Assessing the Performance of Bioretention and Sand Filter Basins using a Full-scale Low Impact Development (LID) Testbed

Abtin Shahrokh Hamedani, Heather Shipley, and Marcio Giacomoni
Department of Civil and Environmental Engineering, University of Texas at San Antonio (UTSA)

1. Pilot-test Study - Column Experiment

- 12 PVC bioretention columns (1ft*3ft)
- Each column is composed of 3 major layers of 10” drainage layer
- 24” filtration layer containing the test media
- 6” transparent bowl for plant addition
- The synthetic stormwater was injected to the columns
- Influuent and effluent samples were collected for water quality analysis including following water quality parameters:
  - Total Suspended Solids (TSS/mg/L)
  - Dissolved and total Nitrogen concentration (mg/L)
  - Dissolved and total Phosphorus concentration (mg/L)

Phase I. Filtration Media Selection
Treatment performances of nine soil media were studied to identify the two top performing media, including:
- Sand
- limestone Sand
- Two standard Biofiltration Mixture
- Five innovative blends using Limestone sand and recycled glass

Phase I - Sand vs limestone sand vs standard biofiltration (Biofilter532) vs Recycled-glass mix
- Overall High TSS removal efficiency of ~90%
- Leaching of Phosphorus for Biofilter532 and R.G.+Biofilter532.
- Nitrogen Removal of 12% for Biofilter532, due to its small infiltration rate.
- Enhanced removal of heavy metals for Limestone sand and Biofilter532 compared to Sand.

Phase I - Bioretention test study
- Lime-Mix 70.2%, Blend#1 63.6% and Blend#2 82.6%
- Higher Nitrogen removal rate for Biofilter433 (13%) due to its smaller infiltration rate compared to other media.
- Enhanced removal of dissolved heavy metals
  - Mean Zinc removal of 81%
  - Mean Lead removal rate of 92%
- Improved copper treatment is achieved that is correlated with phosphorus removal.

Phase II - Vegetation Impact
Three native plants were added to the top two performing media.
- Gulf Muhly
- Inland Sea oats
- Frogfruit
- Impact of plant uptake on pollutant removal rate was studied by comparison of water quality parameters before and after plant addition.

Phase II - Impact of vegetation on pollutant removal for top two filtration media: Blend#1 and Blend433
- Nutrient removal is enhanced significantly by plant uptake.
- No significant difference is observed in removal of heavy metals.
- Enhanced orthophosphate removal from 6.3% to average of 57% for Blend#1.
- Enhanced nitrate removal for both filtration media, from ~7% to ~45% for Blend#1 & from 59% to 68% for Blend433.

2. Field-scale Study - LID Testbed

LID testbed is composed of six parallel cells (9ft*30ft*4.5ft) containing the top performing bioretention designs and sand in duplicates, with and without impermeable liner.

1. Conventional biofiltration mixture (Blend433)
- Regular sand (85-88%), fines (8-12%) and organics (2-5%)

2. Innovative limestone mixture (Blend#1)
- Limestone sand (85-88%), fines (8-12%) and organics (2-5%)
- Silica Sand

Testbed Monitoring
- One year pre-construction monitoring of inlet
- Two year post-construction monitoring of testbed in terms of:
  - Stormwater Quality
  - Flow-paced sampling at inlet and six outlets
  - Stormwater Quantity
  - Monitoring the rainfall, flowrate, water level, soil moisture and evapotranspiration

On June.24th (1-44in), total of 53 samples including 24 inlet and 29 outlet samples were collected.

A total of 10 storm events will be monitored per year to:
- Obtain extensive dataset of runoff quantity and quality
- Assess treatment performance of different designs under same condition
- Study potential impact of liners on aquifer recharge and pollutant removal efficiencies
- Study impact of aging and required maintenance
- Develop models to study the soil-plant interaction, flow path and fate transport

Introduction and Background
- Urbanization impacts water resources due to growing population and more urbanized areas.
- Sustainable stormwater management practices are required to control the quality as well as quantity of stormwater runoff.

San Antonio is one of the fastest growing cities in the U.S. and is located on top of the Edwards Aquifer recharge zone, - the main water supply for south-central Texas - under extreme pressure due to increased water demands and prolonged droughts - provides habitat for endangered species - listed in the top ten endangered karst ecosystems

Low Impact Development or Green Infrastructure
- Sustainable stormwater control measures
- Enhance stormwater quality
- Ensure safe and sufficient recharge of aquifer
- Can be costly and high maintenance
- Limited treatment performance
- Dependent on local conditions

Sand Filter Basin versus Bioretention Areas
Sand filter basins - Filtration LID
- Most commonly used in region
- Reduce peak runoff, runoff volume
- Remove particulate pollutants through physical processes
- Aesthetic and unattractive
- Not effective in removal of dissolved pollutants

Bioretention Basin - Infiltration LID
- Enhanced water quality
- Removal of dissolved pollutants through biochemical processes within the soil-plant interaction
- Aesthetic and habitant for pollinators and particular bird species
- High maintenance and costly

Objectives
- Identify an enhanced and economical biofiltration media using native and abundant material.
- Implement a full-scale LID test bed on the UTSA main campus, composed of a series of parallel bioretention and sand filter cells.
- Enhance education of the public and students about stormwater sustainability.

Methodology
1. A pilot-test study to identify enhanced biofiltration media by conducting column experiments.
2. A field-scale study to assess performance of these enhanced bioretention systems and sand in a full-scale LID testbed under same conditions.