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

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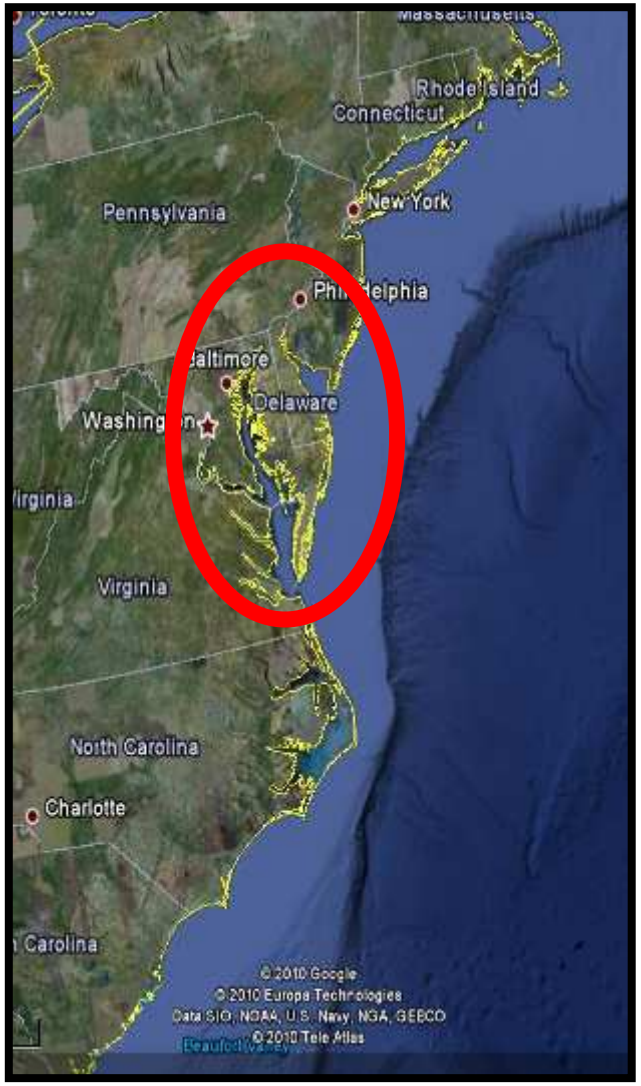
Ditch Drained Systems

