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Prediction of Flow Rates through Various Stormwater Biofilter Media Mixtures

Redahegn Sileshi[1], Robert Pitt[2], Shirley Clark[3]
[1]Assistant Professor of Engineering, Univ. of North Georgia, Oakwood, GA 30566
[2]Emeritus Cudworth Professor of Urban Water Systems, Dept. of Civil, Construction and Environmental Engineering, Univ. of Alabama, Tuscaloosa, AL 35487
[3]Associate Professor of Environmental Engineering, School of Science, Engineering and Technology, Penn State, Harrisburg, PA 17057

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Introduction

- Stormwater bioinfiltration systems are widely used in urban areas to reduce stormwater runoff volume, peak flows and stormwater pollutant loads reaching receiving waters.
- The media selected for use in biofilter systems is critical when determining water quality treatment and stormwater flow control performance of these systems.
- Premature clogging of filtration media by incoming sediment is also a major problem affecting the performance of stormwater biofiltration systems in urban areas.

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Introduction Cont.

- A series of controlled lab column tests conducted using various mixtures of sand and peat to predict changes in flow with changes in the mixture, focusing on media density associated with compaction, particle size distribution (and uniformity), and amount of organic material.
- The results of the predicted performance of these mixtures were also verified using column tests (for different compaction conditions) of surface and subsurface soil samples obtained from Tuscaloosa, AL, infiltration test areas, along with bioretention media obtained from actual Kansas City biofilters, Wisconsin biofilters, and samples of North Carolina biofilter media.

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Laboratory Column Tests

- Controlled laboratory column tests were conducted to determine flow and particle trapping capabilities of sand-peat media mixtures, Tuscaloosa surface and subsurface soils, using challenge water made up of a wide range of particle sizes.

Sand media

Surface (a) and subsurface soil (b) media from Tuscaloosa, AL USA

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Laboratory Column Flow Tests

- The effects of different compaction levels (hand compaction, standard proctor compaction, and modified proctor compaction) on the infiltration rates through various media mixtures were examined during laboratory column testing.
- Four-inch (100 mm) diameter PVC pipes 3 ft (0.9 m) long, were used for these tests
- Both standard and modified proctor compactions follow ASTM standard (D 1140-54).

Lab column construction

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Laboratory Column Flow Tests Cont.

- The media layer was about 0.5 m (1.5 ft) thick.
- Four liters of clean water were poured into each lab column for each test observation (Three replicate tests were conducted for each column).
- The surface ponding depths in the columns ranged between 28 cm (11 in.) and 36 cm (14 in.) to correspond to the approximate maximum ponding depths at biofilters.

Laboratory column setup for infiltration measurements.

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Laboratory Column Particle Trapping Tests

- Particle trapping tests were also performed for the sand-peat media mixtures and the Tuscaloosa surface and subsurface soils, using challenge water having a wide range of particle sizes.

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Laboratory Column Particle Trapping Tests Cont.

- The test sediment in the challenge water was based on a mixture of fine ground silica particulates (Sil-Co-SiL®250), medium sand, and coarse sand, mixed with Black Warrior River water to result in a wide range of particle sizes.
- The mixture added to the water (coarse sand: medium sand: fine Sil-Co-Sil 250 = 10: 15: 75 by mass) resulted in a generally uniform particle size distribution ranging from about 20 μm to 2,000 μm. The smallest particles were from the Black Warrior River water.
- The total concentrations of sediment in the influent challenge water were about 100 and 1,000 mg/L (low and high concentrations during the factorial experiments).

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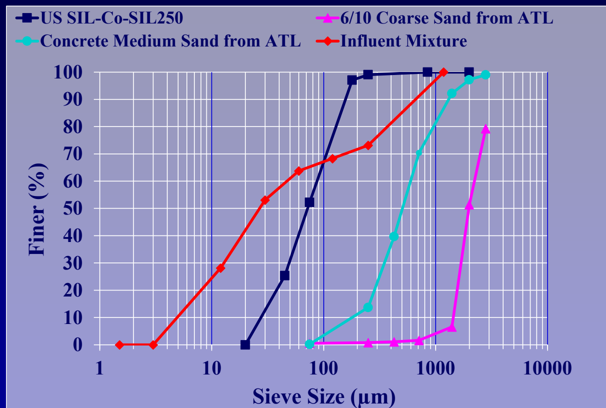
Test Sediment Particle Distribution



Black Warrior River water was used as the test water to which the particulates were added to provide the smallest particles (less than 20 µm) in the challenge water mixture

Laboratory Column Particle Trapping Tests

- The influent solution was split into ten 4 liter portions for testing each of ten columns. These column tests were replicated three times.
- The influent “dirty” water samples were composited for analysis for each batch, while the column effluents were separated for suspended sediment concentration (SSC), total dissolved solids (TDS), particle size distribution (PSD), turbidity, and conductivity analyses.

