Assessment of some heavy metals in various aquatic plants of Al-Hawizeh Marsh, southern of Iraq

DUNYA A.H. AL-ABBAWY[1],♥, BASIM M. HUBAIN AL-THAHAIBAWI[2], ITHAR K.A. AL-MAYALY[3], KADHIM H. YOUNIS[4]

[1]Department of Ecology, College of Science, University of Basrah. Basrah, Iraq.
♥email: dunya.hussain@uobasrah.edu.iq
[2]Ministry of Environment/Directorate Environment of Maysan. Maysan, Iraq
[3]Department of Biology, College of Science, University of Baghdad. Baghdad, Iraq
[4]Department of Marine Vertebrates, Marine Science Centre, University of Basrah. Basrah, Iraq

Abstract. *Al-Abbawy DAH, Al-Thahaibawi BMH, Al-Mayaly IKA, Younis KH. 2021. Assessment of some heavy metals in various aquatic plants of Al-Hawizeh Marsh, southern of Iraq. Biodiversitas 22: 338-345.* In order to describe the degree of contamination of aquatic environments in Iraq, heavy metals analysis (Fe, Ni, Cr, Cd, Pb, and Zn) was conducted for six aquatic macrophytes from different locations of Al-Hawizeh Marsh in southern Iraq. The six species were *Azolla filiculoides* (floating plant), *Ceratophyllum demersum, Potamogeton pectinatus*, *Najas marina* (submerged plants), *Phragmites australis,* and *Typha domingensis* (emergent plants). The results indicate that cadmium, chromium, and iron concentrations in aquatic plants were above the World Health Organization (WHO). In contrast, zinc, copper, and lead were within the allowable limits. *C. demersum* and *N. marina* showed higher concentrations of heavy metal accumulation than the other aquatic plants. The concentration of heavy metals in plant tissues during the summer months was higher than in the different seasons. *C. demersum* and *N. marina* showed higher concentrations of heavy metal accumulation than the other aquatic plants. Heavy metal bioconcentration (BCF) was calculated to assess heavy metals bioaccumulation in the aquatic plants.

Keywords: Accumulation, Al-Hawizeh Marsh, biodiversity, heavy metals, Iraq, macrophytes

INTRODUCTION

Iraq is a country that faces a real challenge in water sufficiency and quality. Restoration and reflooding of drained marshes in Iraq after 2003 need expounded research. Al-Hawizeh Marsh is considered to be evaluated for risk assessment of heavy metals. Aquatic ecosystems are affected by several health stressors that significantly deplete biodiversity. In the future, the loss of biodiversity and its effects are predicted to be more significant for aquatic ecosystems than for terrestrial ecosystems (Al-Homaidan et al. 2020; Geist and Hawkins 2016). One such stressor is the increased pollution and inadequate consideration for environmental impacts of aquatic environments from agricultural practices, industrial development, and urbanization. The indiscriminate release of organic and inorganic liquid wastes and airborne deposition change the physio-chemical characteristics of water, causing hazards to aquatic flora and fauna, and humans (Ghorade et al. 2015). Heavy metals are especially toxic in the environment due to their ability to bind with proteins and prevent DNA replication (Tchounwou et al. 2012). Further, plants accumulate heavy metals at concentrations many times higher than that of the surrounding waters (Bai et al. 2018).

Heavy metals are the naturally occurring elements in the earth's crust, but uncontrolled anthropic inputs have severely altered these metals' natural biogeochemical cycles. After being released from the earth's crust, heavy metals persist in the environment for a long time because they are non-degradable (Wu et al. 2010). Because heavy metals exert toxic effects on microorganisms, plants, animals, and humans, their contamination in the environment has become one of the biggest environmental issues of the present time and is of even greater concern for the future. Several heavy metals, including iron (Fe), cobalt (Co), copper (Cu), manganese (Mn), and zinc (Zn), are crucial for the metabolic activity of biota at low concentrations and are considered essential elements or micronutrients (Peralta-Videa et al. 2009). But when heavy metals concentration exceeds a certain threshold, they produce adverse effects (Ali et al. 2013; Geist and Hawkins 2016).

Heavy metals enter the aquatic environment from both anthropogenic and natural sources (Ghorab 2018)where they are partitioned throughout various aquatic environmental compartments (water, suspended solids, sediments, and biota) and can lead to deleterious effects which may be acutely or chronically toxic to aquatic life within the affected area. Many studies have shown that aquatic plants are sinks for heavy metals in aquatic ecosystems (Xing et al. 2013). Generally, factors such as the stage of plant growth, plant species, and characteristics of the metals themselves affect absorption rates and accumulation in aquatic flora (Rucińska-Sobkowiak 2016).

