Water quality performance of road runoff biofilters : retention of particulate and dissolved phase micropollutants

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Thème : 4.1 Storm water controls and BMPs, LID, SUDS and WSUD

Summary

In order to study the treatment efficiency of a vegetative filter strip and a biofiltration swale, outlet event mean concentrations are compared with those in untreated road runoff for trace metals and organic micropollutants (polycyclic aromatic hydrocarbons, alkylphenols, bisphenol-A, phthalates), distinguishing between the particulate and dissolved phases. While particulate pollutants were generally well removed, leading to a good removal of total pollutants, performance was often poor for dissolved pollutants.

Introduction

As awareness of the chronic contamination of road runoff by suspended solids, metals, nutrients and various organic micropollutants (Markiewicz et al., 2017) has grown, so has interest in strategies for its treatment. Notably, various soil-based, vegetated sustainable urban drainage systems (SUDS) are designed to reduce pollutant loads reaching water bodies (CIRIA, 2015). While studies have shown such systems to be effective in reducing macropollutants and trace metals, relatively few have addressed the retention organic micropollutants or distinguished between the dissolved and particulate phases, for which retention processes are different (LeFevre et al., 2014).

The present study seeks to characterize the in situ water quality improvement achieved by filtration of road runoff through the media of two soil-based SUDS for the particulate and dissolved phases of a wide range of macropollutants and micropollutants.

Materials and Methods

Site Description:

The study site includes a vegetative filter strip (VFS) and a biofiltration swale (BFS), both of which drain water from the RD 212, a highway located in Compans, France in the Paris region. At both of these sites, water is collected from a drain beneath the filter media (a sandy loam) at a depth of 15 and 50 cm, respectively. Water quality is compared to untreated road runoff (RR) collected at another section of the same road (Fig. 1).

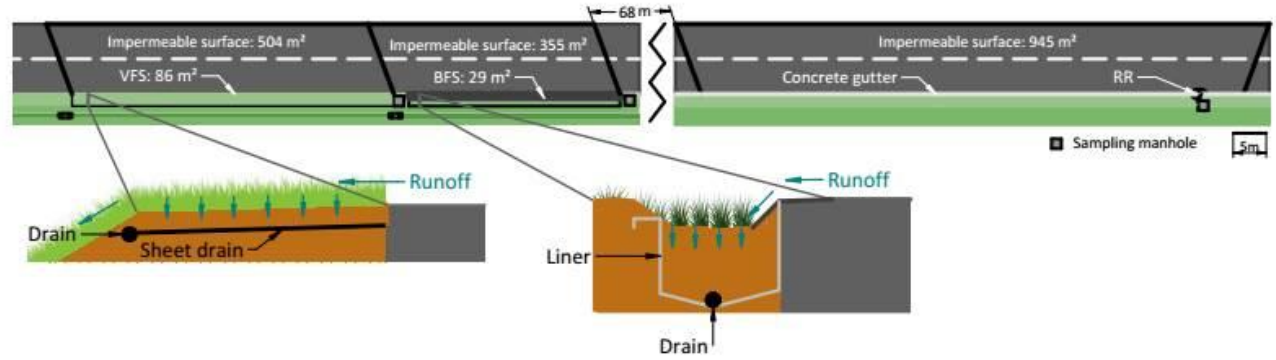

Fig. 1: The Compans experimental site

Sampling and analysis:

Water is collected in proportion to flow volume in order to achieve an event mean concentration (EMC). Sampling began in February 2016 for VFS and RR and in May 2016 for BFS; 12 events have been sampled thus far. While simultaneous sampling of all points was attempted, different starting dates and technical difficulties mean that not all data is paired. Samples are collected within 24h of each rain event and sent to partner laboratories within 24h of collection where they are immediately filtered to distinguish between dissolved and particulate phases. They are analyzed for pH, conductivity, turbidity, suspended solids (TSS), organic carbon, nutrients, 13 trace metals, 9 major ions, total hydrocarbons, 19 polycyclic aromatic hydrocarbons (PAH), bisphenol-A (BPA), 7 alkylphenols and 12 phthalates.

