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M. Saulais, J.P. Bedell, C. Delolme. Cd, Cu and Zn mobility in contaminated sediments from an infiltration basin colonized by wild plants: The case of *Phalaris arundinacea* and *Typha latifolia*. Novatech 2010 - 7ème Conférence internationale sur les techniques et stratégies durables pour la gestion des eaux urbaines par temps de pluie / 7th International Conference on sustainable techniques and strategies for urban water management, Jun 2010, Lyon, France. pp.1-10. hal-03296713

HAL Id: hal-03296713

<https://hal.science/hal-03296713>

Submitted on 22 Jul 2021

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Cd, Cu and Zn mobility in contaminated sediments from an infiltration basin colonized by wild plants: The case of *Phalaris arundinacea* and *Typha latifolia*

Etude de la mobilité du cadmium, cuivre et zinc dans des sédiments d'un bassin d'infiltration colonisé naturellement par des plantes: cas de *Phalaris arundinacea* et *Typha latifolia*

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RÉSUMÉ

Les bassins d'infiltration d'eau pluviale, présentent des dépôts contaminés par des métaux lourds et des polluants organiques, par sédimentation des matières en suspension. Ces bassins peuvent présenter la particularité d'être spontanément colonisés par des plantes qui interviennent alors sur le devenir des métaux lourds soit directement en les accumulant, soit indirectement en modifiant les caractéristiques physico-chimiques du sédiment qui peuvent influencer sur la mobilité des métaux.

Cette étude a pour objectif d'étudier la mobilité potentielle du Zn, Cd et Cu dans un bassin d'infiltration lyonnais dans 2 zones colonisées naturellement par deux espèces dominantes *Phalaris arundinacea* et *Typha latifolia* à trois périodes de l'année. L'étude a été réalisée à l'aide d'extractions chimiques simples: CaCl_2 pour caractériser la phase échangeable, acétate de sodium pour caractériser la phase acido-soluble et DTPA pour caractériser la fraction liée à la matière organique.

Le cadmium, extrait à faibles concentrations, est réparti de manière équivalente dans les fractions liées aux carbonates et à la matière organique. Le zinc présente la même répartition que le cadmium. Les teneurs en zinc extrait par le tampon d'acétate sont corrélées aux teneurs en carbonates de la surface du bassin. La mobilité du cuivre au DTPA est élevée et corrélée à la teneur en Carbone organique dans le sédiment. Les métaux présentent des mobilités différentes dans les deux zones.

ABSTRACT

Infiltration basins are shallow reservoirs in which stormwater is temporarily collected in order to reduce water volume in downstream networks. The settling of stormwater particles leads to a contaminated sediment layer. Wild plants can colonize these basins and can also play a role on the fate of heavy metals either directly by their uptake or indirectly by modification of physico-chemical characteristics of the sediment and therefore by modification of the mobility of heavy metals.

The aim of this study, carried out in a vegetalised infiltration basin, is to assess Cd, Cu and Zn mobility in two zones colonized by different species, *Phalaris arundinacea* and *Typha latifolia*. The study was carried out using three single chemical extractions: CaCl_2 for the exchangeable phase, acetate buffer for the acido-soluble fraction and DTPA for the fraction associated to the organic matter.

Zn and Cd are mainly associated to carbonated and organic matter phases of the sediment. Moreover, acetate buffer-extractable Zn contents are strongly correlated to carbonates content in the sediment. DTPA-extractable Cu contents are strongly correlated with organic carbon sediment contents. We have also noted that extractable contents were significantly different between both zones whatever the metal.

KEYWORDS

Chemical extractions, infiltration basins, heavy metals, *Phalaris arundinacea*, urban sediment, *Typha latifolia*

1. CONTEXT AND OBJECTIVES

1.1 CONTEXT

Infiltration devices are stormwater management techniques that are widely used to reduce stormwater volume. Stormwater contains a complex mixture of contaminants such as heavy metals, hydrocarbons, nutrients, bacteria in a soluble or a particulate form. The settling of stormwater particles leads to the presence of a contaminated layer on the basin surface (Winiarski *et al.*, 2006). These basins can be spontaneously colonized by wild plants. As far as heavy metals are concerned, plants can favor the retention of pollutants in the basin surface or sometimes enhance the mobility (Marschner, 2003; Bedell *et al.*, 2009).

Total heavy metal contents are easily and often measured but they don't provide suitable information about the mobility and bioavailability of potential toxic elements (Sposito, 1989). Limited information is available on the role of plants during their growth on the potential mobility of heavy metals in the case of stormwater infiltration devices.

Plants interactions with metals depend on a large number of factors, including the type of metal, the plant species and even the plant's growth stage. Moreover, the mobility of heavy metals in soils or sediments is also affected by soil or sediment chemical properties such as: pH, minerals composition and organic matter content, microbial activity, redox potential, etc (Marschner, 2003; Sigg *et al.*, 2001. Sposito, 1989).

