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Some Heavy Elements in Water and Aquatic Plant from Kut Al-Fadagh Channel in Basrah City

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ABSTRACT

This study examined the seasonal fluctuations of heavy element concentrations on water surfaces (Fe, Pb, Cd, Zn, Co, Mn, and Se) and how they conform to environmental quality requirements. The highest concentrations of heavy elements were detected in spring, with the highest amounts of iron and zinc. The study additionally examined how heavy element buildup varied by season in different aquatic plant species. The results revealed that *Aster subulatus* accumulates the most iron, lead, and zinc in the spring, *Imperata cylindrica* accumulates the most cobalt in the spring, and *Aster subulatus* reaches peak cadmium levels in the autumn. Different plant species have different preferences for certain heavy elements. Furthermore, manganese accumulates most in *Phragmites australis* during the spring. These results highlighted the importance of choosing the right plant species for phytoremediation projects. The research also identified bioconcentration variables, with *Phragmites australis* being the best at accumulating iron, *Imperata cylindrica* being the best at accumulating lead, and *Convolvulus arvensis* being the best at accumulating zinc. These findings provided important information for managing pollution, conserving the environment, and using aquatic plants in phytoremediation techniques. This work highlighted the intricate interactions between variables affecting the accumulation of heavy elements in aquatic plants and stressed the necessity for a sophisticated ecosystem management strategy that takes into account species-specific variations and environmental circumstances. The complex mechanisms influencing heavy elements buildup, water quality, and the ecological consequences of these discoveries call for more investigation.

INTRODUCTION

Heavy elements' definitions and categorization have drawn a lot of attention in environmental research. According to **Duffus (2002)**, the term "heavy elements " refers to semi-metals (metalloids) that have the potential to harm the environment. **Koller and Saleh (2018)** proposed a specific definition for heavy elements as elements having atomic weights larger than 23 units and densities greater than 5.0g/ cm^3. The correlation between atomic characteristics and weight is shown by this definition. In contrast, **Ali and Khan (2018)** presented a broad definition, expanding the scope to incorporate naturally occurring elements with atomic numbers more than 20 and elemental densities greater than 5g/ cm^3. The natural occurrence and density of these components are taken into account as important identifying factors for heavy elements in this enlarged definition. The choice of definition can significantly impact research in the field of heavy elements, as it determines which elements are categorized as heavy elements and guides regulatory and environmental considerations. Understanding these varying perspectives on heavy elements definitions is essential for the contextualization of research and policy decisions in the realm of environmental science, which seeks to investigate the accumulation of heavy elements in aquatic plant species in a contaminated channel branching from the Shatt al-Arab River; the definitions offered by **Ali and Khan (2018)** and **Koller and Saleh (2018)** serve as crucial reference points.

While some heavy elements are essential for plant development and various biological processes, an excess amount can pose significant hazards **(Al-Abbawy *et al*., 2021)**. Notably, necessary heavy elements including zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), and nickel (Ni) function as co-factors, components, or vital elements of enzymes and play important roles in plant chemistry **(Anum *et al*., 2019)**. However, depending on the individual metal and plant type, different concentration thresholds for these essential heavy elements are permitted.

In contrast, non-essential heavy elements such as mercury (Hg), cadmium (Cd), and chrome (Cr) have no recognized biological functions in plants, making their presence potentially detrimental **(Wuana & Okieimen, 2011)**.

Environmental science is very concerned with heavy elements pollution, especially in aquatic environments like lakes and rivers. Extensive study has been prompted by the need to understand the harmful effects of heavy elements pollution on aquatic life, as well as the persistence and tendency of these pollutants to penetrate and accumulate inside aquatic species **(Bai *et al*., 2018; Ejaz *et al*., 2023)**. Remarkably, aquatic plants' capacity to absorb and store heavy elements has made them important participants in finding solutions to this issue.

