Adsorption of O-Cresol in Landfill Leachate Using Activated Carbon

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Abstract—The adsorptive removal of o-cresol from dilute aqueous solutions was carried using commercial activated carbon. Batch mode studies were performed by varying parameters such as pH, adsorbent dosage and time. It was found that adsorption with activated carbon can remove up to 95% of o-cresol from the wastewater within 10 minutes. The optimum process variables of this adsorption of o-cresol were found as pH 8 and adsorption dosage 5 g/L. The adsorption followed Langmuir Isotherm.

Index Terms—Activated carbon, adsorption, freundlich and langmuir isotherm, o-Cresol.

I. INTRODUCTION

O-cresol is mostly used in the production of pesticides, epoxy resins, dyes, pharmaceuticals, disinfectants and cleaning agents. The worldwide production of o-cresol is approximately 37000-38000 tons/annum [1]. Approximately 60% of o-cresol is derived from coal tar and crude oil using classical techniques such as distillation, stripping, liquid-liquid extraction. Remaining amount is obtained synthetically by alkylation of phenol with methanol, either in the vapour or liquid phase. Cresols are found as contaminants in landfill leachate (Table I) and these are largely released to the groundwater via landfills [2]. Anaerobic sewage sludge experiments in anaerobic groundwater samples showed that cresol isomers display the pattern of degradation as p-cresol > m-cresol > o-cresol, where p-cresol is the most readily biodegradable of the three isomers [2]. Horowitz et al. [3] reported that in anoxic sediments, m- and p-cresol isomers showed the maximum degradation, while o-cresol resisted degradation. Kurata et al. [4] investigated occurrence of phenolic compounds in leachates from 38 Municipal Solid Waste landfills in Japan and found that most of the landfill leachates contained 3.7 µg/L of o-cresol. Most health exposures of o-cresol observed in people include irritation and burning of skin, eyes, mouth, and throat, abdominal pain and vomiting, heart damage, anemia, liver and kidney damage facial paralysis, coma, and death [5].

Table I shows the typical characteristics of landfill leachate as reported in literature [6]. The characteristics of MSW landfill leachate vary with time and from site to site because dependence on type of wastes disposed, rainfall, age of the landfill and design of the landfill etc [7].

Table I: Typical Characteristics of Landfill Leachate

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cresols</td>
<td>µg/L</td>
<td>1-2100</td>
</tr>
<tr>
<td>Phenols</td>
<td>µg/L</td>
<td>0.6-1200</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>µg/L</td>
<td>200-240</td>
</tr>
<tr>
<td>pH</td>
<td>--</td>
<td>4.5-9</td>
</tr>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>140-152000</td>
</tr>
<tr>
<td>BOD</td>
<td>mg/L</td>
<td>20-57000</td>
</tr>
<tr>
<td>TOC</td>
<td>mg/L</td>
<td>30-29000</td>
</tr>
<tr>
<td>Organic Nitrogen</td>
<td>mg/L</td>
<td>14-2500</td>
</tr>
<tr>
<td>BOD/COD</td>
<td>--</td>
<td>0.02-0.8</td>
</tr>
</tbody>
</table>

Source: [6]

Shabiimam and Dikshit [8] investigated the removal of organic load (COD) using coagulation from MSW leachate. Alum and lime (calcium hydroxide) were used as coagulants and a maximum of 69% organic load removal was achieved using lime. In another study, ferrous sulphate and potash alum used as coagulants and maximum removal of 69% COD was reported using the dose of 10 g/L potash alum at optimum pH 6 [9].

Adsorption is also one of physical treatment processes and it is a surface treatment in which specific solutes in liquid are attracted to the surface of solid adsorbent. Activated carbon is widely used adsorbent and it gives high COD reduction efficiency. 91% COD removal was reported in activated carbon column performance studies on biologically pretreated leachate [10]. Rodriguez et al. [11] investigated the removal of non-biodegradable matter from landfill leachate by adsorption using activated carbon and they reported 59% COD removal.

