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Project Title

Development of Mixed Media Filtration for Stormwater Runoff Treatment

University

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Research Needs

Stormwater runoff from highways and urban areas contains large amounts of inorganic and organic pollutants, such as suspended solids, microorganisms, nutrients and heavy metals. Contaminants carried into natural water bodies by stormwater runoff can significantly deteriorate water quality and cause public health concerns (House et al., 1993). Different best management practices (BMPs) have been developed to control the pollutants in stormwater runoff. The removal of runoff contaminants can be achieved by a variety of technologies including bioretention, infiltration, vegetative swales, constructed wetlands and other engineered treatment systems (Clark and Pitt, 2012). However, many of the conventional BMPs (e.g. detention ponds) are designed to control runoff volume and remove particles in the runoff. These conventional BMPs are generally not effective in removing other pollutants such as Escherichia coli (E. coli), nutrients and heavy metals. Infiltration-type stormwater treatment systems are able to remove different contaminants but these systems typically require a large operating footprint and have the risk of contaminating groundwater. There is a need to develop low-cost, low-maintenance, and effective BMPs that can remove multiple contaminants in stormwater runoff.

Media filtration has received increasing attention as an effective technology that can remove particulate and dissolved pollutants from stormwater runoff, using a relatively small footprint.

Many low-cost filter materials have been evaluated for their potential for stormwater treatment. These materials include anthracite coal, sand, sand coated with metallic hydroxide, zeolite, limestone, iron products, steel slags, woodchips, sawdust, and tire crumbles; all of which possess good hydraulic properties and are readily available (Bailey et al., 1999; Lukasik et al., 1999; Hatt et al., 2008; Kim et al., 2010; Wium-Anderson et al., 2012; Reddy et al., 2014a). It has been shown that these low-cost filter materials can remove suspended solids, nutrients, microorganisms, and metals commonly found in stormwater runoff. However, studies also showed that no single filter media could effectively remove all of the contaminants of concern in stormwater (Wium-Anderson et al., 2012; Reddy et al., 2014b). Combinations of several of these filter media are necessary to achieve the removal of multiple contaminants.

Seelsaen et al. (2006) demonstrated that different sorption media mixes (sand, compost, zeolite etc.) can be used as an effective medium for the treatment of dissolved metal contaminants commonly found in stormwater. Prabhukumar (2014) performed column experiments to evaluate the contaminant removal of individual media materials. The results showed that calcite was most efficient for nutrients and suspended solids removal, zeolite was highly effective in removing E. Coli, and iron fillings were effective in removing nutrients and metals. Reddy et al. (2014b) showed that mixed-media filtration (calcite, zeolite, sand and iron fillings) was effective for simultaneous removal of nutrients and heavy metals from stormwater runoff. These studies suggest that mixed-media filtration systems using permeable reactive materials have great potential to remove multiple contaminants in stormwater runoff.

Many surface water bodies in South Dakota are impaired by sediment, nutrients, and bacteria from point and non-point sources. Stormwater runoff has been identified as a source of contamination in surface waters. Mixed-media filtration is a highly promising treatment option that can reduce the concentrations of multiple contaminants in stromwater runoff generated from highways and urban areas. We propose to develop a low-maintenance, low-cost mixed-media filtration system for stormwater treatment in South Dakota.

Research Objectives

In this study, we will conduct laboratory and field experiments to investigate the performance of mixed-media filtration to remove E. Coli, nitrate and phosphate from stormwater runoff. The objectives of this study are to:

1. Provide a comprehensive literature review of the use of filtration for stormwater treatment and select low-cost filter materials for this study.
2. Determine the contaminant removal efficiency of each selected filter material through batch experiments.
3. Construct a lab-scale mixed-media filter and determine its efficiency for contaminant removal from stormwater.
4. Construct a field-scale mixed-media filter and determine its efficiency for contaminant removal from stormwater.
5. Provide recommendations on the application of mixed-media filtration systems for stormwater treatment in South Dakota.

