Experimental Assessment of Nitrate Filtration Capacity of Xeriscaped Stormwater Retention Basin Soils

E.K. Larson[1] and N. B. Grimm[1,2] [1]School of Life Sciences, [2]Global Institute of Sustainability

Abstract: Stormwater retention basins are designed to provide the ecosystem services of flood abatement and groundwater recharge. However, studies have shown that stormwater tends to have high nutrient concentrations, which may incur future costs if groundwater is used for drinking water. If retention basins can store or remove nitrate from stormwater as well as mitigating floods, they would provide an additional valuable ecosystem service to the CAP LTER, which has documented high levels of nitrogen input regionally. Researchers in more mesic climates have found that soils in retention basins effectively remove pollutants within the top few centimeters, but the filtration capacity of basins in arid areas has not been investigated. As a preliminary laboratory evaluation of retention basin soils, we collected replicate cores of approximately 10 cm depth from a non-grassy basin. We then had two treatments groups of pure water and water amended with potassium nitrate. Bulk analyses on all cores were performed and leachates and soil extracts were collected for ion and organic carbon content analysis. Initial treatments indicated an overall flushing of ions in all treatments, indicating that the soils add nitrate to recipient systems. Results from these manipulations will be coupled with future field investigations to assess the filtration capacity of xeriscaped stormwater retention basins, a common feature in the CAP LTER.

Introduction:

- Retention basins are common approach to on-site flood attenuation in new urban developments, and are often required by municipal, county, and state agencies for projects of a minimum size.
- Stormwater is known to have high concentrations of nutrients, especially nitrogen (N).
- Therefore, retention basins receive large amounts of nutrients and water, making them likely locations for biogeochemical "hot-spots."
- Biogeochemical processes stimulated by the addition of N and water may impact water quality as it moves into recipient systems (groundwater or surface water).

Do retention basin soils remove nitrate (NO_3^-), a common N pollutant, from stormwater?

Hypotheses:

The nitrogen cycle is very complex, with many microbes transforming N from reduced to oxidized forms and back, depending on environmental conditions. For the specific case of NO_3^-:

- Stormwater entering soils stimulates **removal** of NO_3^- from the water via adsorption, incorporation into biomass, or denitrification (microbial conversion of NO_3^- to gaseous N_2).
- Stormwater entering soils mobilizes stored NO_3^- (deposited from the atmosphere), and/or stimulates nitrification (conversion of NH_4^+ to NO_3^-), **adding** NO_3^- to the water flowing through the system.

Approach:

We collected soil samples and intact cores of 10 cm height in plastic sleeves for laboratory experimentation (Figures 1 and 2) from a local retention basin (see photographs above). Half of the cores were treated with water alone, the other half received water + NO_3^-. Leached water and soil extracts were collected for chemical analysis to determine if contact between soil and water altered the chemical makeup of either constituent.

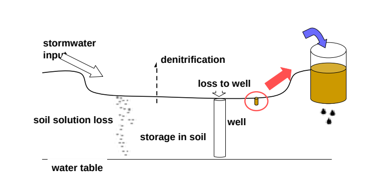

Figure 1: Graphical representation of a stormwater retention basin, showing major components and abstraction of soil cores.

Figure 2: Laboratory setup of suspended soil cores with bottles beneath to collect leachate.

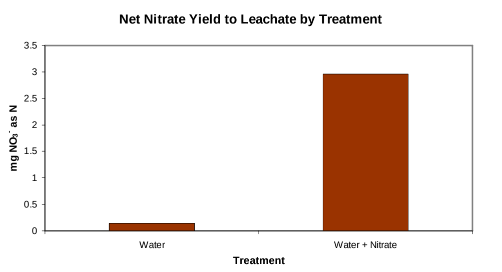

Figure 3: Addition of nitrate to water leaching through soil cores. In treatment 2, more nitrogen came out of the core than was put in. Even the cores receiving water alone (treatment 1) resulted in a positive yield in the leachate.

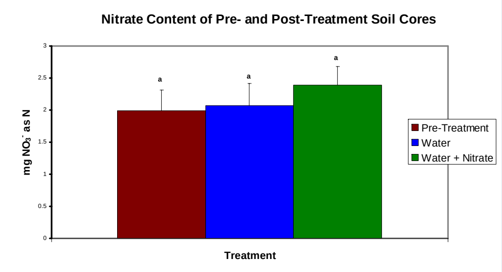

Figure 4: Amount of extractable nitrate from pre- and post-treatment soil cores. Error bars are standard errors. Note that there is no significant difference among treatment groups, i.e. addition of water, or water + nitrate, did not effect net nitrate content.

Results:

Both types of treatments resulted in an increase in nitrate in the water leaching through the system (Figure 3).

- For the first treatment of water only, water moving through the core mobilized 0.14 mg NO_3^-
- In the second treatment of water + 1.4 mg NO_3^-, there was a net yield (OUT – IN) of 2.96 mg NO_3^-

Interestingly, despite the loss of nitrate to leaching water, the nitrate content of the soil cores did *not* change appreciably after treatment (Figure 4). Water moving through the soil did not diminish average soil nitrate content. While some of the soil nitrate may have left via the leachate, the net biological and physical processes in the cores maintained a relatively stable nitrate stock.

Conclusion and Future Plans:

Many urban development plans include stormwater retention basins that are xeriscaped, similar to the retention basin in this study. While engineered to provide the valuable ecosystem service of flood abatement, this research indicates that, at least on a short temporal scale, ***infiltration through basin soils increases nitrate export to recipient systems, such as groundwater***.

However, the principles of mass balance define limits to the magnitude of export. That is, ***over the long term, exports cannot continue to exceed inputs.*** Further investigation of the temporal dynamics of basin soils and the underlying mechanisms of nitrate production, consumption, and removal will help elucidate the general behavior of these types of basins.

The supply and quality of organic carbon to microbes in the soil will have a significant effect on heterotrophic biological processes. Since many basins are sodded for use as playing fields and parks, investigation of soil activity when overlain with turf will be vital for comparison biogeochemical functioning between the two types of retention basins.

Field assessment of several xeriscaped retention basins is underway to evaluate seasonal and basin-scale biogeochemical patterns.

Special thanks to Kayla Graham for field and laboratory assistance.