Bioaccumulation, Enrichment and Translocation Factors of some Heavy Metals in Typha Angustifolia and Phragmites Australis Species Growing along Qalyasan Stream in Sulaimani City /IKR.

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Abstract

The current study was undertaken to evaluate the mobility, bioaccumulation and transfer of the heavy metals; Cr, Mn, Cu, and Pb from the wastewater of Qalyasan stream to roots tissues and from roots tissues to shoots tissues by means of bioaccumulation factor (BAF), enrichment factor (EF) and translocation factor (TF) in the macrophytes species of *T. angustifolia* and *P. australis* at two sites. The analyzed macrophytes plant species were sampled along the streambank of Qalyasan in Sulaimani city. Qalyasan stream is used as a source for irrigation water and also as a sink for the untreated urban and industrial domestic's wastewater effluents. Domestic and industrial discharges are probably the most two main sources for heavy metal contamination in the water of the stream. Our results showed that concentrations of the studied metals in the root and shoot tissues of the macrophyte species were much higher than those in the samples of wastewater from Qalyasan stream. Bioaccumulation factor and enrichment factor values in both species were above 1. High variation among the values was noticed, this indicating that these plants could be considered as trace metals accumulators and both have potential for phytostabilization and phytoextraction. The ranking order of bioaccumulation factor by *T. angustifolia* for the studied heavy metals was Mn> Cu > Pb > Cr, while by *P. australis* was Mn> Cu > Cr > Pb. Translocation factor values for Cr, Mn and Cu was higher than 1 by *P. australis*, whereas by *T. angustifolia* the values only for Cr and Mn were greater than 1, this is evident that the uptake and accumulation of these metals were higher in the shoot tissues rather than root tissues of the investigated macrophyte species.

Keywords: *Bioaccumulation factor (BAF); Enrichment factor (EF); Qalyasan stream; Heavy metals; Phytoremediation; Macrophytes; Pollution indicators; Translocation factor (TF).*

Introduction

The large-scale industrialization and production of variety of chemical compounds has led to global deterioration of the environmental quality [1]. The researchers [2] have pointed out that environmental pollution with toxic metals has increased dramatically due to rapid industrialization and surge in pollution. Environmental pollution with heavy metals is a global disaster that is related to human activities such as mining, smelting, electroplating, energy and fuel production, power transmission, intensive agriculture, sludge dumping, and melting operations [3]. The accumulation of heavy metal in plants from anthropogenic sources has increased the attention on inorganic pollution and established plants as passive bio-monitors [4 and 5]. A variety of plant species have been used as biological monitors since, these species have a tendency to assimilate metals from the surrounding environment [6].

In recent years, the amount of wastewater produced from several activities has increased as a result of the rapid improvement of living standards [7]. Although some communities treat their wastewater in a suitable way, others lack convenient treatment systems and discharging untreated wastewater into the natural environment, IKR or Iraq as a whole is an example of such a case. Pollutants enter aquatic systems via numerous pathways, including effluent discharge, industrial, urban and agricultural run-off [8]. Many researches from around the world are concerning to find cost-effective technologies and the possibility of using the biosystem as "tools" in bioremediation activities for cleaning up the contaminated soil or aquatic ecosystems by heavy metals [9]. Therefore, plants can be used to ameliorate heavy metal pollutants from the soil and wastewater. This cost effective approach is called phytoremediation which referred as green solution [10]. Depending on the ability of plants used as a phytoremediation medium to absorb, accumulate and tolerate heavy metals, available plants are classified into three categories of hyperaccumulators, indicators and excluders [11].

An important parameter used in environmental toxicology and risk assessment is the bioaccumulation factor [12]. Bioaccumulation factor also called bioconcentration factor (BCF) and both are the metrics traditionally used by regulatory agencies [13], but BCFs are generally standardized, laboratory-based bioaccumulation indicators [14].

