Analysis of Bioretention Capabilities in Removing Microplastic Particles from Stormwater

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Highlights

- Providing experimental insights on the microplastic transport processes in bioretention systems.
- Evaluation of the effects of bioretention media characteristics, microplastic particle specifications, and stormwater parameters on microplastic removal efficiency.

Introduction

Due to the high rate of plastic production, a matter of recent global concern is microplastic (< 5 mm) particles (Alimi et al. 2018). These emerging environmental pollutants may enter into human bodies (even placentas of unborn babies) through eating food, drinking water, and breathing air and cause serious health issues (Carrington 2020). For example, Americans eat and inhale over 70,000 microplastics (MPs) each year (Oaklander 2019). Currently, MPs are present in waters bodies ubiquitously (from rivers to oceans and even polar areas) (Ross et al. 2021). Since the removal of MPs in the environment is challenging, an efficient way for the environment protection from these dangerous pollutants is to sequester them from land-based stormwater before entering to water bodies.

One of the most popular Best Management Practices (BMPs) across the world is bioretention (Davis Allen et al. 2009), which has shown its capability in removing various stormwater pollutants like oil & grease, nutrients, and heavy metals (Davis Allen 2008). However, the bioretention performance in removing microplastics (MPs) and the possible interaction between MP particles and other co-contaminants are highly unknown. While a field study has recently reported the promising results on the general effectiveness of a bioretention cell in filtering out MPs (Smyth et al. 2021), researchers are now facing several research questions within this area, such as the removal efficiency of nano-sized plastic particles (a.k.a. nanoplastics that are smaller than 100 µm), potential impacts of stormwater co-contaminants, etc. Our current research plans to develop the first bioretention design that can effectively sequester stormwater MPs through understanding the transport processes of MP particles in bioretention systems.

Methodology

As shown in Figure 1, a glass column of bioretention system is implemented with 4" diameter, 12" maximum ponding height, 18-24" filter media height, and 3" drainage layer. The filter media consists of 70-85% washed sand and 15-30% compost by volume while unique particle size distributions (PSD) are created for the filter media by conducting a sieve analysis (ASTM C136).

The study uses synthetic stormwater that can mimic the real stormwater closely. Flow rates are determined using Rational Method by considering runoff coefficient C = 0.9 while 24-hour storm rainfall amounts are considered in the tests (Li and Davis Allen 2008).

We conduct the experiments for various sizes of MP and soil filter particles. We assess the MP concentration by measuring the fluorescence of water samples (DeNovix DS-11 FX+ M/C/F technology) and comparing the fluorescence signal with a calibration curve. To measure baseline binding of MPs (with and without co-contaminants) to the column wall, we use blank samples in the column without soil media.

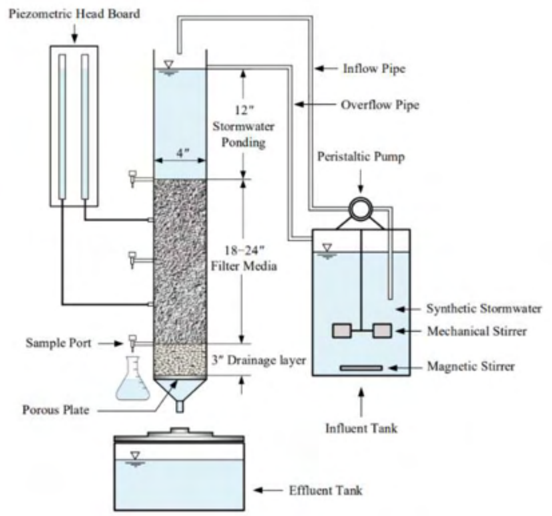

Figure 1. Experimental Setup

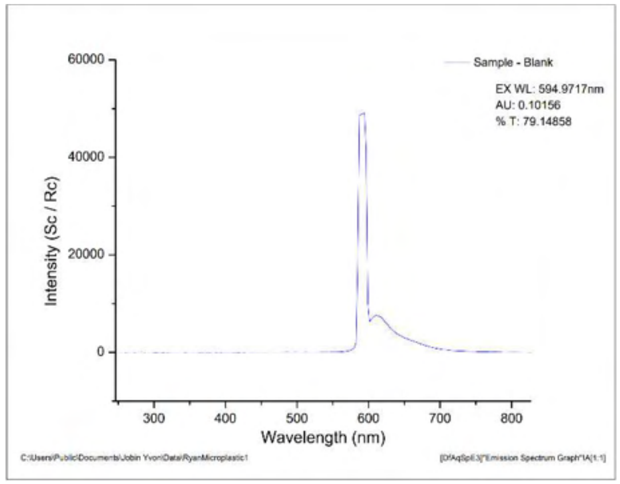

Figure 2. Emission Spectrum Graph Used for Calibration Curve

Design of Experiments

Design of Experiments (DoE) may have various purposes including screening potential parameters, evaluating main effects of parameters and their interactions, regression model extraction, and response optimization. In this study, we will primarily focus on screening a high number of potential parameters, of which 4 are essential for new research areas to avoid collecting a large amount of data on relatively insignificant parameters. The screening design is designed based on one-factor-at-a-time (OFAT) methodology that requires a reasonable number of experiments (Frey et al. 2003, Zhang 2007). OFAT can also determine the main effects of parameters (providing a fair evaluation on screened parameters) compared to pure-screening designs like Plackett-Burman (Liu Tang 2010). The parameters are mainly arranged in three levels to determine their main effects on the MP removal efficiency of a bioretention. The repetitive tests for data uncertainty determination are bolded and shown in blue. It is worth noting that the experimental setup has a 1:1 scale, and thus our results can be directly extended to real-world prototypes without any possible scale effects (Sangsefidi et al. 2018).

Results and discussion

Preliminary results demonstrate the ability to detect MP particles using emission fluorometry technology. Figure 2 provides an example of an emission spectrum graph for a known concentration of MP particles. The combination of known concentrations and emission spectrum intensities are used to establish a calibration curve.

Conclusions and future work

The detection of MP particles via fluorometry is established as a reliable method for determining MP concentrations in storm water. Ongoing experiments are now in progress to give insight on the transport process of soil media and assess the effectiveness of bioretention in sequestering microplastics.

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