

## **Accumulated sediments in a large dry stormwater retention-detention basin: physico-chemical spatial characterization and evolution - Estimation of metals, pesticides, PAHs and Alkylphenols contents**

Caractérisation spatiale et évolution physico-chimique des sédiments accumulés dans un bassin de retenue-décantation des eaux pluviales - Évaluation des charges en métaux, pesticides, HAPs et Alkylphénols

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### **RÉSUMÉ**

La caractérisation physique et chimique des sédiments piégés dans les bassins de rétention des eaux pluviales est un enjeu fort car leur transport et traitement pour valorisation coûtent cher et dépendent fortement de leur contenu. Ainsi des sédiments accumulés depuis 6 ans ont-ils été échantillonnés dans un grand bassin sec de rétention des eaux pluviales situé à l'exutoire d'un bassin versant industriel. La caractérisation concerne des paramètres physiques tels que matière sèche, volatile, granulométrie ou densité et les concentrations en métaux, HAPs et de manière plus originale pesticides et Alkylphénols. Globalement les sédiments sont très pollués en termes de métaux, HAPs et dans une moindre mesure en Alkylphénols, Diuron et Glyphosate/AMPA. On observe une variabilité spatiale et temporelle pour la granulométrie mais faible et une certaine homogénéité pour les contaminants à l'exception des pesticides dont la variabilité est élevée. Les caractéristiques physiques et chimiques évoluent avec le temps en lien avec les contributions du bassin versant et l'hydrodynamique du bassin. Une variabilité physique et chimique inter-couches a également été observée mais reste peu exploitable.

### **ABSTRACT**

Physical and chemical characterization of sediments trapped in retention basins is at stake because transport and treatment for valorization are expensive and depend on their contents. Six-year accumulated sediments in a large dry detention basin at the outlet of an industrial catchment were sampled. The characterization is related to physical parameters such as dry and volatile matter, particles size distribution (PSD), density, concentrations of metals, PAHs and in a more original way pesticides and Alkylphenols contents. Globally the sediments are highly polluted in terms of metals, PAHs and in a lesser extent in Alkylphenols, Diuron and Glyphosate/AMPA. A heterogeneous spatial distribution, however low, was noticed for PSD and a rather good spatial homogeneity found for chemical contents except for pesticides whose variability is high. Physical and chemical pollutants contents changed over time in relationship with catchment contributions and the hydrodynamism of the basin. Inter-sediments layers variability was also highlighted but is unusable in practice.

### **KEY-WORDS**

Micropollutants, Physical characterization, Retention-detention basin, Sediments

## 1 INTRODUCTION

Nowadays, stormwater retention/detention basins are largely used in urban drainage both for flood and pollution mitigation. If they are recognised to trap sediments, they are also known to accumulate large amounts over time (Yousef *et al.*, 1994; Guo, 1997). Therefore substantial questions remain about the better way to manage them. The management of sediments depends not only on their quantity but also on their quality, which is at stake. For that purpose deposition mechanisms linked to turbulence and hydrodynamics were studied in such compartment (Marsalek *et al.*, 1992; Torres, 2008). Physical and chemical characterization studies were also carried out but they mainly concerned current parameters (e.g. dry and volatile matter) or common substances like metals or hydrocarbons (Marsalek & Marsalek, 1997; Ruban, 2005) and very few of them deal with the large range of substances described in the European Water Framework Directive (EC, 2000). Moreover, some samples are collected and depth characterization is not well documented.

A 6-year accumulated sediments layer in a large dry detention basin was investigated. Physical and chemical spatial distributions, chemical content evolution and depth characterization were studied. The investigation concerns current parameters and content of metals and PAHs but also other organic substances such as pesticides and alkylphenols which is new in the domain of stormwater management.

## 2 METHODS

### 2.1 In-situ experimentation

#### 2.1.1 Experimental site location

All experiments were conducted in a detention basin called Django Reinhardt at Chassieu near Lyon, France (69). This basin is located at the outlet of a 185 ha industrial catchment drained by a separate stormwater network. The imperviousness coefficient of the catchment is about 75%. The pipe network and then the basin collect dry weather flows, in fact “clean” water (or supposed to be clean) coming from cooling of industrial processes.

