Engineered Infiltration System for Urban Stormwater Reclamation

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Introduction

The world's increasing population has caused an increase in urbanization. With this increased level of urbanization comes a large area of impervious structures including paved roads and sidewalks. These impervious structures prevent natural infiltration of rainwater and increase the amount stormwater runoff (Figure 1). An increase in stormwater runoff increases the number of flash floods in urban areas. Additionally, the runoff flows across the pavement and collects many contaminants, including chemicals and pathogens, before flowing into the sewer drains.

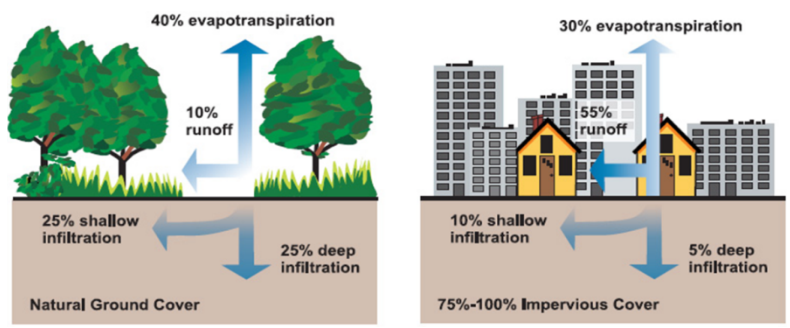

Figure 1. Change in water cycle due to urbanization

Bioinfiltration systems are currently being placed in urban settings for beautification and flood control purposes. A typical bioinfiltration system, e.g., rain garden, consists of a top plant layer, a middle soil or geomedia layer, followed by a lower gravel layer (Figure 2). Stormwater flows from the top layer to the bottom layer and then into the sewer drain. The existing bioinfilitration systems are not designed to remove contaminants from stormwater. Currently, the high levels of pollution in urban stormwater prevent its safe reuse. We are focusing on redesigning the soil or geomedia layer to remove contaminants from infiltrating stormwater. Specifically, we are focusing on removing *E. faecalis,* our model bacteria, from stormwater by using iron oxide coated sand. We hypothesized that (1) iron oxide coated sand (IOCS) will remove bacteria from stormwater and (2) phosphate and natural organic matter (NOM) in stormwater will decrease the removal capacity of IOCS.

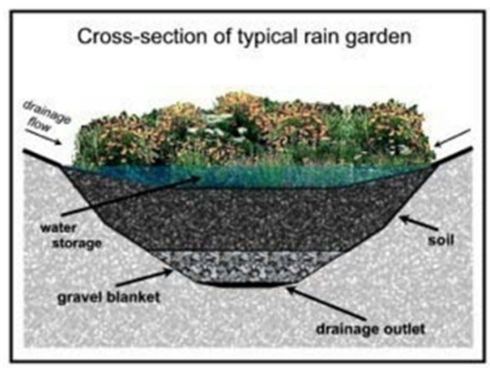

Figure 2. Design of a typical rain garden

Procedure

Batch experiments were conducted in 15 mL polyethylene vials. Approximately, 1 g of sand or iron oxide coated sand (IOCS) was mixed with 10 mL of deionized water in each vial at 150 rpm for 1 hour on an orbital shaker. To each vial, 100 µL of highly concentrated *E. faecalis* was spiked to prepare 10^7 CFU/mL of *E. faecalis.* The vials were mixed again for 1 hour before testing for the remaining amount of bacteria in water. We plated 100 µL of the water from each vial onto petri dishes filled with agar and incubated the dishes at 37°C for 24 hours. We counted the number of colonies forming on each plate that gave us a measure of the bacteria that remained in our artificial stormwater. The batch experiments were repeated using stormwater containing known quantities of phosphate and natural organic matter.

Results and Discussion

We had two major outcomes from the batch experiments. First, we found out that iron oxide coated sand is significantly better than uncoated sand at removing *E. faecalis* from stormwater. Under the conditions listed in the procedure, coated sand removed 99.99% of total bacteria present in our artificial stormwater (here, deionized water), whereas regular sand only removed around 40%. This difference occurred because bacteria and regular sand are inherently negatively charged and bacteria are repelled from attaching to sand, thus remaining in the stormwater. On the other hand, the iron oxide coating is positively charged and bacteria are electrically attracted to attaching to this coating.

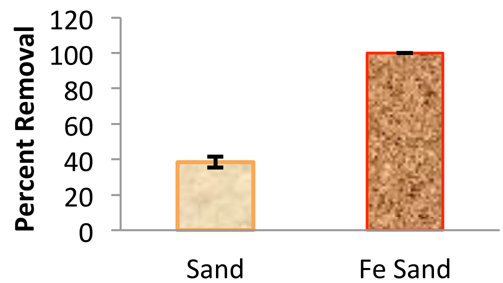

Figure 3. Removal of *E. faecalis* by sand and iron oxide coated sand (IOCS)

The second major outcome was that chemical contaminants typically found in stormwater, like phosphates (PO_4) and natural organic matter (NOM), decrease the amount of bacteria that can be removed from stormwater by iron oxide coated sand. For the specific ratio of bacterial concentration to iron oxide coated sand listed in the procedure, removal was decreased by at least 50% at phosphate levels above 1 mM (Figure 4a). Also for the same ratio, no removal of bacteria was observed when stormwater contained above 50 mg C L^{-1} of NOM (Figure 4b).

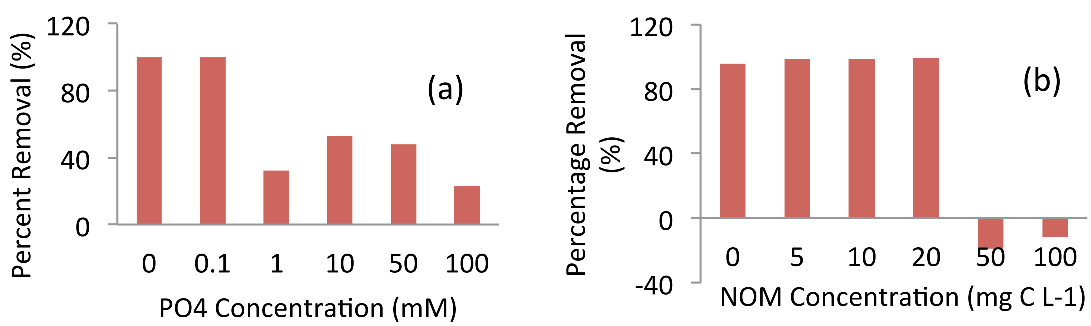

Figure 4. Effect of (a) phosphate and (b) NOM on removal of *E. faecalis* stormwater by IOCS

Our results suggest that phosphate and NOM can attach to the positively charged sites on the iron oxide coated sand thereby blocking sites for the bacterial attachment. Therefore, we conclude that chemical contaminants in stormwater hinder the removal of bacteria by IOCS. We recommend that if iron oxide coated sand is used in the geomedia portion of rain gardens to remove bacteria from stormwater, a layer of geomedia that removes these chemical contaminants should be placed above the iron oxide coated sand layer.