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First Flush Reactor for Stormwater Treatment for Elevated Linear Transportation Projects

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) Municipal Separate Storm Water Sewer System (MS4) Program regulations require municipalities and government agencies including the Louisiana Department of Transportation and Development (LADOTD) to develop and implement stormwater best management practices (BMPs) for linear transportation systems to reduce the discharge of pollutants, thereby protecting water quality. The BMPs commonly used for linear transportation systems include exfiltration trench devices, infiltration devices, vegetated bio-filter devices, and detention devices. While many of these BMPs have varying degrees of viability, none are applicable for the many sections of elevated roadways in Louisiana. In addition, most existing stormwater BMPs require high hydraulic conductivity topsoil for infiltration; however, the soils in coastal Louisiana are typically composed of clay and silt, which have low permeability and may result in the failure of infiltration-based BMPs. Therefore, an efficient and cost-effective stormwater treatment device is urgently needed for complying with MS4 regulations.

OBJECTIVE

The primary objective of this study was to design and test a first flush-based stormwater treatment device for elevated linear transportation projects/roadways that is capable of complying with MS4 regulations. The innovative idea behind the device is to combine a first flush collection device with layered reactive filter media to form a first flush reactor and, thereby, capture and treat the most polluted portion of runoff from a catchment site.

SCOPE

The scope of the research reported in this study was restricted to testing the contaminant removal efficiency of various filter media used in a pilot-scale first flush reactor using stormwater samples collected from the I-10 elevated roadway section over City Park Lake in urban Baton Rouge, LA. The contaminants analyzed in the laboratory tests included total suspended solids (TSS), nutrients, fecal coliform bacteria, heavy metals, and hydrocarbons. Methods for design, construction, and maintenance of first flush reactor are also presented.

METHODOLOGY

This research included three specific tasks.

Task 1: Bench Scale Column Experiments with Continuous Influent

The research objective under this task was to test the performance of various filter media in removing different types of contaminants from linear transportation system runoff. To accomplish the objective, bench-scale column experiments

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were conducted under well-controlled laboratory conditions. Natural stormwater samples were collected using two coolers from the I-10 elevated roadway section over City Park Lake in urban Baton Rouge. Laboratory experiments were subsequently conducted using three columns with different combinations of filtering material layers. Influent (raw stormwater) and effluent (treated stormwater) samples were analyzed for conventional water quality parameters [(TSS, total nitrogen (TN), NO_2, NO_3, total kjeldahl nitrogen (TKN), total petroleum hydrocarbons (TPH), fecal coliform)] and heavy metals.

Task 2: Laboratory Testing of Pilot Scale First Flush Reactor with Intermittent Influent

The research objective under this task was to evaluate the performance of the first flush reactor optimized in Task 1 under conditions of intermittent loadings. The initial recoveries of the reactor after three dormant periods of 45 days, 50 days, and 56 days were studied by measuring effluent concentrations and subsequently determining contaminant removal efficiencies.

Task 3: Manual Preparation for Design and Construction and Maintenance of First Flush Reactor

The research objective under this task was to develop guidelines for field construction, operation, and maintenance of the first flush reactor to achieve the stormwater pollutant removal efficiency required in the MS4 program. The following guidelines are presented for the implementation of stormwater BMPs: (1) general description of MS4 regulations related to linear transportation systems, stormwater BMPs, and the first flush reactor; (2) stormwater treatment principles/mechanisms; (3) performance/reduction rate for each type of pollutants; (4) detailed design procedure for the first flush reactor; (5) construction requirements; (6) operation requirements; (7) maintenance requirements; and (8) cost estimation.

CONCLUSIONS

A novel first flush-based stormwater treatment device, first flush reactor (FFR), has been developed in this study for elevated linear transportation projects/roadways for complying with MS4 regulations. The FFR has the following features.

The passive first flush reactor is composed of (1) a first flush diverter for capturing the first flush and diverting subsequent runoff to downspout or stormwater drain by means of a floating ball, (2) multilayer reactive filter media, and (3) a reactor container with underdrain for holding reactive filter media and the first flush portion of stormwater runoff.

In terms of contaminant removal efficiency, the optimum filter medium combination determined based on the column tests consists of (1) the mixture of Smart Sponge and Hydra CX2 (top layer), (2) zerolite, (3) sand, (4) sawdust, and (5) gravel (bottom layer).

The current design of FFR is able to remove most contaminants, including TSS, nutrients, bacteria, and toxic metals. Specifically, a first flush reactor with optimized filter medium layers is able to remove over 85% of TSS, 90% of total phosphorus, 99% of NO_2-N and NO_3-N, and 70-90% of fecal coliform bacteria.

In general, removal rates of heavy metals through the recommended filter media are higher than 80%. The removal rates of three toxic heavy metals including cadmium (Cd), copper (Cu), and lead (Pb) are higher than 90%.

Hydrocarbon levels in the stormwater samples were too low to be detected. It is expected that the hydrocarbon removal rate of the FFR should be higher than 50%, meeting MS4 regulations.

RECOMMENDATIONS

A further study is needed to significantly increase the removal rates of TKN and the toxic metal zinc (Zn) in the first flush reactor by conducting additional column tests and possibly replacing Hydra CX2 with other types of fiber mulch.

It is recommended that a pilot-scale first flush reactor be constructed and installed at the I-10 roadway section at City Park Lake in urban Baton Rouge for field monitoring and demonstration.