The detention basin covers 11,000 m<sup>2</sup> and has a storage capacity of 32,000 m<sup>3</sup>. Stormwater enters the basin via two 160 cm wide circular pipes. The bottom of the basin is made of bitumen and is equipped with a low-flow trapezoidal gutter collecting dry weather flows or small amount of stormwater. The banks are covered with a plastic lining. Outflow of the basin is restricted to 350 L/s thanks to a flow control device (Hydroslide®). A wall is placed to improve settling (see Figure 1). Last total sediment removal was carried out in early 2006.



Figure 1. Django Reinhardt retention / detention basin (source : Google map - 2012)

#### 2.1.2 Sampling

Accumulated sediments were collected by grab samples at five different points (Figure 3). For the different points, two kinds of sample procedure were used: (i) one is based on homogenized core samples representative of the total sediment depth (mean sample); (ii) the second is based on samples taken at different levels (mainly top, middle and bottom).

Simple mixing or quartering technics were used depending on the objectives of the campaign. Quartering method was chosen when a large amount of sediment was necessary to analyze and compare different characteristics on a same sample (chemical, physical, ecotoxicological and bacterial - not presented here). Simple mixing technic was used in the other cases. The top, middle and bottom layers were sampled by dividing the sediment core into three equal parts.

The different points sampled were chosen according to sediment depth (Figure 2). Point 1 and 2, close to the gutter but not in the gutter, were identified as very contaminated in a preliminary campaign (Sébastien *et al.*, 2011). That is the reason why point 1 & 2 were more precisely investigated in terms of contamination with depth and point 2 sampled for all the campaigns.

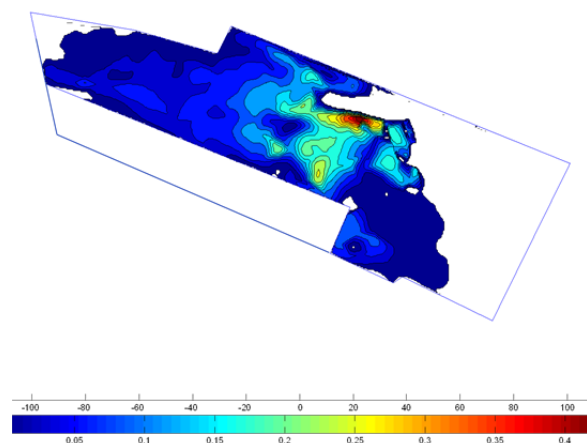


Figure 2. Contour lines of observed sediments thickness (m) - Yan *et al.*, 2012 (the right part of the basin was not investigated because of low thicknesses of sediment in these parts)

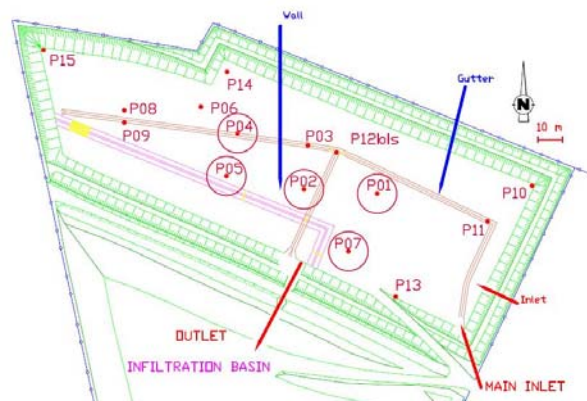


Figure 3. Location of the points sampled

### 2.1.3 Physical analysis

Physical characterization of accumulated sediments was systematically conducted at least on 3 replicates according to national standards.

Dry and volatile contents were respectively assessed by drying the samples during 24 h at 105°C and calcination during 2 h at 550°C according to (NF EN 12880, 1997) and (NF EN 12879, 1997) standards. The volatile content is supposed to be volatile organic fraction (VOM).

Particle size distribution (D50) was estimated with a laser diffraction device (NF ISO 13320, 2009).

Bulk density was measured with a metallic ring according to (NF ISO X31-501, 1992) and particles density with a pycnometer (NF P 94-054, 1991).

Global uncertainties linked to physical parameters (except particles size distribution) were calculated by applying the Law of Propagation of Uncertainties (LPU) to measurement system and heterogeneity (link to replicates). The standard deviations between replicates are also mentioned.

