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# BIOACCUMULATION DYNAMICS AND SEDIMENT QUALITY ASSESSMENT OF HEAVY METALS IN THE SOUTHERN IRAQI MARSHLAND ECOSYSTEM

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## ABSTRACT

The present study aims to assess the concentrations and accumulation of heavy metals in surface water, sediments and key aquatic macrophytes namely *Ceratophyllum demersum, Phragmites australis, Arundo donax* and Typhain the marshes of Iraqi south. Analysis of the water samples showed that the concentration of all the metals were found low and were within the safety limits of class II. But, sediments showed localized high level of V, Co, Cu, and Pb above background concentrations which indicates anthropogenic stresses. The bioaccumulation efficiency of the presence of the metals differed significantly from species to species with the submerged macrophyte C. demersum showing maximum of bioaccumulation, particularly for Ti, Cr, V, and Pb, which is attributed to the presence of large contact surface with water column for these metals mainly. Emergent species (P. australis and A. donax), on the other hand, were able to separate out the essential metals (Zn and Cu) and obstruct the movement of toxic metals to shoot tissues. In conclusion, aquatic plants, particularly those that are submerged, act as important bioindicators and natural biofilters which is a major role in phytoremediation and wetlands conservation.

**Keywords:** Aquatic Plants; Heavy Metals; Marshland Ecosystem, Bioaccumulation

## 1 INTRODUCTION

Most aquatic bodies of water (lakes and rivers) are heavily contaminated with heavy metals because they are toxic, non-degradable and can readily bioaccumulate. It is one of the important barriers to sustainability and is a cause that results in annual loss of human settlement in these locations [1]. Many studies have revealed that aquatic plants serve as sink for heavy metal pollutants in aquatic environment [2] and that the accumulation of heavy metals of different species vary among different aquatic plants. For instance, floating plants like Eichhornia crassipes [3,4], emergent plants like Typha latifolia, and submerged plants such as hydrilla verticillata, ceratophyllum demersum and Potamugeton malaianus have been proven to have a considerable capacity for heavy metal accumulation. Some species of plants have been utilized due to their ability to take up heavy metals in the water plants such as Water hyacinth and others are aquatic plants that remove them in large numbers. [5,6,7,8]. The ability of aquatic plants to accumulate tends to be lower with submerged than with floating dioecious plants and then lower still with emerging plants, although this will depend on the plant species and the aquatic environment. [9]. The elements sources can be of industry, environment or due to human consumption and can be correlated to the present mineral concentrations in the water. Surface sediments play one of the key roles in the transport of heavy metals in aquatic environment and are an important reservoir for heavy metals. Aquatic plants can passively and/or actively take up significant amounts of water and/or sediment derived metals. The absorption capacity varies, depending on the absorption organs - roots, stems and leaves - of the plants, and is sensitive to fluctuations in the level of the heavy metals in the aquatic environment. [10,11,12] However, knowledge is still lacking about the ability of various aquatic plants to accumulate, and the association between aquatic plants and concentrations of minerals in water and sediments. [13,14] More information should be gathered through direct observations of the different aquatic plants' accumulation ability. In addition, the heavy metals uptake by aquatic plants can be used to obtain time bound information on presence of heavy metals. Minerals in Aquatic ecosystems. Pollution has affected the human living and the quantity of vegetation in the marshes, which didn't receive proper care. Although attention has been directed towards mineral contamination in the lakebed sediments and in the water (suspended particulate matter) [15,16] little is known about the incorporation of heavy metals by aquatic plants. The environment is dominated by large aquatic plant life; and the heavy mineral content of the sediments encouraged us to explore the potential of aquatic plants in the marsh's lakes and rivers to sequester heavy metals. In this study, the bioaccumulation of heavy metal (HMs) in aquatic plants was compared. The objective of our study was to explore the differences by the concentration of heavy metals in the water, sediments and various plant species of the marshes.

## 2 METHODS

### 2.1 Description of the Research Area

The marshes, located in southern Iraq in the Nasiriyah Governorate, are among the largest natural plant reservoirs [17]. They receive runoff from neighboring countries in addition to rainwater. Due to low rainfall, the marshes have suffered from severe water pollution since the 1980s. The pollution is particularly concentrated in the eastern part [18], where people live and depend on the marshes for sustenance, and where buffalo and some bird species live, potentially impacting the aquatic plants in that area.

### 2.2 Sample Collection and Analysis

In October 2024 water and sediment samples were collected at 6 river locations (surrounding rivers, SR) and 10 lake locations (Figure 1). Three of the most common aquatic plant species were collected which were Ceratophyllum demersum, Phragmites australis and Arundo donax.

