ADSORPTION STUDIES ON REMOVAL OF Cr (VI) FROM AQUEOUS SOLUTION USING SILK COTTON HULL CARBON

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ABSTRACT

Activated carbon prepared from silk cotton hull carbon (SCHC) was used to remove Cr(VI) from aqueous solutions by adsorption technique under varying conditions of agitation time, metal ion concentration, adsorbent dosage and pH. Adsorption followed both Langmuir and Freundlich isotherm models. The adsorption capacity was found to be effective with the particle size of 125-250mm at room temperature (30±2°C) and an initial pH of 3±0.2.

INTRODUCTION

Heavy metals in the environment are of global concern due to their non-degradability and biomagnification. Among several heavy metals, chromium compounds are used extensively in industrial processes such as electro plating, leather tanning and in the manufacture of paints, dyes, paper, explosives and ceramics. Hexavalent and trivalent chromium possesses carcinogenic properties (Hueper and Payne, 1962). Large doses of hexavalent chromium lead to corrosive effects in the intestinal tract and to nephritis. Many conventional methods can be adopted for the removal of Cr from wastewater. However

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the methods are expensive in Indian context where economy plays a major role. This resulted in a quest of low-cost, non-conventional adsorbents for heavy metal removal such as coir pith carbon, coconut saw dust carbon (Selvi et al. 2001), and peanut hull carbon (Periasamy & Namasiyavam 1995).

This study deals with the use of activated carbon prepared from silk cotton hull as an adsorbent for the removal of Cr (VI) from aqueous solution. Silk Cotton hull is dumped in and around silk cotton processing industries and available as large mass of causing disposal problem in industries. Coimbatore is the place where more silk cotton processing industries are present, ranking second among the countries. The main aim of this work was to evaluate the feasibility of using silk cotton hull carbon for Cr (VI) removal.

MATERIALS AND METHODS

Adsorbent

Silk Cotton Hull (SCH) obtained from silk cotton processing unit was cut into small pieces, dried in sunlight until the moisture was partially evaporated and was further dried in a hot air oven at 60°C for 24 h. The dried material was chemical activated by treating with 50% sulfuric acid and ammonium per sulphate (0.5%) with constant stirring. The charred material was kept in hot air oven at 100 ± 5°C for 24 hours and washed with double distilled water. Then the material was soaked in 5% sodium bicarbonate solution and allowed to stand overnight to remove any residual acid, washed with distilled water until the pH of the adsorbent attains a pH of 3 ± 0.2 and dried in a hot air oven at 100 ± 5°C for 12 hours. The dried material was sieved to get the particle size of 125 - 250 µm and was used in this study.

Adsorbate

1000 mg/L of Cr (VI) was prepared by dissolving 2.8287 g of potassium dichromate in double distilled water. The stock solution was diluted with distilled water to obtain the required standard solutions.

Batch mode adsorption studies

The working solution of 10, 20, 30, 40 mg/L of Cr (VI) was prepared from stock solution. Batch mode adsorption studies were carried out with 250 mg of the adsorbent and 50 mL of Cr (VI) solution of desired concentration at a pH of 3.0±0.2, agitated at 120 rpm in a mechanical shaker at room temperature. The adsorbate solution was separated from the adsorbent by centrifugation at 500 rpm and estimated spectrophotometrically at 540 nm using diphenyl carbazide (APHA, 1980). The effect of carbon dosage on percent removal of Cr (VI) was studied with solutions of 30 and 40 mg/L for particle size 125 - 250µm. Effect of pH on Cr (VI) removal was studied for metal ion concentrations 10, 20mg/L using 250mg of carbon dosage. Langmuir isotherm concentration of Cr (VI) ion onto activated carbon. The values of kad were calculated from sorption in 1/min. The linear plots of log10 (qe-q) Vs t for different metal ion concentrations indicate applicability of the above equation for the adsorption rate expression given by Lagergren.

Where q & qe are the amount of metal ion adsorbed by the adsorbent at time ‘t’ and at equilibrium time respectively. Kad is the rate constant of adsorption in 1/min. The linear plots of log10 (qe-q) Vs t for different metal ion concentrations indicate applicability of the above equation for the adsorption of Cr (VI) ion onto activated carbon. The values of kad were calculated from the slope of the linear plots and are presented in Table 2.

Effect of carbon dosage on percent removal

The effect of carbon dosage on percent removal of Cr (VI) from aqueous solution by activated carbon prepared from silk cotton hull is shown in Fig (2). The removal rate was rapid initially and then slowed down gradually until it attained equilibrium beyond which there was no significant increase in the rate of removal. The equilibrium was attained with in 180 min for all the concentrations studied (10 to 40 mg/L). The curves obtained were single, smooth and continuous till the saturation of Cr (VI) onto activated carbon surface.

Adsorption Kinetics

The rate constants of Cr (VI) adsorption onto SCH carbon follows first order rate expression given by Lagergren.

