Vegetated filters for source control of pollutants associated with road runoff. Case study of Rosny-sous-Bois (France)

Filtres végétalisés pour la maîtrise à la source de la contamination des eaux de ruissellement. L'exemple de Rosny-sous-Bois

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ABSTRACT

The sustainable drainage systems are more and more implemented in the urban space, though their operational efficiencies are not always well known. This article presents the first results of follow up of a set of planted filters in Rosny-sous-Bois in Paris suburbs, as part of the Roulepur project. The horizontal sand filter, equipped upstream and downstream for a quali-quantitative monitoring shows a satisfactory efficiency for most of the monitored parameters. On one hand it reduces and delays the hydraulic extremes and on the other hand it shows efficiencies in the order of 60% for the TSS and associated pollutants.

RÉSUMÉ

Les techniques alternatives sont de plus en plus implémentées dans l'espace urbain, cependant leurs efficacités opérationnelles ne sont pas toujours bien connues. Cet article présente les premiers résultats de suivi d'un ensemble des filtres plantés situés à Rosny-sous-Bois en banlieue parisienne, dans le cadre du projet Roulepur. Les filtres à sable horizontaux, équipés en amont et en aval pour un suivi quali-quantitatif montre une efficacité satisfaisante pour la plupart des paramètres suivi. D'une part il amortie et temporise les extrêmes hydrauliques et d'autre part il montre des efficacités de l'ordre de 60% pour les MES et les polluants associés.

MOTS CLÉS

Flow reduction, Pollutants retention, Horizontal filter, Micro-Pollutant, Sustainable urban drainage system, SUDS, Road Run-Off,

1 INTRODUCTION

Road runoff consists of a complex matrix of pollutants, mainly originating from automobile traffic, but also from leaching of urban infrastructures. In order to preserve better receiving water bodies, source control or even runoff depollution, are needed. Various technical solutions for sustainable management of runoff pollutants have been developed over the past years (Barbosa et al., 2012; Hilliges et al., 2013; Li et al., 2014; Revitt et al., 2014). Their efficiency in terms of hydraulic control and pollutant load reduction, need however to be better evaluated. The French research project ROULÉPUR (Gromaire et al., 2016; Ramier et al., 2016) proposed therefore to help evaluate in situ, the operation of four different source control solutions together with their administrators. They have been selected in order to represent solutions with different levels of technicity, adapted to different contexts and having emerged in France over the last years: vegetated parking surface, horizontal landscape filters, filtration swales along road side and a compact industrial depollution device for city gully. The present paper proposes a focus on the horizontal sand filter.

2 MATERIAL AND METHODS

The studied catchment (0.76 ha) is situated in the east suburbs of Paris, in the municipality Rosny-sous-bois with mainly residential land use (coordinates 48.8629308,2.4958384). It's composed of a road section of 150 meter (3410 m², impervious surface 2900 m²) and an adjacent scholar complex, equipped with sustainable drainage (4200 m², contributing surface 2540 m²).

The main collector of the catchment is connected to a landscape filter system for hydraulic regulation and pollution control. The system, operated since 2008, is installed in a public square and the superficial part is freely accessible to the public. It's composed of three treatment filters in parallel (red in figure 1B), connected in series with other three storage filters (blue in figure 1B). Each filter in the form a rectangle has a surface of 16 m² and is filled with 1-meter substrate. The substrate layer is covered with 40 cm soil and grassland. A threefold layer of geotextile separates the vegetated soil from the sand layer, allowing infiltration of exceeding irrigation water, but no capillary uptake by the vegetation. The filter is operated horizontally. When the filtration capacity is exceeded (observed each year), water overflows into a storage layer at the filter surface, bypassing the filter and flowing directly to the sewer. The discharge of the three filters is regulated by a vortex for flows exceeding 10 l/ha/s. For extreme flows (never observed) the filters storage layer of 40 cm, can overflow to a line of storage filters. The filter vegetal cover is maintained by the municipality of Rosny-sous-Bois, while the filters are operated by the County council Seine-Saint-Denis waste water treatment section, DEA93. Figure 1 shows detail of a treatment filter and the principal of hydraulic functioning of the system.

