Selecting Stormwater (Bio)(In)Filtration Sites and Soil-Based Media

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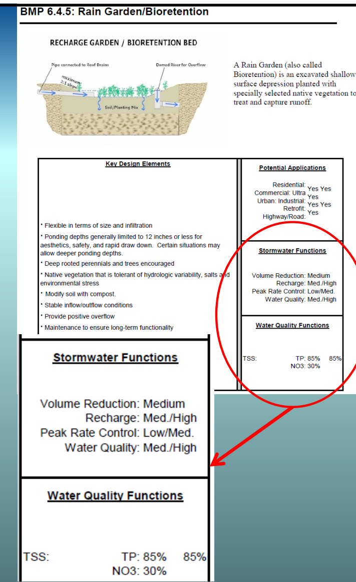
Introduction

- Biofiltration typically reduces water volume and some pollutant loads through plant uptake and pore space retention in the media.
- Many guidance documents apply expected pollutant removals based on literature.
  - However, typically presented as percentages of removal and have been misinterpreted and misapplied.
  - Also difficult to remove 85% of pollutants in "clean" water.



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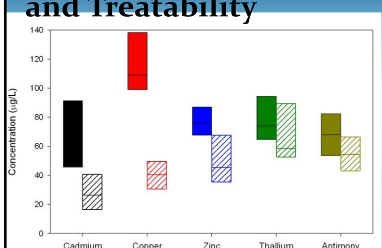
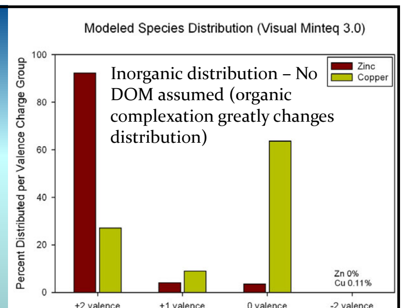
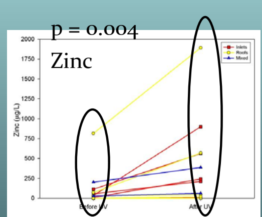
Influent Water Quality and Treatability





What form are those compounds that pass through a 0.45-µm filter?



	% Ionic	% Bound as organometallic complexes
Zinc	15	85
Copper	70	30
Cadmium	10	90
Lead	12	88

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Design for Treatment Contact Time

- Starting off with conflicting requirements:
  - Rapid infiltration to prevent flooding, protect against standing water, etc.
  - Slow infiltration to allow for sufficient time for pollutants to be removed from the water and adhered to the media.
  - These requirements are balanced by using depth filtration (sufficient media depth to ensure adequate contact).
- Soil physical characteristics that affect infiltration rate and contact time:
  - Texture, which affects the following (some states dictate soil texture class for infiltration devices):
    - Porosity
    - Bulk density
    - Permeability
  - Degree of compaction during and after construction (affects porosity, bulk density, permeability).
  - Degree of clogging (affects porosity, permeability)
- Choice of soil texture components to meet drain down time affects pollutant removals (chemical composition of media components).

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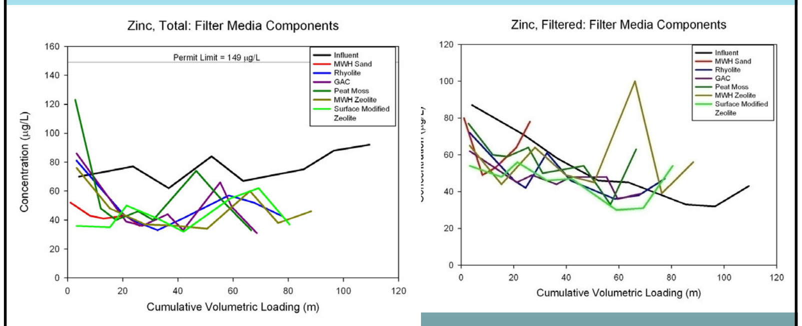
Initial Design Question: Pollutant Form – Particulate Associated or Dissolved/Colloidal?



