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

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Introduction

Stormwater runoff is a threat to public health. When it rains, runoff transports harmful pollutants like biocides (i.e. herbicides and pesticides), corrosion inhibitors, and anti-freezing agents 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. The DoD has made efforts to remediate polluted sites, however, there is no infrastructure in place to protect already cleaned areas. In my research project, I'm designing black carbon amended biofilters that capture and treat stormwater in order to prevent sediment recontamination at such sites.

The first part of this project relates to the hydraulic conductivity of different geomedia. Ideally, biofilters would contain black carbon such as regenerated granular activated carbon or biochar because of their relatively low cost and ability to sorb contaminants and metals. However, black carbon is known to have a lower hydraulic conductivity than sand (Barnes et al., 2014). I aim to answer the following question: ***How does increasing biochar and zeolite amendment affect the hydraulic conductivity of geomedia biofilter?***

The second part of this project relates to background dissolved organic carbon (DOC). DOC is picked up by stormwater runoff as if flows over impervious surfaces. DOC collected from varying sources (e.g. urban lawns vs naturally-forested areas) have different properties. Researchers have discovered that high concentrations of DOC inhibit the sorption of pollutants in biofilters (Lim et al., 2014; McElmurry et al., 2013). To design an effective biofilter, we must know more about how DOC will affect sorption to the geomedia used to construct the biofilter. 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?***

HYDRAULIC CONDUCTIVITY

Experimental Set Up

A series of column tests were conducted to test the hydraulic conductivities of different combinations of zeolite (BioGreen; Boulder, CO), Biochar Supreme (Everson, WA), and sand (CEMEX; Houston, TX). The column was constructed using a 6-inch long (3-inch diameter) PVC pipe. Different ratios of biochar supreme and sand were tested in the column. The column was dry packed with the desired, unsieved geomedia and saturated with DI water for at least 40 hours to minimize the amount of air in the system. Experiments were conducted in an upflow configuration with a constant head reservoir.

Once packed and saturated, at least 5 trials, with each trial having a different hydraulic head condition, were conducted in triplicate to calculate the hydraulic conductivity. The volume of water that flowed through the column was timed for about 70-90 seconds and recorded. The flow rate (Q), length of the column (L), cross-sectional area of the column (A), and change in head (dH) were used to calculate the hydraulic conductivity of each run as seen in Equation 1 below.

$$K = \frac{Q \times L}{A \times dH} \qquad (1)$$

Current Findings

The hydraulic conductivities of Biochar Supreme and Zeolite-amended columns were plotted against flow rate in Figures 1. As flow rate increased, the hydraulic conductivity of every material decreased. Similarly, as the percent of biochar or zeolite increased in the column, hydraulic conductivity decreased with the exception of the Sand and Zeolite 30% v/v column. This column may have had a lower hydraulic conductivity than expected because it was not flushed with the same amount of water as the other columns with zeolite. Additional data show as flow rate increased, the hydraulic head needed to attain that flow rate increased, more steeply for the columns that have a higher percent of biochar supreme and zeolite (with the same exception as above). These data display that columns with more geomedia have lower hydraulic conductivities and require a greater hydraulic head if a higher flow rate is desired. Because of this, biochar and zeolite-amended biofilters are at risk for clogging especially during heavy rain events (i.e. high flow rates). Biofilters must be designed with an adequate ratio of geomedia and sand and an adequate hydraulic head to avoid this issue.

One column was tested with sand, Biochar Supreme, and Zeolite in a 40/30/30% v/v ratio. This column was tested for four days to allow the flow rate to stabilize and fine, geomedia particles to leave the system. The hydraulic conductivity for this column was lower than the zeolite-amended columns, but still higher than the sand column with the highest amount of Biochar Supreme (Figure 1). These results indicate that designing a biofilter with both biochar and zeolite is feasible as long as the hydraulic head is large enough to achieve a desired flow rate.

DISSOLVED ORGANIC CARBON

Experimental Set Up

Tea solutions of several DOC sources (petals, pavement sediment, leaf litter, redwood bark, soil from Jasper Ridge, dead grass, live grass) were created by soaking ~15 mL of each material in 40 mL of DI water in Falcon tubes and placing them on a shaker table at a speed of 150 rpm for 3 days. They were left at room temperature in the light. Their DOC concentrations were measured and recorded using the Shimadzu TOC-L analyzer. Each material's specific ultraviolet absorbance (SUVA) was calculated as well by dividing its absorbance by its DOC concentration.

