Curtis Hinman
Senior Scientist
Key project experience: Research specialist in the performance and design of LID practices.
AGENDA

1. introduction
2. media primer
3. water quality treatment strategies
4. performance
5. wrap-up

LOGISTICS

Statewide LID Training Program

SCHEDULE
8-hour training
Lunch on your own

OTHER LOGISTICS
- Restrooms
- Food
- Turn off cell phones
- Sign in and sign out

LEARNING OBJECTIVES

1. Gain an advanced level understanding of the physical and chemical characteristics of bioretention media components and blends necessary to meet specific performance objectives.
2. Understand the flow control and water quality treatment performance of current bioretention media specifications.
3. Know the options for meeting BMP T5.13, and strategies for determining site soil conditions and developing a soil management plan.
**Statewide LID Training Program**

**PROGRAM OVERVIEW**

- **2012:** Public and private partners engage state legislature to fund program
- **June 2012:** LID Training Steering Committee convened
- **2012-2013:** Washington State LID Training Plan developed: [www.wastormwatercenter.org/statewide-lid-training-program-plan](http://www.wastormwatercenter.org/statewide-lid-training-program-plan)
- **2014:** Training program built from state LID Training Plan

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**PROJECT LEAD**

**ADDITIONAL TRAINING SUPPORT**

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<thead>
<tr>
<th>TEAM</th>
<th>CORE TEAM</th>
</tr>
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<tr>
<td><a href="http://www.herrera.com">HERRERA</a></td>
<td><a href="http://www.cascadia.com">CASCADIA</a> <a href="http://www.veda.com">Veda</a></td>
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<td><a href="http://www.endinghydro.com">ENDING HYDRO</a> <a href="http://www.workingpads.com">WORKING PADS</a></td>
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<td>Introduction</td>
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**TRAIN THE TRAINERS**

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<tr>
<td>9.2</td>
<td>All Topic Reports</td>
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</table>
**Statewide LID Training Program**

**In the beginning there wasn’t much...**

2002
- First bioretention applications with monitoring (Seattle SEA Street).
- Primarily topsoil based media.

2009
- Issues with BSM consistency using topsoil emerge.
- PSAT funds small project through WSU to ID alternative and potentially more consistent materials for BSM. Flow focused. Sand- and compost-based media guideline developed.
- Sand spec well-tested and performs well hydraulically. OM content spec too high.

2011
- WSU LID research facility comes online. Media blend research focus (no funding to conduct fundamental media component characterization).

**Statewide LID Training Program**

2012
- Export of N, P and Cu identified at WSU facility and City of Redmond swale monitoring.
- Individual BSM component characterization studies begin at Port of Olympia (Herrera), City of Redmond (Herrera) and at WSU (primarily compost).
- Ecology funds approximately $3 million in media study projects through Kitsap County (Herrera technical lead), City of Tacoma (UWT technical lead) and City of Redmond (Herrera technical lead).

2013
- Kitsap County project examining a broad range of individual media components.
- City of Tacoma project focused on WTRs.
- Redmond focused on full-scale monitoring of swales (component characterization included).

2015
- Significant new data coming available to hopefully improve BSM performance and consistency.
- We may be a few years from developing a reliable, affordable and non-proprietary BSM to treat a broad suite of pollutants.

**BACKGROUND**

Today’s focus:
- Bioretention media for advanced water quality treatment (direct release to receiving waters, over shallow drinking water aquifers, industrial sites, remedial sites...)
- There are many applications where a conventional sand and compost or topsoil-based media will perform well.
BACKGROUND

Context
- For advanced treatment media, we are opening a complex black box...
- And attempting to reliably replicate a dynamic biological system with complex structures and processes to treat a broad range of contaminants to very low levels...a worthy challenge!

INTRODUCTION

• Flow Entrance
• Pre-Settling
• Ponding Area
• Bioretention Soil
• Mulch/Compost
• Vegetation
• Filter Fabric (?)
• Liner (optional)
• Underdrain (optional)
• Overflow

Introduction
media primer
water quality treatment strategies
performance
wrap-up
Factors influencing hydraulic conductivity

- Percent fines
- Particle size distribution

Hydraulic conductivity strongly related to percent fines (passing #200 sieve)

Hydraulic conductivity strongly related to coefficient of uniformity
Factors influencing hydraulic conductivity

- Percent fines
- Particle size distribution
- Compaction
- Organic material
- Plants

Control structures

- ASTM D2434
WATER QUALITY TREATMENT PRIMER

All primary pathways for removing pollutants from storm flows are active in bioretention

- Stormwater volume reduction
- Sedimentation
- Filtration
- Phytoremediation
- Thermal attenuation
- Sorption
- Complexation
- Volatilization

WATER QUALITY TREATMENT PRIMER

Factors influencing water quality treatment

- pH
- Temperature
- Hydraulic residence time
- Media (organic material, particle size, porosity, chemistry)
- Competing ions, ionic chemistry
- Soil water condition
- Influent concentration
Is the following statement correct?

