

Assessment of heavy metal pollution in sediments and their bioaccumulation in *Phragmites australis* from Nil river (Jijel-Algeria)

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Abstract

The content of heavy metals in sediment and the aquatic plant *Phragmites australis* (roots and leaves), collected from six different stations along the Nil river, were determined providing information about heavy metals pollution status of this aquatic ecosystem.

The results showed that the abundance of heavy metals measured in the sediments decreased in the order: Fe>Zn>Pb>Cr>Cd. Apart from Cr and Fe, the concentration of heavy metals exceeded the background values. Metals concentrations were found decreasing with the increasing distance from the river mouth, suggesting that anthropogenic inputs, related to agricultural and domestic discharge into the river, are the major sources of heavy metals in the river sediments and aquatic plants.

The assessment of heavy metals pollution was carried out using geoaccumulation index (I_{geo}) and enrichment factor (EF). According to the mean values of I_{geo}, the sediment of Nil river is considered as moderately polluted with Pb and Cd, unpolluted to moderately polluted with Zn and unpolluted with Cr and Fe. The mean values of enrichment factor indicate that all stations presented moderate enrichment with Zn, minor enrichment with Cr and moderately to severe enrichment with Pb and Cd in three stations.

Regarding the plant samples, the results showed that the concentration of the elements analyzed in *Phragmites australis* did not exceed the threshold of phytotoxicity.

Mean concentrations of all elements were less in the plants organs compared to the concentrations of the same elements in the corresponding sediment sample. Metals accumulated by *P. australis* were mostly distributed in root tissues, as shown by the values of translocation factors (TF) which were <1. A positive association between the metal concentrations in *P. australis* organs and its environment was also found; this suggests that this plant can be used as biological indicator in biomonitoring studies.

Keywords: Nil river, Heavy metals, Sediments, Pollution, *Phragmites australis*.

1. Introduction

Heavy metals in aquatic ecosystems are considered as serious pollutants due to their environmental persistence, toxicity and ability to be incorporated into food chains (Banerjee *et al.*, 2012). They enter these aquatic systems mainly through natural inputs such as weathering and erosion of rocks and anthropogenic sources including urban, industrial and agricultural activities, terrestrial runoff and sewage disposal (Barakat *et al.*, 2012).

Once released in aquatic environments, heavy metals are generally bound to particulate matter, which eventually settle down and become incorporated into sediments. Therefore, surface sediments are the most important reservoir or sink of metals and other pollutants in aquatic environments (Boudet *et al.*, 2011).

In the sediments, metals accumulate through complex physical and chemical adsorption mechanisms depending on the nature of the sediment matrix and the properties of the adsorbed compounds (Çevik *et al.*, 2009). Moreover, accumulation or release of metals in sediments is largely controlled by their geochemistry, in particular, type and quantities of organic matter, grain size and cation exchange capacity (Naji *et al.*, 2011).

Generally, it has been recognized that natural aquatic sediments absorb persistent and toxic chemicals to levels many times higher than the water column concentration (Milenkovic *et al.*, 2005; Banerjee *et al.*, 2012).

The increasing load of heavy metals cause imbalance in aquatic ecosystems and the biota growing under such habitats accumulate high amounts of heavy metals (Cu, Zn, Cd, Cr, Ni, etc.) which in turn, are being assimilated and transferred within food chains by the process of magnification (Kuntal *et al.*, 2014).

Knowing the mechanism of accumulation, distribution and metabolism of metals in aquatic macrophytes is of great ecological, scientific and practical importance. From the

environmental point of view, the importance is reflected in the fact that aquatic macrophytes could be used as biological indicators of pollution (Štrbac *et al.*, 2014). Due to its ability to accumulate metals, availability throughout the year and large biomass, *Phragmites australis* (common reed) is suitable for biomonitoring studies for the evaluation of load levels of trace metals in aqueous ecosystems. The heavy metals concentration in *P. australis* tissues can be several ten to several thousand times higher than those in the surrounding water (Kastratović *et al.*, 2013).

In this study the objectives were; to determine the distribution and concentration of trace metals in surface sediments and *P. australis*; to identify the quality assessment of surface sediments using geo-accumulation index (Igeo) and enrichment factor (EF) and to evaluate mobility according to the translocation factors (TF) and

bioconcentration factors (BCF) for leaf and root in *P. australis*.