Results and Discussions

Metals were found to be largely particulate in RR (medians of 95, 93 and 99% for Zn, Cu and Pb). Total EMCs in treated water were both much lower and less variable than those in found in RR (Fig. 2 a-c). However, retention of dissolved pollutants seems to be much less effective (Fig. 2 d-f). Indeed, dissolved VFS EMCs were often found to be higher than paired RR EMCs, indicating that the filter is actually leaching rather than retaining dissolved metals. BFS, a newer system (constructed in March 2016 v. September 2012 for VFS) with a greater media depth, does not show this effect. Total EMC reductions are thus driven by the retention of particulate pollutants.

Three PAHs were quantified at RR in both the particulate and dissolved phases for all events: Fluoranthene (Fluo), Pyrene (Pyr) and Phenanthrene (Phen). These contaminants are all mainly particulate in RR (97, 96 and 91% respectively), and total EMCs are found to decrease significantly in VFS and BFS (Fig. 3, a-c). VFS effectively reduces dissolved PAH EMCs (Fig. 3 d-f), though our evaluation is limited by the limit of quantification (LOQ). However, while BFS seems to retain Phen, both Fluo and Pyr EMCs increase drastically, likely due to leaching from construction materials, a hypothesis supported by decreases in these concentrations over time.

BPA, a more hydrophilic molecule, was found to be well retained in the dissolved fraction, with a reduction in median EMCs of 85% for VFS and 60% for BFS from those at RR (Fig. 4). Particulate analyses are in progress.

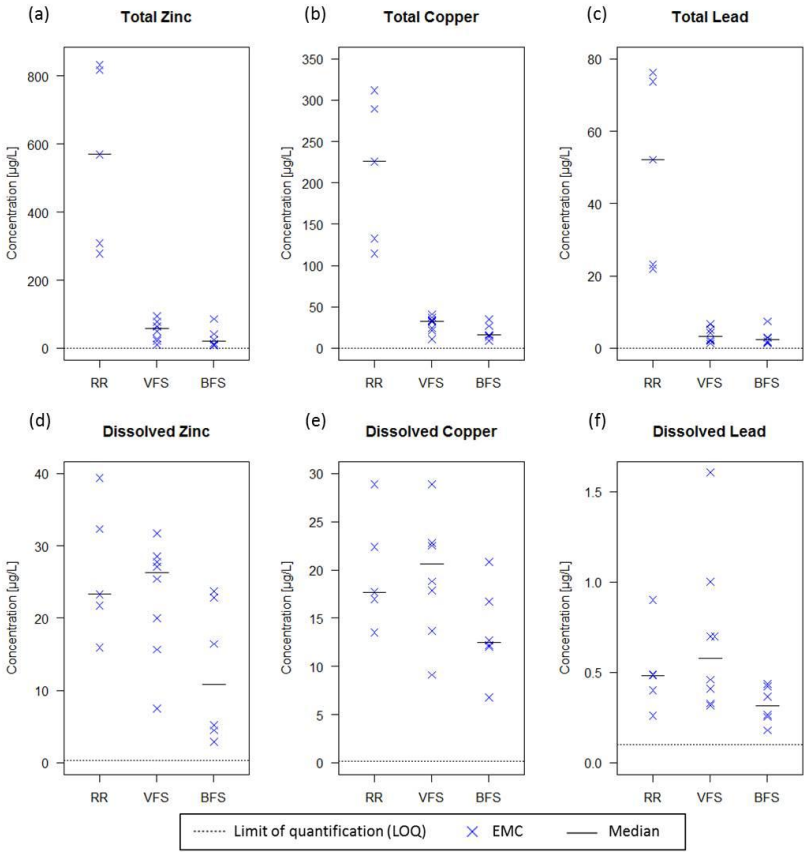

Fig. 2: Heavy metal event mean concentrations (EMCs)