Research Methods

This research will be conducted through a literature review, laboratory batch experiments, laboratory column experiments, and field scale experiments to achieve the objectives. As the first part of this project, a comprehensive literature review will be conducted to summarize the latest developments in using filtration for stormwater treatment. This review will focus on low-cost media and their ability to remove a variety of contaminants from stormwater. Based on the results of the literature review, we will select applicable filter materials for this study. These materials may include sand, limestone, steel byproducts, calcite, natural zeolite, and others.

After we obtain the selected filter materials for this project, we will perform laboratory batch experiments to determine adsorption capacity for each material. We will vary the experimental parameters to simulate a range of stormwater treatment conditions. The removal efficiency of E. Coli, nitrate and phosphate of each filter material will be determined. We will develop adsorption models for each material to quantify their adsorption capacity and longevity.

We will select filter materials for the column experiments based on the results of batch adsorption experiments. Selected media will be mixed together to form a mixed-media filter for the column study. The mixing ratios of different materials will be determined based on the batch experiment results. We will operate the mixed-media filter using simulated stormwater and real runoff collected from highways or urban areas to investigate the long-term performance of the filter.

After we complete the batch and column experiments, we will work with municipalities or SD DOT to identify a site to install a field scale filter with mixed media. We will determine the contaminant removal efficiency of the filter under field conditions.

Expected Outcomes

This research focuses on developing a mixed media filtration technology for stormwater runoff treatment. The expected outcomes of this project include:

1. A mixed media filtration technology that can be used to remove multiple contaminants from stormwater runoff
2. An understanding of the contaminants adsorption capacity of various permeable reactive materials
3. Recommended application conditions of the mixed media filtration for stormwater treatment

Relevance to Strategic Goals

The proposed project and its expected outcomes are directly related to the goals of Environmental Sustainability, Livable Communities, and Economic Competiveness. This research aims to develop a mixed media filtration BMP to reduce the concentrations of multiple contaminants in the runoff from highways and urban areas. The mixed media filtration is a highly promising technology than can reduce the environmental impact of transportation and urban development to protect natural water resources.

Educational Benefits

A master's level student will work on this project under the direction of the PIs. The graduate student will develop a mater thesis based on the results of this study.

Work Plan

Task 1 Literature Review and Selection of Filter Materials

A comprehensive literature review will be conducted to summarize the latest developments in using filtration for stormwater treatment. We will select appropriate filter materials for this study based on the reported contaminant removal capacity and their availability and cost.

Task 2 Conduct Laboratory Batch Adsorption Experiments

We will use a temperature controlled incubator to perform the batch adsorption experiments. We will test different filter materials for their ability to remove E. Coli, nitrate and phosphate. The pH, reaction time, temperature, and contaminant concentrations will be varied during the batch experiments to simulate a range of stormwater treatment conditions.

Task 3 Construct a Mixed-Media Filter and Conduct Column Experiments

We will construct a mixed-media filter for the column experiments. The mixing ratios of different filter materials will be determined by their adsorption efficiency. We will operate the mixed-media filter continuously using simulated stormwater to evaluate the long-term performance of the filter under controlled conditions. Simulated stormwater will be prepared according to typical contaminant concentrations in highway and urban runoff. Real runoff samples will also be collected from highways or urban areas, and will be tested to evaluate the removal efficiency of E. Coli and nutrients by the mixed media filtration. We will monitor filter clogging, hydraulic conductivity, and contaminant removal during the column experiments.

Task 4 Install and Test a Field Scale Mixed-Media Filter

We will work with municipalities or SD DOT to identify a site to install a field scale filter with mixed media. The selection of the media for the field installation will be based on the results of batch and column experiments. We will monitor the treatment performance of the filter after it is installed.

Task 5 Project Reporting

The PIs will write and submit the final report. The reports will summarize the experimental results and recommendations for the application of mixed-media filtration systems for stormwater runoff treatment.

Table 1 Proposed Project Schedule

Tasks	Months							
	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24
1. Filter Media Selection								
2. Batch Experiments								
3. Column Experiments								
4. Field Scale Experiments								
5. Project Reporting								

Project Cost

Project Costs:	$140,384
MPC Funds Requested:	$ 70,042
Matching Funds:	$ 70,342
Source of Matching Funds:	East Dakota Water Development District, $30,000 South Dakota State University, $40,342

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