ASSESSING SUBSURFACE FILTRATION AND DILUTION PROCESSES IN RIVERBANK FILTRATION TREATMENT

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Meeting on Crypto Removal by Riverbank Filtration
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Processes Taking Place at an RBF site

River

Subsurface Filtration

(Adsorption + Biodegradation)

RBF Extract

Dilution

Groundwater
ASSESSING REMOVAL CAPABILITIES OF RBF

Difficult to assess removal capability:

– What is the travel time from the river to the well?
– due to subsurface filtration?
– due to groundwater dilution?
PROJECT OBJECTIVES

• To assess riverbank filtration as a viable treatment and pretreatment option;

• To quantify the contribution of river water and groundwater to the RBF extraction water;

• To compare riverbank filtration to slow sand filtration in terms of particulate, organic precursors and microbiological removal capabilities expressed in log removal credits.
OPERATIONAL FIELD SITES SELECTED

- Pembroke, NH (8/01-11/02, n=19)
- Milford, NH (11/01-11/02, n=13)
- Jackson, NH (5/02-11/02, n=3)
- Louisville, KY (9/01-5/03, n=11)
- Cedar Rapids, IA (9/02-4/03, n=5)
<table>
<thead>
<tr>
<th>Sampling Site</th>
<th>Source river water</th>
<th>Distance between the RBF well and the river</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembroke (NH)</td>
<td>Soucook River</td>
<td>54.9m</td>
</tr>
<tr>
<td>Milford (NH)</td>
<td>Souhegan River</td>
<td>22.9m</td>
</tr>
<tr>
<td>Jackson (NH)</td>
<td>Ellis river</td>
<td>5 infiltration galleries each: 6.1m long, 1.2m deep, 1.2m wide</td>
</tr>
<tr>
<td>Louisville (KY)</td>
<td>Ohio River</td>
<td>Horizontal well RBF sampling lateral 12.2m below the riverbed</td>
</tr>
<tr>
<td>Cedar Rapids (IA)</td>
<td>Cedar River</td>
<td>19.5m</td>
</tr>
</tbody>
</table>
What is the estimated travel time from the river to the well?

<table>
<thead>
<tr>
<th>Sampling Site</th>
<th>Travel Time</th>
<th>Evaluation of Travel Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembroke, NH</td>
<td>5 days</td>
<td>Darcy’s Law in terms of seepage velocity</td>
</tr>
<tr>
<td>Milford, NH</td>
<td>1 day</td>
<td>Darcy’s Law in terms of seepage velocity</td>
</tr>
<tr>
<td>Jackson, NH</td>
<td>&lt;2hrs</td>
<td>Infiltration Gallery</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>1 day</td>
<td>Information provided by the LWC (AWWARF, 2002)</td>
</tr>
<tr>
<td>Cedar Rapids, IA</td>
<td>5 days</td>
<td>Information provided by the City of Cedar Rapids Water Department (Schulmayer, 1999)</td>
</tr>
</tbody>
</table>
How much removal is due to filtration and how much due to dilution with groundwater?

<table>
<thead>
<tr>
<th>Location</th>
<th>% river water in RBF well</th>
<th>% Groundwater in RBF well</th>
<th>Parameter upon which ratio is based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembroke, NH</td>
<td>40.7±3.7</td>
<td>59.3±3.7</td>
<td>Conductivity</td>
</tr>
<tr>
<td>Milford, NH</td>
<td>40.8±6.4</td>
<td>59.2±6.4</td>
<td>Sulfate</td>
</tr>
<tr>
<td>Jackson, NH</td>
<td>100</td>
<td>0</td>
<td>Infiltration Gallery</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>78.1±4.4</td>
<td>21.9±4.4</td>
<td>Hardness</td>
</tr>
<tr>
<td>Cedar Rapids, IA</td>
<td>70</td>
<td>30</td>
<td>Groundwater Flow Modeling</td>
</tr>
</tbody>
</table>
## SELECTED WATER QUALITY PARAMETERS REMOVALS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>% Total Removal Range</th>
<th>Weighted % average of RBF total removals observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOC</td>
<td>18-92</td>
<td>63</td>
</tr>
<tr>
<td>UV254 abs.</td>
<td>23-100</td>
<td>73</td>
</tr>
<tr>
<td>True Color</td>
<td>50-100</td>
<td>89</td>
</tr>
<tr>
<td>Particle Counts</td>
<td>70-99</td>
<td>94</td>
</tr>
<tr>
<td>Turbidity</td>
<td>72-99</td>
<td>87</td>
</tr>
</tbody>
</table>
INFLUENCE OF GROUNDWATER DILUTION ON SELECTED PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>% TOTAL Removal</th>
<th>% Removal due to DILUTION</th>
<th>% Removal due to SUBSURFACE FILTRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>87</td>
<td>10</td>
<td>77</td>
</tr>
<tr>
<td>DOC</td>
<td>63</td>
<td>29</td>
<td>34</td>
</tr>
</tbody>
</table>
MICROBIAL ANALYSES

- Total coliforms and *E.coli*
- Aerobic Spore Forming Bacteria
- Virus indicators (male specific & somatic bacteriophage)
- Enteric Viruses
  - Adenovirus Type 40 and 41
  - Astrovirus
  - Enterovirus (poliovirus, coxsackie virus, rotavirus and echovirus)
TOTAL COLIFORMS (CFU/100mL)

Typical Total Coliforms (CFU/100mL) Variations (n=19) as a Function of River Discharge in Pembroke, NH (8/01-11/02) Including Groundwater Dilution Impacts

