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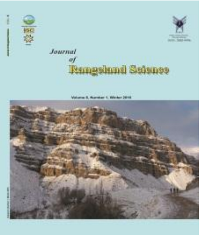

Research and Full Length Article:

Common Reed (*Phragmites australis)* as a Bio Refining and Monitoring Plant of Pollution Resulting from Heavy Metals (Case Study: Dez River, Dezful, Iran)

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Abstract. One of the most important methods to investigate heavy metals as pollutants is more likely to use bio-monitors which can be applied as an appropriate index to express the quality of environment. In current study, in order to investigate the effects of dominant plants in the desired region and role of aquatic macrophytes in monitoring such elements as zinc (Zn), lead (Pb), copper (Cu) and cadmium (Cd) in underground organs, leaves and stems of a specific aquatic macrophyte named *Phragmites australis* as well as sediment samples of Dez River, Iran in 2012 were studied. Given samples were prepared with the ratio of 4 to 1 nitric acid to perchloric acid and the concentrations of elements were measured by atomic absorption spectrometry. In this study, Enrichment Factor (EF), Bio-accumulation Index and Translocation Factor (TF) were measured. Results indicated that the concentration of metals was reduced in the underground organs, leaves and stem, respectively (stem<leaves<underground organs). Also, there was a positive correlation between the concentration of Pb in the sediments and roots ($P<0.05$); thus, it was expected that the roots of *Phragmites australis* may be of suitable monitoring for pollution resulting from Pb in the regional sediments of Dez Watershed. Enrichment Factor showed that because of anthropological resources, stations of two, three and five were more polluted. In addition, the underground organs of *Phragmites australis* were introduced as the accumulator of Cu, Zn, Pb and Cd by Bio-accumulation Index. Translocation Factor was increased from the underground organs to aerial organs for Pb, Cd, Cu and Zn, respectively.

Key words: Bio monitoring, Dez River, Iran, Heavy metals, *Phragmites australis*

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Introduction

Water pollution of rivers can be accounted as one of the most important environmental pollution indices due to human activities (Whitton, 1975). Since riverbed is the main acceptor and storage of different pollutants including heavy metals, the riverbed sediments can be regarded as a suitable index to show the environmental condition of studied region. Metal pollutants, especially heavy ones will be biologically enlarged due to the bioaccumulation potential and biological reduction resistance while exposing the organism body; it is considered as a distinguishable feature for the environmental performances of heavy metals as compared to the other toxic pollutants (Gu*et al.*, 2014). Since 1980, the usage of plants for the refining and clearing of environment and their roles in restraining and controlling the pollution have been discussed as an effective method in order to conduct soil treatments *in situ*; since 1990, it has been utilized in a variety of studies scientifically. Their economics and environmental compatibility are two advantages of these methods (Ghanadpour and ZandMoqadam, 2010). It is possible to use plants as monitors for studying the spatial distribution and time changes of accessible metals concentrations. Given that aquatic plants allocate the natural part of every ecosystem, they play crucial roles in purifying the ecosystem and balancing the environment ecologically. High tolerance of these species leads to their appropriateness to purify the polluted soil as compared to the pollutants (Bonanno and Lo Giudice, 2010).

Using bio-monitors growing in a specific area results in valuable information on available tensions caused by human activities and significantly the adverse effects made by the mentioned tensions. One of the best species is *Phragmites australis* as a cosmopolitan species with a wide distribution to decrease the accumulation of heavy metals and their impact on water, soil and consequently, food chain. High production and biomass of this species are introduced as its obvious properties in the moist environments and it may be of more capability for the metal accumulation with high concentrations due to a fibrous root system and high contact surface (Ebrahimi *et al.*, 2012). Worldwide, after the species of *Typha latifolia*, it has been addressed as one of the best plant species for the purification purposes (Fallahi *et al.*, 2012). In this regard, several studies have been conducted in the other countries; Ait Ali *et al.* (2002) studied the metal absorption of *P. australis* and *Zea mays* in Guadalentin River, Spain. Results demonstrated that *P. australis* was significantly resistant to Cu as compared to *Zea mays*. Furthermore, bio-concentration factor (BCF) was higher in the roots than stems regarding two above-mentioned species and finally, *P. australis* was specified as a suitable plant to refine the wastewater for removing Cu (Ait Ali *et al.*, 2002). Bragato *et al.* (2006) studied two dominant macrophytes including *Phragmites australis* and *Bolboschoenus maritimus* in order to investigate heavy metals left in Venice lagoon, Italy. Their findings indicated that the metal accumulation in *P. australis* was more than *B. maritimus*; also, the metal accumulation was increased at the end of growing season (Bragato *et al.*, 2006). They had surveyed the accumulation of four heavy metals involving nickel, Zn, Cu and chromium in *Phragmites australis* in Po River, northern Italy. Results showed that the level of metals was high in rhizome and stem against leaves during the growing season and the plant could be effectively applied to remove the metals from the shoots during harvest (Bragato *et al.*, 2009). In 2010, the accumulation of heavy metals including Pb, Zn, nickel and Cd in *Typha latifolia* and sediments of Arvand River and Bahmanshir in Khozestan, Iran were measured. Results demonstrated that rhizome of *Typha*