Several plant species including water hyacinth (*Eichhornia crassipes*) and *Hydrilla verticillata* are two examples of plants that have shown to be highly effective in removing heavy elements from wastewater. Moreover, similar high ability for heavy elements absorption has been shown in submerged plants such as *Potamogeton malaianus* **(Harguinteguy *et al*., 2014)**, *Typha latifolia* **(Duman *et al*., 2015)**, and *Ceratophyllum demersum* **(Romero-Oliva *et al*., 2015)**. This presents intriguing opportunities for using these plants in low- cost, environmentally friendly methods to reduce heavy element pollution in aquatic settings. Given that the complex mechanisms driving heavy element accumulation in various aquatic plant species remain poorly known, it is crucial to understand the underlying causes of these variances.

MATERIALS AND METHODS

Study area

The study area is located in Abu Al-Khaseeb, in the Basrah Governorate, the southernmost section of Iraq, about 10 kilometers from the city center of Basrah. Summers in this region are often hot and dry, but winters are generally more tolerable.

Abu Al-Khaseeb is renowned for its number of date palm groves and several water channels that branch off the Shatt al-Arab River. Samples were taken at these GPS coordinates for the Kut Al-Fadagh channle: N: 302745.54, E: 475456.72. This location is bordered by date palm groves and has aquatic vegetation. On both banks of the river, there are some residential properties. Some of these residential buildings release sewage water into the river. The Shatt al-Arab River nourishes the Kut Al-Fadagh channel, and the water from this river is utilized to irrigate the orchards.

Collection of water samples

Water samples were collected from various points along the waterway during low tide, specifically at depths ranging from 20 to 30cm beneath the surface. Afterwards, a 1000mL sample was carefully collected in HDPE (High-Density Polyethylene) bottles that were previously thoroughly cleaned with an HNO_3 solution.

100mL of water sample was mixed with 5mL of pure nitric acid. The mixture was then heated until it was almost completely dehydrated. Subsequently, an additional 5mL of concentrated nitric acid was added, and the mixture was heated to ensure complete digestion of the sample. After cooling, the liquid was then poured into a volumetric flask. Sample volume was filled to reach 100ml using deionized water. A Japanese- made atomic absorption spectrophotometer (Shimadzu AA7000) was used to determine the presence of heavy elements in samples of digested water material.

Plant samples

Throughout the period from 2022- 2023, plants were seasonally harvested from each area,. washed with water, subjected to sonication to remove debris from the channel, and brought to the lab in plastic bags. The samples were rinsed with deionized water and placed on paper towels to air dry. Once dried, the plant samples were finely ground into a powder using an electric grinder and sieved through a 2mm mesh sieve.

Plant samples were collected according to the method described by **Estefan *et al*. (2013)**. Subsequently, an additional 5mL of concentrated nitric acid HNO_3 was added to 1gm of the plant sample. The mixture was then left for 8 hours. Furthermore, an additional 10mL of a 4: 9 mixture of nitric acid and perchloric acid was added. The temperature was then progressively raised between 180 and 200ºC until all the thick white vapors dissipated. Afterward, the mixture volume was adjusted to 50mL with deionized water. The concentration of heavy elements in the digested plant samples was analyzed using an atomic absorption spectrophotometer.

The analysis of the heavy elements in both water and plant samples was performed at the Chemistry Laboratory, Marine Science Center, Basrah University, Basrah, Iraq.

Bioconcentration factor (B.C.F)

The **Kumar *et al*. (2009)** equation was used to calculate BCF by dividing the sum of each element's concentrations in the selected tissue (A) by their sum in the water (B), as follows:

B.C.F = A/B.

Statistical analysis

The statistical analysis was conducted using GenStat V.7 software. The experimental design involved complete randomized plots for two-factor experiments. The first experiment incorporated variations in seasons and aquatic plants, while the second experiment focused solely on the season, comprising one factor. Significance was established at a probability level below 0.05.