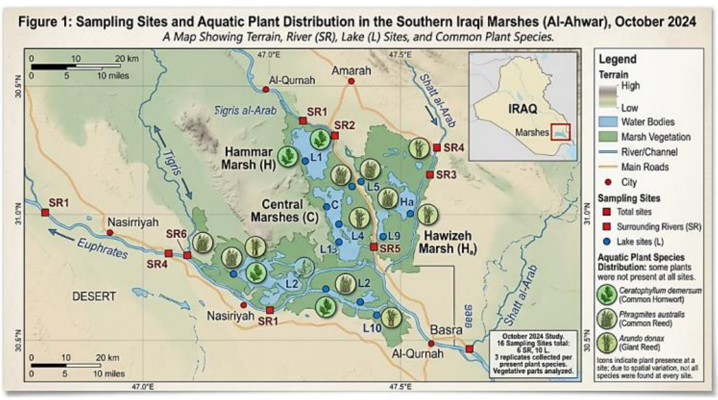


**Figure 1: Sampling sites in the southern marshes.**

All the water samples were collected and transported to the laboratory immediately for initial laboratory processing and the samples were then stored in dark rooms at 4°C. 50 mL of sediment samples were taken in centrifuge tubes that were frozen and stored in the laboratory. Because of the different spatial distribution, some of the plants were not in all the locations so replicates of 3 were taken of each plant species. Vegetative parts of the plants were collected, washed with deionized water and brought in polyethylene bags in refrigerated containers to work done in the laboratory.

The filtered water samples were collected in water sample bottles after passing through a vacuum glass filter and 0.45-μm cellulose acetate membrane. Samples of sediments and aquatic plants have been freeze dried at -50°C for 48 hours, after which they are ground to pass through a 100-μm sieve. Before use all containers were washed in acid to ensure that there were no traces of contamination. A microwave accelerator system (Mars 5, CEM Inc., Matthews, NC, USA) was used for microwave digestion of sediment and plant samples using hydrochloric acid, nitric acid, hydrofluoric acid and perchloric acid, respectively. Detection of heavy metals was performed with an inductively coupled plasma mass spectrometer (ICP-MS; Perkin Elmer SCIEX Elan 9000, Perkin Elmer, Shelton, CT, USA) with a Riton cross-flow spray (Perkin Elmer, Shelton, CT, USA). All metals showed a relative error less than 8% and the percentage of recovery for the reference material (GBW-07310, Medical Technology Research Center, Al-Nahrain University) ranged from 89%-105% for all metals.

### 2.3 Statistical Analyses

Data analysis was done in IBM SPSS Statistics (Version 24) at a significant level of P<0.05. Pearson correlation coefficient was used to assess the correlation of various metal concentrations acquired from the aquatic plants, water and sediments. One-way Analysis of Variance (ANOVA) and Tukey's HSD post hoc range test was used to determine significant differences in concentrations of elements in water, sediment and plant. In addition, an independent t-test was used to see if the accumulation of the various metals differed significantly from that of the plant stems to the plant leaves.

## 3 RESULTS

The concentration of the heavy metals assessed in surface water and sediment samples of the Iraqi marshes is given in the table 1. Generally, the concentration of heavy metal in water samples of surface water were low with below the permissible limit of Grade II environmental quality standard (GB3838-2002). The highest mean concentration was observed for the surface water sample of Chromium (Cr) with a value of 13.4 ± 0.1 μg $L^{-1}$ which was not beyond the standard limit (45.5 μg $L^{-1}$). Heavy metals abundance(ies): They differed significantly among the studied elements in the sediments. Concentrations of the metals V, Co, Cu and Pb in the sediments were greater on average than the background values of these metals suggesting possible accumulation of metals. Conversely, Ti and Cr concentrations in sediments (4398.97 ± 564.1 and 23.44 ± 0.33 mg $kg^{-1}$, respectively) remained below their baseline levels (4562.57 ± 1376 and 26.33 ± 4.5 mg $kg^{-1}$).

**Table 1:** Heavy metal concentrations in water and surface sediments.

| Element | Marsh surface (μg $L^{-1}$) Mean ± SD | ) Grade II( | Marsh deposits (mg $kg^{-1}$) Mean ± SD | ) Background Value( |
|---|---|---|---|---|
| Ti | 0.27 ± 0.1 | 98.57 | 4398.97 ± 564.1 | 4562.57 ± 1376 |
| V | 0.27 ± 0.01 | 48.57 | 254.27 ± 54.6 | 85.57 ± 40.6 |
| Co | 0.00 ± 0.1* | 998.57 | 38.97 ± 2.4 | 13.17 ± 10.4 |
| Cu | 2.97 ± 2.0 | 998.57 | 53.47 ± 10.0 | 21.97 ± 14.4 |
| Pb | 0.00 ± 0.1* | 8.57 | 68.17 ± 9.7 | 20.57 ± 12.0 |
| Cr | 13.4± 0.1 | 45.5 | 23.44± 0.33 | 26.33± 4.5 |

* Statistically significant difference compared to baseline values ($P < 0.05$).