2. Materials and methods

2.1. Study area

The study area (Nil river) is located in Jijel, North East of Algeria, between Latitude: 36°49'40.04"N and longitude 5°56'14.32"E. The Nil river springs in the mountains of Chahna and flows into the mediterranean sea. It has an approximate distance of 120 km and catchment area of about 303 km². Boukaraa, Saayoud and Tassift are its major tributaries.

The river receives domestic wastewaters from the adjoining communities (Taher, Chekfa, Bazoul, Jimar) and runoff from agricultural land in its drainage basin. Its water is extensively used for irrigation.

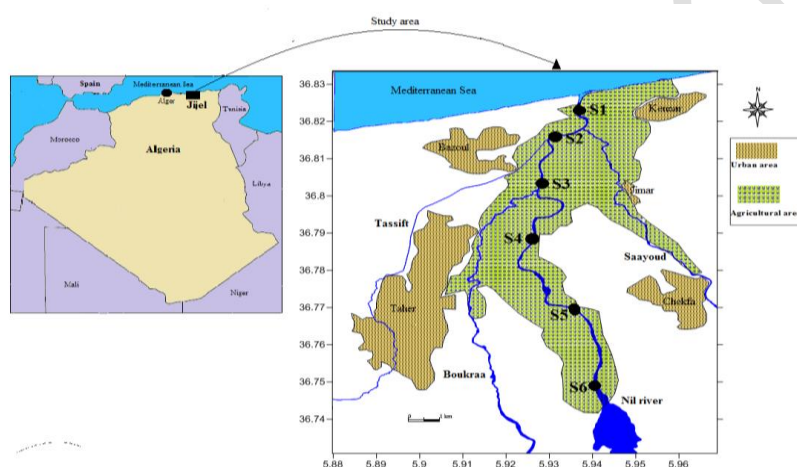


Figure 1. Sampling stations along the Nil river

2.2. Ecology and morphology of *P. australis* (common reed)

P. australis, known as common reed, is a kind of perennial grass that belongs to Poaceae family (Osma *et al.*, 2015). It grows in marshes and swamps, along streams, lakes, ponds, ditches, and wet wastelands (Aksoy *et al.*, 2005). It is a rhizomatous hemicryptophyte/geophyte whose stems grow to 2–6 m, and leaves are lanceolate, 20–50 cm long and 2–3 cm broad. *P. australis* can develop 6–10 m horizontal runners which put down roots at the nodes (Bonanno *et al.*, 2010).

2.3. Sample collection and analytical procedure

2.3.1. Sediment

The sediment samples were collected from six different stations along the Nil river between February and June 2014 (Figure 1). At each site, 9 samples were taken using a clean plastic spoon at a depth of 20 cm from the surface. The collected sediment samples were packed and sealed in pre-washed polyethylene bags and transferred to the laboratory for pretreatment and analyses.

In the laboratory, the sediment samples were air-dried at room temperature, powdered, and sieved through a 2 mm and 63µm stainless steel sieve. The finest fraction (particles <63 µm) was used to determine the heavy metals concentration and the <2 mm fraction was used for the evaluation of sediment physicochemical parameters. Sediment's pH was measured with a pH meter in a suspension of 50 ml de-ionized water and 20 g of sediment (1/2.5, sediment/ water ratio) after equilibration for 2 h.

The grain size distribution in surface sediments was determined by pipette method.

The organic matter content of the sediment was evaluated by revised Walkley–Black titration method.

For the determination of total metals content, sediment samples were digested with aqua regia (1/3; HNO₃/HCl); about 1g of sediment was digested, with a mixture of 3 ml HCl and 1 ml of HNO₃ at 120 °C.

2.3.2. Plant

Plant samples were collected from the same sites of sediment sampling. In the laboratory they were thoroughly rinsed with water to remove any sediment

particles attached to the surface. The aboveground (leaves) and underground (roots) tissues were then separated, dried at 75 °C to a constant weight, and ground into fine powder.

The prepared samples were digested with a mixture of 3 ml HNO₃, 3 ml of H₂O₂ and 1ml of H₂SO₄ at 120 °C (Hoenig, 1990).

The concentrations of heavy metals (Pb, Cd, Zn, Cr and Fe) in all samples (sediments and plant) were measured by Atomic Absorption Flame Emission Spectrophotometer (SHIMADZU AA6200).

