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Determination of some heavy metals in two macrophytes of *Typha domingensis* and *Potamogeton pectinatus* in Al-Shamiyah River, Iraq

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Abstract: Heavy metal accumulation within water, sediment, and aquatic biota including aquatic plants, needs to be estimated and analyzed, because metals can continuously move from one trophic level to another. The present study aimed to evaluate the contamination of the two aquatic plants of *Typha domingensis* and *Potamogeton pectinatus* in the Al-Shamiyah River in Al-Diwaniyah, Iraq, with heavy metals of copper, manganese, cadmium, lead, zinc, and chromium. The concentrations of heavy metals in *T. domingensis* were as follows: Cu: 24.56-76.40, Mn: 174.47-642.97, Cd: 0.70-23.58, Pb: 1.84-127.75, Zn: 2.70-150.14, and Cr: 1.34-35.26 μg/g dry weight. The Content of these metals in *P. pectinatus* were as follows: Cu: 16.59-348.72, Mn: 299.74-642.84, Cd: 1.51-34.75, Pb: 1.72-30.44, Zn: 30.57-152.59, and Cr: 1.15-34.99 μg/g dry weight. The results highlight the role of these two large aquatic plants as monitoring tools for heavy metals pollution as well as the rehabilitation of the aquatic habitats.

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Introduction

Water pollution is defined as a change in the properties of water so that it exceeds normal limits due to external influences, most of which are due to human activities, including waste from factories, sewage wastes, and agricultural operations (Vareda et al., 2019). Aquatic environment pollution sources are numerous and varied, posing significant threats. It is expected that new sources of pollution will emerge in the future due to the continuous and tremendous progress in technology and industry. Natural waters are contaminated with various pollutants, such as heavy metals (Satarug et al., 2023). Pollutants constitute a serious risk to the aquatic environment, mainly originating from industrial processes and agricultural residues from irrigation. They enter the aquatic environment, causing pollution, each of which contributes differently in terms of toxicity and impact on aquatic life and water pollution.

Heavy metals, a share of these wastes (Hussain et al., 2017; Khan et al., 2023), are dangerous because of their non-degradable property (Tashla et al., 2018; Doğan et al., 2022), bioaccumulative ability in the food chain, and toxicity to aquatic organisms (Gall et al., 2015; Hamidian et al., 2023; Rajak et al., 2024). They come in the water bodies from various sources, the most important of which include effluents from industrial activities, agricultural runoff, and urban wastewater (Borrell et al., 2016; Alavian Petroody et al., 2017; Mohanta et al., 2020). Hence, pollution of water bodies is the main problem in countries around the world, including in Iraq. Due to the expansion of industrial activities, the levels of heavy metals in water, sediments, and aquatic organisms, including river plants—have increased (Daripa et al., 2023).

Although these metals are naturally found in aquatic environments in small quantities, they are highly toxic in high concentrations, harming human health (Ali et al., 2016; Antoniadis et al., 2017; Briffa et al., 2020). Heavy metals persist in nature and accumulate in aquatic organisms, such as aquatic plants, and thus are able to amplify in the food chain

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Table 1. The coordination of the study sites.

Sites	longitude	latitude
site 1	44°36'68'E	32°18'53'N
site 2	44°53'83'E	32°04'45'N
site 3	44°62'40'E	31°83'92'N
site 4	44°55'39'E	31°63'92'N

over time (Aydin-Önen and Öztürk, 2017; Loureiro and Hepp, 2020). Several studies have been performed on the levels of these metals in water and sediments within aquatic environments, with higher concentration values obtained (Torregroza-Espinosa et al., 2018; Hossain et al., 2020; Zhao et al., 2020). Submerged plants can extract toxic substances such as heavy metals from the liquid. They bioaccumulate these heavy metals and keep them in their tissue or convert them to a non-toxic form (Li et al., 2019). They are also used as bioindicators for the health status of freshwater ecosystems (Mânzatu et al., 2015; Shahid et al., 2018; Compaore et al., 2020). Some aquatic plants can accumulate a great deal of biomass very rapidly, and they can be grown under adverse conditions; therefore, they are pollutant-elimination species like heavy metals (Liu et al., 2016).

