La gestion alternative des eaux pluviales permet-elle une maîtrise efficace des flux de micropolluants? Retour d'expérience des projets Matriochkas, MicroMégas et Roulépur

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How efficient are stormwater control measures for micropollutant management? Feedback from Matriochkas, MicroMégas and Roulépur projects

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RÉSUMÉ

La mise en commun de résultats issus des projets français Matriochkas, MicroMégas et Roulépur, dans le cadre d'un groupe de travail d'échanges et d'harmonisation méthodologiques, permet d'analyser l'efficacité de la gestion alternative des eaux pluviales en termes de réduction des flux de micropolluants, pour 12 dispositifs de gestion et 9 contextes urbains différents. Les résultats soulignent la diversité des niveaux de contamination des eaux de ruissellement, et de leur distribution entre phases dissoutes et particulaires. Ils démontrent des abattements importants des polluants particulaires pour l'ensemble des systèmes basés sur la filtration, et moindre pour ceux ne permettant que la sédimentation. Les performances sont plus limitées pour les concentrations dissoutes, de sorte que seul un abattement des volumes de ruissellement, dans les ouvrages favorisant l'évapotranspiration, permet une réduction significative des flux de micropolluants dissous.

ABSTRACT

The pooling of results from three French projects (Matriochkas, MicroMégas and Roulépur), within the framework of a working group on methodological harmonisation, makes it possible to analyse the performance of a wide range of stormwater control measures (SCMs) in terms of micropollutant load reduction. Data covers 12 management systems, in 9 different urban contexts. The results highlight the diversity of runoff contamination levels and of their distribution between dissolved and particulate phases. They show significant reductions in particulate pollutants for all filtration-based systems, and less for those that only allow sedimentation. Performance is more limited for the dissolved phase, for which concentration reduction is limited and significant load reductions are only achieved due to a reduction in runoff volumes in structures promoting evapotranspiration.

MOTS CLÉS

Micropollutants, Monitoring, Runoff, Stormwater Control Measures, Treatment

INTRODUCTION

Urban runoff is known to be a significant source of diffuse pollution of aquatic environments. Its contamination has been widely documented for several trace metals, hydrocarbons and PAH. It is also a source of less documented organic micropollutants, such as plasticisers, surfactants, biocides and flame retardants (Gasperi et al 2014). In view of the limits of centralized treatment solutions, alternative stormwater management and source control of urban runoff are widely promoted today (Fletcher et al 2014). Some of these stormwater control measures (SCM) are mainly designed for hydrologic management while others specifically target depollution objectives. However the efficiency of these solutions for micropollutant load reduction, as a function of the type and size of the contributing watershed, is still insufficiently documented. This is all the more difficult as the nature of urban runoff and the extent of its contamination may vary greatly depending on catchment characteristics.

The present communication is based on a pooling of results from three French research projects (Roulépur project in Greater Paris, Matriochkas in Nantes metropolitan area and MicroMégas in Metropolitan Lyon), funded by the French Biodiversity Agency and the Water Agencies, under the same national call on “Innovations and changes in practice: Control of micropollutants in urban water”. All three focused on in-situ evaluations of the performance of various urban runoff management structures, from both the hydrologic and pollutant load point of view.

1 METHODOLOGY

A total of 12 SCMs were studied on 9 different sites over the 3 projects (Table 1). They cover a wide range of solutions, from very diffuse implementation (pervious parking lot, vegetated filter strip, infiltration or bioretention swale, infiltration trench, compact industrial product) to more centralized ones (dry and wet ponds). The ratio α between the surface of the SCM and the impervious surface of the catchment ranges from almost 0% to 100%. Only 4 out for the 12 devices have been specifically designed for depollution, i.e. reduction of pollutant concentrations (compact industrial product, sand filter, bioretention swale and vegetated filter strip), while the other ones were initially intended for hydrological runoff management (pervious parking, infiltration trenches or swales, detention or retention basins), even if some retention processes are intrinsically present in these systems. The studied catchments included a variety of roads and car parks, as well as an industrial catchment and a mixed urban catchment, with impervious areas ranging from 94 m² to 138 ha.

SCM type			SCM code	$S_{BV\ imp}$	α %	Catchment type	Catchment name
Source control	Pervious parking lots	Vegetated pervious parking	VPa [1]	1270 m^2	100	Residential or campus parking lot	Villeneuve #
		Pervious concrete on a porous structure	PPa [1]	94 m^2	100		Lyon #
	Infiltration trench		ITr [1]	123 m^2	21		
	Swale	Infiltration swale	ISw [1]	135 m^2	23		
		Transportation swale	TSw [1]	1,3 ha	0,4	Dense residential + swales	Nantes *
		Biofiltration swale	BSw [1]	352 m^2	4,3	High traffic road	Compans #
	Vegetated filter strip		VFS [1]	504 m^2	15		
	Compact industrial product		CIn [2]		0		Paris
	Horizontal sand filter		HSF [1]	3410 m^2 +(4186)	1,4 (0,6)	Low traffic road + (school complex)	Rosny *
sedtraliCen	Detention basin	Impervious settling pond	IDB [2]	138,7 ha	0,8	Industrial	Chassieu
		Grassed detention pond	GDB [2]	4,8 ha	4,5	Road with biofiltration swale	Coueron *
	Retention basin	Wet pond	WRB [2]	8,4 ha	0,8	Mixed urban	Vertou

