Soil Moisture and Nitrogen Removal Dynamics within a Bioretention Basin

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Abstract

There has been little attention paid to the frequent wetting and drying cycles of soil matter in a bioretention basin, however preliminary studies have shown that a prolonged antecedent period prior to a storm event alters the effectiveness and reliability of a bioretention basin. This study will aim to characterize the influence of intermittent wetting and drying and the resulting changes in soil moisture conditions within a bioretention basin on nitrogen removal through lab and field methods. Soil moisture and total nitrogen was measured for three storm events in a 4ft x 10ft, high plant diversity basin and a column study was conducted utilizing a prepared bioretention soil mix at four different treatment levels (determined via the gravimetric water content analysis method): 100% saturated, 50% saturated, 25% saturated, 0% saturation (no added moisture).

Introduction

A bioretention cell or basin is a contemporary and innovative method of Green Stormwater Infrastructure (GSI) meant to treat and filter incoming storm water, resulting in a treated outflow with considerably lower pollutant concentrations and total suspended solids (TSS) loads. Due to the nature and purpose of these systems, they are often exposed to alternating periods of wetting and drying between storm events. This intermittent wetting and drying can result in variable soil moisture levels, as there are shifting amounts of moisture retained following the wet phase period of each storm event (Subramaniam et al. 2014). Furthermore, retained moisture from a previous storm event or the lack thereof (i.e., from a prolonged antecedent dry period) can alter the hydrograph qualities, and influence nutrient concentrations as well as nutrient retention capacities of a bioretention cell, limiting the efficiency of these systems to mitigate the negative impacts of urbanization and impervious land cover (Bush et al. 2014).

Figure 1 – cross section of a Bioretention basin

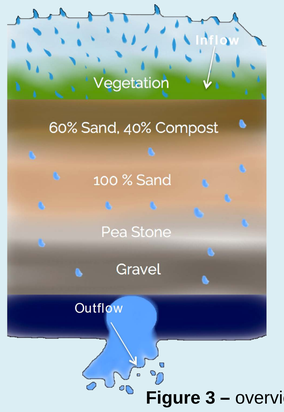


Figure 2 – Flooded Bioretention Basin

Figure 3 – overview of a Bioretention basin

Methods

Field Study:

- 4 x 10 ft basin located in an urban watershed area – receives run off from an adjacent, high traffic road
- High diversity plant cover (7 native perennials – shallow/deep rooted, salt tolerant)
- Time-based, composite sampling of influent and effluent run off (every 4 minutes, every 2 minutes) via ISCO automatic water sampler – analyzed for 3 distinct storm events (6/1/15, 6/8/15, 7/1/15)
- Analyzed for total nitrogen (dissolved & particulate) via alkaline persulfate digestion method and flow injection analysis (FIA)
- Time-based, discrete sampling of soil volumetric water content (VMC) via a Frequency-domain reflectometry (FDR) based sensor at a depth of 2ft

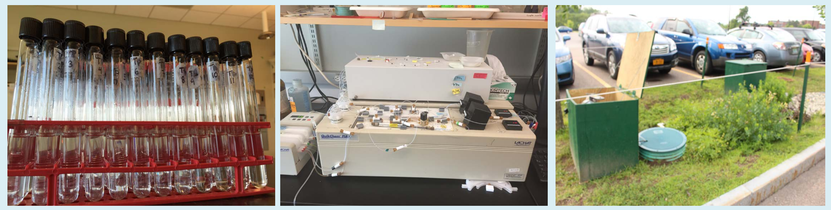


Figure 4 L-R: Persulfate digestion, Flow Injection Analysis apparatus, overview of basin (ISCO sampler, influent/effluent drains)

Soil Column Study:

- 64 cm height, 4 cm diameter Polycarbonate Column
- Engineered bioretention media, sieved through 2mm sieve - 85 to 88 percent by volume sand (USDA Soil Textural Classification); 8 to 12 percent fines by volume (silt and clay); and 3 to 5 percent organic matter by weight (ASTM D 2974 Method C)
- Four treatment levels, 4 repetitions (16 columns total) – 100% saturated, 50% saturated, 25% saturated, 0% saturation (no added moisture)
    - Water content determined via Gravimetric Water Content Analysis method
- 1 µg/L nitrogen solution (NO_3) added instantaneously into column to simulate rain event
- 24 hour draining period; leachate analyzed for dissolved nitrogen via flow injection analysis (FIA)

Figure 5: Experimental set up of soil column study

Results

Field Study:

- Significant negative correlation in total nitrogen (µ/L) in influent run off and soil moisture (r^2=-0.54) in 7/15/15 storm (Figure 6 and Figure 7).
- Significant positive correlation in total nitrogen (µ/L) in effluent runoff and soil moisture (r^2=0.59) in 7/15/15 storm.
- Varying, inconsistent and insignificant relationship between total nitrogen in influent and effluent runoff and soil moisture for remaining events.

Figure 6

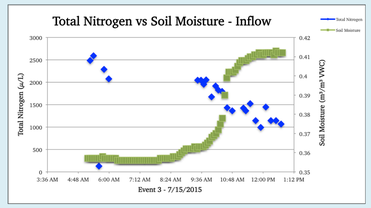
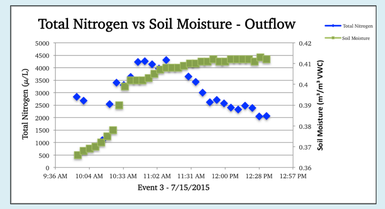


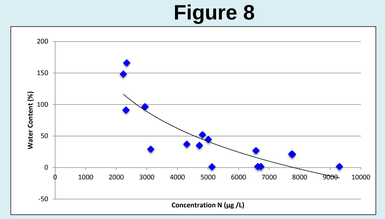
Figure 7



Soil Column Study:

- Logarithmic trend(r^2=0.72) between water content (%) of soil and concentration of nitrogen (µg/L) (Figure 8).

Figure 8



Discussion

The results of this study showed a significant negative correlation (r^2=-0.54) in total nitrogen and soil moisture in influent run off and a significant positive correlation (r^2=0.59) in total nitrogen and soil moisture in effluent run off for one of the four events sampled. Similarly, the column study resulted in a logarithmic correlation (r^2=0.72). These results are in tandem with literature results, as high variability was found with increasing antecedent dry period. However, given the small sample set and limited inquiry into this subfield, further study is needed to arrive at a comprehensive understanding of wetting and drying cycles within a bioretention basin. Additionally, this study did not consider nitrogen removal on a continual basis (i.e. throughout the draining process) and future studies may benefit in doing so, as previous studies have identified a stabilization period at the onset of storm events following an antecedent dry period.

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