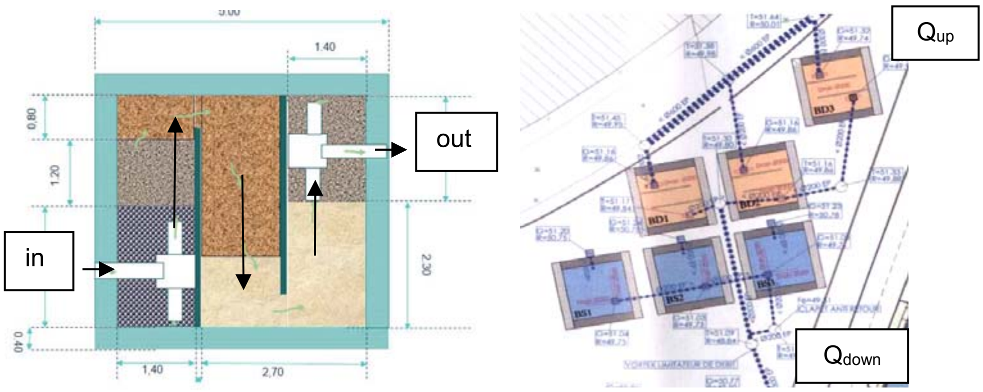

Figure 1: (A) Structure of sand filter, with dimensions in meters. The substrate particle diameter is decreasing form the inlet to the outlet: gravel, fine gravel, coarse sand, fine sand, (fine gravel). (B) Interconnection of different type of filters. *(Viewed from the top)*

In the framework of the project ROULEPUR the existing system was equipped by DEA93 with flowmeters, an electromagnetic flow sensor (Krohne, Tidalflux 4300 F) up-streams and a triangular weir system (Hydreka / Sigma) down-streams and linked to dataloggers. The bypass frequency was measured by a separated level probe at the filter one entrance. The vortex was equipped with a second level probe for flow verification. Hydraulic parameters studied were principally peak flow reduction, delay of peak flow and time of restitution.

Both flow-meters were connected with automatic, refrigerated water samplers to sample proportionally to time (inflow, Bülher 1029) or proportionally to flow (outflow, Sigma-AS950) to obtain event mean samples, either in polyethylene recipient for global and trace metal analysis, either in glass recipient for organic pollutant analysis. About ten events were sampled by DEA93 between 2017 and 2018. The selected contaminants include global parameters (TSS, DOC, POC), nutrients, 12 metals and three families of organic micropollutants (PAH, alkylphenols and bisphenolA, phtalates). Immediately after collection, the samples were transferred to the partner university laboratories and analysed according to the French standards AFNOR (AFNOR, 2005) or the APHA Standard methods for water quality analysis (APHA et al., 2012). The particulate fractions and the dissolved fractions were treated separately, whereby the particulate fraction for metal analysis was analysed after complete digestion by Fluor-hydric acid. The concentrations served to calculate the pollutant flux generated by the watershed and its reduction by sustainable drainage system (SUDS).

3 FIRST OUTCOMES AND DISCUSSION

The system receives run-off through a collector with a diameter of 60 centimetres on which the flowmeter is mounted about 2 meters before the inlet of the first filter (Fig 1). This means that during important rain event like that of 1/7/17 (Fig 2) this part will fill up with runoff, and will be emptied as function of hydraulic resistance of the filters. This can lead to almost stagnation of water with flow velocities as low as 1 mm/s, causing sedimentation of suspended solids, especial in the diversion boxes and the filter inlets. These sediments were estimated and removed yearly by suction, but are not measured as suspended solids.

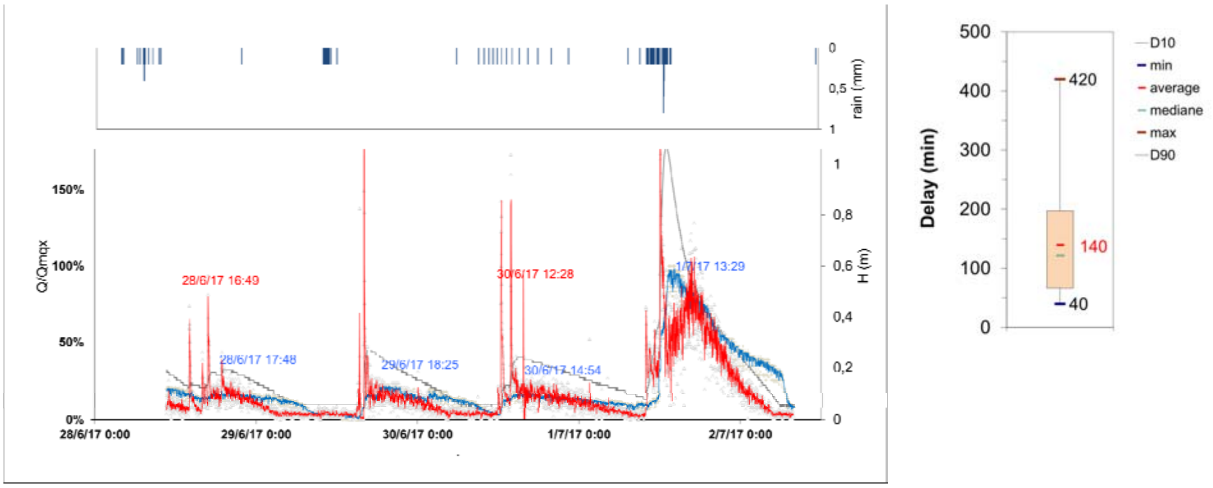

Figure 2: (A, left) Example of inflow (red) and outflow (blue) of the first serie of filters and (B, right) the delay of peak flow for the period June – September 2017 estimated for 14 events. Smooth grey line indicates the water level at the entrance of the first filter.

