

Can the deficit of epuration performance of stormwater management systems for trace metals be explained by colloidal particulate fractions?

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Highlights

- Size fractionation of runoff waters for investigation of colloidal particles between]8 µm; 5 kDa]
- Settling of particulate fractions (>8 µm) of Cu, Zn, Ni and Pb in surface water
- But colloidal fraction, along with dissolved fractions contribute to purification deficit of SUDS

Introduction

Transportation, especially road transport, is the main French source of copper air emissions (92% of copper total emissions) (CITEPA, 2019). The major contributor to these emissions is brake pad wear (Weckwerth 2001; Figi et al. 2010; Hagino et al. 2016). The contaminant emitted and deposited on road surfaces is then leached by stormwater runoff which is considered like a non-point source of contamination to receiving waters. Sustainable urban drainage systems (SUDS) collect runoff waters not only to reduce instantaneous pressure on urban watersheds due to high imperviousness but also to store contaminants carried by these runoffs. However, the epuration performance of SUDS for copper was shown to be low in some studies in Nantes metropolis. The knowledge of partitioning of trace metals load discharge from the stormwater system is important to its performance epuration evaluation (Tuccillo 2006; Béchet et al. 2009; Wikström and Österlund 2016; Lange et al. 2020; Lindfors et al. 2021). This study is carried out to evaluate if the presence of trace metal in the overflowing water from a stormwater management system can be explained by its distribution among dissolved, colloidal and particulate fractions.

Methodology

Study site

The experimental site is a retention-infiltration basin collecting runoff waters of the south part of the Cheviré bridge in Nantes, France. The average daily traffic counts on this bridge section during study period were 86 710 vehicles and the total bridge drainage area was 20 639.4 m². The runoff water was sampled at the concrete inlet of the basin, with an automatic sampler to take samples every 15 or 30 minutes according to the expected duration of a rain event. Surface waters and infiltration waters were sampled 48 hours after the rain events, in 3 zones of the basin: entry, middle and exit. The infiltration water sampling was carried out through mini-piezometers of 40 mm in diameter, installed at 75 cm depth of the basin substrate with 30 cm slotted. The basin with water and sediment compartments is described in Figure 1.

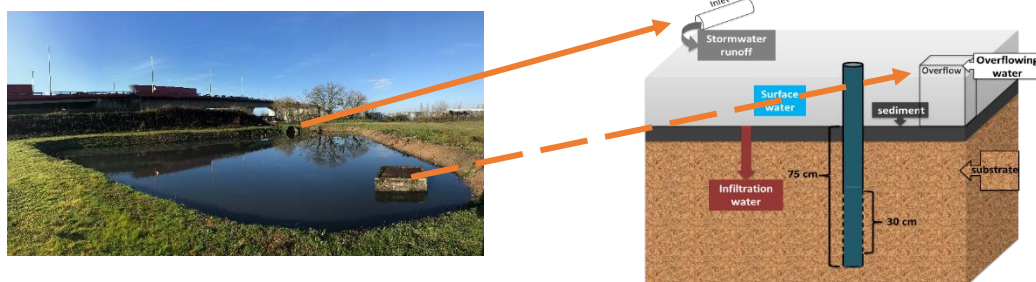


Figure 1. Cheviré study site (left). Water and sediment compartments in the basin (right).

Analyses

The physico-chemical characteristics (pH, conductivity, suspended matter) of every sample were measured on site or at laboratory. Total concentrations of major elements (Al, Fe, K, Mg, Na, P, Ca) and trace metals (Cu, Zn, Ni, Pb, Cr) in each sample were obtained by filtration through a 0.45 μm pore size membrane and by combination of analyses of filters and filtrates. The total organic carbon (TOC) of raw samples and the concentration of anions in the filtrates were also analysed. Major and trace element concentrations were determined by inductively coupled plasma-mass spectrometry and optical emission spectrometry (ICP-MS and ICP-OES).

Size fractionation

To characterize the distribution of elements between particulate, colloidal and dissolved fractions, size fractionations were implemented for runoff water, surface water and infiltration water by using filtration and ultrafiltration series. The upper size limit of aquatic colloids is defined to be around 10 μm (Buffle and Leppard 1995; Tranvik and von Wachenfeldt 2014). The lower limit is considered to be 5 kDa referred to the limit between dissolved species and very small natural organic colloids (Béchet et al. 2009). The fraction cut-offs used were defined by millipore nitrocellulose membranes with 8, 1.2 and 0.45 μm pore sizes for filtration and biomax polyethersulfone membranes with molecular weight 5 kDa for ultrafiltration. Therefore, five fractions were obtained for element analyses: $] ; 8 \mu\text{m}]$ correspond to particulate form, $]8 \mu\text{m}; 1.2 \mu\text{m}]$, $]1.2 \mu\text{m}; 0.45 \mu\text{m}]$, $]0.45 \mu\text{m}; 5 \text{ kDa}]$ correspond to colloidal form and $]5 \text{ kDa}; [$ to dissolved form. Among 8 campaigns of size fractionation (between June 2020 and February 2021) for runoff, surface and infiltration water, duplicate analysis has been applied on 10 samples of runoff water and 3 of surface and infiltration water.