For example, studies have shown that floating plants such as water hyacinth (*Eichhornia crassipes*) (Newete et al. 2016), emergent plants such as cattail (*Typha latifolia*) (Duman et al. 2015), and submerged plants such as *Ceratophyllum demersum* (Romero-Oliva et al. 2015) and *Potamogeton malaianus* (Harguinteguy et al. 2014) have significant capacity to accumulate heavy metals.

Generally, the accumulation capabilities of aquatic plants are the most pronounced in submerged plants and decrease in capacity in floating plants and emergent plants, but this is often influenced directly by the plant species and other parameters in the aquatic environment (Harguinteguy et al. 2014). The metal concentrations in water typically reflect the current conditions, whereas sediments are reservoirs of heavy metals that may have been deposited in the aquatic environment long ago. Aquatic plants can uptake large amounts of metals from water and sediments via both active and passive absorption by different organs such as roots, stems, and leaves, making these plants suitable for heavy metal amelioration in the aquatic environment (Cai et al. 2018). Moreover, measuring the accumulation of heavy metals in various aquatic plants can provide time-integrated information about metals in aquatic ecosystems.

Bioconcentration factor (BCF) is usually used to assess heavy metal bioaccumulation (Usman et al. 2019). BCF can be defined as the ratio of the steady-state metal ions concentration in the plant versus the concentration in water. The development and expansion of chemical compounds used in Iraq industries lead to the widespread deposition of heavy metals into the environment. Increasing pollution of heavy metals of Iraq southern marshes has been the subject of considerable interest (Al-Saad and Mustafa, 1994). Although plants are considered an essential part of these marshes' food web (Al-Saadi and Al-Mousawi 1988), little is known about the region's plant ecology. Only slightly more is known about the limnological parameters.

In this work, concentrations of Fe, Cu, Zn, Ni, Cr, Cd, and Pb in aquatic plant species (*Ceratophyllum demersum* L., *Potamogeton pectinatus* L, *Najas marina* L, *Phragmites australis* (Cav.) Trin. ex Steud., *Typha domingensis* Pers., and *Azolla filiculoides* Lam.) from the Al-Hawizeh Marsh were determined. We compared the composition of aquatic plant species and heavy metal bioaccumulation in the study area; previous literature included Al-Abbawy and Al-Mayah (2010) and Al-Haidarey et al. (2010).

The purpose of this paper was to study macrophyte species composition of Huwaizah marsh, determination of the heavy metal concentrations in chosen macrophyte species, and to evaluate heavy metals bioconcentration factors (BCFs).

MATERIALS AND METHODS

Study area
Al-Hawizeh Marsh lies to the east of the Tigris River, straddling the Iran-Iraq border, and is approximately 70 km from Ammara. The marsh is distributed with 79% in Iraq and 21% in Iran (Muhsin 2011), extending between (latitude/longitude: 31°00'-31°45'N, 47° 25'-47° 50'E). It is about 80 km in length, from the Iraqi-Iranian borders to the east of the Tigris River, and about 30-40 km wide (Khudair 2018). Thus, the marsh size is approximately 2400 km², which expands to 3500 km² during the flood season and shrinks to 650 km² during dry seasons with only the deepwater areas remaining. This marsh's reservoir retains about 7000 billion m³ of water and is 2-4 meters above sea level (Orson et al. 1992). The marsh is mostly fed by the Tigris River's main tributaries near Al-Ammarah city, known as the Al-Musharah and Al-Kahla Rivers (Figure 1). It is also provided by rainfall and rivers flowing from Iran, such as the Al-Karkha, Tayib, and Duwayaraj, which empty into the Sanaf Marsh, supplying the Al-Hawizeh Marsh. The climate in the marsh is arid subtropical, with less than 200 millimeters of annual rainfall. It is considered by hot summers (with average of around 43°C) and cool winters (with average of around 4°C). In the summer, dust storms are common, and heatwaves can raise the temperature to 48°C. Humidity is low, and evaporation from free water surfaces is high, causing water losses due to evaporation (Hashim et al. 2019).

Sampling and heavy metal determination
Water sample analysis
Water samples were taken from different sites distributed around the marsh collected every season (n=20). The sampling procedure involves water samples from the subsurface (10 cm). A representative sample of water (1000 mL) was added in HDPE bottles, previously washed with HNO_3 solution. To determination the heavy metals concentrations, all collected samples were prepared. In this respect, water samples' digestion with aqua regia (HNO_3 67%: HCl 37% = 3:1) was achieved.

