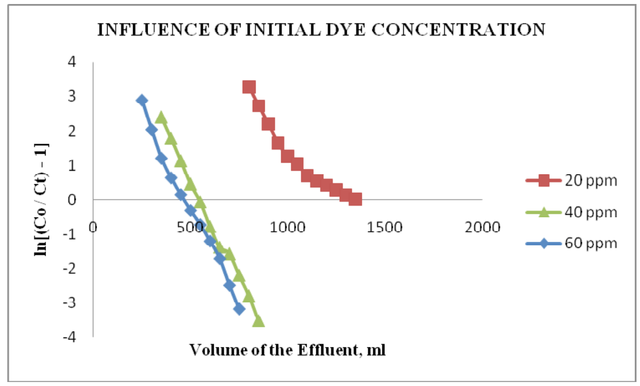

Fig. 2: Volume of the effluent Vs $\ln(C_o/C_t - 1)$.

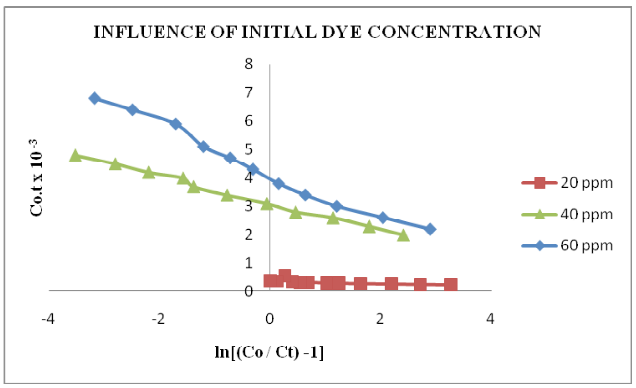

Fig. 3: ln $(C_o/C_t - 1)$ Vs $C_o.t \times 10^{-3}$.

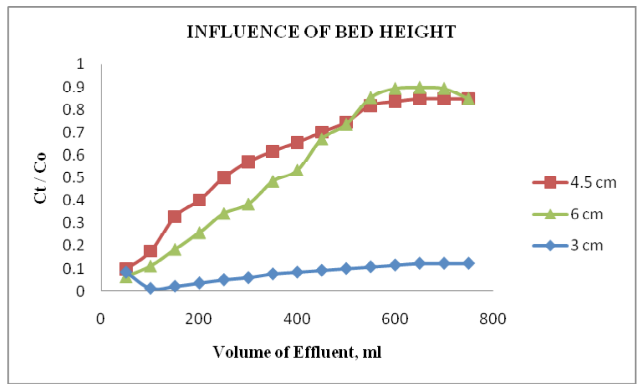

Fig. 4: Volume of the effluent Vs C_t/C_o.

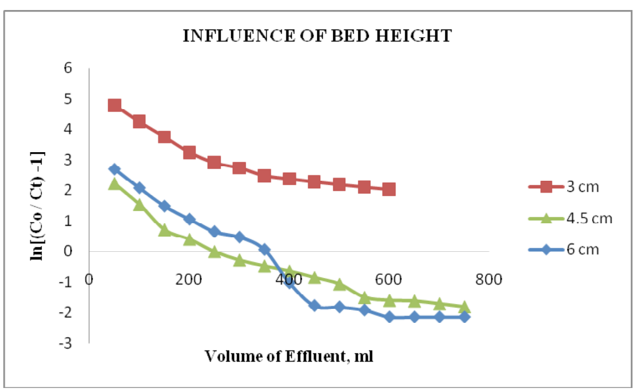

Fig. 5: Volume of the effluent Vs $\ln(C_o/C_t - 1)$.

