Soils and Stormwater Management - Practical considerations from the field

The 2006 Stormwater Management BMP manual introduced the need for systematic soil testing to be incorporated into the design and construction of stormwater management projects in Pennsylvania. Soil scientists working throughout Pennsylvania and the Mid-Atlantic states offer their experiences from the field and offer practical considerations that may not be reflected in the current regulations. Through these field experiences come procedures and methods that may need to be incorporated into current and future stormwater management manuals and regulations.

Circular Soils: Waste-Based Materials for Green Infrastructure

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Highlights

- Glass-based soil (GBS) outperforms standard sand-based GSI soil in several key hydrologic metrics.
- GBS has higher infiltration rates, lower compaction, and higher moisture retention than standard soils.
- GBS has little to no effect on plant growth and soil health (microorganisms and fungal biomass).

Introduction

Can engineered soils, designed for green stormwater infrastructure (GSI), include recycled pulverized glass rather than virgin sand to simultaneously reduce reliance on environmentally damaging materials and provide a sustainable outlet for a major waste stream? This session will detail the Circular Soils initiative - a practice-based research project that seeks to answer this question by developing high-quality GSI soils for the urban environment of Philadelphia and the Delaware Valley that are renewably sourced. By developing a standardized recycled urban soil blend optimized for water quality, infiltration and plant health, this project aims to provide a means of building better green infrastructure more efficiently while also creating green jobs and supporting a circular economy. The project has been the recipient of Phase I+II SBIR funding from the US EPA, and the findings will be openly shared with municipalities across the country, to move the needle on domestic recycling and life cycle cost reduction in the built environment. This session will primarily focus on the Phase II findings related to a full-scale green stormwater infrastructure (GSI) field experiment in Philadelphia and the expansion of glass-sand production locally.

Methodology

Field Trial

In collaboration with the Philadelphia Water Department (PWD) and Philadelphia Parks & Recreation (PPR), an existing stormwater bioretention basin was retrofitted with a glass-based soil (GBS) mix and observed over a one-year period for plant health, hydrologic, and hydraulic performance. Metrics for water quality, soil moisture, infiltration, compaction, flow rate, plant transpiration, and plant health were monitored. During the session, the project team will provide in-depth analysis of research results, opportunities, challenges, and next steps for the initiative.

Research Questions

To measure bioretention function, the team divided the stormwater basin into four zones for their data collection. Monitoring was conducted to determine how GBS soil mix impacted the water quality and water quantity functions of the bioretention system. Data was collected over a 12-month period. Specific research questions included:

- Does the GBS soil mix impact water quality design targets for pH, temperature, total suspended solids, and dissolved oxygen?
- Does the GBS soil mix impact the runoff release rate from the outlet control system?
- Are there additional parameters of interest based on the pilot study's results?
- Are there design modifications necessary for bioretention systems using the GBS soil mix?

To measure plant performance and soil health, the team established a total of ten test plots for data collection (five on each side), specifically to measure vegetative cover and plant height. Specific research questions included:

- Does the GBS mix impact vegetative cover?

- Does the GBS mix impact plant growth or transpiration rates? If yes, is this impact the same across species?
- Does the GBS mix impact the presence of microorganisms and microarthropods?
- Does the GBS mix contain higher levels of metal concentrations when compared to the control

Key Findings

Monitoring and analysis indicate that the glass-based soil media did not adversely impact the water quality or water quantity performance of the bioretention system. Infiltration rates in glass-based media were double those in sand-based media and soil moisture levels were significantly more stable. Monitoring and analysis indicate that the glass-based soil media had little to no adverse impact on the plant growth of plants in the bioretention system. No adverse impacts on soil health were observed. The successful pilot installation demonstrates the efficacy of our engineering process and encourages public and private entities to adopt the GBS specification, creating a demand for the new material and by extension, new demand for the locally produced glass-sand and food waste compost. It may also decrease the (economic and environmental) costs of topsoil to the City of Philadelphia and improve the city's glass recycling rates. The proof of concept will make it possible to build new networks of public and private entities in other cities to implement similar plans.

