MPC-690
May 24, 2022

Project Title

Pilot Scale Evaluation of Escherichia Coli Removal from Stormwater Runoff Using Steel Byproduct Filtration

University

South Dakota State University

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Research Needs

Stormwater runoff is the one of the most common forms of non-point source pollution, which can degrade surface water quality. Compared to point source pollution, non-point source pollution is more difficult to manage due to its diffuse nature. Stormwater runoff can be generated from various sources including highways, urban areas, and agricultural settings. Urbanization has increased impervious surface and reduced natural filtration of stormwater into soil. In addition to the increased flooding, urban stormwater may contain a variety of chemical and biological contaminants including nutrients, heavy metals, hydrocarbons, pathogens and suspended solids. The US Environmental Protection Agency estimated that stormwater from urban areas has led to water quality deterioration of 13% of river segments, 18% of lakes, and 32% of estuaries surveyed (USEPA, 2002). South Dakota Department of Agricultural and Natural Resources (SDDANR) assessed about 5,916 stream miles in South Dakota from 2012 to 2017, and the results showed that 73.5% of assessed stream miles did not support one or more beneficial uses (SDDENR 2018). Nonsupport for fishery/aquatic life uses was caused primarily by total suspended solids from nonpoint sources and natural origins. Nonsupport for recreational uses was primarily caused by Escherichia coli (E. coli) contamination from livestock and wildlife contributions. As we continue to expand urbanization, transportation, and agricultural production to support population growth, stormwater runoff from various sources may lead to increased

contamination of surface waterbodies in the future. Thus, it is important to improve management of stormwater runoff to protect natural water resources.

Fecal indicator bacteria such as E. coli has been recognized as major contaminants that prevent the potable and non-potable reuse of stormwater runoff. The presence of E. coli in stormwater runoff indicates potential fecal contamination which has been linked to increased risk of waterborne illness during recreational exposures. Many best management practices (BMPs) have been developed to reduce the negative impacts of stormwater runoff. These BMPs include roadside vegetation ditches, retention ponds, biofilters, constructed wetlands and other engineered treatment systems (Clark and Pitt, 2012). However, most of these BMPs are designed to control the volume of runoff and trap suspended particles. These conventional BMPs are generally not effective in removing other pollutants such as E. coli, nutrients and heavy metals. Media filtration is an emerging stormwater treatment technology that has shown great potential to remove multiple contaminants from non-point source pollution. A variety of filtration materials have been evaluated for stormwater treatment, including natural minerals (e.g., calcite, limestone, and zeolite), industrial byproducts (e.g., steel slag, fly ash, and drinking water treatment residuals), and commercial synthetic products (Seelsaen et al., 2006; Chardon et al., 2012; Prabhukumar 2014; Lalley et al., 2016; Soleimanifar et al., 2016). Many of the prior studies that evaluated stormwater media filtration focused on nutrients and metals. Few studies have examined materials that can remove fecal indicator bacteria, such as E. coli. Microbial pathogens in stormwater runoff are becoming a primary source of water quality impairment in receiving water bodies. There is an urgent need to develop practical technologies to remove E. coli in stormwater to protect public health.

Recycled steel byproducts are a new filtration material that can be used for stormwater runoff treatment (Goodwin et al., 2015; Hua et al., 2016; Sellner et al., 2019). Steel byproducts include various forms and sizes of steel wool, chips, and turnings that are generated as waste materials from steel machining, cutting, and grinding processes. These steel processing waste materials are typically landfilled or recycled back into the steel making industry. Another group of steel byproducts, steel slag, has also been evaluated for stormwater treatment. Steel slag is a byproduct of the steel making industry that is typically rich in aluminum, calcium, and iron. Steel chips and steel slag have demonstrated effective phosphate removal capacities in laboratory experiments (Sellner et al. 2019). The surface of steel byproducts may consist of various forms of positively charged iron oxides, which could be used to remove negative charged bacteria (Zhang et al. 2010). Laboratory batch and column studies conducted at South Dakota State University (SDSU) have shown that recycled steel chips effectively removal E. coli from simulated stormwater runoff (Dai, 2019). Following the laboratory study, a field study was conducted at the City of Brookings, South Dakota to evaluate E. coli removal from stormwater using steel byproduct filter. The field filter was constructed using a mixed media of steel chips and steel slag and was installed at a residential stormwater retention pond. The results of the field study at the City of Brookings showed that the steel byproduct filter was able to remove an average of 50% of influent E. coli during the 2019-2020 stormwater seasons (Olevson, 2021). The laboratory and field stormwater filtration studies of SDSU indicate that recycled steel byproducts are effective materials for E. coli removal. It is recommended that large scale pilot filter installation and evaluation should be conducted to verify the performance of steel byproduct filtration for E. coli removal. More studies are also needed to evaluate various factors