- If an influent concentration of 5 µg/L into a bioretention area results in an effluent concentration of 10 µg/L then
- an influent concentration of 50 µg/L will result in an effluent concentration of 100 µg/L.

### Sorption

- Ionic charge and speciation
- Functional groups (moiety)
- Organic material (TOC and DOC)
- Competing ions and ion exchange
- Clay (particle size)

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<thead>
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<th>Metal Fraction</th>
<th>Mobility</th>
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<tr>
<td>Exchangeable</td>
<td>High. Changes in major cationic compositions may cause release due to ion exchange</td>
</tr>
<tr>
<td>Fe-Mn Oxides Bound</td>
<td>Medium. Changes in redox conditions may cause release</td>
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<tr>
<td>Carbonate Bound</td>
<td></td>
</tr>
<tr>
<td>OM Bound</td>
<td>Medium/high. Decomposition/oxidation with time.</td>
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<tr>
<td>Residual Fraction</td>
<td>Low. Available after weathering.</td>
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### System

<table>
<thead>
<tr>
<th>System</th>
<th>Copper, µg/L</th>
<th>Lead, µg/L</th>
<th>Zinc, µg/L</th>
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<tbody>
<tr>
<td>U</td>
<td>140 ± 32</td>
<td>61 ± 3</td>
<td>600 ± 8</td>
</tr>
<tr>
<td>L</td>
<td>3.4 ± 1.6</td>
<td>&lt;2</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Range</td>
<td>3.2±0.2</td>
<td>&lt;2.77</td>
<td>&lt;2.45</td>
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<tr>
<td>Reduction, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>91 ± 2</td>
<td>95 ± 2</td>
<td>93 ± 3</td>
</tr>
<tr>
<td>L</td>
<td>98 ± 1</td>
<td>&gt;98</td>
<td>&gt;97</td>
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</table>
Media primer

water quality treatment strategies

performance

wrap-up

Media basics

TREATMENT STRATEGIES

• Sorption and metal complexes
  • Metal atom associated with group of molecules or anions
  • Organically bound Cu often dominant fraction in soils

“Cu however, has a high affinity for soluble organic ligands and the formation of these complexes may greatly increase Cu mobility in soils.” (EPA 1992)

Media basics

TREATMENT STRATEGIES

• Implications for copper
  • To best manage Cu we will likely have to manage DOC
  • Fe and Ca may be (likely), important for DOC capture
  • Identify aggregate and organic materials with low Cu content and flushing potential
TREATMENT STRATEGIES

- Primary mechanisms for P management
  - Plant and microbial uptake
  - Sorption and precipitation. Sorption materials include Al and Fe hydroxides and Ca
  - Reactions are pH dependent. Calcium likely not a reliable material for binding P (higher pH best for precipitation)

Sorption materials include Al and Fe hydroxides and Ca.

Reactions are pH dependent. Calcium likely not a reliable material for binding P (higher pH best for precipitation).
TREATMENT STRATEGIES

Implications for phosphorus
- Design with lower organic material content and upper range for C/N ratio (i.e. 35/1)
- Use organic material that is refractory (probably the older the better)
- Bind P with Al or Fe hydroxides
- Identify aggregate material with little to no P flushing
- Likely will need a polishing layer/filter if using compost
- Above design considerations likely most important for at least three years of installation

TREATMENT STRATEGIES

Methods for managing nitrate (biological transformations)

NO₃⁻: electron acceptor not O₂ in anaerobic conditions

\[ 2\text{NO}_3^- + 10\text{e}^- + 12\text{H}^+ \rightarrow \text{N}_2 + 6\text{H}_2\text{O} \]

Electron donor may be sugar, hydrocarbon (simple) or complex (mulch).
MEDIA BASICS

TREATMENT STRATEGIES

Methods for managing nitrate (60-15-15-10 columns)

Implications

- Design with an elevated under-drain (multiple advantages to this approach)
- Caution: we don’t fully understand the potential for metal and P desorption in the anoxic zone

TREATMENT STRATEGIES

PERFORMANCE

TREATMENT STRATEGIES

Nitrate-nitrite (mg/L)