Results and discussion

Total concentrations of copper in different types of waters in the studied basin are presented in Figure 2 with the mean value obtained from sampling campaigns for runoff water, surface water and infiltration water. The total concentrations were higher in runoff water than surface and infiltration water for Cu and Zn while the total concentration of Ni and Cr in infiltration water was higher than runoff and surface water. Among the 3 types of water, the concentration of trace metals in surface water was found to be the lowest.

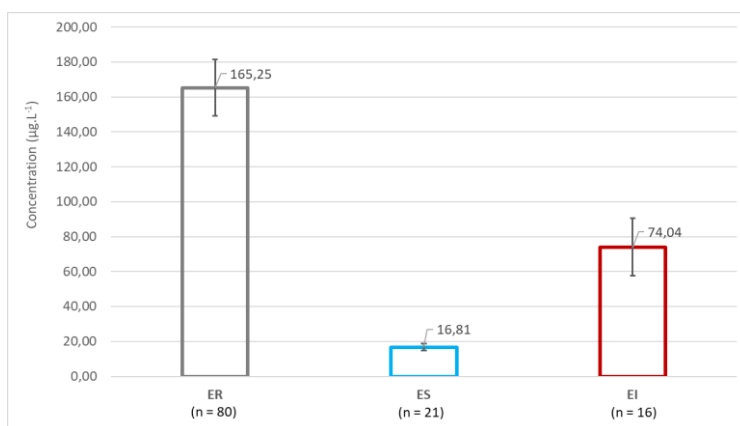


Figure 2. Mean total concentrations of copper in runoff water (ER), surface water (ES) and infiltration water (EI)

Size fractionation of copper is shown in Figure 3. Trace metals were predominantly associated with particles higher than 8 μm in runoff and infiltration water. In surface water (ES), colloidal and dissolved form were mainly represented in the distribution of Cu, Zn, Ni and Pb whereas Cr was present mainly as particulate form. Cu and Zn have the same distribution patterns in runoff, surface and infiltration water with around 50% of colloidal-bound copper in surface water.

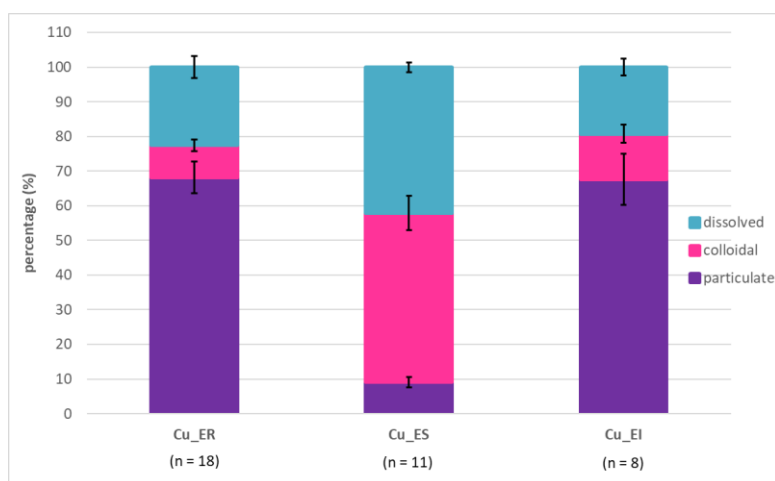


Figure 3. Distribution of copper in the particulate, colloidal and dissolved fractions in runoff water (ER), surface water (ES) and infiltration water (EI).

Conclusions and future work

Trace elements were present mainly in particulate form in runoff and infiltration water. The decrease of particulate form of trace elements in surface water shows the effect of the retention of these elements in stormwater management structure by the process of sedimentation in the basin. However, a high content of mobile trace elements (dissolved and colloidal fractions) observed in surface water stay available for living organisms in case of overflowing into receiving waters. To assess the environmental impact, characterization of chemical speciation of trace metals in surface water need to be carried out, for example lability studies by diffusive gradients in thin films.

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