RESULTS AND DISCUSSION

Heavy elements in water surface

In this study, we investigated seasonal fluctuations in the levels of heavy elements (Fe, Pb, Cd, Zn, Co, Mn, and Se) found in the water surface and assessed their compliance with environmental quality standards. Table (1) summarizes the average concentrations of these elements across different seasons.

The spring season exhibited the highest iron content (341.24mg/ L), significantly surpassing other seasons. This increase is likely attributed to precipitation absorbing iron as it percolates through soil layers and interacts with soil components. These findings align with results recorded in previous studies of **Al Hejuje (2014)**, **Moyel *et al*. (2015)** and **Abdulnabi *et al*. (2016)** in Shatt al-Arab River.

In the spring season, the lead concentration reached its peak at 3.571mg/ L, a value significantly higher than all other seasons. Conversely, during the autumn, winter, and summer seasons, lead concentrations were notably lower at both study sites, measuring 0.004, 0.026, and 0.076mg/ L, respectively. These values did not show significant differences among them. The reason for the high lead in the spring may be due to the frequent use of fertilizers and pesticides in this season in addition to industrial discharges, and organic material breakdown. These results are consistent with studies conducted by **Mahmoud (2008)** and **Al-Saffawi and Al Sinjari (2019)**.

Cadmium concentrations peaked during the autumn season at 0.01196mg/ L, a value which is not significantly different from that of the winter season (0.01100mg/ L). In contrast, the summer season exhibited significantly lower levels compared to other seasons, measuring 0.0031mg/ L. These fluctuations coincide with previous research by **Al-Asadi *et al*. (2020)**, who linked elevated cadmium levels in autumn and winter to heightened runoff from highways and agricultural regions, along with increased emissions from exhaust and pollutants. Additionally, the spring season exhibited the highest zinc content (9.957mg/ L), significantly exceeding the levels of the other seasons. Increased agricultural activities and the use of zinc- containing fertilizers likely contributed to this rise. These findings corroborate those reported by **Al-Atbee *et al*. (2019)**, highlighting the influence of diverse pollution sources and sewage discharge on seasonal variations.

On the other hand, cobalt exhibited its highest concentration during the spring season, peaking at 4.762mg/ L, and significantly surpassing levels observed in previous seasons. This surge can be attributed to the use of inorganic and organic fertilizers, which serve as significant sources of heavy element contamination in agricultural settings. Additionally, the discharge of heavy elements is primarily linked to practices such as liming, sewage disposal, irrigation water usage, and pesticide application **(Arif *et al*., 2016)**.

"Manganese concentrations peaked during the summer at 0.3115mg/ L and reached their lowest levels in the autumn at 0.0311mg/ L. This pattern can be ascribed to the widespread use of fungicides and insecticides during warmer months, with these chemicals likely entering agricultural drainage water. Previous studies, such as that of **Al**

Asadi *et al*. (2020), have reported similar findings. Reduced manganese levels in the autumn and winter seasons may be due to adsorption on soil surfaces and accumulation in aquatic plants. In addition, it was noticed that, selenium levels peaked in winter (0.003272mg/ L) and remained below the limit of detection (ND) during summer. These levels remained within the permissible bounds (0.02mg/ L) according to NEQS regulations, posing no threat to plant development **(Saleem *et al*., 2012)**.

Table 1. Heavy elements concentrations in surface waters of Kut Al-Fadagh channel

Element	Seasonal Changes				Permissible value	LSD
	Autumn mean(mg/ L)	Winter mean(mg/ L)	Spring mean(mg/ L)	Summer mean(mg/ L)		
Fe	1.03	0.17	341.24	4.44	0.30	**3.241**
Pb	0.004	0.026	3.571	0.076	0.01	**0.2547**
Cd	0.01196	0.01100	0.00220	0.00031	0.05	**0.00164**
Zn	0.181	0.003	9.957	0.080	3.00	**0.4140**
Co	0.007	0.033	4.762	0.000	0.05	**0.2134**
Mn	0.0311	0.0680	0.1670	0.3115	0.02	**0.04476**
Se	0.000693	0.003272	0.000113	(ND)	0.02	**0.0000825**

ND= Not deduction, means labeled with the same letter are not significantly different from each other at a 5% significance level.

