Prevention of Sediment Recontamination by Improved BMPs to Remove Organic and Metal Contaminants from Stormwater Runoff

Unit Stormwater Treatment Processes

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

Jourdyn-Evonne Lee[1], Conrad Pritchard[2], Richard Luthy[2]

[1]State University of New York College of Environmental Science and Forestry, [2]Stanford University

Project #1: Hydraulic Conductivity

Stormwater runoff transports harmful pollutants to nearby bodies of water or to groundwater via infiltration. These threats are exacerbated at sites owned by the Department of Defense (DoD) where substances like polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), per-and polyfluoroalkyl substances (PFAS), and heavy metals are commonly found. There is no current infrastructure at DoD sites to protect areas from being contaminated. In my research project, I'm studying the hydraulic conductivity of several geomedia in order to design biofilters that maximize pollutant uptake while avoiding clogging in order to prevent sediment contamination at such sites. I am to answer the following question: ***How does increasing biochar and zeolite amendment affect the hydraulic conductivity of geomedia biofilters?***

Column Setup

- Column made from 6 in (3 in diameter) PVC tube
- Up flow model with a constant head reservoir
- Water travels from the bucket (1) to the tubing (2), up through the column (3+4), and exits at the end of the tube (5)
- Dry packed with different combinations of sand, Biochar Supreme, and zeolite

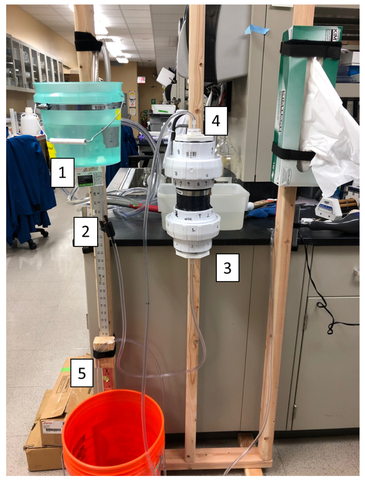


Figure 1. Hydraulic Conductivity Column Setup

Methods

Calculating HC

$$K = \frac{Q \times L}{A \times dH}$$

K – hydraulic conductivity [cm/h]
Q – flow rate [cm^3/h]
L – length of column [cm]
A – cross-sectional area [cm^2]
dH – change in head [cm]

Equation 1

- Equation 1 was used to calculate the hydraulic conductivity
- The flow rate of the column was measured by collecting water flowing through the column for at least 70 seconds
- At least 5 trials were conducted, each having a different hydraulic head
- Every trial was conducted in triplicate

Progress to Date

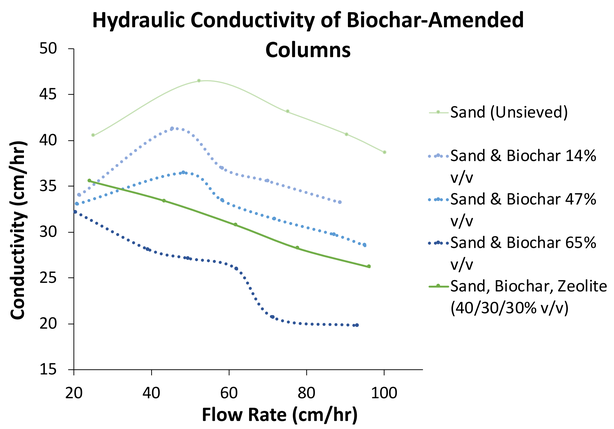


Figure 2a. The hydraulic conductivity of biochar-amended columns over flow rate

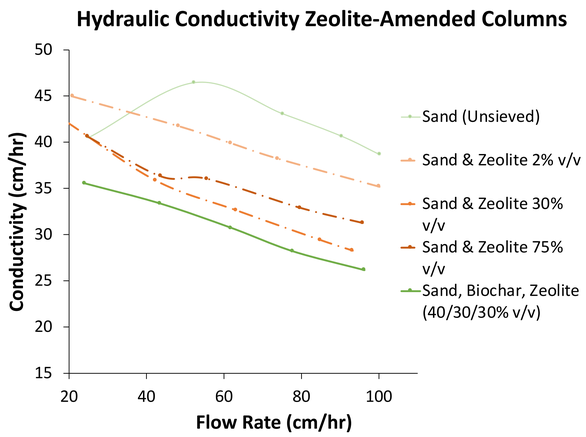


Figure 2b. The hydraulic conductivity of zeolite-amended columns over flow rate

Figure 3a. The hydraulic head needed for biochar-amended columns over flow rate

Figure 3b. The hydraulic head needed for zeolite-amended columns over flow rate

Major Findings

- As flow rate increased for all columns, hydraulic conductivity decreased and the hydraulic head increased (see Figures 1 and 2)
- As percent volume of biochar and zeolite increased, hydraulic conductivity decreased and hydraulic head needed to achieve flow rates increased (see Figures 1 and 2)
- Biochar-amended columns had slightly lower hydraulic conductivities compared to zeolite-conducted columns (see Figure 1a and 1b)
- The hydraulic conductivity and head results of the sand/zeolite/biochar were similar to the median biochar and zeolite columns as expected