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latifolia could be applied as a pollution index of Cd and Zn in soil and sediments of the studied region (Ghanadpour and ZandMoqadam, 2010). At that year, the accumulation of few heavy metals in water and sediment samples as well as the organs of *Phragmites australis* had been investigated in Sicily River, Italy. Results reported that the underground organs might be the primary sites for the accumulation of mentioned metals and their accumulation has had a decreasing trend in the root, rhizome, leaf and stem, respectively (root > rhizome ≥ leaf > stem). In addition, a positive relationship was observed between the accumulation of heavy metals in water, sediments and plant organs. Therefore, this plant ability was discussed with respect to the monitoring of pollution resulting from heavy metals in water and sediment (Bonanno and Lo Giudice, 2010). Ebrahimi *et al.* (2012) used *Phragmites australis* in a study in order to refine the soil polluted by such heavy metals as Zn, Cu and chromium in Industrial District of Lia, Qazvin, Iran. Results indicated that the least metal accumulation in the plant organs, soil and water was related to Cu and the accumulation in four plant organs had a decreasing trend in the root, rhizome, leaf and stem, respectively (stem<leaf<rhizome<root). Finally, the species *P. australis* was introduced as a bio-monitor for the refinement of polluted soil (Ebrahimi *et al.*, 2012). A study was done by Cheraghi *et al.* (2012) in Emam Khomeyni Port, Iran to investigate the accumulation of heavy metals including Pb, Cu, Zn, Cd and nickel in the sediments, leaves and roots of mangrove plant. Results demonstrated that a positive correlation was seen between these metals in the sediments and plant leaves (Cheraghi *et al.*, 2012).

The purpose of this study was to investigate *P. australis* capabilities in refining heavy metals and its dense colonies in natural reeds at the riverbank as well as Dez River in the region, Iran. It is necessary to investigate whether this plant can be a suitable index which is the indicative of pollution state resulting from heavy metals in Dez River; thus, the concentrations of such metals as Cd, Cu, Zn and Pb were measured in the sediments and organs of given macrophyte, *P. australis*.

Materials and Methods

Considering the discharge rate, Dez River is the second biggest river in Iran as it supplies the drinking water for people and irrigation water for the adjacent industrial and agricultural lands. The river is originated from Lorestan province, passing Dezfol city and discharged into Karon River and finally, led to Persian Gulf. Field studies and visits had been done during August-November 2012 by six sampling stations along Dez River passing Dezfol city. Since the most plant storage is simultaneous with the peak growing period of *P. australis* considering the phenological stages, samples had been taken from the riverbank and tidal zone at the late November. In every station, three samples of *P. australis* were collected in a 5×2 m^2 plot and samples of sediments were taken from surface layer of plant sample locations in each station with four replicates (Table 1).

Table 1. Location of sampling sites

Station	Altitude (m)	Latitude (N)	Longitude (E)	Site Description
1	142	27″ 27′32°	40″ 29′48°	Bakeri boot camp Dez entrance in to Dezfol
2	141	58″ 26′32°	58″ 27′48°	Surface water pumps
3	138	33″ 24′32°	28″ 25′48°	Dolat park
4	127	41″ 23′32°	44″ 23′48°	Dez river sit recreation area
5	121	27″ 22′32°	04″ 23′48°	Fifth bridge
6	111	45″ 21′32°	28″ 21′48°	Milad forest park (Dez exit from Dezful)

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Geographical coordinates and information of each station have been recorded; afterwards, samples were coded and transferred to an ice-containing freezer. After separating the roots, stems and leaves, plant samples along with sediment samples were placed in an oven to achieve a fixed weight. After drying the samples, plant samples were crushed in a mortar and sediment ones were sieved (Bonanno and Lo Giudice, 2010). To digest the samples, one gram of dried plant or sediment was first digested by the composition of ratio of 1:4 perchloric acid and nitric acid on a heating block at 40 and 140°C for 1 and three hours, respectively. Then, samples were distilled twice by distilled water to reach the desired volume and filtered by Whatman filter paper number one (Yap *et al.,* 2002). Concentrations of metals in plant and sediment samples were measured by ContrAA 700 analytic Jena atomic absorption spectrometry.

Enrichment Factor (EF)

Enrichment factor (EF) was used to estimate the sediment chemistry in relation to natural and anthropogenic pollution resources. EF was calculated using the following (Equation 1) (Suthar *et al.*, 2009):

(Equation 1)

$$\mathrm{EF}\,(\%) = (\mathrm{C} - \mathrm{CMin})/(\mathrm{CMax} - \mathrm{CMin}) \times 100$$

Where

C=the mean metal concentration in sediment (mg kg^{-1})

C_{max}, C_{min} =the maximum and minimum concentrations (mg kg^{-1}), respectively.

Bio-accumulation Index

Bio-accumulation index or coefficient which specifies the plant ability to tolerate and accumulate heavy metals in its organs will be computed by the (Equations 2 and 3 as follows (Zacchini *et al.*, 2008):

$$\text{Bio-accumulation coefficient of underground organs} = \frac{\text{metal concentration of underground organ}}{\text{metal concentration of soil}} \quad \text{(Equation 2)}$$

$$\text{Bio-accumulation coefficient of aerial organs} = \frac{\text{metal concentration of aerial organ}}{\text{metal concentration of soil}} \quad \text{(Equation 3)}$$

Translocation Factor (TF)

Translocation Factor (TF) or coefficient which specifies the plant ability to absorb and transfer metals from the sediments and then store them in the upper part of surface of the Earth will be computed by the (Equation 4) as follows (Zacchini *et al.*, 2008; Malekzadeh *et al.*, 2011):

$$\text{Translocation factor of underground organ to aerial organ} \frac{\text{metal concentration of aerial organ}}{\text{metal concentration of underground organ}} \quad \text{(Equation 4)}$$

Assessment of sediment Quality: Sediment Quality Guidelines (SQGs)