Based on the data provided in Table (1) and the mean concentrations of heavy elements in different seasons, we ranked pollution levels for these elements from the highest to the lowest across the seasons:

spring season: (Fe> Zn> Co> Pb> Mn> Cd> Se)
winter season: (Fe> Mn> Co> Pb> Cd> Se> Zn)
summer season: (Fe> Mn> Zn> Pb> Cd> Co> Se)
autumn season:(Fe> Zn> Mn> Cd> Co> Pb> Se)

These rankings highlight the spring season as having the highest pollution levels for most of the heavy elements, particularly iron, zinc, cobalt & lead. The winter season follows with elevated concentrations of cobalt and selenium. While, the summer season generally exhibits lower concentrations of these heavy elements, with selenium concentrations often falling below the limit of detection (ND).

Seasonal dynamics of heavy elements accumulation in aquatic plants

The seasonal fluctuations in heavy elements buildup among diverse aquatic plant species were addressed in the current study. We studied the presence of iron (Fe), lead (Pb), cadmium (Cd), zinc (Zn), cobalt (Co), manganese (Mn), and selenium (Se) in plant species (Table 2)

Iron (Fe) accumulation

In the spring and autumn seasons, *Aster subulatus* exhibited the highest iron accumulation values of 784.9 and 705.6µg/ g dry weight, respectively, with no significant differences between them. During the summer season, all plants displayed the lowest iron accumulation levels. Interestingly, the plant *Arundo donax* exhibited the highest iron accumulation during the summer season.

Lead (Pb) accumulation

In the spring season, *Aster subulatus* exhibited the highest lead accumulation concentration of 21.43µg/ g dry weight, significantly distinguishing it from other seasons across all plants. The lowest value was recorded in the winter season for *Glycyrrhiza glabra, Convolvulus arvensis* & *Arundo donax*, and in the summer season for *Phragmites australis, Glycyrrhiza glabra, Aster subulatus,* and *Arundo donax,* with a value of 0.00µg/ g dry weight, indicating the device's insensitivity to these levels.

Cadmium (Cd) accumulation

In the autumn season, *Aster subulatus* recorded the highest value of cadmium accumulation with a concentration of 1.369µg/ g dry weight), which was significantly distinguished over the rest of the plants included in the study. It was noted that, in the spring season, *Imperata cylindrica* recorded the lowest value of cadmium accumulation with a concentration 0.041µg/ g dry weight.

Zinc (Zn) accumulation

The spring season of *Aster subulatus* recorded the highest value of zinc accumulation with a concentration of 66.55µg/ g dry weight, followed by *Convolvulus arvensis* in the autumn season with a concentration of 53.28µg/ g dry weight. Whereas, the lowest value recorded was during the autumn season for *Imperata cylindrical*, with a concentration of 10.96µg/ g dry weight.

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Cobalt (Co) accumulation

Imperata cylindrica in the spring season showed the highest accumulation value, with a concentration of 31.973µg/ g dry weight, which significantly differed compared to the remaining plants under study. It was remarked that, the lowest values were recorded in the spring season for *Phragmites australis* and *Arundo donax,* while *Imperata cylindrica* and *Phragmites australis* (ND) exhibited their lowest values during autumn.

Manganese (Mn) accumulation

The spring season witnessed an accumulation of manganese at its highest value in *Phragmites australis*, recording a concentration of 748.9µg/ g dry weight, which was distinguished significantly over the rest of the plants during all seasons, while the lowest value was recorded in autumn for *Imperata cylindrical*, with a concentration of 3µg/ g dry weight. This value did not differ significantly from the autumn season with respect to *Phragmites australis*, *Glycyrrhiza glabra*, *Convolvulus arvensis*, *Aster subulatus* and *Arundo donax*, which showed concentrations of 3.1, 3.5, 4.2, 3.3, 4.4µg/ g dry weight, respectively.