BAF is used in the determination of the degree of intake and component storage of toxic compounds in plants and animals [15]. The BAF refers to the ratio of plant metal concentration in roots tissues to the soil or polluted environment [(Metal) root/ (Metal) polluted environment or substrate]. While, [16] have defined the BAF as the ratio of contaminant concentration measured in biota in the field (or under multiple exposure conditions) to the concentration measured in the surrounding water. This ratio should be greater than one for inclusion into the hyperaccumulator category [12]. Several authors [17 and 18] classify the bioaccumulation factor as an element for classification as a hyperaccumulator species. The researchers; [19, 20, 21 and 22] have pointed out that the ability of phytoremediation has commonly been characterized by a translocation factors (TF), which is defined as the ratio of the metal concentration in the shoots tissues to that in the roots tissues [(Metal) shoot/ (Metal) rot]. Plants with TF values greater than 1 are classified as high-efficiency plants for metal translocation from the roots to shoots [23]. The identification of metal hyperaccumulators, plants capable of accumulating extra ordinary high metal levels, demonstrates that plants have the genetic potential to clean up contaminated soil. Hyperaccumulators are also characterized by a shoot to root metal concentration ratio (i. e. the translocation factor of more than 1, whereas nonhyperaccumulator plants usually have great metal concentrations in the roots than in the shoots [24]. According to [25 and 26], establishing of enrichment factor (EF) approach is an alternative method used to characterize the degree of anthropogenic pollution. The enrichment factor is calculated as the ratio plant shoot concentration to contaminated environmental medium (e.g. soil and wastewater) concentration [(Metal) shoot/ (Metal) polluted substrate], [27].Therefore, the general objectives of this study were to: 1) Determine the concentrations of the heavy metal of Cr, Mn, Cu, and Pb in wastewater and plant organs (roots and shoots) of the macrophytes species of *T. angustifolia* and *P. australis* at Qalyasan stream, 2) Define which species and which plant organ exhibit the greatest accumulation, 3) Assess whether these species could be usefully employed in biomonitoring studies , 4) Calculate of BAF, EF and TF indices to assess the tolerance categories developed by these species and to evaluate their potential for phytoremediation purposes.

MATERIAL AND METHODS

1-Site description and sampling

Qalyasan Stream lies in the southwest to south of Sulaimani city. Geographically, it is positioned between latitudes 35° 35' 01" N to 35° 28' 44" N, and between longitudes 45° 21' 39" E to 45°26' 17" E in Sulaimani city/Iraq, and elevated 656-787 m above sea level. The length of the stream is about 10 km till to the downstream point of the stream with Tanjaro river and flows southward through many agricultural fields and used as a source for irrigation and livestock drinking purposes (for agriculture purpose), it is also used as a sink for the untreated urban and industrial domestic's wastewater. Therefore, the good quality of the stream changed from protected to impacted and finally to degraded. Degradation of water quality in Qalyasan stream increased year after year because of discharging many pollutants directly into the stream from the expanding human habitats (domestic) and vibrant industrial, institutional, and socio-economic activities sources.

Regarding selection of the investigated sites, two points were taken into consideration, first the abundant of the two macrophytes plant species, since they are not regularly grown along the stream and not available along the complete length of the stream due the industrial activities. Second, many effluent discharges of untreated wastewater way into the stream, hence, as a consequence of that fact, the selected sites were between the first main outlet of Sarchinar district and the next outlet of Kawstaha-Jahm and Awal villages .Site one (S1) was selected after about 300 meters far from the first main outlet or effluent into Qalyasan stream (Sarchinar outlet) with a GPS coordinates of (35° 34' 51" N and -45° 22' 43" E). Site two (S2) was near to the Qalyasan Bridge and has a GPS coordinates of (35° 34' 05" N and -45° 22' 31" E). The overall distance between the sample site S1 to sample site S2 was about (2) km (Figure 1). For carrying out the intended objectives of this study, representative water samples from the two sites of Qalyasan stream as well as two abundant and dominating macrophytes plant species grown at some zones along waterway of the stream were collected. The macrophytes plant species *were T. angustifolia* (common cattail, locally known as Laban)) and *P. australis* (common reed, locally known as Qamish). Reed and Cattail were selected because they are wetland macrophytes of broad geographical distribution [28], and are widely used in wastewater treatments [29].

2-Analytical methods

In situ measurement was adopted to determine some physico-chemical parameters of water including; pH, EC and DO by portable meters. The measurements have been carried out twice for each parameter and then the mean values were undertaken

