Accumulated sediments in a retention/detention basin: What about the contamination in terms of emerging pollutants?

Sédiments accumulés dans un bassin de retenue-décantation : qu'en est-il de la contamination par les substances émergentes ?

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RÉSUMÉ

Les bassins de retenue-décantation sont très souvent utilisés pour la gestion des eaux pluviales dans les villes. Ils permettent de diminuer les risques contre les inondations et de réduire les rejets de polluants particulaires dans les milieux récepteurs. Leur fonctionnement sur le long terme pose cependant le problème de la gestion des sédiments accumulés. En effet, les opérations de curage deviennent à leur tour une réelle problématique pour les gestionnaires, d'un point de vue économique et réglementaire. Leur traitement et leur potentielle réutilisation dépendent de leur contamination et de leur toxicité. Dans le cadre du projet ANR CABRRES, une caractérisation des zones de dépôts en termes de contamination chimique est réalisée dans un bassin de rétention/décantation localisé dans l'Est Lyonnais (France) afin d'évaluer les variabilités spatio-temporelles de la contamination. Trois familles de micropolluants encore peu étudiés dans ce contexte sont présentés – les PBDE, les alkylphénols et le bisphénol A. Cinq points ont été échantillonnés lors de 6 campagnes réparties entre 2012 et 2015 (avec un temps d'accumulation et des saisons différents). Les résultats préliminaires sur 2 campagnes montrent une hétérogénéité des teneurs en alkylphénols. Pour le bisphénol A, il est observé seulement une hétérogénéité spatiale. Ces résultats préliminaires restent toutefois à confirmer avec les données des autres campagnes.

ABSTRACT

Stormwater detention basins are nowadays widely used to manage stormwater in cities. This practice is an interesting option that tends to reduce water volumes and runoff peak flows in downstream networks or water courses, mitigating pollution conveyed to surface waters. These structures are characterized by an accumulation of sediments and pollutants. The amount and the characterization of accumulated sediments are also a very important issue for practitioners because these solids have to be frequently removed and managed as waste. Their treatment and potential reuse also depend on their pollution level. In this context related to the CABRRES national project, a chemical characterization of accumulated sediments is carried out in the Django Reinhardt detention-settling basin in Chassieu (France) to estimate the spatio-temporal variability of the contamination. Three micropollutant families – PBDE, alkyphenols and bisphenol A are monitored. Little is known on their behavior in the sediment matrix. Five points have been sampled on seven campaigns from 2012 to 2015. The preliminary results show a spatio-temporal heterogenity for alkylphenols. For bisphenol A, we noticed only a spatial varaibility. More data must be acquired to draw more rigorous conclusions.

MOTS CLÉS

Micropollutants, detention basin, sediments, spatio-temporal distribution

1 INTRODUCTION

Stormwater detention basins are nowadays widely used to manage stormwater in cities and their suburbs in order to contribute to the long-term monitoring of stormwater runoffs. This practice is an interesting option that allows (i) to reduce water volumes and runoff peak flows in downstream networks or water courses and (ii) mitigate pollution discharges to surface waters (trapping particulate pollutants (e.g. metals, PAHs, etc.) by means of settling processes).

These systems are characterized by an accumulation of sediments and pollutants (El-Mufleh, 2011). The amount and the characterization of accumulated sediments are a very important issue for practitioners because these sediments have to be frequently removed and managed as waste. Indeed, their treatment and potential reuse depend on their pollution level and toxicity. Different ways to enhance them have been proposed (e.g. filling material in urban environments, new materials in civil engineering, etc.), but each process used requires an assessment of environmental and human health risks (Petavy 2007; Ruban et al. 2009).

This study is a part of the multidisciplinary CABRRES project (CAractérisation chimique, microbiologique, écotoxicologique, spatio-temporelle des contaminants des Bassins de Retenue des eaux pluviales urbaines – évaluation et gestion des Risques Environnementaux et Sanitaires associés) supported by the French National Research Agency. One of the objectives of this project is to improve the knowledge on the physcico-chemical characteristics of the accumulated sediments in a retention/detention basin.

In the project, target substances include alkylphenols (4-nonylphenol (NP), 4-tert-octylphenol (OP), bisphenol A (BPA)), nonyl and octylphenol mono and diethoxylates (NP1EO, NP2EO, OP1EO and OP2EO), bisphenol A analogues (tetrachloro- and tetramethyl-bisphenol A), and nine polybrominated diphenyl ethers (PBDE).