Plant sampling
Six specimens (whole plant samples) of each mature species of the three plant groups (1 x free-floating, 2 x emergents, and 3 x sub-emergents) were collected seasonally from each location during December 2017 and November 2018. Plant samples were collected manually (n=20), washed with water and sonicate from the marsh, and saved in plastic bags until they reached the laboratory. Samples were then thoroughly cleaned using running tap water and rinsed with deionized water (Orson et al. 1992). The plant samples were then oven-dried at 100° C for 24 hours and pulverized with an electric blender to a fine powder for easy digestion and then sieved through a 2 mm mesh sieve. Next, 5 mL of 4:1 mixture of $HNO_3:HClO_4$ was added to 1 g of plant weighed with an analytical weighing balance. This was then heated at a temperature of 105° C for 1 hour until dried (Kakulu and Jacob 2006) and allowed to cool. It was added to a volumetric flask filled to the 50 mL mark with 1M HNO_3. The solution was centrifuged using a HARRIER 15/80 model centrifuge for 30 min then transferred into sampling bottles for analysis. Heavy metal determination (LIST) of both water and plant samples digested were analyzed using Jena 300 Analyst AAS (Atomic Absorption Spectrophotometer) from Germany.
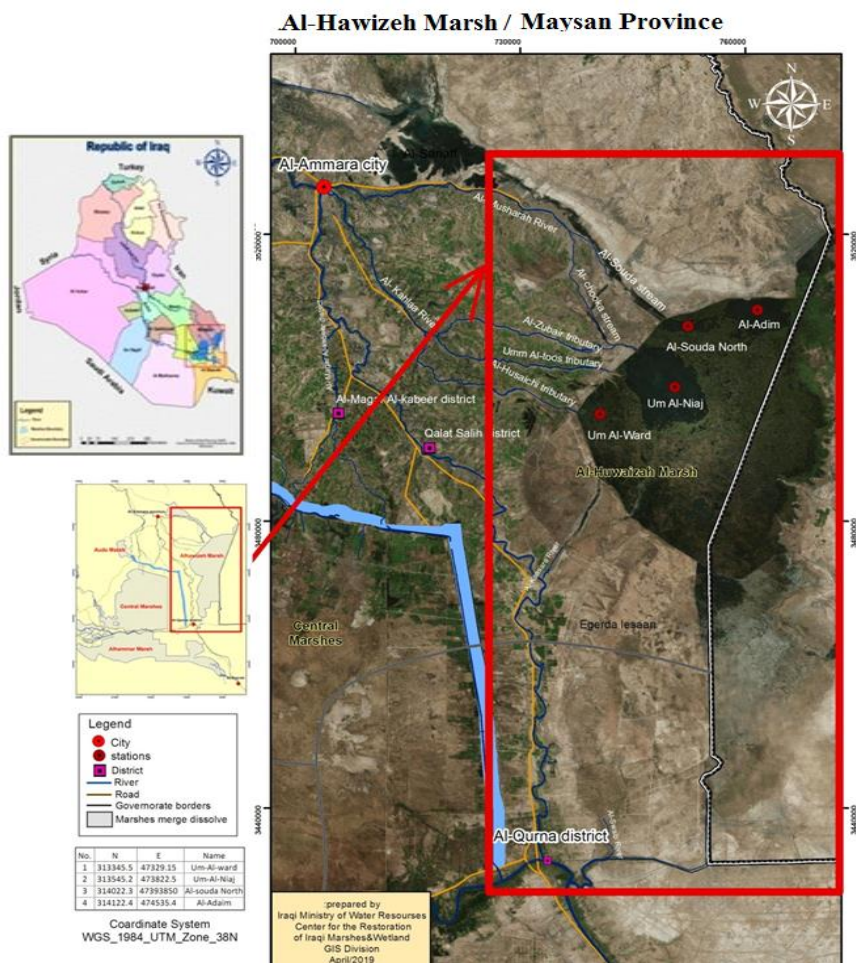
Figure 1. Al-Hawizeh Marsh location in Maysan Province, southern Iraq. (Source: CRIM 2019)

Bioconcentration factor (BCF) values were calculated as described by Gobas et al. (2009) where:

$$BCF = C_{macrophyte\ (mg.\ Kg^{-1})} / C_{water\ (mg.\ l^{-1})}$$

Statistical analysis

Differences in heavy metal concentration among the species and the seasons were tested using a Two-way ANOVA with post-hoc comparisons made using Fisher's least significant difference (LSD). The test for normality and variance homogeneity was carried first.

RESULTS AND DISCUSSION

Heavy metals in water

Concentrations of heavy metals (Fe, Cu, Ni, Zn, Cr, Pb, and Cd) in Al-Hawizeh Marsh were below the permissible limits in water according to (MPDC, 1967). Metals concentration in water ranked as the following trend: Fe>Ni>Cr>Cd>Pb>Zn. Furthermore, the Iron (Fe), Nickel (Ni), and Zinc (Zn) showed a higher concentration of metals in water than other metals (Table 1).

The highest mean ± standard deviation (SD) of Iron was 0.091±0.0373 mg/L^{-1} during the spring, while the lowest was 0.028±0.0096 mg/L^{-1} during winter. The results showed significant differences (P≤0.05) were detected in Iron (Fe) values among seasons, where the highest values recorded during spring and the lowest values detected during the winter.

