Micropollutants removal efficiency of stormwater control measures: comparison of a centralized system with source control structures

Mesure de l'efficacité des systèmes de gestion des eaux pluviales en matière d'abattement de micropolluants : comparaison d'un système centralisé et de systèmes à la source.

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RÉSUMÉ
Les collectivités territoriales soutiennent de plus en plus l'implantation de solutions alternatives pour diminuer les flux d'eau (lutte contre les inondations) et à décroitre la contamination des eaux (lutte contre la pollution des milieux aquatiques) soit par des processus de décantation de la pollution particulaire (systèmes centralisés de type bassins) soit par limitation des émissions, du lessivage et/ou par piégeage par filtration (systèmes à la source). Si des études ont été menées sur l'efficacité de différentes solutions vis-à-vis de certains polluants comme les métaux, les hydrocarbures ou les nutriments, peu d'éléments existent sur leurs performances vis-à-vis d'une large gamme de micropolluants (MP) et peu ont comparé les grands types de solutions alternatives que sont les bassins de retenue à l'exutoire de grands bassins versants vs des solutions à la source. Cet article a pour objectif de comparer la qualité des rejets de trois ouvrages de gestion des eaux pluviales à la source (une tranchée infiltrante, une noue d'infiltration et une chassée à structure réservoir en béton drainant) à ceux d'un bassin de rétention collectant les eaux pluviales d'un bassin versant de 185 ha. Les capacités de rétention des flux d'eau et des flux de polluants (métaux, Alkylphénols, pesticides et PBDE) des systèmes sont évaluées. Les analyses des concentrations et masses en micropolluants à l'exutoire des systèmes montrent que les systèmes à la source sont plus performants que les systèmes centralisés.

ABSTRACT
Municipalities support and encourage the use of stormwater control measures in order to diminish rainwater runoffs (lowering risks of flooding) and decrease water body contamination and pollution. These systems are either based on particulate pollution decantation (centralized structures like retention basins) or on filtration processes (source control systems such as swale, infiltration wells, etc…). Research projects studied and investigated the performances of these kinds of structures regarding heavy metal, PAHs and nutrient pollution removal, however very few exists regarding a larger range of micropollutants (MP) (especially emerging micropollutants such as flame retardant or alkylphenols). Moreover, scarce are ones investigating the behavior of the different scale structures such as retention basins at the outlet of big catchments compared to much smaller source control systems. This article aims to palliate this lack of knowledge by comparing the performances regarding MP removal of three source control measures (an infiltration swale, an infiltration trench and a porous pavement with reservoir structure) to a retention basin draining rainwater runoffs from a 185 ha catchment. Water retention and pollution removal (concentration and loads) regarding a wide range of MP (heavy metals, PAHs, alkylphenols, pesticides, flame-retardants and Bisphenol A) show that source control structures are more efficient than centralized systems regarding runoff and pollution discharge in water body.

MOTS CLÉS
Micropollutants, purification efficiency, source control systems, stormwater control measures, centralized structure

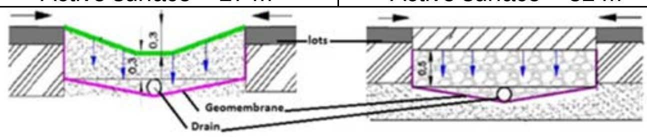
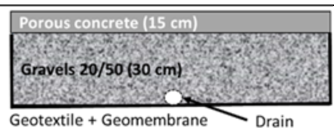
INTRODUCTION

Protecting urban infrastructures and environment from rainwater flooding and pollutions is currently one of the greatest challenges for urban conurbations. Since the promulgation of the European Water Framework Directive (EWFD 2000), more and more urban drainage research studies focused on determining the severity of receiving body pollution due to wash-off of micropollutants (MP) such as metals, metalloids and PAHs. More recently, studies detected and quantified the contamination from emerging micropolluants (Alkylphenols, pesticides, phthalates, Bisphenol A, flame retardant…) suspected to present health and environmental risks, in rainwater urban discharges (Birch 2012, Becouze-Larreure et al, 2019). Since several years, French municipalities also encourage the use and implementation of small-scale on site infiltration/retention systems as an alternative to usual centralized structure such as retention/detention basins. It is assessed and known that the stormwater control measures (SCM), and even more so source control systems, have a beneficial effect on flow management and particulate pollutants releases such as heavy metals, PAHs) (Silva et al. 2010, Strecker et al. 2004).
This communication presents the first results of the Micromegas project which aims to study the MP treatment performance of three source control systems (a parking lot drained by a swale, a trench and a porous pavement with reservoir structure) compared to those from a classical retention basin. The current treatment efficiency of the different sites and their comparison cover a shorter list of MP: Cu,Pb,Zn, light PAHs, heavy PAHs, Bisphenol A (BPA), 4-Tert-Octylphénol (4-OP), 4-Nonylphénol (4-NP), Glyphosate (Gly) and PBDE-209. Efficiency is for now discussed regarding total concentrations in MP.

