Are different catchment areas at one heavily trafficked road comparable as monitoring sites for stormwater quality improvement devices?

Différents tronçons d'une même route à fort trafic constituent-ils des sites d'étude comparables pour le suivi d'ouvrages de traitement des eaux pluviales?

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RÉSUMÉ

Il est généralement admis que les essais *in situ* font partie des approches les plus appropriées pour étudier des ouvrages de traitement des eaux pluviales soumis à des conditions réelles. Cet article présente les résultats d'une campagne de mesures menée sur 12 mois, au niveau de trois tronçons d'une route urbaine à fort trafic, chacun alimentant un ouvrage de traitement différent ; l'objectif de l'étude est d'analyser la comparabilité de ces trois sites. Les trois sous-bassins versants sont peu espacés les uns des autres, et sont soumis à des conditions aux limites comparables. La distribution des matières en suspension (MES) dans les eaux de ruissellement est dominée par la fraction fine (< 63 µm), qui représente 83% (en médiane) des MES sur les 3 sites étudiés. Sur l'un des trois sous-bassins versants, les concentrations en cuivre, zinc et MES présentent des distributions significativement moins dispersées que sur les deux autres. Les données montrent que même à l'intérieur d'une zone peu étendue, les flux de contaminants sont susceptibles de varier spatialement ; cela peut jouer sur la comparabilité des résultats de mesures *in situ*, même si celles-ci sont acquises dans des conditions très similaires. La raison principale d'une telle observation réside dans des différences de comportement hydraulique entre les trois sous-bassins versants: sur l'un d'entre eux, le débit médian à l'exutoire était environ 2 à 3 fois supérieur à celui des deux autres.

ABSTRACT

Field tests of stormwater quality improvement devices (SQIDs) are widely accepted for representing real conditions in the most appropriate way. This study presents the data analysis of a 12-month monitoring campaign of three catchment areas at a heavily trafficked urban road as influent of three SQIDs to analyze the comparability of these sites. All three catchment areas are located next to each other and the boundary conditions are comparable. In the runoff of all three sites mainly fine suspended solids (SS63) were found as a fraction of 83% (median) of the total suspended solids (TSS). One of the three catchment areas showed a distinctively narrower distribution of copper, zinc and TSS concentrations in the road runoff compared to the others. The present data indicate that even within a small area, the contaminant loads differ, which could influence the comparability of field test results, even under very comparable test site conditions. Main reason for this is that due to different flow patterns in the catchment areas the hydraulic characteristics differed. One of the catchment areas exhibited an approximately 2 to 3 times higher discharge rate (median) than the other two catchment areas.

KEYWORDS

Road runoff, traffic area runoff, monitoring, TSS, heavy metals, hydraulic characteristics

1 INTRODUCTION

Stormwater quality improvement devices (SQIDs) are currently assessed based on lab-scale, full-scale experiments and full-scale field tests (Lucke et al., 2017). Field tests are widely accepted for being closest to reality. However, most SQIDs are tested at different locations and under various boundary conditions. This raises the question of how comparable field tests can be.

Currently we are monitoring three SQIDs at the same sampling location. This approach promises highest comparability of the treatment efficiencies of the tested SQIDs. After 12 months of operation, it is cognizable that the hydraulic characteristics and contaminant loads of the three catchment areas differ, even under very similar boundary conditions. The aim of this study was to analyze the variance and the impact factors on the contaminants by using measured hydraulic and contaminant concentrations data. Based on that knowledge limitations of field tests, using the best practice, were illustrated.

2 MATERIAL AND METHODS

2.1 Sampling Location

To investigate the contamination of road runoff and the treatment efficiency of SQIDs under equal conditions, we installed three different SQIDs at a heavily trafficked road in Munich, Germany. Because this study is focusing on road runoff, respectively influent to SQIDs, the SQIDs do not need to be further specified. Subsequently, the different catchment areas were named: F, H and M. In consideration of the different designs of the SQIDs, different catchment areas are attached to the SQIDs (A: 1600 m², B: 473 m², C: 100 m²). Two traffic lanes, one accelerating lane and one emergency lane form the cross-sections of all catchment areas. The material of the road surface is Stone Mastic Asphalt (SMA) and the annual average daily traffic (AADT) is approximately 24.000 vehicles per day. On the road in the opposing direction, an AADT of 22.000 vehicles per day was determined. However, the lanes of the opposing direction are separated from the catchment area by a greened median strip. Although an additional load on the catchment area can be expected due to dry and wet deposition. Next to the road is a park located with lawns and trees. Especially in autumn, this increases the organic load.