Bioaccumulation of heavy metals in Macrophytes species

Six aquatic plant species belonging to six families were found and collected from four stations within Al-Hawizeh Marsh during the winter, spring, summer, and autumn seasons. The species belonged to six families: Ceratophyllaceae, Potamogetonaceae, Najadaceae, Salviniaceae, Poaceae, and Typhaceae. The samples were either submerged, free-floating, or emergent species, all within the flowering plant (Angiospermae), as shown in Table 2.

The study results showed that the heavy metals concentrations varied among plant samples during the Al-Hawizeh Marsh study. Concentrations and mean ± SD of heavy metals found in the plants during the four seasons are shown in Table 3 and Figures 2 to 8.

Table 1. Concentrations and (mean ± standard deviation (SD)) of heavy metals (ppm) and permissible values in water samples of Al-Hawizeh Marsh, Iraq during the four seasons

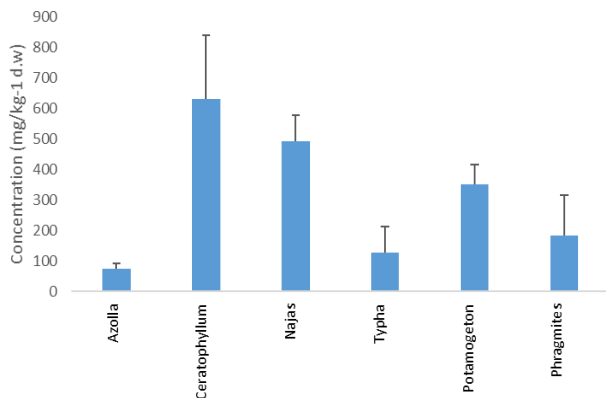| Metal	Winter	Spring	Summer	Autumn	Average	±SD
Iron (Fe)	0.02850	0.09075	0.03900	0.04250	0.05019	0.027688
Nickel (Ni)	0.0028	0.0105	0.0213	0.0077	0.01056	0.007817
Chrome (Cr)	0.0002	0.0013	0.0026	0.0005	0.00116	0.001067
Cadmum (Cd)	0.0002	0.0014	0.0009	0.0016	0.00103	0.000602
Lead (Pb)	0.0013	0.0018	0.0110	0.0043	0.00456	0.004488
Zinc (Zn)	0.0083	0.0445	0.0540	0.0248	0.03288	0.020444

Table 2. List of families and macrophytes species according to habitat, general appearance, habit, and plant group in Al-Hawizeh Marsh, Iraq

Family	Macrophyte species	Habitat	General appearance	Habit	Plant group
Ceratophyllaceae	*Ceratophyllum demersum* L.	Submerged	Herb	Perennial	Dicot
Potamogetonaceae	*Potamogeton pectinatus* L.	Submerged	Herb	Perennial	Monocot
Najadaceae	*Najas marina* L.	Submerged	Herb	Perennial	Monocot
Salviniaceae	*Azolla filiculoides* Lam.	Free-floating	Fern	Perennial	Fern
Poaceae	*Phragmites australis* (Cav)Trin. ex Steud	Emergent	Grass	Perennial	Monocot
Typhaceae	*Typha domingensis* Pers.	Emergent	Herb	Perennial	Monocot

**Table 3.** Concentrations and (mean ± standard deviation (SD)) of heavy metals (mg/kg Dw) and permissible values in aquatic plants of Al-Hawizeh Marsh, Iraq during the four seasons