The heavy metal potential mobility evaluation by chemical extraction can be useful to predict metal uptake by plants or leaching to the subsoil. Based on the solubility of solid compounds and the specificity and selectivity of chemical reagents, chemical extractions provide a gradient for the strength of the chemical association between metals and solids. However, chemical extractions are limited by their lack of selectivity, the diversity of protocols and possible adsorption and precipitation during extraction; nevertheless, they are useful for highlighting differences in potential mobility in a particular environmental context. CaCl_2 -extractability often appears to provide an efficient evaluation of mobility. It is a way to evaluate exchangeable pools through cationic exchange reactions (Lebourg *et al.*, 1996). Other authors have used acetate buffer for measuring metals bound to carbonates (Chaignon *et al.*, 2003) and subjected to be mobilized in acidic conditions. DTPA extractability is mainly studied to access to fractions chelated with organic matter (Lebourg *et al.*, 1996).

1.2 OBJECTIVES

The main objectives of this study, conducted in a vegetated infiltration basin, are:

- To assess Cd, Cu and Zn potential mobility in two zones colonized by two wild plants *Typha latifolia* and *Phalaris arundinacea* and to determine main differences between both zones.
- To establish relationships between results of chemical extractions of Cd, Zn and Cu and sediment properties colonized by plants.
- To study potential variations of mobility according to three sampling dates corresponding to three growth phases of plants.

2 MATERIAL AND METHODS

2.1 Study area

The study was carried out in a basin situated in an industrial watershed of 185 ha in the east of Lyon (France). The total area of the basin is about 8000 m². According to physical characteristics, two zones have been distinguished in the basin: a zone defined like a meadow (zone 1) and a zone defined like a wetland (zone 2). Zone 2 is mainly colonized by aquatic vegetation and is organized in patches with 6 main species: *Polygonum mite*, *Scirpus lacustris*, *Rumex crispus*, *Typha latifolia*, *Phalaris arundinacea*, *Eleocharis palustris* (Figure 1)

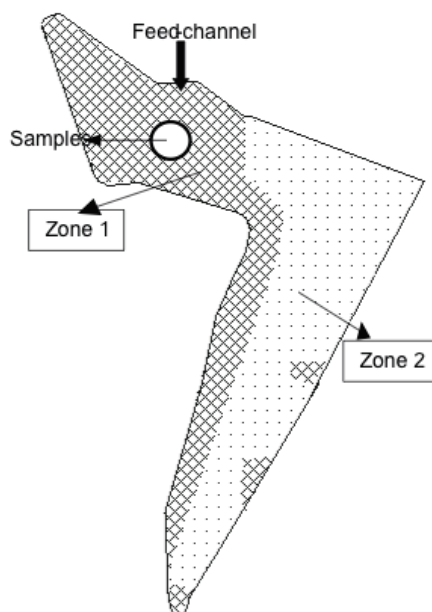


Figure 1: Zones of the Infiltration basin studied

Two species among the most abundant species of the wetland were selected: *Phalaris arundinacea*, and *Typha latifolia*. These two species are notably known to accumulate heavy metals in roots and leaves (Blake *et al.*, 1984 and Vymazal *et al.*, 2007). *Typha latifolia* is used for waste water treatment whereas *Phalaris arundinacea* is an invasive plant: this plant has gradually come to dominate neglected grasslands in Europe (Kim *et al.*, 2006). These species have colonized distinctive zones on the basin; *Typha latifolia* was directly submitted to the stormwater flow whereas *Phalaris arundinacea* was more disconnected from the flow. The two species chosen have grown well: *Typha latifolia* measured more than 250 cm and *Phalaris arundinacea* measured more than 165 cm which are the usual length found in the literature (Vymazal and Kröpfelova, 2005).

2.2 Sediment layer analysis

The samples were taken in the zones colonized by the studied plants at three different dates of the year (June, August, December) corresponding to 3 different stages of plant growth (upgrowing, steady state, senescence). Sediment samples were taken on a square meter surface from the upper layer of the deposits between 0 and 10 cm depth.

Sediments were sorted separating roots, waste of plants, worms of the sediment. Then, the sediment was 8 mm sieved. Finally, a part of sediment samples were dried at 105°C for 24 h in order to measure chemical parameters. Parameters measured in sediment were: pH [NF ISO 10390], water content [NF ISO 11465], loss in ignition (OM), organic carbon content (C) [NF ISO 10694], total nitrogen (N) [ISO 13878], C/N ratio (noted CN), conductivity [NF ISO 11265], cation exchange capacity (CEC) [NF X 31-130], carbonates content [NFX 31-105], exchangeable cations (Ca, Mg, K) [NF EN ISO 11885], NH₄ content [NF T90-015-1], exchangeable anions (SO₄, Cl, NO₃) [NF EN ISO 10304-1], PO₄ content [ISO 15681-2], aluminium content (Al) [NF EN ISO 11885], Iron content (Fe) [NF EN ISO 11885] and total contents of Cu (noted CuS), Cd (noted CdS) and Zn (noted ZnS) [by mineralisation in aqua regia and measured using graphite furnace atomic absorption spectrometry (GF-AAS) [NF ISO 11885]].