### 2.1.4 Chemical analysis

Chemical analyses were conducted on different groups of micropollutants (MP), chosen according to the European Water Framework Directive (WFD) requirements (EC, 2000). In France, there is no regulation on threshold values concerning sediments of detention basins. Values are given for specific contaminated soils and it is quite difficult to compare these data to ours. So, the chemical contents were compared to existing Dutch standards on contaminated soils, (standard soil with 10% of organic matter and 25% of clay) (NMHSPE, 2000), rather used in literature.

Finally, 45 substances were studied among five groups (5 heavy metals, 16 PAHs, 2 Alkylphenols and 22 pesticides). Moreover, 23 other pesticides were investigated in a screening campaign (see Table 1). These pesticides were chosen because usually employed in urban field and/or considered as emergent substances.

The samples were analyzed either by using standards or assessed according to recent analytical methods in particular for MP (Barrek *et al.*, 2009; Becouze *et al.*, 2011). Analyze of metals was performed by ICP-MS (ISO 17294-1/2, 2004).

Chemical parameters were assessed with analytical and sampling uncertainties. A global analytical

uncertainty was estimated at about 25% for organic compounds (PAHs, Alkylphenols and pesticides). For the metals, this uncertainty was assessed for each compound by inter-labs trials (Ni, Pb, Cu: 10%; Zn: 11% and Cd: 26%).

Table 1. List of substances

Metals	Nickel Ni *	Lead Pb *	Copper Cu	Zinc Zn	Cadmium Cd **
PAHs	Naphtalene Nap *	Acenaphthylene Acy	Acenaphthene Ace	Fluorene Flu	Phenanthrene Phe
	Benzo(b)fluoranthene BbF**	Benzo(k)fluoranthene BkF**	Benzo(a)pyrene BaP **	Indeno(1,2,3-cd)pyrene IP**	Dibenzo(a,h)anthracene Dah
	Fluoranthene Flh *	Pyrene Pyr	Benzo(a)anthracene BaA	Chrysene Chr	Anthracene A **
	Benzo(g,h,i)perylene Bper**				
Alkylphenols	4-Tert-Octylphenol 4-OP *	4-Nonylphenol 4-NP **			
Pesticides	Alachlor Ala *	Atrazine Atr *	Simazine Sim **	Chlorpyrifos Chlor *	Delta hexa Dhex
	Op DDT Op DDT *	Pp DDT Pp DDT *	Endrine End *	Alpha hexa Ahex	Endosulfan beta Enb **
	Gama hexa Ghex	DDD pp DDD pp	DDE pp DDE pp	Beta hexa Bhex	Trifluralin Tri *
	Diuron Di *	Endosulfan Alpha Ena **	Aldrin Ald *	Isodrin Iso *	
	Chlorfenviphos Chlorf *	Isoproturon Isop *	Dieldrin Die *		
Pesticides (screening)	Metaldehyde Meh	Mecoprop Mec	2_4_D 24D	2_4, MCPA 24M	S-metolachlore Sme
	Carbendazim Car	Isothiazolinone Itz	Chlorothalonil Clo	Pendimethalin Pen	Acetochlore Ato
	Metazachlor Met	Tebuconazole Teb	Epoxiconazole Epo	Diflufenicanil Dif	Deltamethrine Del
	Fenpropidine Fen	Trichlopyr Trp	Folpel Fol	Irgarol 1051 Irg	Terbutryne Ter
	Glyphosate Gly	Glyphosate ammonium GIA	AMPA AMPA		

\*priority substances

\*\*priority hazardous substances

according to WFD

## 2.2 Campaigns

Four campaigns were conducted (see Table 2).

Table 2. Campaigns on accumulated sediments

N°	Date	Points	Layer	Methods	Physic	Metals	Organic
A	2011-06-14	2	Mean	Simple mixing	X	X	X
B	2012-03-14	2, 4, 5, 7	Mean/Top	Simple mixing	X	X	X
		1	Top/Mid/Bottom	Simple mixing	X	X	X
C	2012-05-02	1, 4, 7	Mean	Quartering	X		X
		2	Top/Mid/Bottom		X		X
D	2012-07-09	2	Mean	Simple mixing	X	X	X

## 3 RESULTS AND DISCUSSION

### 3.1 Physical characterization

The next tables (Table 3, Table 4) present all of the physical results.