2.4. Data analysis

2.4.1 Sediment pollution indices

The geo-accumulation index (I-geo) and enrichment factor were employed to assess the pollution of metals in the sediment of Nil river.

Geo-accumulation index is a quantitative measure of the degree of pollution in aquatic sediments (Rabee *et al.*, 2011). It was determined by the following mathematical equation according to Müller (1969):

$$I_{geo} = \log_2 (C_n/1.5 \times B_n)$$

Where, C_n is the measured concentration of the heavy metal (n) in the sediment and B_n is the geochemical background value in average shale of element n. The factor 1.5 is introduced to minimize the effect of possible variation in the background values that are due to lithological variations. The values of the average shale used in this work are those proposed by Turekian and Wedepohl (1961), (Table 2).

Müller (1981), proposed the following descriptive classes for increasing I_{geo} values:

Unpolluted (Class 0, I_{geo} ≤ 0), unpolluted to moderately polluted (Class 1, 0 < I_{geo} ≤ 1), moderately polluted (Class 2, 1 < I_{geo} ≤ 2), moderately to strongly polluted (Class 3, 2 < I_{geo} ≤ 3), strongly polluted (Class 4, 3 < I_{geo} ≤ 4), strongly to very strongly polluted (Class 5, 4 < I_{geo} ≤ 5) and very strongly polluted (Class 6, I_{geo} > 5).

The enrichment factor (EF) was based on the standardization of a tested element against a reference one. The most common reference elements are Sc, Mn, Ti, Al and Fe (Loska *et al.*, 2004). In this study iron (Fe) is taken as a reference element. The enrichment factor (EF) is defined as follows:

$$EF = \frac{(M \text{ sample} / Fe \text{ sample})}{(M \text{ average shale} / Fe \text{ average shale})}$$

Where:

M sample: concentration of the examined metal in the examined sediment

Fe sample: concentration of the reference metal in the examined sediment

M average shale: concentration of the examined metal in the average shale

Fe average shale: concentration of the reference metal in the average shale (Çevik *et al.*, 2009).

The EF values were interpreted as described by Chen *et al.*, (2007). Where EF < 1 indicates no enrichment, EF < 3 is minor enrichment, EF = 3-5 is moderate enrichment, EF = 5-10 is moderately severe enrichment, EF = 10-25 is severe enrichment, EF = 25-50 is very severe enrichment and EF > 50 is extremely severe enrichment.

2.4.2. Bioconcentration factors (BCF) and translocation factors (TF)

The ability of plant to accumulate metals from their surrounding environments can be estimated using the bioconcentration factors BCF, which is defined as the ratio of metal concentration in the roots to that in sediment ([Metal] Root/ [Metal] sediment) (Yoon *et al.*, 2006).

The capacity of plant to translocate metals from the roots to the shoots is measured using the translocation factors TF, which is defined as the ratio of metal concentration in the shoots to the roots ([Metal] Shoot/ [Metal] Root) (Yoon *et al.*, 2006).

2.5 Statistical analysis

One-way ANOVA was used to determine any significant difference in metal concentrations among different sampling stations. The correlation coefficients were used for estimating the correlation among metals and analyzed sediment parameters and among metal concentrations in sediment and plant organs. Values were reported as mean ± standard deviation (SD). A significance level of 0.05 was used (p < 0.05).

3. Results and discussion

3.1 General sediments characteristics

The results of physicochemical parameters in surface sediments at different stations (S1-S6) are summarized in Table 1.

The results showed that the sediments of all the study stations were sandy to silty. The most widespread grain size in the sediments was the sand grains. Station 1, located at the vicinity of the mouths of Nil river, had the lowest percentage of sand, whereas station 6 had the highest sand.

As shown in Table 1, the pH of sediments from 6 stations was neutral to slightly alkaline with the minimum and maximum value; 7.39 and 8.47 respectively. According to Barakat *et al.*, (2012), the neutral to slightly alkaline pH, probably related to carbonate nature of the sediment and the organic matter accumulation in sediment, seems to be favorable for the immobilization of heavy metals.

The organic matter in the sediment ranged between 0.91% and 1.98%. It was observed that the higher values were recorded at downstream stations (S1 and S2), while the lowest value was observed at station 6. The relatively high content of organic Matter in downstream stations might be the result of the abundance of riparian vegetation and the high organic matter flux to sediments due to direct discharge of domestic wastewaters and rubbish in these stations.

