Adsorption of dye Green B from a textile industry effluent using two different samples of activated carbon by static batch method and continuous process

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Removal of dye Green B using two different samples of activated carbon by static-batch method and continuous process was studied. Experimental data on optical density of blank solutions of different concentrations ranging from 10 to 100mg/L and optical density of solutions after adsorption on activated carbon samples were taken and analyzed. Calibration curves were plotted and the amount of dye adsorbed was calculated. The data was fitted to Langmuir and Freundlich isotherms for two different carbon samples and concentration values. Constants were calculated from the slope and intercept values of the isotherm. Coefficient of correlation $R^2$ and standard deviation SD were also noted. The data fitted well to the isotherms. Carbon sample C$_1$ showed considerably higher potential to adsorb the dye Green B as compared to carbon sample C$_2$. Adsorption was better in batch process in respect to continuous flow method. From the analysis of the data it is shown that both activated carbon samples had a good capacity to remove the textile dye from the residue wastewater.

Keywords: Adsorption, Green B, Activated carbon, Textile industry effluent

Man has known the art of dyeing textiles since time immemorial. Till most of the nineteenth century all dyes being used were from natural sources but with the discovery of the first synthetic dye the dyeing industry saw a revolutionary change$^1$. The synthetic dyes have proved to be a severe environmental hazard resulting in poor water quality thereby destroying plant and animal/aquatic life and causing allergic reactions, certain types of cancers and poisoning. Treatment of large volumes of wastewater emerging from a dyeing and printing unit in order to make it safe for human consumption (drinking, cooking, washing etc.) hence becomes of utmost importance.

An overview of conventional and advanced sorbents for the treatment of wastewaters is reported by Petar and Maja$^2$. The use of activated carbon and zeolites in colour removal and removal of heavy metal ions from textile effluents is also discussed in detail. The potential of low-cost or cost-effective sorbents as an alternative to the conventionally used sorbents is also given.

Huang$^3$ studied the treatment of textile wastewater by physiochemical methods. It was pointed out that the major components in dyeing wastewater are dyes, surfactants, starch, chemical aids and suspended solids. Dyes are divided into hydrophilic and hydrophobic group. The former is removed effectively by activated carbon and chlorine while the later is removed by floatation. Results showed that water from cotton dyeing and processing unit when treated as above could be reused as effectively as river water while for rinsing processes the treated water was not as good.

Perrich$^4$ recommends the use of activated carbon for removing dye colour from effluent of textile dyeing and finishing industry before letting it flow into streams and sewers. Removal of some reactive dyes from textile processing wastewater using powdered activated carbon have been discussed by Pala et al.$^5$. Colour removal from a dyestuff industry effluent using activated carbon has been discussed by Rao et al.$^6$. Mittal and Venkobachar$^7$ studied the adsorption of Rhodamine B (Basic violet 10) and Sondolan Rhodine (Acid red 1). El-Guendi$^8$ observed adsorption of basic dyes onto natural clay in batch adsorbers. Basic blue 69 and Basic red 22 were the dyestuffs adsorbed onto natural clay.

Adsorptive removal of Methylene blue from aqueous solutions using activated carbon was studied by Goyal et al.$^9$. It was found that adsorption of Methylene blue was more on granular activated carbon as compared to fibrous carbon. This may be
due to the difference in chemical nature of the carbon surface and not just due to the difference in surface area.

Al-Degs et al.\textsuperscript{10} have also explained the differences in the capacity of adsorbents for same adsorbate due to their surface properties. The surface of adsorbent materials can not contain one but at least five markedly different types of surface groups. Different samples of carbon or any other adsorbent for that matter can have different amount of pores and adsorption sites and show higher or lower adsorption capacity towards organic dyes/pollutants. This reactivity arises from the complexity of the chemical surface.

In the present work, experiments were conducted on dye Green B to generate isotherm data. Green B \([\text{C}_{10}\text{H}_{5}\text{NO}_{5}\text{SNa}_{3}]\) is a direct dye used for dyeing wool and silk. It is also called Acid green and belongs to the azoic group of dyes. The present work forms a part of continuing study for the removal of dye from textile industry effluent using carbon and other low cost adsorbents.

**Experimental Procedure**

**Static –batch method**

Samples of granular activated carbon C\textsubscript{1} and C\textsubscript{2} used were obtained from Brillex Chemical Ltd., Punjab and Industrial Carbon Pvt. Ltd., Gujarat. Surface area of granular activated carbon C\textsubscript{1} used in the study was 950 m\textsuperscript{2}/g and that of sample C\textsubscript{2} was 600 m\textsuperscript{2}/g. Bulk density of the two was 500-550 and 600-1000 g/L respectively. The ash content was 6% in C\textsubscript{1} and 5% in C\textsubscript{2}.

A stock solution of dye with a concentration of 1000 ppm was prepared and dilutions were made with distilled water to make different concentrations as described earlier\textsuperscript{11}. Optical density of all the solutions was measured on a spectrophotometer (ELICO make, wavelength range 200-900 nm). One gram of activated carbon was placed in each 50 mL solution of 10 to 100 ppm. The solutions were shaken and kept in a thermostat for 24 h. The samples were then filtered and analyzed spectrophotometrically.

**Continuous adsorption process**

A rotameter was calibrated to give the required flow rate of the dye solution. Three columns connected in series were filled with granular activated carbon (GAC) sample C\textsubscript{2} (randomly selected) to a height of 26 cm. Columns A, B and C contained 175, 183 and 172 g of GAC respectively. The flow diagram of the experimental set up is shown in Fig. 1. The storage tank was filled with 130 L of dye solution of 100 ppm concentration. After taking care of leakages and driving off the trapped air from the set up the dye was allowed to run at three different constant flow rates on different days. Each experiment was run till a breakthrough time was reached. Samples of the feed were drawn at regular intervals from all the three columns and were analyzed for their concentration.