Typha domingensis is a newly found pollutant bioaccumulator (among heavy metals) which tolerates life under a toxic environment for the same reasons as for other pollutants (Mukhtar and Abdullah, 2017; Al-Abbawy et al., 2021; Eid et al., 2020; Gupta et al., 2023; Maki et al., 2024). *P. pectinatus* is a common pioneer species resistant to high levels of heavy metals that also grows rapidly in polluted aquatic environments where other species cannot survive (Sivaci et al., 2008). According to the aforementioned background, this study was performed to assess the concentration of Cu, Mn, Cd, Pb, Zn, and Cr in *T. domingensis* and *P. pectinatus* in the Al-Shamiyah River at Al-Diwaniyah/Iraq.

Materials and Methods

Study area: The spatial scope of the current study represented by the administrative boundaries of Al-Shamiyah district, one of six districts in Al-Qadisiyah Governorate, with a geographical location in the northwestern part of Al-Qadisiyah Governorate between latitudes 31°30'-32°70'And and longitudes 44°30' -44°52'E**.** After the Euphrates River leaves Al-Kifl District in Iraq for a distance of 1 km, it branches into two branches, the Al-Kufa River and the Al-Shamiyah River. The Al-Shamiyah River, which is the river under study in Al-Shamiyah District, begins from the Abbasiya township and reaches Al-Shanafiya District. The length of the Al-Shamiyah River from Al-Abbasiya town to the Al-Shanafiya District is 125 km, with a discharge of 180 m/s.

Study sites and period: The four study sites on the Al-Shamiyah River were selected using a GPS device (Table 1). Site one was in Abbasiya township, Site two in Al-Salahiya township, with a distance of 43 km from Site one, and the third site was in Al-Shamiyah township, about 40 km away from Site two. Site four was after the Ghammas township, approximately 42 km away from Site 3. All four sites contain *P. pectinatus* and *T. domingensis*, and the plants were collected from the study sites during 2023-2024 (spring, summer, and autumn 2023, and winter and spring 2024).

Sample collection: Samples of *P. pectinatus* and *T. domingensis* were obtained from the study sites. They were washed with river water after collection to eliminate unwanted materials, mud, and residues, and placed in clean plastic bags, on which the information of each plant was recorded. They were rinsed with tap and distilled waters to eliminate all residues in the laboratory (APHA, 2017).

Measurement of heavy metals: The plants were dried and treated with acids for digestion and extraction of heavy metals, as described by Antonijevic and Maric (2008). To measure the heavy metal, a flame atomic absorption spectro-photometer was used according to APHA (2017).

Table 2. Content of Cu and Mn (μg/g) in *Typha domingensis* in the studied sites of the Al-Shamiyah River.

Element	Sites / Seasons	Site 1	Site 2	Site 3	Site 4
Cu	Spring 2023	54.13	53.87	54.46	42.96
	Summer 2023	76.4	69.49	69.23	60
	Autumn 2023	35.87	42.29	49.91	27.02
	Winter 2024	40.39	36.65	58.85	24.56
	Spring 2024	41.89	42.56	44.15	55.09
Mn	Spring 2023	174.48	247.75	303.56	263.73
	Summer 2023	181.55	260.79	258.4	262.45
	Autumn 2023	494.13	559.6	516.4	642.97
	Winter 2024	381.75	507.1	500.35	534.13
	Spring 2024	380.5	507.71	500.34	558.55

Table 3. Concentration of Cd and Pb (μg/g) in *Typha domingensis* in the studied sites of the Al-Shamiyah River.

Element	Sites / Seasons	Site 1	Site 2	Site 3	Site 4
Cd	Spring 2023	0.91	1.71	23.58	12.74
	Summer 2023	4.56	15.17	3.14	11.89
	Autumn 2023	3.02	3.13	0.86	1.55
	Winter 2024	1.07	2.36	0.7	1.07
	Spring 2024	1.18	2.48	0.9	1.52
Pb	Spring 2023	80.17	18.28	15.32	12.92
	Summer 2023	3.38	3.08	1.84	3.05
	Autumn 2023	6.7	7.22	5.49	5.19
	Winter 2024	17.84	13.17	15.87	42.35
	Spring 2024	127.75	15.72	12.33	13.77

Statistical analysis: The SAS (2018) was applied to analyze the data, comparing the heavy metal contents in aquatic plants between sites and examining the impact of site and seasonal variations on the distribution of metals. The least significant difference test compared the significant differences between the means –LSD.