Selenium (Se) accumulation

During summer, *Convolvulus arvensis* exhibited the highest selenium accumulation concentration of 0.767µg/ g dry weight, which is not significantly different from *Phragmites australis* and *Imperata cylindrica*, which recorded concentrations of 0.639 and 0.673µg/ g dry weight, respectively. In contrast, the lowest values were recorded in *Arundo donax* during the spring season and *Aster subulatus* during the autumn season (ND).

Table 2. Seasonal variations of heavy elements (µg/ g dry wight) in aquatic plants

Plant species	**Season**	**Heavy elements concentrations(µg/ g)**						
		Fe	**Pb**	**Cd**	**Zn**	**Co**	**Mn**	**Se**
Imperata cylindrical	Autumn	520.3	0.47	0.997	10.96	0	3.0	0.154
	Winter	366.9	1.30	0.550	37.45	1.500	61.7	0.018
	Spring	575.2	13.02	0.052	33.42	31.973	134.9	0.087
	Summer	204.8	2.93	0.155	29.72	0.325	44.0	0.673
Phragmites australis	Autumn	592.1	0.47	0.892	18.76	0	4.4	0.120
	Winter	404.9	1.30	0.200	14.05	7.550	190.3	0.100
	Spring	333.4	10.92	0.060	30.01	0	748.9	0.096
	Summer	191.5	0	0.129	27.10	0.395	179.4	0.639
Glycyrrhiza glabra	Autumn	564.4	0.33	1.081	29.72	0.803	3.3	0.294
	Winter	326.9	0	0.300	16.75	3.000	155.3	0.174
	Spring	669.1	15.13	0.129	44.88	1.361	174.5	0.118
	Summer	109.1	0	0.474	27.79	0.420	32.0	0.219
Convolvulus arvensis	Autumn	684.3	0.35	1.129	53.28	1.079	4.2	0.012
	Winter	316.8	0	0.550	44.45	2.000	84.2	0.394
	Spring	414.0	17.23	0.189	49.68	3.061	103.9	0.146
	Summer	110.8	0.97	0.172	31.32	0.560	46.0	0.767
Aster subulatus	Autumn	705.6	0.35	1.369	46.98	1.999	3.5	0
	Winter	377.6	1.30	0.650d	38.95	3.500	92.0	0.244
	Spring	784.9	21.43	0.207	66.55	4.762	280.4	0.003
	Summer	193.0	0	0.310	46.79	0.515	43.3	0.053
Arundo donax	Autumn	564.0	0.48	1.055	30.35	0.257	3.1	0.153
	Winter	390.6	0	0.850	31.50	2.000	155.5	0.053
	Spring	500.1	15.13	0.224	38.25	0	163.5	0
	Summer	233.0	0	0.551	31.58	0.535	57.5	0.384
LSD		**112.94**	**1.629**	**0.2337**	**11.660**	**0.5140**	**1.36**	**0.1831**

Means labeled with the same letter are not significantly different from each other at a 5% significance level.

Bioconcentration factor (BCF)

The bioconcentration factor (BCF) for various heavy elements in different aquatic plant species was evaluated in our study. It is evident that no single plant species can be universally regarded as a superior accumulator for all heavy elements based on the highest BCF values for each element. Instead, many plant species exhibited varying levels of accumulation for specific elements (Fig. 1). According to the highest BCF values, the data presented in Fig. (1) indicate significant bioaccumulators among plant species for specific elements, including:

For iron (Fe): *Phragmites australis* exhibits the highest BCF of 1354ppm.
For lead (Pb): *Imperata cylindrica* demonstrates the highest BCF at 60ppm.
For cadmium (Cd): *Arundo donax* showcases the highest BCF at 315ppm.
For zinc (Zn): *Convolvulus arvensis* boasts the highest BCF at 2131ppm.
For cobalt (Co): *Aster subulatus* showcases the highest BCF at 217 ppm.
For manganese (Mn): *Phragmites australis* records the highest BCF of 1154ppm.

