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Publication date:
2021

Document Version
Peer reviewed version

Citation (APA):
Favarin, M., Bertuzzo , E., Biondi, S., Sambo, F., Knudsen, I. M., Mikkelsen, P. S., Nielsen, K., & Vezzaro, L. (2021). *Testing a combined monitoring-modelling approach for quantifying micropollutant loads from separate stormwater systems*. Abstract from 15th International Conference on Urban Drainage.

Testing a combined monitoring-modelling approach for quantifying micropollutant loads from separate stormwater systems

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Highlights

- Data from online sensors and passive sampler are combined with mathematical models.
- The combined monitoring approach has been tested in Denmark and Italy.
- Monitoring creates a huge database on stormwater quality to assess impacts.

Introduction

Reducing pollutant emissions from separate stormwater systems require a solid data background on the pollutant occurrence and the released fluxes at the catchment scale. However, stormwater quality at a single discharge point is characterized by a high inherent variability, driven by the intensity of the rain, and by the high variability of pollutant sources in the upstream catchment (for a review, see the overview in Müller et al., 2019).

Stormwater carries a wide range of micropollutants (e.g. heavy metals, PAH, etc.) which can negatively affect the chemical and environmental status of the receiving water body. Measuring these substances with traditional sampling approaches (e.g. autosamplers) and collecting a sufficient number of data to represent their variability in stormwater discharge, is a challenging task both financially and logistically. Birch et al. (2013a) presented a novel monitoring approach, combining (a) high-time resolution data (from online sensors monitoring traditional indicators such as flow and turbidity), (b) passive chemical sampler (monitoring micropollutants) and (c) dynamic mathematical models. This approach has now been extended to two pilot sites, one located in Copenhagen (Denmark, 2019/2020) and one in Venice (Italy, 2020/2021), The aim of this study is to test an improved version of the passive samplers and combine the results with sensor data, to quantify micropollutant emissions from separate systems.

Methodology

Improved combined monitoring approach

The studies performed by Birch et al. (2013a,b) relied on Sorbisense velocity-dependant samplers, which can measure different range of pollutants commonly present in stormwater (e.g. heavy metals, PAH, PFAS and VOC) by using different sorbent media (Figure 1a). The new installation setup ensures easier field installation and does not need a permanent water level above the sampler. This studies specifically targeted heavy metals (Cd, Cu, Cr, Hg, Ni, Pb, Zn), as they were expected to be the dominant pollutants in both monitored catchments. The passive samplers allow long sampling campaigns over several rainfall events, and detection of low pollutant concentrations. As the installation of Sorbisense allows for velocity dependant sampling, this enables an easier quantification of micropollutants fluxes compared to sampler based on simple adsorption (Birth, 2013).

The other elements of the combined monitoring approach include water level and quality sensors providing high-time resolution data (1-10 min resolution): water pressure sensors, and a multiparametric probe (measuring pH, turbidity, electrical conductivity and temperature), respectively. These high-resolution data provide information on the dynamics of the stormwater discharges. The data are then combined with the measurements from the passive samplers through a dynamic stormwater quality model, allowing the estimation of the micropollutant fluxes in the monitored flows.

