The Dual Roles of Activated Carbon as an Adsorbent and Photocatalyst for Azo Dye Removal

INTRODUCTION

• The growth of the fast fashion and textile industries has proliferated the release of toxic azo dye effluent, contributing to 20% of global industrial pollution [1-3]
• Industrial wastewater consists of many different azo dyes [4]
  → a universal treatment is urgently needed
• Mordant Orange 1 (MO1) (Fig. 1A) and Reactive Black 5 (RB5) (Fig. 1B) are structurally diverse [5-8]
• Among conventional methods, adsorptive removal by activated carbon (AC) is inexpensive and viable for easy operation [9, 10]
• AC can generate reactive radicals under UV light [11-13]

How are AC’s dual roles as an adsorbent and photocatalyst employed for MO1 and RB5 dye removals?

METHODOLOGY

• MO1 and RB5 solutions were stirred with AC under UV light or no light for 60 min and 120 min, respectively
• Data on RB5 concentrations in solution overtime were fit to the Langmuir-Hinshelwood (LH) kinetic model
• Lactone, carboxyl, hydroxyl, and aldehyde groups were computationally added to AC’s structure with the Amsterdam Modeling Suite

RESULTS AND DISCUSSION

MO1 Removal by AC with and without UV light

• Abs peak at 373 nm attributed to the azo bond and its surrounding chemical moieties [11]
• Under darkness, Abs peak decreased over time (Fig. 2)

dB removal of MO1 (430 mg/L at t=0) by AC (20 mg) under darkness at room temperature. MO1 absorbance peak at 373 nm decreased over time. Determined with UV/Vis spectrophotometry. Image created by the student author.

• MO1 removal by AC was similar under UV light and no light (Fig. 3)
• MO1 is a salicylic acid, a group known for its radical scavenging activity → diminishes the effects of reactive radicals [15-17]

MO1 removal with AC occurs by a non-photolysis assisted mechanism → ADSORPTION

Impacts of Chemical Modifications on AC’s Band Gap

• AC’s photocatalytic ability is determined by the band gap → a smaller band gap energy enhances photocatalytic properties [21]
• Difference in band gap varied with the identity and quantity of chemical groups added (Fig. 6)

Band gap energy decreased by adding aldehyde groups

<table>
<thead>
<tr>
<th>[RB5]a(L/mg)</th>
<th>50</th>
<th>50</th>
<th>100</th>
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<tbody>
<tr>
<td>Kc (mg/L/min)×10^-2</td>
<td>2.1 ± 0.2×10^-2</td>
<td>1.4 ± 0.7×10^-2</td>
<td>1.6 ± 0.5×10^-2</td>
</tr>
<tr>
<td>k_R (mg/L/min)/R²</td>
<td>0.8 ± 0.2×10^-2</td>
<td>1.3 ± 0.5×10^-2</td>
<td>7.4 ± 2.0×10^-3</td>
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<tr>
<td>R²</td>
<td>0.9990</td>
<td>0.9942</td>
<td>0.9891</td>
</tr>
</tbody>
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*Best fit value ± 95% confidence interval

Kc (Equilibrium constant for RB5 adsorption on AC) is AC amount-independent [20]
• Statistically similar Kc values and high R² values suggest that the LH model is a good RB5 removal model (Table 1)
• k_R (reaction rate constant) increases with greater amount of AC (Table 1) → AC acts as a photocatalyst in RB5 removal

CONCLUSION

AC is universal, versatile, and efficient for azo dye removal through its mechanisms of adsorption and photocatalysis

Proposed Reaction Mechanism for RB5 Removal

Future Investigations & Applications

AC is universal, versatile, and efficient for azo dye removal through its mechanisms of adsorption and photocatalysis

• Integration of a process to separate and recycle AC after azo dye removal (Fig. 8) [26]
• Azo dye removal via AC should be tested in situ [27]
• AC can be used to treat diverse azo dyes used in the fast fashion and textile industries with a large-scale reactor [28, 29]

The dual roles of activated carbon as an adsorbent and photocatalyst are utilized for the removal of azo dyes.

1. RB5 dye adsorbs on AC (Fig. 7) [22]
2. H₂O are generated from H₂O → H⁺ + OH⁻ → OH⁻ → H₂O− under UV light [22], catalyzed by AC [23, 24]
3. HO- reacts with and degrades RB5 adsorbed on AC [25]