Performance of and Amendments to Urban Bioretention Systems for Removal of Stormwater Contaminants

Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)

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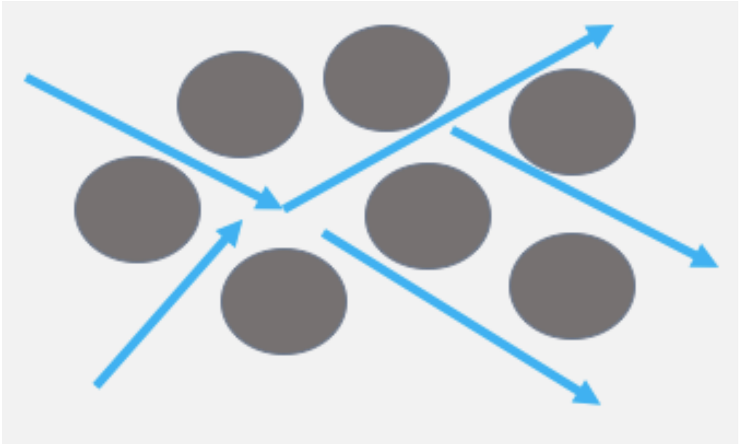
Summary

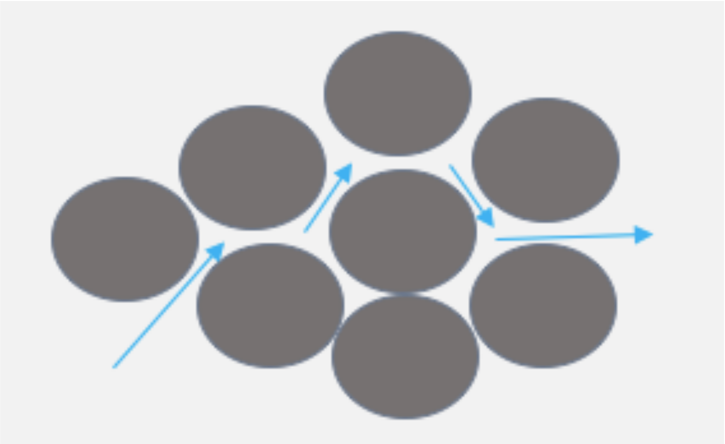
As urbanization has expanded, polluted urban stormwater runoff has become a greater concern. While originally installed to control water quantity by smoothing out urban runoff hydrographs, best management practices such as bioretention systems may also remove contaminants in runoff. This project had three primary goals: 1) to evaluate the performance of the Iris Rain Garden with respect to the removal of dissolved trace organic contaminants, 2) to determine the hydraulic conductivity of various geomedia, and 3) to determine the removal of targeted metal contaminants by various geomedia. It was found that the Iris Rain Garden reduced the amount of atrazine, caffeine, carbendazim, and triphenyl phosphate in stormwater runoff. Furthermore, hydraulic conductivity values for various types of geomedia were determined. Currently, work is being done with various geomedia to characterize the removal of heavy metals.

Background

- Non-point source contaminants are found in urban runoff, such as pesticides, herbicides, insecticides, flame retardants, and traffic-related pollutants (Schwarzenbach et al., 2006).
- Best Management Practices (BMPs), such as the Iris Rain Garden may remove trace organic contaminants (TOrCs), as well as toxic metals such as Cd, Cu, Pb, and Zn (LeFevre et al., 2014).
- Factors that affect the removal of contaminants from stormwater runoff:
  1. Hydraulic conductivity and retention time of media
  2. Type of geomedia used
- Hydraulic Conductivity (K) – how easily a fluid can flow through a media



High K



Low K

Research Hypotheses

H1: The Iris Rain Garden will demonstrate removal of a variety of trace organic contaminants.

