Evolution of micropollutants in a constructed wetland treating road runoff in Paris (France)

Évolution des micropolluants dans un filtre planté pour le traitement de ruissellement de voirie à Paris (France)

J. Roux[1], M. Seidl[2], N. Bousserrhine[1], P. Branchu[3], M.C. Gromaire[2], P. Neveu[4],

[1]Laboratoire Eau Environnement et Systèmes Urbains (LEESU), 61 avenue du Général de Gaulle, 94010 Créteil Cedex, FRANCE

[2]LEESU, 6-8 avenue Blaise Pascal, Cité Descartes, Champs sur Marne, 77 455 Marne-La-Vallée Cedex 2, FRANCE

[3]Team Unit, CEREMA, 12 Rue Teisserenc de Bort, 78197 Trappes-en-Yvelines Cedex,FRANCE

[4]Direction de la Propreté et de l'Eau (DPE) Ville de Paris, 103 avenue de France, 75013 Paris, FRANCE

(corresponding author : martin.seidl@enpc.fr)

RÉSUMÉ

Pour limiter les rejets polluants en Seine, la municipalité de Paris (France) a mis en place un filtre planté de roseaux pour le traitement des eaux de ruissellement d'une portion du boulevard périphérique dans le cadre du projet européen Life Adsorb. La zone humide construite est partagée en deux avec une composition de substrat légèrement différente, l'une uniquement avec du sable et l'autre avec une couche adsorbante supplémentaire. Les principaux objectifs sont de suivre l'efficacité du traitement et comprendre le devenir des contaminants au sein des différents substrats. Cet article propose un bilan succinct de l'accumulation des micropolluants métalliques et organiques après un an de fonctionnement. Les premiers résultats montrent une accumulation rapide des micropolluants dans une couche de sédiments nouvellement formée et un début de rétention dans la couche de sable subjacente. L'accumulation est plus importante dans les couches superficielles et à l'entrée du filtre que dans les couches inférieures et à la sortie. Les métaux traces sont plus retenus que les alkylphénols étudiés. A ce stade, les données ne sont pas suffisamment consistantes pour confirmer une meilleure capacité de rétention du substrat absorbant.

ABSTRACT

In order to reduce impacts on river Seine, the municipality of Paris (France) has set up a reed bed filter for urban runoff treatment as a part of the European Life Adsorb project. The constructed wetland is separated in two parts with a slightly different substrate composition, one only with sand and second with an additional adsorbent layer. The main objectives are to monitor the evolution of the treatment efficiency and to understand the fate of contaminants within the different substrates. This paper proposes a short balance of the accumulation of metallic and organic micro pollutants after one year of functioning. The first results show a fast accumulation of micro pollutants in a newly formed sediment layer and a starting retention in the sand layer just below. The accumulation is more important in the surface layers and at the inlet than in the lower layers and at the filter outlet. Accumulation is more important for trace metals are than for alkylphenols. At this stage, the data are not sufficiently consistent to confirm a better retention capacity of the specific absorbent substrate.

KEYWORDS

organic micro pollutant, reed bed filter, storm water, trace metals

1 INTRODUCTION

Urban runoff is well known for its contamination with trace metals and organic compounds, issued mainly from road traffic (Markiewicz et al., 2017). These waters contribute to degradation of receiving aquatic environments if they are discharged without treatment. In order to limit the contaminant fluxes to the Seine River, the municipality of Paris has set up in 2019 the Life Adsorb project. The project consists of a vertical reed-bed filter adapted to its natural landscape and treating highway runoff. The aim of the Life Adsorb project is to reduce both particulate and dissolved micro pollutant loads and to understand the processes involved in their treatment so as to model the system for better dissemination of nature based solutions for runoff treatment (Neveu et al., 2019). The processes focused in this presentation are accumulation of traces elements and organic micro pollutants in the different filter compartments.