2.3 Chemical extractions

Among the various extractants described in the literature, we chose CaCl₂ to evaluate exchangeable fraction, acetate buffer to evaluate acido-soluble fraction and diethylenetriamine-pentaacetic acid (DTPA) to evaluate the metal fraction associated to organic matter.

For all extractions, 10g equivalent dry weight (DW) sediment were shaken for 7 hr in 100 mL of either 0.01 M CaCl₂, or acetate buffer [1 M NaCH₃COOH and CH₃COOH buffered at pH=5], or DTPA solution [0.1 M triethanolamine TEA, 0.01 M CaCl₂ and 0.005 M DTPA buffered at pH 7.3]. Then the suspension was centrifuged (10 min at 3073 g), the supernatant was filtered (0.22µm cellulose acetate filter) and acidified with HNO₃ (ultrapure grade reagent) before analysis. Cd, Cu and Zn contents were measured by GF-AAS. Certified samples, such as Surface Water Level 2 (Spectrapure standards),

were used to check the calibration of the metals quantified.

2.4 Statistical analysis

Most data analysis were performed with the free software R. Analysis of variances (ANOVA) presented were mainly performed to test the cross effect of the factor “species” and “season” except for “carbonates contents” for which each factor had to be separately studied. Significance level was $\alpha=0.5$. Normality of residues (Shapiro Wilk test) and homoscedasticity (Levene test) were checked. It is important to note that we will use abusively the term “species” to study the effect of the zone colonized by one specie: The “*Typha latifolia* zone” will be noted “*Typha latifolia*” and the “*Phalaris arundinacea* zone” will be noted “*Phalaris arundinacea*”. The sampling date factor will be noted “season”.

A principal components analysis (PCA) was performed using the software ADE-4 in order to study correlations between the different chemical parameters of the sediment and the potential mobility of metals and identify possible trends according to species and seasons. The original variables (physico-chemical values) of the different samples are orthogonally transformed and the PCA consists in finding the best spatial system to represent the different data. The analysis helped to determine the main parameters that discriminate the different samples collected. The analyzed data were constituted of 38 variables measured on 18 samples (triplicate samples of 2 zones for 3 dates).

3 RESULTS

3.1 Physico-chemical characterisation of sediments

Main physico-chemical characteristics of the first campaign are presented in Table 1. The following summarises the main findings which could be related to heavy metal mobility. “*Typha latifolia* Zone” is located on the main way of water flow entering the basin and constitutes a favorable zone for suspended matter deposits. *Typha latifolia* roots and stems seem to be a barrier for particles that are forced to settle. The *Phalaris arundinacea* zone is more isolated from the water flow.

Total Heavy metals contents are in the same range as previous measurements made in this basin or in other sediment layers of stormwater infiltration basins (Clozel *et al.*, 2006, Badin, 2009). In their study, Clozel *et al.* (2006) found values ranging from 1.8 to 7.8 mg/kgDW for Cd, from 111 to 325 mg/kgDW for Cu and from 890 to 1847 mg/kgDW for Zn. These sediment layers are highly contaminated in regards to the threshold values for polluted soil (dutch or french values) (Badin, 2009).

Carbonates contents measured on the surface layer are relatively high. An other study on the same basin found similar contents: 162 mg/kgDW (Badin, 2009). This high content can be explained by the calcareous nature of the watershed subsoil (250 mg/kgDW) (Lassabatere *et al.*, 2007) producing calcareous eroded particles that are part of the suspended particles settling in the infiltration basin. We can add that carbonates contents are significantly different in the two zones: Sediment of *Phalaris arundinacea* is less carbonated than *Typha latifolia*.

	pH	Water Content % DW	Volatile Solids % DW	Organic C g/kgDW	Carbonate g/kgDW	Zn mg/kgDW	Cd mg/kgDW	Cu mg/kgDW	CEC meq/kgDW
<i>Typha latifolia</i> zone	7.5	62.82	18.89	84.77	160.0	1397	3.83	245	130.7
	±0.1	±1.35	±0.13	±22.25	±3.6	±12	±0.11	±16	±2.1
<i>Phalaris arundinacea</i> zone	7.6	60.43	19.51	83.10	135.7	1260	3.22	188	172.0
	±0.1	±0.7	±0.45	±10.57	±3.2	±62	±0.07	±7	±6.1

Table 1: Physico chemical characteristics of samples sampled in June 2008

Organic matter content is about 20% in both zones. According to Durand *et al.* (2005) and Clozel *et al.* (2006), the organic matter content can be considered as very high and comparable to the organic-matter content in such retention and infiltration basins. In their study, Clozel *et al.* (2006) found also from 12% to 25 % of organic matter in the sediment. High organic matter contents can be explained by the accumulation of fine surface particles which come from both anthropogenic sources and natural

ones like vegetation debris drained from the watershed or produced in the infiltration basin. This leads to the dual natural and anthropogenic nature of organic matter in such sediment deposits (Durand *et al.*, 2005; Badin *et al.*, 2008).

Finally, cation exchange capacity is particularly high compared to other studies: Deschesne *et al.* (2004) found a CEC value around 100 meq/kgDW in a sediment of an urban stormwater infiltration basin. These authors associate the CEC to the high proportion of organic matter. We also noticed that there is a significant difference between the zones: *Phalaris arundinacea* zone presents a much higher CEC than *Typha latifolia*. The contribution of plants species debris to the composition of the organic matter in the sediment layer could explain the different CEC in both zones.