Sediment Quality Guidelines (SQGs) were used to protect the aquatic biota against the toxic and harmful effects related with sediment-bound contaminants. These guidelines are regarded as a useful tool to evaluate the pollution potential and investigate the chemical forms of sediment-based pollutants for interpreting the quality of sediments. Also, they are used for rating and prioritizing the polluted regions in future surveys (Díaz-de Alba *et al.,* 2011). Sediment Quality Guidelines have been categorized at three levels of ERL (effect range low), ERM (effect rang medium) and rarely (<ERM); occasionally (ERL-ERM) or frequently (ERM≤) associated with the adverse biological effects. Mean ERM quotient (mERM-Q) is proposed for assessing the potential effects of multiple heavy metal contamination in the sediments using the (Equation 5), (Long *et al.*, 2005):

$$\mathrm{mERM} - \mathrm{Q} = \frac{(\sum_{i=1}^{n} \mathrm{ERM} - \mathrm{Qi})}{\mathrm{n}} \quad \text{(Equation 5)}$$

$$\mathrm{ERM\text{-}Qi} = \mathrm{Ci} / \mathrm{ERMi}$$

Where

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mERM-Q= the effect-range median quotient of multiple metal contamination,
C_i =total concentration of selected metal "i",
ERM_i = the ERM value of selected metal "i"
n =the number of selected metals.
mERM-Q has been classified into four classes: low priority site (≤0.1), low-moderate priority site (0.1-0.5), moderate-high priority site (0.5-1.5) and high priority site (1.5<) (Yu *et al.*, 2011).

To conduct statistical analyses, normality of data was first investigated by $Minitab_{15}$; afterwards, $SPSS_{21}$ software was used to determine the correlation coefficient of metal concentrations (Pb, Cu, Zn and Cd) in the sediments and plant organs. The correlations between plant organs also were estimated.

To compare the concentrations of metals with international standards, one sample-T test was applied.

Finally, the concentration of metals in surface sediments was compared using Interim Sediment Quality Guideline (ISQG) and mERM-Q value was estimated in order to identify the local priorities for monitoring bio-pollution for further studies.

Results

Fig. 1 shows the concentration of each metal in plant organs and sediments. It can be pointed out that the highest concentrations of Cu, Pb and Zn have been found in the sediments but the highest concentration of Cd was observed in the roots (Fig. 1).

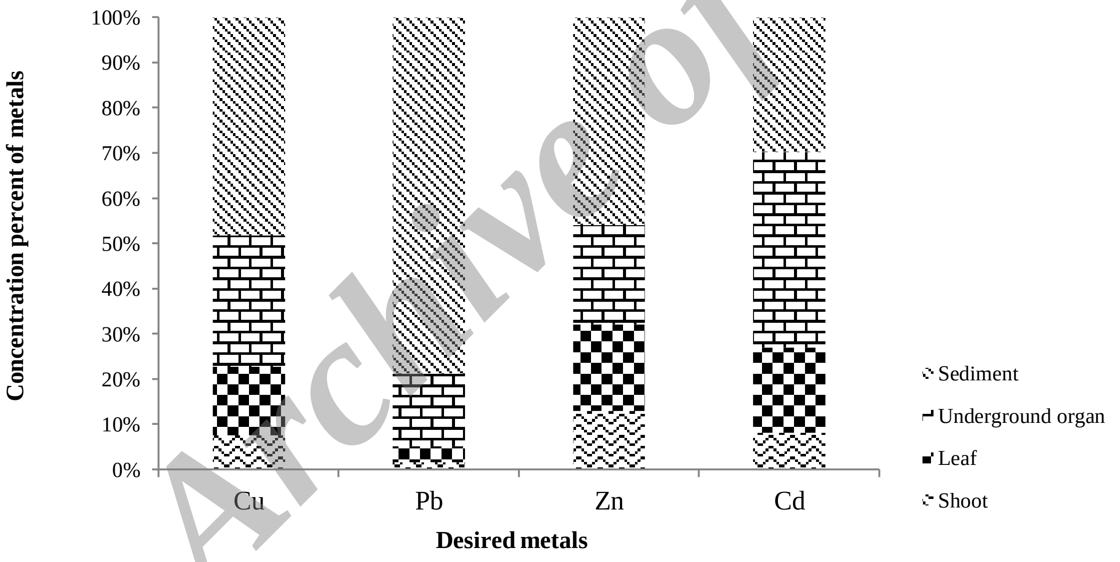

Fig. 1. Concentration percent of each desired metal in plant organs and sediments

Enrichment Factor (EF)

Enrichment Factor values are presented in Table 2. The lowest value of this factor was found for all the studied metals in the first station and the highest value was estimated for Cu and Zn in the fifth station and for Pb and Cd in the second and third stations based on type of metal and contamination source, respectively (Table 2).

The mERM-Q values calculated by the average quotient of an effective range of heavy metals are presented in Table 2. As it has been shown, the highest and lowest values of mERM-Q were estimated for the stations two, three and five and one, respectively (Table 2).

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Table 2. Enrichment Factor (EF) of different metals in sediments (%) and mERM-Q values in various stations

Stations	Enrichment Factor (EF) (%)				mERM-Q
	Cu	Pb	Zn	Cd	
1	25.70	18.60	13.56	4.63	0.076
2	42.59	82.83	42.14	12.96	0.105
3	56.60	50.85	38.68	93.52	0.101
4	35.77	30.05	40.55	56.48	0.095
5	84.03	52.66	55.53	89.81	0.113
6	63.73	19.88	33.27	45.37	0.091

Pollution extent evaluation

Fig. 2 shows the ERM-Q_i for the studied metals in various stations. As it has been shown, the highest and lowest values of ERM-Qi were related to the stations five and one concerning all of metals, respectively (Fig. 2).

