Managing Agricultural Drainage Waters to Protect Water Quality

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Ditch Drained Systems

- Flat, low-lying, poorly drained coastal plain soils
- Extensive ditching: In MD approximately 1321 kilometers (821 miles) of ditches drain 74,060 hectares (183,000 acres) of land
- High density poultry production has led to elevated soil P
- Primarily corn, wheat, soy rotation (or variation thereof)
Soil test P summary

Restricted to fields where the Maryland P Index was run (FIV > 150 only)

Mean Maryland P Fertility Index Value

- Green: 150 - 200
- Light Green: 200 - 250
- Yellow: 250 - 300
- Orange: 300 - 350
- Red: 350 - 400

Average P FIV = 374
Ditch Project at UMES: What it Taught Us

Monitoring network

Flume

Automatic sampler
2005-2006 phosphorus loads

All fields ranged from 382 – 467 mg/kg M3-P

- Ditch ID
  - 1, 2, 3, 5, 6, 7, 8

- P Loss (kg/ha)
  - 0, 10, 20, 30

- Sediment bound
- Dissolved

UMES Research Farm

Mehlich-3 P 3,113 mg/kg

Courtesy: P. Kleinman
Do incidental transfers from fields contribute to dissolved P in ditches?

Dissolved P (mg/L)

Manure spread

Field

Courtesy: P. Kleinman
APPARENTLY NOT

Dissolved P (mg/L)

Field
Ditch

Manure spread

Apr May June July Aug Sept 2003

Courtesy: P. Kleinman
Surface runoff from the field only accounted for 3-9% of annual ditch flow. Surface runoff from the field only accounted for 5-22% of annual ditch P export.

Courtesy: P. Kleinman
Lessons Learned

• Small contributing areas with high P source that are connected to ditches can deliver large P loads
  – Ditches I7 & I8 drained only 19% of area but accounted for 66% of P loss
• Even small field ditches can carry a lot of P directly to surface waters
  – >50 lbs P from a 600’ ditch at UMES
• Given high P source within a field P loading is dominated by water export
• Majority of the P is transported through (shallow) subsurface flow
• Phosphorus concentrations in 12 ditches over 5 years ranged from 0.25 – 3.59 mg L$^{-1}$ with an average of 1.67 mg L$^{-1}$
Take Home Message

• Historically efforts to control P losses have focused on:
  - Overland flow BMPs
  - Riparian zones and buffer strips (particulate P)
  - No-till (particulate P)
  - Band applied P and reduced application rate
  - Timing of application (incidental transfers)
  - No P zones

There is good science that shows these practices reduce P in overland flow and losses of sediment bound P...

However it appears that overland flow makes only a minor contribution to P loads in ditch drained ag systems!!

• Stop accumulation and maintenance in critical source areas
  - P index, nutrient management planning

- No P Zones

• There is good science that shows these practices reduce P in overland flow and losses of sediment bound P...
Delaware Phosphorus Balance

-5 0 5 10 15 20 25 30

lbs/acre/year

P-Management P-In/Out

Accounts for legacy P in soils

Education, Nutrient Management Planning, and Poultry Diet Changes
Regional Distribution of PSI Scores

<table>
<thead>
<tr>
<th>Region</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Shore</td>
<td>8%</td>
<td>2%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Lower Shore</td>
<td>36%</td>
<td>13%</td>
<td>1%</td>
<td>88%</td>
</tr>
</tbody>
</table>

- **Upper Shore**: No P applications!
- **Lower Shore**: P-based planning only
- **Lower Shore**: P-based planning 2 years of 3
Historically efforts to control P losses have focused on overland flow BMPs
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Stop accumulation and maintenance in critical source areas
- P index, nutrient management planning

Reduce water export
- Flow control structures

Reduce P concentration of water
- The “ditch filter”
Take Home Message

- The nature of the problem demands an approach that couples targeting (identification) of problem areas with solutions to the problem

- Long-term
  - Continue to address (Legacy) source

- Near-term
  - Control water movement
  - Reduce concentration in water at source

- Stop accumulation and maintenance in critical source areas
  - P index, nutrient management planning

- Reduce water export
  - Flow control structures

- Reduce P concentration of water
  - The “ditch filter”
The Ditch Filter

- Structure filled with P sorbing materials (PSMs)
- Alter hydraulic head in ditch to force flow through filter material
- Primary designs:
  - Confined bed
  - Stormwater pond filter
  - Cartridge
  - Tile filter
Confined bed filter