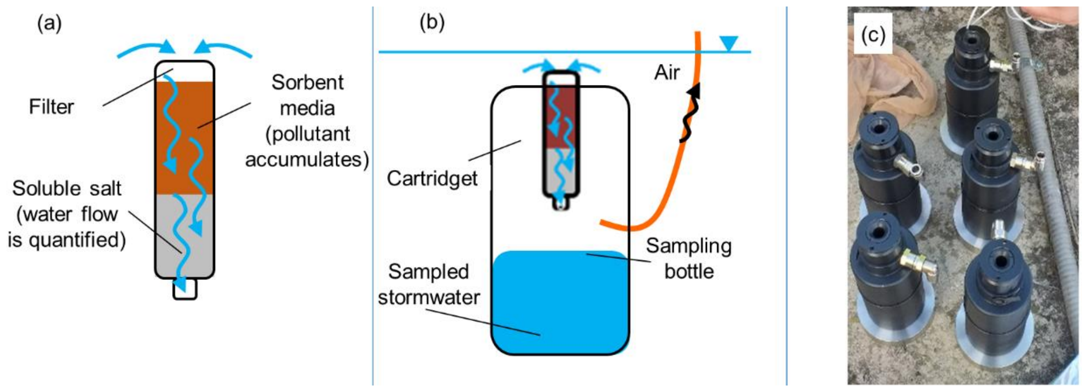

Figure 1. Schematization of the Sorbisense passive sampler cartridge (a), installation of passive sampler in sample bottle (b), and example of several sampling bottles before installation in the Italian case study (c).

Catchment characterization and setup installation

A similar monitoring setup was applied in the two locations, which are characterized by different pollutant sources. In the Danish case, the catchment (1 ha) is located in the historical city centre of Copenhagen, where road and roofs runoff is normally conveyed to the combined sewer. During intense rainfall events, the stormwater runoff is diverted directly to the harbour and when the combined sewers reach maximum capacity these too will discharge to the harbour. The catchment is characterized by light traffic roads, apartment buildings and commercial activities, with building material and metallic roof representing the major source of pollutants. The Italian case (0,5 ha) is located along a high traffic highway (Passante di Mestre, 71000 vehicles/day), where runoff is treated with adsorption filters and then discharged to the Venice lagoon. A schematization of the monitoring setup in the two site is shown in Figure 2: in the Danish case the passive samplers are located at two different levels (to monitor the two discharge fluxes going to the combined system and to the harbour, respectively), while in the Italian case the samplers are located before and after the stormwater filtration systems (to allow the estimation of the filter removal efficiency). The monitoring campaigns were carried out from summer 2019 to autumn 2020 in Copenhagen and from January to October 2021 in Venice.

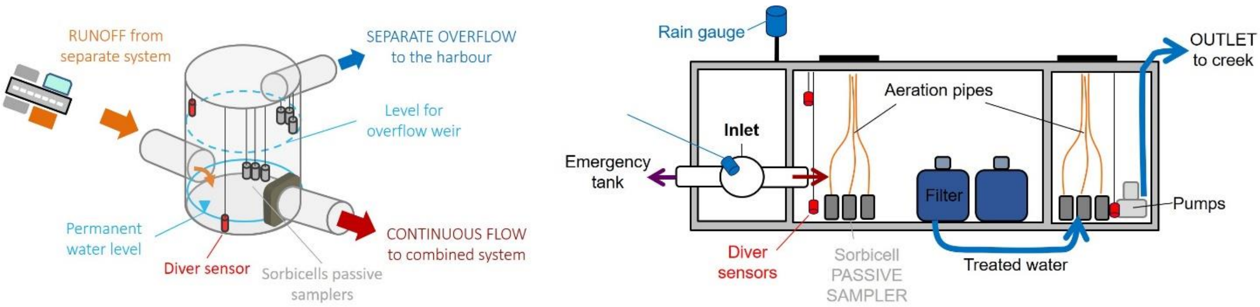

Figure 2. Schematic setup of the case study in Denmark (left) and in Italy (right).

Results and discussion

Figure 3 shows some of the data collected during the monitoring campaign in Copenhagen. The high-resolution data (Figure 3a) show the dynamic behaviour of the monitored systems, displaying the variation in the water quality and water level indicators as consequence of rainfall events. The results from the passive samplers (Figure 3 b,c) highlight the inter-event variability in the concentrations of discharged pollutants. The current data background is currently too small to draw solid conclusions on the different quality of the two monitored fluxes in Copenhagen, or on the performance of the filter system in Venice. The analysis of Sorbisense triplicates generally show good precision, stressing the robustness of this monitoring approach.