Two no-parametric statistic tests were used to compare the spatial distribution, evolution over time and accumulated sediments layers: Wilcoxon (W) when one parameter was compared for two datasets and Kruskal-Wallis (KW) when more than two datasets had to be compared.

#### 3.1.1 Physical characterization of the different points, evolution over time

The values of VOM and D50 are in the range of those found in literature (e.g. Ruban *et al.*, 2003; Petavy *et al.*, 2009).

Spatial distribution of volatile organic matter (VOM) was studied for campaign (B) and (C). For both campaigns a small heterogeneity was found according to KW test at a 5% level. Campaign (C) was a little more homogenous than campaign (B). For campaign (C), the last rain event occurred 3 days before with a total rainfall depth of 33 mm whereas the dry weather time period before campaign (B) was about 1 week with a lower rainfall depth. The important rain event with a short antecedent dry period could explain these results.

According to standard deviation, it is very difficult to conclude to an evolution over time of VOM even if an increase seems to occur (KW test *p-value* of 0.03), at point 2 from  $19.4 \pm 0.1$  % DM (A) to  $20.4 \pm 0.3$  % DM (D) with the same global uncertainty (2.8%).

Particles size distribution variability was observed between the different points on campaign (C) (KW

test *p-value* of 0.008). Such results were also found in the literature on other experimental sites (e.g. Jacopin, 1999; Durand, 2003; Petavy, 2007) and were already explained by particular hydrodynamic processes in the basins depending on the different events.

Despite uncertainties, particles size distribution was a little bit different with time on points 2 and 4 but with no real tendency. For example, on point 2, D50 decreased between the first and second campaign (respectively  $50 \pm 12 \mu\text{m}$  and  $33 \pm 1 \mu\text{m}$ ) and increased in the last ( $56 \pm 3 \mu\text{m}$ ).

However the global range of particle size distribution and VOM are roughly similar whatever the point and the date.

Table 3. Physical characterization - mean samples (standard deviation) [global uncertainty]

		Points						
Unit		1	2*	4**	5	7**		
DM	%	<i>min</i>	62.4 (0.0) [2.0]	56.4 (0.6) [1.3]	58.9 (0.0) [1.9]	65.4 (0.2) [2.5]	64.4 (0.0) [2.1]	
		<i>max</i>	-	61.1 (0.1) [1.4]	59.7 (0.6) [5.0]	-	65.3 (0.3) [3.0]	
VOM	%DM	<i>min</i>	21.2 (0.3) [2.6]	19.4 (0.1) [2.8]	16.7 (0.7) [5.7]	14.8 (0.3) [3.6]	14.8 (0.3) [3.6]	
		<i>max</i>	-	20.4 (0.3) [2.8]	25.5 (0.3) [2.4]	-	25.6 (0.1) [2.4]	
D50	$\mu\text{m}$	<i>min</i>	42 (4)	33 (1)	27(0)	32 (1)	33 (1)	
		<i>max</i>	-	56 (3)	34 (2)	-	35 (3)	
bulk density	$\text{kg/m}^3$	<i>min</i>	-	532 (-) [66]	583 (-) [74]	688 (-) [86]	667 (-) [84]	
		<i>max</i>	-	776 (-) [97]	-	-	-	
particles density	$\text{kg/m}^3$	2,475 (37) [248]		-	2,460 (30) [245]	-	2,393(16) [233]	

\*: campaigns (A), (B), (D)

\*\* : campaigns (B), (C)

### 3.1.2 Physical characterization of sediments layers

Two points (Point 1 and Point 2) were sampled on three different layers. Globally considering the results for volatile organic matter, the sediments situated at the bottom are less organic than at the top. It seems that there is a normal segregation of the particles in the accumulated sediment. Volatile organic matter on both points differed with depth. A decrease was observed on point 1 (top:  $27 \pm 0.2$  %DM; middle:  $16.1 \pm 0.3$  % DM; bottom:  $8.4 \pm 0.0$  %DM) and point 2. This observation was also highlighted in literature (Yousef *et al.*, 1990; Bedell *et al.*, 2004).