### 3.1 Heavy Metal Accumulation in Aquatic Plants and Phytoremediation Evaluation:

The levels of heavy metals in the macro-aquatic plants (*Ceratophyllum demersum, Phragmites australis, Arundo donax*) vegetatively analysed are presented in figures 1 and 2. These analyses do show that there are important variations, depending on the chemical element as well as on the plant species. Concerning accumulation in the plants, Titanium (Ti) accumulated more than other elements reaching up to 100 mg/kg DW in C. demersum, Zinc (Zn) concentrations in the plants were over 70 mg/kg DW in both C. demersum and P. australis. This high uptake of zinc (Zn) is mainly due to the essential role of zinc as micronutrient in plant metabolism and a high bioavailability of titanium (Ti) in the soil sediments. On the other hand, the concentration of non-essentials and toxic metals, such as lead (Pb) less than 10 mg/kg dry weight and cobalt (Co) less than 3 mg/kg dry weight of plants was the lowest with various plant species, showing minimum transportation mechanism which did not allow entry of toxic ions into the plants organs. In terms of phytoremediation potential, C. demersum is found to have the highest bioaccumulation potential for most of the metals (titanium, chromium, vanadium and lead) as compared to C. quassifolia and C. rotundifolia. This excellent performance can be directly ascribed to its fully submerged culture system that creates a maximum surface area to directly take up ions in the water column. A similar and high accumulation was found in the two emerging species, P. australis and A. donax. However, the plants of T. domingensis demonstrated strategies to take up metals such as zinc, copper and vanadium, being the plant that having the most efficient uptake while having the lowest accumulation. However, overall, these results emphasize that submerged plants are good at bioaccumulation and improve the water quality significantly because they act as water quality purifiers in the water column while the emerging plants are important for cleaning the water column and for stabilizing the swamp.