Poor removal of total and filtered zinc components – likely because most of the zinc was dissolved/colloidal.
Water chemistry model predicted mostly ionic +2 form because OM effects not well characterized.
Historical data has shown zinc 85% bound by organic matter.
Zinc likely to form many complexes with Cl, OH, Cu, etc.

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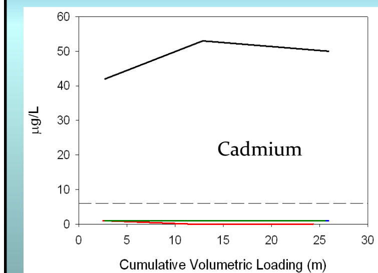
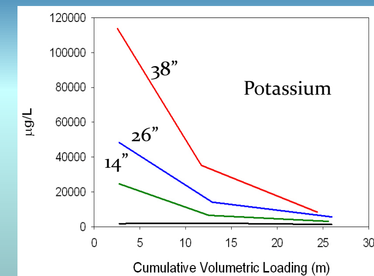
Initial Design Question: Contact Time Control Using Media Depth

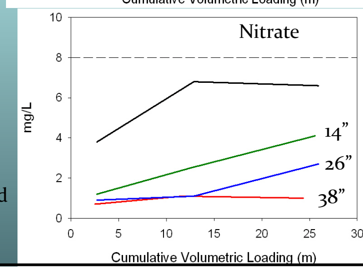




Spiked Influent
38"
26"
14"
Permit Limit

Example:
GAC-Sand

Results are media and parameter specific.



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Soil and Water Chemistry Effects on Design to Be Considered

- Remove pollutants in the upper layers of the device. The deeper into the soil profile that the pollutants penetrate, the greater the likelihood of groundwater contamination or transport out of the device through an underdrain.
- Potential properties of interest in predicting removal (based on literature and batch-testing in the lab):
  - Soil and water pH
  - Pollutant forms (relationship to solids loading and PSD)
  - CEC (and AEC)
  - Mineral matter
  - Organic content
  - Phosphorus content
  - Oxidizing or reducing environment
  - Salinity and SAR

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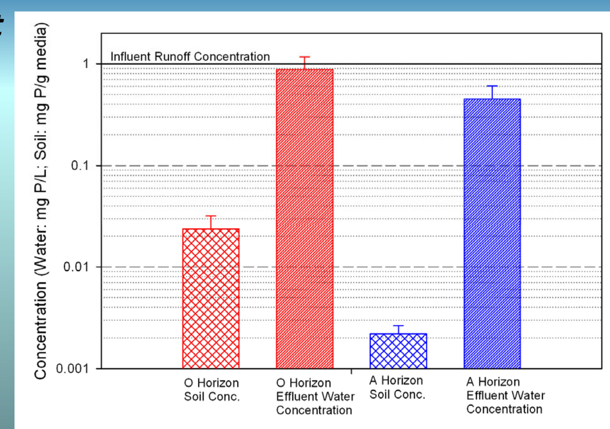
Initial Design Question: Impact of Initial Soil P Content



- Organic horizon has higher P content and minimal P removal.
- Mineral horizon has lower initial P content and thus P retention occurs.

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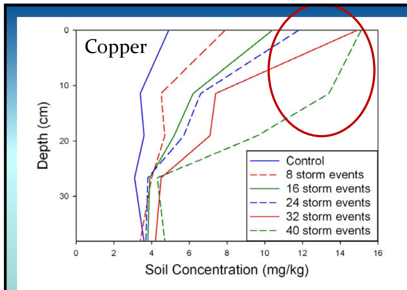
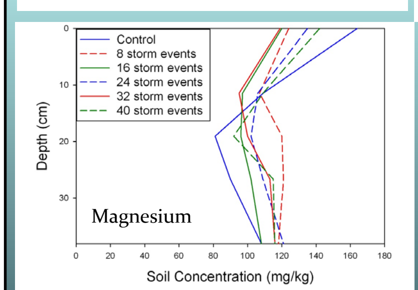
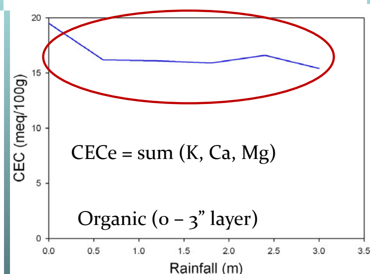