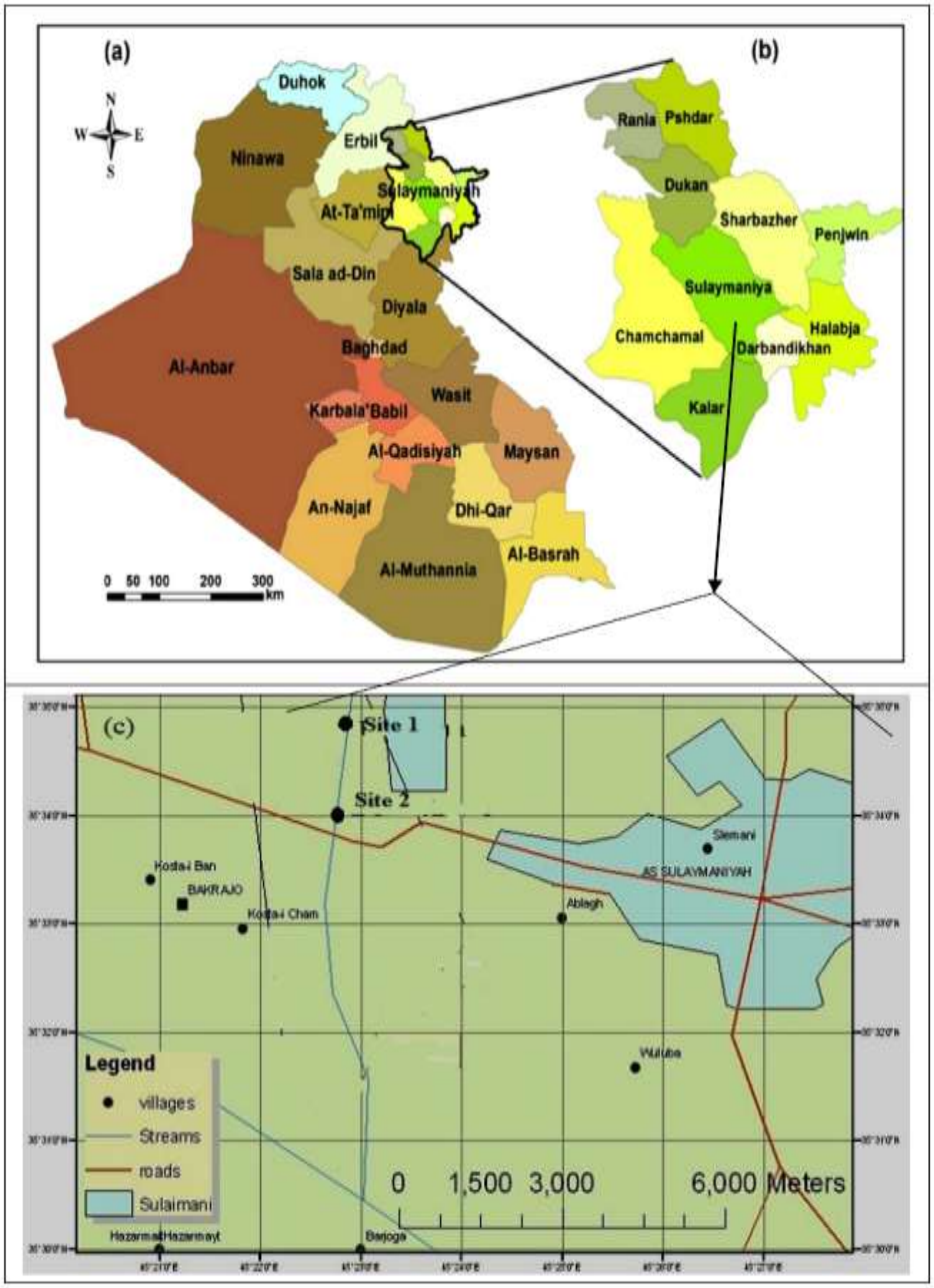

Fig. 1 Location of experiment and sampling sites: (a) shows Iraqish map, (b) shows Sulaimani governorate's map and (c) shows experiment and sampling sites map.

In order to get the representative plant sample, random plant samples were performed in triplicate and then the average dry matter for a single plant was considered. The roots and shoots of the plant samples were pretreated according to [30] by washing or rinsing with running tap water and then acidified distilled water (0.1% HCl), followed by distilled water, dried by a hot air oven at 70 ^oC for 24 hours after placing them in new paper bags, then gently grinded with stainless-steel grinder, sieved through a 40 mesh of stainless-steel sieve and finally stored in plastic container for heavy metal analysis according to [31]: A duplicate 1.0 g dry matter sample was digested separately with 20 ml mixture of concentrated H_2SO_4 and H_2O_2 of 37% in a ratio of 1:1 at room temperature for 30 minutes for each sample, then digested at 350 ^oC using Kjeldahl digester (model Buchi Speed Digester K-425/Switzerland). Once the digest became clear, was diluted with deionized water, filtered through an ashless Whatman 41 filter and diluted to 100 ml with excess distilled water, then stored in polyethylene bottles at 4 ^oC for the heavy metals analysis of; Cr, Mn, Cu, and Pb by the inductively coupled plasma-optical emission spectroscopy ICP-OES instrument (model PerkinElmer, precisely Optima 2100/USA).Likewise, this final step of the procedure was conducted for water samples after completing the digestion process.

The water samples were analyzed in duplicate as described by standard methods of [32]for thirteen physico-chemical parameters namely; pH (Hydrogen ion concentration), EC (Electrical conductivity), DO (Dissolved oxygen), turbidity, TH (Total hardness), ions of Ca^{2+} (Calcium), Mg^{2+} (Magnesium), Na^{+} (sodium), K^{+} (potassium), Cl^{-} (chloride), SO_4^{2-} (sulfate), NO_3^{-} (nitrate) and PO_4^{3-} (phosphate).