For selenium (Se): *Glycyrrhiza glabra* demonstrates the highest BCFat 121.5ppm.

These findings coincide with those of **Al-Abbawy *et al.* (2021)** and **Hanaf (2022)**. They offer useful information on how various aquatic plant species differ in their ability to accumulate particular heavy elements and informations that can be significant in ecological and environmental analyses.

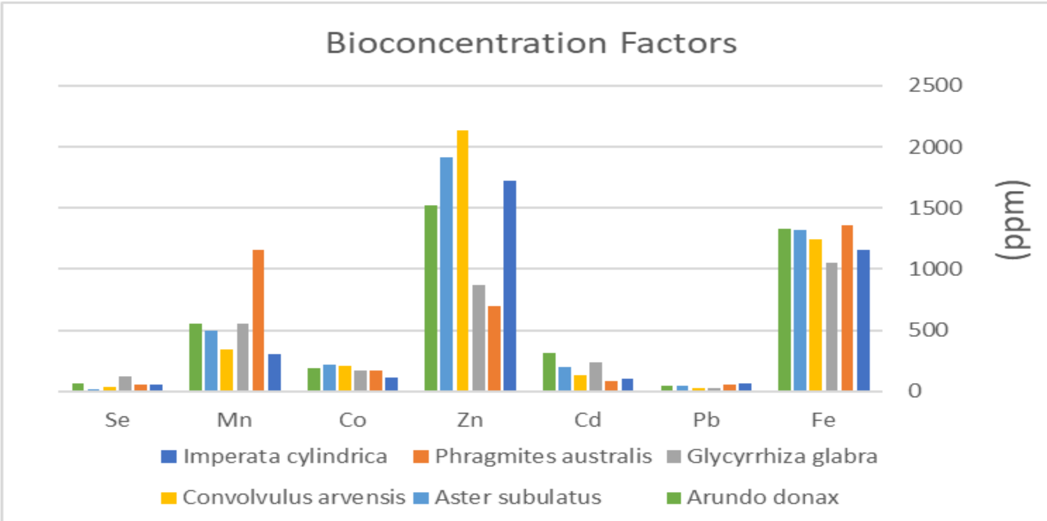

Fig. 1. Bioconcentration factors of heavy elements in various aquatic plants under study

Aquatic plants are a reliable approach for heavy elements detection because they have the capacity to concentrate heavy elements inside their tissues. Moreover, these plants grow quickly and easily adapt to a range of habitats, growing in basic conditions. The concentration of heavy elements in plant tissues may differ depending on the particular plant species **(Hanaf, 2022)**.

The data set unmistakably illustrate that heavy elements' accumulation within the studied plant species fluctuates significantly across different seasons. Notably, the order of heavy elements accumulation by these plants exhibits marked variations with iron (Fe)> manganese (Mn)> zinc (Zn)>lead (Pb)> cobalt (Co) cadmium (Cd) > and selenium (Se) (Fig. 2), showcasing pronounced seasonal differences. The highest and lowest accumulation levels vary with season (Table 2). These fluctuations underscore the substantial impact of seasonal changes on the uptake and accumulation of heavy elements by these aquatic plants. This observation aligns with previous studies on the seasonal variability of heavy elements accumulation in aquatic plants, as reported by **Ding *et al.* (2007)**.