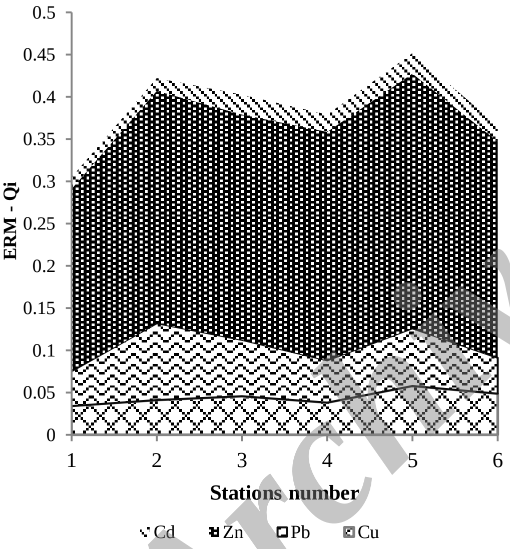

Fig. 2. Valuesandgeneral state ofERM - Qidesired metal in various stations

Bio-accumulation Index and Translocation Factor

Bio-accumulation index values are presented in Table 3. According to the results, the value of this index in the roots of plants was higher than the shoots except for the metals and totally, the highest accumulation value has been attributed to Cd in the roots (Table 3).

Translocation factor values are also presented in Table 3. According to the results, the highest values of this factor were given to Zn and Pb, respectively (Table 3).

Table 3. Bio-accumulation and translocation indices values for underground organ to aerial organ

Metals	Bio-Accumulation Index		Translocation Factor (TF)
	Aerial Organs	Underground Organs	
Cu	0.472	0.600	0.787
Pb	0.065	0.205	0.317
Zn	0.697	0.481	1.451
Cd	0.910	1.455	0.625

Correlation of plant organs and sediments

Based on Table 4, there was a positive correlation between leaf and stem for Cu concentration ($r=0.78$, $p<0.01$). Similarly, a positive relationship was observed between leaf and underground organ for the Cu metal ($r=0.74$, $p<0.01$). There was a negative correlation between stem and underground organ for Pb concentrations ($r=- 0.57$, $p<0.05$). Similarly, a negative correlation was observed between stem and sediments for Pb concentrations ($r= - 0.65$, $p<0.01$).

A positive correlation was observed between sediments and underground organ for Pb concentrations ($r=0.76$, $p<0.01$). Moreover, there was a positive relationship between stem and underground for Zn concentrations ($r=0.67$, $p<0.01$). A positive correlation was observed between leaf and underground organ for Cd concentrations ($r=0.89$, $p<0.01$).

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Table 4. Correlation coefficients of elements among plant organs and sediments

Plant Organs	Metal	Stem	Leaf	Underground Organ
Leaf	Cu	0.787^{**}		
	Pb	0.334		
	Zn	0.330		
	Cd	0.277		
Underground organ	Cu	0.378	0.749^{**}	
	Pb	-0.578^{*}	0.043	
	Zn	0.678^{**}	0.467	
	Cd	-0.024	0.894^{**}	
Sediments	Cu	-0.264	-0.109	0.157
	Pb	-0.655^{**}	-0.302	0.760^{**}
	Zn	0.011	0.074	0.156
	Cd	0.110	-0.255	-0.291

* and** =Correlation coefficients are significant at 0.05 and 0.01 probability levels, respectively

Sediment Quality Guideline

Based on Table 5 and specific limits given by metal concentrations comparisons using SQGs, probable metal effects can be interpreted with respect to their concentrations and the related guidelines.

Table 5. Comparison results of SQGs and probable metal effects (Sundaray *et al.*, 2011)

Sediment Quality Guide line		Effect
TEL and PEL guidelines	<TEL	Not associated with adverse biological
	Between TEL-PEL	May occasionally be associated with adverse biological effects
	>PEL	Frequently associated with adverse biological effects
LEL and SEL guidelines	<LEL	Dredged sediments may have no contamination
	Between LEL-SEL	The impact is moderate
	>SEL	Severely impacted
ERL and ERM guidelines	<ERM	Minimal effects rang
	Between ERL-ERM	Effects would occasionally occur
	>ERM	Effects would frequently occur

Discussion

Results indicate that the heavy metal concentrations in the organs of *P. australis* were different. As it has been already stated, underground organs had higher metal accumulations as compared to the aerial organ due to the bio-access to these elements in the sediments (Fig. 1). Underground organs in *P. australis* can accumulate high amounts of metals because of parenchymal tissue with lots of intercellular space filling by air (Bonanno and Lo Giudice, 2010).

In present research, the metal concentration in the leaf is higher than stem (1<) since in the plant aerial organs, metals are usually accumulated in the vacuoles of leaves. Ebadati *et al.* (2005) and Ebrahimi *et al.* (2012) reported similar results. In general, the following trends were found in terms of four regarded metals:

Underground organs >leaves>stems

Zn>Cu>Pb>Cd

The highest values of enrichment Factor were attributed to the stations two, three and five that have been proposed as the main sources of metal pollution along Dez River. The lowest value of enrichment factor was related to upper parts of sampling site in the station one (as unpolluted location) indicating direct effects of tensions and pressures caused by human activities on water quality of Dez River in Dezfol.

High levels of pollution were obtained in station two. It is because of the entrance of agricultural nearby drainage water and consumption and leakage of fossil fuels in surface water pumps. The station three is located in "Dolat" recreational park and is exposed to

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pollution from human sewage and wastes. Also, lots of fertilizers were used in highland agricultures. In station four, there were lots of reeds that could boost the risk of sediment pollution refinery. In station five, with respect to field studies, the wastes caused by road repairs, Hospitals and urban waste entrance, the probability of pollution was out of town and a forest park. Probably, it can cause the dilution of pollutants and the reed plant colonies refinery.

Bio-Accumulation and Translocation Indices

Based on the results given by Ma *et al.* (2001) who classified bio-accumulation indices of BCF≈0, BCF<1 and BCF>1 as excluder, accumulator and hyper accumulator respectively, the species *P. australis* acts as an absorbent plant in relation to Cu and Zn in the aerial organs and underground organs as well as Pb in the underground organs; Regarding Cd, it serves as a super-absorbent plant in the underground organs. Plant aerial organs were considered as high Cd-absorbent organs with bio-accumulation index given as 0.91 (Table 3). Considering Pb, the aerial organs having bio-accumulation index given as approximately zero are the repellent of this metal.