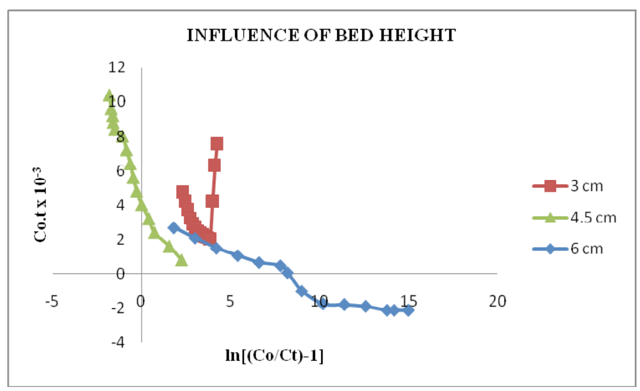

Fig. 6: ln $(C_o/C_t - 1)$ Vs $C_o.t \times 10^{-3}$.

1, 2 and 3 depict the breakthrough curves of adsorption of Acid blue 25 at different initial dye concentrations as a plot of dimensionless concentration (C_t/C_o) versus volume (V) of dye treated.

The Thomas equation was used to estimate the column adsorption parameters. It is shown that the adsorption capacity increased as the initial dye concentration increased. This is due to the concentration gradient. Higher the concentration gradient, higher the mass transfer driving force. High initial dye concentrations led to a high adsorption.

Effect of mass of adsorbent: The observed breakthrough curves of Acid blue 25 for column at three different masses of adsorbent are displayed in Figs. 4, 5 and 6 plotted as the effluent concentration ratio versus the throughput volume.

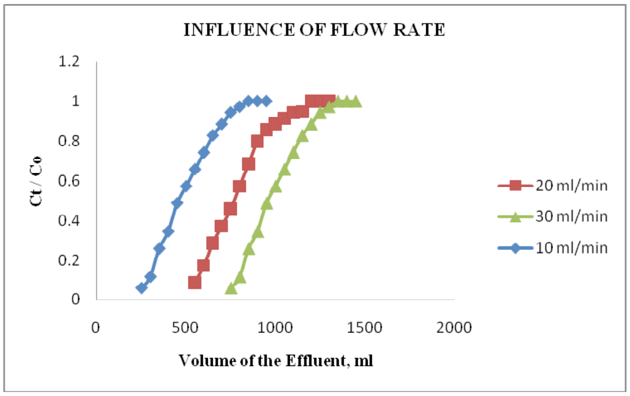

Fig. 7: Volume of the effluent Vs C_t/C_o.

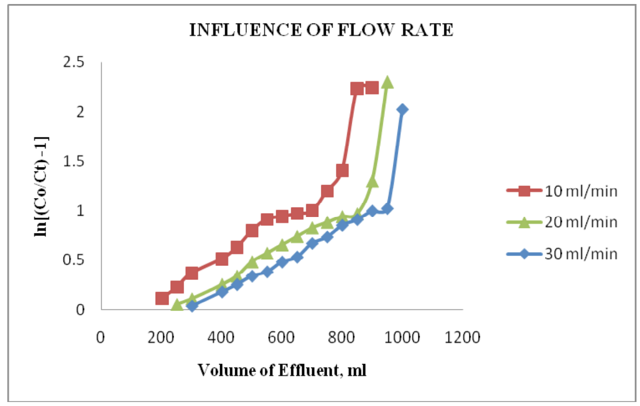

Fig. 8: Volume of the effluent Vs $\ln(C_o/C_t - 1)$.

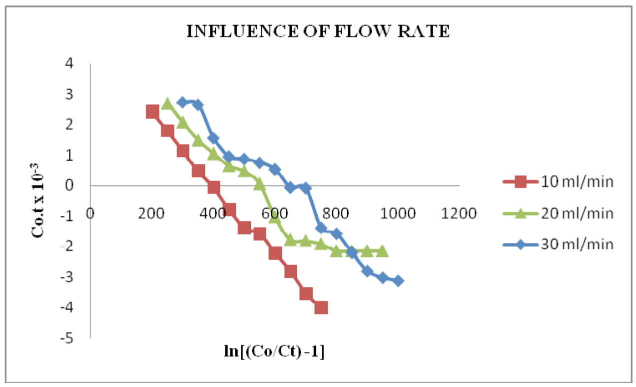

Fig. 9: $\ln (C_o/C_t - 1)$ Vs $C_o.t \times 10^{-3}$.