These micropolluants were chosen because they were already found in many urban catchments. PBDE are used as flame retardant in synthetic materials such as plastics, including bulding materials, car items, etc (SOCOPSE, 2009). Alkylphenols and their ethoxylates are used as precursors in the detergents, as additives for fuels and lubricants, polymers, and as components in phenolic resins. These compounds are also used in tires, adhesives, coatings and high performance rubber products (Lampréa-Bretaudeau and Gromaire, 2012). Bisphenol A (BPA) is employed to make certain plastics and epoxy resins. BPA-based plastic is found in a large variety of common consumer goods, such as water bottles, sports equipment. Bisphenol A is also a precursor to the flame retardant tetrabromobisphenol A, and formerly was used as a fungicide (Cousins et al, 2002).

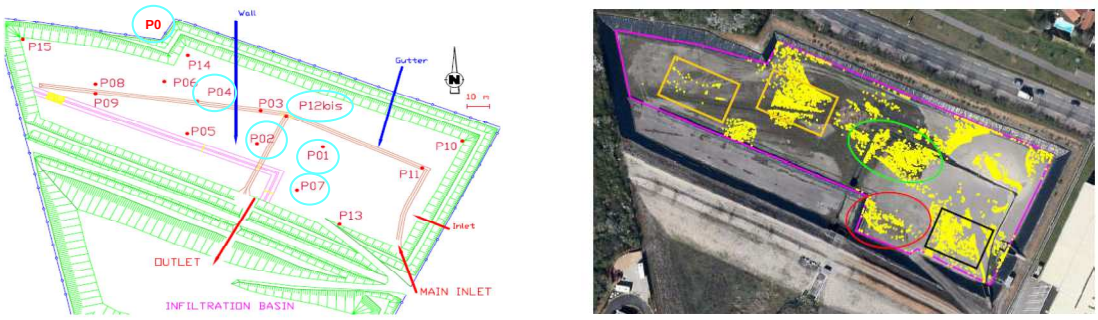
The purposes of this paper are *(i)* to describe the analytical methods used to measure PBDE, AP and BPA concentrations for the sediment matrix and *(ii)* to compare the characteristics of accumulated sediments in stormwater detention basins (spatial distribution, heterogeneity of sediment characteristics).

2 MATERIAL AND METHODS

2.1 Experimental site and sampling locations

The study was carried out on a detention basin situated at Chassieu, France (www.othu.org). The basin is located at the outlet of an urban and industrial catchment of 185 ha with an impervious coefficient of about 75 % and drained by a separated stormwater system. It also receives dry weather effluent from industrial activity supposed to be clean such as water cooling. The basin has been operating for more than thirty years and was rehabilitated in 2002. The basin was cleaned in 2006 and in April 2013.

Five sampling points (P01, P02, P04, P07, P12 bis) were chosen according to an hydrodynamic modelling of the movement of solids in the basin, flow patterns and preferential sedimentation zones (Figure 1). Point P12bis corresponds to a rough oil separator (in fact a small settling tank) which is supposed to trap hydrocarbons and waste from dry weather flows. A reference point P0 is integrated in the study. It is located at the top of the basin and samples taken at a 10 cm depth. This point will be used to compare sediments brought by stormwater runoff. The sediment sampling in the basin is based on the quartering method (Gy, 2004). Sediments were collected and homogenized from a square area of 80 x 80 cm quartered four times. Sediments collected were stored in amber glass bottles and freezed until the analysis.



(a) (b)

Figure 1. (a) Sampling location of sediments; (b) hydrodynamic of detention basin

2.2 Analytical methods

Analysing the target compounds in sediments is a real challenge. At first, we tried to develop only one extraction method for all the molecules but it was impossible. Three different extraction methods were developed based on solid-liquid extraction with isopropanol for alkylphenols and BPA analogues, an accelerated solvent extraction, coupled with solid phase extraction (SPE) for alkylphenols mono and diethoxylates and the "QuEchERS" approach for PBDE. Moreover, great care was adopted to avoid any plastic in the glassware used for extraction and analysis of alkylphenols. Finally, the extracts were analysed by liquid chromatography (Agilent 1290) coupled with tandem mass spectrometry (ABSciex 3200 QTrap), operated in negative mode for alkylphenols and BPA analogues and in positive mode for nonyl and octylphenol mono and diethoxylates, and by gas chromatography (6890 Agilent) coupled to a Time of Flight (ToF) mass spectrometer GCT Premier from Water. In order to correct for recoveries and matrix effects, internal standard calibration was performed using stable isotope labelled analogues. For the analyses, 0.5 g of sediments for alkylphenols and alkylphenols ethoxylates were taken and 1 g for PBDE. After finding optimum conditions, limits of quantification between 5 and 50 ng/g were achieved.