| Aquatic plant	Winter	Spring	Summer	Autumn
Azolla filiculoides				
Fe	55.6625d* ±0.668	71.1575c ±0.271	91.6425a ±0.514	82.525b ±0.318
Ni	1.445a ±0.012	1.045b ±0.012	0.9575c ±0.035	0.625d ±0.012
Cr	0.14c ±0.008	0.08d ±0.014	1.25525a ±0.045	0.7475b ±0.029
Cd	0.1625d ±0.018	0.2675c ±0.017	0.61a ±0.026	0.4225b ±0.027
Pb	0.44d ±0.018	0.6225c ±0.018	0.8625a ±0.017	0.665b ±0.020
Zn	0.15d ±0.008	9.355ab ±0.023	9.36a ±0.034	8.5025c ±0.078
Ceratophyllum demersum				
Fe	724.3925b ±1.755	325.32d ±1.171	795.82a ±4.289	676.71c ±1.211
Ni	2.5825a ±0.483	1.73b ±0.064	0.611cd ±0.014	0.855c ±0.059
Cr	1.915b ±0.020	0.3325d ±0.022	2.7075a ±0.392	1.545c ±0.083
Cd	0.3125d ±0.017	0.6275c ±0.022	0.85225b ±0.023	0.94a ±0.025
Pb	1.16b ±0.109	1.0375c ±0.116	1.51025a ±0.204	1.2775b ±0.062
Zn	0.32d ±0.021	8.505c ±0.064	13.18625a ±0.140	10.475b ±0.270
Najas marina				
Fe	393.2795d ±2.555	442.596c ±0.797	551.4525b ±0.984	577.075a ±1.335
Ni	1.2675b ±0.168	1.525a ±0.089	0.274d ±0.041	0.455c ±0.034
Cr	0.265 ±0.015	0.24 ±0.013	2.67025 ±0.412	1.755 ±0.103
Cd	0.23d ±0.018	0.295c ±0.012	0.91075a ±0.008	0.865b ±0.031
Pb	0.9b ±0.092	1.3025a ±0.102	0.56d ±0.014	0.755c ±0.045
Zn	0.24d ±0.067	8.2675a ±0.225	7.33575b ±0.227	6.45525c ±0.483
Typha domingensis				
Fe	82.1975c ±0.884	251.445a ±0.491	64.3575d ±0.458	110.875b ±0.309
Ni	1.3775b ±0.030	7.5125a ±0.068	0.33825d ±0.017	0.5725c ±0.035
Cr	0.36d ±0.016	0.6625c ±0.030	1.6555a ±0.040	1.455b ±0.020
Cd	0.2675d ±0.043	0.86a ±0.025	0.379c ±0.021	0.77b ±0.018
Pb	0.65 ±0.040	0.945 ±0.034	0.57 ±0.031	0.865 ±0.026
Zn	0.2575d ±0.068	11.05a ±0.238	6.08825b ±0.094	5.3725c ±0.042
Potamogeton pectinatus				
Fe	389.12b ±1.759	419.2575a ±0.804	310.6425c ±0.577	289.35d ±0.574
Ni	1.44a ±0.228	1.19b ±0.104	0.244d ±0.009	0.74c ±0.043
Cr	0.2725c ±0.033	0.255c ±0.042	1.13a ±0.146	0.925b ±0.026
Cd	0.2075b ±0.017	0.8125a ±0.061	0.85325a ±0.005	0.8375a ±0.037
Pb	0.325d ±0.012	0.855a ±0.040	0.4365c ±0.005	0.77b ±0.018
Zn	0.22d ±0.025	7.29a ±0.256	6.21625b ±0.213	4.4c ±0.182
Phragmites australis				
Fe	118.355c ±0.142	379.145a ±0.970	93.37d ±0.487	142.9325b ±0.548
Ni	2.3875c ±0.101	7.225a ±0.123	2.19925d ±0.103	3.235b ±0. 055
Cr	6.5475a ±0.106	0.365d ±0.031	1.299b ±0.047	0.8525c ±0.030
Cd	0.305d ±0.059	0.7375c ±0.022	0.8445b ±0.004	0.9275a ±0.017
Pb	0.945c ±0.044	1.9425a ±0.049	0.86925d ±0.018	1.2175b ±0.062
Zn	0.3225d ±0.027	8.87a ±0.065	6.27475b ±0.060	5.62c ±0.097

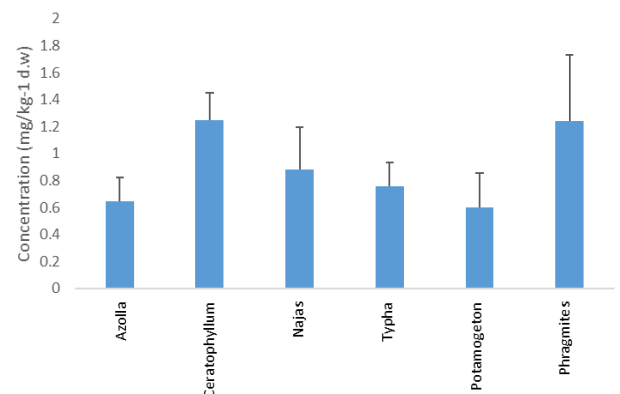Note: Same numbers mean no significant differences among them (p<0.05)