**Results and Discussion**

**Adsorption isotherms**

The results were analyzed with the help of Langmuir and Freundlich isotherms. Langmuir constants Q and b were calculated from the slope and intercept of linear plot between \(1/q_e\) and \(1/C_e\) as shown in Fig. 2. The values of these constants along with dimensionless separation factor \(R^2\) and SD are given in Table 1. \(Q\) indicates the affinity of dye to the adsorbent in different experimental conditions. C\textsubscript{1} shows greater affinity to the dye as compared to C\textsubscript{2}.

The linear plot of log \(q_e\) and log \(C_e\) for Freundlich isotherm is shown in Fig. 3. Freundlich constants \(K_f\) and n calculated from the slope and intercept of log \(q_e\) and log \(C_e\) along with \(R^2\) and SD are given in Table 1. Value of \(K\) indicates that C\textsubscript{1} showed better adsorption as compared to C\textsubscript{2}.

Both adsorption isotherm models were found to generate a satisfactory fit to the experimental data. The data reveals that both Langmuir and Freundlich isotherms for the present system exhibit monolayer coverage of the adsorbate on the outer surface of the adsorbent. Langmuir equation yielded better fit than Freundlich equation as observed from the values of SD.
Adsorption of Green B in static batch method on two samples of activated carbon

It was found that at lower concentrations adsorption of dye Green B was better as compared to its adsorption at higher concentrations. The adsorption was 89% at 10 ppm and 56.8% at 100 ppm on C₁. It was 48% at 10 ppm and 27.5% at 100 ppm on C₂. Figure 4 shows the comparison of amount of dye adsorbed by C₁ and C₂ at initial pH 7.5.

Adsorption of Green B in continuous process

It was found that on contacting C₂ with a continuous stream of dye solution of concentration 100 mg/L the dye was adsorbed on C₂ resulting in the effluent solution gradually being depleted of its dye content. The amount of dye adsorbed, mg/L in different columns found from the calibration curve drawn for a dye Green B at initial pH 7.5 is also shown in Figs 5 – 7.

The breakthrough time $T_b$ is the time when C₂ achieved the breakthrough capacity which is 25-50% of the theoretical capacity. Table 2 shows the breakthrough times for the three columns at different flow rates.

The portion of the bed where the adsorption is minimum is called the Equilibrium Zone (EQZ). In between the EQZ and the unused bed is the Mass Transfer Zone (MTZ) where the adsorption falls from maximum to minimum. This is the zone where the dye is being transferred to C₂. At breakthrough the bed consists of EQZ and MTZ.

Under steady flow conditions the MTZ gradually advances through the bed and at equilibrium $T_e$ the trailing edge of MTZ reaches the unused edge of the bed. At $T_e$ the effluent concentration becomes equal to...
feed concentration i.e. 100 mg/L. Values of \( T_e \) were found from Figs 5–7 and are shown in Table 2 for all columns at different flow rates.

All the adsorption data and concentration versus time data was analyzed in terms of stoichiometric breakthrough. At stoichiometric time \( T_s \) the effluent concentration instantaneously changed from minimum to maximum. To reach a value of \( T_s \) a vertical line was drawn on breakthrough plots such that: area (abdca) = area (abgea). In other words the used adsorbent capacity within the mass transfer zone was balanced with used adsorbent capacity for stoichiometric breakthrough. In Figs 5–7 the rectangle hcdkh represents length of equilibrium section (LES)

<table>
<thead>
<tr>
<th>Time (H)</th>
<th>Flow rate (mL/min)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>( T_b )</td>
<td>Column A</td>
</tr>
<tr>
<td>1 h</td>
<td>1 h</td>
</tr>
<tr>
<td>5 h 21 min</td>
<td>6 h 6 min</td>
</tr>
<tr>
<td>14 h</td>
<td>14 h</td>
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<tr>
<td>( \varphi )</td>
<td>0.314</td>
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</tbody>
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Fig. 5—Concentration versus time for Column A at different flow rates.

Fig. 6—Concentration versus time for Column B at different flow rates.
and rectangle dcefd represents the unused bed LUB in which the loading is minimum. The values of $T_s$ were obtained from these Figures and are given in Table 2. The fractional capacity of carbon bed used within the mass transfer zone\(^{13}\) was calculated as $\Phi = \frac{\text{area (abgea/baefb)}}{\text{area}}$. This is the measured capacity of granular activated carbon. Values of $\Phi$ for all the columns at different flow rates are shown in Table 2.

The data of amount of dye Green B adsorbed on C\(_2\) in dynamic –continuous process has been compared with that of static-batch process. The value of $\Phi$ at different flow rates indicates that the efficiency of C\(_2\) to adsorb Green B is less in continuous process as compared to batch process.

**Conclusion**

From the results of the present study it may be observed that percentage removal of dye decreased with increase in initial concentration from 10 to 100 mg/L. It was seen to be as high as 89% at 10 mg/L concentration and it fell down to 56.8% at 100 mg/L concentration in static batch process. Adsorption was higher in static-batch process as compared to that in dynamic continuous process. In the continuous process adsorption was higher at slower flow rate as compared to that at faster flow rate. Adsorption followed both Langmuir and Freundlich isotherms whereas Langmuir equation gave a better fit. More amount of dye was adsorbed on carbon sample C\(_1\) as compared to that on C\(_2\).

**References**