For determination of the intended heavy metals in the representative water bodies of Qalyasan stream, samples were collected at the two designated sites by lowering precleaned 500 ml plastic bottles into the bottom of the water body, 30cm deep, and allowed to over flow before withdrawing. Then a 100 ml of the sampled water was evaporated and digested as described by [32]. The water samples for heavy metals were also analyzed in duplicate.

3-Phytoremediation efficiency of macrophyte species in current study.

Three indicators were used to determine the potential of the two macrophytes species for phytoremediation and they are; bioaccumulation factor (BAF), enrichment factor (EF) and translocation factor (TF). Bioaccumulation Factor (BAF) was calculated from the following relation:

$$BAF = \frac{Cr}{Cw}$$

Where, *BAF* is Bioaccumulation Factor

Cr represents metal's concentration in roots of the studied macrophytes species.

Cw represents metal concentration content of water body in Qalyasan stream.

The Enrichment factor (EF) is calculated as the metal's ratio of plant shoot concentration to polluted substrate or contaminated environmental medium (e.g. soil and wastewater) concentration using the relation below:

$$EF = \frac{Cs}{Cw}$$

Where, *EF* is Enrichment factor

Cs represents metal's concentration in shoots of the studied macrophytes species.

Cw represents metal concentration content of water body in Qalyasan stream.

For heavy metals translocation from root to shoot in the studied macrophytes species, translocation factor (TF) was measured using the relation below:

$$TF = \frac{Cs}{Cr}$$

Where, *TF* is Translocation Factor;

Cs represents metal's concentration in shoots of the studied macrophytes species.

Cr represents metal's concentration in roots of the studied macrophytes species.

RESULTS AND DISCUSSION

a) Physico-chemical and heavy metals concentrations in the representative wastewater samples.

The values of the physicochemical parameters and the concentration level of the heavy metals of Cr, Mn, Cu, and Pb in water body of Qalyasan stream are presented in Tables (1). In general, the results indicated that the values of most parameters such as (EC, DO, turbidity, TH, Ca^{2+}, Na+, K^{+}, Cl^{-}, NO_3^{-} and PO_4^{3-}) were beyond the permissible limits and exceeding the permissible limits as described by World Health Organization (WHO) standards for drinking water [33]. Several scientists have studied mineral levels in different bodies of water, and have found that the high levels of phosphates and nitrates heavily impact the overall health of the water and its inhabitants [34].

The high level of those ions may be attributed to the discharge of wastewater from domestic activities and hazardous waste of industrial and agricultural activities into Qalyasan stream.

Regarding the studied heavy metals of Cr, Mn, Cu, and Pb in the water body of Qalyasan stream, the concentration were; (0.026, 0.076, 0.005 and 0.002) and (0.021, 0.062, 0.004 and 0.002) mg L^{-1} at both studied sites respectively. It was obvious that the concentration of the studied heavy metals except of Pb was relatively lower at site 2 as compared to site 1, and that is due to the purification effect by the macrophytes species through the stream flow path towards the downstream.

As comparison assessment, concentration of the metals in the studied water body of Qalyasan stream was compared with the maximum permissible limits of drinking standard regulated by World Organization Health (WHO). As a whole, concentrations values were greater than the WHO limits except for Cu. The maximum permissible limits standards of the studied metals by WHO are (Cr^{+6} =10; Mn =500; Cu =1000; and Pb =10 μg L^{-1} water), [30].

Current research results for the heavy metal concentration of Cr and Mn being greater, but for Pb being lower as compared those obtained by [35] in wastewater samples which ranged from 0.0006 to 0.0007, 0.0001 to 0.0014 and 0.0092 to 0.108, mg L^{-1} respectively. On the other hand, the results found by the current study for Cr and Pb in wastewater were more lower than those revealed by [36], which ranged from 0.120 to 0.311 and 0.039 to 0,075 mg L^{-1} respectively. Metals like lead, mercury, cadmium, copper, and chromium can cause physical and mental developmental delays, kidney disease, gastrointestinal illnesses, and neurological problems [37].

Table 1: Physico-chemical parameters and heavy metals concentrations in the representative water body samples of Qalyasan stream.

Paramet_ ers	Unit	value	Heavy Metal mg L^{-1}	mg L^{-1}	
				Site 1	Site 2
pH	-	7.03	Cr	0.026	0.021
EC	µS/cm	567.0	Mn	0.076	0.062
DO	mg.L^{-1}	0.26	Cu	0.005	0.004
Turbidity	(NTU)	38.0	Pb	0.002	0.002
TH	mg L^{-1}	258.6			
Ca^{2+}	mg L^{-1}	324.0			
Mg^{2+}	mg L^{-1}	147.0			
Na^{+}	mg L^{-1}	94.2			
K^{+}	mg L^{-1}	23.4			
Cl^{-}	mg L^{-1}	58.0			
NO_3^{-}	µ L^{-1}	28.4			
PO_4^{3-}	mg L^{-1}	13.31			
TSS	mg L^{-1}	83.0			

b) Heavy metals concentration, uptake and dry matter production for the studied macrophyte plant species.