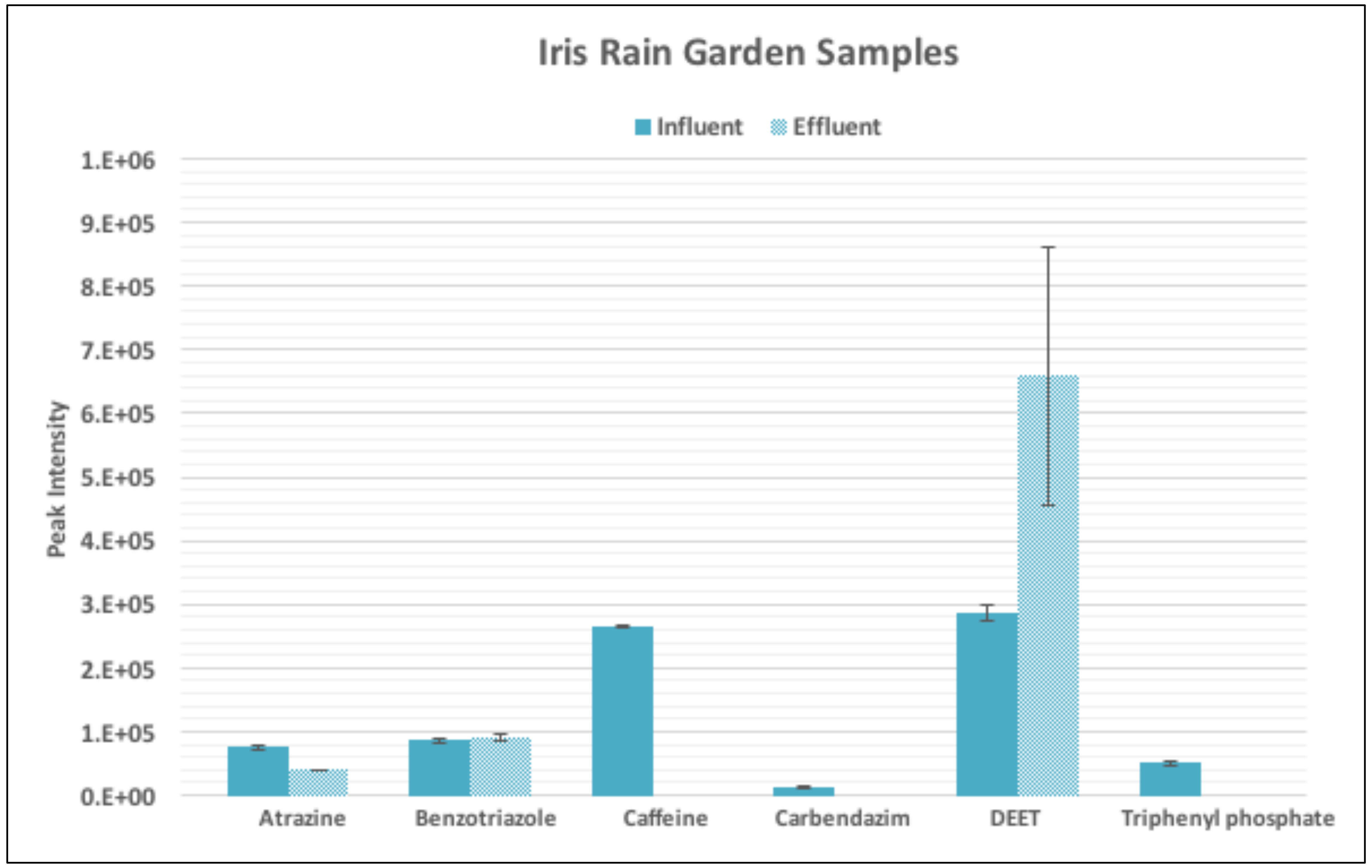
H2: Varying geomedia will have different hydraulic conductivity values, with coarser materials having higher values and finer materials having lower values.

H3: Different geomedia will sorb heavy metals to varying extents, with zeolites exhibiting more effective removal than sand and woodchips.

Iris Rain Garden Case Study

- Influent and effluent samples collected from the bioretention system
- Samples filtered using a 2.7 μm filter followed by a 0.7 μm filter to remove suspended solid particulates
- Solid Phase Extraction (SPE) was run followed by a nitrogen gas blow down and reconstitution with methanol
- Targeted Liquid Chromatography- Mass Spectrometry (LC-MS) analysis was then performed for a list of 33 TOrCs to determine the presence of these compounds

The Iris Rain Garden, located in Lakewood, CO.



Four of the target contaminants were removed, while benzotriazole remained and DEET levels increased.