Table 1 : Description of study sites and SUDS

[1] Measured outlet = underdrain ; [2] measured outlet = surface outflow

*: other SCMs present on the catchment, upstream of the studied SCM (Nantes: all runoff is transported by vegetated swales; Rosny: green roof and vegetated dry pond in the adjacent educational complex; Coueron: road runoff is filtered through a pervious shoulder before reaching the studied pond)

#: a reference catchment is used to evaluate the micropollutant loads on similar catchments without SUDS (Lyon and Villeneuve : reference = nearby asphalt parking ; Compans : reference = nearby portion of the same road but with gutter)

All sites have been instrumented so as to monitor both flow and quality at the entry of the system (or on a reference catchment when there was no centralized entry) and at its outlet. For some SCMs (VFS, ITr, ISw, BSw) this outlet consists of a drain beneath a substrate/soil layer and is representative of the water that would have been infiltrated to the underground in real situation, while for the other ones it represented the water that would have been send to sewer or directly to surface waters, either through an underground drain or a surface outlet.

This presentation focuses on a selection of micropollutants that were common to at least 2 projects: trace metals (analysed in the same lab for all 3 projects), PAHs, and 3 organic compounds (BPA, 4-nonylphenol (NP) and 4 tert-octyl phenol (OP); analysed in the same lab for Roulépur and MicroMégas).

2 RESULTS

2.1 Runoff contamination

As expected, the contamination levels vary in a wide range from one study site to another (Figure 1). The highest pollutant concentrations were measured for the two roads with heavy traffic (Compans and Paris), while very low concentrations were measured for Coueron and Nantes. For the latter, the runoff is pretreated before its entry into the studied SCM by other SCMs (grassed swales and biofiltration swale, see Table 1), and therefore presents or very low particulate loads. Median suspended solids (SS) concentrations range from 4 mg/l to 291 mg/l between sites. Much higher Cu, Zn, OP and NP concentrations, and to a lesser extend higher PAH and BPA concentrations, are measured for the two high traffic roads. No clear relation between the scale of the catchment and the pollutant load could be drawn.

