WATER RESOURCES RESEARCH GRANT PROPOSAL

Title. Engineered Bioretention for Removal of Nitrogen from Stormwater Runoff

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Congressional District. 5th District of Maryland

Statement of Critical Regional or State Water Problems

Nitrogen compounds represent some of the most important pollutants in water bodies. Nitrate and ammonia in natural waters promote eutrophication--excess growth of aquatic algal organisms--in lakes, rivers, and reservoirs. Decay of this excess growth depletes water oxygen levels, stressing aquatic wildlife. Such deleterious effects were the impetus for the development of nutrient reduction as a primary goal in the Chesapeake Bay restoration program, with year 2000 goals of 40% removal from 1985 baseline levels. Additionally, excess nitrogen and phosphorus in stormwater runoff to rivers have recently been suggested as the triggers for several outbreaks of Pfiesteria piscicida in rivers in Maryland and other East Coast states. Pfiesteria is a microorganism that produces a toxin that is very toxic to fish and recent evidence has suggested a neurotoxic effect on humans. Furthermore, there are other human health concerns associated with the presence of nitrate in drinking water, in particular the development of methemoglobinemia in infants.

Nitrate and nitrite are regulated in drinking waters by the Safe Drinking Water Act. Both nitrate and nitrite have an enforceable MCL (maximum contaminant level) of 10 mg/L as N. Other forms of nitrogen, such as ammonia and organic N can be converted to nitrate/nitrite within the water supply or during treatment. Consequently, all water utilities are concerned with various nitrogen species in the source water, both from surface and ground water supplies. Rather than focus on treatment of nitrate in drinking water, a better alternative is to limit the input of nitrogen to the water supply. This is one focus of watershed management by water utilities. A major portion of Maryland receives drinking water from surface waters, especially in the populous central areas of the state.

The Baltimore-Washington corridor is already greatly developed and major development pressures are being felt in areas surrounding these major cities. Management of stormwater runoff in developed areas is one important aspect of watershed management. Non point source runoff in urban areas is a critical water quality issue. For example, urban areas make up 10% of the Chesapeake Bay watershed and contribute 11% of its nitrogen load. As a result, addressing the quality of stormwater runoff from developed areas is critical in minimizing the impacts of the development both on the local environment, and further downstream.

Statement of Results or Benefits

Increasingly, stormwater runoff is being implicated in water quality problems. From eutrophication, to Pfiesteria, to nitrates in drinking water supplies, nitrogen species are a major water quality issue. Although nitrogen pollution of waters is usually associated with agriculture, recent investigations of urban stormwater runoff have shown high levels of several nitrogen species, indicating the significance of this source. The control and removal of nitrogen compounds from stormwater represent a significant step in minimizing nitrogen concerns in natural waters. The proposed work focuses on the fate of nitrogen in bioretention systems, which are simple, low impact runoff treatment/infiltration facilities for use in developed areas. Bioretention is an integral part of low-impact development, and is being promoted as a stormwater Best Management Practice by Prince George's County, MD. Nitrogen uptake, transformation and removal in bioretention systems will be investigated in this proposed work. Specifically, this work will focus on the removal and biological transformation of nitrate.

Current versions of bioretention systems are plant- and soil-based infiltration areas to provide treatment to stormwater runoff. Recently completed work by the PI has shown that these systems are very efficient in the removal of heavy metals from runoff, but less efficient for other pollutants, including nitrogen compounds. However, with proper selection of bioretention media, plants, moisture levels, and flow path, these systems can be engineered to remove and even assimilate nitrogen pollutants. Specifically, a modification to include a continuously submerged anoxic zone with an overdrain will be evaluated for its capacity for nitrate removal via denitrification. Nitrate is the focus of the proposed research because it is the most difficult of the nitrogen species to deal with and is not attenuated in a typical, conventional bioretention system. Any nitrate that is carried to lower anoxic portions of the bioretention system will be converted to N2 through optimized denitrification reactions. The release of the nitrogen into the soil gas provides nitrogen removal from the system. Although biological denitrification has a proven record in municipal wastewater treatment, it has not been investigated in stormwater runoff applications. Thus, conditions ideal for the denitrification reaction must be determined so that design parameters can be established for use in bioretention. Results from the evaluations of biological transformations of nitrate will allow designs to optimize nitrate removal from bioretention systems that treat stormwater runoff. Specifically, experimental results will select parameters such as the anoxic zone porous media (which can affect water conditions and biofilm growth) and the electron donor and carbon source type and content to promote efficient denitrification. An additional constraint is that the materials selected for use in bioretention are to be low maintenance and low cost. This work will be integrated with future research on interactions of other forms of nitrogen in bioretention (ammonia and organic N). This will provide not only optimum treatment, but also multiple barriers against nitrogen accrual in streams, lakes, and reservoirs. Based on an overall analysis of project results, recommendations on bioretention application, design, operation, and maintenance will be made. Close ties between the PI and the Prince George's County Government make it likely that recommendations from this study will be implemented in field bioretention studies.

Nature, Scope, and Objectives of the Research

A low impact treatment facility to remove nitrogen species from stormwater runoff before it enters receiving waters would be extremely beneficial. Effective use of such a facility for the treatment of stormwater runoff can minimize impacts of land development on local water quality. In particular, nitrate is the nitrogen compound of the most concern in stormwater runoff. This concern stems from the fact that nitrate has near negligible affinity for soil components due to its anionic form, and consequently it is very mobile in soil/groundwater systems. This proposed work builds on previous work by the PI on the use of bioretention for pollutant removal from stormwater runoff. The focus of bioretention has been in parking or roadway areas where stormwater is concentrated into several collection areas or small individual facilities constructed on each lot. With modifications, bioretention facilities can also be employed in rural areas.

This work will systematically examine methods to remove nitrate from urban runoff by re-engineering the concept of bioretention. Specifically, the facility will be modified to create a permanent anoxic zone at the bottom (Figure 1). This anoxic zone will contain an appropriate electron donor and carbon source for denitrifying bacteria in order to promote biological denitrification during storm events. Important issues to be addressed include:

- Determining an electron donor and carbon source that will be stable for a long period of time in the subsurface, but still not limit the denitrification process. This could be either an organic substrate (e.g., sawdust (Schipper and Vojvodic-Vukovic 1998)) for chemoorganotrophic denitrifying bacteria, or an inorganic substrate (e.g., a sulfur/limestone bed) for chemolithotrophic denitrifying bacteria.
- Evaluating media that will support a denitrifying population, but not interfere with the flow characteristics during a storm event. Media to be evaluated include gravel of various sizes and porous solids that may allow for a more stable fixed-film bacterial population.
- Investigating designs that will keep the anoxic area wet and the bacterial population viable during the potentially prolonged periods between storm events.
- Investigating the optimum compromise between rapid stormwater conveyance, degree of treatment, and costs.