Next Steps

To continue this research, tests with larger columns should be conducted to mimic the conditions of a biofilter in the field. Additionally, the flow rates and hydraulic conductivity should be monitored for longer periods of time (i.e. weeks instead of days) to see if there any significant changes. Further experiments should also focus on testing different ratios of sand, biochar, and zeolite and evaluating how the hydraulic conductivity changes with each new ratio.

Acknowledgements

Conrad Pritchard, PhD Mentor
Richard Luthy, Principal Investigator
YeoMyoung Cho, Senior Research Professor
Pamela McLeod, Director of Education and Outreach
The Department of Defense

References

Barnes, R.T., Gallagher, M.E., Masiello, C. A., Liu, Z., Dugan, B. 2014. Biochar-Induced Changes in Soil Hydraulic Conductivity and Dissolved Nutrient Fluxes Constrained by Laboratory Experiments. PLoS ONE 9(9).

Learn more about our research:
www.renuwit.org

Supported by the National Science Foundation under EEC-1028968

Prevention of Sediment Recontamination by Improved BMPs to Remove Organic and Metal Contaminants from Stormwater Runoff

Unit Stormwater Treatment Processes

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

Jourdyn-Evonne Lee[1], Conrad Pritchard[2], Richard Luthy[2]

[1]State University of New York College of Environmental Science and Forestry, [2]Stanford University

Project #2: Dissolved Organic Carbon

The Department of Defense (DoD) is seeking a solution to prevent sediment contamination via stormwater runoff at their sites. Pollutants as well as dissolved organic carbon (DOC) are picked up by stormwater runoff as if flows over impervious surfaces. Previous research has shown that different background sources of organic material may produce DOC with varying properties and that high concentrations of DOC inhibit the sorption of pollutants in biofilters. [2] To design an effective biofilter, we must know more about how DOC will affect the sorption performance of geomedia used in biofilters. I aim to answer the following question: ***How does the quality (source) and quantity (concentration) of DOC affect the sorbent's ability to sorb trace organic contaminants and heavy metals?***

Methods

DOC Stock Solutions

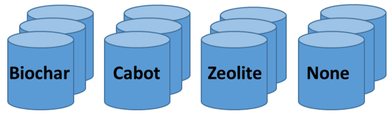
- Multiple background DOC solutions were created by adding 15 mL of each material in Falcon tubes with 40 mL of DI water and shaking them for 3 days at a speed for 150 rpm
- Our background sources included petals, pavement sediment, leaf litter, redwood bark, soil from Jasper Ridge, live grass, dead grass, and sediment from a Navy Base
- After analyzing their DOC concentrations and specific ultraviolet absorbance, several stock solutions were used for the batch tests

Batch Tests

- All batch tests were conducted in 250 mL glass amber jars with ~235 mL of synthetic stormwater and 100 µg/L of trace organic contaminants (fipronil, benzotriazole, and atrazine) and 50 µg/L of heavy metals (cadmium, copper, nickel, lead, and zinc)
- First set: Biochar Supreme, zeolite, and Cabot Regenerated Granular Activated Carbon were spiked with 5 mg/L of DOC made from pavement sediment (see Figure 4a)
- Second set: Biochar Supreme was spiked with 5, 10, and 50 mg/L of pavement DOC (see Figure 4b)
- Third set: Biochar Supreme were spiked with 5 mg/L of DOC from sediment from the Navy Base, redwood bark, petals, and pavement sediment (see Figure 4c)
- All glass jars were shaken for 7 days at a speed of 250 rpm. The results in Figure 5 display data collected on the fourth day of the batch test. Only concentrations of benzotriazole and atrazine were analyzed.

Batch Test Setup

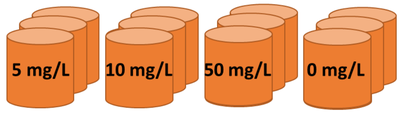
How do different sorbents interact with the same amount of DOC?