Particles size distribution was compared between top and bottom layers. A decrease can be observed for both points. However taking into account standard deviation the decrease for point 1 is not significant (*W* test *p-value* of 0.1) but is attested on point 2 (*W* test *p-value* of 0.0087). Finer particles could have migrated more easily as frequently observed.

VOM content and particle size distribution homogeneity on the top layers were validated by Kruskal-Wallis test on four top layers but not for grain size (*p-value* of 0.26 for VOM and 0.07 for D50). Sampling points locations (on the left and right part of the gutter) and hydrodynamics could also explain this tendency. Input sediments are firstly spread and then settled or are re-suspended.

Table 4. Physical characterization – sediments layers mean values (standard deviation) [global uncertainty]

		Top/Mid/Bottom						Top			
		1T	1M	1B	2T	2M	2B	2T	4T	5T	7T
DM	%	51.6	59.1	64.7	56.6	57.1	53	53	52.2	58.4	59.3
		(0.5) [4.1]	(1.4) [10.2]	(1.5) [10.6]	(0.0) [1.8]	(0.0) [1.9]	(0.0) [1.7]	(0.2) [2.4]	(0.6) [4.8]	(0.2) [2.3]	(0.1) [2.0]
VOM	%DM	27	16.1	8.4	17.3	18.2	13.8	21.9	23.3	22.4	21.7
		(0.2) [2.8]	(0.3) [3.2]	(0.0) [2.5]	(0.3) [2.7]	(0.3) [2.7]	(1.1) [2.8]	(1.4) [10.4]	(1.2) [9.1]	(0.2) [3.0]	(0.6) [4.9]
D50	$\mu\text{m}$	52 (3)	33 (1)	32 (1)	58 (7)	45 (3)	48 (2)	27 (0)	30 (1)	30 (0)	30 (1)

T: Top

M: Middle

B: Bottom

## 3.2 Chemical characterization

Micropollutants contents are presented in Table 6.

### 3.2.1 Metals

All of the five heavy metals were detected in sediments. Concentrations are high (nearly always higher than Dutch intervention values for Cu and Zn) and always much higher than target values. However, they are in the range of values found in the literature (see Table 5). Their spatial distribution is quite homogeneous between points and campaigns. Sediments whatever their location are much polluted in terms of heavy metals.

Table 5. Heavy metals content distribution and comparison with literature values (mg/kg DM)

	Our study	NMHSPE, 2000	Marsalek & Marsalek, 1997	Scholes <i>et al.</i> , 1998	Färm, 2001	Petavy <i>et al.</i> , 2009
Cd	2.5-5.5	12		8.7-9.6	0.85	0.6-2.6
Cu	174-269	190	20-80	12-178	78	161-281
Ni	45-75	210		147-187	53	31-107
Pb	97-245	530	39-149	350-332	45	102-357
Zn	927-1,704	720	112-406	675-830	269	411-1,949

Taking into account analytical uncertainties, heavy metals contents are highest in the campaign (B) with an increase from 30 to 55 % between the first (A) and (B) campaign (see Figure 4).

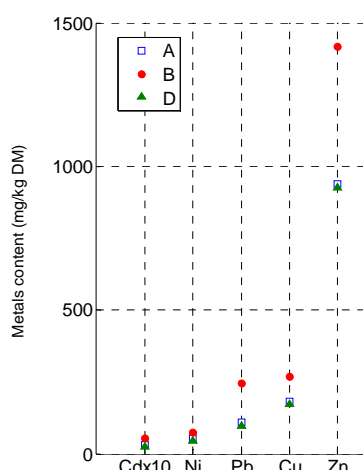


Figure 4. Metals content evolution - Point 2 in campaigns (A), (B), (D)

Chemical distribution was assessed on the accumulated sediments layers in point 1 and point 2. A vertical distribution variability was highlighted. Highest contents were observed at the top for Ni and Zn, in the middle layer for Cu and at the bottom layer for Cd and Pb but with a little difference considering analytical uncertainties. Contrarily to a previous study on a dry stormwater detention basin the metals content did not decrease with depth except for Zinc (Guo, 1997).