- 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

Tile Drained Filter

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- PSM
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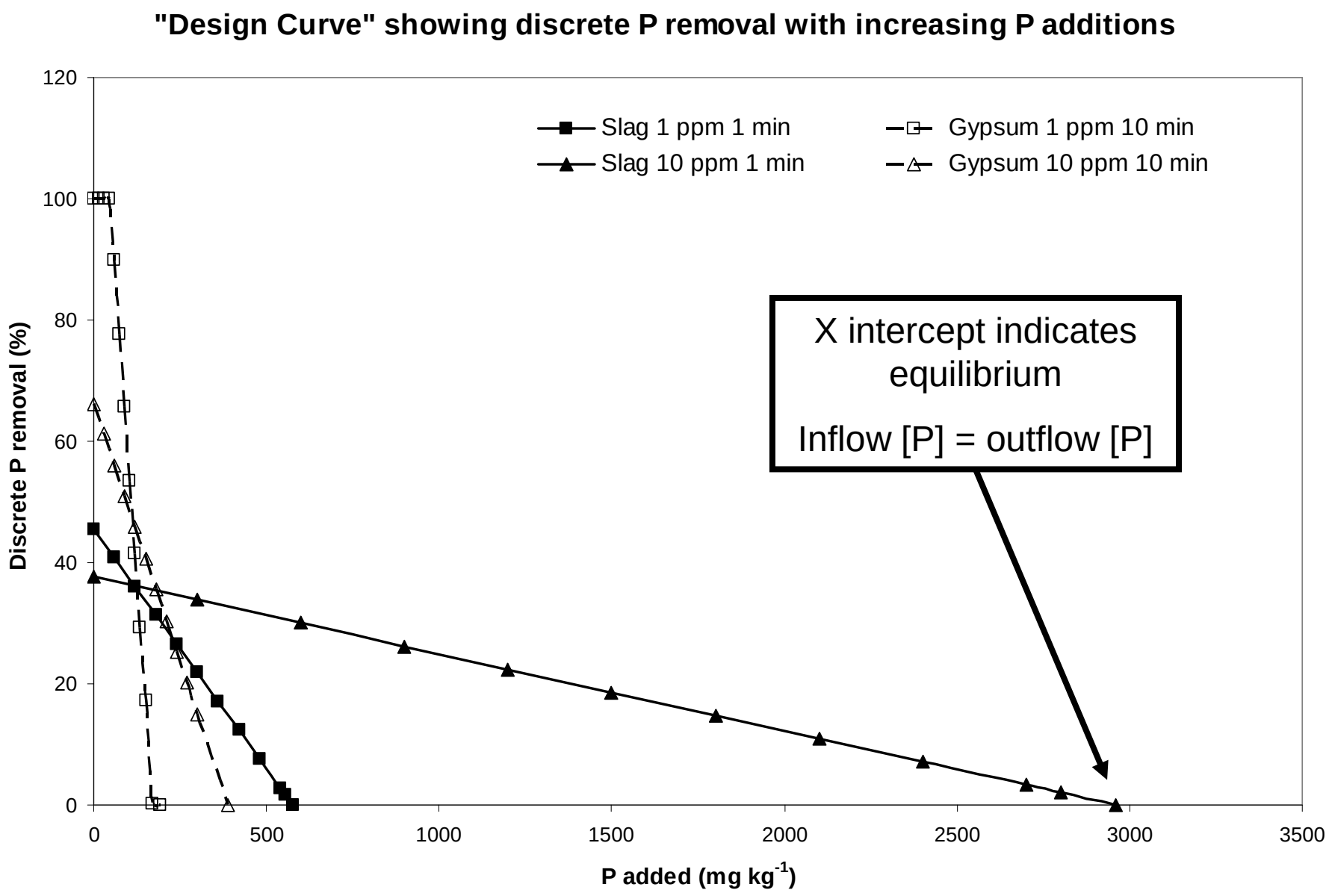
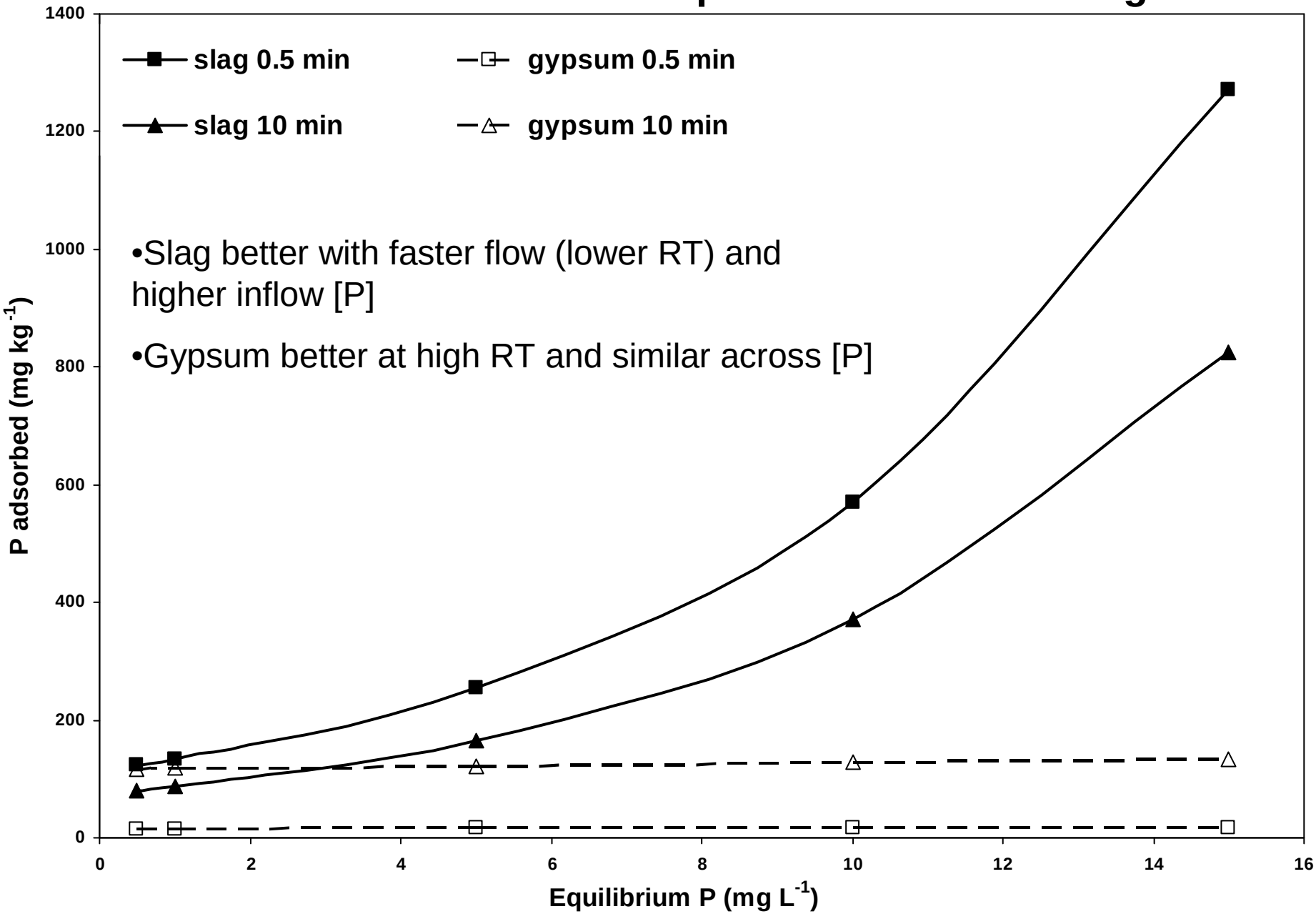
Design Guidance