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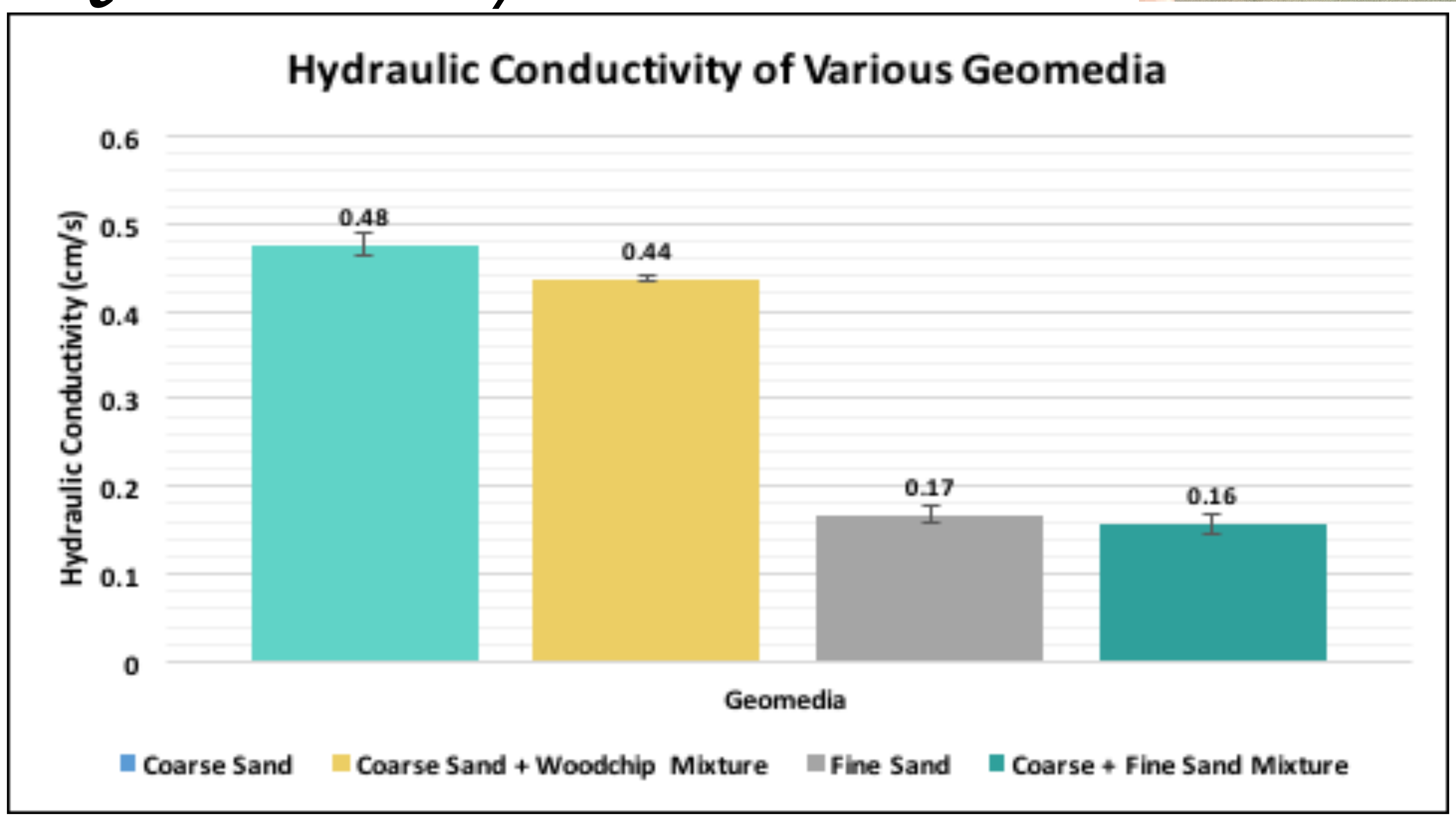
Hydraulic Conductivity Testing

- Columns systematically packed with desired media
- Tap water run through the column via a reservoir creating a hydraulic gradient (dh / dL)
- Flow rate of the water through the system measured (Q)
- Derived hydraulic conductivity (K) according to Darcy's law using known cross-sectional area (A):

$$Q = -\boldsymbol{K} A \, dh/dL$$



The presence of coarse or fine sand significantly impacts the hydraulic conductivity of geomedia used in a BMP.

