Characterizing *Escherichia coli* and *Staphylococcus aureus* Transport in modified sand filters

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Introduction: Increasing urban development has led to larger areas of impervious surfaces and consequently larger volumes of runoff during storm events. This runoff often contains a wide variety of both chemical and biological contaminants including suspended solids, nutrients, petroleum hydrocarbons, heavy metals, emerging organic contaminants, and pathogens (EPA 2015). There are many stormwater management practices that use sand and other filter media to allow stormwater to infiltrate into the groundwater or be directed via an underdrain system to a surface water body. Current filter systems focus primarily on reducing the volume of stormwater runoff. These techniques often do not provide adequate treatment to meet national water quality standards and therefore pose a major risk for both groundwater and surface water contamination (Roy-poirier, Champagne, Asce, & Filion, 2010). Pathogens are currently the number one cause of impaired water bodies in the United States (EPA, 2008) and with current bioretention systems averaging just 35% bacteria removal rates, there is a dire need to improve current stormwater management practices to treat for biological contaminants (Tilman et al., 2011). In order to address this issue new types of media such as biochar are being studied as potential filter media additives for bioretention and biofiltration systems (Mohanty, 2014, Mohanty, 2013 Grebel et al., 2013). With the addition of new media these modified filter systems would be able to not only provide protection for both groundwater and surface water bodies but also facilitate direct and indirect forms of potable and non-potable water reuse.

Research Goals and Procedure: Previous research has found that media additives increase the removal of fecal indicator bacteria (FIB). As a result the first research goal of this project was to characterize the bacteria removal efficiencies in modified sand filters using biochar and coconut coir as media additives. Biochar and coconut coir are both very porous materials with small particle sizes. These characteristics increase the surface area of the material and reduce the area between particles which could increase bacteria removal in a filter system. Also in previous studies FIB were typically used when studying the removal of biological contaminants in stormwater. To the best of our knowledge, studies comparing FIB removal with actual pathogen removal in modified filter systems are limited. As a result the second goal of this project was to fill in this gap in knowledge and compare the removal of Escherichia coli, a FIB, and Staphylococcus aureus, a human pathogen.

In order to accomplish the project objectives, a packed column set-up was used and three types of media mixtures were tested (30% biochar and 70% sand; 5% biochar and 95% sand; and 5% biochar, 10% coconut coir, and 85% sand). These media mixtures were dry packed into columns and then rinsed with DI water and synthetic stormwater. The synthetic stormwater contained .75 mM of $CaCl_2$, .075 mM of $MgCl_2$, .33 mM of Na_2SO_4, 1mM of $NaHCO_3$, .072mM of NH_4Cl, .016mM of Na_2HPO_4, and 20mg/L of Suwannee River natural organic matter. Previous literature showed that this stormwater mixture accurately reflects the ions and concentrations found in urban stormwater (Mohanty, 2014 and Grebel et al., 2013). Synthetic stormwater with an *E.coli* or *S.aureus* concentration of 10^4 to 10^5 CFU/mL was then pumped vertically upward through the columns. The stormwater effluent was then captured in half pore volume fractions and plate enumeration was used to find the concentration in the effluent.

Results: The results from all of the experiments are summarized in Table 1. It can be seen that the media mixture containing 30% biochar and 70% sand demonstrated the highest removal efficiency and overall the removal of *S.aureus* was higher than that of *E.coli*. The significant difference in removal between *S.aureus* and *E.coli* is also shown in figure 1. This figure also displays the significant increase in bacteria removal when the percentage of biochar is increased from 5% to 30%. Note that the results shown in table 1 and figure 2 also indicate that coconut coir increases the removal of *E.coli*.

Discussion: The results found in this study are promising and supported by the findings of previous studies. Both biochar and coconut coir have smaller particles sizes than sand and both are also very porous materials which increases the surface area of the materials. This increased surface area could provide more area for bacteria attachment to the materials. Also due to the smaller particle size it is possible that the space between particles is decreased which could increase the bacteria straining in the filters. The results also showed a difference in the removal of *S.aureus* and *E.coli*. *S.aureus* is a gram positive bacteria with a zeta potential of approximately -39 mV while *E.coli* is a gram negative bacteria with a slightly more negative zeta potential of -49 mV (Materi, 2010).It can be hypothesized that the more negative zeta potential of *E.coli* increases the electrostatic repulsion between it and the media in the filter, decreasing *E.coli* attachment. However, further research is necessary to identify the primary mechanisms involved in varying removal among *E.coli* and *S.aureus* strains.

Table 1: Log removal rates of *E.coli* and *S.aureus* in various media.

	S.aureus avg. log removal	*E.coli* avg. log removal
30% biochar and 70% sand	4.28 ± .5	1.93 ± .04
5% biochar and 95% sand	1.19 ± .05	.22 ± .002
5% biochar, 10% coconut coir, and 85% sand	n/a	.65

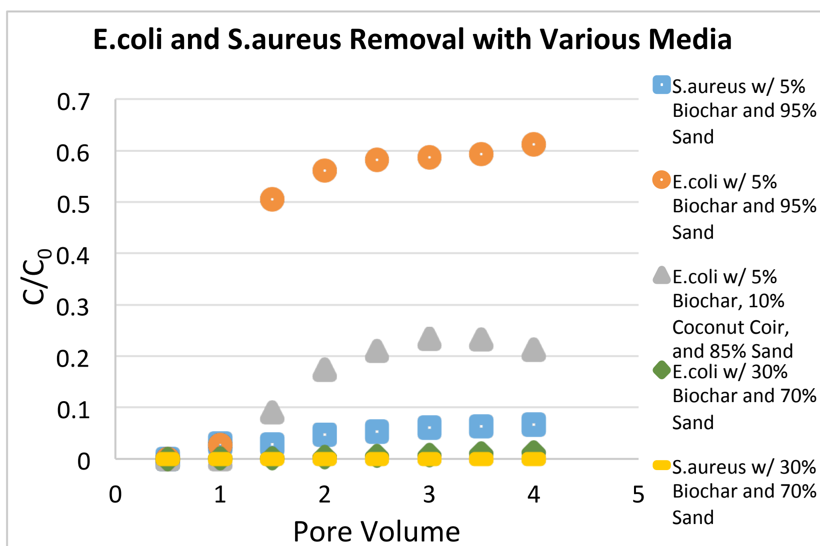

Figure 1: This figure displays the break through curves for *E.coli* and *S.aureus* with various media.

Conclusion: It is evident from the results that biochar and coconut coir are promising potential media additives to remove *E.coli* and *S.aureus* from synthetic stormwater. However, due to the difference in removal of *E.coli* and *S.aureus* more research is needed to characterize the removal of both FIB and human pathogens.

Works Cited

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