The time needed to reach the breakthrough point is low. The increase in the dye uptake capacity with the increase of the adsorbent mass in the column was due to the increase in the surface area of the adsorbent, which provides more binding sites for adsorption.

Effect of flow rate: In column studies contact time is the most significant variable, and therefore, bed depth and dye flow rate are the major parameters. Consequently, adsorption of Acid blue 25 was studied at the flow rates of 10, 20 and 30 mL/min in order to investigate the effect of flow rate on the adsorption behaviour. Initial dye concentration, pH and particle size were maintained constant. The experimental results of the effect of flow rates are illustrated in Figs. 7, 8 and 9. It is clearly shown that the breakthrough time increased with a decrease in the flow rate.

Adsorption isotherms: The adsorption studies conducted at fixed-bed column for obtaining initial concentration of Acid blue 25 and by varying adsorbent dose and the adsorption data were fitted to the Bohart-Adams and Thomas model isotherms (Morais et al. 2000).

Thomas Model : Thomas (1948) derived the mathematical expression for a column with a typical breakthrough curve:

$$\frac{C_t}{C_O} = \frac{1}{1+\exp\,[K_T(q_O\,m - Co\,V)\,/\,Q]} \qquad ...(1)$$

$$\ln\left(\frac{C_t}{C_O}\right) = \frac{K_T q_o m}{Q} = \frac{K_T C_o}{Q} V \qquad ...(2)$$

Where, C_O is the initial dye concentration (mg/L), C_t is the equilibrium concentration (mg/L) at time *t* (min), K_T is the Thomas constant (L/min mg), Q is the volumetric flow rate (L/min), q_o is the maximum column adsorption capacity (mg/g), *m* is the mass of adsorbent (g) and *V* is the throughput volume (L). Hence, a plot of $\ln (C_o/C_t - 1)$ versus V gives a straight line with a slope of $(-K_T C_o/Q)$ and an intercept of $(K_T q_o m/Q)$. Therefore, K_T and q_o can be obtained.

Bed depth-service time model (BDST): Bohart & Adams (1920) brought out the relation between the bed-depth of the adsorbent and service time (BDST). The Bohart-Adams equation varies linearly with the plot of service time Vs Bed depth. The slope of the linear plot yields the value [q_o/C_o]. From this value, the value of the adsorptive capacity can be calculated. And in turn, from the intercept, the rate constant can be calculated. If an adsorbate-adsorbent system obeys BDST model, a linear trace is expected for a plot of C_o Vs ln (C_o/C_t -1) where C_o and C_t are the initial effluent dye concentration and concentration of effluent at time *t*, respectively.

The linear relationship between bed depth *Z*, and service time *t*, is:

$$\ln\left(\frac{C_O}{C_b} - 1\right) = \ln\left(e^{KaNoZ/Q} - 1\right) - Ka\, C_O t \quad ...(3)$$

Because the exponential term, $e^{KaNoZ/Q}$, is usually much higher than unity, the unity term within the brackets on the left-hand side of equation is often neglected. Therefore, the linear relationship between the bed depth, *Z*, and the service time at breakthrough t_B, is:

$$t_B = \ln\left(\frac{N_O}{C_O Q}\right) Z - \frac{1}{K_a C_O} \ln\left(\frac{C_O}{C_b} - 1\right) \quad ...(4)$$

$$t_B = a_z + b$$

Where, C_o is the initial dye concentration (mg/L), C_b is the breakthrough dye concentration (mg/L), *Z* is the bed depth (dm), N_o is the column adsorption capacity of BDST model (g/L), Q is the flow rate (L/min), Ka is the adsorption rate constant (L/g min), *a* is the slope and *b* is the intercept of the equation.

CONCLUSION

Taking in view of the data, it is concluded that activated carbon can be used to remove colour from waste before it is being discharged into the aquatic systems. The procedure is simple and economical. This is fast and requires no chemical treatment. Adsorbed dye can be eluted and can be utilized as a raw material. Column could be reutilized, thus no waste management problem arises.

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