Batch Sorption Experiments With Various Geomedia

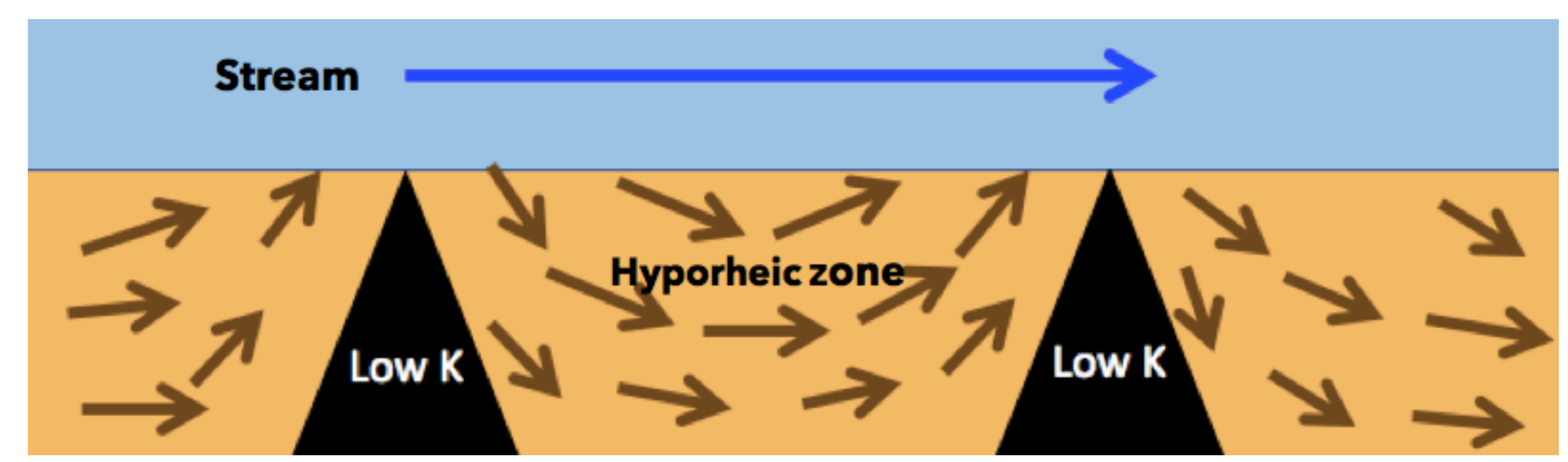
- Contact solution prepared containing metals Cu, Cd, Pb, and Zn
- Contact solution placed into test tubes with desired geomedia and put on a shaker table
- Samples of the contact solution taken over the course of two hours to determine amount of metals sorbed by geomedia over time
- Samples analyzed via Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)
- Variables changed:
  - Type of geomedia (Clinoptilolite zeolites, woodchips, coarse sand)
  - pH of contact solution (5.5 and 6.5)
- Experiments ongoing

Conclusions

- The Iris Rain Garden demonstrated removal of atrazine, caffeine, carbendazim, and triphenyl phosphate, but showed an increase in the level of DEET and no change in the amount of Benzotriazole.
- The hydraulic conductivity varies with type of geomedia. Grain size plays a crucial role in the hydraulic conductivity, while the K for mixtures needs to be experimentally determined.
- The composition of geomedia does impact how a system removes contaminants, and bioretention systems should be customized according to the contaminants of concern for a particular environment.

Future Directions and Impact

- Continue characterization of the Iris Rain Garden
- Complete batch sorption testing, and expand range of geomedia to be studied and temperature of the contact solution.
- Applications to other BMPs, such as Biohydrochemical Enhancements for Streamwater Treatment (BEST).



The BEST system, developed by Dr. Skuyler Herzog.

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Acknowledgements

The authors would like to thank ReNUWIt and the NSF for funding this project. The authors would also like to thank Urban Drainage and Flood Control District for providing samples from the Iris Rain Garden.

This material is based upon work supported by the National Science Foundation under Grant No. EEC-1559984. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.