Figure 2A shows an example of the evolution of inflow and outflow as function of the precipitation, covering four rain events end of July 2017. To better compare upstream and downstream, all flows were normalized to the maximum of outflow. The maximum run off (inflow) for this period was 4 l/s or 5 l/s/ha of watershed or 10 l/s/ha if expressed for contributing surface. The outflow was here reduced to 1 l/s respectively 1,3 l/s/ha and 2,4 l/s/ha. This reduction is principally due to filter media as the vortex starts at 3 l/s. Fourteen rain events in 2017 were used to calculate the average delay between the run off peak and the maximum of restituted flow, which was in average 2 hours (Fig 2B).

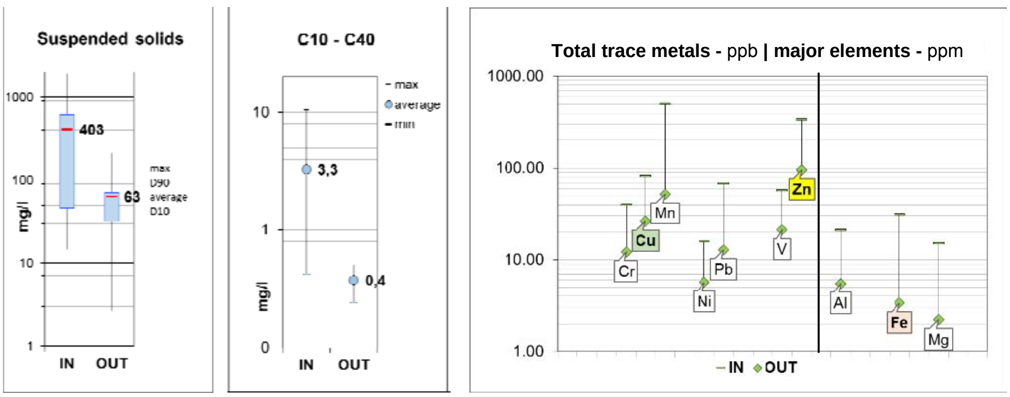

Figure 3: Water quality data of influent (runoff) and effluent. Suspended solids (A) data are based on 14 events. Total hydrocarbons (B) and average of total metals (C) are based on 4 events.

If we look on the water quality (Fig 3), we observe a relatively good retention of the pollutants by the filter. The average retention of solids is 67% (Figure 3A) and the total hydrocarbons, mainly linked to suspended solid showed similar elimination of 58%. The PAH, represent only a small fraction of total hydrocarbons. The retention of trace metals is something lower, varying between 20% (Copper) and 53% (Lead). These values were lower especially for events with low suspended solid content, frequent during rainy periods. On other side high levels might be due to resuspension of settled solids during the fill up of the collector. As the analysis does not include the solids removed by settling in the diversion boxes and adjacent collectors, the overall efficiency of the system might be better than estimated from inlet and outlet concentrations only.

The similar retention of trace metals and major elements indicates filtration as main retention processes. This finding is supported by the low exchange capacity of filter medium, the short retention time of water in the media and the low organic matter with low biodegradability, limiting strongly the anaerobic conditions.

CONCLUSIONS AND PERSPECTIVES

The hydraulic behaviour of the system studied, is quite complex in its design and was therefore difficult to monitor. The operation may induce an important water storage in the upstream pipe, modifying the hydraulics and the water quality, aspects not taken into account in the design. The electromagnetic flow meter, placed relatively close to the filter entry, suffered of water remanencies during important rain events, disturbing flow measurement and sample collection. Some of the water samples collected at this point, might therefore not be representative of the runoff produced by the catchment. A complementary source of error could be the operation, focused on process management rather than on (scientific) data collection. Nevertheless, the overall of data collected during two years allow to draw some interesting conclusions.

The first results show the effectiveness of flow regulation, whereby the flow is effectively kept under the legal 10 l/ha/sec principally by the filter action. The peak flow is hereby delayed by about 2 hours. On the qualitative side, important water quality improvement is reached between the entry and the exit of the filter, especially for events with the highest SS concentrations. For pollutants with important dissolved fractions this efficiency is lower due to physical retention of the particulate fraction.

The presentation will bring more details about the hydrological functioning like frequencies of system overflow, respect of legal limits and more extend treatment of organic micro-pollutants.

ACKNOWLEDGMENTS

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