$- \frac{dq}{dt} = k_a q_e (1-q_e/q)$

Where q & qe are the amount of metal ion adsorbed by the adsorbent at time ‘t’ and at equilibrium time respectively. Kad is the rate constant of adsorption in 1/min. The linear plots of log10 (qe-q) Vs t for different metal ion concentrations indicate applicability of the above equation for the adsorption of Cr (VI) ion onto activated carbon. The values of kad were calculated from the slope of the linear plots and are presented in Table 2.

Effect of carbon dosage on percent removal

The effect of carbon dosage on percent removal of Cr (VI) is shown in Fig (3). When the carbon dosage increases, the percent removal also increases. It was found that 100% removal of 30 & 40 mg/L of Cr (VI) require 450 and 550 mg
of carbon respectively.

**Adsorption Isotherm**

The Langmuir isotherm can be applied for adsorption equilibrium of Cr (VI) onto SCH carbon

\[
\frac{C_e}{q_e} = \frac{1}{Q_0 b} + \frac{C_e}{Q_0}
\]

Where, \(C_e\) is the equilibrium concentration (mg/L), \(q_e\) is the amount of Cr (VI) 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 model (Fig. 4). The value of \(Q_0\) & \(b\) calculated for 10mg/L concentration were,

\[Q_0 = 30.30 \text{ mg/g}\]
\[b = 0.420 \text{ 1/min}\]

Langmuir isotherm can be expressed in terms of dimensionless separation factor or equilibrium parameter (Mckay et al. 1980) and can be written as,

\[R_L = \left(\frac{1}{1 + \frac{C_0}{Q_0}}\right)\]

Where,

\(C_0\) is the initial Cr (VI) concentration in mg/L and \(b\) is the Langmuir constant (L/mg).

**Table 1. Characteristics of Activated Carbon**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (1% Solution)</td>
<td>7.69</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>2.86</td>
</tr>
<tr>
<td>Ash content (%)</td>
<td>1.987</td>
</tr>
<tr>
<td>Decolourising power (mg/g)</td>
<td>22.5</td>
</tr>
<tr>
<td>Phenol adsorption capacity (mg/g)</td>
<td>11.2</td>
</tr>
<tr>
<td>Ion-exchange capacity (milli equi/g)</td>
<td>0.0145</td>
</tr>
<tr>
<td>Apparent density (g/mL)</td>
<td>0.42</td>
</tr>
<tr>
<td>Water soluble matter (%)</td>
<td>2.0</td>
</tr>
<tr>
<td>Acid soluble matter (%)</td>
<td>7.0</td>
</tr>
<tr>
<td>Surface area (m²/g)</td>
<td>228.0</td>
</tr>
</tbody>
</table>

**Table 2. Lagergren Rate Constant for Cr (VI) Adsorption**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Cr (VI) Concentration mg/L</th>
<th>Rate constant (K_w) (1/ min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>- 3 ± 0.2</td>
<td>10</td>
</tr>
<tr>
<td>Carbon dosage</td>
<td>- 250 mg/50mL</td>
<td>20</td>
</tr>
<tr>
<td>Particle size</td>
<td>- 125 – 250 mmin</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40</td>
</tr>
</tbody>
</table>

The type of isotherm can be revealed by RL value.

<table>
<thead>
<tr>
<th>RL value Type of isotherm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RL &gt;1</td>
<td>Unfavorable</td>
</tr>
<tr>
<td>RL = 1</td>
<td>Linear</td>
</tr>
<tr>
<td>0 &lt; RL &lt; 1</td>
<td>Favorable</td>
</tr>
<tr>
<td>RL = 0</td>
<td>Irreversible</td>
</tr>
</tbody>
</table>

The linear form of Freundlich equation can be given by

Where, \(x\) is the amount of Cr (VI) adsorbed at equilibrium (mg), \(m\) is the
weight of adsorbent used (mg), \( C_e \) is the equilibrium concentration of Cr(VI) in solution (mg/L). \( k_f \) and \( n \) are constants. Linear plot of \( \log x/m \) Vs \( \log C_e \) shows that the adsorption follows Freundlich isotherm (Fig.5). The Freundlich constants \( k_f \) and \( n \) are found to be 3.588 and 0.5263 respectively for the concentration of 10mg/L.

Effect of pH on Cr (VI) removal

Effect of pH on Cr(VI) removal is shown in Fig. (6). Adsorption decreases with increase in pH. Lower adsorption of Cr(VI), at alkaline pH is probably due to the presence of excess of OH- ions competing with the metal ions for the adsorption sites. The highest percent removal was possible at an initial pH of 3±0.2.

Desorption Studies

Attempts were made to degenerate metal ion from the laden carbon using various strengths of NaOH (0.25 to 1.75 N). Desorption data indicates the
mechanism of adsorption is the ion-exchange process and the complete regeneration of adsorbate and adsorbent are possible. Fig. 7 shown the effect of NaOH on Cr (VI) adsorption

CONCLUSION

The activated carbon prepared from silk cotton hull carbon can be used for the removal of Cr (VI) from aqueous solution effectively. The adsorption depends on solution pH, initial metal ion concentration, and carbon dose. The adsorption followed both Langmuir & Freundlich isotherm models. Desorption data indicates the mechanism of adsorption is the ion-exchange process and the complete regeneration of adsorbate and adsorbent are possible

REFERENCES