2 METHODOLOGY

2.1 The constructed wetland

The filter, located in the Bois de Boulogne Park in the West of Paris (France, 48°52'28.6"N 2°15'43.6"E) is subdivided into 2 parallel bean form parts of approximately 100 meters long, 5 meters large and 1 meter deep. Their structure is similar; from top to bottom, we can find a filtering layer (40 cm), then a transition layer (10 cm) and finally a submerged drainage layer (50 cm). The difference between these two parts is the composition of the filtration layer. The conventional one (SAND) is composed of 40 cm of sand (0.4-0.7 mm) while in the innovative one (RCl), a layer of 20 cm of an industrial adsorbent Rainclean® is inserted between two layers of 10 cm of sand (figure 1). The filters are planted with common reeds (*Phragmites australis*), contributing to the hydrological processes and rhizosphere microorganisms support (Wang and al., 2022). The total treatment surface is 1200 m². The filters are fed by pumps from runoff storage, alternately one month each. During heavy rainy periods, the filters work simultaneously with a downward vertical flow up to 20 L/s.

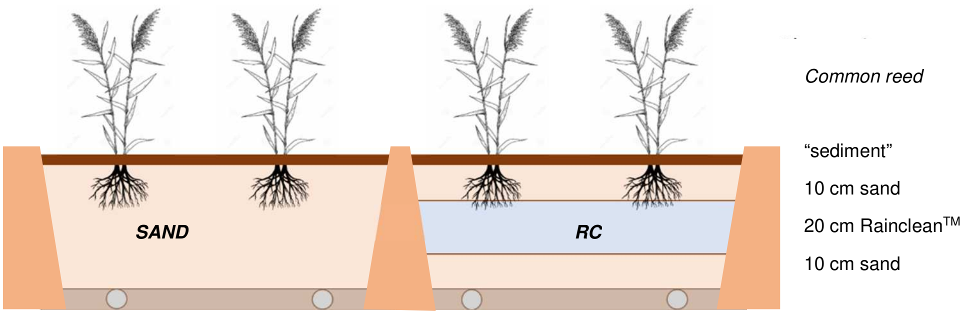

Figure 1. Vertical profile of the Life Adsorb constructed wetland. The conventional one (sand) on the left and the innovative one (RC) on the right. The layer thickness and compositions are shown on right. The sediment corresponds to retained runoff suspended matter and decayed local reed material.

2.2 Sampling and analysis

The filter is fed with contaminated runoff since February 2021 (almost 2 years of feeding). Substrate sampling campaigns were carried out, in September 2020 (T0), 2021 (T1) and 2022 (T2) to study the spatial and temporal evolution of the pollutants and biomass. During each campaign, core samples of the filtering layer were collected in the inlet zone, in the centre and in the outflow zone. The core was divided in sediment layer if present, first 0 – 10 centimetres of sand, following 10 – 30 centimetres, which is either sand or RC, and final sand layer of 30 – 40 cm depth.

To characterise physico-chemically the filters pH, cation exchange capacity (CEC), particle size, (in)organic carbon (TIC and TOC) and nitrogen (TN) were analysed. To assess the accumulation of micro-pollutants, analysis of their total contents were carried out on total, lyophilized, mortar crushed samples. The trace metals Cd, Cr, Cu, Ni, Pb and Zn were studied after HNO_3/HCl digestion and ICP-AES analysis (Roux, 2020). To estimate more precisely the spatial distribution almost one hundred of surface samples were analysed by X-ray fluorescence and mapped. The organic micro pollutants studied, selected according to the literature, were polycyclic aromatic hydrocarbons

(PAH), total hydrocarbons (THC), as well as less documented pollutants such as alkylphenols, phthalates and bisphenol-A. A contaminant specific solvent extraction and analysis by GS-MS or UPLC-MS –MS was applied to total samples described previously.

As the microbial communities are the main factor of organic micro pollutant evolution in the constructed wetlands, scarcely documented in the literature, three microbiological approaches were carried out: abundance of bacteria and fungi (MPN method), total genetic diversity (DNA sequencing) and estimation of environmental enzyme activities (Biolog™).

