Flocculation and membrane filtration of stormwater - Laboratory experiments

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Abstract: Stormwater run-off from for example industrial areas as well as roads with heavy traffic may contain considerable amounts of pollutants. Run-off from these areas may require special treatment to fully comply with existing environmental regulations and safeguard the receiving water bodies. In this study, flocculation and membrane filtration are tested to evaluate their efficacy in removing heavy metals, mineral oil and particles from stormwater run-off. The experiments will be carried out at laboratory scale using synthetic stormwater.

Keywords: particle removal; flocculants, membrane filtration

Introduction

Increasing urbanisation and a higher volume of vehicular traffic the past decades have resulted in stormwater becoming an important pollution source to control in order to safeguard the nearby receiving waters and their ecosystems. A high concentration of pollutants can be found in stormwater runoff from industrial areas and high-traffic roads and highways. In areas with greater exposure to pollutants, such as industrial areas and highways, extra treatment measures should be considered (Aryal et al. 2010). Flocculation and membrane filtration, combined as a single system or separate, may be considered as viable treatment options for heavily polluted stormwater. Both methods have great potential to decrease sediment and pollutant concentrations and are both used to various degrees in wastewater treatment and drinking water production.

Several flocculants (e.g. aluminium salts, ferric chloride, poly acrylamide, chitosan and others) have been previously tested on a diversity of matrices (detention ponds, lamellar clarifiers, channel run-offs, retained stormwater) to varying degrees of success (Heinzmann, 1994; Wood et al. 2005; Johir et al. 2009; Isteniç et al. 2012; Nielsen et al. 2015).

Membrane filtration is a common technique for industrial water and wastewater but few studies have employed it for stormwater treatment (Kus et al. 2012; Perov et al. 2014). The results are promising but further research needs to be conducted to investigate the effectiveness of different membrane types and the importance of stormwater quality. There also exists commercially available filtration devices including sorption media specifically designed for stormwater treatment on the market; one example would be the StormFilter

cartridge from Contech which houses a filter media customised to remove targeted pollutants (eg. total phosphorus or oils).

This study aims at investigating the efficiency of flocculation and membrane filtration treatment methods for heavily polluted stormwater and is conducted in laboratory scale with the use of a synthetic stormwater.

Material and Methods

Quality changes in synthetic stormwater over time

A synthetic stormwater was prepared consisting of pre-sieved stormwater sediment from a stormwater sedimentation basin south of Stockholm mixed together with tap water adjusted to a target TSS level of 165 mg L^{-1}. To achieve contaminant concentrations common in heavily polluted stormwater, the sediment mixture was amended with dissolved metals to target concentrations of 1.05 mg Cd L^{-1}, 16 mg Cr L^{-1}, 70 mg Cu L^{-1}, 0.28 mg Hg L^{-1}, 12 mg Ni L^{-1}, 26 mg Pb L^{-1} and 400 mg Zn L^{-1}. Prior to the use of the synthetic stormwater for the laboratory experiments, a pre-study was carried out to investigate possible changes in quality of the synthetic stormwater over a time period of one week. The experiment aimed to elucidate the stability of constituent concentrations over time. The synthetic stormwater mixture was placed in a tank and continuously stirred, samples were taken on days 1, 2, 3, 5, 8, 11 and analysed with respect to oil, total and dissolved polycyclic aromatic hydrocarbons (PAH), total organic carbon (TOC), dissolved organic carbon (DOC), total and dissolved metals, particle size analysis, pH, conductivity and total suspended solids (TSS).

Experimental design and set-up

The two treatment methods, flocculation and membrane filtration, will be evaluated using a developed synthetic stormwater (described in 2.1 and 3.1). Pollutant concentrations (Cd, Pb, Hg, Ni, Cu, Zn, Cr, mineral oil and PAH) and physical water properties (pH, turbidity, conductivity and particle size distribution) will be analysed pre and post treatment to investigate the removal efficacy of the methods.

