Efficiency of three stormwater management systems for the reduction of flow and micropollutants from urban and road runoff

Efficacité de trois ouvrages de gestion des eaux pluviales - réduction des débits et des micropolluants issus du ruissellement urbain et routier

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RÉSUMÉ

L'efficacité de trois ouvrages de gestion des eaux pluviales (un bassin sec, un bassin en eau et une noue) pour la réduction des débits, des concentrations en métaux trace, hydrocarbures aromatiques polycycliques (HAP) et pesticides a été étudiée. A l'exception du cadmium, les concentrations en métaux en entrée des ouvrages dépassent les normes de qualité environnementales. Les concentrations en HAP et pesticides sont généralement faibles mais certaines concentrations en pesticides (glyphosate,T-butyl, bifenthrine, oxyfluorfène et imidaclopride) sont supérieures aux limites. Les métaux sont majoritairement sous forme dissoute surtout dans la noue où seuls Cr, Pb et Ti sont préférentiellement sous forme particulaire. Les molécules quantifiées en entrée et sortie des ouvrages sont les mêmes ; une augmentation de la fraction dissoute en sortie est observée. Les concentrations en sortie ne sont pas systématiquement réduites mais en raison de la diminution des débits on observe une réduction des masses de certains métaux.

ABSTRACT

The efficiency of three stormwater management systems (a dry basin, a wet basin and a vegetative swale) for the reduction of flow, trace metals, polycyclic aromatic hydrocarbons (PAHs) and pesticides was studied. Metal concentrations (with the exception of cadmium) at the inlet of the three systems are generally above the standards for good freshwater quality. The occurrence and concentration of PAHs are low. Most pesticide concentrations meet the standards, however, glyphosate,T-butyl, bifenthrine, oxyfluorfene and imidaclopride concentrations are sometimes above the limits. Most metals are in the dissolved form with the swale having the largest part of dissolved metals (only Cr, Pb and Ti are mostly in the particulate fraction). The same molecules are generally quantified at the outlet of the three systems; an increase in the dissoved phase is observed. There is no reduction in the concentrations at the outlet but due to the flow reduction the metal mass is reduced for some metals.

MOTS CLÉS

Bassins de rétention, débit, micropolluants, noue, ruissellement

1 INTRODUCTION

Increased urbanization and especially the development of impervious surfaces induce an increase in runoff and the deterioration of receiving waters (Burns et al., 2012). During the past decades, Best Management Practices (BMPs) have been widely used to protect surface water quality and mitigate the adverse impacts of stormwater runoff on receiving water. The performance of these technics to reduce flow, suspended solids, metals and PAHs has been widely studied, however, few studies are devoted to pesticides.

In this context, one objective of the Matriochkas project was to evaluate the performance of these BMPs to reduce of flow and micropollutants (trace metals, PHAs and pesticides). This presentation shows the first results of the project; a dry basin, a wet basin and a vegetative swale were studied

2 MATERIALS AND METHODS

2.1 Experimental sites

The dry basin BO3 has a surface of 2 175 m^2; it is located along an express way and supports a heavy traffic of 68 370 veh/day. The wet basin Ville au Blanc has a surface of 650 m^2; the contributive area is an enterprise zone and a low-traffic road. The vegetative swale is 11,5m-long and 4,5 m-wide; it is located in a residential area with a low traffic. The sites were monitored continuously during 1 year minimum, in the period 2016-2018, with 2 monitoring locations, upstream and downstream in the device.