Figure 2 illustrates the correlation circle based on the projection of points representing variables (reduced centered physico-chemical parameters) on axis 1 and 2 of the factorial map of the PCA. The more the variables are close, the more the correlation is high, which is illustrated by the correlation coefficient noted R^2 . The farther a variable plots from the origin, the more influential it is in the analysis. The nearer a variable plots to an axis, the more this direction is explained by this variable. The sample points can be superimposed on the same map and the analysis of both maps can help to understand the structure and the relation between the variables and the samples.

The first two factorial axes explain 68% of the total inertia of the data analyzed and are chosen to represent the multivariate analysis of variables and samples.

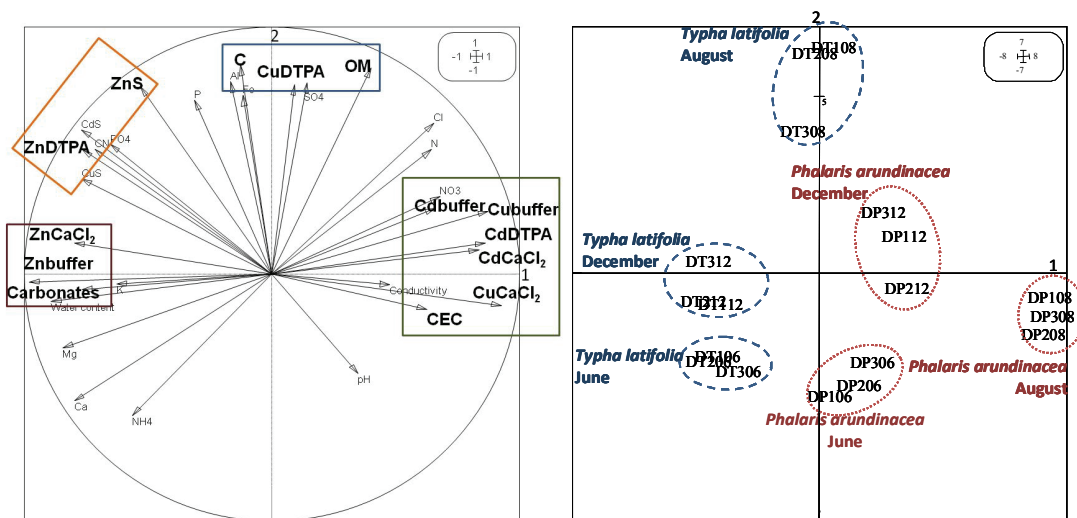


Figure 2: PCA maps: correlation circle (axis 1 and 2) and factorial map (axis 1 and 2)

The correlation circle shows that CaCl_2 -extractable Cd contents, acetate buffer-extractable Cd contents, CaCl_2 -extractable Cu contents, acetate buffer-extractable Cu contents are associated positively to axis F1, whereas acetate buffer-Zn contents and CaCl_2 -extractable Zn contents are anticorrelated to the previous ones. CaCl_2 -extractable Zn contents and acetate buffer-extractable Zn contents are highly correlated (R^2 equal to 0.79).

There is a correlation between extractable elements and total heavy metal contents. Total contents of Zn in sediment are weakly correlated to acetate buffer-extractable Zn ($R^2=0.5$) whereas there are highly correlated with DTPA-extractable Zn contents ($R^2=0.77$). Mobility is specific to the metal and has to be studied jointly with other physico-chemical parameters. Concerning the other physico-chemical characteristics of the sediment, several correlations can be underlined. On axis F2, there is a significant correlation between DTPA-extractable Cu and total organic content ($R^2=0.74$). This strong correlation confirms the known affinity of Cu for organic matter in soils. Moreover, we notice a high correlation between acetate buffer Zn and carbonate contents ($R^2=0.78$). Zn is known to interact with carbonates (surface precipitation, calcium exchange and sorption) (Lassabatere *et al.*, 2007). CEC is not well represented in this factorial map and the correlation with CaCl_2 -extractable Cd contents is weak ($R^2=0.58$). Moreover, very low Cd contents are extracted by CaCl_2 and interpretation of the PCA has to be taken with caution for these two parameters.

The samples factorial map highlights two different groups: *Typha latifolia* samples are positioned on the left part of factorial map and *Phalaris arundinacea* samples on the right one. It means that *Typha latifolia* is notably distinguishable from *Phalaris arundinacea* by high CaCl_2 -, acetate buffer- and

DTPA-extractable Zn contents. On the contrary, *Phalaris arundinacea* seems to show overall higher contents for CaCl₂-, acetate buffer-, DTPA-extractable Cd and Cu than *Typha latifolia*.

