Filtering phosphorus out of surface runoff with a phosphorus removal structure

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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
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

Introduction
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

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

Sources

- Tile flow
- P leaching

Transport

- Erosion
- Runoff
- Water Body

Subsurface flow
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 (PSM)

- Treatment of runoff and drainage water prior to reaching 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
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
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 could have fertilizer value

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

- Material Availability
- Cost & Transportation
- Potential contaminants
  - pH
  - Soluble salts
  - Total, acid soluble, and water soluble Na & heavy metals
- Sorption characteristics
- Physical Properties
  - Particle size distribution and bulk density
  - Hydraulic conductivity
Potential Application

Agricultural runoff

Urban storm water runoff
Potential Application: Barnyard Runoff

- Treat runoff P originating from around poultry barns or manure storage areas
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: Stillwater Country Club Slag Filter
Distribution Manifold and Drain

Effective for 7-8 months: 25% overall dissolved P removal

Structure has handled flow rates over 100 gpm

Overflow weir
P removal structure at SCC

- Cost: $2,000 for steel and welder time
- Slag was free (3 tons sieved)
- $200 to sieve and transport slag from Ft. Smith to Stillwater
- $2,200 total
Model development

• Developed a user friendly empirical model based on laboratory material characterization and flow-through P sorption experiments:
  • Testing 14 different materials
    - Add P at constant rate
    - Vary retention time and P concentration
    - Measure P in outflow
Model Development

• Ultimately, the model can be used for:
  - Sizing structures for removing targeted P loads at “hot spots”
  - Use to predict the life of a constructed structure

• Users only need
  - basic watershed/runoff characteristics
  - typical P concentrations
  - routine characterization of material
    » i.e. pH buffer capacity, pH, total Ca, Al, Fe, water soluble Ca
Model Prediction

Prediction of 28% cumulative removal at 0-8 saturation:
measured at 25%

Measured
Predicted

P removed (mg kg\(^{-1}\))
P added (mg kg\(^{-1}\))

\(\triangle\) Measured
\(\triangle\) Predicted
Comparison to other BMPs

• In the short term there is no BMP that can appreciably reduce soluble P losses
  
  - P “mining” with hay crops to reduce soil P levels
    
      • Bermuda grass and Rhyegrass-bermuda grass
        
          - 3 years to reduce soil P (Mehlich-3) from 300 to 240 ppm in Mississippi
    
  - Poultry litter transport programs
    
      • Only prevents soil P from increasing, does not decrease soil P
Cost of technology?

- Depends on available material and watershed characteristics

- Example of dairy farm watershed in NY
  - 400 acres delivered 94.5 lb DP/yr
  - Using WTR similar to Tulsa, need 4 tons/yr for 30% reduction
    - Assume DP in runoff is 0.5 ppm
  - 3 inch deep, 476 ft², $10/ft², transport costs, annual cleanout, profit by private company
    - = $41 per lb DP removed over 7 yr period.
Questions?