3 RESULTS AND DISCUSSION

3.1 Campaigns

Seven sampling campaigns were carried out on accumulated sediments (Figure 2) between May 2012 and April 2015. They were scheduled in order to observe a potential impact of the climatic conditions on the sediment contamination. After the first campaign (C0), the basin have been scrapped in April 2013 after 72 months of operation. After this date, the contamination evolution of the accumulated sediments (from 6 to 24 months) was evaluated.

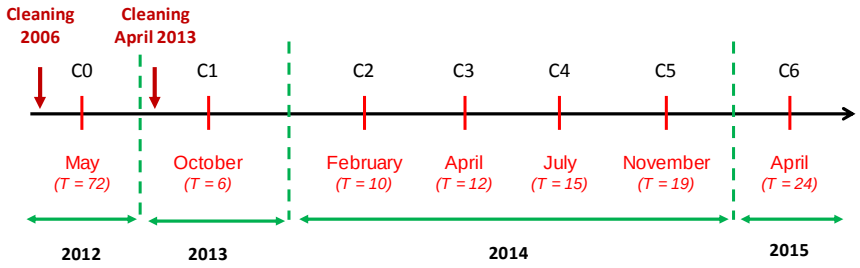


Figure 2. Campaign chronology. In braket the accumulation time (in months) of sediments after the cleaning of the basin.

3.2 Preliminary results

Only alkylphenols and bisphenol A concentrations are presented for campaigns C3 and C4 on Figure 2. The results of others campaigns and of other pollutants (PBDE) are still under analysis. The spatial distribution and the pollutant contents will only be discussed.

For alkylphenols (NP and OP), a spatial difference was observed. For campaign C3, P01 and P02 presented the lowest concentration while P12 bis presented the highest values. For campaign C4, an

increase of P01 contamination (about four times higher than C3 for NP, 16 times for OP and Twice higher for BPA) was observed. For BPA, same distribution for the 2 campaigns was observed. The highest contents were measured in P04 and P07 sampling points.

In comparison to the reference point P0 (outside of the basin), the AP concentrations were lower than P0 content. On the contrary for BPA, the accumulated sediments presented higher values. Moreover, the comparison of the contents with the regulatory threshold established for river sediments (NQE_NP = 35 ng/g dw, NQE_OP = 24 ng.g dw and PNEC_BPA=26 ng/g dw) (DCE20015/12) showed a high contamination of accumulated sediments and soil around the basin.

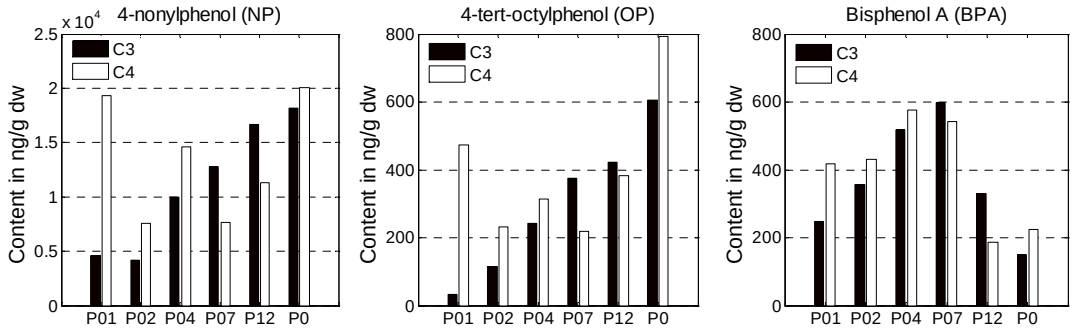


Figure 3. NP, OP and BPA content (ng/g dw) in accumulated sediments for 2 campaigns: C3 (12 months of accumulation) and C4 (14 months of accumulation)

4 CONCLUSION

Thanks to the use of advanced analytical techniques, limits of quantification consistent with ultra-traces detection can be achieved. As preliminary results conducted on two campaigns on AP and BPA, the research showed contents of AP and BPA higher to regulatory threshold (DCE2005/12). A spatio-temporal heterogeneity of AP was observed and maybe due to movement of sediments in the basin, differential degradation process or pollutant inputs between campaigns. For BPA, the contents were similar for the two campaigns but a spatial difference was observed. More data must be acquired to draw more rigorous conclusions. Further investigations, including physical characterization (grain-size, density, etc.) could contribute to better understand key mechanisms related to sediments fate in dry stormwater retention/detention basin in order to allow identifying their potential reuses.

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