As far as the seasons variations are concerned, the samples are mainly distributed along the second axis that is related to OM and DTPA-extractable Cu contents variations. The organic matter content varies differently in the two zones: it raises progressively from June (19.5%) to December (21.3%) for *Phalaris arundinacea* whereas it increases from June (18.9%) to August (22.5%) and decreases in December (18.6%) for *Typha latifolia*. Carbonate contents decrease slightly with the season: from 160 g/kg DW in June to 136 g/kgDW in December for *Typha latifolia* and from 136 g/kgDW in June to 115 g/kg DW in December for *Phalaris arundinacea*.

3.2 Evolution of extractable metals according to the sample's location and seasons

3.2.1 CaCl₂: an extraction with limits

The exchangeable part of heavy metal is very low: about a few tens of µg/kg DW for Cd and Cu and about 1 mg/kg DW for Zn (Figure 3). This low exchange property can be notably explained by the fact that contrarily to other studies, we have used a low concentrated 0.01M CaCl₂ solution (Table 2). This low concentration was motivated by the fact that water entering in the infiltration basins and solubilizing heavy metal has a low ionic strength and conductivity.

We can mention different studies carried out with the same extractant content either on 10 contaminated soils (Pueyo *et al.*, (2004), or on dredged sediments (Bedell *et al.*, 2009), or on vineyard soils (Brun *et al.*, 2001). Pueyo *et al.* (2004) found CaCl₂-extractable Cd ranging from 27µg/kgDW to 932µg/kgDW for total contents around a few mg/kgDW. Values of Bedell *et al.* (2009) were slightly higher than in our study with extractable Cd contents ranging from 10 to 27 µg/kg DW for an total content of 2.9 mg/kgDW. Globally, Cd is not exchangeable in the conditions of our study, whereas Cd is known to be very mobile as an exchangeable cation (Pueyo *et al.*, 2004; Clozel *et al.*, 2006; Bedell *et al.*, 2009). Pueyo *et al.* (2004) found CaCl₂-extractable Cu contents ranging from 101 to 5715 µg/kgDW with total contents around to 250 mg/kgDW as in our study. Brun *et al.* (1998) measured from 100 to 560 µg/kgDW of CaCl₂-extractable Cu for total contents varying from 20 to 251 mg/kg in high carbonated vegetated vineyard soil. As far as zinc is concerned, our values are lower than those found by Bedell *et al.* (2009) (7mg/kgDW for a total content of 640mg/kgDW) or those found by Pueyo *et al.* (2004) with CaCl₂-extractable Zn contents from 0,22 to 217 mg/kgDW for an initial total content between 1000 and 2000 mg/kgDW.

Our results show that in the presence of low concentrated exchangers like Ca, the three heavy metals studied are poorly mobilized. The metals are supposed to be strongly associated with solid phases (carbonates, organic matter) and are not susceptible to be easily mobile in the presence of soluble major cations. The presence of plants in the surface layer does not seem to modify these characteristics.

		Cd			Cu			Zn		
		CaCl ₂	acetate buffer	DTPA	CaCl ₂	acetate buffer	DTPA	CaCl ₂	acetate buffer	DTPA
<i>Typha latifolia</i> zone	june 2008	0%	21%	17%	0%	5%	25%	0%	25%	25%
	august 2008	0%	24%	21%	0%	11%	53%	0%	19%	26%
	december 2008	0%	21%	12%	0%	9%	41%	0%	24%	27%
<i>Phalaris arundinacea</i> zone	june 2008	0%	32%	30%	0%	9%	41%	0%	24%	25%
	august 2008	0,1%	42%	42%	0%	13%	52%	0%	21%	20%
	december 2008	0%	35%	25%	0%	24%	46%	0%	21%	20%

Table 2: Percents of extractable heavy metals ([extractable content]/[total content])

3.2.2 A very low mobility of Cd with acetate buffer and DTPA

Total contents of Cd in sediments are low, only a few mg/kg DW for both species (Table 1). Therefore, even if the extractable Cd concentrations are low (only around 1mg/kgDW for both species), % of acetate buffer- and DTPA- extractable Cd constitute a high fraction of sediment total contents (Table 2) showing that carbonates and organic matter mainly control the mobility of Cd in the surface infiltration basin.

Moreover, acetate buffer-Cd contents and DTPA-extractable Cd contents are higher for *Phalaris arundinacea* than for *Typha latifolia* whatever the season. The differences of mobility between the two species could be namely explained by the different release of plants exudates in the rhizosphere. Indeed the rhizosphere activity depends namely on genetic factors (Waizel *et al.*, 2002). These organic molecules can be acidifying and lead to a dissolution of carbonated phases. They are also chelating and reducing agent modifying heavy metals solubility (Sigg *et al.*, 2001).