Biochar Supreme, Cabot, and Zeolite
5 mg/L of Pavement DOC

Figure 4a. Sorption of TrOCs with DOC Set Up

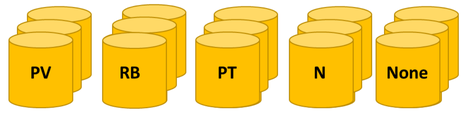
How does biochar interact with the varying amounts of DOC?



Biochar Supreme
5, 10, and 50 mg/L of Pavement DOC

Figure 4b.. Sorption of TrOCs to Biochar with Varying Concentrations of DOC Set Up

How does biochar interact with the same amount of DOC from different sources?



Biochar Supreme
5 mg/L of DOC from 4 sources

Figure 4c. Sorption of TrOCs to Biochar with Various Background DOC Set Up

Progress to Date

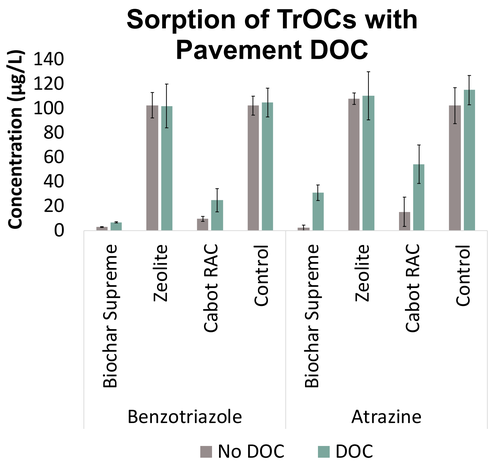


Figure 5a. Sorption of TrOCs with DOC Results

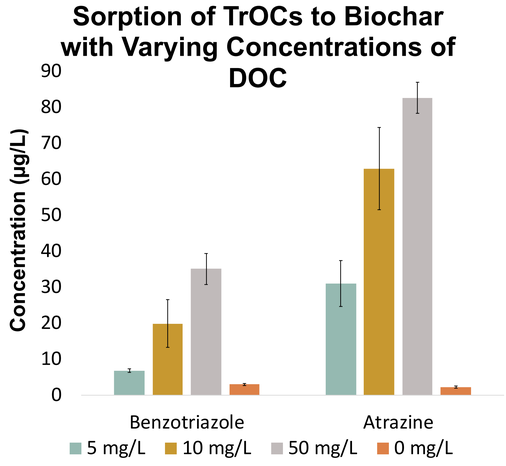


Figure 5b. Sorption of TrOCs to Biochar with varying Concentrations of DOC Results

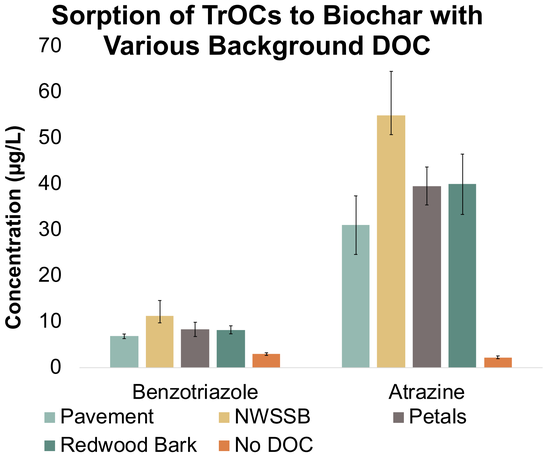


Figure 5c. Sorption of TrOCs to Biochar with Various Background DOC Results

Major Findings

- All three sorbents interacted differently with the presence of DOC (see Figure 5a)
- As the concentration of DOC increases, sorption performance decreases (see Figure 5a and 5b)
- Each background DOC source may affect the sorption of TrOCs differently (see Figure 5c)

Next Steps

To continue this research, more batch tests should be conducted that test complex conditions to mimic real-world situations (e.g. more than one DOC stock solution in a test). Further research should also focus on how to eliminate the negative effects of DOC in pollutant uptake so that biofilters can be modified for successful contaminant removal.

Acknowledgements

Conrad Pritchard, PhD Mentor
Richard Luthy, Principal Investigator
YeoMyoung Cho, Senior Research Professor
Pamela McLeod, Director of Education and Outreach
The Department of Defense

References

[2]McElmurry, S.P., Long, D. T., Voice, T.C. 2013. Stormwater Dissolved Organic Matter: Influence of Land Cover Environmental Factors. Environmental Science and Technology. 48, 45-53.

Learn more about our research:
www.renuwit.org

Supported by the National Science Foundation under EEC-1028968