- 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

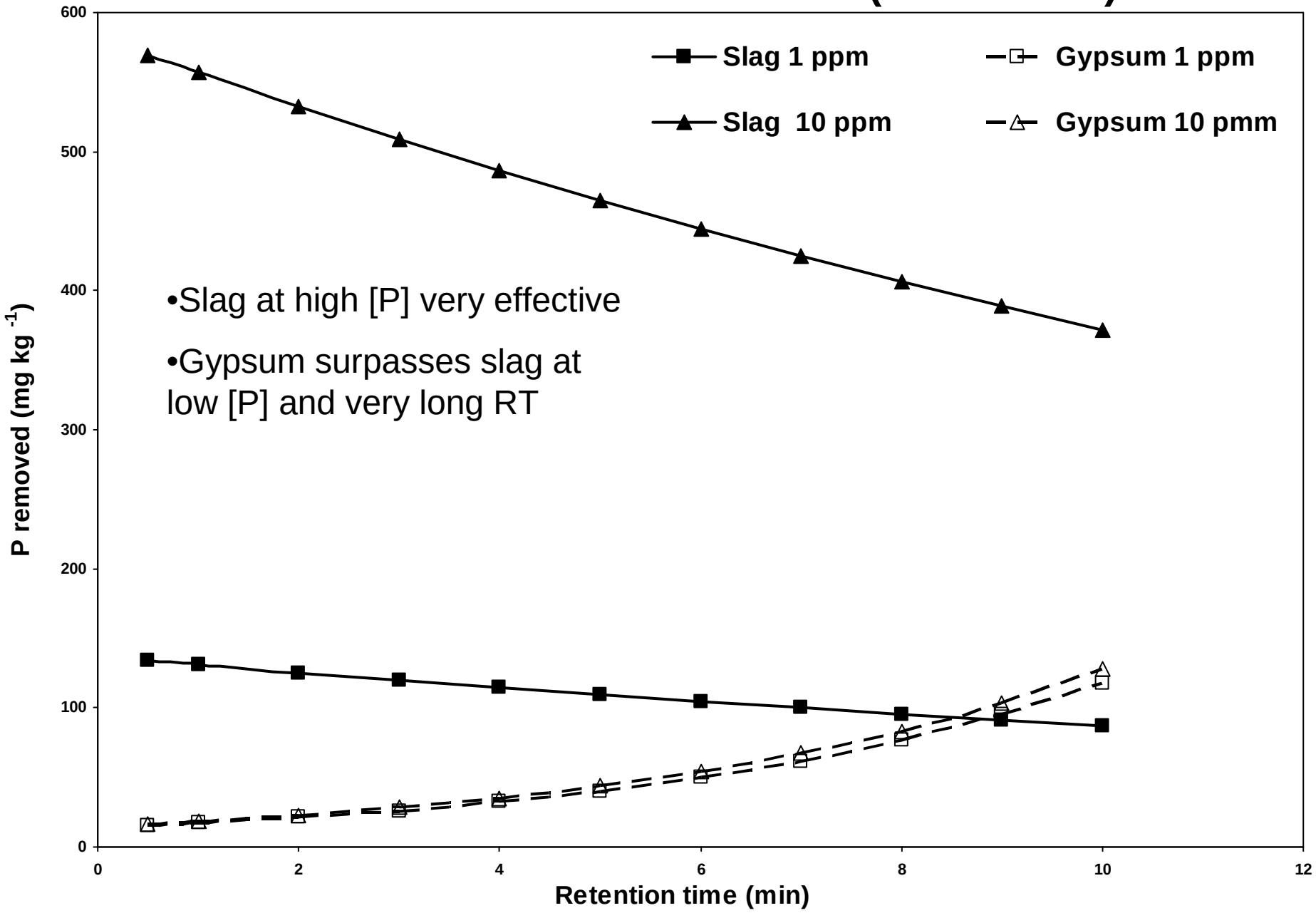
- Currently developing a user friendly model based on laboratory characterization and flow-through P sorption experiments.
  - Use for designing P removal structures for target loads
  - Use to predict the life of a constructed structure
  - Users need only a simple characterization of the materials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


"Design Curve" showing discrete P removal with increasing P additions
Slag 1 ppm 1 min
Slag 10 ppm 1 min
Gypsum 1 ppm 10 min
Gypsum 10 ppm 10 min
X intercept indicates equilibrium
Inflow [P] = outflow [P]
Discrete P removal (%)
P added (mg kg-1)
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
3500