1 METHODOLOGY

The study relies on *in situ* monitoring and sampling of three source control systems draining runoff water from parking lots in Villeurbanne and one retention/detention basin draining a 185ha wide mixed urban area (69, France). Tab 1 succinctly presents their characteristics. For the experimental needs (monitoring and sampling), the three source control systems are lined with an impervious geomembrane at the bottom and sides and drained in order to catch all the infiltrated waters. Runoff water from a nearby 94 m² impervious asphalted parking is also collected and serves as a reference in order to compare water flows and MP loads with the outlet of the source control systems. A simple inlet/outlet comparison is conducted to assess the performances of the centralized retention basin. Each site is monitored and sampled with its own metrology installation at the oulet of the source control systems (flow measurement, conductivity, temperature, sampling) (Garnier et al. 2017 for more details) and inlet and outlet for the basin. The samples are acquired flow proportionally for an event mean concentration analysis.

Table 1. Sites specification of Micromegas project

Location	EcoCampus Lyon Tech de la Doua (Villeurbanne - 69)			Chassieu
Treatment structure	Vegetated Swale	Gravel Trench	Porous pavement with reservoir structure	Retention Basin (RB)
System				
Catchment Surface	302 m² Active surface = 27 m²	260 m² Active surface = 32 m²	94 m² Active surface = 94 m²	1 850 000 m² Active surface = 647 500 m²
Structure and dimensions				

2 RESULTS

2.1 Comparison of MP concentration at the outlet of the catchment supplying the retention basin and the reference catchment of source control systems

The comparison of the contamination of the inlet of the centralized basin and the reference asphalted parking allows discussing the difference of scale and nature of the watersheds.The first step of the analysis have then been to study if wether or not the MP charcteristics level of contamination at the inlet of the retention basin (outlet of the large urban catchment) was in the same range than the reference (asphalted parking) despite the huge difference in scale.

It turned out that most of the micropollutants were found in the same forms. For both scales, the trace metals (except Sr and Mo) and PAHs were mainly in particulate phases (> 75%), pesticides (<10%) and bisphenol A (BPA) (<5%) mainly in dissolved phase whereas alkylphenols were more various (between 5 and 40%).

The order of magnitude in concentrations varies as well as the occurency (number of non-nil concentration values) (Tab 2). Nonetheless, despite a huge variability inter-event, the two site outflows do not present fundamental differences.

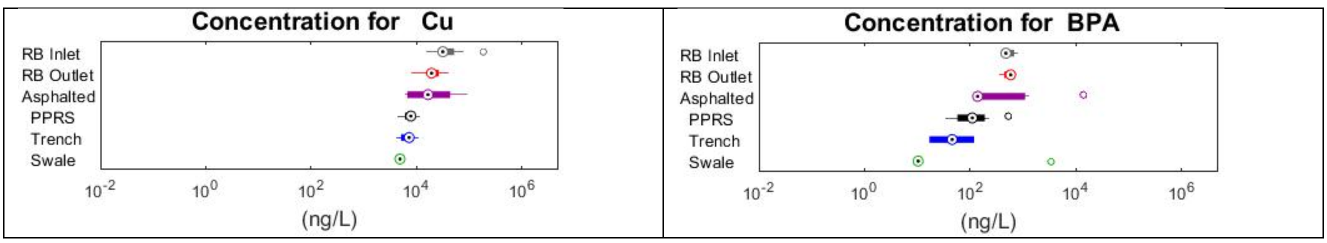
Table 2: order of magnitude of median values and occurence (% of samples when the MP is quantified) for the MP studied at the outlet of the asphalted reference and inlet of the retention basin.

Occurence									
> 75%	**Parking outlet**			OP, NP, Carbendazim, BDE 209	Cd, Mo, light PAH, BPA, 4NP	As, Co, Cr, Ni, V, Pb, heavy PAH	Cu, Sr, Zn	Ti	
	Urban catchment outlet		Diuron, Isoproturon, Atrazine	OP, Carbendazine, BDE 209	Cd, Mo, light PAH, heavy PAH, BPA, 4NP, NP	As, Co, Cr, Ni, V	Cu, Sr, Pb	Ti, Zn	
∈ [30%; 75%]	**Parking outlet**	Diuron, Isoproturon	Atrazine	Mecoprop					
	Urban catchment outlet	Mecoprop	AMPA						
µg/L		**0.001**	**0.01**	**0.1**	**1**	**10**	**100**	**1000**	
Order of magnitude		**ng/L**			**µg/L**			**mg/L**	

2.2 Efficiency in terms of concentrations

The following graphs show the ranges of total concentrations at the outlet of all the SCMs, the reference site, and the inlet and outlet of the retention basin. It shows the wide range of concentrations from one event to another and confirms the important variability of MP production from one event to another (Sébastian et al, 2015), whatever the scale.