Figure 2. Concentrations of Fe (mg/kg^{-1} dry wt.) in aquatic plant species from Al-Hawizeh Marsh, Iraq
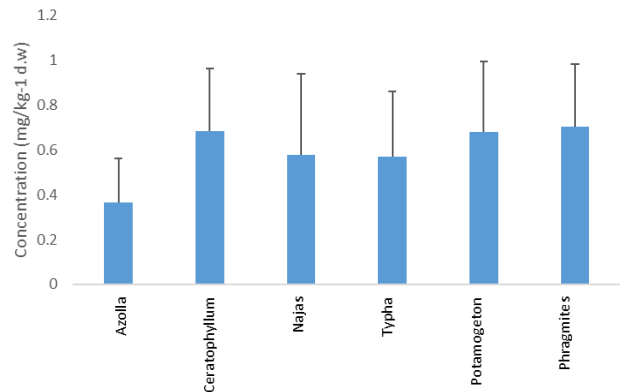
Figure 6. Concentrations of Cd (mg/kg^{-1} dry wt.) in aquatic plant species of Al-Hawizeh Marsh, Iraq
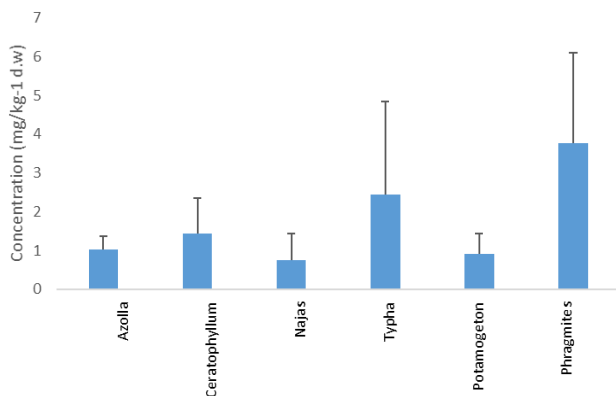
Figure 3. Concentrations of Ni (mg/kg^{-1} dry wt.) in aquatic plant species of Al-Hawizeh Marsh, Iraq

Figure 7. Concentrations of Pb (mg/kg dry wt.) in aquatic plant species of Al-Hawizeh Marsh, Iraq
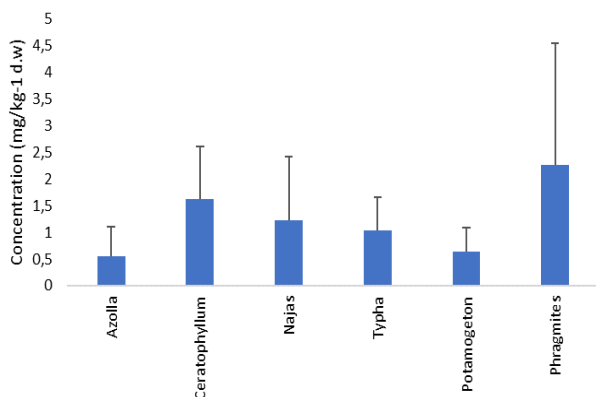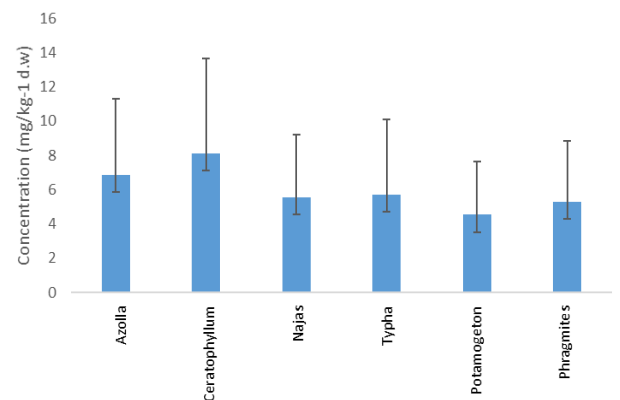

Figure 5. Concentrations of Cr (mg/kg^{-1} dry wt.) in aquatic plant species of Al-Hawizeh Marsh, Iraq

Figure 8. Concentrations of Zn (mg/kg dry wt.) in aquatic plant species of Al-Hawizeh Marsh, Iraq

The concentrations of iron (Fe) ranged from 55.66 mg/kg^{-1} dry wt. in *Azolla filiculoides* in the winter to 795.82 mg/kg^{-1} dry wt. in *C. demersum* during the summer (Figure 2). However, the highest mean and standard deviation results for Fe were 630.56±209.29 mg/kg^{-1} dry wt. within *C. demersum*, while the lowest (mean ±SD) value

for Fe was 75.34±15.51 mg/kg^{-1} dry wt. within *A. filiculoides* (Table 3). The differences detected in Fe concentrations among aquatic plant species during the study period were significant (P≤0.05). In all plant samples, the iron concentration was above the permissible limit (20 mg/kg) (WHO 2006). The higher amounts of Fe

in each season may have resulted from broader contamination by leachate migration. Vegetation that absorbs excessive amounts of Fe and other metals (Table 1) may adversely influence the health of animals living within the marsh ecosystem (Vongdala et al. 2018).

Nickel (Ni) ranged from 0.244 mg/kg^{-1} dry wt. in *P. pectinatus* during the summer to 7.51 mg/kg^{-1}dry wt.) in *P. australis* during spring (Figure 3). The highest mean and standard deviation of Ni, 10.33±2.19 mg/kg^{-1} dry wt.., was found in the *C. demersum* sample. In contrast, the lowest, 3.48±0.66 mg/kg^{-1} dry wt., was recorded in *A. filiculoides* (Table 3). The final concentrations were beyond the permissible limits recommended by WHO (10 mg/kg). The differences in concentrations of Nickel (Ni) among aquatic plant species were not significant (P>0.05) except *for P. australis* and *T. domingensis*.