Flocculation

Several coagulants, including polyferric chloride, polyaluminium chloride, cationic and anionic polyacrylamide, water glass (sodium silicate), sodium alginate and guar gum will be tested in a jar test and evaluated with regard to the parameters mentioned above and the floc formulation time response. The jar tests are carried out in 1000 mL beakers with synthetic stormwater. When the coagulant is added, fast stirring is applied for 1 minute, as suggested by (Bratby, 1980). After this period, the stirrers are set to low speed for c. 14 min. The aggregate will then be allowed to settle in the jars for 15 to 30 min. A pre-test will be carried out to screen the above coagulants and find the three most effective ones. In the pre-test, TSS will be measured in the supernatants to facilitate a simple evaluation. In the main experiment, the effects of different coagulant dosing, coagulant type and temperature on the reduction of TSS, turbidity, conductivity, heavy metals, and PAH are tested in a 2^2 factorial design with centre points.

Membrane filtration

Two types of filters with differing pore sizes and filtration modes will be evaluated, one hydrophilic ultrafiltration membrane with a pore size of 20 nm and one membrane at the edge between ultra- and nanofiltration.

Results and Conclusions

Results from the pre-study on quality changes in synthetic stormwater over time

No major property changes of the synthetic stormwater could be observed during the sampling period. Figures 1 and 2 present the variation of the parameters total suspended solids, turbidity and total metal concentrations during the investigation period. The sharp increase at sampling day 8 observed for all parameters (Fig. 1 and Fig. 2) can be attributed to an accumulation of sediment in the collection outlet.

There exist minor reservations, not presented in data here that need to be considered before continuing the flocculation and membrane filtration experiments. A particle size distribution measurement recorded no particles with a diameter <2 μm, and concentrations of PAH were comparably low to other records. The synthetic stormwater may need a fraction of small particles added as well as PAH to better correspond to a real stormwater.

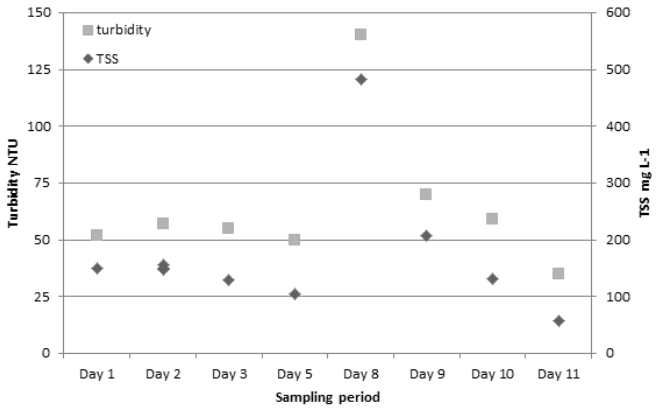

Figure 1 Turbidity and concentration of total suspended solids (TSS) in synthetic stormwater. Sampling on day 2 was carried out in triplicate to study sample variation

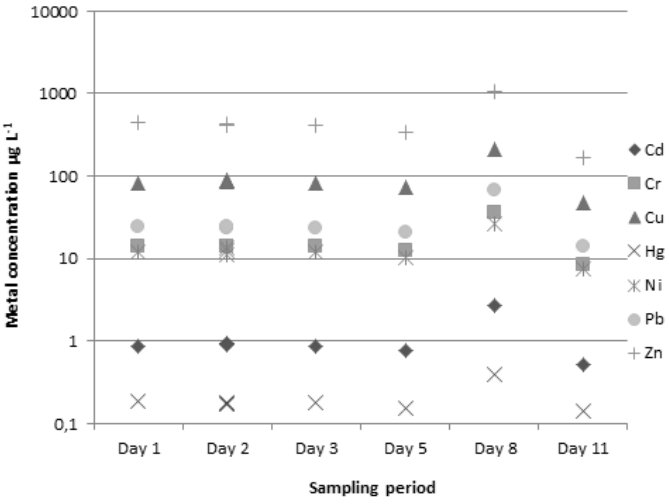

Figure 2 Total metal concentrations in synthetic stormwater. Sampling on day 2 was carried out in triplicate to

study sample variation.

Impact of results

The results from studying the treatment effects from the flocculation and filtration methods will serve as a base for further research into advanced treatment methods of stormwater specifically designed for highly polluted areas such as industrial areas and roads with heavy traffic. In particular, dose-response curves from different flocculants can be used to select proper flocculation chemicals to optimise the treatment. Insight on how different types of filter perform in regard to reduction of filtrate colloid concentration is also necessary for proper decision making in selecting any additional treatment method. In addition, combinations of these treatment methods can be further evaluated and may be considered for extremely polluted stormwater.

By identifying viable treatment options for highly polluted stormwater it is possible to further innovate and find possible solutions that will work in practice and on-site in the urban environment.

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