### 3.2.2 PAHs

Although all PAHs studied were detected, contents in accumulated sediments are usually different from one site to another. For example, contents in Fluoranthene are less than 200  $\mu\text{g}/\text{kg DM}$  in Django Reinhardt detention basin whereas contents between 2,900 and 13,800  $\mu\text{g}/\text{kg DM}$  were found in two different motorway basins (Durand *et al.*, 2004) and not detected in another detention basin at the outlet of an industrial catchment (Petavy, 2007). Dutch standard target value (1,000  $\mu\text{g}/\text{kg DM}$ ) was exceeded in our study for the sum of 10 PAHs whereas the intervention value (40,000  $\mu\text{g}/\text{kg DM}$ ) was never reached (NMHSPE, 2000).

Spatial distribution variability can be discussed for PAHs, considering analytical uncertainties. Point 4, in the gutter receiving cooling water during dry weather, is supposed to be solicited by sediment inputs. However, PAHs contents on point 7 and 5 (respectively on the right and left part of the gutter) are also high.

Considering evolution over time, PAHs contents increased between the first (A) and last campaign (D) (see Figure 5). Indeed, the 10 PAHs contents sum was respectively  $470 \pm 118$ ,  $569 \pm 142$  and  $1,020 \pm 255$   $\mu\text{g}/\text{kg DM}$  in campaigns (A), (B) and (D). Acenaphthylene (Acy) and Chrysene (Chr) contents evolution was different with highest Acy content and lowest Chr content in the second campaign. Chr is present in fossil fuel and Acy is a constituent of tar. A contribution from the industrial catchment could explain such results.

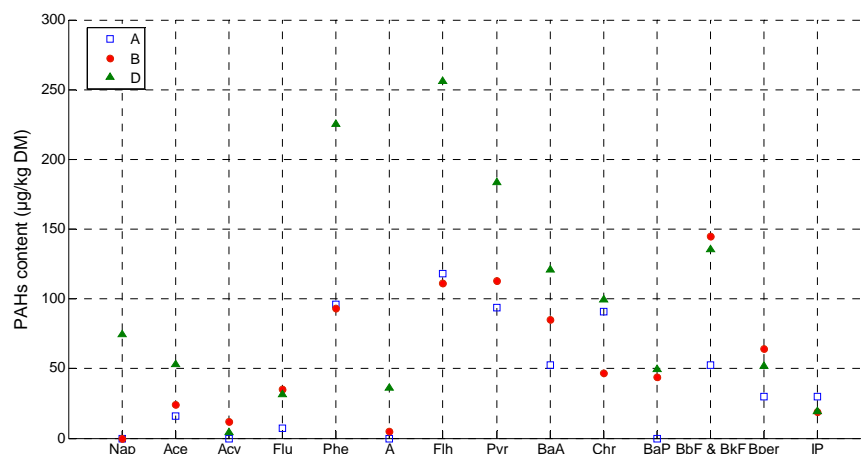


Figure 5. PAHs content evolution - Point 2 in campaigns (A), (B), (D)

PAHs contamination did not seem to vary with depth. Considering analytical uncertainties, the sum of 10 PAHs contents was not so different between top, middle and bottom layers for point 1 and point 2. Moreover, comparing the top layers values on points 2, 4, 5 and 7, PAHs contents were quite homogeneous between points except for Anthracene and Naphtalene.

### 3.2.3 Pesticides

Pesticides described in the European Water Framework Directive were never quantified except Aldrin, Chlorpyrifos, Diuron and Isoproturon (see Table 6). One-third of the pesticides screened were quantified (8/23). Few literature data are available on pesticides contents in sediments from stormwater detention basin. However, Diuron was already found in an infiltration basin with a content equal to  $200 \mu\text{g}/\text{kg DM}$  (Datry *et al.*, 2003). This value can be compared to our data ( $<\text{LOD}$  to  $630 \pm 158 \mu\text{g}/\text{kg DM}$ ). Diuron was also studied in treated sludge from 15 French WWTPs with a mean content of  $10 \mu\text{g}/\text{kg DM}$  (Choubert *et al.*, 2011). In our study, few other pesticides were quantified (see Table 6).

Important spatial distribution variability was observed for pesticides. For example, Diflufenicanil, synthetic herbicide was quantified in points 2, 5 and 7 and no detected in point 4. Glyphosate was also quantified in huge content (Table 6).