The translocation indices estimate the plant ability for the refinement purposes. According to Kabata-Pendias and Pendias (2000), if translocation factor ranged from 0.01 to 1, the plant accumulation and access are moderate. Accordingly, the plant accumulation and access are moderate in relation to Cu, Pb and Cd except Zn. Regarding Zn, this value is greater than 1 (Table 3); thus, the accumulation and access of Zn in this plant were high. It demonstrates the efficiency of metal translocation system which stops the metals in the vacuoles of leaves and apoplastes (Sasmaz *et al.,* 2008). Resultant translocation factor values follow the below model:

Translocation factor of underground organs to aerial organs: Zn>Cu>Cd>Pb

The model which was presented by Ghanadpour and ZandMoqadam (2010) concerning the species *Typha latifolia* is in conformity with the present results.

Translocation factor of underground organs to aerial organs: Ni>Zn> Cd>Pb

Based on the results of translocation and bio-accumulation indices, it can be stated that *P. australis* is a resistant species against Cd due to its defensive solutions involving the increased activity of antioxidant enzymes. Particularly, it has been specified that roots can be addressed as Cd accumulators with their ability of Cd detoxification; these findings are confirmed by Bonanno and Lo Giudice (2010).

According to the reports of Zacchini *et al.* (2008), the species has a bio-accumulation coefficient in the underground organs that is greater than one and translocation factor in the aerial organs is smaller than one, it is a suitable species for the plant fixation; in other words, a species having a bio-accumulation coefficient in the shoots greater than one is suitable for harvest. On the other hand, Fattahi Kiasari *et al.* (2010) expressed that in order to select plants for the plant refinement, a species with high element absorption and translocation factor from underground organ to stem is more appropriate. Therefore, *P. australis* can be discussed as a suitable plant for the plant Cd fixation in this paper.

Correlations between plant organs and sediments

Results indicate that there was a positive relationship between the Cu concentration in the leaves and underground organs as well as stem and leaf. Cu tends to be accumulated in the underground organs. Given that the plant underground organs act as filters and prevent from transferring this metal into the aerial organs, it is reasonable that a significant relationship was observed

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between Cu concentrations of stem and leaf. This strategy in the plants was considered as an effective solution in preserving the aerial organs from the toxicity caused by harmful amounts of Cu. On one hand, the accumulation of Cu in the leaves was more than stem; it has been confirmed by Baldantoni *et al.* (2004), Bragato *et al.* (2006), Bonanno and Lo Giudice (2010) and Ebrahimi *et al.* (2012). Therefore, when a metal is transferred from the underground organs to the aerial organs, it will be accumulated in the leaves due to the existence of vacuoles in these organs indicating a positive significant relationship between the metal concentrations of leaf and underground organs.

There was a positive relationship between Pb concentrations of underground organs and sediments whereas a negative relationship was observed between Pb concentrations of stem and sediments. It can be resulted from relative mobility of Pb in soil and its tendency to be accumulated in the underground organs; finally, small amounts of it will be transferred to the aerial organs (Siedlecka *et al.*, 2001). A negative significant relationship was found between Pb concentrations of stem and underground organs because there was lack of tendency for Pb to be transferred from underground organs to aerial organs. A positive correlation exists between Zn concentrations of stem and underground organs because it will be transferred from the underground organs to the stem. As it can be observed by estimating translocation factor, this metal had a high ability for being transferred from the underground organs to aerial ones.

With respect to Cd, no relationship was observed between Cd concentrations in sediments and different plant organs except leaf and underground organ. Given results for bio-accumulation index, the plant underground organs were of high ability for Cd accumulation and they were introduced as Cd accumulators (Iannelli *et al.*, 2002); it may not be transferred to the aerial organs.

Metal accumulation in plant organs depends on nutrition source (water or sediments). Results showed that Cu is primarily caused by sediments and Zn is mostly originated from water column in the plant organs. In this regard, Campbell *et al.* (1985) reported that Cu accumulated in rhizome and stem of *Nuphar variegatum* may be originated from sediments whereas Zn is resulted from water column. Source of Pb existing in the underground organs was the sediments but its source in the aerial organs was related to the fluid in water column.

Studies conducted by Welsh and Denny (1980) demonstrated that the accumulation of Cu was mostly done through the root absorption from the sediments whereas the accumulation of Cu was because of root absorption from water. In this paper (Welsh & Denny, 1980), it seems that Zn is originated from water column in the plant organs. Studies on a macrophyte called *Spartina alterniflora* reported that the decreased amounts of Zn in the leaves might be caused by the increased effects of dilution; but the variable concentrations in the roots were more likely to depend on the chemical changes in rhizosphere leading to a different access to metals through sediments to roots. In the roots, Cd source is mainly the sediments but in the aerial organs, it will be affected by the environment. According to the findings expressed by Bonanno and Lo Giudice (2010), Cd concentration in plant tissues has been significantly attributed to the sewage, fertilizers and road traffic.

Pollution Extent Evaluation

In order to evaluate the pollution of heavy metals in surface sediments, the achieved concentrations have been compared and then interpreted by the

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means of sediment quality guidelines in Table 5. These guidelines are scientific tools to assess the pollution degree and probable capacity of sediments exposed to biological effects (Shirneshan *et al.,* 2013).

Comparing the achieved results and sediment quality guidelines indicated that the concentrations of studied metals were lower than those of the given guidelines showing that the sediments had not associated with adverse biological status with respect to TEL and PEL guidelines in the studied region; on the other hand, regarding LEL and SEL guidelines, the dredged sediments might have no contamination. Considering ERL and ERM guidelines, they were found in the range of minimal effects. This is due to less contamination sources which could not create a problem and the existence of reed colonies as a plant refiner in the region.