II. MATERIALS AND METHODS

A. Chemicals

All chemicals used in the present study were of analytical grade (A.R.), purchased from Merck chemicals, Mumbai, India. Powdered activated carbon (having methylene blue...
rated adsorption capacity as greater than 180 mg/g) was also procured from Merck Chemicals and was used as an adsorbent in this study.

B. Analytical Methods

pH of the wastewater was measured by a digital pH meter (Polmon, LP-1395, India). COD was determined by the standard closed reflux method using a COD reactor (Hach, DRB200 COD reactor, USA) [12]. TOC was measured using a TOC analyzer (Shimadzu, TOC-V, CSH, Japan).

C. Estimation of o-Cresol

o-Cresol was estimated using spectro-photometric method as proposed by APHA [12]. o-cresol was rapidly condensed with 4-Aminoantipyridine followed by its oxidation with potassium ferricyanide at pH 7.9 to yield red coloured compound. The absorbance was measured at 510 nm using UV-Visible spectrophotometer (Thermoelectron Corporation, GENESYS 20, USA).

D. pH Study

The optimum pH for the process was determined from the data obtained from experiments carried out at varying initial pH (2, 4, 6, 8, 10 and 12) and all subsequent experiments were carried out at this pH.

E. Dosage Study

Adsorbent dosage was optimized by performing the experiments at varying adsorbent dosage (2, 3, 4, 5, 6 and 7 g/L) at optimum pH. Aliquots of the sample were collected at specified time intervals (10, 20, 30, 40 min) and analyzed by TOC and o-cresol by spectro-photometric method. The data obtained were used to plot isotherms to describe the adsorption process.

F. Batch Adsorption Study

o-cresol (500 mg/L, TOC 417 mg/L) was used as the model compound for adsorption studies. All the adsorption experiments were done in 100 mL glass-stoppered bottles containing pre-determined amount of activated carbon as adsorbent with 50 mL of synthetic wastewater. The flasks were labeled and kept in an orbital shaker (Trishul equipments, Thane) at a speed 120 rpm for 60 minutes. Batch experiments were carried out to evaluate the effect of the following parameters on the removal of o-cresol from the wastewater: pH, adsorbent dose and time. To evaluate the efficiency of adsorption, o-cresol and TOC of the wastewater before and after the treatment were determined. All the runs were carried out in duplicate to confirm the results.

III. RESULTS AND DISCUSSION

In this study, adsorption of a specific organic compound, o-cresol, was studied, which is a normal component of landfill leachate.

A. Characteristics of Landfill leachate

The landfill leachate was collected from an old MSW dumping ground at Mumbai, India and its physical and chemical characteristics were determined and are presented in Table III.

B. Characteristics of o-Cresol

The characteristics of o-cresol are shown in Table IV. Initial pH was 6.8 and 417 mg/L of TOC.

C. Effect of pH on the Adsorption of o-Cresol

Results obtained from the adsorption of o-cresol at varying initial pH values are presented in Fig. 1a. Powdered activated carbon dose was kept 2 g/L in all the runs. It can be seen that TOC removal was maximum at pH 8 and showed 65.3% reduction from the initial value.
TABLE IV: CHARACTERISTICS OF o-CRESOL

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>6.8</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td></td>
<td>1655</td>
</tr>
<tr>
<td>TOC (mg/L)</td>
<td></td>
<td>417</td>
</tr>
<tr>
<td>Melting-Point</td>
<td>°C</td>
<td>31</td>
</tr>
<tr>
<td>Boiling-point</td>
<td>°C</td>
<td>191</td>
</tr>
<tr>
<td>Density</td>
<td>kg/m³</td>
<td>1046</td>
</tr>
</tbody>
</table>

Hence, all subsequent experiments were carried out at pH 8. Similar trend was also obtained for the concentration of o-cresol at different pH values (Fig. 1b).