Table 1. Grain size and physicochemical characteristics of the sampled sediments at different stations

Stations	TOM (%)	pH	Sand (%)	Silt (%)	Clay (%)
S1	1.98±0.01	8.16±0.04	70.82±1.60	26.48±2.66	2.69±0.86
S2	1.97±0.01	7.39±0.04	71.91±1.30	24.49±1.98	3.59±0.94
S3	1.80±0.04	8.12±0.04	79.33±1.33	16.87±1.29	3.79±0.34
S4	1.65±0.02	7.94±0.05	81.70±0.94	16.13±1.97	2.80±0.88
S5	1.41±0.02	8.47±0.06	82.89±1.26	13.52±2.45	3.43±0.43
S6	0.91±0.02	7.52±0.06	84.59±1.53	12.05±1.39	3.36±0.92

3.2. The concentration and distribution of heavy metals in sediments

The results of the trace metal levels in the examined sediments are outlined in Table 2. The mean heavy metal concentration ($\mu\text{g/g}$) ranged from (65.13-85.15) Pb; (0.52-1.57) Cd; (148.35-166.22) Zn; (47.55-62.17) Cr and (18164.54-19118.55) Fe. It was found that the order of abundance of these metals in sediments was as follows: Fe > Zn > Pb > Cr > Cd. Generally, most of the elements show a similar distribution patterns along the Nil river. Metals content was found decreasing with the increasing distance from the river mouth. According to the result of one-way ANOVA test, the concentration of all metals showed a significant difference among the stations ($p < 0.05$) (Table 2).

The lowest values of all metals were observed at station 6. This can be explained by the fact that at this station there

Table 2. Heavy metal concentrations ($\mu\text{g/g}$) in sediments of Nil river

Stations	Pb	Cd	Zn	Cr	Fe
S1	85.15±4.78	1.57 ±0.03	166.22±4.22	57.82±4.71	19118.55±8.36
S2	83.48±5.47	1.40± 0.02	164.27±3.87	62.17±4.17	19017.49±4.15
S3	80.08±5.10	1.18 ±0.01	161.73±4.25	51.76±3.63	18164.54±5.14
S4	74.25±5.66	1.33± 0.56	155.91±4.06	54.61±4.65	18540.55±1.42
S5	68.01±5.34	0.72 ±0.06	151.27±6.38	50.02±3.72	18300.87±5.35
S6	65.13±4.30	0.52 ±0.04	148.35±1.89	47.55±2.73	18771.03±4.86
*Aver. Shale	20	0.3	95	90	47200
p	0.0017	0.0008	0.0012	0.0078	0.00

*Turekian and Wedenphol (1961), $p < 0.05$

The results of geo-accumulation index reveal that sediments of Nil river are moderately polluted with Pb, unpolluted to moderately polluted with Zn and unpolluted with Cr and Fe. Igeo values of Cd indicate that sediments at S5 and S6 are unpolluted to moderately polluted, while the other stations are moderately polluted (Figure 2).

The values of enrichment factor indicate that all stations record moderate enrichment with Zn and minor enrichment with Cr. Cd has the highest EF values and it is classified as severe enrichment in S1, S2, S3 and S4, moderately severe enrichment in S5 and moderate enrichment in S6. For Pb, the values of EF indicate that S1, S2 and S3 record severe enrichment while S4, S5 and S6 are moderately severe enrichment (Figure 3).

3.2.2. Correlation analyses

Correlation matrix for analyzed sediment parameters was used to investigate the factors controlling trace metals in sediments and to reveal if some of the metals were interrelated with each other. The results are presented in

were less anthropogenic activities when compared to the other stations. However, the highest concentrations of metals were recorded at sampling stations which were adjacent to river mouths (station 1 and 2). This may be attributed to the important quantity of untreated wastewater, rubbish and effluents of agricultural land discharged into the river at these stations. Furthermore, the mean concentration of Pb, Cd and Zn exceeded the background values (average shale) as proposed by Turekian and Wedepohl, (1961) (Table 2). Whereas, the average concentration of Cr and Fe was less than average shale. This indicates that metals, except Cr and Fe, were not originated from natural sources and anthropogenic sources have a great contribution to the enrichment of these metals.