A series of batch tests were then conducted. All the batch tests were conducted in 250 mL glass amber jars with the ~235 mL of synthetic stormwater. All vials had a concentration of 100 µg/L of trace organic contaminants (fipronil, benzotriazole, and atrazine) and 50 µg/L of heavy metals (cadmium, copper, nickel, lead, and zinc metals). In the first set of batch tests, ~10 mg Biochar Supreme, ~200 mg of zeolite, and ~10 mg of Cabot Regenerated Granular Activated Carbon (Alpharetta, GA) were spiked with 5 mg/L of DOC made from pavement sediment. Results from the first batch test will answer the following question: ***How do different sorbents interact with the same amount of DOC?*** In the second set of batch tests, ~10 mg of Biochar Supreme were spiked with three different concentrations of DOC made from pavement sediments (5, 10, and 50 mg/L). Results from the second batch test will answer the following question: ***How does biochar interact with varying amounts of DOC?*** In the third batch test, ~10 mg of Biochar Supreme were spiked with 5 mg/L of DOC from four different sources (sediment from a Navy Base, redwood bark, petals, and pavement sediment). These DOC sources were chosen because of their differing SUVA values and DOC concentrations. Results from the third batch test will answer the following question: ***How does biochar interact with the same amount of DOC from different background sources?***

The glass jars were covered and placed on shaker table for one week at a speed of 250 rpm. Samples were gathered at three time spots and were analyzed using liquid chromatography-mass spectrometry (API 3000 LC-MS/MS System, Applied Biosystems, MDS SCIEX). All batch tests were completed in triplicate with controls. Only concentrations of benzotriazole and atrazine were analyzed.

Current Findings

The following results display data collected on the fourth day of the batch test. Figure 2 (a) shows the results from the first part of the batch test. The results show that all three sorbents interacted differently with the presence of DOC. Zeolite did not sorb benzotriazole or atrazine with DOC and without DOC, however there were differences in sorbent performance with Biochar Supreme and Cabot GAC. The presence of DOC reduced the sorption of both TrOCs.

Figure 2 (b) shows the results from the second part of the batch test. These results display as DOC concentration increases, the sorbent performance of Biochar Supreme decreases. Though both TrOCs were spiked at the same concentration, atrazine was found at a much higher concentration in the batch tests than benzotriazole.

The results from the third batch test show that each background source of DOC may affect the biochar sorption differently. The Navy DOC seemed to impact the sorption of the TrOCs slightly more while the pavement DOC seems to have slightly less of an impact. Despite these differences, the contaminant concentrations are somewhat within the same range of each, so further experiments need to be conducted to determine if these different concentration levels are significant.

CLOSING

Through studying hydraulic conductivity and dissolved organic carbon, we will have a greater grasp on how to design biofilters to be as effective and long-lasting as possible. Once more is known about the hydraulic conductivity of geomedia like zeolite and biochar, we can create a biofilter that combines them so pollutant uptake is maximized and issues like clogging is avoided. To continue this research, larger column tests should be conducted to mimic the conditions of a biofilter in the field. 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.

Once more is known about DOC and how it interacts with sorbents, we can model how biofilters will be impacted with different background sources and concentrations of DOC. To continue this research, more batch tests should be conducted that test more conditions (e.g. different TrOCs and metals, more than one DOC source in a test, etc). 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.

The threat that contaminated stormwater runoff poses will be reduced through biofilters. The implementation of this green infrastructure will be incredible, not only to the DoD, but to cities and communities who are looking to protect and preserve the water sources around them.

