Removal of reactive blue 2 dye from aqueous solution using turmeric industrial waste activated carbon

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ABSTRACT

Removal of Reactive Blue 2 (RB 2) dye, using Turmeric Industrial Waste Activated Carbon (TWAC) as an adsorbent in a batch system with respect to various temperatures (303, 318 and 333K) and contact time was carried out and reported. The investigation clearly shows the adsorption reaction is found to be endothermic. Various kinetic models viz. pseudo first-order, pseudo second-order and Elovich models were applied to adsorption of reactive blue-2 dye on Turmeric Waste Activated Carbon. Results prove that the pseudo second order kinetic model was found to correlate the experimental data well. Langmuir and Freundlich adsorption isotherm studies were also measured and to propose plausible mechanism of adsorption involved in this process.

Keywords: Reactive Blue 2, Dye removal, Elovich model, Turmeric waste.

INTRODUCTION

The reactive dye is used for dyeing wool, cotton, nylon, silk, and modified acrylics. The presence of dyes in the effluents from various industries like textile industries, dyeing, paper industries and food industries creates severe environmental issues to the living things and also they are highly toxic to human beings and animals.

In this present work, Turmeric industrial waste activated carbon (TWAC) was prepared from Turmeric industrial waste material, which is used to remove Reactive Blue 2 (RB 2) from aqueous solution with respect to various temperatures and contact time parameters were studied.

MATERIALS AND METHODS

Batch adsorption studies: All reagents used were of AR grade (E Merck). 50ml of Reactive Blue 2 solution of known concentration (C₀) and initial pH was taken in a 100ml screw-cap conical flask with a required amount of adsorbent and was agitated at a speed of 200 rpm in a thermostatic shaker bath at 30° C for a specified period of time. Then the solution was filtered through a 0.45 µm membrane filter. The concentrations of dye in solutions were determined before and after adsorption using UV-spectrophotometer (Elico make). The amount of dye adsorbed and adsorption efficiency were calculated. The maximum absorption wavelength (λmax) for Reactive Blue 2 is measured to be 607nm.

Adsorption dynamics: The kinetics of Reactive Blue 2 (RB 2) adsorption on the activated carbons were analyzed using pseudo first order (Lagergren 1898), pseudo second order (Ho et al. 2000) kinetic models and Elovich equation (Chien and Clayton 1980).

Isotherm models: The study of the Langmuir and Freundlich isotherms are essential in assessing the adsorption efficiency of the adsorbent. At equilibrium conditions, the adsorption capacity, can also be predicted by using the above isotherms.

RESULTS AND DISCUSSION

Optimum pH: The adsorption behavior of Reactive Blue 2 on the adsorbent was studied over a wide pH range of 2.0-10.0. According to the effect of pKa (5.5) of RB 2 dye and pHzpc (5.9) of chosen adsorbent TWAC, the pH 6.0 was selected as optimum pH for the effective removal of reactive dye RB 2 and used the same for further studies.

Effect of Temperature on Kinetic Rate Constant and Rate Parameters: For adsorption process, adsorption experiments were now carried out with different temperature viz. 30°C, 45°C and 60°C, the results indicates that the adsorption of RB 2 on the turmeric industrial waste activated carbon (TWAC) is best described by second order rate equation with regression coefficient value is greater than 0.99.

![Figure 1. Effect of temperature on Pseudo second order plot for Reactive Blue 2 adsorption.](image-url)
Table 1. The adsorption kinetic model rate constants for TWAC at different temperature.

<table>
<thead>
<tr>
<th>Adsorbent</th>
<th>Initial Temperature</th>
<th>Pseudo first order</th>
<th>Pseudo second order</th>
<th>Elovich Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k_1 (min^-1)</td>
<td>r^2</td>
<td>k_2 (g mg^-1 min^-1)</td>
<td>h (mg g^-1 min^-1)</td>
</tr>
<tr>
<td>TWAC</td>
<td>30°C</td>
<td>-0.035</td>
<td>0.9452</td>
<td>0.0012</td>
</tr>
<tr>
<td></td>
<td>45°C</td>
<td>-0.025</td>
<td>0.965</td>
<td>0.00099</td>
</tr>
<tr>
<td></td>
<td>60°C</td>
<td>-0.024</td>
<td>0.9826</td>
<td>0.0098</td>
</tr>
</tbody>
</table>

Thermodynamic Parameters: ΔH and ΔS were obtained from the slope and intercept of Van’t Hoff plot (1/t vs lnK). Table 2 gives the value of ΔG, ΔS and ΔH for the adsorption of TWAC. The negative values of free energy change (ΔG) indicate the feasibility and spontaneous nature of adsorption of TWAC. The positive value of ΔS is due to the increased randomness during the adsorption of adsorbent. The positive value of ΔH also indicates the reaction is endothermic.