The assessment of heavy metals pollution was carried out using geoaccumulation index and enrichment factor.

Table 3. These results showed that all metals have positive correlation with organic matter and silt and negative correlation with percentage of sand ($p < 0.05$). This comply with Halcrow *et al.*, (1973) who mentioned that the heavy metals concentration increases with decrease in the particle size and increase of organic matter content. Sediments containing high levels of organic matter are likely to contain higher concentration of heavy metals as compared to sediments lacking organic matter (Ugwu *et al.*, 2012). The fine-grained fraction ($\leq 63\mu\text{m}$) has a high specific surface area per unit quantity of material and, because of surface coatings of iron and manganese oxides and natural organic matter, it is more likely to adsorb organic and trace contaminations (Çevik *et al.*, 2009; Naji *et al.*, 2011). Furthermore, it was observed that the heavy metals were positively correlated with each other (except Fe) ($p < 0.05$), which may suggest a common pollution sources or a similar geochemical behavior for these metals (Ong *et al.*, 2013).

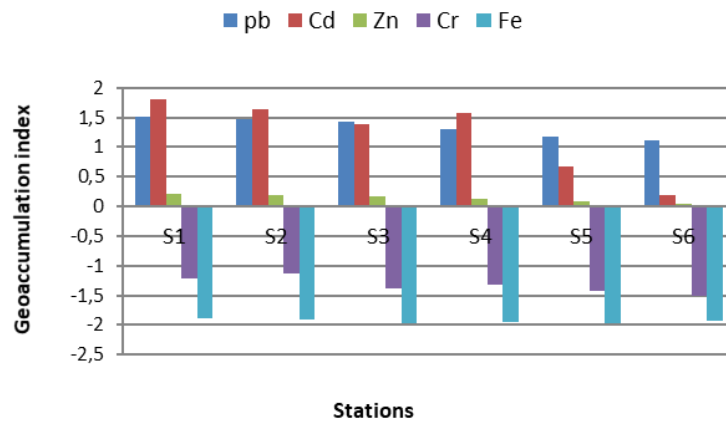


Figure 2. Geoaccumulation Index (I-geo) in surface sediments of Nil river

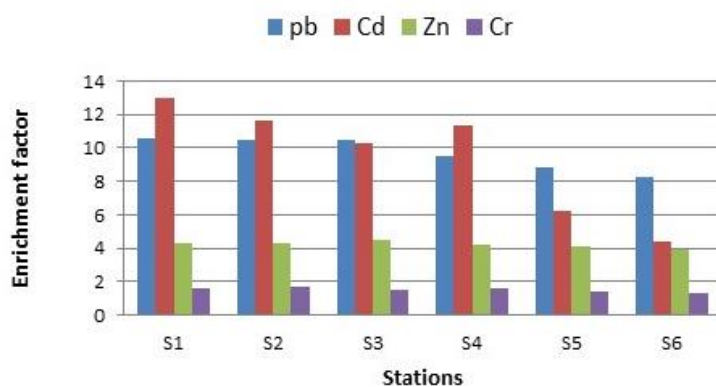


Figure 3. Enrichment factor (EF) in surface sediments of Nil river

Table 3. The correlation coefficients between sediment properties and heavy metals

	Pb	Cd	Zn	Cr	Fe
pH	-0.05	-0.03	-0.02	-0.30	-0.53*
TOM	0.82*	0.84*	0.83*	0.71*	0.25
Sand	-0.81*	-0.70*	-0.80*	-0.69*	-0.66*
Silt	0.81*	0.71*	0.78*	0.68*	0.69*
Clay	-0.28	-0.31	-0.24	-0.19	-0.43
Pb	-				
Cd	0.63*	-			
Zn	0.69*	0.80*	-		
Cr	0.64*	0.75*	0.66*	-	
Fe	0.37	0.37	0.36	0.52*	-

*Correlation is significant at the 0.05 level

3.3. Heavy metals in plant

The concentrations of Pb, Cd, Zn, Cr and Fe in the organs of *Phragmites australis* (roots and leaves) are given in Table 4. The mean concentration values of these metals in both roots and leaves were observed in decreasing order as following: Fe > Zn > Pb > Cr > Cd.