Comparison results of SQGs and probable metal effects demonstrate that the obtained values for all the metals are less than the least limit as compared to the guidelines and it can be stated that the probable metal effects are not related to the pollution.

Regarding the results of mERM-Q for various stations, all the stations have been classified as low priority ones in relation to pollution and only station five had a higher value and higher priority in comparison with the other stations; it is more clearly to be seen in the graph of ERM-Qi but there is a decreasing trend in different stations:
Station five>station two>station three>station four>station six>station one

In most studies, the given values on the mentioned metals were higher than those reported by current research (Suthar *et al.,* 2009; Varol, 2011; Varol and Şen, 2012; Bonanno and Lo Giudice, 2010; Sasmaz *et al.,* 2008). Based upon the results, the metal concentrations in the sediments in India, Hindon River, Imera, Italy and Meridionale except Cd were higher than the studied regions with regard to the given metals; these differences were greatly related to environmental conditions, contamination sources, geological substrates and some effective factors.

Comparing the concentrations in various plant organs of reed estimated in this paper and the other studied (Windham and Weis, 2003; Sasmaz *et al.,* 2008; Bonanno and Lo Giudice, 2010; Ebrahimi *et al.,* 2012; Ghanadpour and Zndmoqadam, 2010), in most cases, the concentrations reported by present research were lower than those of other studies due to plant species, specific metal, and organs roles for absorption and transfer of metals from environment and water. Of course, it has been tried to use the existing studies concerning the same species and aquatic ones in order to reduce their effects.

According to Table 6, heavy metal levels were lower than those of international standards at a warning level. Results of T-Test indicated a significant difference between these values and international standards (T value was not shown).

Table 6. Metal concentration comparisons of Cu, Pb, Zn and Cd in the sediments of Dez River and international standards

Metals	Case study	NOAA [Long *et al.*, 1995]		CCME, 1999 ISQGs			USEPA, 1996 [Bowen, 1979]	
		Effects RangeMedian	Effect rangelow	Probable Effect Level	Threshold Effect Concentration	ProbableEffect Concentration	Lowest Alert Level	Highest Alert Level
Cu	12.021	270	34	108	31.6	149	2	270
Pb	12.982	218	7.46	112	35.8	128	2	218
Zn	108.485	410	150	271	121	459	5	410
Cd	0.189	9.60	1.20	4.20	0.99	4.98	0.04	9.60

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In general, the following trends were achieved for four studied metals and plant organs, respectively.

Zn>Cu>Pb>Cd

Underground Organs >Leaves>Stems

Important relationships of metal concentrations between plant organs and sediments show that *P. australis* reflects the general effects of environmental effects that are in accordance with the findings of other studies demonstrating that aquatic macrophytes record temporary changes of heavy metals (Vardanyan and Ingole, 2006). Ye *et al.* (1997) and Bonanno and Lo Giudice (2010) expressed that *P. australis* was more likely to have an inherent resistance against such metals as Zn, Pb and Cd. Evidence confirms this finding that common reed colony lives in the polluted areas. Thus, these plant organs act as a biological index and can be used as bio-monitors. Bio-monitors are defined as organisms providing qualitative estimates concerning environmental qualities (Bonanno and Lo Giudice, 2010; Ngayila *et al.*, 2009). Regarding the existing differences in heavy metal concentrations in the plant organs and sediments, *P. australis* was totally suggested as a usable plant for the reduction of heavy metals in sediments and as a bio-monitor for biological monitoring plans in order to assess the environmental conditions quantitatively with respect to the sediments of studied region; it is in accordance with the finding reported by Ebrahimi *et al.* (2012).

Conclusion

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 desired 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, namely *P. australis* as compared to the other plant organs. Underground organs had the highest metal accumulation amount in comparison with the aerial organs; underground organs serve as a super-absorbent of Cd. In addition, although there were obvious differences among heavy metal concentrations in plant organs and sediments, the species *P. australis* regarded as an absorbent and accumulator can be generally proposed in order to decrease heavy metal amounts in the regional sediments. Important relationships of metal concentrations between plant organs and sediments demonstrate that *P. australis* reflects total impact of environmental pollutions. Therefore, the species organs act as a biological index and can be applied as bio-monitors in order to provide quantitative estimates of environment qualities. Finally, it may be claimed that in spite of differences among heavy metal concentrations in the plant organs and sediments, *P. australis* is suggested as a useful plant for the reduction of heavy metals in sediments and as a bio-monitor for biological monitoring plans in order to evaluate the environmental conditions quantitatively with respect to the sediments of studied region.

Literature Cited

Ait Ali, N., Pilar Bernal, M., Ater, M., 2002. Tolerance and bioaccumulation of copper in *Phragmites australis* and *Zea mays*. *Jour.* Plant and Soil 239: 103-111.

Baldantoni, D., Alfani, A., Di Tommasi, P., Bartoli, G., Virzo De Santo, A., 2004. Assessment of macro and microelement accumulation capability of two aquatic plants. *Jour.* Environmental Pollution 130(8): 149-156.

Bonanno, G., and Giudice, R. L., 2010. Heavy metal bioaccumulation by the organs of *Phragmites australis* (common reed) and their potential use as contamination indicators. *Jour.* Ecological Indicators 10: 639-645.

Bowen, H. J. M., 1979. Trace Element in Biochemistry. New York, Academic press, 241-244.

Archive of SID

Bragato, C., Brix, H., Malagoli, M., 2006. Accumulation of nutrients and heavy metals in *Phragmites australis* (Cav.) Trin. Ex Steudel and *Bolboschoenus maritimus* (L.) Palla in a constructed wetland of the Venice lagoon watershed. *Jour.*Environmental Pollution 144: 967-975.