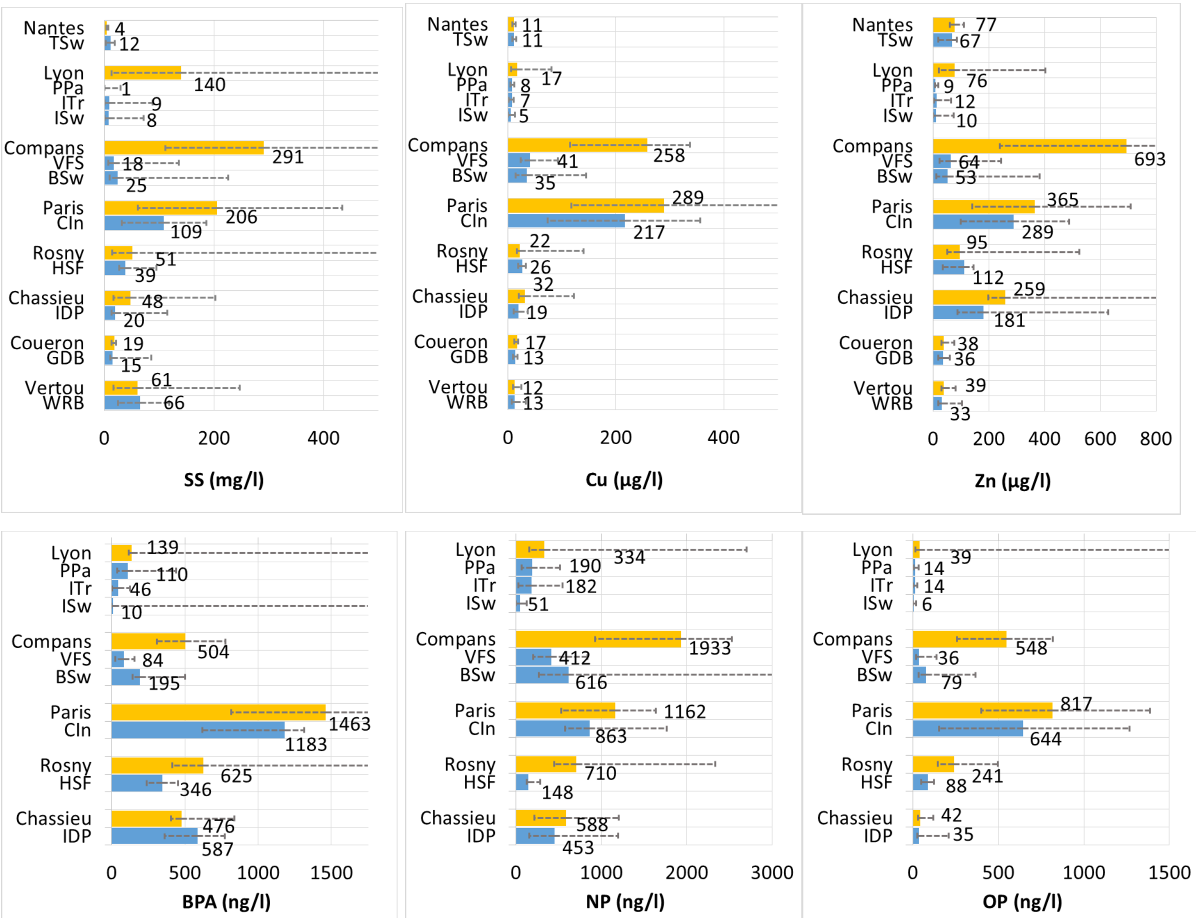

Figure 1 : D10, D50 and D90 of event mean concentrations (EMCs) measured in the runoff from the different study sites (inlet in yellow and outlet in blue)

The studied micropollutants and study sites differ in the distribution between dissolved and particulate phase, which has consequences on the efficiency of treatment processes. BPA was mainly found in the dissolved fraction (median particle/total <28%) while PAH were particle bound (>70%) for all sites. For Cu, Zn and NP, the proportion of particle bound pollutants varies greatly from one site to another as function of SS concentrations: >72% in median for Compans to <20% for the sites with the lowest SS. Dissolved concentrations of BPA (median up to 1100 ng/L), NP (median up to 420 ng/L, environmental quality standard EQS = 300 ng/L), and OP (median up to 400 ng/L, EQS = 100 ng/L) reach high levels on sites with heavy traffic, industrial activities or construction works.

2.2 Concentration and load reduction in SCMs

The best concentration reduction performances (Figure 1 and Figure 2) were obtained for SCMs that allow for filtration, especially those with relatively fine-graded (sandy loam or finer) vegetated soils (ISw, BSw, VFS), while those SCMs that allow only for settling (CIn, TSw, IDB, GDB, WRB) presented lower performance, or even a slight increase in concentrations when entry SS concentrations were very low. The highest concentration reduction concerned particulate pollutants. For dissolved fractions, and for contaminants with a large dissolved part (BPA, NP) performances are low, which underlines that the main processes are physical filtration and settling. Whatever the SCM, a reduction of Cu or Zn concentrations below 10 µg/L seems difficult to reach. For NP, outlet concentrations remain superior to the EQS on several sites, even after treatment. Inter-event concentration variations are attenuated at the outlet of most SCMs, which are effective in buffering extreme concentrations (Figure 1).

Load reduction performance are considerably improved, compared to concentration reductions, for those SCMs that allow for evapo(transpi)ration or infiltration (ITr, ISw, TSw, WRB). Volume reduction appears as a major factor of pollutant load control, especially for dissolved pollutants. For the BSw that allowed good concentration reductions, the global load reduction performance was however degraded by an insufficient hydraulic capacity leading to the overflow of untreated water.

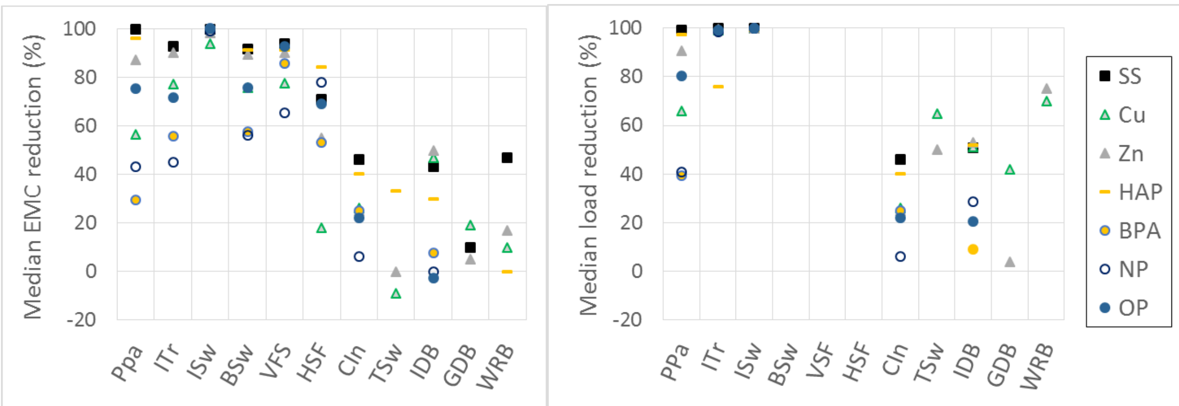

Figure 2 : median EMC and event load reductions per SCM for total fraction

3 CONCLUSION

Micropollutant concentration and load data measured in-situ, as a part of three French research projects, were pooled, so as to compare the performances of a wide range of stormwater control measures (SCMs). This was made possible by an exchange and harmonization working group that linked the three projects. Data acquisition is still in progress on some sites, and further data analysis and data intercomparison will continue through in the next months. One can already notice the very good performances of filtering devices for particulate load reductions, as well as the need to promote evapotranspiration in order to limit dissolved pollutant loads.

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