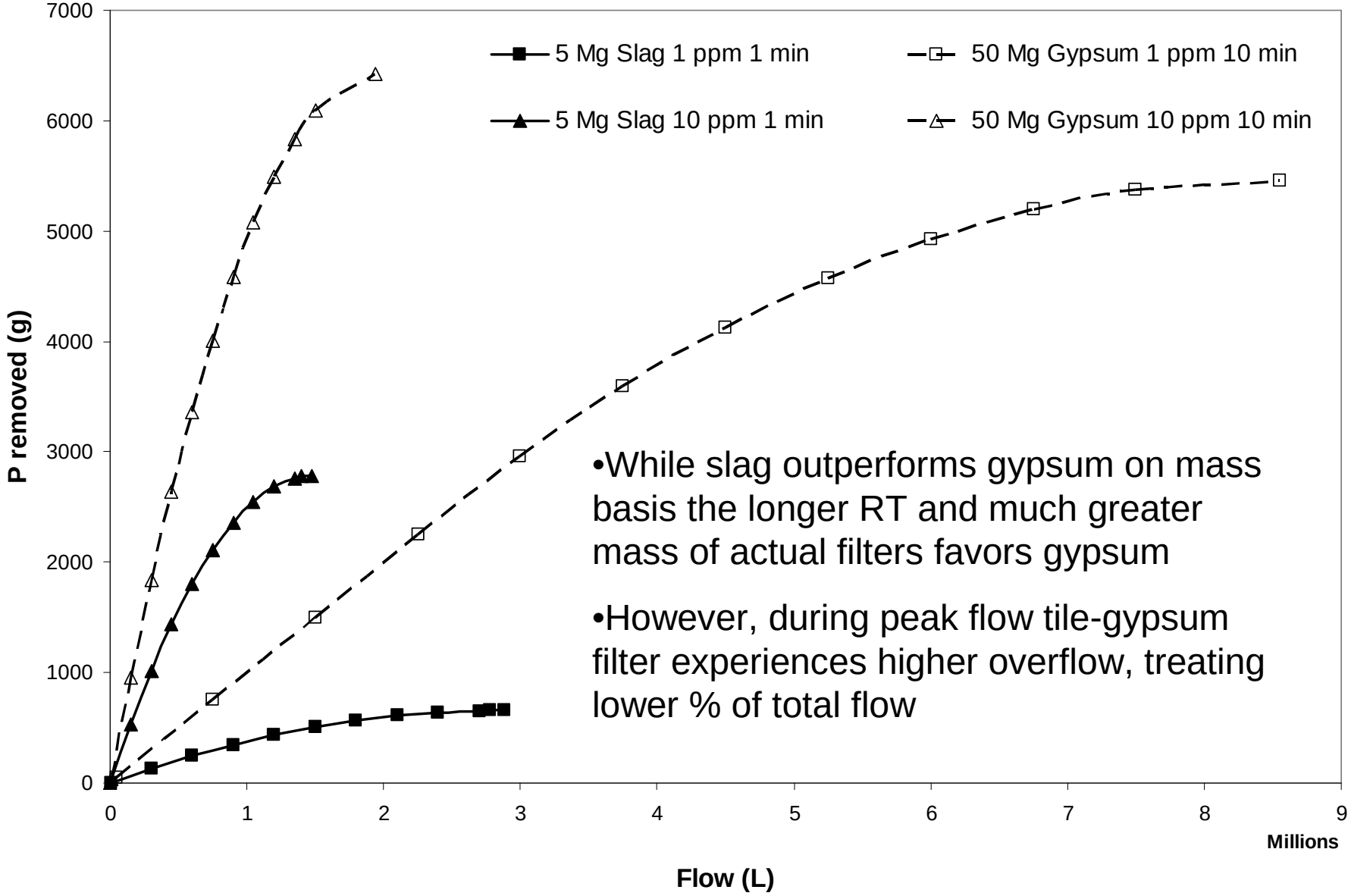
Cumulative P adsorbed at equilibrium - flow through