Table (2) summarizes the amount of dry matter in gram per plant (g $plant^{-1}$) and also the mean concentrations of the studied heavy metals of Cr, Mn, Cu, and Pb in microgram per gram dry matter (µg g^{-1} dry matter) in shoots and roots tissues of the macrophytes plant species. The results showed that the amount of dry matter values varied from 2.5 to 2.7 and from 5.1 to 6.2 g $plant^{-1}$ at both sites, respectively. The amount of roots dry matter was lower than those in shoots for both of the macrophytes species (Table 2). Concentration of the heavy metals Cr, Mn, Cu, and Pb were ranged between (0.3 to 5.1, 137.9 to 205.6, 0.7 to 2.8 and 0.2 to 0.4) and (0.9 to 4.1. 37.6 to 201.1, 1.5 to 5.7 and 0.3 to 1.2) µg g^{-1}, in shoot and root samples respectively.

The findings of this study indicated that the extent of heavy metal concentrations differed among the investigated plant species, tissue bodies (root and shoot) and types of heavy metal, because plant communities respond differently to heavy metal that present in wastewater depending on their ability to accumulate and detoxify various heavy metals [38]. Therefore, no systematic pattern was observed for the distribution of the studied metals in the investigated species and their organ tissues of root and shoot. However, trace metals sequestration from the wastewater to these plants characterized them as trace metals pollution indicators.

In general, *T. angustifolia* species was characterized by high level concentration of Mn and Pb in its root and shoot system, while the *P. australis* species was characterized by high level concentration of Cr in both its root and shoot system. But for Cu, the highest level concentration was found in shoot system of *P. australis* species at site 1 and the lowest level concentration in root system of *T. angustifolia* species at site 1 also. These results were almost in compliance with the report of the researcher [39], who demonstrated that the accumulation of selected metals varied greatly among plants species and the uptake of an element by a plant is primarily dependent on the plant species, its inherent controls, and the soil quality.

Table 2: Heavy metals concentration in dry matter of *T. angustifolia* and *P. australis* Macrophytes.

Macrophytes	Location	Dry matter (g plant^{-1})		Mean concentration (µg g^{-1})			
				Cr	Mn	Cu	Pb
T. angustifolia	Site 1	Shoots	5.5	2.9	205.6	0.7	0.4
		Roots	2.7	1.4	201.1	5.7	1.2
	Site 2	Shoots	5. 1	0.3	148.0	1.3	0.3
		Roots	2.5	0.9	152.4	1.5	0.7
P. australis	Site 1	Shoots	6. 2	5.1	137.9	2.8	0.2
		Roots	2.6	4.1	37.6	2.0	0.3
	Site 2	-*	-	-	-	-	-
		-*	-	-	-	-	-

* The macrophytes species *P. australis* was not available at site 2

The subsequent increasing order of concentration for the investigated metals in root and shoot system of *P. australis* were as follow; Mn > Cr > Pb > Cu, similar trend also occurred in shoot system of *T. angustifolia*. However, in root system of *T. angustifolia* the following trend Mn > Cu > Cr > Pb of increasing concentration was observed, (Table 2).

Table (3) presents the calculated uptake of the investigated heavy metals by *T. angustifolia* and *P. australis* macrophytes species in µg plant^{-1}. Special attention has been given to the uptake and biotransformation mechanisms occurring in plants (particularly edible plants) and its role in bioaccumulation and impact on consumers, especially human beings. Some concerns have been raised about the possibility of toxic concentrations of certain elements being transported from plants to higher strata of the food chain, since plants constitute the foundation of the food chain [40]. Plant uptake of chemical species from the plant growth system is also dependent on a number of plant factors. These include: physical processes such as root intrusion, water, and ion fluxes and their relationship to the kinetics of metal solubilization in soils; biological parameters, including kinetics of membrane transport, ion interactions, and metabolic fate of absorbed ions; and the ability of plants to adapt metabolically to changing metal stresses in the environment [41].

As it is shown in Table (3), the highest uptake for all the studied metals and in both of the macrophytes species except for Cu at site 1 were recorded in the shoot system as compared to the root system. In general, the shoot system of *P. australis* has got more uptakes of Cr, Mn, and Pb except for Mn at site 1 as compared with the shoot system of *T. angustifolia*. But for the metal Pb, the high level of uptake or accumulation was in shoot system of *T. angustifolia* rather than *Phragmites australis*. Normally, accumulation of selected metals varied greatly among plants species and uptake of an element by a plant is primarily dependent on the plant species, its inherent controls, and the growth system quality [39].