Results

Concentration of heavy metals in *T. domingensis*: The recorded heavy metal contents in the *T. domingensis* are shown in Table 2. For Cu, the lowest concentration was 24.56 μg/g dry weight in winter 2024 at Site 4, and the highest one was 76.40 μg/g dry weight in summer 2023 at Site 1 (Table 2). The lowest seasonal concentration of Mn in *T. domingensis* was 174.48 μg/g dry weight in spring 2023 at Site 1, while the highest one was 642.97 μg/g dry weight in autumn 2023 at Site 4. The results revealed significant seasonal variations ($P \leq 0.05$) and study sites for Cu and Mn concentrations.

The results revealed the seasonal changes in Cd concentration in *T. domingensis*, ranging from 0.7 μg/g dry weight in winter 2023 at Site 3 to 23.58 μg/g dry weight at the same site in spring 2023 (Table 3). The lowest concentration during the seasons for Pb decreased to 1.84 μg/g dry weight in summer 2023 at Site 3 and increased to the highest level at 127.75 μg/g dry weight in spring 2024 at Site 1 (Table 3). The results revealed significant differences

Table 4. Contents of Zn and Cr (μg/g) in *Typha domingensis* in the studied sites of the Al-Shamiyah River.

Element	Sites / easons	Site 1	Site 2	Site 3	Site 4
Zn	Spring 2023	12	53.93	2.7	13.65
	Summer 2023	41.72	37.03	36.2	28.69
	Autumn 2023	60.74	79.34	30.6	43.63
	Winter 2024	54.62	150.14	32.12	42.26
	Spring 2024	64.1	122.01	33.19	38.85
Cr	Spring 2023	1.34	1.71	1.78	2.08
	Summer 2023	14.58	13.96	6.76	5.94
	Autumn 2023	14.21	17.26	13.33	23.27
	Winter 2024	13.75	18.8	13.86	34.12
	Spring 2024	12.28	17.78	13.79	35.26

Table 5. Concentration of Cu and Mn (μg/g) in *Potamogeton pectinatus* in the studied sites of the Al-Shamiyah River.

Element	Sites / Seasons	Site 1	Site 2	Site 3	Site 4
Cu	Spring 2023	162.09	29.41	16.59	21.99
	Summer 2023	259.47	246.1	348.72	256.9
	Autumn 2023	45.45	45.69	30.55	28.43
	Winter 2024	39.28	28.37	35.07	32.61
	Spring 2024	41.56	29.2	33.18	35.58
Mn	Spring 2023	299.74	318.78	642.84	354.4
	Summer 2023	357.08	450.26	614.35	314.4
	Autumn 2023	434.21	531.13	588.89	362.41
	Winter 2024	512.67	523.82	511.55	354.94
	Spring 2024	511.7	523.42	434.05	345.5

($P≤0.05$) between seasons and study sites for Cd and Pb contents.

The minimum value of Zn was 2.70 μg/g dry weight in spring 2023 at Site 3, and the highest was 150.14 μg/g dry weight in winter 2023 at Site 2 (Table 4). The minimum value of Cr was 1.34 μg/g dry weight in spring 2023 at Site 1, and the highest one was 35.26 μg/g dry weight in spring 2024 at Site 4. Between seasons and study sites for Zn and Cr concentrations, significant differences ($P≤0.05$) were found.

Concentration of heavy metals in *P. pectinatus*: The lowest concentration of Cu was recorded in the *P. pectinatus* as 16.59 μg/g dry weight. In spring 2023, the highest concentration (348.72 μg/g dry weight) was recorded at Site 3 (Table 5). The lowest concentration of Mn was recorded in spring 2023 at Site 1 (299.74 μg/g dry weight). The maximum concentration was also observed in spring 2023, but at site 3 (642.84 μg/g dry weight) (Table 5). The findings indicated significant variations ($P≤0.05$) between seasons and study sites for Cu and Mn concentrations.

The concentrations of Cd showed seasonal changes in *P. pectinatus*, and the lowest concentration was recorded in winter 2023 at Site 4, which was 1.51 μg/g dry weight, and the highest concentration was 34.75 μg/g dry weight in spring 2023 at Site 3 (Table 6). The lowest concentration of Pb was 1.72 μg/g dry weight at Site 1 in summer 2023 (Table 6). The highest concentration was 30.44 μg/g dry weight in autumn 2023 at Site 3. The presence of a significant difference ($P≤0.05$) between the seasons and study sites on Cd and Pb concentrations was observed from the results obtained. Cu, Cd, and Zn were higher in *P. pectinatus*.

The least amount of Zn was observed in autumn

Table 6. Content of Cd and Pb (μg/g) in *Potamogeton pectinatus* at the studied sites in the Al-Shamiyah River.