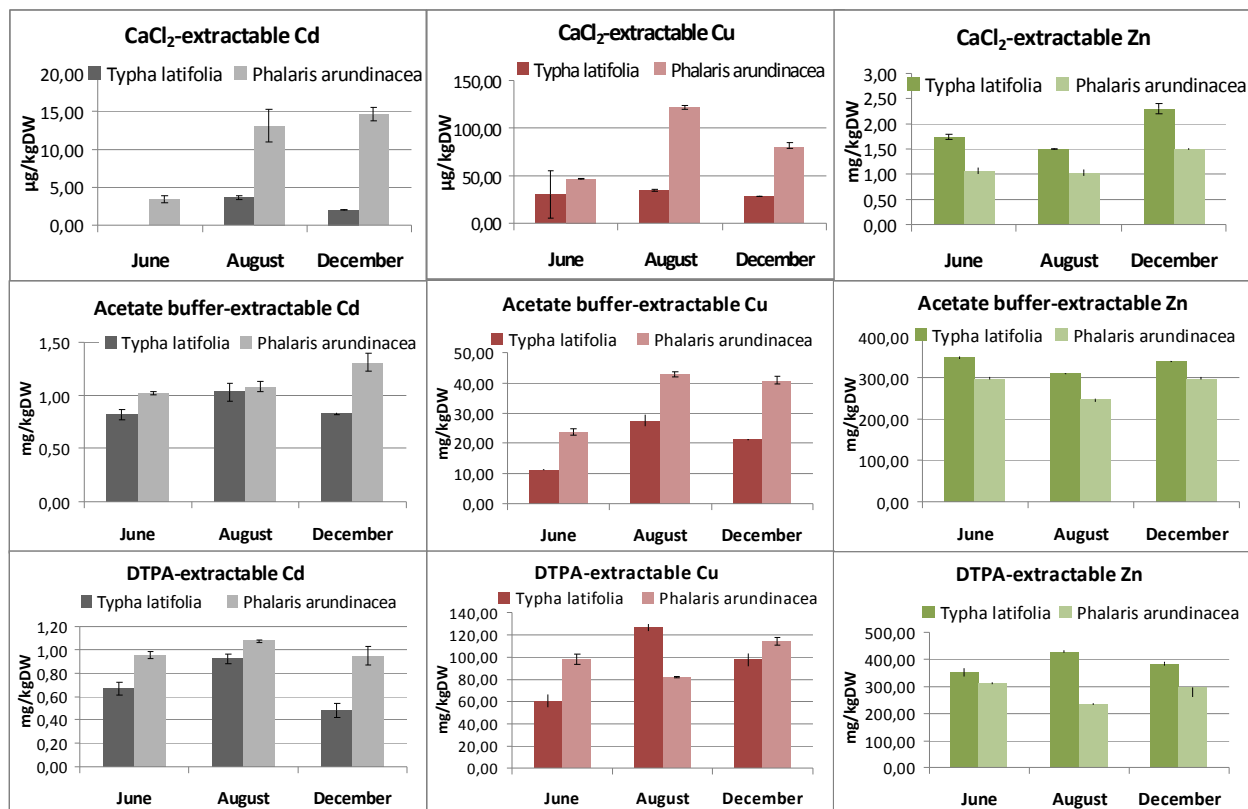


Figure 3: Mobility of heavy metals with the different extractants

3.2.3 Mobility of Cu

DTPA-extractable Cu contents are much higher than acetate buffer-extractable Cu concentrations for both *Phalaris arundinacea* and *Typha latifolia* (Figure 3): As far as *Typha latifolia* is concerned, DTPA-extractable Cu contents vary from 60.57 to 127.17 mg/kgDW and acetate buffer-extractable Cu contents vary from 11.30 to 27.63 mg/kgDW (Figure 3). DTPA-extractable Cu contents vary from 81.67 to 114.2 mg/kgDW and acetate buffer-extractable Cu contents vary from 23.77 to 42.87 mg/kgDW (Figure 3) for *Phalaris arundinacea*. In August, DTPA-extractable Cu represents around 50% of total contents for both zones. This very high value confirms the strong affinity of Cu for organic matter already supposed by the correlation between total organic carbon and DTPA-extractable Cu contents in the PCA. The percents of DTPA-extractable Cu are particularly high in our study compared to the 25% obtained in vineyards soils by Brun *et al.* (1998). This difference could be explained both by the high amount of organic matter in these sediments and its anthropogenic nature (hydrocarbons, wastewater) with a high solubility (Badin *et al.*, 2008).

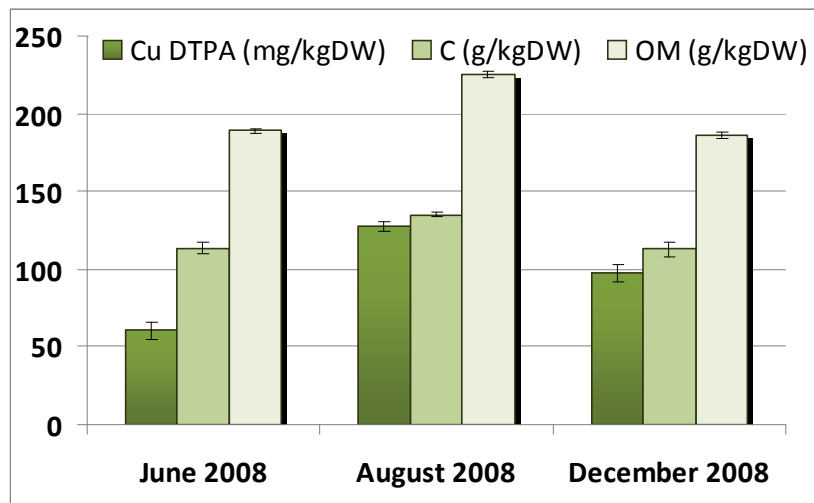


Figure 4: Evolution of DTPA-extractable Cu contents, Total carbon, Organic matter in *Typha latifolia*