Chromium (Cr) concentrations varied from 0.08mg/kg^{-1} dry wt.in *A. filiculoides* during the spring to 6.54mg/kg^{-1} dry wt. in *P. australis* during the winter (Figure 5). The highest Cr value was 2.26±2.87 mg/kg^{-1} dry wt. recorded in *P. australis*, while the lowest value was 0.55±0.54 mg/kg^{-1} dry wt. in *A. filiculoides* (Table 3). The differences in concentrations of chromium (Cr) among aquatic plant species were significant (P<0.05). The concentration of Cr in *C. demersum* and *P. australis* was above the permissible limit during winter, in *C. demersum, N. marina, P. australis,* and *T. domingensis* during summer, and in *C. demersum, N. marina,* and *T. domingensis* during autumn. This was compared with limits recorded by Meharg (2011)

Cadmium (Cd) in plant samples differed from 0.16mg/kg^{-1} dry wt. in *A. filiculoides* during the winter to 0.94mg/kg^{-1} dry wt. in *C. demersum* during the autumn (Figure 6). The highest Cd value was 0.70±0.27mg/kg^{-1} dry wt. in *P. pectinatus*, while the lowest value was 0.36±0.19mg/kg^{-1} dry wt.in *A. filiculoides* (Table 3). The differences in concentrations of Cadmium (Cd) among aquatic plant species were found not significant (P<0.05). In all plants, cadmium concentration was above the permissible limit (0.02 mg/kg). Cd is relatively mobile in soils and thus readily available for plants, although the uptake mechanisms are not well known (Thakur et al. 2016).

Lead (Pb) concentrations in plant samples ranged between 0.33 mg/kg^{-1} dry wt. in *P. pectinatus* during the winter to 1.98 mg/kg^{-1}dry wt. in *C. demersum* during the summer (Figure 7). The highest Pb value was 1.25±0.49 mg/kg^{-1} dry wt. in *P. australis*, while the lowest value was 0.65±0.17 mg/kg dry wt. in *A. filiculoides* (Table 3). Non-significant differences (P>0.05) were found in concentrations of lead (Pb) among the studied aquatic plant species. In all plant samples, the concentration of lead was below the permissible limit. In plants with high lead concentrations, the production of reactive oxygen species (ROS) quickens, causing lipid membrane damage that ultimately leads to damaged chlorophyll and photosynthetic processes and suppresses the overall growth of the plant (Najeeb et al. 2017).

Concentrations of zinc (Zn) in plant samples ranged from 4.6mg/kg^{-1} dry wt.in *P. pectinatus* during the autumn to 13.303 mg/kg^{-1} dry wt. in *C. demersum* during the

summer (Figure 8). The highest Zn value was 10.98±1.97 mg/kg^{-1} dry wt.in *C. demersum*, while the lowest value was 5.98±1.13 mg/kg^{-1} dry wt. They were recorded in *P. pectinatus* (Table 3). The differences in concentrations of Zinc (Zn) among aquatic plant species were not found to be significant (P>0.05).

The study results showed that BCF of the heavy metals varied among plant samples during the Al-Hawizeh Marsh study, as shown in Table 4. The bioconcentration factor describes the uptake rate of metals by plants from their surrounding environment. the bioconcentration factor was calculated as the ratio between the metal concentration in plant tissue and its concentration in water. Concentrations of heavy metals in aquatic plants are known to be a useful tool for environmental research. Soluble fractions of metal cations are rapidly caught either by clays or organic compounds and deposited in bottom sediments, or root tissues of aquatic plants absorb them. Metals usually soluble in the aquatic phase by dissolution.

Table 4. Bioconcentration factor of heavy metals in aquatic plants of Al-Hawizeh Marsh, Iraq during the four seasons

