FEASIBILITY STUDY OF WATER TREATMENT PLANT RESIDUALS TO IMPROVE POLLUTANT REMOVAL IN SCMS

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Typical Water Treatment Process Sequence

1. Raw water reservoir
   - Large objects removed
2. Flocculation tank
   - Oxygen content increased
   - Flocculating agents added
3. Settling tank
   - Flocs settle
4. Water filtered and chlorinated

Goals of this Study

• Determine the applicability of water treatment plant residuals (WTRs) addition to improve stormwater control measure (SCM) performance.

• Explore options to improve residuals performance via residual modification.
Scope

• The residuals used for this study were from a water treatment plant that uses alum coagulation.

• Water treatment plant residuals (WTRs) containing alum have potential to improve SCM performance due to their phosphate removal ability.

• Investigations are needed to determine if WTRs will be an effective infiltration material.

• It is also important to determine the extent of aluminum leaching that may occur.
Water Treatment Plant Residuals (WTRs)

• Residuals used were from after the filter press (termed “as-received residuals”).

• Moisture content – 70.3% (± 2.1%, n=3)

• Volatile content of the dried residuals – 30.0% (± 0.1%, n=3)

• The majority of the residuals have a grain size between 0.01 and 0.074 mm and plastic/liquid limit analysis resulted in a USCS classification of CH (i.e. fat clay).
Research Plan

Compare “as-received” residuals performance to drying (105°C) and baking (1000°C) regarding the following parameters:

1) hydraulic conductivity
2) phosphate adsorption potential
3) aluminum leaching
Residuals Modification

- As Collected Material
- Dried at 105°C
- Ignited at 1000°C
1) Hydraulic Conductivity

• Rigid wall falling head hydraulic conductivity test (ASTM D5856-95)
• Residuals packed using a modified version of the Reduced Proctor Energy Test (Daniel and Benson, 1990)
Hydraulic conductivity for WTRs measured by others in the range of $7.3 \times 10^{-8}$ cm/s to $9.7 \times 10^{-6}$ cm/s (Hsieh and Raghu, 1997).
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Hydraulic Conductivity

<table>
<thead>
<tr>
<th>Condition</th>
<th>Conductivity (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-received</td>
<td>$1 \times 10^{-5}$</td>
</tr>
<tr>
<td>Dried</td>
<td>$1 \times 10^{-4}$</td>
</tr>
<tr>
<td>Dried then 30% Moisture</td>
<td>$1 \times 10^{-3}$</td>
</tr>
<tr>
<td>Baked</td>
<td>$1 \times 10^{-3}$</td>
</tr>
</tbody>
</table>
Hydraulic Conductivity

Average hydraulic conductivities reported in literature ($8.3 \times 10^{-5}$ to $2.0 \times 10^{-3}$ cm/s - Emerson and Traver, 2008; Asleson et al., 2009) for infiltration SCMs.
2) Phosphate Sorption Potential

• Phosphate sorption experiments based on Graetz and Nair (2009).

• ~1 g (dry wt) of residuals added to 25 ml of 0.01 M KCl containing different concentrations of phosphate in 50 ml centrifuge tubes.

• Rotated at 100 RPM at room temperature (21-23°C) for 24 h.

• Filtered (0.45 µm) and analyzed using a Hach DR/4000 Spectrophotometer with Hach method 8048.
Phosphate Sorption Potential

Initial Phosphate Conc. (mg-P/L) vs. Phosphate after 24h (mg-P/L)

- as-received
Phosphate Sorption Potential

- as-received
- dried (105 C)

Initial Phosphate Conc. (mg-P/L) vs. Phosphate after 24h (mg-P/L)
Phosphate Sorption Potential

- as-received
- dried (105 C)
- baked (1000 C)

Phosphate after 24h (mg-P/L)

Initial Phosphate Conc. (mg-P/L)
Phosphate Sorption Potential
Baked vs Soil

[Graph showing data points for different treatments: as-received (diamond), dried (105°C, square), baked (1000°C, triangle), and native soil (circle). The x-axis represents initial phosphate concentration (mg-P/L) while the y-axis shows phosphate after 24h (mg-P/L).]

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3) Aluminum Leaching

- Aluminum leaching experiments based on Mortula et al. (2009).
- ~1.2 g (dry wt) of residuals added to 50 ml of rain barrel stormwater runoff in 50 ml centrifuge tubes.
- Rotated for 1 h on shaker table and then stored in dark for 30 days.
- Filtered (0.45 µm) prior to analysis.
- Triplicates performed with no pH adjustment (existing stormwater has a pH = 5.3) as well as at pH = 4 and pH = 7.
Aluminum Leaching

![Bar graph showing aluminum leaching levels at different pH levels (pH=4.1, pH=5.3, pH=6.9) for different conditions: No residuals, As-received, Dried, Baked. The solid horizontal line indicates the detection limit.](image-url)
Copper Removal by Residuals

Copper (mg/L)

- No residuals
- As-received
- Dried
- Baked

Solid Horizontal Line = Detection Limit

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Lead Removal by Residuals

Solid Horizontal Line = Detection Limit
Zinc Removal by Residuals

Zinc (mg/L)

Solid Horizontal Line = Detection Limit
Arsenic Removal by Residuals

![Graph showing arsenic removal by residuals]

- **Rainbarrel water**
- **Spiked rainbarrel**
- **As-received 0.2g**
- **As-received 0.5g**
- **As-received 1g**

Solid horizontal line = Detection Limit
Manganese Leaching/Re-Suspension

![Graph showing manganese levels at different pH values and conditions.](image)

- **No residuals**
- **As-received**
- **Dried**
- **Baked**

**Legend:**
- Red: pH=4.1
- Blue: pH=5.3
- Green: pH=6.9

**Solid Horizontal Line = Detection Limit**

VILLANOVA URBAN STORMWATER PARTNERSHIP
Manganese Transport Column Exp.

Column 1
- 0.5 ft dried WTR on top
- 1.5 ft of gravel below

Column 2
- 0.5 ft dried WTR on top
- 1.5 ft of soil below

- Each column was supplied 5 L of roof runoff
- Effluent collected over time
Manganese Transport Column Exp.

Cumulative Mn Transported (mg)

Cumulative Volume Passed Though Column (L)

WTR then Gravel
Manganese Transport Column Exp.

Cumulative Mn Transported (mg)

Cumulative Volume Passed Through Column (L)

- WTR then Gravel
- WTR then Soil
Conclusions

• Drying significantly increased the hydraulic conductivity of post-filter press ("as-received") residuals.

• As-received residuals and dried residuals were excellent at removing phosphate. Baked residuals had a phosphate removal efficiency similar to native soils tested.

• Aluminum from residuals did not significantly leach.

• Manganese was leached in as-received and dried (but not baked) residuals.

• Residuals removed copper, lead, and zinc from stormwater runoff.
Acknowledgements

- Aqua Pennsylvania, Inc.
- Villanova Urban Stormwater Partnership (VUSP)
Acknowledgements

- Laura Nikkel-dumyahn
- Erica Forgione
- Isabel Sarriera
- Carli Joseph
- Sarah Bates

Komlos, J., A. Welker, V. Punzi and R. Traver. "Feasibility Study of As-Received and Modified (Dried/Baked) Water Treatment Plant Residuals for use in Stormwater Control Measures (SCMs)"

*Journal of Environmental Engineering* 139:1237-1245
Thank You!

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