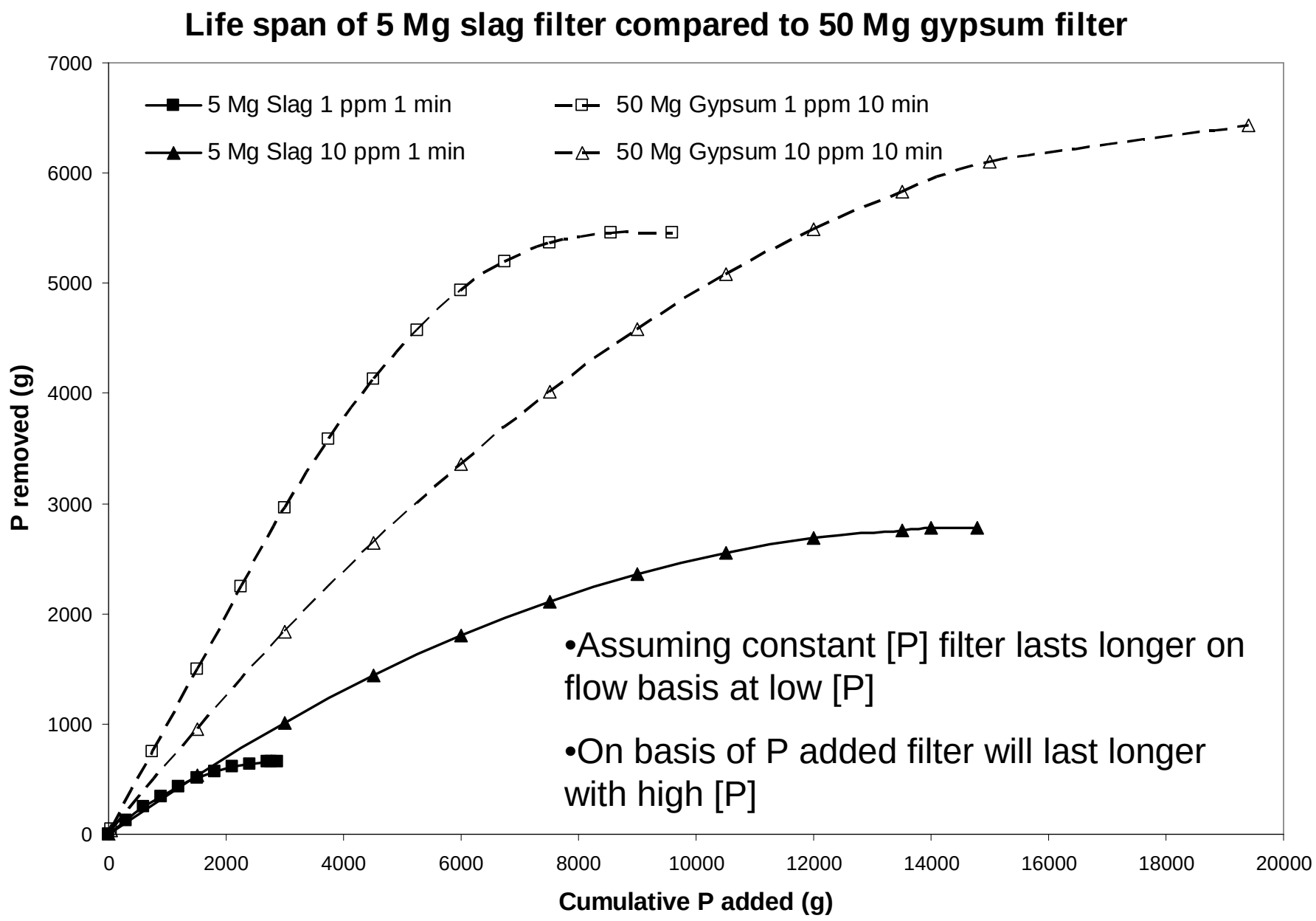
Effect of retention time on P removal (mass basis)



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
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
P removed (g)
Cumulative P added (g)
0
1000
2000
3000
4000
5000
6000
7000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
•Assuming constant [P] filter lasts longer on flow basis at low [P]
•On basis of P added filter will last longer with high [P]

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!