that affect the attachment and detachment of E. coli from steel byproducts to provide information for stormwater filtration process design.

Research Objectives

The overall objective of this study is to evaluate E. coli removal from stormwater by a pilot scale steel byproducts filter. In this study, a large scale pilot filter will be installed at a stormwater site at the City of Sioux Falls and the performance of E. coli removal of the filter will be determined. The objectives of this study are to:

1. Identify a stormwater site at the City of Sioux Falls for the filter installation.
2. Collect and characterize steel chips and steel slag for stormwater filtration.
3. Design and construct a steel byproduct filter at the selected stormwater site.
4. Evaluate E. coli removal of the steel byproduct filter during stormwater events.
5. Provide recommendations on the full scale application of steel byproduct filtration for E. coli removal from stormwater runoff.

Research Methods

The project team will work with the City of Sioux Falls to identify a stormwater site for this study. The team will visit several stormwater BMP structures and determine the best location for the installation of the steel byproduct filter. After the pilot study site is selected, the project team will design a flow-through structure for the stormwater filtration study. Recycled steel byproducts from a recycling company in Minnesota and steel slag from a steel making company in Nebraska will be collected for this project. Both materials from these two locations have been used by the PIs in previous stormwater treatment studies. The quantities of the steel byproducts and steel slag will be determined based on the flow-through filter structure design and treatment requirements. After the project team receives the filter materials, laboratory experiments will be conducted to evaluate factors affecting E. coli removal from each material. The project team will work with the City of Sioux Falls to construct the filter structure at the selected stormwater site and install the filter media. The project team will complete the design and installation of the stormwater filter before the 2023 stormwater season. Stormwater samples before and after the filter will be collected from different storm events in 2023 to determine the long-term performance of the filter for E. coli removal. In addition to E. coli, the phosphate removal will also be monitored to evaluate the nutrient removal efficiencies of the filter.

Expected Outcomes

This project aims to evaluate the long-term E. coli removal performance of a large scale pilot stormwater filter using steel byproducts. The development of low-cost filtration technology for E. coli removal from stormwater runoff has significant implications in surface water quality improvement and public health protection. The results of this project will help the application this technology in stormwater management practice. The expected outcomes of this project include:

1. An understanding of the E. coli removal efficacy of a large sale steel byproduct filter.
2. An understanding of the impact of various flow conditions on E. coli removal of steel byproduct filters.

3. Recommended full scale design conditions of steel byproduct filtration for E. coli removal.

Relevance to Strategic Goals

The proposed project and its expected outcomes are directly related to the strategic goals of Environmental Sustainability, and Livable Communities. Bacteria contamination originated from stormwater runoff is a major water quality concern in natural water resources protection. The project will determine the E. coli removal performance of a large scale pilot stormwater filter using steel byproducts. This new bacteria control management tool can be used to reduce the environmental impact of stormwater from different sources and protect natural water resources.

Educational Benefits

One PhD student and one MS student will work on this project under the direction of the PIs and receive training on stormwater treatment, pilot scale filtration design, bacterial removal experiments, and water quality analytical skills. This study involves stormwater management, laboratory and field experiments, and water quality analyses, which provide great training opportunities for the student. The students will learn about applying an innovative water treatment technology in real world application to solve an important water quality issue, which will improve their critical thinking and problem solving ability. The students will present the results at regional and national conferences, and prepare manuscripts for peer-reviewed journals. These opportunities will improve students' skills in written and oral communication.