Element	Sites / Seasons	Site 1	Site 2	Site 3	Site 4
Cd	Spring 2023	8.83	12.85	34.75	6.96
	Summer 2023	6.4	26.97	6.75	5.3
	Autumn 2023	1.82	21.93	5.74	5.59
	Winter 2024	1.68	2.75	2.28	1.51
	Spring 2024	1.66	2.44	2.55	1.75
Pb	Spring 2023	16.96	17.23	6.09	5.72
	Summer 2023	1.72	11.09	27.74	7.78
	Autumn 2023	4.31	26.25	30.44	5.84
	Winter 2024	3.36	3.07	2.64	2.64
	Spring 2024	3.55	3.77	2.6	3.24

Table 7. Content of Zn and Cr concentration (mg/g) in *Potamogeton pectinatus* at Moroccan sites of the Al-Shamiyah River.

Element	Sites / Seasons	Site 1	Site 2	Site 3	Site 4
Zn	Spring 2023	38.56	55.83	39.28	35.97
	Summer 2023	139.22	48.68	34.7	42.16
	Autumn 2023	152.59	45.51	30.57	55.12
	Winter 2024	109.38	75.45	52.93	58.93
	Spring 2024	104.63	85.55	38.45	55.6
Cr	Spring 2023	18.58	21.33	15.06	29.26
	Summer 2023	24.16	12.25	13.41	18.02
	Autumn 2023	28.94	32.47	32.78	5.49
	Winter 2024	25.38	34.99	30.91	2.52
	Spring 2024	1.16	2.64	1.15	2.36

2023 (30.57 μg/g dry weight) from site 3, and the highest amount was recorded (152.59 μg/g dry weight) in the same season but from site 1 (Table 7). The lowest concentration of Cr was recorded as 1.15 μg/g dry weight in spring 2023 in site 3. The highest concentration was 34.99 μg/g dry weight in winter 2023 at Site 2 (Table 7). The results revealed significant differences ($P \leq 0.05$) between seasons and study sites for Zn and Cr concentrations.

Discussions

The current study results showed that high heavy metals had high accumulation in these two aquatic plants due to the fact that their cell walls consist of polysaccharides, proteins, as well as lipids with diverse functional groups (such as hydroxyl, carboxyl, amino, ester, and carbonyl groups). These groups are involved in the chelation of heavy metal ions and sequestration in plant tissues (Hejna et al., 2020; Khan and Khan, 2023). In the current study, the accumulation of heavy metals in *T. domingensis* was aligned with that reported by Bonanno and Cirelli (2017) and Mukhtar and Abdullahi (2017).

Mn, Pb, and Zn (642.97, 127.75, and 150.14 μg/g, respectively) showed the highest acculumation values in *T. domingensis* in the Al-Shamiyah River. However, the values of Mn, Cu, and Zn in *P. pectinatus*, were 642.84, 348.72, and 152.59 μg/g, respectively. These macrophytes absorb and accumulate heavy metals through various mechanisms, including phytoextraction, phytofixation, and phytovolatilization (Hazra et al., 2015).

In addition, the findings revealed that the lowest Cd, Pb, and Cr values were 0.7, 1.84, and 1.34 μg/g, respectively, recorded in *T. domingensis*, and they were 1.51, 1.72, and 1.15 μg/g in *P. pectinatus*, respectively. The fluctuations in the levels of heavy metals in different plants might be ascribed to differing environmental conditions and differences in climatic conditions that exist between the sampling seasons (Bonanno and Lo Giudice, 2010). It could also be attributed to the alteration of the optimum outputs of heavy metals and heavy-metal-containing wastewater.

Bioaccumulation of heavy metals in aquatic plants is controlled by the concentration of heavy metals in water and sediments (Zhang et al., 2017). The variation in the degree of heavy metal's concentration in *T. domingensis* can be associated with its very plastic structure, allowing it to acclimate to multiple extreme environmental parameters and thereby support the process of removing heavy metals (Hadad et al., 2010), stating that, *T. domingensis* is an environmentally friendly plant for removing them from polluted water (Eid et al.; 2020: Haroon, 2022).