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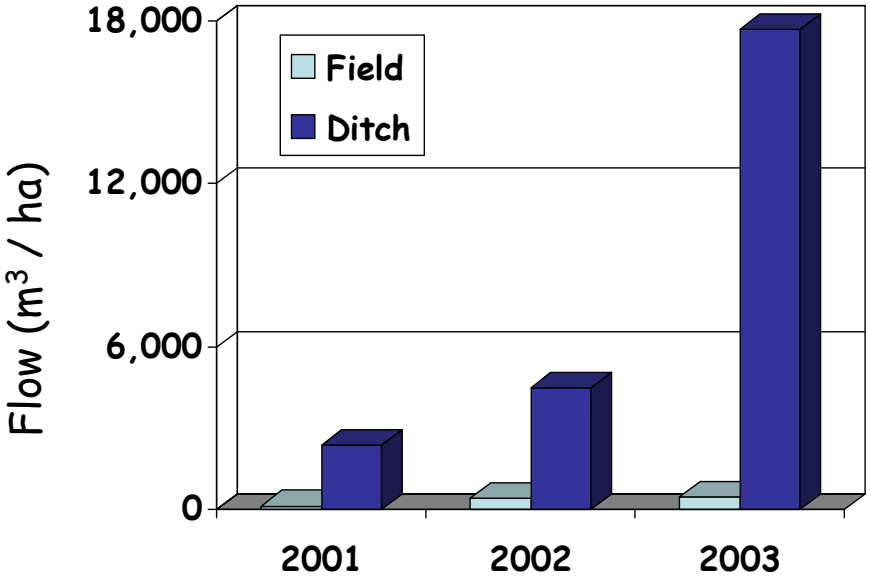
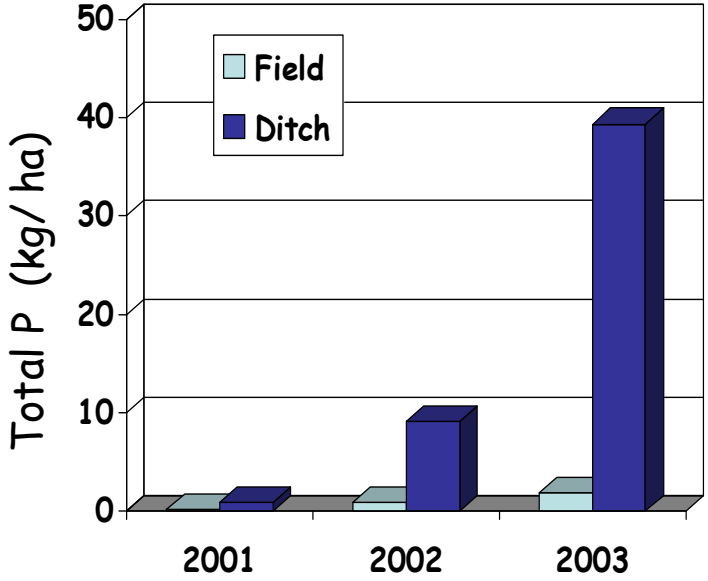
Field runoff vs. total ditch flow