The results of this study showed that mean concentrations of all elements were less in the plants organs compared to the concentrations of the same elements in sediment. Positive correlation was found between the concentrations of metals in the sediment and plant organs (roots and leaves) (Table 5). This implies that the metal content in the plant was a result of the

plant metal uptake from the sediments. Norozi Fard *et al.*, (2016) reported that the soil fluid around the roots was the first source for the entry of heavy metals into the plant tissues and in total, the increased heavy metal concentration in the sediments increases the access of the plant. To this reason, the increase of metal amounts in surface layers of sediments mostly causes the increased accumulation of metals in the underground organs of the studied species.

Metals accumulated by *P.australis* were mostly distributed in root tissues, as shown by general TF values <1, except for pb in S1 and S2 (Table 6). These results are in accordance with the findings of other studies

demonstrating that accumulated metals in the common reed are not distributed evenly. The underground organ shows a higher storage capacity than the above ground parts (Štrbac *et al.*, 2014; Kucaj *et al.*, 2015). Nouri *et al.*, (2009) reported that the root tissues accumulate higher concentrations of metals than shoots, which indicated greater plant availability of the substrate metals, as well as interior limited mobility of the plant. According to Bonanno *et al.*, (2010), the fact that roots showed high accumulation of elements may imply relevant availability in the sediment. Roots and rhizomes of *P. australis* can accumulate a great quantity of heavy metals because of the cortex parenchyma with large intercellular air spaces. Some plant species develop a strategy to avoid accumulation of toxic trace elements by storing them far away from the metabolically active structures, especially in the roots, so that even the elements absorbed in great quantities do not act as a phytotoxin to the plant (Mendonça *et al.*, 2015).

Cadmium is a non-essential element for metabolic processes (Sasmaz *et al.*, 2008), it is noted as one of the main eco-toxic metals that reveals catastrophic effects on the plants and entire physiological processes of living organisms (Norouznia *et al.*, 2014). Kabata-Pendias and Pendias (2001) reported that Cd is easily absorbed by both root and leaf. According to the results of our study, Cd concentrations in the roots and leaves of *P. australis* were the lowest of all the investigated elements, due to low Cd content of the sediments. The mean Cd values detected (0.08-0.32 µg/g) were not in the phytotoxic range (5–100 µg/g) which is suggested by Chaney (1989).

Lead is not an essential element for plant growth but absorbed by the plant with other elements (Aksoy *et al.*, 2005). It is particularly present in aquatic environments in areas with heavy traffic and neighboring cities (Kastratović *et al.*, 2013).

In this present study, the mean concentrations of Pb in examined tissues (12.34-14.48 µg/g) were below the phytotoxic range which is 30–300 µg/g (Roos., 1994).

Cr is not essential for plants, it belongs to the group of elements that are harmful, and plants do not accumulate it in great amounts (Kucaj *et al.*, 2015). Pais and Jones (2000) reported that Cr concentrations higher than 10 mg/kg had a phytotoxic effect on plants. In the current investigation, the mean values of Cr in the roots and

leaves of *P. australis* (2.09-4.21 µg/g) do not exceed this limit.

Iron, directly or indirectly, is involved in many life processes of plants: Chlorophyll biosynthesis, photosynthesis, respiration, fixation of elemental nitrogen, nitrate and nitrite reduction, metabolism of carbohydrates and in different redox systems. However, high concentrations of this metal may result in oxidative stress for plant (Brankovic *et al.*, 2011). Fe is the most abundant of all the investigated elements in *P. australis*, although its mean concentrations remain below the threshold of toxicity, ranging from 1000 to 3000 µg/g (Kabata-Pendias *et al.*, 2001).

Zn is an essential and useful element for plants, mainly as a part of various metallo-enzymes (Kastratović *et al.*, 2013). Among the examined elements, Zn was the most abundant element after Fe. Mean Zn concentrations ranged from 10.30 µg/g to 38.29 µg/g in examined tissues. These values were below the threshold of phytotoxicity which is 500–1500 µg/g as proposed by Chaney (1989).

To assess the ability of plant to accumulate and translocate heavy metals in their organs, *Bioconcentration factors and translocation factors were calculated.*

As shown in table 6, the mean calculated BCF decreased in the following order: Zn>Cd>Pb>Cr>Fe. Iron shows the lowest BCF although it is present in high concentrations in the sediment and in common reed. This result obtained confirms the earlier assumption that the metals in the sediment originating from the decomposition of rocks are usually connected in the form of chemical compounds that are not easily bioavailable to wildlife (Štrbac *et al.*, 2014).