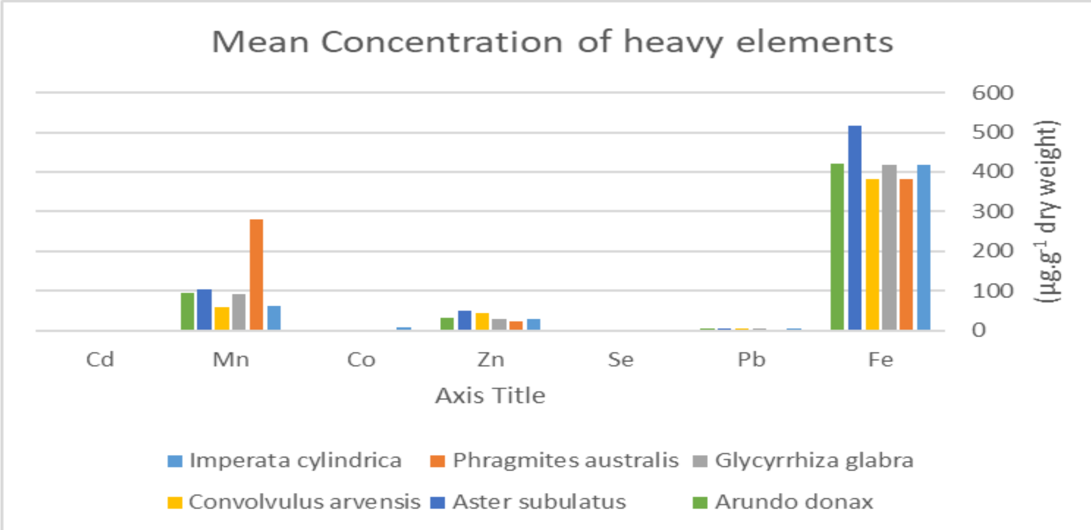

Fig. 2. Mean concentration (µg/ g dry weight) of heavy elements in aquatic plant during the study period

Furthermore, the observed variability in heavy elements accumulation among different plant species underscores the need for a nuanced approach to phytoremediation and ecosystem management. Each plant species demonstrates varying affinities for different heavy elements, highlighting the importance of selectivity in choosing the appropriate species for phytoremediation efforts. It is crucial to acknowledge that not all aquatic plants will serve as effective bio- accumulators for every type of heavy elements. Therefore, the selection of plant species tailored to the specific contaminants in a given ecosystem is pivotal to the success of phytoremediation initiatives.

Additionally, the influence of water conditions including pH and salinity, on the bioavailability and mobility of heavy elements in aquatic environments is a complex and multifaceted aspect. The intricate relationship between water chemistry and heavy elements accumulation in plants warrants further investigation. Subsequent research should delve into the mechanisms governing the uptake and translocation of heavy elements under varying water conditions, shedding light on the nuanced interactions between plant physiology and the surrounding aquatic environment.

The data reveal intriguing and distinct accumulation patterns among various plant species. For instance, *Aster subulatus* displays unique accumulation patterns when compared to *Phragmites australis*, *Glycyrrhiza glabra*, *Convolvulus arvensis*, *Imperata cylindrica*, and *Arundo donax*..

Additionally, **Al-Abbaway *et al*. (2021)** provided valuable insights into the heavy elements concentrations in six aquatic macrophytes from different locations in Al-Hawizeh Marsh in southern Iraq. The data exhibited significant variations among species and seasons. Some plant species, such as *Phragmites australis*, *Potamogeton pectinatus*, and *Typha domingensis*, are highlighted as having the potential for phytoremediation, referring to their ability to clean up contaminated water, groundwater, and wastewater. This information underscores the complex interplay of factors affecting heavy elements accumulation in aquatic plants, ranging from species-specific variations to the broader environmental context.

CONCLUSION

The study uncovers the intricate relationship between heavy element accumulation in aquatic plants, seasonal variations, species- specific differences, and environmental factors. These findings offer valuable insights for ecological conservation, pollution management, and the potential utilization of aquatic plants in phytoremediation strategies. Further research in this field is warranted to better comprehend the complex dynamics of element accumulation and its broader ecological implications

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