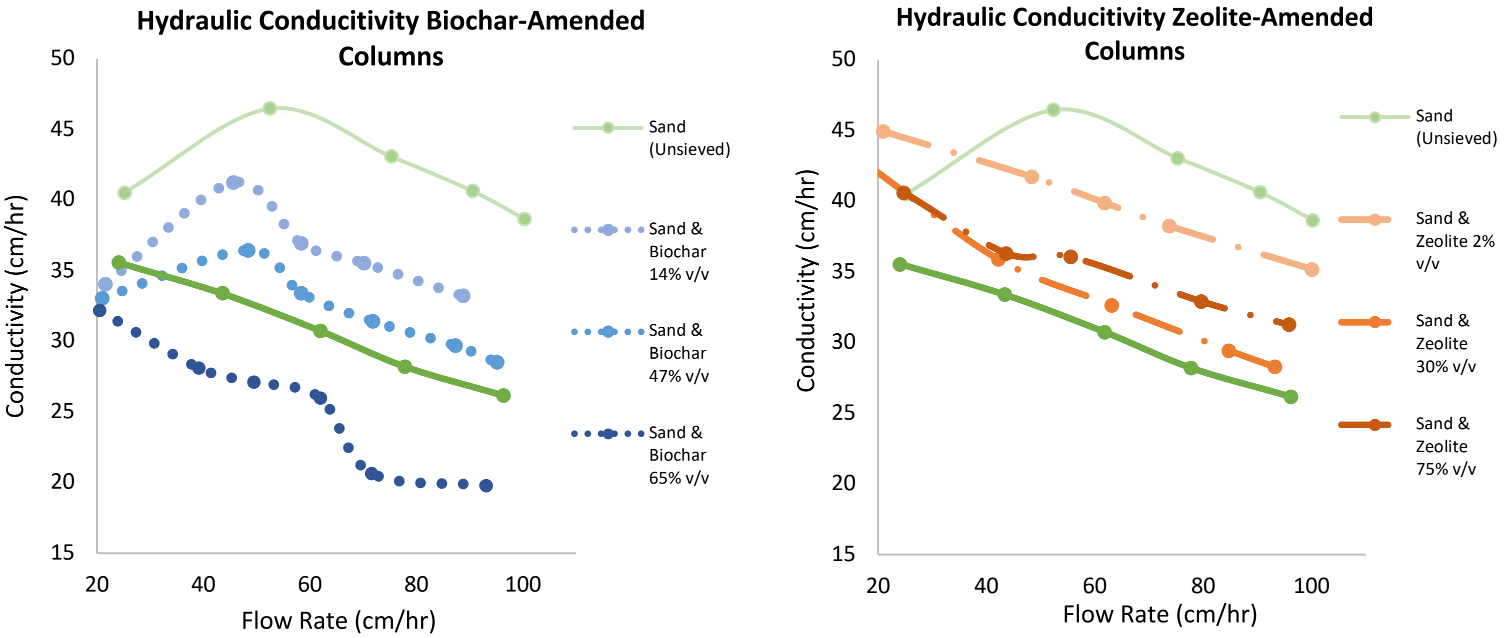

Figure 1. Hydraulic Conductivity Results featuring Biochar Supreme-amended columns (a) and zeolite-amended columns (b).

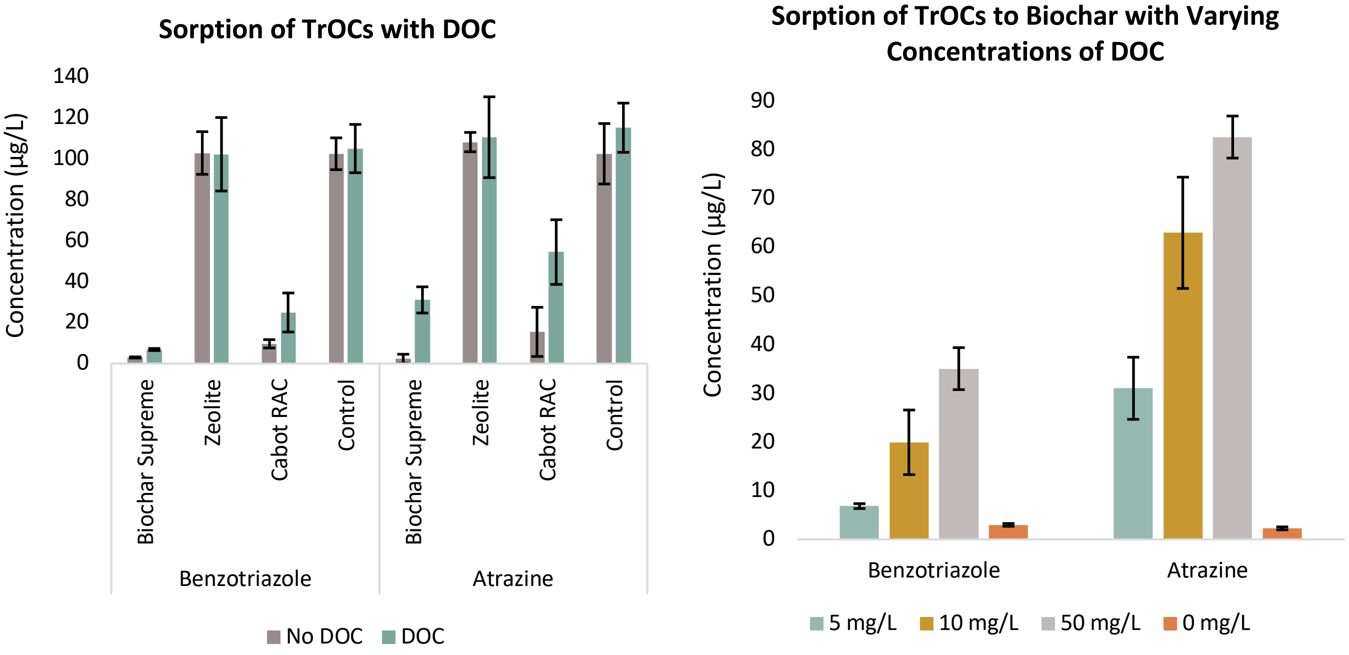

Figure 2. Sorption batch Test results featuring the sorption of TrOCs with DOC (a) and Sorption of TrOCs to Biochar Supreme with Varying Concentrations of DOC (b).

References

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