Breakthrough

- Copper Accumulation in Upper Layers of Soil with Subsequent Downward Migration
- Limited Release of CEC Cations or Decrease in CECe (sum of K, Ca, Mg)
- May be also complexation/chelation / exchange with organic compounds, which is not measured in CECe calculations





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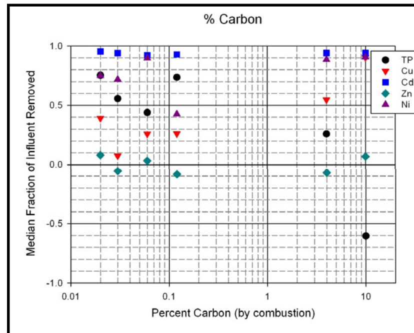
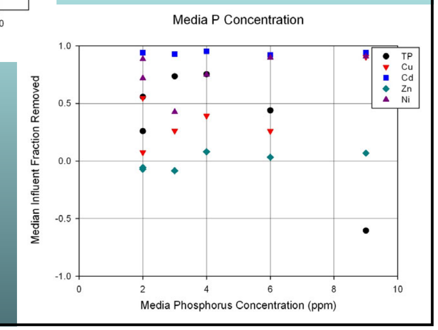


No trend seen in metals removal as a function of % soil C or % soil P until possibly when %C > 3% and soil P > 6 ppm.

Similar trends for all metals. Differences are in amount removed with minimal removal for zinc.

General trend of P removal decreasing as both % soil C and % soil P increase



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Observed Correlations Between Soil Parameters and Chemical Capacity (Batch Testing of 16 Media)

	Al	Ca	Cd	Cu	Fe	Ni	Mg	Mn	Zn	K	Cr	Tl	Sb	NH3	TP
Soil CEC			+	+	-	+			+	-		+			
Soil OM		+	+	+		+	+				-	+			
Soil C		+	+	+		+	+				-	+	+		
Soil N			+	+	-	+			+	-		+			-
Soil P			+		-	+			+	-				+	
Soil pH	+							+			+		+		
Soil K									+	-					
Soil Mg			+	+	-	+	+		+			+			
Soil Cu								-							
Soil S															
Soil Zn			+		-	+			+	-				+	-
Soil Ca			+		-	+			+						

Significance level of p = 0.05.

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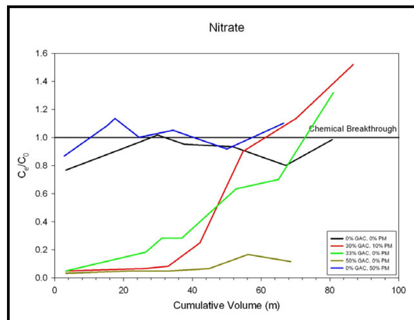
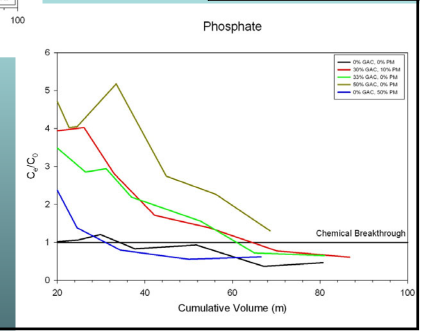


Trade-Offs in Media Mix Components and Ion-Exchange

- 0% GAC, 0% PM
- 30% GAC, 10% PM
- 33% GAC, 0% PM
- 50% GAC, 0% PM
- 0% GAC, 50% PM

Inverse removal behavior of nitrate and phosphate.

Reducing GAC content reduces nitrate removal life, but decreases amount of phosphate released.