Table 1 – Main characteristics of the experimental sites

Site	*Contributive surface area / Impervious fraction*	*Catchment uses*	*Flowrate measurement*	*Sampling method*
BO3-Chezine Coueron Dry basin	4,8 ha 90%	Heavy traffic road	Water level & velocity (Doppler) Sigma AS950	Flow proportional automatic sampling
Ville au Blanc Vertou Wet basin	300 ha 28%	Road with low traffic & enterprise zone		
Noue Dumont Nantes Vegetated swale	1,7 ha 75%	Residential housing	Water level with triangular weir threshold Campbell CS451	Manual sampling

2.2 Sampling and analyses

Doppler flowmeters were installed at the inlet and outlet of the three systems for a continuous monitoring of the flow with a 5-minute timestep (Dry and wet basins) and a 2-minute timestep (swale). Water sampling at both inlet and outlet of the 2 basins was flow dependant and samples were collected by means of automatic samplers. For the swale, samples were collected manually. ICP-MS was used the determination of metals while GC-MS/MS was used for PAHs and ICP-MS/MS or GC-MS/MS for pesticides.

3 RESULTS AND DISCUSSION

3.1 Flow

Based on a set of hydrological data of about 10 months and about 30 rain events, we analysed the flowrate attenuation on each site. This attenuation regroups both volume and peakflow reduction, and Figure 1 focus on the peakflow reduction for various types of rainfall events. The vegetated swale (Noue Dumont) shows a larger attenuation than both other devices. This is due to the infiltration function of this swale, compared to both other basins. The attenuation may be very strong for small rain events, and tends to decrease with the cumulative rainfall, which is typical of the BMPs hydrological behaviour.

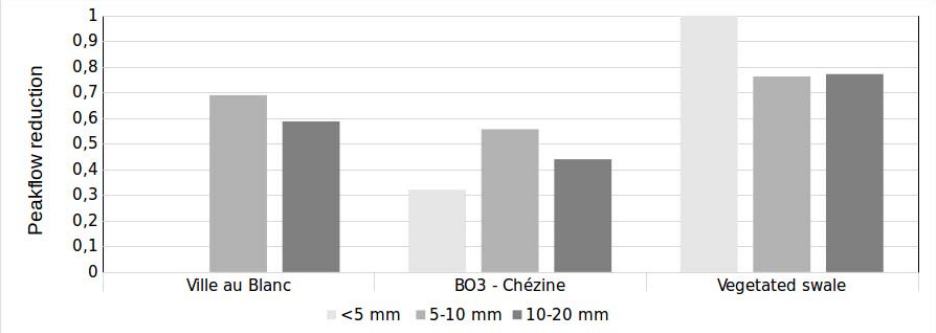

Figure 1 – Peakflow reduction along with various classes of rainfall depth. The peakflow reduction was not estimated for small rain events in Ville au Blanc due to very few available data

3.2 Pollutant concentrations in the three systems

3.2.1 Metals

Table 2 reports the total metal concentrations in the three systems. At the inlet, most concentrations are above the standards for good water quality, only Cd always meets the standards. These concentrations vary greatly from one campaign to the other and are in the range of those previously reported in Nantes (Lamprea and Ruban, 2011) and generally in the lower range of those reported elsewhere (Rossi, 1998; Sabin et al., 2005; Flanagan et al., 2018). Concentrations at the outlet are sometimes higher than those at the inlet, which could be explained by the high proportion of metals present in the dissolved fraction.

Table 2. Metal concentrations in runoff water from the three systems

Metal	NQE/VGE (μgL^{-1})	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
		Dry basin Min-Max μgL^{-1}		Wet basin Min-Max μgL^{-1}		Swale Min-Max μgL^{-1}	
As	0,83*	2,91-10,26	3,48-12,05	32,5-62,0	34,6-63,3	32,5-62,0	34,6-63,3
Cd	0,08-0,25*	0,03-0,11	0,04-0,14	0.06-0.10	0.06-0.15	0.06-0.10	0.06-0.15
Co	0,3**	0,5-1,7	0,8-7,7	0.5-1,6	0.8-2,4	0.5-1,7	0.8-2,4
Cr	3,4*	1,4-7,5	1,1-9,7	3,0-28,0	3,9-17,2	3,0-28,0	3,9-17,2
Cu	1,0*	12,0-20,3	8,9-17,5	9.0-27,7	8,4-20,7	9.0-27,7	8,4-20,7
Mo		0,9-2,5	0,81-2,02	0,7-1,0	0,8-1,1	0,8-1,0	0,8-1,1
Ni	4,0*	5,5-23,1	6,5-16.0	3,6-11,6	4,3-8,9	3,6-11,6	4,3-8,9
Pb	1,2*	2,2-4,2	1,6-5,3	2,1-14,0	2,6-7,6	2,1-14,0	2,6-7,6
Sr		22,9-60,6	25,1-67,0	0,6-21,0	0,5-77,6	0,6-21,0	0,5-77,6
Ti		32-185	37-280	44-2	85-466	44-2	85-466
V	2,5**	1,60-7,12	1,68-10,98	2,95-34,67	4,37-18,48	2,95-34,67	4,37-18,48
Zn	7,8*	30-140,	21-87	29-95	26-54	29-95	26-54

