MODELING OF PARTICULATE REMOVAL IN MIXED MEDIA FILTERS USING A POWER EQUATION

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PROJECT SPONSORS

• Water Environment Research Foundation

• U.S. Environmental Protection Agency: ORD NRMRL Urban Watershed Management Branch

OBJECTIVES

• Develop a modeling algorithm to predict the life of a stormwater filter/adsorber, accounting for physical clogging
  – Laboratory-scale column experiments using 1.825-in and 4-in ID columns
• Compare laboratory-scale results to pilot-scale results in order to evaluate scale-up issues
• Preliminarily investigate upflow filtration as a method of increasing the use of the filter media’s chemical capacity

VISIBLE CLOGGING DEPTH
Surface/Near Surface Straining

Compost-Sand  Sand  Carbon-Sand
Visible Depth of Red Clay Penetration at Clogging (flow rate < 1 m/day)

<table>
<thead>
<tr>
<th>Media</th>
<th>Penetration Depth at Clogging (cm)</th>
<th>Penetration Depth as % of Filter Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>8.9</td>
<td>19</td>
</tr>
<tr>
<td>Carbon-Sand</td>
<td>4.8</td>
<td>10</td>
</tr>
<tr>
<td>Peat-Sand</td>
<td>1.9</td>
<td>4</td>
</tr>
<tr>
<td>Compost-Sand</td>
<td>3.8</td>
<td>8</td>
</tr>
<tr>
<td>Zeolite-Sand</td>
<td>3.8</td>
<td>8</td>
</tr>
<tr>
<td>Cotton-Sand</td>
<td>1.3</td>
<td>3</td>
</tr>
<tr>
<td>Agrofiber-Sand</td>
<td>8.3</td>
<td>18</td>
</tr>
</tbody>
</table>

Suspended Solids Loading on 2-in. ID Filters

MODEL DESCRIBING THE EFFECT OF SUSPENDED SOLIDS LOADING ON FLOW RATE

\[ u = k_i x L_m^{c} \]


COEFFICIENTS FOR MODEL OF FILTRATION: \( u = k_i x L_m^{-c} \)

<table>
<thead>
<tr>
<th>Media</th>
<th>( k_i )</th>
<th>95% CI on ( k_i )</th>
<th>( c )</th>
<th>95% CI on ( c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>44,500</td>
<td>30, 3.2 x 10^3</td>
<td>1.02</td>
<td>0.17, 1.9</td>
</tr>
<tr>
<td>Carbon-Sand</td>
<td>14,800</td>
<td>49, 4.9 x 10^3</td>
<td>0.77</td>
<td>0.06, 1.5</td>
</tr>
<tr>
<td>Peat-Sand</td>
<td>2,000</td>
<td>22, 2.8 x 10^3</td>
<td>0.71</td>
<td>0.1, 1.3</td>
</tr>
<tr>
<td>Compost-Sand</td>
<td>1.6 x 10^3</td>
<td>2.6 x 10^3, 1.1 x 10^3</td>
<td>4.09</td>
<td>3.5, 4.7</td>
</tr>
<tr>
<td>Zeolite-Sand</td>
<td>60</td>
<td>18, 200</td>
<td>0.23</td>
<td>0.08, 0.39</td>
</tr>
<tr>
<td>Cotton-Sand</td>
<td>( u = 106 - 0.01 L_m^{agrofiber} )</td>
<td>Int (79, 134)</td>
<td>Slope (0.08, 0.02)</td>
<td></td>
</tr>
<tr>
<td>Agrofiber-Sand</td>
<td>( u = 205 - 0.09 L_m^{agrofiber} )</td>
<td>Int (195, 217)</td>
<td>Slope (0.08, 0.095)</td>
<td></td>
</tr>
</tbody>
</table>

MEDIA TESTED

PEAT, SAND, COMPOST
DOWNFLOW CONTRUCTION

Influent

12 inches
Filtration Media
Mixed 50/50 (v/v) with Sand

6 inches
Sand

3 inches
Gravel

Effluent

BEFORE TESTING

DATA COLLECTION

Side-by-Side Comparison of Varying Influent Concentrations on Physical Breakthrough (Clogging): Upflow versus Downflow Modes
UPFLOW CONTRUCTION

- 1 inch Gravel
- 6 inches Sand
- 12 inches Filtration Media Mixed 50 50 (v/v) with Sand
- 3 inches Gravel
- Influent
- Effluent

EFFECT OF CUMULATIVE VOLUME LOADED ON FLOW RATE:
 Bench-scale versus Pilot-scale testing
**UPFLOW FILTRATION RESULTS**

- Drawback to downflow filtration is the need for pretreatment. Upflow filtration may remove need for pretreatment.

- Upflow filter behavior can be divided into three categories:
  - Particles primarily removed at the surface through straining. Penetration far into the filter’s depth not observed, and therefore, depth not an issue in design. These were the fibrous materials (cotton and agrofiber mixed with sand).
  - Particulate removal occurred through complete medium depth. Sediment traveled slowly upward, eventually breaking through. Life of filter depends on filter’s depth. These were the granular media (activated carbon, zeolite, compost and sand).
  - Filter media separated into two layers. After the clay broke through the sand, the peat-sand layer floated as a mass above the sand. Water passed around the peat-sand, with little filtration/straining occurring.

**CONCLUSIONS**

- For chemical pollutant removal, initial flow rate control set to hydraulic residence time (HRT) predicted from batch sorption studies. However, suspended solids loading may quickly control hydraulic residence time.

- Given large clogging potential, media with smaller pollutant removal capacities become more economically feasible than expensive media with large pollutant removal capacities.

- Ability to scale up the results from laboratory tests to field predictions still ongoing. Power equation can be used to model filter run length, but it is setup-specific, and transfer of data from lab-scale to field is not applicable.

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