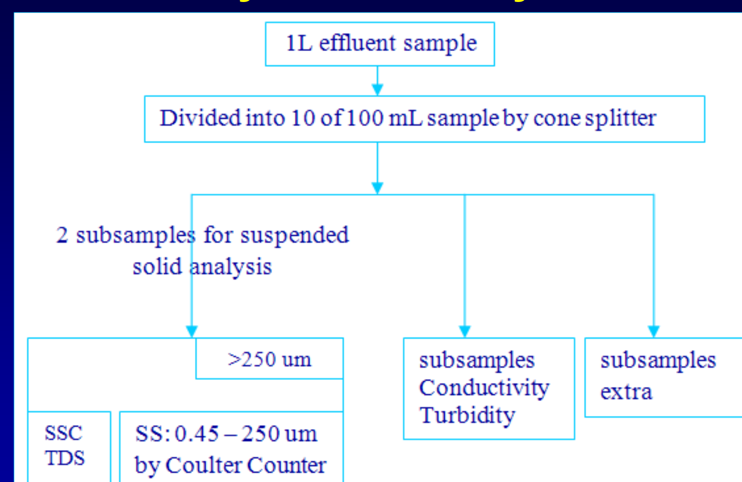
Laboratory Solids Analysis

The constituents analyzed included:

- SSC
- TDS (< 0.45 um particles)
- PSD (by sieves and Coulter Counter)
- turbidity (continuous with portable turbidimeter and laboratory meter for samples)
- conductivity analyses (continuous and for samples).

USGS/Dekaport cone splitter used to split samples for tests.

Laboratory Solids Analysis Cont.



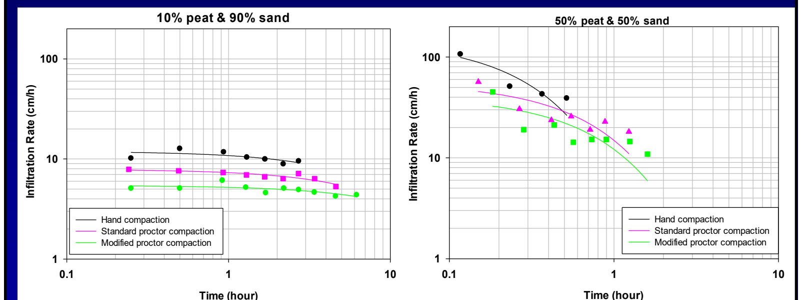
Laboratory Column Flow Tests

- Three levels of compaction were used to modify the density of the media in the columns during the tests (hand compaction, standard proctor compaction, and modified proctor compaction) on the infiltration rates through the various media mixtures was examined.

- Both standard and modified proctor compactions follow ASTM standard (D 1140-54).
- The bottom of the columns had a fiberglass window screen secured to contain the media and were placed in funnels.
- To separate the gravel layer from the media layer, a permeable fiberglass screen was placed over the gravel layer.
- The columns were then filled with the various media mixtures added on top of the gravel layer.
- The densities were directly determined by measuring the weights and volume of the media material added to each column.

Infiltration Test Results

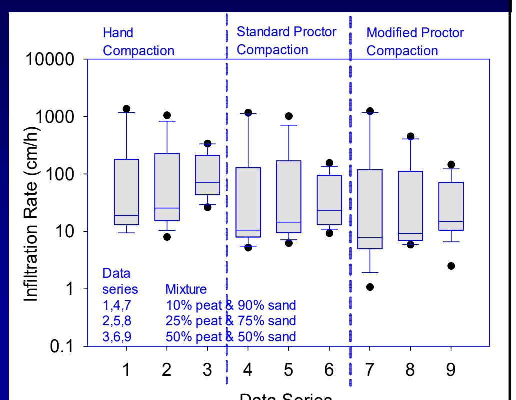
Example infiltration data for different test trials were fitted to Horton's equation to estimate f_c (final infiltration) based on the observed data



Infiltration Test Results Cont.

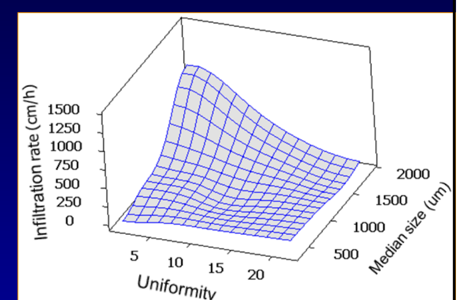
Box and Whisker plots of the different test conditions, comparing different compaction conditions with varying amounts of peat amendments.

