Sorption Studies of Acid Dye by Mixed Sorbents

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Abstract. The sorption of Acid Blue 9 onto the mixture of activated clay and activated carbon has been studied in terms of pseudo-first order and pseudo-second order chemical sorption processes. The batch sorption model, based on the assumption of a pseudo-second order mechanism, has been developed to predict the rate constant of sorption and the equilibrium capacity with the effect of initial dye concentration, mass of mixed sorbent, temperature and initial solution pH. The rates of sorption were found to conform to pseudo-second order kinetics with good correlation. Batch isotherm studies showed that the sorption of Acid Blue 9 by the mixed sorbent from aqueous solution was described by the Langmuir isotherm equation. A comparison of the evaluated equilibrium capacity of sorption has been made by the pseudo-second order rate equation as well as by the Langmuir isotherm and operating line method. In addition, an activation energy of sorption has also been determined based on the pseudo-second order rate constants.

Keywords: sorption, kinetics, acid dye, mixed sorbent

Introduction

In modern industrial society, dyes are used everywhere. Because they are inert and nontoxic when discharged into waste streams, people always overlook their undesirable nature. Some are harmful to aquatic life in rivers where they are discharged. Decolourizing of textile and dye-manufacturing wastewater is currently a major problem for environmental managers. Coloured effluent treatment has not received much attention as it was thought to be of only aesthetic concern. Sorption techniques produce high quality treated effluents and sorption processes have been investigated as a method to remove dyes from wastewater. The most widely used sorbent for industrial applications is activated carbon (Walker and Weatherley, 1997; Khalil and Girgis, 1998; Porter et al., 1999). There are still problems associated with its use; namely, activated carbon is expensive and the higher the quality the greater the cost. Extensive investigations are being carried out to identify suitable relatively cheap sorbents capable of removing significant quantities of acid dyes. Table 1 shows a number of cheap sorbents available for acid dye sorption.

In recent years, clay has been accepted as one of the most appropriate low cost sorbents. For the treatment of colours, such as carpet effluents containing mainly Metomega Chrome Orange GL (Gupta and Shukla, 1996), the popular chrome dye, Omega Chrome Red ME (Gupta et al., 1992) and the acid dye (Khattri and Singh, 1998) as well as the treatment of heavy metals, such as lead(II) (Yadava et al., 1991) and cesium (Sawhney, 1966), the application of sorption techniques using clay has been tested. In addition, the mixed sorbent systems, such as the sorption of lead(II) by

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Table 1. A number of cheap available sorbents for sorption of acid dyes.

<table>
<thead>
<tr>
<th>Sorbents</th>
<th>References</th>
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<tbody>
<tr>
<td>Peat</td>
<td>Poots et al. (1976)</td>
</tr>
<tr>
<td>Wood</td>
<td>Ho and McKay (1998)</td>
</tr>
<tr>
<td>Woodmeal</td>
<td>McKay and McConvey (1985)</td>
</tr>
<tr>
<td>Wood sawdust</td>
<td>Ibrahim et al. (1997)</td>
</tr>
<tr>
<td>Chitin</td>
<td>McKay et al. (1987)</td>
</tr>
<tr>
<td>Linked chitosan fiber</td>
<td>Yoshida et al. (1993)</td>
</tr>
<tr>
<td>Biomass</td>
<td>Laszlo (1994)</td>
</tr>
<tr>
<td>Slag</td>
<td>Ramakrishna and Viraraghavan (1998)</td>
</tr>
<tr>
<td>Clay</td>
<td>Khattri and Singh (1998)</td>
</tr>
<tr>
<td>Water hyacinth root</td>
<td>Lee et al. (1999)</td>
</tr>
<tr>
<td>Pth</td>
<td>Ho and McKay (1999)</td>
</tr>
<tr>
<td>White rot fungus</td>
<td>Nagarajan and Annadurai (1999)</td>
</tr>
</tbody>
</table>

Adsorption on china clay and wollastonite (Yadava et al., 1991), and the heterogeneous mixture of alumina and clay to remove the colour of dyes (Khattri and Singh, 1998) have also been investigated.

In this paper, experiments have been carried out to expect the sorption capacity and kinetics of Acid Blue 9 from aqueous solution using the mixture of activated clay and activated carbon. The factors studied include the influence of initial dye concentration, mass of mixed sorbent, temperature and initial solution pH on the sorption kinetics of the system. A rate parameter, \( k \), has been defined and used to describe the sorption of acid dye onto mixed sorbent. In addition, a comparison of a pseudo-first order rate parameter, \( k_1 \), and a pseudo-second order sorption parameter, \( k \), has also been discussed.

Materials and Methods

Acid Blue 9, AB9, (was provided by Taiwan I-Hwa Co. and Bayer Chemical Co.), solutions were prepared with reverse osmosis treated water to make 500 ml of solutions at pH 3.0, which were maintained at a desired temperature prior to the experiment (Solution A). Activated carbon and activated clay (was purchased from Laporte Industries Singapore Pte., Ltd.) had been placed in an oven for more than 24 hours, that were accurately weighed for a required amount and were placed in the stirring chamber containing 400 ml of reverse osmosis treated water with pH adjusted to 3.0, and temperature was preset to a desired value. The ionic strength of the dye solution at pH 3.0 was adjusted to 0.02 M with sodium sulfate (Solution B). Before mixing, 100 ml of Solution A was drawn for the measurement of the initial dye concentration, \( C_0 \), while the remaining 400 ml was immediately decanted into Solution B for the sorption experiment. At intervals of 0.5, 1, 2, 5, 30, 60 and 120 minutes, about 2 ml of the sample was drawn using a 20 ml syringe. It was then filtered through a membrane filter (it was placed in a filter with a diameter of 25 mm, provide by Gelman Co.). The filtrate was diluted with reverse osmosis treated water for optical measurement. To study the effects of experimental parameters such as the initial dye concentration, the ratio of activated carbon to activated clay, pH, and temperature on AB9 sorption, we proceeded by changing one parameter at a time while holding the others constant.

Results and Discussion

Sorption Isotherm

The equilibrium isotherm for the sorption of AB9 on mixed sorbent was determined with 6.5 g mixed sorbent, activated clay 6 g and carbon 0.5 g, with 0.8 dm³ of dye solutions of various concentrations. The systems were agitated for 2.5 hours in a constant temperature using water bath. The sorption process was confirmed to fit with the following Langmuir isotherm:

\[
q_e = \frac{C_e}{1 + \frac{a_C}{K_L} C_e}
\]

(1)

The experimental points are shown in Fig. 1 and compared with a solid Langmuir isotherm line, having a correlation coefficient of 0.996 and equation:

\[
q_e = \frac{C_e}{9.75 \times 10^{-2} + 1.62 \times 10^{-2} C_e}
\]

(2)

Figure 1 also shows the operating line which is generated with a slope of solution volume/mass of mixed sorbent. The final equilibrium solution concentration is predicted from the point of intersection of the operating line on the Langmuir isotherm, for the sorption of AB9. The operation line is the line which predicts the time dependence of a sorption process and integrates this dependence into the equilibrium isotherm. The dye material balance equation for batch dynamic studies is:

\[
(C_0 - C_t) V = (q_t - q_0) m
\]

(3)