Bragato, C., Schiavon, M., Polese, R., Ertani, A., Pittarello, M., Malagoli, M., 2009. Seasonal variations of Cu, Zn, Ni and Cr concentration in *Phragmites australis* (Cav.) Trin ex steudel in a constructed wetland of North Italy. *Jour.* Desalination 246: 35-44.

Campbell, P. G. C., Tessier, A., Bisson, M., Bougie, R., 1985. Accumulation of copper and zinc in the yellow waterlily, *Nuphar variegatum*: relationships to metal partitioning in the adjacent lake sediments. *Jour. Fisheries and Aquatic Science*, 42(10): 23-32.

CCME (1999) (Canadian Council of Ministers of the Environment). 1999. Canadian environmental quality guidelines. Canadian Council of Ministers of the Environment Winnipeng.

Chakraborty, P., Babu, P. V. R., Sarma, V. V., 2012. A new spectroflorometric method for the determination of total arsenic in sediments and its application to kinetic speciation. *Jour. Environmental Analytical Chemistry*, 92: 133–147.

Cheraghi, M., Dadalahy Sohrab, A., Safahyeh, A. R., Ghanemi, K., Douraghi, A. M., 2012. investigation of accumulation of heavy metals in bed, leaves and roots of mangrove (*Avicennia marina*) in the province of Khuzestan, *Jour. Marine Science and Technology*, 11(4): 46-56. (In Persian).

Díaz-de Alba, M., Galindo-Ria˜no, M. D., Casanueva-Marenco, M. J., García-Vargas, M., Kosore, C. M., 2011. Assessment of the metal pollution, potential toxicity and speciation of sediment from Algeciras Bay (South of Spain) using chemometric tools. *Jour. Hazardous Materials*, 190: 177–187.

Ebadati, F., EsmailSari, A., RiahiBakhtiari A. R., 2005. A mount and how changes heavy metals in organs aquatic plants and sediment Miankaleh pond. *Jour. Environmental Studies*, 37: 57-53 (In Persian).

Ebrahimi, M., Jafari, M., Savaghebi, Gh., Azarnivand, H., Tawil, A. and Madrid, F., 2012. Investigation of phytoremediation species of *Phragmites australis* (Cav.) Trin.ex Steudel in soils contaminated with heavy metals (Case study, Industrial area Lia-Ghazvin). *Jour. Rangeland*, 1: 1-9. (In Persian).

Fallahi, F., Ayati, B., Ganjidoust, H., 2012. Lab Scale Study of Nitrate Removal By Phytoremediation. *Jour.Water & Wastewater*, 1: 57-65. (In Persian).

Fattahi kiasari, A., Fotovat, A., Astaraei, A. R., Hqqnia, Gh. H., 2010. The effect of Sulfuric acid and EDTA on phytoremediation lead in soil by three sunflower, corn and cotton. *Jour. Science and Technology of Agriculture and Natural Resources, Water and Soil Science*, 51: 57-68. (In Persian).

Ghanadpour, J., Zndmoqadam, A., 2010. Accumulation ofheavy metals lead, zinc, nickel and cadmiumin (*Typhalatifolia*) and river sediments Arvand and Bahmanshir in winter season. *Jour. Wetlands*, 5: 29-36. (In Persian).

Gu, Y. G., Lin, Q., Jiang, Sh. J., Wang, Zh. H., 2014. Metal pollution status in Zhelin Bay surface sediments inferred from a sequential extraction technique, South China Sea. *Jour. Marine Pollution Bulletin*, 81: 256–261.

Iannelli, M. A., Pietrini, F., Fiore, F., Petrilli, L., Massacci, A., 2002. Antioxidant response to cadmium in *Phragmitesaustralis* plants. *Jour. Plant Physiolgy and Biochemistry*, 40: 977–982.

Kabata-Pendias, A., H. Pendias. 2000. Trace Elements in Soils and Plants,3rd Edit, Bocaraton New York, CRC Press.

Long, E. R., Ingersoll, C. G., MacDonald, D. D., 2005. Calculation and uses of mean sediment quality guideline quotients: a critical review. *Jour. Environment Science and Technology*, 40: 1726–1736.

Long, E. R., MacDonald, D. D., Smith, S. L., Calder, F. D., 1995. Incidence of adverse biological effects within ranges of chemical concenterations in marine and estuarine sediments. *Jour. Environmental Management,* 19: 81-97.

Ma, LQ., K. M. Komar, C. Tu, W. Zhang, Y. Cai, E.D. Kenell. 2001. A fern that hyper accumulates arsenic. *Jour.* Nature 409: 579-582.

Malekzadeh, A., Alikhani, H. A., Savaghebi Firoozabadi, Gh. R., Zareei, M., 2011. Interaction arbuscular mycorrhizal fungies and bacteria PGPR resistant to Cadmium in phytoremediation Cadmium. *Jour. Water and Soil (Agricultural Science and Technology),* 25: 274-266. (In Persian).

Ngayila, N., Botineau, M., Baudu, M., Basly, J. P., 2009. Myriophyllum alterniflorum DC.Effect of low concentrations of copper and cadmium on somatic and photosyntheticendpoints: a

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chemometric approach. *Jour. Ecolgical Indicator*, 9: 307–312.

Sasmaz, A., Obek, E., Hasar. H., 2008. The accumulation of heavy metals in *Typha latifolia* L. grown in a stream carrying secondary effluent. *Jour. Ecological Engineering*, 33: 278-284.

Shirneshan, G., Riyahi Bakhtiari, A., Seyfabadi, S. J. and Mortazavi, S., 2013. Environmental Geochemistry of Cu, Zn and Pb in Sediment from Qeshm Island Persian Gulf, Iran: a Comparison Between the Northern and Southern Coast and Ecological Risk. *Jour. Geochemistry International,* 51(8): 670–676.