The values of translocation factors are shown in Table 6. Generally, the translocation factor (TF) showed low transport of elements from roots to shoots (TF<1), indicating the inefficient translocating action from the root to the aerial plant parts (Al-Haidarey *et al.*, 2010). In S1 and S2, the TF of pb was lower than one (concentration in the leaves is higher than in the roots), this may be explained by the fact that the leaves accumulate lead by deposition from the air (Štrbac *et al.*, 2014), which is polluted by exhaust gases emitted from traffics (Brankovic *et al.*, 2011).

Table 4. Heavy metal concentrations (µg/g) in roots and leaves of *Phragmites australis*

		S1	S2	S3	S4	S5	S6
Pb	R	13.11±0.60	13.09±0.55	12.93±0.67	12.91±0.50	12.85±0.12	12.78±0.23
	L	14.48±0.43	13.64±0.69	12.84±0.28	12.63±0.02	12.63±0.03	12.34±0.12
Cd	R	0.32±0.03	0.27±0.02	0.26±0.05	0.23±0.04	0.16±0.03	0.11±0.02
	L	0.19±0.09	0.17±0.03	0.16±0.09	0.14±0.01	0.10±0.08	0.08±0.04
Zn	R	38.29±2.03	37.15±2.15	34.14±4.73	29.13±1.87	31.41±2.27	28.93±1.37
	L	28.41±7.44	19.13±2.33	21.99±1.16	12.11±3.79	13.46±2.13	10.30±0.64
Cr	R	4.03 ±0.12	4.13±0.10	3.21±0.17	3.59±0.02	3.17±0.16	3.06±0.35
	L	2.48±0.11	2.51±0.06	2.36±0.14	2.55±0.10	2.25±0.08	2.09±0.03
Fe	R	371.32±19.45	358.38±25.84	336.89±2.34	349.80±10.72	347.03±9.9	352.08±20.37
	L	304.05±5.56	289.6±3.95	281.74±1.53	283.44±2.88	280.28±3.75	285.18±4.30

R: Roots, L: Leaves

Table 5. Correlation coefficients of heavy metals among plant organs (roots and leaves) and sediments

	PbS	CdS	ZnS	CrS	FeS				
PbR	0.62*	CdR	0.88*	ZnR	0.65*	CrR	0.80*	FeR	0.96*
PbL	0.81*	CdL	0.49*	ZnL	0.76*	CrL	0.60*	FeL	0.77*

S: Sediments, R: Roots, L: Leaves, *Correlation is significant at the 0.05 level.

Table 6. Bioconcentration factors (BCF) and translocation factors (TF) of metals in *Phragmites australis*

	BCF					TF				
	Pb	Cd	Zn	Cr	Fe	Pb	Cd	Zn	Cr	Fe
S1	0.15	0.20	0.23	0.069	0.0194	1.10	0.59	0.74	0.61	0.818
S2	0.15	0.19	0.22	0.066	0.0188	1.04	0.62	0.51	0.60	0.808
S3	0.16	0.22	0.21	0.062	0.0185	0.99	0.61	0.64	0.73	0.836
S4	0.17	0.17	0.18	0.065	0.0188	0.97	0.60	0.41	0.71	0.810
S5	0.18	0.22	0.20	0.063	0.0189	0.98	0.62	0.42	0.70	0.807
S6	0.19	0.21	0.19	0.064	0.0187	0.96	0.72	0.35	0.68	0.809

4. Conclusion

Given the results obtained in this study, it may be inferred that Nil river is facing serious environmental pollution, especially with Pb, Cd and Zn, which result from the continuous discharge of effluents in the river. Thus, the public health might be at highest risk since the water of river is extensively used for irrigation in the study area.

It is also noteworthy that the most severe pollution in river occurred at outfall where urban wastewater and effluents of agricultural land is discharged.

In the other hand, the results demonstrate that the concentration of heavy metals in the plants organs were less than those in the sediment and the metals accumulated by *P. australis* were mostly distributed in roots tissues. A positive association between the metal concentrations in *P. australis* organs and its environment was also found; this suggests that this plant can be used as biological indicator in biomonitoring studies.

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