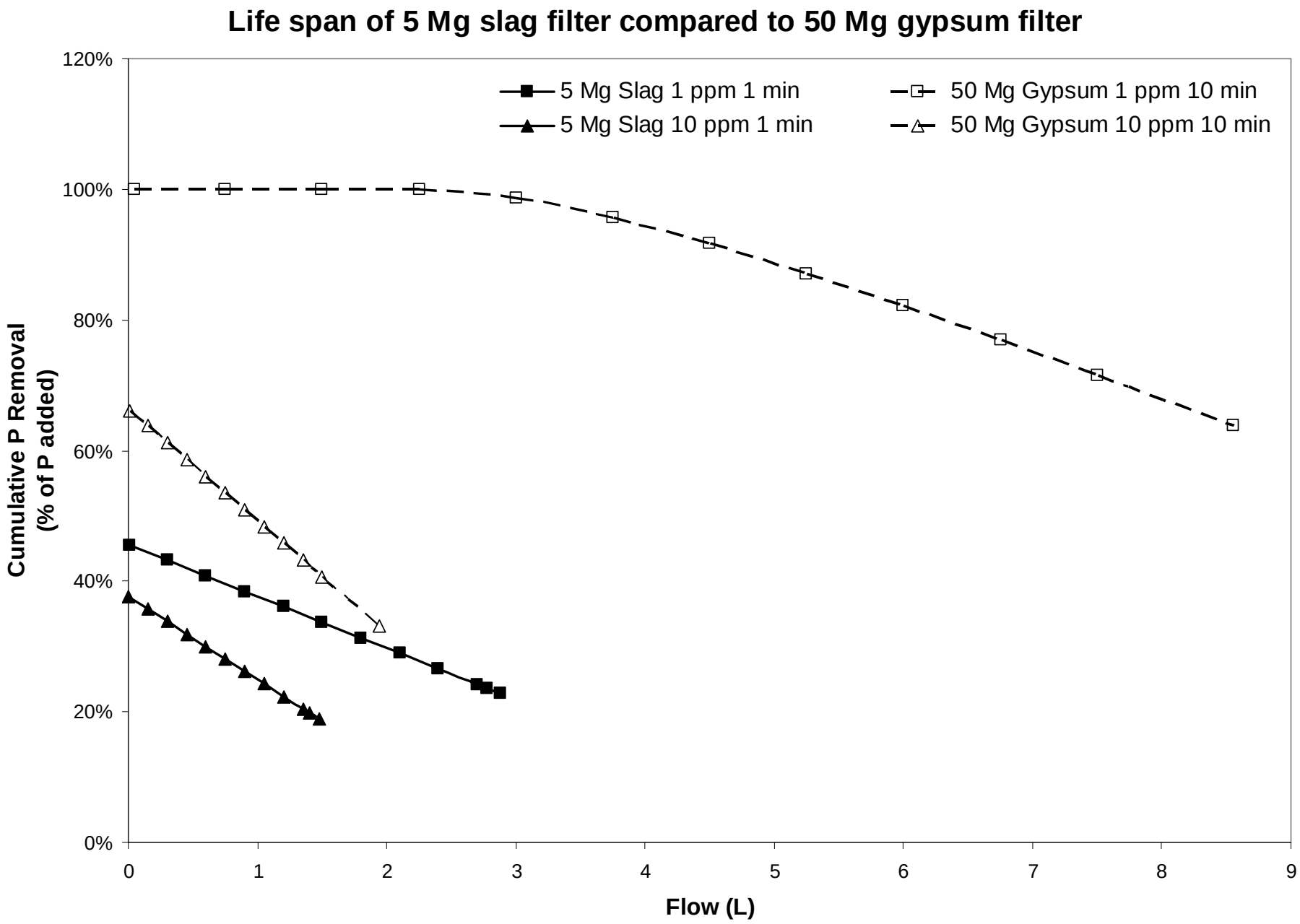




Surface runoff from the field only accounted for 3-9% of annual ditch flow.