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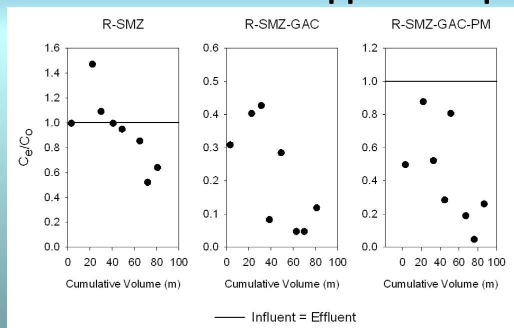
Selecting the Media Mixture from a Set of Potential Components: "Dissolved" Copper Example



- Modified sand and zeolite mixture – best removal 50%, but generally poor removal.
- GAC and peat moss were better than sand and zeolite; GAC performing better for filtered copper, but may not support plant life
- Adding small amount of peat moss as organic matter for plant life support reduced performance by about half.

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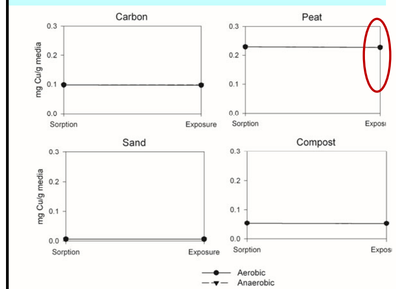
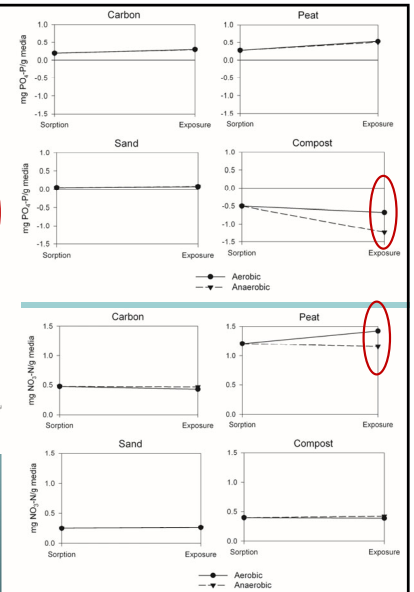
Additional Considerations: Changes in Soil and Porewater Chemistry between Storms



Heavy metals mostly retained.

Release of nutrients (N from peat [release captured N], P from compost [increased release]) under anaerobic conditions.



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Conclusions (to date)

- Most devices fail because of clogging.
  - Design for clogging first (assume with vegetation, solids loading for most media mixes approximately 25 kg/m²).
  - Maintenance has limited effectiveness. Vegetation likely will extend lifespan because of biological disturbance of soil.
- Evaluation of potential chemical removal.
  - Physical removal primary mechanism, even in media with "good" sorption/ion-exchange potential.
  - Removal based on influent quality (including "speciation" or "association" of pollutants with particulates of all sizes).
  - Evaluate media choices (either individually or as part of a mix) based on both adequate removal of pollutants and ensuring that the exchanged ions are not causing degradation.
    - CEC, AEC, OM, P-content, SAR, soil pH predict, but may not be able to quantify, removal efficiency or effluent quality. Also not precise measurements of lifespan of media performance.
    - Increasing OM and P content has an unquantified maximum effect. Above a certain amount, the media release nutrients, color compounds, and colloids that may have associated pollutants.

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Acknowledgments

- The authors gratefully thank all the current and former students for their work on these projects.
  - Penn State Harrisburg: Dan Treese, Brad Mikula, Christine Siu, Danielle Harrow, Natasha Nicholson, Ryan Burrows, Mukesh Pratap
  - University of Alabama: Renee Morquecho, Noboru Togawa, Sree Usha
  - University of Alabama at Birmingham: Amanda Elledge, Carla Neggers, Blaine Collier, Mukesh Pratap
- We would also like to thank Ms. Betsy Graham for her tireless efforts spent analyzing the metals samples.
- Sponsors: U.S. EPA UWMB, WERF, GeoSyntec (and their industrial client)

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