Determining the concentration independence threshold of the sorption of organic compounds by biochar and granular activated carbon (GAC)

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Introduction
- Contaminants in stormwater are nonpoint source pollutants that are attributed to urban and agricultural runoff. These contaminants include organic contaminants (OCs) such as pesticides, herbicides, pharmaceuticals, and hormones\(^(2)\).
- Activated carbon has been used in the past to remove OCs from contaminated water\(^(3)\) and is a solution to treating stormwater. Biochar is a viable option for low cost stormwater remediation because it can have similar sorption properties to activated carbon\(^(4)\).
- Previous studies have shown that the proportional removal of OCs, in the presence of DOM, is independent of their initial concentration until the initial concentration of the sorbate surpasses a concentration threshold. This is important because determining the % removal at one concentration for a target compound can be assumed to be true at any other concentration below the threshold. This threshold may be impacted by compound properties and the concentration of DOM.
- The ideal adsorbed solution theory - equivalent background compound (IAST-EBC)\(^(6)\) model predicts such phenomena:

\[
\frac{C_A}{C_A^e} = \frac{1 + \alpha_A^{\text{e}}}{\frac{1}{\alpha_A} + \frac{1}{\alpha_A^e}} \quad \frac{C_B}{C_B^e} = \frac{1 + \alpha_B^{\text{e}}}{\frac{1}{\alpha_B} + \frac{1}{\alpha_B^e}}
\]

Objectives
The following three hypotheses were tested in the study:
1. The adsorbability of the compound will affect the threshold.
2. The type of sorbent (biochar vs. GAC) will not demonstrate a difference in the threshold.
3. The initial concentration of the background dissolved organic matter will affect the threshold.

Materials & Methods
- Two sorbents were utilized in the experiments: biochar pyrolyzed at 850°C and GAC. Both were ground to pass a 325 US mesh sieve.
- Probe compounds cyclohexanol, phenanthrene, phenol, and benzoic acid were used. The compounds were radiolabeled with C-14 and 3-H in order to be analyzed using liquid scintillation counting.
- 170 gallons of stormwater were collected from the stormwater reservoir at the University of Colorado Boulder.
- Different concentrations of the target sorbate were spiked into 1L jars with the stormwater solution and placed on a jar-tester and mixed at 150 rpm with each of the sorbents for contact time of 30 minutes.
- After 30 minutes of contact, the solution was filtered using glass fiber filters and placed in a liquid scintillation counter.

Results

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Biochar</th>
<th>GAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclohexanol</td>
<td><img src="image1" alt="Biochar Dose Response" /></td>
<td><img src="image2" alt="GAC Dose Response" /></td>
</tr>
<tr>
<td>Phenol</td>
<td><img src="image3" alt="Concentration Variation with Biochar" /></td>
<td><img src="image4" alt="Concentration Variation with GAC" /></td>
</tr>
<tr>
<td>Phenanthrene</td>
<td><img src="image5" alt="Varying TOC Concentration" /></td>
<td><img src="image6" alt="Cyclohexanol vs Phenol Competition" /></td>
</tr>
</tbody>
</table>

Conclusion
- Biochar performs moderately well as it needed 10X the dose of GAC. Considering it is 2-13% the cost of GAC it could still be cost effective.
- In general, OCs in stormwater have similar concentration independence thresholds, which is significant considering the range in adsorbability of the compounds studied as well as their different chemical structures.
- The TOC concentration did not significantly impact the independence threshold.
- The threshold most likely does not vary for different compounds and stormwater strengths because different DOM components compete with the different target compounds.

Environmental Significance
- This study informs practitioners when a simple modeling approach can be used based on the initial concentration of the target compound and the initial concentration of other contaminants.
- The performance of biochar, relative to GAC, is the same for a wide range of compounds.

References