On the same point, an inter-substances variability was also noticed. On point 1, Diuron content was the highest at the top of the accumulated sediments ( $320 \pm 80 \mu\text{g}/\text{kg DM}$ ) whereas Glyphosate contents were in the same range on the three layers ( $7,671 \pm 1,918$ ,  $8,870 \pm 2,218$  and  $7,980 \pm 1,995 \mu\text{g}/\text{kg DM}$ ).

### 3.2.4 Alkylphenols

Alkylphenols were detected and contents in accumulated sediments are in the same range as literature data on marine or freshwater sediments. An international review presents 4-NP range contents from values less than 0.04 to  $2,960 \mu\text{g}/\text{kg DM}$  and 4-OP values less than 1.5 to  $670 \mu\text{g}/\text{kg DM}$  (Micic & Hofmann, 2009). Canadian recommendations for quality sediments indicate 4-NP contents of 1,400 and  $1,000 \mu\text{g}/\text{kg DM}$ , respectively for freshwater and marine sediments (CCME, 2012).

Concerning spatial distribution of Alkylphenols assessed on campaign (C), contents are in the same range for 4-NP (between  $1,098 \pm 275$  and  $1,168 \pm 292 \mu\text{g}/\text{kg DM}$ ) and 4-OP (between  $37 \pm 9$  and  $46 \pm 12 \mu\text{g}/\text{kg DM}$ ). Alkylphenols were analyzed on point 2 on campaigns (A) and (D). An important increase was noticed for 4-NP and 4-OP, (respectively  $83$  to  $2,807 \mu\text{g}/\text{kg DM}$  and  $38 \pm 10$  to  $81 \pm 20 \mu\text{g}/\text{kg DM}$ ). Once again, an important contribution is suspected.

