Bioretention Column Study: Early Results

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Experimental Background

Emerging Bioretention Design Features

• **Saturation Zone** (Zinger, et al., 2007)
  – Microbial Denitrification

• **Vegetation** (Bratieres, et al., 2008)
  – More than Aesthetics!

• **Soil Amendments** (Lucas and Greenway, 2011)
  – Water Treatment Residuals (WTR)

Ski-Pix Aerial Photography
Research Focus

- Nutrient Management
  - Nitrate and Ortho-Phosphate
- Puget Sound Design
- Early Establishment

Research Objectives

- Optimize nitrate removal through utilization of a saturation zone (denitrification)
- Evaluate the role vegetation plays in nitrate and ortho-phosphate removal
- Assess nutrient and heavy metal removal capabilities of an emerging bioretention soil media
Experimental Methods

Column Design

- **Ponding Zone**: 6" height
- **Bioretention Soil Mix (BSM)**: 12" height
- **Type-26 Drainage Layer**: 6" height
- **Riser Pipe**
- **Saturation Control Valves**
- **BSM Sampling Port**
- **Drainage Layer Sampling Port**
Design Features

- **Saturation Zone** (Puget Sound LID, 2004)
  - Drainage layer
- **Vegetation** (Bratieres, et al., 2008)
  - Carex Flacca sedge
- **Water Treatment Residual’s**
  - Anacortes Water Treatment Facility
  - Aluminum based

Test Conditions

- **Treatment 1**: BSM + Saturation Zone
- **Treatment 2**: BSM Only
- **Treatment 3**: BSM + Vegetation
- **Treatment 4**: BSM + Saturation zone + Vegetation
Bioretention Soil Media (BSM)

- 60% Sand / 15% Compost / 15% Shred Bark / 10% WTR
BSM Mixing

BSM Loading

Trans-Planting
Greenhouse Test Facility
Design Storm
• 6 month, 24 hour storm
• 6.5% sizing
• 90% imperviousness
• 45 liters per mesocosm

Stormwater
• WSU-Puyallup runoff
• Spiked concentrations
  – Nutrients + Heavy Metals

Stormwater Delivery System
• 300 gallon HDPE mixing tank
• 1-hp pump / eductor mixing system
• Needle valve flow control
Experimental Schedule
- 4 test events
- 1-week drying period

Experimental Procedures
- Loading regime 3.2 +/- 0.25 hr
- 1-liter flow-weighted composite samples
- Samples on ice

Laboratory Analysis
- Center for Urban Waters
- Department of Ecology certified laboratory
Nutrient Results

Nitrate

<table>
<thead>
<tr>
<th>Date</th>
<th>Influent</th>
<th>BSM+Sat</th>
<th>BSM</th>
<th>BSM+Veg</th>
<th>BSM+Sat+Veg</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/14/11</td>
<td>0.40</td>
<td>0.35</td>
<td>0.40</td>
<td>0.45</td>
<td>0.40</td>
</tr>
<tr>
<td>12/21/11</td>
<td>0.60</td>
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<td>0.60</td>
<td>0.65</td>
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<tr>
<td>12/28/11</td>
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<td>0.70</td>
<td>0.75</td>
<td>0.80</td>
<td>0.75</td>
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<tr>
<td>1/3/12</td>
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<td>0.45</td>
<td>0.50</td>
<td>0.55</td>
<td>0.50</td>
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</tbody>
</table>
Analyzing Effects of Saturation - Nitrate

Wilcoxon rank sum test

data:  EffluentC by Saturation
W = 36, p-value = 0.002165

Leaching experiments on 12/21/2011
Ortho-Phosphate

Concentration (mg/L)

Influent
BSM+Sat
BSM
BSM+Veg
BSM+Sat+Veg

12/14/11 Test
12/21/11 Test
12/28/11 Test
1/3/12 Test
Analyzing Effects of Saturation - Phosphate

Wilcoxon rank sum test

data: EffluentC by Saturation
W = 0, p-value = 0.002165

Leaching experiments on 12/28/2011

![Box plot showing ortho-phosphate effluent concentration for saturated conditions with and without saturation.](image)
Total Nitrogen

<table>
<thead>
<tr>
<th>Date</th>
<th>Influent</th>
<th>BSM+Sat</th>
<th>BSM</th>
<th>BSM+Veg</th>
<th>BSM+Sat+Veg</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/14/2011</td>
<td>4.0</td>
<td>3.7</td>
<td>3.0</td>
<td>2.9</td>
<td>3.3</td>
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<td>12/21/2011</td>
<td>3.5</td>
<td>3.2</td>
<td>2.8</td>
<td>2.7</td>
<td>3.0</td>
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<tr>
<td>12/28/2011</td>
<td>3.0</td>
<td>2.8</td>
<td>2.5</td>
<td>2.4</td>
<td>2.7</td>
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<tr>
<td>1/3/2012</td>
<td>2.5</td>
<td>2.3</td>
<td>2.0</td>
<td>1.9</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Total Phosphorus

Concentration (mg/L)

- Influent
- BSM+Sat
- BSM
- BSM+Veg
- BSM+Sat+Veg

Dates:
- 12/14/2011
- 12/21/2011
- 12/28/2011
- 1/3/2012
Heavy Metal Results

Zinc

<table>
<thead>
<tr>
<th>Condition</th>
<th>Total Zinc</th>
<th>Dissolved Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent</td>
<td>200 μg/L</td>
<td>150 μg/L</td>
</tr>
<tr>
<td>Condition 1</td>
<td>10 μg/L</td>
<td>5 μg/L</td>
</tr>
<tr>
<td>Condition 2</td>
<td>10 μg/L</td>
<td>5 μg/L</td>
</tr>
<tr>
<td>Condition 3</td>
<td>10 μg/L</td>
<td>5 μg/L</td>
</tr>
<tr>
<td>Condition 4</td>
<td>10 μg/L</td>
<td>5 μg/L</td>
</tr>
</tbody>
</table>

Diagram: Bar chart showing the concentration of Total Zinc and Dissolved Zinc under different conditions.

Legend:
- Total Zinc
- Dissolved Zinc
Aluminum

[Bar chart showing aluminum concentration in influent and conditions 1 to 4, with error bars for total (mg/L) and dissolved (μg/L)].
Additional Observations

• Low influent suspended sediment
  – 4-20 mg/L
  – Removal implications (Hatt et al., 2008; Clark and Pitt, 1999)
  – Double edged sword (Lucas and Greenway, 2011a)

• High effluent suspended sediment
  – 70-150 mg/L
  – Saturation zone dependent

• Design implications
  – High infiltration rate (47.9 +/- 8 in/hr)
  – Early establishment (7 weeks)
  – Mulch layer (Davis et al., 2009)
Next Steps

- Repeat testing after extensive establishment
- Addition of mulch layer
- Analysis of other stormwater pollutants
- Analysis of other variables
- Comparison with LID mesocosm data
- Toxicology analysis
Acknowledgements

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Questions?