CAPTURING PHOSPHORUS USING WASTE PRODUCTS IN BIO-RETENTION SYSTEMS

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The staff working in the labs at the City of Tacoma
Rain Garden Soil Mixes

- Characterization
- Phosphorus overview

Phase 1
- Year Long Study
  - Capturing phosphorus

Phase 2
- This Summer’s Research
  - Combine phase 1 & 2
  - New rain garden design

Phase 3
Storm Water is the Problem

- Water collects contaminants as it flows
- Impermeable surfaces force urban runoff into storm drains

(stancounty.com) (pugetsoundstartshere.org)
Sources of Pollutants

- Urban Development
- Automobiles
- Fecal Matter
- Detergents
- Lawn Care
Storm Water Impacts

- 75-89% of female Coho Salmon die before spawning upon entering Longfellow Creek

- Eutrophication
  - > 0.05 mg / L of P

- Storm water
  - ≈ 0.30 mg / L of P

(NOAA.gov) (lakescientist.com)
Are Rain Gardens the Solution?

- Allows water to better infiltrate soil surface
- Filters metal particles and hydrocarbons
- Lessens amount of pollutants that enter rivers and streams

(bhbuilders.com)
Bio-Retention Soil Mix (BSM)

- Storm Water Management Manual for Western WA
- Sand used for high infiltration rates
- Compost used to fertilize plants

60% Sand
40% Compost
Phase 1 Overview

- Characterization of Media
  - Bio-Retention Soil Mix (BSM)

- Proposed Amendments to BSM
  - City of Tacoma’s TAGRO
    - Alternative to compost
  - Water Treatment Residual (WTR)
    - Used to capture phosphorus
TAGRO Garden Mix

- Composed of Class A bio-solids pasteurized to eliminate pathogens

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>Bio-Solids</td>
</tr>
<tr>
<td>25%</td>
<td>Sand</td>
</tr>
<tr>
<td>25%</td>
<td>Sawdust</td>
</tr>
</tbody>
</table>

(weeklyvolcano.com)
Water Treatment Residuals (WTR)

- 25 – 50 % Aluminum and Ferric Sulfates (additive)
- 15 – 25 % Organic Matter (source water)
- 35 – 50 % Clay / Silt (source water)

(ecy.wa.gov)
Adsorption and Absorption

- WTR captures ortho – P through dual process
  - Adsorption – Fast process
    - Easily reversible
  - Absorption – Slow process as particles dry-out
    - Uptake into matrix of particle

(reefkeeping.com)  (intechopen.com)
Soil Mixes

SAND
- Sand 100%

BSM
- Sand 60%
- Compost 40%

BSM / WTR
- Sand 60%
- Compost 31.3%
- WTR 8.7%

TAGRO MIX
- Sand 60%
- Bio-solid 25%
- Sawdust 15%
Methods

- Columns dosed with ≈ 2 years storm water
  - 10:1 – Drainage : Retention

- Leaching Period - To condition media
  - 75 Liters ≈ 1 year storm water
  - 8 Liters twice per week

- Polluting Period – To show how it reacts to pollutants
  - 75 Liter ≈ 1 year storm water
  - 4 Liters twice per week

- Sampling – 1st Liter of rain event ≈ every 20 Liters
Leaching Period

- Cistern water is reject water from making Deionized water, and runoff from green roof

(Waterworld.com)
Polluting Period

- Sludge to make storm water acquired from City of Tacoma
- Wet Sieved < 150µm
- ≈ 50-300 mg/L TSS

(americleanpumping.com)
What We Are Looking For

**Nutrients and Physical Traits**
- Major Anions
- Alkalinity and pH
- Infiltration Rates
- Total Phosphorous
- Ortho Phosphorus
- Total Suspended Solid
- Total Kjeldahl Nitrogen
- Total Organic Carbon
- Dissolved Organic Carbon

**Metals (Total and Dissolved)**
- Aluminum
- Arsenic
- Cadmium
- Copper
- Lead
- Nickel
- Zinc
Ortho - Phosphorus

- Causes eutrophication in fresh water

Sources of ortho - phosphorus:

- Decomposing organic phosphorus in compost and bio-solids
- Storm water runoff
Ortho - Phosphorus

Leaching Period

Polluting Period

- Influent
- TAGRO Mix
- Bio-retention Soil Mix
- Bio-retention Soil Mix / WTR
- Sand
- Inflow

Concentration (mg / L)

Influent Through Column (L)
- Can control the life span of rain-garden

- Rain-garden infiltration rates range between 12 to 1 in / hr

- Constant Head Method
  - Darcy’s Law formula
Phase 1 Conclusions

- WTR retains ≈ 50-60% of Phosphorus

- Infiltration rates slow down regardless of amendments
  - Could be controlled by fine grain particle loading