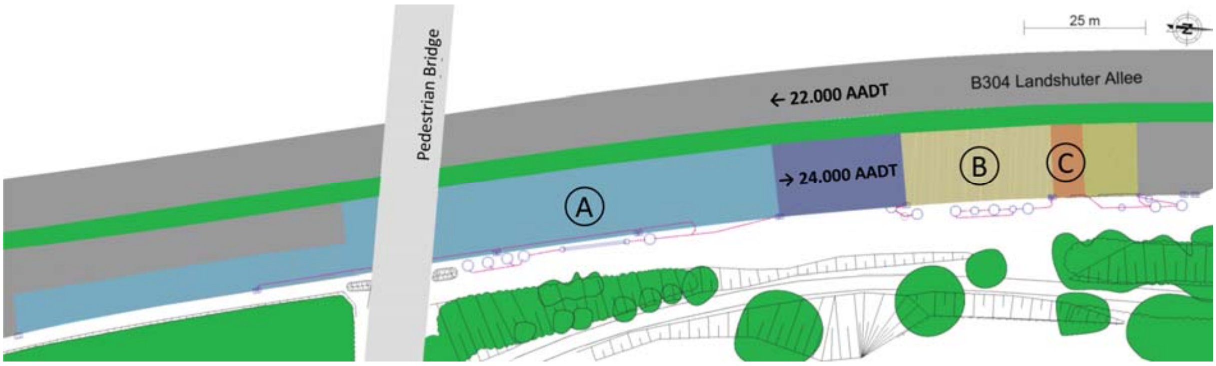

Figure 1. Layout of the monitoring site, the different colors indicate different catchment areas.

2.2 Sampling and Analyses

Samples were withdrawn volume proportionally with automatic samplers (WaterSam WS 316, Edmund Bühler PP 84) in the period from November 2017 to October 2018. The sampling was triggered by electro-magnetic flow meters (Krohne OPTIFLUX 2300 C or 1300 C, Krohne IFC 300 C, DN250 for A, DN40 for B, DN25 for C). The flow data were recorded with a frequency of 30 s. The sampling started, if the inflow exceeded the threshold value longer than 1 min. If the inflow was 15 min below the threshold value, sampling stopped. The threshold value was set to 0.4 L s^{-1} ha^{-1} discharge, based on the determined catchment areas. This threshold value was lowered after 5 sampled events (3 for A). It was attempted to sample all three SQIDs at the same time, however this was not possible at each event due to failure. The samples were kept in coolers at 4±1 °C. One composite sample for each discharge event, using the discrete samples of each automatic sampler. Analyses of pH, electric conductivity (EC) and suspended solids (TSS) and fine suspended solids (SS63) were performed within 72 h. The samples for the analyses of heavy metals were acidified to pH < 2 with nitric acid (65%). The analysis of TSS and SS63 followed the method, described in Rommel and Helmreich (2018). Total concentrations of sodium (Na), calcium (Ca), magnesium (Mg) cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb) and zinc (Zn) were determined after aqua regia digestion. The analyses of Na, Ca, Mg, Fe, Cr and Zn were conducted using ICP-OES (Horiba Jobin Yvon Ultima II, DIN EN ISO 11885), Cd, Cu, Ni, Pb was analyzed with ICP-MS (Perkin Elmer NexION 300D). The limits of quantification (LOQs) were 10 µg/L

Na, 20 µg/L Ca, 5 µg/L Mg, 8 µg/L Fe, 0.1 µg/L Cd, 1 µg/L Cr, 0.1 µg/L Cu, 0.4 µg/L Ni, 0.1 µg/L Pb and 2 µg/L Zn. Measured concentrations below the LOQ were set to the LOQ value.

3 RESULTS AND DISCUSSION

During the monitoring period, we were able to simultaneously sample only seven discharge events of the three catchment areas, due to the remarkably dry weather in 2018 and temporary failure of measuring devices. Hereafter, data of those synchronously sampled events is presented.