Table 3: Heavy metals uptake by *T. angustifolia* and *P. australis* macrophytes

Macrophytes	Location	Dry matter (gm plant^{-1})		Uptake µg plant^{-1}			
				Cr	Mn	Cu	Pb
T. angustifolia	Site 1	Shoots	5.5	15.95	1130.8	3.85	2.20
		Roots	2.7	3.78	542.97	15.39	3.24
	Site 2	Shoots	5. 1	1.53	754.8	6.63	1.53
		Roots	2.5	2.25	381.0	3.75	1.75
P. australis	Site 1	Shoots	6. 2	31.62	854.98	17.36	1.24
		Roots	2.6	10.66	97.76	5.20	0.78
	Site 2	-*	-	-	-	-	-
		-	-	-	-	-	-

*The macrophytes species *P. australis* was not available at site 2.

Note: The uptake amount of the heavy metals in µg plant^{-1} were calculated by applying the following formula **(Source; the researchers of this study)**

Uptake (µg plant^{-1}) = C x DM

Where C= denotes concentration of the heavy metal in ppm or µg gm^{-1} plant

DM= gram dry matter per plant (table 3).

The results showed that the uptake of Cr, Mn, Cu, and Pb by the macrophytes plants corresponded to the increasing level of water contamination. According to [24], it has been found that both *P. australis* and *C. laevigatus* were found to be the best candidates among seven native plant species (*Calotropis* procera , *Citrullus colocynthis* , *Rhazya stricta* , *Cassia italic, P. australis, Cyperus laevigatus and Argemone Mexicana)* for biomonitoring and phytoremediation programs of polluted soils by most metals of (Cd, Cr, Co, Cu, Fe, Ni, Pb and Zn) in Riyadh city/Saudi Arabia, due to their high accumulation capability of these species.

c) Bioaccumulation Factor (BAF), Enrichment Factor (EF) and Translocation Factor (TF) in the investigated macrophyte plant species.

As described by [42], bioaccumulation in animal tissue or uptake in plants is the process where chemicals of potential ecological concern (CPECs) in the surrounding media are accumulated within the tissues of ecological receptors, especially to concentrations higher than in the surrounding media. On the other hand, [43] defined bioaccumulation as the process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical. Bioaccumulation can occur in an organism any time a chemical is taken up and stored faster than it is eliminated (i.e., metabolized and/or excreted), and it represents the combined accumulation from diet and direct uptake from abiotic media. The bioaccumulation factor was calculated as the ratio of the studied heavy element concentration in root tissues of the macrophyte species to metal concentration content of wastewater in Qalyasan stream, whereas enrichment factor (EF) was determined as the metal's ratio of plant shoot concentration to metal's concentration of polluted substrate or contaminated environmental medium (e.g. soil and wastewater) [31].

As presented in Table (4) and Figure (2), the BAF values for *T. angustifolia* species of the investigated heavy metals of Cr, Mn, Cu and Pb were found to be in the ranges of 42.9 to 53.8, 2458.1 to 2646.1, 375.0 to 1140.0, and 350.0 to 600.0, respectively at site 1 and 2. While for *P. australis* species the values were 157.7, 494.7, 400.0 and 150.0 respectively at site 1, since in site 2 *P. australis* species was not available.

Table 4: Bioaccumulation Factor (BAF) and Enrichment Factor (EF) values for the investigated heavy metals in macrophyte species *T. angustifolia* and *Phragmites australis.*

Macrophyte Species	Factors	Site No.	BAF and EF values for the studied heavy metals			
			Cr	Mn	Cu	Pb
T. angustifolia	Bioaccumulation (BAF)	1	53.8	2646.1	1140.0	600.0
		2	42.9	2458.1	375.0	350.0
	Enrichment Factor	1	111.5	2705.3	140.0	200.0
		2	14.3	2387.1	325.0	150.0
P. australis	Bioaccumulation (BAF)	1	157.7	494.7	400.0	150.0
		2	-*	-	-	-
	Enrichment Factor	1	196.15	1814.5	560.0	100.0
		2	-	-	-	-

* The macrophytes species *P. australis* was not available at site 2.

The trend in the average values of BAF by *T. angustifolia* was in the ranking order of Mn> Cu > Pb > Cr, whereas by *P. australis* was in the ranking order of Mn> Cu > Cr > Pb. Among the heavy metals, BAF value was found to be the highest for Mn by both the macrophyte species and at the two sites, the lowest BAF value was found for Cr in *T. angustifolia* and for Pb in *Phragmites australis*. The food chain (environment-plant-human) is mainly known as one of the major pathways for exposure of human to environmental contaminants. Environment to plant transfer is one of the key processes of human exposure to toxic heavy metals through the food chain [44]. According to [45], when BCF < 1 or BAF = 1, it denotes that the plant only absorbs the heavy metal but does not accumulate when BCF > 1, and this indicates that plant accumulates the heavy metals.