<table>
<thead>
<tr>
<th>Date/Year</th>
<th>Influent</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Treatment 3</th>
<th>Treatment 4</th>
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<td>0.028</td>
<td>0.027</td>
<td>0.042</td>
<td>1.62</td>
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<td>0.028</td>
<td>0.028</td>
<td>0.109</td>
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<tr>
<td>10/22/14</td>
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<td>0.207</td>
<td>0.150</td>
<td>1.570</td>
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<tr>
<td>10/28/14</td>
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<td>0.186</td>
<td>0.352</td>
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<tr>
<td>11/03/14</td>
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<td>0.195</td>
<td>0.385</td>
<td>1.580</td>
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<tr>
<td>11/10/14</td>
<td>0.037</td>
<td>0.194</td>
<td>0.366</td>
<td>1.570</td>
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</tr>
<tr>
<td>11/17/14</td>
<td>0.028</td>
<td>0.194</td>
<td>0.362</td>
<td>1.570</td>
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10/30/14

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<th>Treatment 3</th>
<th>Treatment 4</th>
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<td>0.097</td>
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<td>10/28/14</td>
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<td>0.164</td>
<td>0.198</td>
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<td>11/03/14</td>
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<td>0.159</td>
<td>0.200</td>
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<tr>
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<td>0.164</td>
<td>0.200</td>
<td>0.851</td>
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<tr>
<td>11/17/14</td>
<td>0.07</td>
<td>0.7</td>
<td>0.64</td>
<td>0.52</td>
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TREATMENT STRATEGIES

Filtration: 60/40 bioretention media provides excellent filtration of TSS (depending on PSD and permeability)...

Does not appear to be concentration dependent

HYDRAULIC PERFORMANCE

ASTM D2434 tests performed 2011 as part of a project to standardize test methods across regional labs (60/40 media)

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Dry Density (pcf)</th>
<th>% Compaction</th>
<th>Mean Diameter (in)</th>
<th>Day 1 (in./hr)</th>
<th>Day 2 (in./hr)</th>
<th>Day 3 (in./hr)</th>
<th>Day 4 (in./hr)</th>
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<td>AES</td>
<td>94.8</td>
<td>85.0%</td>
<td>6</td>
<td>3.4</td>
<td>3.8</td>
<td>4.1</td>
<td>4.7</td>
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<td>GeoTest</td>
<td>91.5</td>
<td>84.5%</td>
<td>6</td>
<td>10</td>
<td>15</td>
<td>16</td>
<td>27</td>
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<tr>
<td>Geologists</td>
<td>96.8</td>
<td>85.3%</td>
<td>6</td>
<td>3.8</td>
<td>3.7</td>
<td>3.7</td>
<td>3.8</td>
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<tr>
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<td>102.0</td>
<td>90.3%</td>
<td>6</td>
<td>1.8</td>
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<td></td>
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<tr>
<td>MWA</td>
<td>95.1</td>
<td>84.9%</td>
<td>6</td>
<td>19</td>
<td>25</td>
<td>23</td>
<td>22</td>
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<td>Shannon &amp; Wilson</td>
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<td>5.2</td>
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<td>84.9%</td>
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<td>17</td>
<td>21</td>
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<td>SFW</td>
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<td>4</td>
<td>19</td>
<td>19</td>
<td>40</td>
<td>42</td>
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HYDRAULIC PERFORMANCE

- **Soil treatments**
  - 60% sand – 40% compost
  - 80% sand – 20% compost
  - 60% sand – 30% compost – 10% WTRs
  - 60% sand – 15% compost – 15% shredded bark – 10% WTRs
  - 60% sand – 10% biosolids – 15% shredded bark – 5% sawdust – 10% WTRs

- **Mesocosm Falling Head Permeability Test (May-June 2011)**

- **Mesocosm Falling Head Permeability Test (June 2012)**
HYDRAULIC PERFORMANCE

- Mesocosm Falling Head Permeability Test (June 2013)

**ASTM D2434 tests performed 2015 as part of a project to develop a high performance water quality treatment media**

**HYDRAULIC PERFORMANCE**

Implications

- Consider carefully acceptance/verification requirements...the system may be hydraulically functional, but not meet specific guidelines at that time
- Consider how to size and operate a system that may be evolving over time

Side note

- The region may becoming more accepting of high flow media with control structures
Lunch