Technology Transfer

The findings of this project will be transferred to other researchers, professionals and practitioners through conferences, meeting presentations, and publications.

1. The project team will present the result of study at regional and national conferences including the Big Sioux River Water Summit, Eastern South Dakota Water Conference and WEFTEC.
2. A MS thesis and a PhD dissertation will be developed based on the results of this project. The thesis and dissertation will be available to the public through Open Prairie, the South Dakota State University public access institutional repository.
3. The project team will submit manuscripts to peer-reviewed journals based on the results of this project.

Work Plan

Task 1 Literature Review on Stormwater Filtration for E. coli Removal

A comprehensive literature review will be conducted to summarize the latest developments in E. coli control in stormwater runoff. This review will focus on media filtration technologies, low-cost filtration materials for E. coli removal, and field applications of stormwater filters. The project team will select the filter design approach for the stormwater filtration study at the City of Sioux Falls based on this review and the results of previous studies at SDSU.

Task 2 Select a Stormwater Site for the Filtration Study

The project team will work with the City of Sioux Falls to identify several possible sites for the stormwater filtration study. Site visits will be conducted to evaluate the feasibility of each site for this project. A final study site will be selected based on the following criteria.

1. The site should allow the installation of a flow through filtration unit.
2. The site should be accessible for the installation of the filter and sample collection.
3. The stormwater from this site should have reasonable Escherichia coli concentrations to allow filtration performance evaluation.
4. It is desirable to have a filter hydraulic detention times of > 0.5-1 minute during filtration. High flows of stormwater runoff can flow over the filter or be bypassed.
5. It is desirable to have low amounts of sediment in the stormwater before the filter to reduce the clogging potential of the filter.

Task 3 Collect and Characterize the Steel Byproducts for the Stormwater Filtration Study

The project team will work with the City of Sioux Falls to collect recycled steel chips from a recycling company in Minnesota and steel slag from a steel making company in Nebraska, or other locations. Steel slag will be used as a supporting material and steel chips will be used as the main E. coli removing material for the stormwater filter. Laboratory experiments will be conducted to evaluate various factors affecting E. coli attachment and detachment from the filter materials. These factors include intermittent flows, organic matter concentration and filter media particle size. The quantities of each material for the selected stormwater filter site will be determined based on the laboratory experimental results and the design of the filter structure.

Task 4 Design and Construct the Stormwater Filter

The project team will work with the City of Sioux Fall to design the filter structure for the selected stormwater site. The filter design will be based on the size, physical conditions, and hydraulic conditions of the study site. The project team will work with the City of Sioux Falls to finalize the stormwater filter design and construct the filter for this study. Filter media will be added to the filter structure after its construction.

Task 5 Evaluate E. Coil Removal by the Stormwater Filter

The project team will start the evaluation of the filter performance for E. coli removal after the filter installation. A stormwater sampling plan will be developed based on the filter structure and site conditions. The influent and effluent of the filter will be monitored during storm events. Samples from different storm events will be collected during this project to evaluate the long-term performance of the filter. E. coli and phosphate concentrations will be measured for each sample to evaluate bacteria and nutrient removal efficiencies of the filter.

Task 6 Project Reporting

The PIs will write and submit the final report. The reports will summarize the pilot scale experimental results and recommendations for the application of steel byproduct filter for bacterial removal from stormwater runoff.

Table 1 presents the proposed project schedule.

Table 1 Proposed Project Schedule					
Tasks	Quarters				
	May 2022	August 2022	December 2022	April 2023	July 2023
1. Literature Review					
2. Site Selection					
3. Filter Materials					
4. Design and Construction					
5. Filter Performance					
6. Project Reporting					

Project Cost

Total Project Costs:	$240,000
MPC Funds Requested:	$120,000
Matching Funds:	$120,000
Source of Matching Funds:	East Dakota Water Development District, $50,000 South Dakota State University, $70,000

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