Table (4) and Figure (2) also showed that the enrichment factor (EF) values of Qalyasan stream for the investigated heavy metals by *T. angustifolia* were found to be in the ranges of Cr (11.5 to 11.5), Mn (1974.4 to 2705), Cu (140.0 to 260), and Pb (150 to 200) at both sites and in the ranking average order of Mn > Cu > Pb > Cr for both site. Moreover, the maximum values of EF except for Cu were at site 1.But, the enrichment factor (EF) values of the studied heavy metals of; Cr, Mn, Cu, and Pb in *P. australis* were found to be 196.15, 1814.5, 560.0 and 100.0, respectively and in the ranking order of Mn > Cu > Cr > Pb. Among the estimated metals, the maximal enrichment was found in case of Mn and Cu for the wastewater of Qalyasan stream (Figure 2).

[46] reported that EF values greater than 1 indicate higher availability and distribution of metals in the contaminated wastewater, subsequently increasing the metal accumulation in plants species. According to [22], the success of phytoextraction process depends on heavy metal removal by the shoots tissues. Therefore, we could propose that the investigated plant species could be considered as an accumulators or hyperaccumulators for phytoremediation, since they had generally the higher metal concentrations in their shoots tissues rather than in their roots tissues.

TF values by *P. australis* were 1.24, 3.66, 1.4 and 0.66 for the metals Cr, Mn, Cu and Pb respectively, it was observed the values except for Pb greater than 1, and root-to-shoot transfer factor (TF) values decreased from Mn >> Cu > Cr > to Pb. TF greater than one (> 1) represent that translocation of metals effectively was made to the shoot from root [49, 50 and 51]. Plants with both bioaccumulation and translocation factors greater than one (BCF and TF>1) have the potential to be used in phytoextraction. Besides, plants with Bioaccumulation factor greater than one and translocation factor less than one (BCF>1 and TF <1) have the potential for phytostabilization [21].

In general, plant's ability to translocate metals from the roots to the shoots is measured using the translocation factor. TF was calculated as recommended by [47 and 48] as the ratio of the total concentration of elements in the shoot tissues or aerial part of the plant (C_{shoot}) to the concentration in the root tissues (C_{root}) and the values are given in Figure 3 and Table 6.

Present study showed that the values of translocation factor (TF) of *T. angustifolia* species for the studied heavy metals ; Cr, Mn, Cu and Pb were ranged between 0.33 to 2.07, 0.97 to 1.02, 0.12 to 0.87 to and 0.33 to 0.42 respectively at both sites. Findings indicated that TF was less than 1 by T. *angustifolia* species for all the studied metals at site 2 and also for Cu and Pb at site 1. This means the quantities of trace elements accumulated in the roots tissues exceeded those in the shoots tissues, moreover the subsequent increasing order of the average TF values for both sites was as follows; Cr > Mn > Cu > Pb.

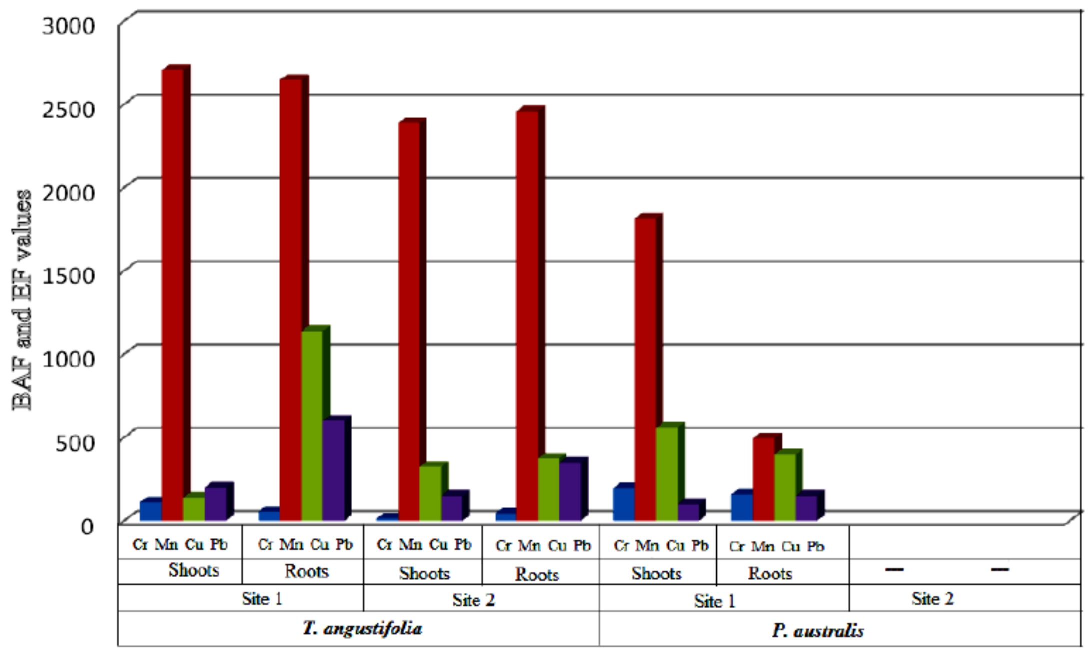

Fig. 2 Bioaccumulation Factor (BAF) and Enrichment Factor (EF) values for the investigated heavy metals in macrophyte species *T. angustifolia* and *Phragmites australis.*