Plant	Metal	Winter	Spring	Summer	Autumn
Azolla filiculoides	Fe	1953.070	784.1047	2349.808	1941.765
	Ni	525.454	99.52381	45.05882	80.90615
	Cr	700.00	61.53846	482.7885	1423.81
	Cd	722.2222	187.7193	659.4595	272.5806
	Pb	352.00	355.7143	78.40909	159.4118
	Zn	18.18182	210.2247	172.2685	343.5354
Ceratophyllum demersum	Fe	25417.28	3584.793	20405.64	15922.59
	Ni	939.0909	164.7619	28.75294	110.6796
	Cr	9575.0	255.7692	1041.346	4800.0
	Cd	1388.889	440.3509	921.3514	606.4516
	Pb	928.0	592.8571	137.2955	300.5882
	Zn	38.78788	191.1236	244.1898	423.2323
Najas marina	Fe	13799.28	4877.091	14139.81	13578.24
	Ni	460.9091	145.2381	12.89412	58.89968
	Cr	1325.0	184.6154	1027.019	3342.857
	Cd	1022.222	207.0175	984.5946	558.0645
	Pb	720.0	744.2857	50.90909	177.6471
	Zn	29.09091	185.7865	135.8472	260.8182
Phragmites australis	Fe	4152.807	4177.906	2394.103	3363.118
	Ni	868.1818	688.0952	103.4941	418.7702
	Cr	32737.5	280.7692	499.6154	1623.81
	Cd	1355.556	517.5439	912.973	598.3871
	Pb	756	1110	79.02273	286.4706
	Zn	39.09091	199.3258	116.1991	227.0707
Potamogeton pectinatus	Fe	13653.33	4619.917	7965.192	6808.235
	Ni	523.6364	113.3333	11.48235	95.79288
	Cr	1362.5	196.1538	434.6154	1761.905
	Cd	922.2222	570.1754	922.4324	540.3226
	Pb	260	488.5714	39.68182	181.1765
	Zn	26.66667	163.8202	115.1157	177.7778
Typha domingensis	Fe	2884.123	2770.744	1650.192	2608.824
	Ni	500.9091	715.4762	15.91765	74.11003
	Cr	1800	509.6154	636.7308	2771.429
	Cd	1188.889	603.5088	409.7297	496.7742
	Pb	520	540	51.81818	203.5294
	Zn	31.21212	248.3146	112.7454	217.0707

The BCF values for the plants confirmed the hypothesis indicating the species as an accumulator for different metals. The BCF value for metals indicates the plants are suitable species for phytoremediation purposes (Nirola et al. 2015).

Mesopotamian marshes are easily influenced by environmental factors such as surface runoff, groundwater, dissolution from sediment, deposition from the atmosphere, and anthropogenic pollutants (Al-Saad et al. 2010). Therefore, the variation in heavy metal accumulation results could have been attributed to the interactions between the numerous factors that affect the concentrations of dissolved metals, such as the phytoplankton and aquatic plant densities absorbing or adsorbing the ionic metals, and the fuel burn emissions within the marsh during the summer season (Al-Haidarey et al. 2010).

Although Cr, Cd, and Zn are known as essential elements to plants, higher concentrations of these heavy metals can be toxic (Karthick et al. 2012). The accumulation of Pb, Cd, and Cr in plants of Al-Hawizeh Marsh may have been from the discharge of sewage from houses and treatment units in the Maysan province. On the other hand, heavy metals' absorption varies depending on the plant species (Shahid et al. 2016). It is affected by the metals' bioavailability, the extent of their survival in the water, the pH, and the sediments' organic matter content. The accumulation of heavy metals varies between plant species and between the individual plant parts (roots, stems, leaves) (Yabanli et al. 2014).

The concentration of heavy metals in the tissues of plants during the summer was higher than in any of the other seasons, which may have been due to increased salinity and pH, which works to increase deposition of suspended materials in sediments as well as organic carbon in sediments which absorb the heavy metals. In this case, plants have a greater chance of absorbing these metals from the sediments through their roots and storing them in other parts. This is consistent with the research conducted by others (Farhood 2016).

Wetland plants can accumulate heavy metals through their roots and shoots. They are often proposed as pollution monitoring organisms (Eid et al. 2020), although the metal concentrations vary with the plant species and the wetland type. In this study, the lowest concentration of Zn was 0.15 mg/kg in *A. filiculoides* during the winter, while it was 13.303 mg/kg dry wt. in *C. demersum* during the summer, suggesting that the plants of Al-Hawizeh Marsh were not contaminated. In our study, Cu concentrations were 3.25mg/kg in *A. filiculoides*, but were 7.47 mg/kg in *T. domingensis* during the spring, implying Cu contamination in plants is not severe. Though heavy metals like Cd, Pb, and Ni are not essential for plant growth, they may accumulate in plants (Singh et al. 2011) where they are readily taken up and accumulated in toxic forms. Heavy metal concentrations in the soil solution play a vital role in controlling metal bioavailability to plants.

Several plants, such as *P. australis, P. pectinatus*, and *T. domingensis*, play a significant role in phytoremediation, as they are the best and cheapest clean-up technologies for contaminated water, groundwater, and wastewater.

However, the high contamination of heavy metals in these plants affects cattle's health, which requires further investigation. Although some metals are essential for biological systems in humans and animals, acting as structural and catalytic components of proteins and enzymes, in higher concentrations, they can be toxic (Nazir et al. 2015; Liu et al. 2017). This study is the first to examine plants' heavy metal contamination in the Al-Hawizeh Marsh in the last ten year.

Overall, our results showed that concentrations of cadmium, chromium, and iron in plants were above the permissible limits set by WHO. In contrast, zinc, copper, and lead were all below the allowable limits.

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