3 RESULTS AND DISCUSSION

Results of the physicochemical properties (data not shown) reveal that sediment and Rainclean are much more organic (respectively 150 and 20 g-C/kg respectively) than sand (less than 10 g-C/kg). The samples taken at the inlet after one year of operation (T1) are richer in organic carbon than the rest of the filters as the particulate organic matter settles as soon as it enters the wetland. In consequence, the majority of organic micro-pollutants is similarly retained near the inlet. All trace metals studied decrease also with the treatment pathway from inlet to outlet, on the one hand due to sedimentation and on other hand due to more frequent charge of the inlet compartment. Figure 2A, shows the example of Zn content decreasing from 65 to 20 mg/kg between the inlet (top sand layer of Zone 1) and outlet (bottom sand layer of Zone 1 and top sand layer of Zone 3).

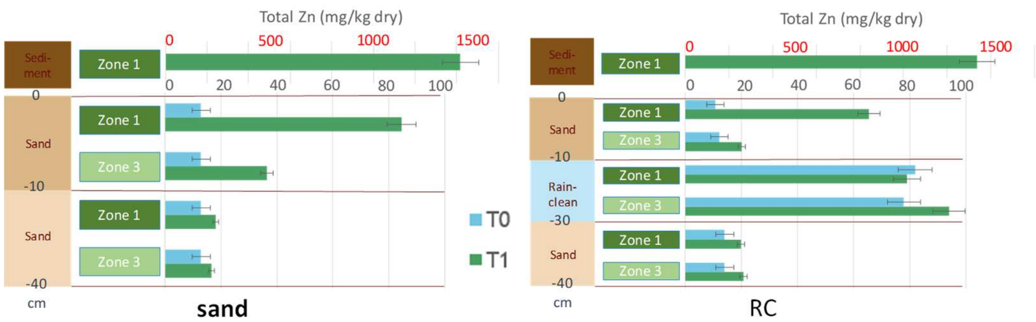

Figure 2. Evolution of vertical and longitudinal concentration profiles for both filters after one year of functioning

After one year of functioning a sediment layer appears, composed of suspended matter issued from runoff and local dead organic matter from present vegetation, with significant levels of trace metal contamination (574 to 656 mg/kg for Cu, 204 to 215 mg/kg for Pb and 1337 to 1418 mg/kg for Zn). The accumulation of trace metal elements in the surface sand layers) indicates that these pollutants are associated preferentially with particulate matter and retained therefore by filtration. Their content decreases consequently with depth. The contents found are of the same magnitude as found by (Walaszek, 2018) in a comparable situation.

Over the same period, the organic micro pollutants (BPA, OP and 4-NP) show less significant accumulation than the metals (not shown) most probably due to their biodegradability. As for trace metals, the sediment shows the highest contamination levels (0.6 to 0.7 µg/g for BPA, 0.11 to 0.33 µg/g for 4-OP and 2.9 to 3.1 µg/g for 4-NP), but 10 times less in the surface sand (0.007 to 0.023 µg/g OP and 0.040 to 0.178 µg/g for NP). The RC and the lower sand layers were more contaminated with these compounds at T0 than at T1 suggesting leaching and/or degradation of initial contamination. The 4-NP is the most present compound, which is consistent with other authors studying runoff of Paris (Gasperi et al., 2022). Compared to levels measured by Flanagan et al. (2019) in swale substrate treating highway runoff in Paris suburbs, the reed bed was globally less contaminated. The filter sediment was however richer, for example 20 times for BPA and 6 times for 4-NP.

The microbiota, determining strongly the fate of organic pollutants was essentially present in the sediment (10^6 UFC/g) and less in the surface sand layer (10^4 UFC/g) according to their probable association with particulate matter and the filtration process. Their abundance was lower in the RC than in equivalent sand but increasing since the beginning of the treatment. The presentation will give more insight in organic micro pollutants accumulation and the possible links with microbial activity.

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