In-Situ Treatment of Agricultural Drainage Water Using Industrial By-Product Phosphorus Sorbing Materials

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Ditch Drained Systems

- Flat, low-lying, poorly drained coastal plan 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
- 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
- 90% of P loss occurs in subsurface flow
The Ditch Filter

- Structure filled with P sorbing materials (PSMs) – gypsum and slag
- Alter hydraulic head to allow water to flow through at rate similar to ditch flow
- Primary designs:
  - Confined bed
  - Stormwater pond filter
  - Cartridge
  - Tile filter
  - Stormwater pond 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
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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" showing discrete P removal with increasing P additions

X intercept indicates equilibrium

Inflow [P] = outflow [P]
Cumulative P adsorbed at equilibrium - flow through

- Slag better with faster flow (lower RT) and higher inflow [P]
- Gypsum better at high RT and similar across [P]
Effect of retention time on P removal (mass basis)

- Slag at high [P] very effective
- Gypsum surpasses slag at low [P] and very long RT
Life span of 5 Mg slag filter compared to 50 Mg gypsum filter

- While slag outperforms gypsum on mass basis the longer RT and much greater mass of actual filters favors gypsum
- However, during peak flow tile-gypsum filter experiences higher overflow, treating lower % of total flow
Life span of 5 Mg slag filter compared to 50 Mg gypsum filter

- Assuming constant [P] filter lasts longer on flow basis at low [P]
- On basis of P added filter will last longer with high [P]

![Graph showing comparison of P removed vs Cumulative P added for 5 Mg Slag and 50 Mg Gypsum filters.](graph.png)
Summary

- Flow through isotherms show that slag efficiency improves with faster flow and at higher P concentration.
- Gypsum improves with slower flow and behaves similarly across P concentrations evaluated.
- 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
- Cartridge and box style filter recently installed awaiting results
- To date model predicts P removal accurately
- Need more robust lab data set to extend limits of model
- 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!
Field runoff vs. total ditch flow

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
Life span of 5 Mg slag filter compared to 50 Mg gypsum filter

![Graph showing Cumulative P Removal (% of P added) vs Flow (L) for 5 Mg Slag and 50 Mg Gypsum filters at different concentrations and flow rates.]

- 5 Mg Slag 1 ppm 1 min
- 50 Mg Gypsum 1 ppm 10 min
- 5 Mg Slag 10 ppm 1 min
- 50 Mg Gypsum 10 ppm 10 min
Life span of 5 Mg slag filter compared to 50 Mg gypsum filter

- 5 Mg Slag 1 ppm 1 min
- 5 Mg Slag 10 ppm 1 min
- 50 Mg Gypsum 1 ppm 10 min
- 50 Mg Gypsum 10 ppm 10 min

Cumulative P added (g)

Cumulative P Removal (% of P added)
Effect of retention time on percent P removal

Retention time (min)

Cumulative P removed (%)