Siedlecka, A., Tukendorf, A., Sko´rzyn´ska-Polit, E., Maksymiec, W., Wo´jcik, M., 2001. Angiosperms (Asteraceae, Convolvulaceae, Fabaceae and Poaceae; other than Brassicaceae). In: Prasad, M. N. V. (Ed.), Metals in the Environment. Analysis by Biodiversity. Marcel Dekker, Inc., New York, 171–217.

Sundaray, S. K., Nayak, B. B., Lin, S., Bhatta, D., 2011. Geochemical speciation and risk assessment of heavy metals in the river estuarine sediments-A case study: Mahanadi basin, India. *Jour. Hazardous Materials*, 186: 1837–1846.

Suthar, S., Nema, A. K., Chabukdhara, M., Gupta, M. S. K., 2009. Assessment of metals in water and sediments of Hindon River, India: Impact of industrial and urban discharges. *Jour. Hazardous Materials,*171: 1088-1095.

Vardanyan, L. G., Ingole, B. S., 2006. Studies on heavy metal accumulation in aquatic macrophytes from Sevan (Armenia) and Carambolim (India) lake systems. *Jour. Environmental International*, 32: 208–218.

Varol, M., 2011. Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques. *Jour. Hazarous Materials*, 195: 355-364.

Varol, M., Şen, B., 2012. Assessment of nutrient and heavy metal contamination in surface water and sediments of the upper Tigris River, Turkey. *Jour. Catena*, 92: 1-10.

Welsh, R. P. F., Denny, P., 1980. The uptake of lead and copper by submerged aquatic macrophytes in two English lakes. *Jour.* Ecolgy 68: 443–455.

Whitton, B. A., 1975. River Ecology. Studies in Ecology. Vol. 2, Oxford, Black-well Scientific Publications 725p.

Windham, L., Weis, J. S., 2003. Uptake and distribution of metals in two dominant salt marsh macrophytes, *Spartinaalterniflora* (cordgrass) and *Phragmites australis* (common reed). Estuarine, *Jour. Coastel and Shelf Science*, 56: 63-72.

Yap, C. K., Ismail, A., Tan, S. G., Omar, H., 2002. Concentrations of Cu and Pb in the offshore and intertidal sediments of the west coast of Peninsular Malaysia. *Jour. Environment International*, 28: 467–479.

Ye, Z. H., Baker, A. J. M., Wong, M. H., Willis, A. J., 1997. Zinc, lead and cadmium tolerance, uptake and accumulation by the common reed, *Phragmites australis* (Cav.) Trin. ex Steudel. *Jour. Ann Bot*, 80: 363–370.

Yu, G. B., Liu, Y., Yu, S., Wu, S. C., Leung, A. O. W., Luo, X. S., Xu, B., Li, H. B., Wong, M. H., 2011. Nconsistency and comprehensiveness of risk assessments for heavy metals in urban surface sediments. *Jour. Chemosphere*, 85: 1080–1087.

Zacchini, M., Pietrini, F., Mugnozza, G., lori, V., 2008. Metal tolerance, accumulation and translocation in poplar and willow clones treated with cadmium in hydroponics. *Jour. Water Air Soil Pollution*, 197: 23-34.

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گیاه نی(***Phragmites australis*** **(Cav.) Trin.exSteudel**) به‌عنوان پالایشگر و پایشگر زیستی آلودگی ناشی از فلزات سنگین (مطالعه‌ی موردی: رودخانه دز، دزفول)

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چکیده. یکی از مهم‌ترین روش‌های بررسی فلزات سنگین به‌عنوان آلاینده، استفاده از پایشگرهای زیستی است که می‌توانند به‌عنوان شاخصی مناسب جهت بیان کیفیت محیط زیست مورد استفاده قرار گیرند. در پژوهش حاضر به‌منظور بررسی تأثیر گونه‌های گیاهی غالب موجود در منطقه و نقش ماکروفیت‌های آبزی در پایش عناصر روی(*Zn*)، مس(*Cu*)، سرب (*Pb*) و کادمیوم (*Cd*) در اندام‌های زیرزمینی، ساقه و برگ‌های گونه ماکروفیت آبزی ***Phragmites australis*** و همچنین نمونه‌های رسوب رودخانه دز در سال ۱۳۹۱، مورد مطالعه قرار گرفت. آماده‌سازی نمونه‌ها با ترکیب چهار به یک اسید نیتریک به اسید پرکلریک انجام گرفت و غلظت عناصر با دستگاه جذب اتمی اندازه‌گیری گردید. در این پژوهش فاکتورهای غنی‌شدگی، شاخص تجمع زیستی و فاکتور انتقال اندازه‌گیری شد. نتایج نشان داد که غلظت فلزات در اندام‌ها به ترتیب از اندام زیرزمینی، به برگ و ساقه کاهش می‌یابد. همچنین در میان فلزات مورد مطالعه، همبستگی مثبت و معنی‌داری در سطح احتمال ۵٪ بین غلظت سرب در رسوبات و اندام‌های زیرزمینی گیاه وجود داشت؛ بنابراین احتمال می‌رود اندام زیرزمینی گیاه نی***Phragmites australis***، پایشگری مناسب برای آلودگی ناشی از عنصر سرب در رسوبات منطقه باشد. میزان شاخص غنی‌شدگی نشان داد: ایستگاه‌های دو، سه و پنج در نتیجه فعالیت‌های انسانی آلوده‌ترین بخش‌ها هستند. همچنین شاخص تجمع زیستی اندام زیرزمینی گیاه نی را جاذب عناصر مس، روی، سرب و کادمیوم معرفی می‌کند. مقادیر حاصل از شاخص انتقال از اندام زیرزمینی به هوایی نیز به ترتیب برای سرب، کادمیوم، مس و روی افزایش می‌یابند.

کلمات کلیدی: پایش زیستی، رودخانه‌ی دز، ایران، فلزات سنگین، گیاه نی

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