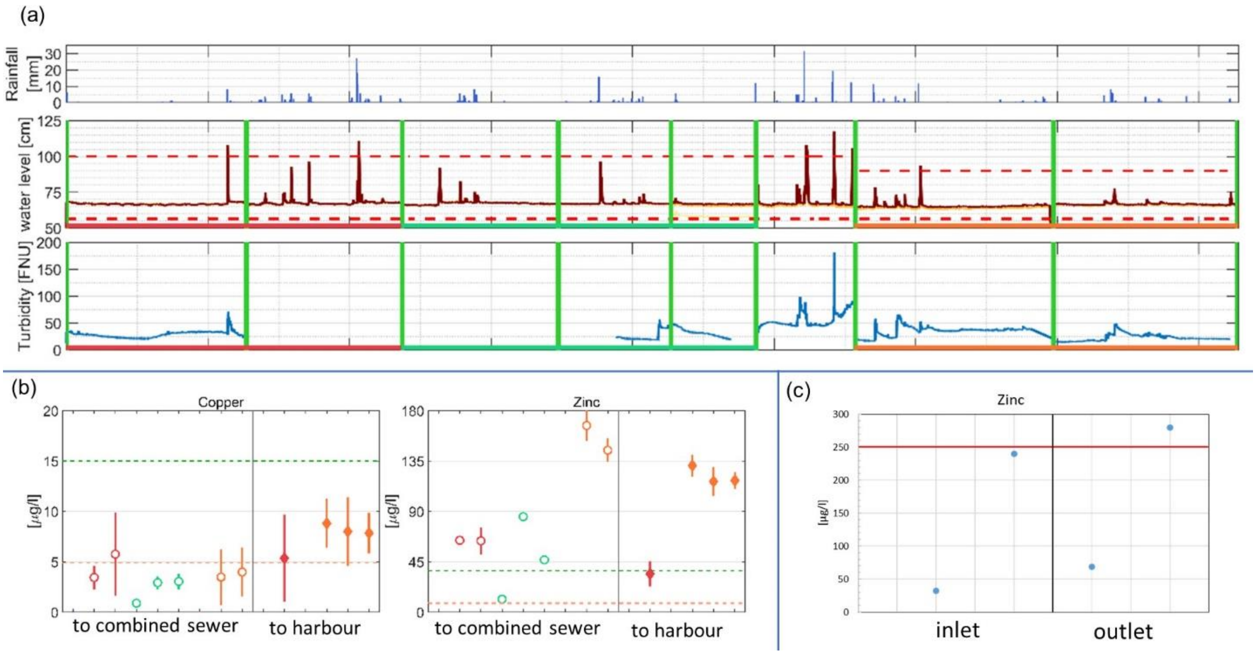

Figure 3. (a) high resolution data from Copenhagen: rainfall intensity, water level and turbidity. Horizontal colour bars show the time intervals when different Sorbisense cartridges were installed, horizontal red lines show the two installation level of Sorbisense cartrigdes, while vertical green line show sensor maintenance; (b) results (mean plus/minus standard deviation based on triplicates) from passive samplers for Cu and Zn (horizontal green and orange lines show acute and chronic Environmental Quality Standards, respectively); (c) results from passive sampler in Venice (red line represent the Italian legislation limit).

Conclusions and future work

The first results from the two monitoring campaigns suggest that the improved combined monitoring approach (combination of passive samplers with high-resolution sensors) can represent a cost-effective alternative for monitoring micropollutant fluxes in stormwater discharges, compared to autosamplers. Moreover, it requires limited installation efforts compared to traditional monitoring techniques.

Future research activities include the integration of the collected data (both high-resolution and average concentrations from the passive samplers) with a dynamic stormwater quality model, (i.e. model parameters will be estimated by using the collected data). By using historical rainfall data as input to the calibrated model, it will be possible to predict pollutant loads and environmental impact in the future for the two monitored systems. Indeed, stormwater quality models can be used as an integrated part of a monitoring strategy, providing information regarding the analysed system beyond the time interval of the sampling campaign.

Overall, the proposed monitoring approach will facilitate an easier and wider collection of data on micropollutants discharged by stormwater systems, enabling a growing knowledge on their impacts, and allowing the development of effective pollution control strategies.

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