DTPA-extractable Cu contents are significantly different according to the season ($p=3.39 \times 10^{-9}$): For *Typha latifolia*, the highest DTPA-extractable Cu content is reached in August. It corresponds to the highest organic carbon and organic matter content in *Typha latifolia* sediment (Figure 4). We have noticed that it is the only season where DTPA-extractable Cu content is higher for *Typha latifolia* than for *Phalaris arundinacea*. For *Phalaris arundinacea*, DTPA-extractable Cu contents decrease from June to August then it increases in December (Figure 3). Moreover, variations of total carbon and organic matter are less pronounced than for *Typha latifolia*. We have noticed *in situ* that leaves of *Typha latifolia* began to fall in August whereas *Phalaris arundinacea* were still upright and few leaves were on the ground. Consequently, in August, there can be a plant contribution to the raise of organic matter in the “*Typha latifolia*” zone.

3.2.4 Mobility of Zn

DTPA-extractable Zn concentrations are equivalent to acetate buffer-extractable Zn concentrations for both *Phalaris arundinacea* and *Typha latifolia*: As far as *Typha latifolia* is concerned, DTPA-extractable Zn contents vary from 353 to 453 mg/kgDW and acetate buffer-extractable Zn contents vary from 310 to 349 mg/kgDW. DTPA-extractable Zn concentrations vary from 233 to 314 mg/kgDW and acetate buffer-extractable Zn contents vary from 247 to 297 mg/kgDW for *Phalaris arundinacea*.

For both species, % of DTPA-extractable Zn and % of acetate buffer-extractable Zn contents represent around 25% of total contents in the sediment. These values are in the same range as Bedell *et al.* (2009) who found between 25 and 32 % of DTPA-extractable Zn in dredged sediments. In our study, Zn is extracted in both carbonated and organic fractions which is not what has been found by previous studies in other urban sediments (Clozel *et al.*, 2006) where Zn was mainly in the acido soluble phase.

Acetate buffer and DTPA-extractable Zn contents are always significantly higher ($p=0.002811$) for *Typha latifolia* than for *Phalaris arundinacea* (Figure 3). The hypothesis can be again established on the different nature of exudates released by the two species. There is a slight decrease of DTPA-extractable Zn contents from June to August and an increase from August to December for *Phalaris arundinacea*. We can note that the highest mobility of Zn with DTPA is reached in August for *Typha latifolia*. As we have seen for Cu.

4 CONCLUSION & PERSPECTIVES

The main objective of this study was to emphasize main differences on Cd, Cu and Zn mobility between two zones of an infiltration basin colonized by wild plants but also to highlight the main relationships between physico-chemical characteristics of the sediment and heavy metal mobility. In our study, mobility of Cd, Cu and Zn is poorly explained by cation exchange reactions. Mobility is rather linked to the dissolution of carbonated phases in acidic conditions or the solubility of organic matter. Even if Cd release contents are very low, it appears to be mainly associated to carbonates and organic matter. As for Cd, Zn is supposed to be associated to the same solid phases. Copper seems

to be strongly correlated to organic matter which has never been shown in this specific basin.

Then, it has been established that there is a significant cross effect of the factor “species zone” and “season” on Cd, Cu and Zn mobility. The zones are notably distinguishable by the presence of two different species of two different families. Therefore, the properties of soil can be influenced by the biological activities of these species and notably the different solute exchanges of the plant in their rhizosphere. Moreover, plants can directly play a role on the nature of organic matter. Plants degradation after their death can contribute differently to the increase and the modification of organic matter in the two zones. The three metals potential mobility is then modified and can be explained by the different composition of the organic matter. In addition to these influences, plants can play a physical role retaining differently the stormwater suspended matter. *Typha latifolia* is a tall plant specie which can easily make a physical barrier and contribute to the retention of suspended matter. Then, in this zone, the anthropogenic organic matter can be easily mixed with the “natural” one. *Phalaris Arundinacea* zone is more remote and this specie can not accumulate so much “urban” organic matter.

We can also point out the complexity of the organic matter of this basin which is due to natural and anthropogenic contribution. It would be very important to investigate on the association between this specific organic matter and heavy metals in order to discriminate the role of both the anthropogenic and the vegetable organic matter on the sorption and mobility of metals.

Finally, the evolution of heavy metal mobility according to the sampling date depends namely on the physiology of the plant and the root activities. The efficiency of solute exchanges in roots depends on the age of plants. The process of plant’s death varies according to the species. Therefore, it’s a parameter that can explain why the evolution between the seasons is not the same in the two zones. The influence of these wild species on heavy metal mobility should be more studied and especially the possible relationship between heavy metals contents accumulated by plants and extractable contents.

This study shows that little is known about the consequences of natural vegetation on the heavy metal mobility accumulated at the surface of urban stormwater infiltration basins. It can favor the pollutants transfer towards the ground water. Stormwater managers have to take into account this vegetation development and adapt their practices according to these wild plants. It is important to pursue studies on the risks of heavy metals transfer to know if the influence due to the plant can have an adverse or a positive impact.