HYDRAULIC PERFORMANCE
Compost-based media

WATER QUALITY TREATMENT PERFORMANCE

TSS Effluent Concentration

Treatment
**WATER QUALITY TREATMENT PERFORMANCE**

- All mesocosms (Phase 1 flushing regime)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Units</th>
<th>Median influent</th>
<th>Min</th>
<th>Median Effluent</th>
<th>Max</th>
<th>n</th>
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<tr>
<td>TSS</td>
<td>mg/L</td>
<td>4.9</td>
<td>1</td>
<td>5.3</td>
<td>22.5</td>
<td>36</td>
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<tr>
<td>Diss Zn</td>
<td>µg/L</td>
<td>71</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Diss Cu</td>
<td>µg/L</td>
<td>3</td>
<td>1.7</td>
<td>8.6</td>
<td>15.9</td>
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<tr>
<td>PO4</td>
<td>mg/L</td>
<td>0.016</td>
<td>0.086</td>
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<tr>
<td>NO3-N2</td>
<td>mg/L</td>
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<td>0.05</td>
<td>0.145</td>
<td>1.03</td>
<td>32</td>
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<tr>
<td>Fecal coliform</td>
<td>CFU/100mL</td>
<td>229</td>
<td>5</td>
<td>22.5</td>
<td>65</td>
<td>32</td>
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**WATER QUALITY TREATMENT PERFORMANCE**

Developing a high-performance WQ treatment media

**Media treatments**

- 60% sand/40% compost (control).
- 70% volcanic sand/20% iron-fused wood chips/10% diatomaceous earth.
- 70% volcanic sand/20% iron-fused wood chips/10% high carbon wood ash.
- 70% volcanic sand/20% coco coir/10% diatomaceous earth.
- 70% volcanic sand/20% coco coir/10% granulated activated charcoal.
- 70% washed sand/20% coco coir/10% high carbon wood ash.
- 70% volcanic sand/20% coco coir/10% high carbon wood ash.
- 90% volcanic sand/10% compost/polishing drainage layer (volcanic sand, activated alumina and bone char).
WATER QUALITY TREATMENT PERFORMANCE

Flushing findings

- 60% sand/40% compost (control) flushing concentrations 1-2 orders of magnitude greater than treatments.

- All treatments exhibit a standard flushing pattern for N and Cu; however, ortho-P flushing increases before decreasing in 60/40. Other research showing extended flushing of ortho-P in compost medias.

- In general, the coco coir pith and GAC or high carbon wood ash best performers for minimal flushing.

---

**TSS (mg/L)**

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<th>205</th>
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<th>40</th>
<th>13.4</th>
<th>No sample</th>
<th>10.6</th>
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<tr>
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<td>41.4</td>
<td>15.3</td>
<td>24.3</td>
<td>9.2</td>
<td></td>
<td>9.6</td>
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<tr>
<td>Percent Reduction</td>
<td>80</td>
<td>90</td>
<td>80</td>
<td>90</td>
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<td>23.8</td>
<td>34.2</td>
<td>4.1</td>
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<tr>
<td>Percent Reduction</td>
<td>3</td>
<td>10</td>
<td>27</td>
<td>92</td>
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Water Quality Treatment Performance

Ortho-P (mg/L)

<table>
<thead>
<tr>
<th>Date</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Treatment 3</th>
<th>Treatment 4</th>
<th>Treatment 5</th>
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<td></td>
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<td></td>
</tr>
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<td>influent</td>
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<td>0.016</td>
<td>no sample</td>
<td>0.102</td>
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<td>0.016</td>
<td>0.217</td>
<td>0.102</td>
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<tr>
<td>Percent Reduction</td>
<td>91</td>
<td>98</td>
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<table>
<thead>
<tr>
<th>Date</th>
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<th>Treatment 2</th>
<th>Treatment 3</th>
<th>Treatment 4</th>
<th>Treatment 5</th>
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<tbody>
<tr>
<td>12/11/2014</td>
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<td>0.028</td>
<td>0.044</td>
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<td>Mean</td>
<td>0.063</td>
<td>0.022</td>
<td>0.064</td>
<td>0.098</td>
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<tr>
<td>Median</td>
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<td>0.023</td>
<td>0.067</td>
<td>0.104</td>
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</tr>
<tr>
<td>Percent Reduction</td>
<td>58</td>
<td>65</td>
<td>54</td>
<td>32</td>
<td>51</td>
</tr>
</tbody>
</table>
WATER QUALITY TREATMENT PERFORMANCE

Dissolved Cu (µg/L)