- Located on golf course in Stillwater, OK
- 2.7 Mg of ¼” slag bed over perforated pipe
- Daily runoff events from irrigation
Stormwater Pond Filter

- 123 x 76 x 76 Perforated steel box
- 10.2 cm pipe positioned vertically inside box – radial flow to discharge.
- Holds ~1.4 Mg of ¼ slag.
- 4 boxes in series to discharge.
- Drains 2 ha from poultry production area
Cartridge Filter

- Filled with ¼” slag
- High flow rates, small ditches - Limited mass of PSM
- Portable and easy to install
- May be replaced by box style used in retention pond
Tile Drained Filter

- 50 Mg FGD Gypsum
- PSM over and under perforated pipes
- PSM can be removed and land applied after filter failure
- Slow retention time
  - Works well with base flow (slow rate, low concentration)
  - Ideal for typical field ditch applications

After re-vegetation
Design Guidance

• Material selection process
  – Material availability
  – Cost/transportation
  – Potential contaminants
  – P sorption characteristics
  – Physical properties

• Structure selection
  – P loads
  – P concentrations
  – Flow rates
  – Peak flow versus base flow
  – Slope

• Currently developing a user friendly model based on laboratory characterization and flow-through P sorption experiments.
  – Use for designing P removal structures for target loads
  – Use to predict the life of a constructed structure
  – Users need only a simple characterization of the materials to plug into model
Design Curve

- Based on flow-through experiments
- Provides discrete efficiency of material versus cumulative P added
- Can be used to design filters based on chemical characteristics of PSM
- Faster flow (short retention time) favors slag
- High inflow P concentration favors slag

![Graph showing Design Curve with two lines, one for EAFS and one for FGDG, indicating P removal versus P added and flow rate.]
Effect of retention time

![Graph showing the effect of retention time on cumulative P removal. The graph includes lines for different concentrations of EAFS and FGDG, with EAFS at 1 mg L⁻¹ and 10 mg L⁻¹, and FGDG at 1 mg L⁻¹ and 10 mg L⁻¹. The y-axis represents cumulative P removed (mg kg⁻¹), and the x-axis represents retention time (min).]
Inflow P concentration

Cumulative P removed (mg kg⁻¹)

- EAFS: RT = 0.5 min
- FGDG: RT = 0.5 min
- EAFS: RT = 13 min
- FGDG: RT = 13 min
- EAFS: RT = 20 min
- FGDG: RT = 20 min

Inflow P concentration (mg L⁻¹)
Filter Performance Across P Concentrations

Darcy’s law used to calculate retention time through filters of prescribed size

- **EAFS**: $RT = 0.28$ min, size = 20 Mg
- **FGDG**: $RT = 11.50$ min, size = 31 Mg

![Graph showing cumulative P removed vs. inflow P concentration](image-url)
Cumulative P removal

EAFS: RT = 0.28 min, size = 20 Mg
FGDG: RT = 11.50 min, size = 31 Mg
Summary

- Flow through experiments show that slag efficiency improves with faster flow and at higher P concentration.
- Slag filters are much smaller than gypsum tile drained filters:
  - Flow rates are faster - shorter retention time
  - Large size of the gypsum filter allows for longer life span
  - However, these filters could have much higher overflow rate, treating less water per event.
- Life span of filter can be defined by cumulative P added or volume of flow – this is dependent on expected P concentration.
  - On the basis of volume of flow through the filter, the filters last longer with low concentration inflow than high concentration inflow
  - On the basis of cumulative P added, filters last longer with high concentration inflow than low concentration inflow
Performance

• Slag confined bed: 43% removal
• Gypsum tile drain: initial (limited) data indicates 67% removal
• Box style filter approximately 20% load reduction
  – Approximately 50% when flow is good
  – Reduced FWMC of TP 25%
  – Reduced FWMC of DRP 29%
• To date model predicts P removal accurately
• Need robust field data to validate model and to predict overflow versus flow through
  – 4 ditches with tile filters
  – 3 ditches with cartridge filters
  – 2 ditches (1 ag and 1 golf course) with confined bed filters
  – 1 retention pond with box filter
• Developing complete guidance for government and private stakeholders
Thank You!

[Logos of various universities and organizations]
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