<table>
<thead>
<tr>
<th>Soil Amendments</th>
<th>Ortho - Phosphorous Removal</th>
<th>infiltration Rate Percent Drop (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Only</td>
<td>-</td>
<td>76</td>
</tr>
<tr>
<td>BSM</td>
<td>-</td>
<td>67</td>
</tr>
<tr>
<td>BSM / WTR</td>
<td>+</td>
<td>94</td>
</tr>
<tr>
<td>TAGRO Mix</td>
<td>-</td>
<td>64</td>
</tr>
</tbody>
</table>
Phase 2 Phosphorus Amendment

- Stratified Layers Sand / WTR
  - Will adding WTR at high volumes improve or harm rain garden function

- Sampling:
  - Ortho-Phosphorus
  - Infiltration rates
Project Design

 Sand / WTR

 Influent: Synthetic storm water
  • 1 mg/L Nitrogen
  • 0.3 mg/L Phosphorus

 Loading Rate:
  • 4 Liters twice a week

 Sampling:
  • 1st Liter about every 30 Liters
Ortho - Phosphate

Ortho - P Concentration (mg/L)

Liters of Influent (L)

200 250 300 350 400 450

Ortho - P Concentration (mg/L)

0.0
0.1
0.2
0.3

Sand / WTR - 50 / 50
Sand / WTR - 75 / 25
Sand / WTR - 90 / 10
Influent

50 % Breakthrough

Ortho - Phosphate

Liters of Influent (L)

200 250 300 350 400 450

Ortho - P Concentration (mg/L)

0.0
0.1
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Sand / WTR - 50 / 50
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Sand / WTR - 90 / 10
Influent

50 % Breakthrough
### Phase 2 Conclusions

<table>
<thead>
<tr>
<th>Sand / WTR</th>
<th>Ortho - Phosphorus 50 % Breakthrough</th>
<th>Infiltration Rate Percent Drop ( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>90/10</td>
<td>≈ 300 L</td>
<td>42</td>
</tr>
<tr>
<td>75/25</td>
<td>≈ 400 L</td>
<td>74</td>
</tr>
<tr>
<td>50/50</td>
<td>&gt; 460 L</td>
<td>71</td>
</tr>
</tbody>
</table>

- Sand / WTR removes ortho – phosphorus in synthetic storm water ≈ 3 – 5 years
Phase 3 TAGRO / WTR mixes as Alternative to BSM

- Combine Phase 1 & 2 research
  - Balance phosphorus retention Vs. infiltration rates

- Building new rain garden design
  - Stratified WTR Layers vs. Mixed Throughout
Problems

- TAGRO and compost leach nutrients
  - Nitrogen and Phosphorus

- Storm Water Management Manual WWA DOES NOT allow Bio-Solids in BSM
Stratified Layers Vs. WTR Mixed Throughout

**Ponding Layer**
- **60% Sand**
- **25% Bio-solids**
- **15% Sawdust**

**Ponding Layer**
- **50.2% Sand**
- **25.8% Bio-solids**
- **15.5% Sawdust**
- **8.5% WTR**
Methods

- Treatments run in triplicate

- Influent:
  - Synthetic storm water
    - 1 mg/L Nitrogen
    - 0.3 mg/L Phosphorus

- Loading Rate:
  - 8 Liters / rain event
  - 2 times / week

- Sampling:
  - 1st Liter & 2-8 Liter composite
WTR Stratified or Mixed

Ortho-P Concentration (mg/L)

TAGRO Average Conc
BSM Average Conc
Influent Average Conc

Rain Events

1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9
Phosphorus in Anoxic Conditions

- **Ponding Layer**: 60% Sand, 25% Bio-solids, 15% Sawdust
- **Saturated Layer**: 50.2% Sand, 25.8% Bio-solids, 15.5% Sawdust
- **Anoxic**:
  - Left: 6in
  - Right: 6in
Saturated Anoxic Layer

Ortho-P Concentration (mg/L)
5
10
15
20
TAGRO Average Conc
BSM Average Conc
Influent Average Conc

Rain Events
1 2 3 4 5 6 7 8 9

Ortho-P Concentration (mg/L)

TAGRO Average Conc
BSM Average Conc
Influent Average Conc

Rain Events
1 2 3 4 5 6 7 8 9
<table>
<thead>
<tr>
<th>Rain Events</th>
<th>Infiltration Rate (in/hr)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
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<td>8</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

- Stratified
- WTR Mixed Throughout
- Stratified Anoxic
- WTR Mixed Throughout Anoxic

Acceptable Infiltration Rate
Conclusion

- WTR may decrease phosphorus in run-off for 3-5 years of storm events
- WTR works better in layers than mixed throughout
- WTR should remain out of anoxic zone
- TAGRO mix may be viable alternative for BSM in tandem with WTR
Future Studies

- Ponding Zone
- Compost Layer
- Phosphorus Treatment
- Nitrogen Treatment

Water Baffle