The first striking difference between the three catchment areas was the flow characteristic (cf. Figure 2). The range of measured mean discharge rates q of the catchment areas B and C were comparable with a mean of 5.7 L s^{-1} ha^{-1} at B and 6.8 L s^{-1} ha^{-1} at C. However, the measured mean q of the catchment A was 12.0 L s^{-1} ha^{-1} and the maximum was 23.5 L s^{-1} ha^{-1}. Because higher flow rates lead to shorter residence times in SQIDs connected to the catchment areas, reduced treatment efficiencies can be expected. In contrast to q, the discharge depths of the different catchment areas were comparable. This verifies that even with different q, the catchment areas create the same volume of runoff. The disparities of q are on the one hand based on differences in the flow patterns within the catchment areas. On the other hand, the design of the attached SQIDs and the flow meters alter the hydraulic characteristics. Increased flow resistance in SQIDs can lead to backwater, which affects the discharge rate. Due to the wide range of monitored catchment area and different SQID designs, we needed to use different flow meters diameters to assure accuracy of measurement and avoid backwater up to the road surface level during heavy rains.

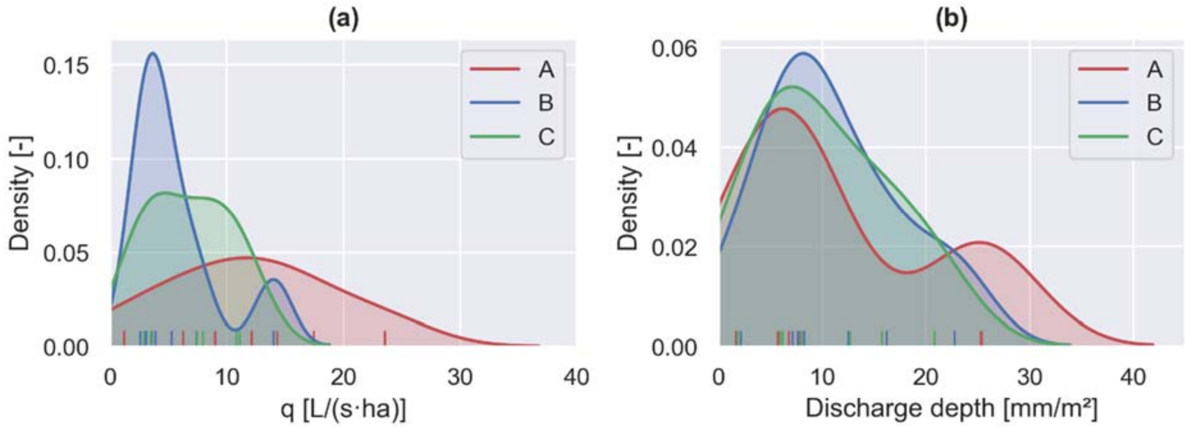

Figure 2. Mean discharge rate q (left) and discharge depth (right) of the three catchment areas, both values are displayed as kernel density estimation (KDE) plots and rug plots (n=7).

In addition to the hydraulic characteristics, the concentrations of Zn, Cu and TSS in the runoff of the different catchment areas varied (Figure 3 and Figure 4a). The pollution of the runoff from B showed a narrower distribution compared to the other two catchment areas. This trend is recognizable in the distribution of Zn, Cu and TSS concentrations.

The particulate matter (PM) mainly (median 83%) occurred in the fraction SS63 in with comparable distributions in the runoff of all three catchment areas. In the runoff of C slightly coarser PM was determined in comparison to the other catchment areas (Figure 4b). It is very likely that this coarser PM can be attributed to the lack of a strainer in the catchment area C. Because catchment area C is drained with a drainage channel, this is a common practice. Instead, A and B are drained with gullies equipped with strainers, which are able to separate coarse PM. Furthermore, A and B have longer flow paths.

It can be assumed that with an increasing sample number the distributions of the measured parameters will vary. However, the present data indicate that even within a small area with comparable boundary conditions, the catchment areas show different flow characteristics and contaminant loads. Furthermore, technical boundaries of measuring devices lead to bias of the data. This knowledge needs to be considered to assess results of field tests of SQIDs on a scientifically founded basis.