For all the systems, micropollutant concentrations are lower at the outlet, confirming the SCM or the basin efficiency. If all sites are globally efficient to reduce heavy metals and PBDE, their performance seem more questionable regarding pesticides, alkyphenols and light PAHs. Regarding all MP families (Figure 2), source control systems management based on infiltration/filtration are globally more efficient than the retention basin mainly based on settling process. Moreover, the swale system to present the higher performance, probably due to internal physico-chemical processes such as filtration or adsorption of MP on the soil even if very few data are still available due to a high capacity of the swale media to retain water.



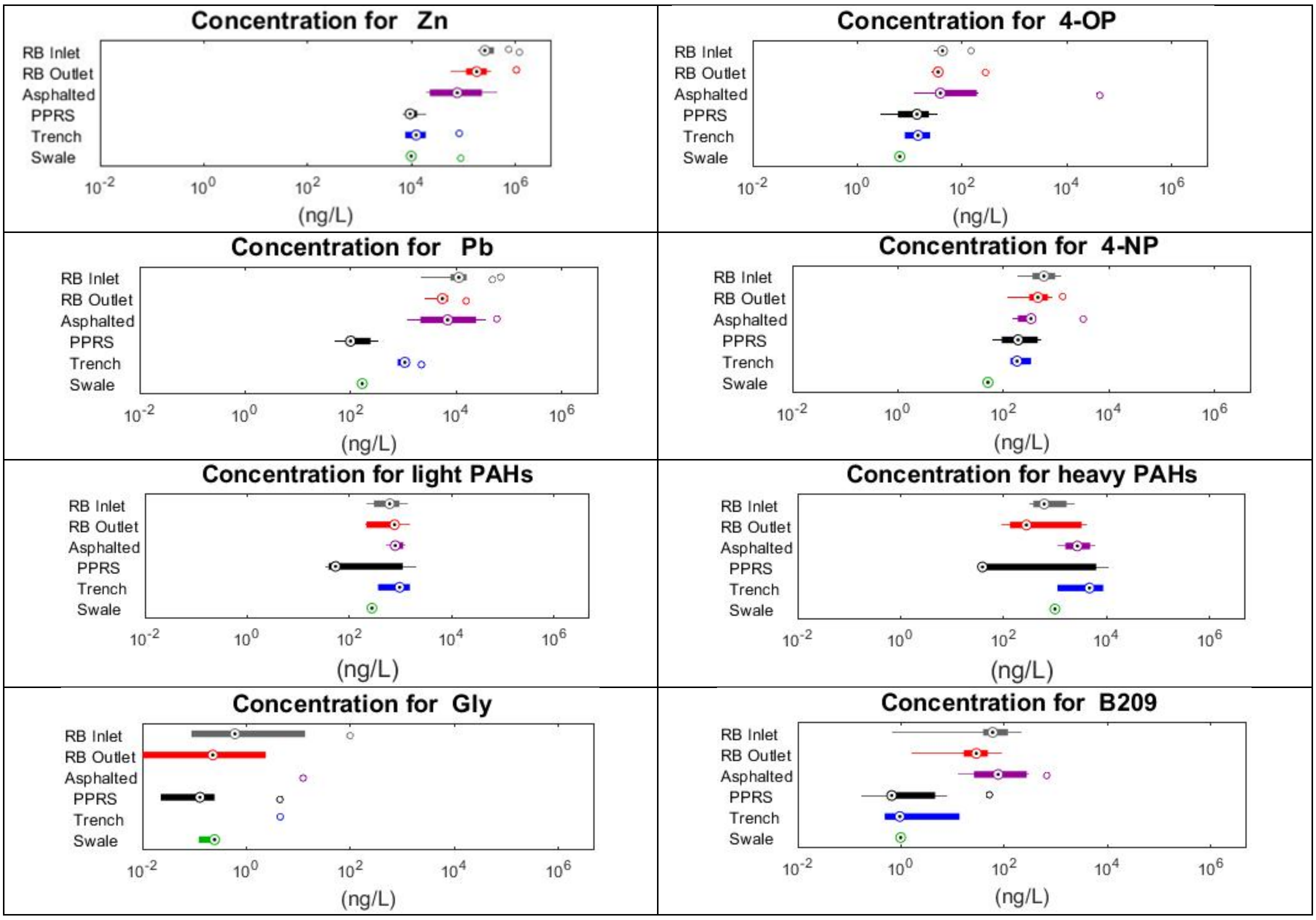


Figure 1 : boxplots of concentrations for micropollutants at the outlet of the source control systems compared to the reference (asphalted parking), and at the inlet/outlet of the retention basin

CONCLUSION

These first results showed that source control systems as porous pavement and reservoir structure, swale or trench are generally more efficient than a centralized structure as a retention basin to handle a wide range of micropollutants in term of concentration decreasing. Their higher performance can partly be explain by their intrinsic properties allowing filtration of runoff water over simple decantation. The swale tends to top these operations through a more efficient filtration combine with physico-chemical reactions with the micropollutants operating through its substrate. More detailed results also show that the beneficial effects of the source control systems are even greater in terms of loads thanks to their ability to retain water volumes.

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