Table 2. Thermodynamic parameters for Reactive Blue 2 on TWAC adsorption.

<table>
<thead>
<tr>
<th>Adsorbent</th>
<th>ΔG x 10^4 (KJ mol^-1)</th>
<th>ΔH (KJ mol^-1)</th>
<th>ΔS (KJ mol^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWAC</td>
<td>-8444.99</td>
<td>-12285.6</td>
<td>-30490.8</td>
</tr>
</tbody>
</table>

Mechanism: According to Michelson et al., (1975) for film diffusion to be rate-determining step, the value of the film diffusion coefficient, D_f should be in the range 10^-6-10^-10 cm^2/sec. If pore diffusion were to be the rate limiting, the pore diffusion coefficient, D_p should be in the range 10^-11, 10^-13 cm^2/sec. In order to find out the nature of the process responsible for adsorption on to chosen adsorbent, attempts were made to calculate the diffusion co-efficient of the process.

Assuming spherical geometry of the sorbents (Bhattacharya et al. 1984), the overall rate constant of the process can be correlated to the pore diffusion coefficient in accordance with the expression.

\[ t_{1/2} = 0.03 \frac{r^2}{D_p} \quad (1) \]

or to the film diffusion coefficient with \( t_{1/2} = 0.23 \frac{r^2 \hat{d}}{D_f} \times \frac{C}{C_e} \quad (2) \)

where, \( r \) is radius of the sorbent (cm), \( D_p \) and \( D_f \) are pore diffusion coefficient (cm^2/sec) and film diffusion coefficient (cm^2/sec) respectively, \( \frac{C}{C_e} \) is equilibrium loading of the adsorbent, \( \hat{d} \) is the film thickness (cm) and \( t_{1/2} \) is the time for half change (sec).

Since the carbon particles used were of the size range (180-250μm), the average diameter of the particle was taken as 0.0215 x 10^-4 cm. Using these values, the film diffusion coefficients and pore diffusion coefficients were calculated. Then considering the pseudo first order rate constant k_1, for the adsorption of Reactive Blue 2, the values of D_p and D_f were calculated under the given set of operating conditions, and are presented in the Table 3.

Table 3. D_p and D_f values for the chosen adsorbent-adsorbate system.

<table>
<thead>
<tr>
<th>Temp. (°C)</th>
<th>t_{1/2}(sec)</th>
<th>TWAC</th>
<th>D_p x 10^{11}, cm^2</th>
<th>D_f x 10^{-9}, cm^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>12.40331352</td>
<td>2.80</td>
<td>1.5046</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>8.948016286</td>
<td>3.87</td>
<td>2.3397</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>3.77546258</td>
<td>9.18</td>
<td>6.0451</td>
<td></td>
</tr>
</tbody>
</table>

The present study indicates the D_p values in the order of 10^{11} cm/sec and the D_f values in the order of 10^{-9} for the respective Lagergren plots for Reactive Blue 2 (RB 2) and hence the investigator conclude that the mechanism of the removal of Reactive Blue 2 (RB 2) in the present study follows pore diffusion mechanism.

CONCLUSIONS

The adsorption of Reactive Blue 2 (RB2) was found to be dependent on pH, temperature and contact time for the adsorbent. Thermodynamic parameters obtained for the adsorbent account for feasibility of the process. Further, the kinetic studies apparently reveal that the removal takes through a pore diffusion process at all temperatures for TWAC. The kinetics of Reactive Blue 2 (RB 2) adsorption on the Turmeric industrial waste activated carbon (TWAC) adsorbent was found to follow a pseudo second-order rate equation.

REFERENCES