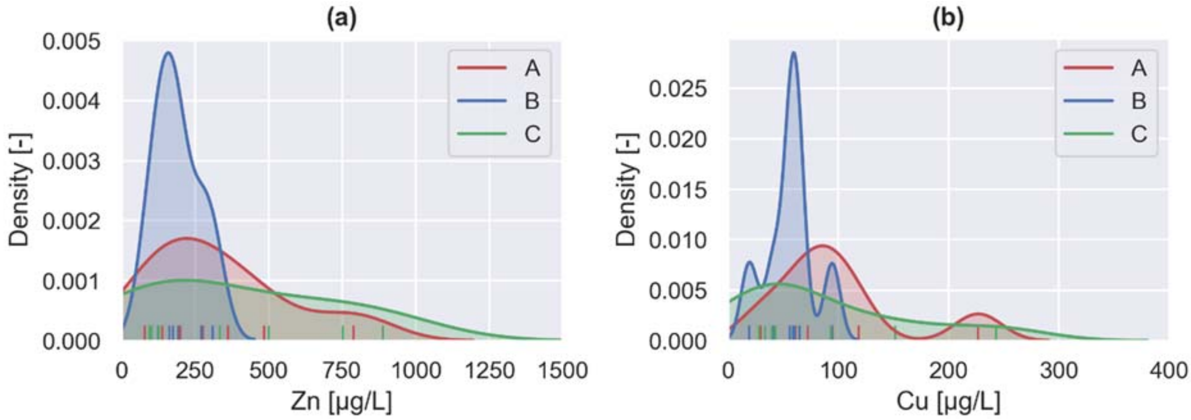

Figure 3. Zinc (Zn) and copper (Cu) concentrations in the runoff of the three catchment areas, both values are displayed as kernel density estimation (KDE) plots and rug plots (n=7).

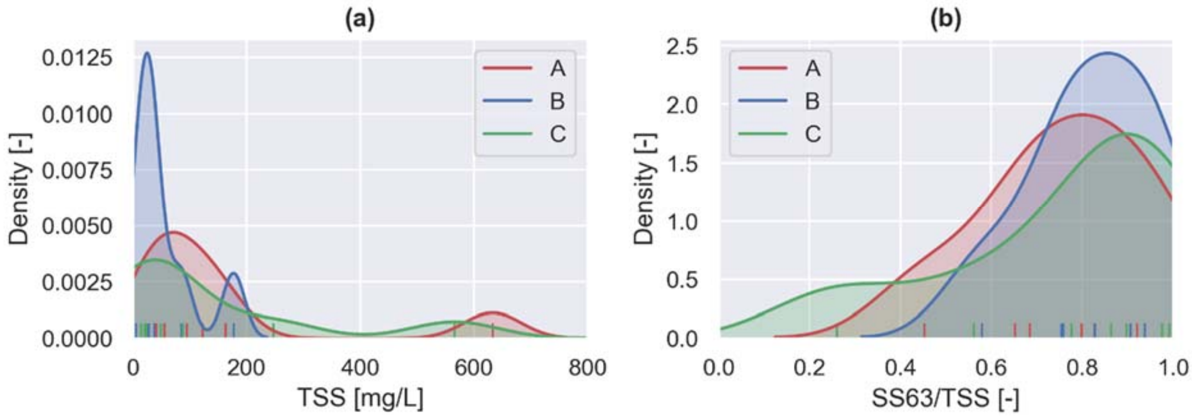

Figure 4. (a) Total suspended solids (TSS) in the runoff of the three catchment areas. (b) Ratio SS63/TSS in the runoff of the three catchment areas. Both values are displayed as kernel density estimation (KDE) plots and rug plots (n=7).

4 CONCLUSION

Three catchment areas of a heavily trafficked road were monitored for 12 months. All three catchment areas were located next to each other and had comparable boundary conditions. However, the distribution of the measured hydraulic characteristics as well as the contaminant concentrations in the runoff differed between the catchment areas. Reasons were assumed to be different flow patterns in the catchment areas, differing contaminant loads, influence of selected measuring devices and uncertainty of measurement. This knowledge illustrates the limitations of comparability of field test results, even under very comparable test site conditions.

The monitoring at the test site will be proceeded. The results about operational aspects, treatment efficiency of the SQIDs and insufficiently investigated substances like antiknock agents (MTBE/ETBE) and cyanides will be published in the future.

ACKNOWLEDGEMENT

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