LIST OF REFERENCES

- Badin A.L., Faure P., Bedell J.P. and Delolme C (2008). Distribution of organic pollutants and natural organic matter in urban storm water sediments as a function of grain size. *Sci. Tot. Environ.*, 403(1-3), 178-187
- Badin A.L. (2009). Répartition et influence de la matière organique et des microorganismes sur l’agrégation et le relargage de polluants dans des sédiments issus de l’infiltration d’eaux pluviales urbaines. (Localization and role of the organic matter and microorganisms on aggregation and mobility of heavy metals in urban stormwater infiltration sediments). Thèse de doctorat. (PhD) INSA de Lyon. 231 p.
- Bedell J.-P., Capilla X., Giry C., Schwartz C., Morel J.L. and Perrodin Y. (2009). Distribution, movement and availability of Cd, and Zn in a dredged sediment cultivated with *Salix alba*. *Environmental and Experimental Botany*, 67, 403-414.
- Blake, G., Gagnaire-Michard, J. and Kirassian, B. (1984). Accumulation of zinc (Zn65) by a macrophyte: *Typha latifolia*. *Revue Française des Sciences de l’Eau*, 3, 241-248.
- Brun L.A., Mailler J., Richarte J., Herrmann P. and Remy J.C. (1998). Relationships between extractable copper, soil properties and copper uptake by wild plants in vineyard soils. *Environmental Pollution*, 102, 151-161.
- Brun L.A., Maillet J., Hinsinger P., and Pépin H. (2001). Evaluation of copper availability to plants in copper-contaminated vineyard soils. *Environmental Pollution*, 111, 293-302.
- Chaignon V., Sanchez-Neira I., Herrman, Jaillard B. and Hinsinger P. (2003). Copper bioavailability and extractability as related to chemical properties of contaminated soils from a vine-growing area. *Environmental Pollution*, 123, 229-238.
- Clozel B., Ruban V., Durand C. and Conil P. (2006). Origin and mobility of heavy metals in contaminated and infiltration ponds. *Applied Geochemistry*, 1781-1798.
- Deschesne M., Barraud S., Bardin J.P. (2004). Spatial distribution of pollution in an urban stormwater infiltration basin. *Journal of Contaminant Hydrology*, 72, 189-205.
- Durand C., Ruban V. and Ambès A. (2005). Characterisation of complex organic matter present in contaminated sediments from water retention ponds. *Journal of Analytical and Applied Pyrolysis*, 73(1), 17-28
- Kim K.D., Ewing K. and Giblin D.E. (2006). Controlling *Phalaris arundinacea* (reed canarygrass) with live willow stakes: a density-dependent response. *Ecological Engineering*, 27, 219-227.

- Lassabatere L., Spadini L., Delolme C., Février L., Galvez-Cloutier R. and Winiarski T. (2007) Concomitant Zn-Cd and Pb retention in a carbonated fluvioglacial deposit under both static and dynamic conditions. *Chemosphere*, 69(9), 1499-1508.
- Lebourg, A., Sterckeman, T. and Proix, N. (1996). Intérêt de différents réactifs d'extraction chimique pour l'évaluation de la biodisponibilité des métaux en trace du sol (relevance of different chemical extractants for the trace heavy metals biodisponibility assessment in soil). *Agronomie*, 16, 201-215.
- Marschner, H. (2003). *Mineral nutrition of higher plants*. Academic press, London, 889 p.
- Pueyo M., Lopez-sanchez J.F., Rauret G. (2004). Assessment of CaCl₂, NaNO₃ and NH₄NO₃ extraction procedures for the study of Cd, Cu, Pb and Zn extractability in contaminated soils. *Analytica Chimica Acta*, 504, 217-226.
- Sigg L., Behra P., Stumm W. (2001). *Chimie des milieux aquatiques-Chimie des eaux naturelles et des interfaces dans l'environnement (Natural Water Chemistry and interfaces in the environment)*. Dunod. Paris 567 p.
- Sposito G. (1989). *The Chemistry of Soils*. Oxford University Press. New York.
- Vymazal, J., Kröpfelova L.(2005). Growth of *Phragmites australis* and *Phalaris arundinacea* in constructed wetlands for wastewater treatment in the Czech Republic. *Ecological Engineering*, 25, 606-621
- Vymazal, J., Svehla, J., Kröpfelova, L. and Chrastny, V. (2007). Trace metals in *Phragmites australis* and *Phalaris arundinacea* growing in a constructed and natural wetlands. *Sci. Tot. Environ.*, 380: 154-162.
- Waizel Y., Eshel A., Kafkafi. (2002) *Plant Roots : The Hidden Half - Third Edition*, Revised and Expanded. Hardcover. M. Dekker, New-York, 1136 p.
- Winiarsky T., Bedell J.P., Delolme C. and Perrodin Y. (2006). The impact of stormwater on a soil profile in an infiltration basin. *Hydrogeology Journal*, 14, 1244-1251.