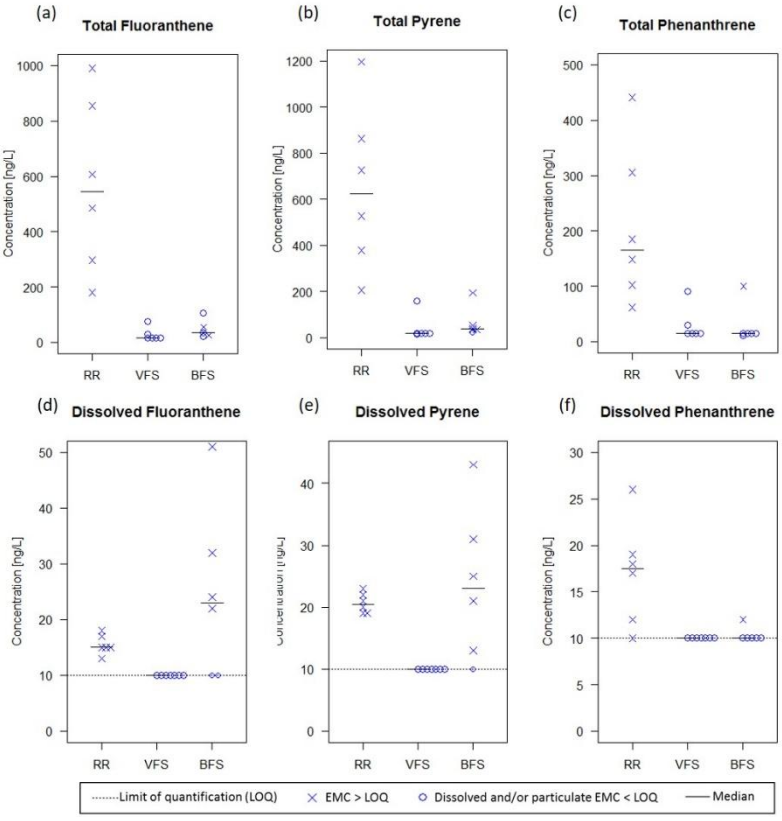

Fig. 3: Polycyclic aromatic hydrocarbon (PAH) event mean concentrations (EMCs)

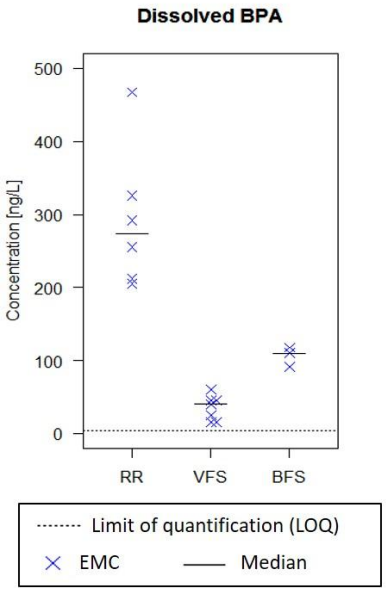

Fig. 4: Bisphenol-A (BPA) dissolved event mean concentrations (EMCs)

Conclusions

EMCs of various pollutants were studied in road runoff and following filtration through the soil of a vegetative filter strip and a biofiltration swale. Both systems were found to be very effective for the mechanical filtration of particulate pollutants, which translated to greatly improved water quality in terms of total concentrations for the pollutants studied. However, retention of the dissolved fraction was less efficient, despite the fact that laboratory batch tests have shown the ability of the media to sorb both metallic and organic pollutants. Indeed, dissolved concentrations sometimes increased at the outlet, due to leaching from the accumulated stock of contaminated particles or from construction materials. Future work will seek to better understand the retention and fate processes of each pollutant through the use of a mathematical model and to establish long-term mass balances by combining water quality data with hydrologic and soil quality measurements.

Acknowledgments

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