A Simple and Effective Filtering System for Pesticide and Nutrient Removal from Surface Water

Chad J. Penn
Department of Plant and Soil Sciences
Oklahoma State University
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Why P management?

- Phosphorus (P) is essential to all forms of life on earth – no known toxic effects
- Adequate P levels in soils are essential for production of agronomic crops
- In most fresh surface water bodies growth of algae or aquatic plants is limited by P availability
P Impact on Plants

• Vigorous crop (Shoot/Root) growth
  - Improved resource utilization
    • water, nutrients
    • positive environmental implications
  - Better resistance to stress
    • disease, pest, moisture, temperature
  - Earlier maturity
    • good grain & fruit development
    • better crop quality, yield
Problem: phosphorus (P) in surface waters
- P is a limiting nutrient among surface waters
  - Excessive P concentrations leads to eutrophication
    - Fish kills, odors, problems with water treatment processes (drinking water) and recreation
P transport to surface waters

• Occurs primarily via surface flow
  - Dissolved P - 100% biologically available
  - Particulate P - carried on eroded particles, not immediately bio-available

• Leaching and lateral subsurface flow very important in golf greens

• If the soil becomes saturated with P the potential for P loss increases significantly
Phosphorus Losses: Source and Transport

Sources

- P leaching
- Tile flow
- Subsurface flow

Transport

- Runoff
- Erosion
- Water Body
P Losses to Surface Water

Risk Increases As Soil P Increases

Potential for P loss

Soil test P

Low  Optimum  High
P losses to surface waters

• Particulate P loss is easy to prevent
  - Erosion control

• Dissolved P loss is difficult to prevent from soils with high P levels or systems with little P retention capacity
  - Even if we stop applying P to high P soils, they will continue to produce dissolved P in runoff for many years
Potential Solution for Dissolved P: P Sorbing Materials

- Chemical additions to soils, manures, and surface waters
  - Al, Fe, and Ca containing materials that chemically bind with P, reducing soluble P concentrations.
    - Al and Fe oxides/hydroxides: precipitation, ligand exchange, and electrostatic attraction
    - Ca: precipitation and electrostatic attraction
  - Many by-products contain potential P sorbing minerals
Examples of PSM's

Highly soluble Ca products (gypsum)

Highly soluble Al and Fe products (alum)

Natural or synthetic Al and Fe oxy/hydroxides (Fe oxides)
Example waste product PSM's

- Acid mine drainage treatment residuals
- Drinking water treatment residuals
- Bauxite mining and production waste (red mud)
- Fly ash
- Steel slag waste
- Paper mill waste
- Waste recycled gypsum
P Sorbing Materials: application to soils, manure, and surface water

• P is still present: simply converted into a less soluble form

• Therefore, one must consider the long term fate of P bound to PSM's
Solution: P removal structure theory

- **High P water**
- **Drainage layer (sand/perforated pipe)**
- **PSM layer with retained P**
- **Low P water**
Advantages of P removal structures

• Ability to remove PSM after becoming saturated
  - P, various metals, and pesticides are removed from the system, preventing long term exposure.
  - spent P saturated material has fertilizer value

• Remove particulate P (PP) in addition to dissolved P (DP)
Selection Process for PSMs

1. Material Availability
2. Cost & Transportation
3. Potential contaminants
   - pH
   - Soluble salts
   - Total, acid soluble, and water soluble Na & heavy metals
4. Sorption characteristics
5. Physical Properties
   - Particle size distribution and bulk density
   - Hydraulic conductivity
Testing Grounds for Materials

OSU Botanical Gardens: pond receives subsurface drainage from turf greens
Algae Blooms
Objective

• Construct a P removal structure for the pond in order to test the P sorption capability of different materials under “real world” conditions
  - Drinking water treatment residuals (WTRs)
  - Fly-ash
  - Steel slag
• The goal was NOT to remediate the pond
Treatment Structure

Pond water is pumped through a bed of PSMs and discharged back into pond.

20 h per day, 7 d per week

Pump
P Removal: Tulsa WTRs

Means of flow: pump
Flow rate: 38 L min\(^{-1}\)
P input range: 0.13 to 0.37 mg L\(^{-1}\)
P removed: 112 mg kg\(^{-1}\)

Days from start vs. P removal efficiency (%)
Visible Removal of Green Color
Summary of materials tested in pond filter

<table>
<thead>
<tr>
<th>Material</th>
<th>Flow rate (L/minute)</th>
<th>Flow method</th>
<th>Input P range (mg/L)</th>
<th>Time until spent (Days)</th>
<th>Total P removed (mg/kg)</th>
<th>P removal rate (mg/kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stillwater WTRs+ 5% alum+ 5% sand</td>
<td>38</td>
<td>pump</td>
<td>0.10 - 0.33</td>
<td>17</td>
<td>79</td>
<td>4.65</td>
</tr>
<tr>
<td>AB-Jewel WTRs</td>
<td>38</td>
<td>pump</td>
<td>0.13 - 0.37</td>
<td>23</td>
<td>132</td>
<td>5.74</td>
</tr>
<tr>
<td>Fly ash (5%) with sand</td>
<td>0.3</td>
<td>gravity</td>
<td>0.17-0.43</td>
<td>na</td>
<td>23.7</td>
<td>2.37</td>
</tr>
<tr>
<td>Slag</td>
<td>1.5 - 8.5</td>
<td>gravity</td>
<td>0.31 - 0.46</td>
<td>na</td>
<td>18.7</td>
<td>2.67</td>
</tr>
<tr>
<td>&gt; 1/4&quot; slag</td>
<td>8.5</td>
<td>gravity</td>
<td>0.26-0.62</td>
<td>15</td>
<td>82.7</td>
<td>5.51</td>
</tr>
</tbody>
</table>
Conclusions

- All materials tested were effective at removing P
  - Gravity-flow structures: hydraulic conductivity may be limiting factor
- More effective to filter drainage and runoff BEFORE it reaches a collection pond
Success Stories: AMDR box filter

- Stainless steel box (1 x 2 m) installed in field drainage ditch (500 lbs AMDR).
- Results: removed 99% of P, Zn, Cu, and As entering the box.
Success Stories: Gypsum Dam Filter

- 0.4 m thick bed of 90 tons FGD gypsum; 3 m wide by 1.5 m deep public drainage association (PDA) ditch.
- Results: removes about 67% of P entering the ditch and is able to treat more water than the former system.
Structure in Progress: Stillwater Country Club

Water flow: accumulation at drain Ditch. Flow carried under and over cart path into ditch: joins Stillwater Creek.
Future Research

• Pesticides
  - Many of the materials used to remove P will also have a strong affinity for organic compounds i.e. pesticides

• Nitrogen
  - More difficult: not held as strong

• Currently developing a simple model for designing structures
  - Based on easily measured characteristics