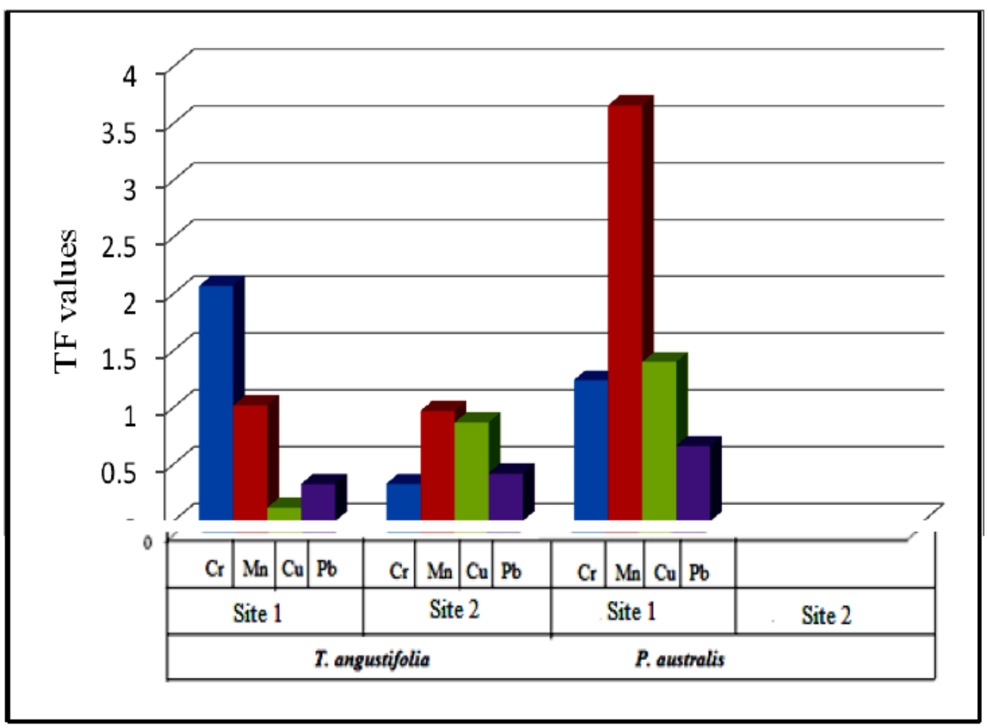

Fig. 3 Translocation Factor (TF) Values for the investigated heavy metals in macrophyte Species *T. angustifolia* and *Phragmites australis*.

Table 6: Translocation Factor (TF) Values of the investigated heavy metals in macrophyte species *T. angustifolia* and *Phragmites australis*.

Macrophyte Species	Locations	Translocation Factor Values			
		Cr	Mn	Cu	Pb
T. angustifolia	Site 1	2.07	1.02	0.12	0.33
	Site 2	0.33	0.97	0.87	0.42
P. australis	Site 1	1.24	3.66	1.40	0.66
	Site 2	-*	-	-	-

*The macrophytes species *P. australis* was not available at site 2

CONCLUSION

Findings from our investigation indicated that due to the purification effect by the macrophytes species along the stream flow path towards the downstream, the concentration of the studied heavy metals except for Pb had relatively decreased at site 2 as compared to site 1. Furthermore, the concentrations of the elements in the plant tissues were affected by the concentrations of the heavy metals in the wastewater body of Qalyasan stream, hence the metals accumulated in increasing quantity in shoots and roots. As a result, bioaccumulation and enrichment factors were above one. The present study showed that plants grown in contaminated areas have a high risk of having heavy metal concentrations beyond the permissible limit for each of them as compared to the less contaminated areas. In addition to that, this study indicated that both of the investigated macrophytes species of *T. angustifolia* and *P. australis* tend to absorb, translocate and accumulate essential and nonessential heavy metals in their root and shoot tissues.

Although no control plant from the examined species has been found for comparison test, we can propose that the studied plants can be considered as accumulators or hyperaccumulators for phytoextraction and phytoremediation, since a suitable plant species is one of the most important factors which can be used to uptake the heavy metals from the environment. We conclude also with the need for further study in order to establish the biotic potential of the investigated macrophyte for phytoremediation of other heavy metals.

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