![Figure 1](image1.png)

(a) TOC (mg/L) as a function of pH

(b) o-Cresol (mg/L) as a function of pH

Fig. 1. Effect of pH on the adsorption of o-cresol. Experimental conditions: activated carbon used = 2 g/L; initial concentration of o-cresol = 500 mg/L; initial TOC = 417 mg/L.

D. Effect of Adsorbent Dose

To observe the effect of adsorbent dose, the runs were conducted at different doses (2, 3, 4, 5, 6 and 7 g/L). From Fig. 2, it can be seen that TOC decreased remarkably when the adsorbent dosage was increased from 2 to 3 g/L. Beyond this adsorbent dose, TOC and substrate concentration continued to decrease. But it was found that any addition of adsorbent in the excess of 5 g/L did not exhibit applicable decrease (< 50% from the previous value). o-Cresol reduction always occurred in the same manner as the TOC was due to o-cresol only. Hence, all subsequent experiments were carried out using 5 g/L dose.

![Figure 2](image2.png)

(a) TOC (mg/L) as a function of dose

(b) o-Cresol (mg/L) as a function of dose

Fig. 2. Effect of adsorbent dose on the adsorption of o-cresol. Experimental conditions: experimental pH = 8; initial concentration of o-cresol = 500 mg/L; initial TOC = 417 mg/L.

E. Effect of pH on the Adsorption of o-Cresol

The effect of reaction time on the overall o-cresol removed was studied by withdrawing samples at an interval of 10 minutes. The total duration of the run was 40 minutes. The adsorbent was taken 5 g/L and the solution pH was kept at 8. The results are plotted in Fig. 3. It can be seen that 95% removal of TOC occurred in 40 minutes. However, most of the removal was achieved within 10 minutes.

![Figure 3](image3.png)

Fig. 3. Effect of time on the adsorption of o-cresol. Experimental conditions: activated carbon used = 5 g/L; pH maintained = 8; initial concentration of o-cresol = 500 mg/L.

Figure 4 shows the adsorption of o-cresol on activated carbon as a function of equilibrium concentration.
F. Langmuir Isotherm

The results obtained for the experimental studies were fitted for Langmuir isotherm [2, 15] described by the following equation:

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

where \( q_e \) is the adsorption capacity (mg/g), \( C_e \) is equilibrium concentration of adsorbate (mg/L), \( K_L \) and \( b \) are Langmuir constants, and \( q_m \) is the Langmuir monolayer adsorption capacity.

G. Freundlich Isotherm

The results obtained for the experimental studies were fitted also fitted for Freundlich isotherm equation [1, 16]:

\[ q_e = K_F C_e^{1/n} \]

where \( q_e \) is adsorption capacity (mg/g), \( C_e \) is equilibrium concentration of adsorbate (mg/L), and \( K_F \) and \( n \) are Freundlich constants.

The obtained equilibrium adsorption data shown in Fig. 4 were fitted to Langmuir and Freundlich isotherms. Fig. 5 shows the Langmuir and Freundlich Isotherm plots while the parameters for both the models are presented in Table V.

| TABLE V: ISOTHERM PARAMETERS FOR THE ADSORPTION OF O-CRESOL ON ACTIVATED CARBON |
|---------------------------------|--------|--------|-----|
| Model                          | \( K_L \) | \( q_m \) | \( b \) | \( R^2 \) |
| Langmuir                       | 142    | 27.78  | 5.142 | 0.997 |
| Freundlich                     | 56.24  | 0.1819 | 5.497 | 0.995 |

IV. CONCLUSION

Optimal leachate treatment is necessary in order to reduce its negative impact on the environment. However, it is difficult to formulate the leachate treatment, in general, as the leachate composition varies with time and with site. Also, leachate characteristics depend on the age of landfill, waste characteristics, and climatic conditions of the area.

The present study demonstrated that the commercial activated carbon can remove up to 95% of o-cresol from the wastewater within 10 minutes by adsorption technique. The results were described by Langmuir Isotherm.

The optimum process variables of the adsorption of o-cresol onto activated carbon were found as pH of 8 at an adsorbent dosage of 5 g/L.

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REFERENCES


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