Table 6. Mean pollutant contents

Substance	Unit	Mean samples					Top/Mid/Bottom						Top			
		1	2*	4**	5	7**	1T	1M	1B	2T	2M	2B	2	4	5	7
Nap	µg/kg DM	30	<LOD - 75	745-38	163	48-784	446	670	326	22	54	44	101	813	37	810
Acy	µg/kg DM	<LOD	<LOD - 12	15-<LOD	14	3-12	11	14	11	7	4	5	10	16	10	13
Ace	µg/kg DM	6	16-53	48-20	31	6-17	34	52	19	53	49	27	31	37	25	22
Flu	µg/kg DM	11	7-32	45-18	33	9-24	30	50	24	38	29	18	29	34	25	29
Phe	µg/kg DM	62	93-226	148-74	98	60-102	115	198	78	253	120	130	115	132	91	114
A	µg/kg DM	19	<LOD - 36	37-23	23-37	16-22	13	22	5	42	29	35	21	23	5.25	23
Flh	µg/kg DM	104	111-256	193-154	136	133-140	146	193	87	380	241	218	187	179	138	195
Pyr	µg/kg DM	86	94-183	192-121	140	106-143	187	184	94	245	179	171	191	181	158	185
BaA	µg/kg DM	21	53-123	155-33	135	29-136	119	138	85	93	65	62	133	164	135	178
Chr	µg/kg DM	42	47-100	131-52	88	50-89	66	89	45	96	73	78	108	105	92	112
BbF	µg/kg DM	92	53-96	209-137	167	131-171	126	154	98	194	143	167	153	187	137	214
BkF	µg/kg DM	38	39-59	72-49	68	50-75	56	72	44	51	42	42	81	77	59	91
BaP	µg/kg DM	41	<LOD- 50	91-58	63	37-38	56	85	61	109	84	90	76	85	52	101
IP	µg/kg DM	26	19-30	81-49	60	38-56	46	51	59	58	44	60	47	60	42	72
Dah	µg/kg DM	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Bper	µg/kg DM	46	60-64	113-73	105	101-63	77	81	92	93	70	103	82	100	65	112
Σ10 PAHs*	µg/kg DM	480	470 – 1,020	1,884-681	1,025	627-1,670	1,210	1,668	919	1,281	880	938	1,028	1,840	801	1,670
Car	µg/kg DM	NS	<LOD	<LOD	210	660	190	192	130	NS	NS	NS	201	<LOD	40	180
Mec	µg/kg DM	NS	29	29	<LOD	<LOD	<LOD	<LOD	<LOD	NS	NS	NS	29	29	<LOD	<LOD
24M	µg/kg DM	NS	<LOD	20	<LOD	<LOD	<LOD	<LOD	<LOD	NS	NS	NS	<LOD	<LOD	<LOD	<LOD
Dif	µg/kg DM	NS	1350	<LOD	37	1830	<LOD	<LOD	37	NS	NS	NS	2,000	2,100	1,850	<LOD
Di	µg/kg DM	<LOD	1-90	<LOD - 20	630	<LOD - 570	320	100	80	<LOD	<LOD	<LOD	230	<LOD	1,710	80
Isop	µg/kg DM	<LOD	<LOD- 10	<LOD - 10	10	<LOD - 30	30	10	10	<LOD	<LOD	<LOD	10	10	40	10
Ald	µg/kg DM	<LOD	<LOD- 570	<LOD	16.2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	16.2	<LOD	<LOD	<LOD
Gly	µg/kg DM	NS	8,683	8,939	<LOD	10,468	7,671	8,870	7,980	NS	NS	NS	8,970	9,500	<LOD	8,347
GIA	µg/kg DM	NS	<LOD	<LOD	2,532	20.1	<LOD	<LOD	<LOD	NS	NS	NS	<LOD	400	1489	<LOD
AMPA	µg/kg DM	NS	<LOD	1884	<LOD	<LOD	<LOD	<LOD	<LOD	NS	NS	NS	<LOD	<LOD	3991	<LOD
Teb	µg/kg DM	NS	<LOD	<LOD	<LOD	<LOD	8900	1215	<LOD	NS	NS	NS	<LOD	<LOD	<LOD	<LOD
Chlo	µg/kg DM	<LOD	<LOD-1	<LOD	NS	<LOD	NS	NS	NS	<LOD	<LOD	<LOD	NS	NS	NS	NS
4-OP	µg/kg DM	46	38- 81	37	NS	44	NS	NS	NS	40	45	61	NS	NS	NS	NS
4-NP	µg/kg DM	1132	83- 2,807	1,098	NS	1,168	NS	NS	NS	1,125	1,153	2,081	NS	NS	NS	NS
Cd	mg/kg DM	NS	2.5-5.5	2.7	2.7	4	1.9	2.9	5.6	NS	NS	NS	2.9	2.8	4	2.5
Cu	mg/kg DM	NS	174-269	262	260	240	266	293	193	NS	NS	NS	268	260	251	263
Ni	mg/kg DM	NS	45-75	73	72	73	70	60	62	NS	NS	NS	75	72	70	68
Pb	mg/kg DM	NS	97-245	155	141	182	124	126	260	NS	NS	NS	146	156	192	145
Zn	mg/kg DM	NS	927-1,517	1,636	1,704	1,317	1,682	1,298	937	NS	NS	NS	1,786	1,634	1,429	1,631

\*: campaigns (A), (B), (D) (min-max)

\*\*: campaigns (B), (C)

T: Top

M: Middle

B: Bottom

Higher than target values (Dutch standards)

Higher than intervention values (Dutch standards)

NS: not studied

Σ10 PAHs \*: Anthracene, Benzo(a)anthracene, Benzo(b)Fluoranthene, Benzo(g,h,i)perylene, Benzo(k)Fluoranthene, Chrysene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Naphtalene, Phenanthrene.



## 4 CONCLUSION AND OUTLOOK

Accumulated sediments were characterized in this study. Globally the sediments are highly polluted in terms of metals, PAHs and in a lesser extent in Alkylphenols, Diuron and Glyphosate/AMPA.

A heterogeneous spatial distribution, however low, was noticed for particles size distribution and a rather good spatial homogeneity found for chemical contents except for pesticides whose variability is high.

Volatile organic content, particles size distribution and chemical pollutants contents changed over time but not with the same tendency.

Inter-sediments layers variability was also highlighted but no link was assessed between volatile organic matter, particles size distribution and pollutants fate so that it remains unusable in practice.

In fact, all the variabilities can be linked to hydrodynamism, catchment contributions and other processes occurring in detention basin (biodegradation, volatilization, photolysis, hydrolysis...). Further research aiming at linking physical, chemical, ecotoxicological and hydrodynamism is in progress in CABRRES project.

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