Recommendations

The hydrologic performance of glass-based soil meets or exceeds the performance of typical sand-based soil in green infrastructure applications based on several metrics including infiltration rate, soil moisture, and compaction. More research is needed to establish a direct comparison of soil performance in terms of water quality measures such as total suspended solids and dissolved oxygen. Large-scale uptake of glass-based soil is hampered by limited supply and cost of glass-sand. Public-private partnerships may help mitigate cost and supply challenges.

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Soil investigations for stormwater management have taken place in accordance with the regulations since 2006. Through numerous site investigations in both the design and post construction inspection stages of malfunctioning systems, we have observed common errors, endemic to soil science, regarding the site investigation, design, specification development, and construction inspection that have led to these malfunctions. Through specific project examples across Pennsylvania and the Mid-Atlantic, we want to highlight these critical stages where soil science considerations must be taken into account in order for stormwater management facilities to function as designed.

Extended Abstract Template

Impacts of de-icing salt loading on nutrient and metal processing in stormwater bioretention

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Highlights

- Deicing salts reduce nutrient, heavy metal, and sediment removal in stormwater bioretention
- Impacts can be somewhat reduced through selection of resilient plants and internal water storage
- Ultimately, it is necessary to reduce deicer salt application to protect water quality and ecosystem health

Introduction

Sodium chloride and other salts are widely applied to roads, sidewalks, and parking lots during wintry weather. Previous work has indicated potential negative impacts of deicing salts on performance of stormwater control measures, but the effects and potential mitigation measures are not yet fully understood.

Methodology

We constructed 48 stormwater bioretention mesocosms (Figure 1), divided into 12 experimental groups of 4 replicates, each with *Panicum virgatum* (switchgrass), *Eutrochium purpureum* (Joe Pye weed), or no vegetation; having an internal water storage (IWS) zone or not; and being exposed to high or low NaCl doses. Groups received synthetic stormwater, including NaCl in the late winter of 2022 and 2023, followed by effluent monitoring through May 2023 and end-of-experiment analysis of soil and plant biomass for nitrogen, phosphorus, copper, zinc, and total suspended solids (TSS).

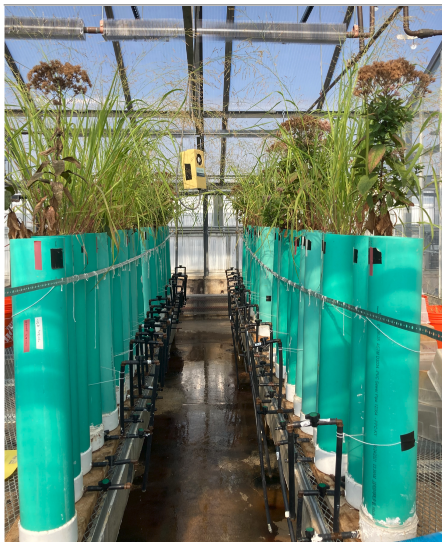

Figure 1. Photograph of stormwater bioretention mesocosms

Key Findings

Effluent phosphorus, copper, zinc, and TSS removal dropped after NaCl dosing. There were brief pulses of zinc export after NaCl dosing, which is of concern for potential acute toxicity impacts to freshwater organisms. Phosphorus, copper, and TSS performance were consistently worse in the mesocosms with higher salt loading. Performance generally recovered by the summer, and annual removal was mostly still satisfactory across all systems. Phosphorus and copper load increases were mitigated by the presence of IWS and vegetation. Nitrogen performance did not have a clear direct relationship with salt loading. However, there was an indirect influence of salt, in that Joe Pye weed mesocosms with higher salt loading experienced plant die-off, and subsequent nitrogen flushing. This flushing was mediated by replacement of the plants. Nitrogen performance was strongly enhanced by presence of vegetation and IWS.

Recommendations

Reduced winter/spring bioretention performance after application of deicing salts poses seasonal risks to aquatic ecosystems. Bioretention performance in the face of deicers can be enhanced by selection of more salt-tolerant plant species, and addition of internal water storage (IWS). Ultimately, it is also critical to reduce application of deicing salts to impervious surfaces.