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>Total removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembroke, NH</td>
<td>&gt;2.1 log</td>
</tr>
<tr>
<td>Milford, NH</td>
<td>&gt;2.6 log</td>
</tr>
<tr>
<td>Jackson, NH</td>
<td>&gt;0.5 log</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>&gt;1.0 log</td>
</tr>
<tr>
<td>Cedar Rapids, IA</td>
<td>&gt;1.4 log</td>
</tr>
</tbody>
</table>
Typical Variations of E. Coli (CFU/100mL) (n=19) as a Function of River Discharge in Pembroke, NH (8/01-11/02) Including Groundwater Dilution Impacts

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>Total removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembroke, NH</td>
<td>&gt;0.6 log</td>
</tr>
<tr>
<td>Milford, NH</td>
<td>&gt;0.8 log</td>
</tr>
<tr>
<td>Jackson, NH</td>
<td>&gt;0.4 log</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>&gt;0.3 log</td>
</tr>
<tr>
<td>Cedar Rapids, IA</td>
<td>&gt;0.7 log</td>
</tr>
</tbody>
</table>
AEROBIC SPORE FORMING BACTERIA (CFU/100mL)

Typical Aerobic Spore Forming Bacteria (CFU/100mL) Variations (n=19) as a Function of River Discharge in Pembroke, NH (8/01-11/02) Including Groundwater Dilution Impacts

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>Total removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pembroke, NH</td>
<td>&gt;1.9 log</td>
</tr>
<tr>
<td>Milford, NH</td>
<td>&gt;2.1 log</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>&gt;3.5 log</td>
</tr>
<tr>
<td>Cedar Rapids, IA</td>
<td>&gt;2.6 log</td>
</tr>
</tbody>
</table>
VIRUS INDICATORS
(PFU/100mL)

- Male Specific Bacteriophage (including MS2)
- Somatic Bacteriophage
- Intensive sampling (Dec 2002): Louisville (n=4) Cedar Rapids (n=5)

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>Total removal of MS</th>
<th>river water</th>
<th>RBF extracted water</th>
<th>Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louisville, KY</td>
<td>≥0.2 log</td>
<td>4622 ±25</td>
<td>3703±22</td>
<td>3402±18</td>
</tr>
<tr>
<td>Cedar Rapids, IA</td>
<td>≥ 0.7 log</td>
<td>3453±20</td>
<td>753±9</td>
<td>BDL</td>
</tr>
</tbody>
</table>

Where Range=average ± analytical error
VIRUSES

- None detected (ICC-RT-nPCR method) in the samples collected in Louisville, KY nor in Cedar Rapids, IA.

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>Liters of water collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louisville, KY (3/03)</td>
<td>100L 1000L</td>
</tr>
<tr>
<td>Cedar Rapids, IA (1/03)</td>
<td>362L 995L</td>
</tr>
</tbody>
</table>
Processes Taking Place at an RBF site

River → Subsurface Filtration → (Adsorption + Biodegradation) → RBF Extract → Dilution → Groundwater
TREATMENT PROBABILITY DUE TO SUBSURFACE FILTRATION (most conservative estimation for RBF)

**TURBIDITY, NTU (n=37)**

**AEROBIC SPORE FORMING BACTERIA, CFU/100mL (n=43)**
TREATMENT PROBABILITY DUE TO SUBSURFACE FILTRATION (most conservative estimation for RBF)

TOTAL COLIFORMS, CFU/100mL (n=48)

E.coli, CFU/100mL (n=41)
## Subsurface Filtration Microbial Probability Removals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>&gt;70% (probability of exceedance)</th>
<th>&gt;90% (probability of exceedance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>73%</td>
<td>55%</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>2.1 log</td>
<td>1.7 log</td>
</tr>
<tr>
<td>E. coli</td>
<td>0.8 log</td>
<td>0.4 log</td>
</tr>
<tr>
<td>ASFB (spores)</td>
<td>2 log</td>
<td>1.5</td>
</tr>
</tbody>
</table>
SUMMARY OF MOST CONSERVATIVE AVERAGE SITE REMOVALS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum removal*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>&gt;74%</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>&gt;1.0 log</td>
</tr>
<tr>
<td>E.coli</td>
<td>&gt;0.3 log</td>
</tr>
<tr>
<td>Aerobic Spores</td>
<td>&gt;1.9 log</td>
</tr>
</tbody>
</table>

*based on subsurface filtration only, limited by river water concentrations, and RBF site of lowest average removals.
# Comparing RBF vs. SSF Removals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>RBF</th>
<th>SSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOC</td>
<td>41-85%</td>
<td>8-20%</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>&gt;1-1.6 log</td>
<td>1-2 log</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>&gt;0.3-0.8 log</td>
<td>2-3 log</td>
</tr>
<tr>
<td>Aerobic spores</td>
<td>&gt;1.9-3.5 log</td>
<td>2.1-2.3 log</td>
</tr>
</tbody>
</table>
CONCLUSIONS

RBF shows potential to be a viable pretreatment and treatment process and warrants log removal credits for microbial pathogen removal.
AKNOWLEDGEMENTS

• EPA for funding this project through the New England Water Treatment Technology Assistance Center
• N. Ballester & J. Fontaine, UNH
• The Pembroke, NH Waterworks personnel
• The Louisville Water Company, KY
• The Milford, NH Fish Hatchery personnel
• The Jackson, NH Waterworks personnel
• The Cedar Rapids Water Department, IA
• M. Smith, UNH
QUESTIONS?