Standards: * refer to Decree of 27/07/2015 of the Ministry of Ecology and Sustainable Development and Energy (EQS-MA, internal surface waters), **refer to Environmental guidelines (Ineris, 2015)

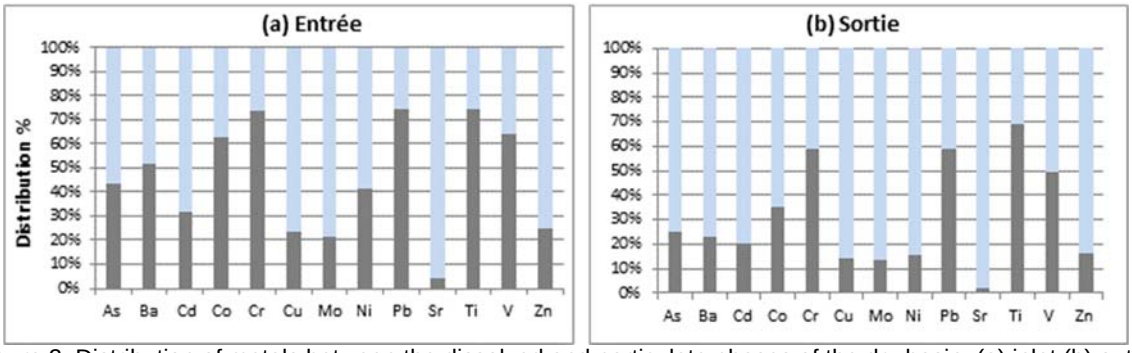

Figure 2. Distribution of metals between the dissolved and particulate phases of the dry basin: (a) inlet (b) outlet

The distribution of metals between the dissolved and particulate phases is shown in figure 1 for the dry basin. The proportion of dissolved metals is higher than that generally reported in the literature (Gasperi et al., 2014). The same pattern is observed for the three systems.

It can be noticed that there is no systematic reduction of the metal mass at the flow event scale.

3.2.2 PAHs and pesticides

PAHs concentrations in runoff water from the three systems are lower than those reported in the literature (Gasperi et al., 2014); only a few molecules are quantified: Benzo(b)fluoranthene, Fluoranthene, Naphthalene and pyrene (in the dry basin); anthracene and pyrene in the swale; benzo(b)fluoranthene, Naphthalene and pyrene (wet basin).

Among the 300 pesticides investigated, only a few were quantified. Glyphosate exceeds the limits in the dry basin; T-butyl, bifenthrine, oxyfluorfene and imidaclopride are above the standards in the swale, which is surprising as the swale is located in an ecodistrict.

4 CONCLUSION

This evaluation of three stormwater management systems for the retention of flow and pollutants shows a high temporal variability of pollutant concentrations. The proportion of metals in the dissolved fraction is higher than that reported in the literature. Most metal concentrations are above the standards for good quality water; only Cd always meets the standards. PAHs concentrations are in the lower range of those previously reported. Regarding pesticides only a few molecules are quantified, however, glyphosate, T-butyl, bifenthrine, oxyfluorfene and imidaclopride are sometimes above the limits. The reduction of the pollutant mass is not systematic at the flow event scale; more campaigns will allow calculating this reduction on an annual basis.

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