Such variations in the accumulation by macrophytes can be due to differences in examined species, types of metal, and the sampling periods applied (Anusuya et al., 2011; Shazili and Yunus, 2003). The values of heavy metals in *P. pectinatus* and *T. domingensis* tissues collected from the AL-Shamiyah River documented in this study were not consistent with those reported for other studies, which could be explained by the discrepancy between metal contents (El-Amier et al., 2018; Eid et al., 2020). Furthermore, plant species and organs where heavy metals deposit also influence the build-up of heavy metal content in plants (Peralta-Videa et al., 2009). Two plant species of *T. domingensis* and *P. pectinatus* differ in composition and anatomy; *T. domingensis* has a large root, while *P. pectinatus* has a small root (Cicero-Fernandez et al., 2016; Saha et al., 2017; El-Amier et al., 2020).

In the current study, we investigated the effects of season on the ability of *T. domingensis* and *P. pectinatus* to accumulate heavy metals. The heavy metal contents in *T. domingensis* decreased during spring and winter. In *P. pectinatus*, metal concentrations decreased in spring 2023. The results also revealed a significant increase in Mn, Zn, and Cu in aquatic plants during the autumn and summer 2023, while the values of other heavy metals mostly decreased in the spring and winter 2023 similar to pervious reports (Delavar and Safari, 2016), who indicated that the concentration of heavy metals in aquatic plants is related to on the location of the plants and season. Also, many factors influence the mobility of heavy metals from the medium in which they are distributed to the plant. The crucial factors are the solubility of the metal in the water and the degree of complexity and development of the aquatic plant (Skorbilowicz, 2009). In addition, the current study agreed with the findings of Soliman et al. (2024), which indicated that seasonal dynamics significantly affected the metal uptake capacity of *T. domingensis* and resulted in marked variations in growth parameters, including density, stem diameter, leaf morphology, and biomass production. However, the concentration of Mn, Pb, Cd, Cu, and Zn in the current study was lower; however, the highest concentrations of Mn and Cu were noticed in autumn and summer in both studies. It was also found that *T. domingensis* can bioaccumulate heavy metals, proving to be a good accumulator of some heavy metal data from other studies (Gomes et al., 2014; Mufarrege et al., 2014; Sompura et al.

In the current study, Mn was accumulated at high levels, and then Zn, followed by Pb, in *T. domingensis*. Heavy metals, like Mn, Pb, and Zn, may occur in sediments in different quantities, resulting in their accumulation at different rates by plants (Bonanno, 2017; Cirelli, 2017). Additionally, high values of Zn and Pb in *T. angustifolia* were in accordance with findings acquired by Fetoshi et al. (2024). The environmental conditions have an impact on heavy metals accumulation by plants, for instance, pH modifies the removal of heavy metals from water and their uptake by plants (Taylor and Crowder, 1983). The uptake and accumulation of metals into aquatic plants is determined by certain other factors, such as plant species, the growing stage of the plant, or properties of heavy metals (Rucińska-Sobkowiak, 2016). Accordingly, biomass of heavy metals in aquatic macrophytes can be affected by biological factors associated with the plant (plant species, age, and period of occurrence), as well as non-biological factors associated with the environment (temperature, season, and nutritional conditions) (Eid et al., 2012).

In this work, Zn and Cr were also found to be bioaccumulated in *T. domingensis*, and *P. pectinatus* until reaching their concentration values for Zn and Cr of 150.14, 35.26 μg/g in *T. domingensis* and 152.50, 34.99 µg/g warrant claims regarding exactly the same concentration of both ions among plants (*P. pectinatus*). This could be attributed to the variation in their parts and levels of collection, and in their Na and K concentrations. These results resonate with the research of Hadad et al. (2018) regarding the bioaccumulation of Cr and Zn in *T. domingensis* organs. Furthermore, our findings are in agreement with those of Mufarrege et al. (2015) in the tolerance of *T. domingensis* to Cr and Zn. Heavy metals can be taken up differently (Suñe et al., 2007; Maine et al., 2016), so that their accumulation in their plant hosts is affected by the bioavailability and residency time of metal in the contaminated environment. Heavy metal accumulation is varied according to the plant species and different organs of the plants (roots, stems, leaves) (Yabanli et al., 2014). According to the results of the current study, the heavy metal concentrations in *P. pectinatus* were lower than those reported by other investigators (Peng et al., 2008).

Conclusions

Typha domingensis accumulates in the following order: Mn > Zn > Pb > Cu > Cr > Cd, and *P. pectinatus* as Mn > Cu > Zn > Cr > Cd > Pb. For Cd and Cr. No significant differences were found in the concentrations of both metals among the tissues of *P. pectinatus*. The *T. domingensis* presented higher Mn, Pb, and Cr concentrations than *P. pectinatus*. Cd and Zn were greater in P. pectinatus than in *T. domingensis*.

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