<table>
<thead>
<tr>
<th>Date</th>
<th>Influent</th>
<th>70%vs/20cp/10gp</th>
<th>70%ws/20cp/10gp</th>
<th>70%vs/20cp/10ash</th>
<th>90%vs/10comp/player</th>
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</thead>
<tbody>
<tr>
<td>10/30/2014</td>
<td>70</td>
<td>11.7</td>
<td>7</td>
<td>14.5</td>
<td>10.9</td>
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<td>12.8</td>
<td>7.7</td>
<td>14.6</td>
<td>10.5</td>
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<td>12.2</td>
<td>8.1</td>
<td>7.7</td>
<td>14.7</td>
<td>10.9</td>
</tr>
<tr>
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<td>7.7</td>
<td>14.7</td>
<td>15.9</td>
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<tr>
<td>Percent Reduction</td>
<td>96</td>
<td>97</td>
<td>95</td>
<td>95</td>
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</tbody>
</table>

<table>
<thead>
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<th>Date</th>
<th>Influent</th>
<th>70%vs/20cp/10gp</th>
<th>70%ws/20cp/10gp</th>
<th>70%vs/20cp/10ash</th>
<th>90%vs/10comp/player</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2.3</td>
<td>1.7</td>
<td>4.4</td>
<td></td>
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<tr>
<td></td>
<td>3.7</td>
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<td>4.4</td>
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</tr>
<tr>
<td>Mean</td>
<td>3.6</td>
<td>2.3</td>
<td>1.7</td>
<td>4.4</td>
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<tr>
<td>Median</td>
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<td>2.3</td>
<td>1.7</td>
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<tr>
<td>Percent Reduction</td>
<td>54</td>
<td>40</td>
<td>20</td>
<td>5</td>
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</table>

Dosing findings

- 60% sand/40% compost (control) effluent concentrations 1-2 orders of magnitude greater for N and P than treatments.
- Significant release of dissolved Cu in treatments with iron coated wood chips during dosing.
- Very good dissolved Cu management at low and high influent concentrations for coco coir pith and GAC or high carbon wood ash treatments.
- Good N and P management at low and high influent concentrations for coco coir pith and GAC or high carbon wood ash.
- Coco coir and GAC or high carbon wood ash best performers for N, P and Cu capture.
BIOLOGICAL EFFECTIVENESS

PERFORMANCE

- More context...

% Reduction in Dissolved Metals

- 99%
- 72%
- 31%
- 91%
- 100%

- Zn, Cu, Ni, Pb, Cd

Animal Model | Effect | Exposure | Reduced | Eliminated
---|---|---|---|---
Juvenile coho | Mortality | 96 h | 100% | ✓
Mayfly nymph | Mortality | 48 h | 100% | ✓
Zebrafish | Mortality | 96 h | 100% | ✓
Daphnid | Mortality | 48 h | 100% | ✓
Reproductive Impairment | 7 d | 100% | ✓
Zebrafish | Cardiac dysfunction | 48 h | 100% | ✓
Growth impairment | 96 h | 100% | ✓
Cardiac edema | 96 h | 100% | ✓
Swim bladder | 96 h | 100% | ✓
Microphthalmia | 96 h | 81% | ✓
CYP1a induction | 48 h | TBD | TBD
Cardiac genes | 48 h | TBD | TBD
Statewide LID Training Program

INTRODUCTORY

1.0 Introduction to LID for Inspectors

2.0 Introduction to LID for Eastern Washington

2.1 Introduction to LID for Inspection & Maintenance Staff

2.2 Introduction to LID for Inspectors & Funding for Green

INTERMEDIATE

3.0 Intermediate LID Design:

3.1 Intermediate LID Design:

3.2 Intermediate LID Design:

3.3 Intermediate LID Design:

3.4 Intermediate LID Design:

3.5 Intermediate LID Design:

3.6 Intermediate LID Design:

3.7 Intermediate LID Design:

3.8 Intermediate LID Design:

ADVANCED

4.0 Advanced Topics in LID Design:

4.1 Advanced Topics in LID Design:

4.2 Advanced Topics in LID Design:

4.3 Advanced Topics in LID Design:

4.4 Advanced Topics in LID Design:

4.5 Advanced Topics in LID Design:

4.6 Advanced Topics in LID Design:

4.7 Advanced Topics in LID Design:

4.8 Advanced Topics in LID Design:

OTHER COURSE OFFERINGS

TRAIN THE TRAINERS

9.1 Service Providers

9.2 LID Topic Experts

ONLINE EVALUATION

- An online evaluation will be sent to you within 5 days following this training
- Feedback will help to refine future trainings
- Feedback is also important to pursue funding to support a long-term statewide LID training program
Two certificates:
• LID Design certificate
• Long-term LID Operations certificate
• Stay tuned for developing certificate policies

Sign out!