Surface runoff from the field only accounted for 5-22% of annual ditch P export

Courtesy: P. Kleinman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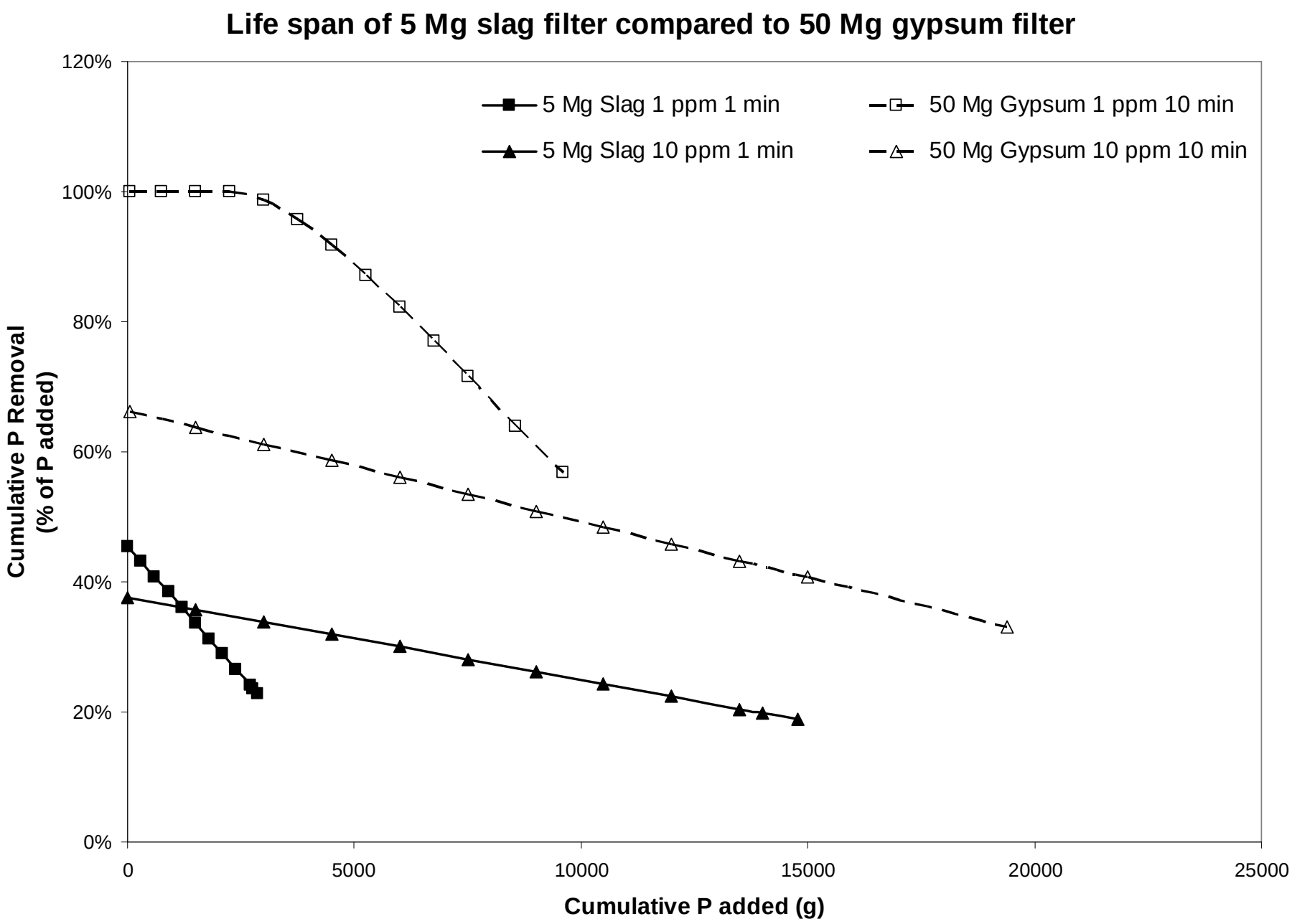
5 Mg Slag 1 ppm 1 min
5 Mg Slag 10 ppm 1 min
50 Mg Gypsum 1 ppm 10 min
50 Mg Gypsum 10 ppm 10 min
Cumulative P Removal
(% of P added)
120%
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
Flow (L)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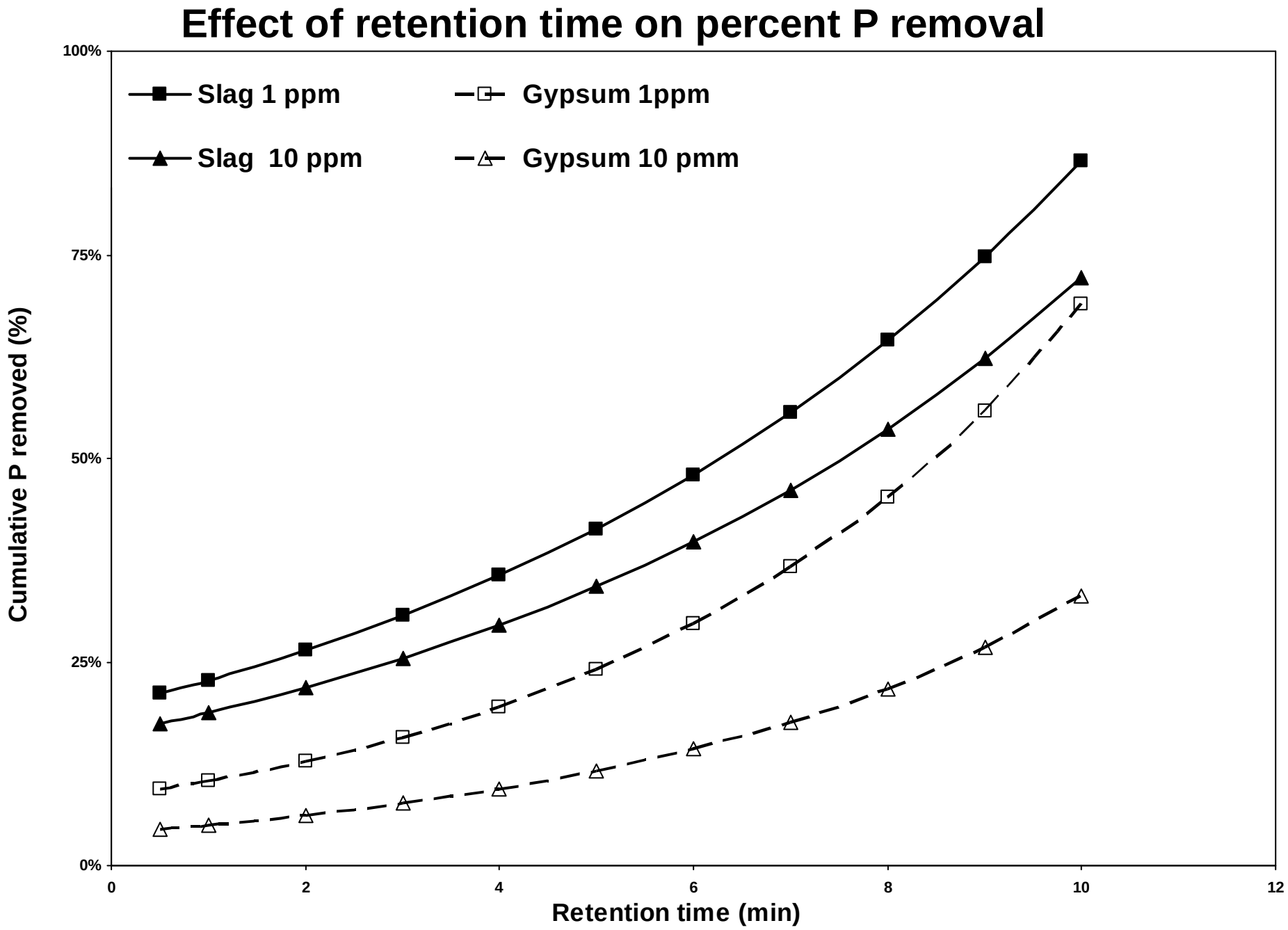
50 Mg Gypsum 1 ppm 10 min
50 Mg Gypsum 10 ppm 10 min
Cumulative P Removal (% of P added)
120%
100%
80%
60%
40%
20%
0%
0
5000
10000
15000
20000
25000
Cumulative P added (g)


Effect of retention time on percent P removal
Slag 1 ppm
Gypsum 1ppm
Slag 10 ppm
Gypsum 10 pmm
100%
75%
50%
25%
0%
Cumulative P removed (%)
0
2
4
6
8
10
12
Retention time (min)