- The avg. infiltration rates of the saturated mixtures indicated that the infiltration rates through the mixtures increased with increases in the percentage of peat.
- Increased compaction always decreased infiltration rates



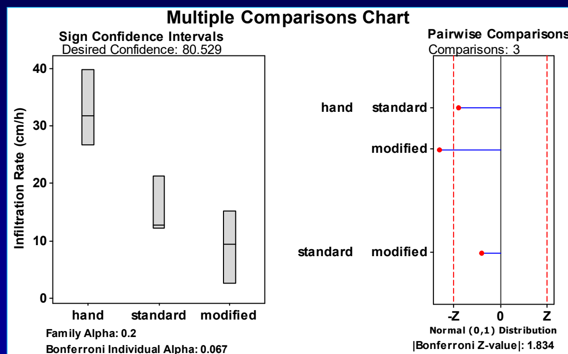
Infiltration Test Results Cont.

- An example surface plot for uniformity and texture effects on the saturated infiltration rate for low organic content conditions.
- Higher infiltration rates were observed for mixtures having low uniformity (narrow range of particle sizes) and higher median size values, as expected.



Infiltration Test Results Cont.

Kruskal-Wallis multiple pairwise comparison test results for different levels of compaction using 50% peat and 50% sand mixture (mixture D_{50} = 1250 um and C_u = 19).



There are significant differences (p = 0.02) between the saturated infiltration rate values for hand vs. modified proctor compaction conditions (but not for standard vs. modified compaction conditions).

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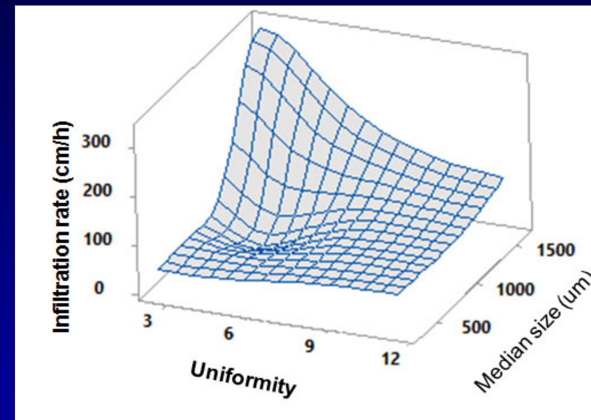
Infiltration Test Results Cont.



surface plot for uniformity and texture effects on the saturated infiltration rate for high organic content conditions.

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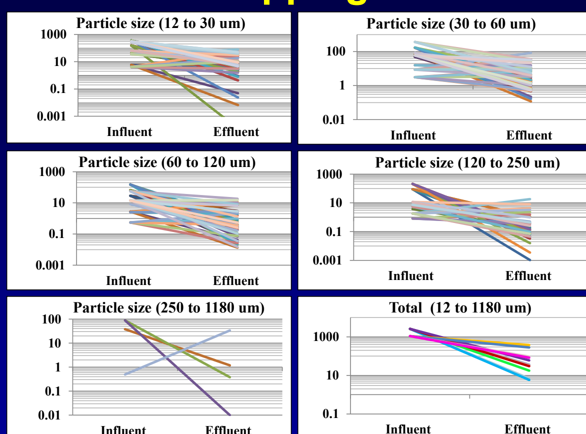
Particle Trapping Test Results



Example performance line plots contrasting influent and effluent concentrations for different particle ranges for a sand-peat media mixture. Reductions occurred for most of these lab column tests.

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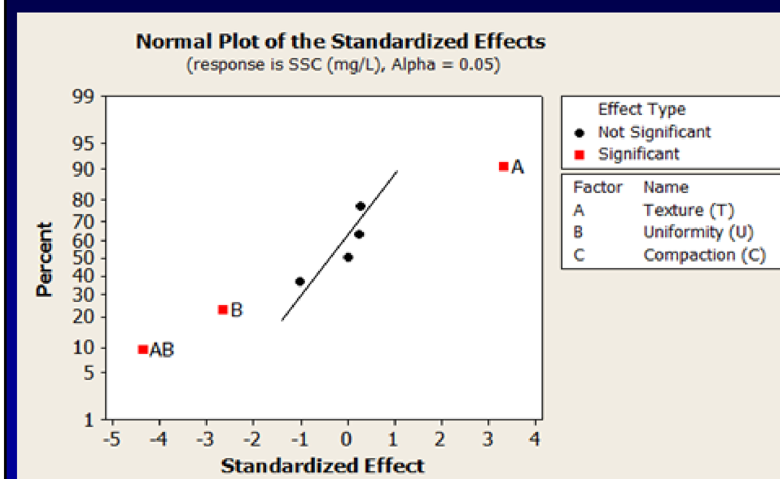
Probability Plot for Different Factors



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Conclusions

- Adding sand to a media having large fractions of silt and clay-sized particles helps minimize the detrimental effects of compaction on the infiltration rates.
- The particle trapping experiments using sand-peat mixtures and Tuscaloosa surface soil samples indicated that significant reductions occurred for most lab columns, with relatively consistent effluent conditions.
- The results of the factorial analysis indicated that texture and uniformity (and their interaction) are significant factors affecting the effluent SSC concentrations. The concentrations are not affected by the compaction, although the flow rates through the media are, as shown previously.

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Questions

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