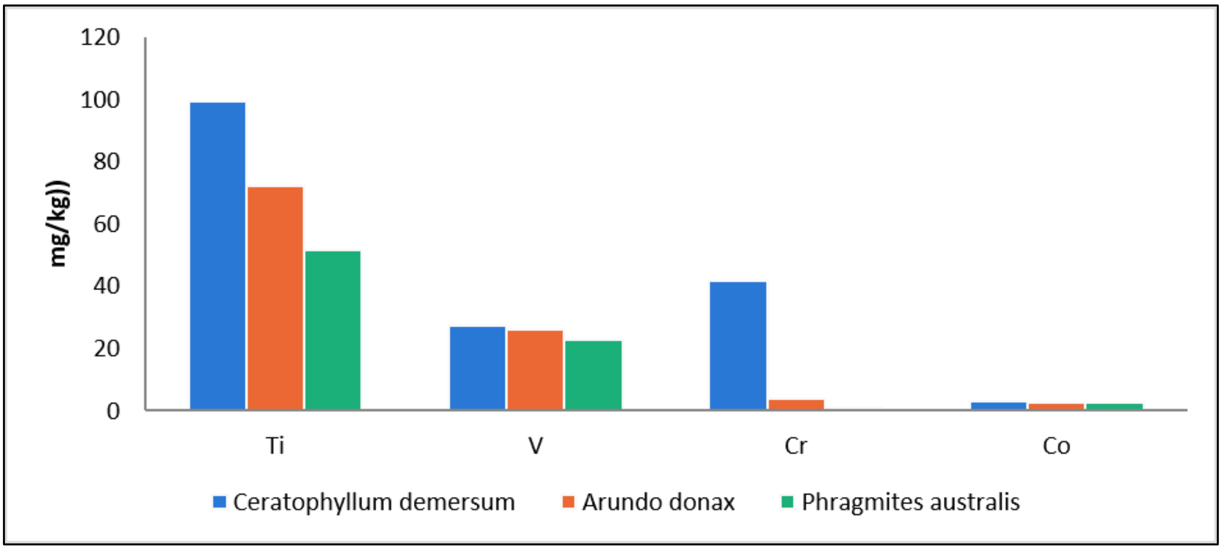


**Figure 2: Heavy metal concentrations in leaves and stems of the chosen aquatic plants (mg $kg^{-1}$,**

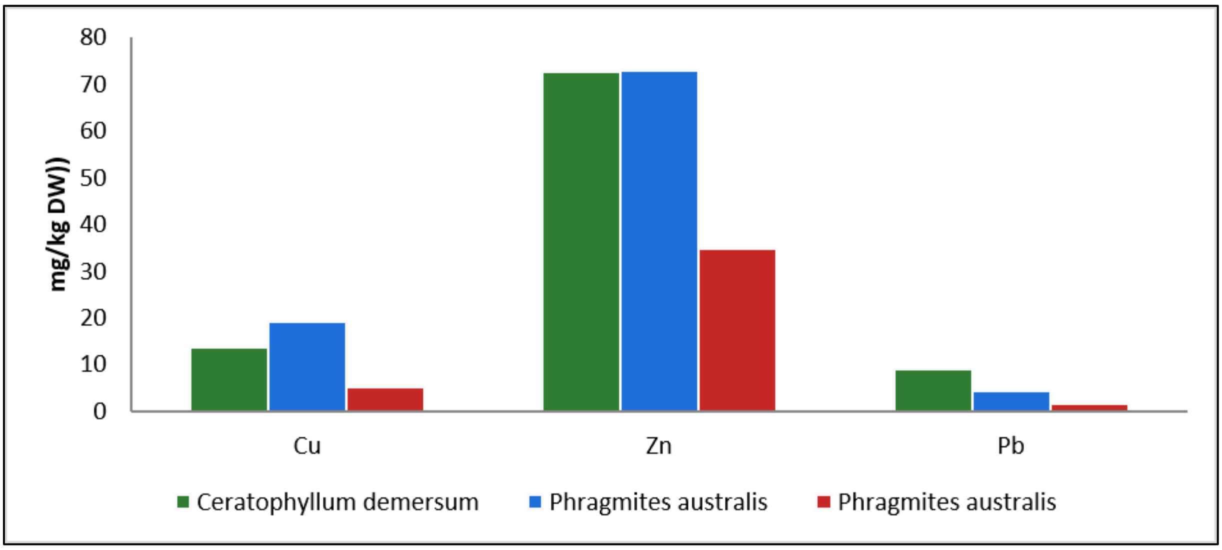


**Figure 3: Heavy metal concentrations in plant of the chosen aquatic plants (mg $kg^{-1}$).**

## 4 DISCUSSION

The low heavy metal concentration found in the surface water of Iraqi marshes (all of them below the second permissible limit) may be due to the complexity of physical-chemical processes which occur in wet lands. Heavy metals, however, seldom persist in the free water column in shallow aquatic systems, with high dissolved organic carbon (DOC) and alkaline pH, they are quickly incorporated into the suspended particulate matter and incorporated into the organic compounds [19] and then settle in the benthic layer. Sediment analyses on the contrary, showed high concentrations of substances and enhanced concentrations of certain metals (mainly vanadium, cobalt, copper and lead) in certain local areas over their geochemical background concentrations. This high bioaccumulation in the sediments draws attention to the importance of benthic layer as an important storage environment for anthropogenic inputs [20]. The build up of these pollutants, particularly lead and copper, is believed to be related to historical agricultural runoff, the municipal wastewater treatment effluent and vehicular exhaust gases from the river channels nearby []. Other elements, principally of a rocky and weathered origin (e.g., titanium and chromium) were also not above geochemical values [21], and therefore do not show signs of contamination from industrial activity. On the other side, the high differences in heavy metal accumulation observed for the large aquatic plants evaluated are due to their physiological, anatomical and environmental adaptations. For most of the metals studied, the bioaccumulation capacity of C. demersum under its submerged condition was the highest, such as Cr, Ti, V and Pb. The highly segmented leaf shape and fully submerged growth directly relate to this outstanding performance, which greatly influences the surface area to volume ratio, directly in contact with the water column. However, C. demersum does not have a true root system and all uptake is direct through its leaves and consequently it is very sensitive to the concentration of metals in the surrounding water, and is an excellent bioaccumulator for water column purification [22].

Emerging aquatic plants use more complex root/ rhizome structure which may directly interact with the water in the pores of sediments [23] and had significant accumulation of essential micronutrients, especially zinc and copper. Their root tissues frequently serve as physical and physiological barriers and large amounts of very toxic non-essential metals (such as Pb) are excluded or bound to cell walls [24] so as to ensure that only small amounts end up in aboveground vegetative organs (stems and leaves). This could be the reason for the significantly lower lead concentrations in P. australis and Phragmites australis than that of C. demersum, T. domingensis showed the lowest overall accumulation efficiency, as the metabolic transpiration rate, as well as the activity of the roots in taking up nutrients through the aerial parts was low, or the defense mechanism proved to be much stronger against the nutrients [25,26]. The role of heavy metal in large aquatic plants in marsh systems is two-fold. These plants on one hand, function as a natural biofilter (phytoremediation), which allows to decrease the concentration of toxic matter in the environment and stabilize the toxic matter in the vegetation matrix [27]. However, at high levels bioaccumulation of the metals in tissues (even within physiologic tolerances) may be an environmental risk due to the biomagnification in the aquatic food chain [28,29]. These macrophytes are an important food source for herbivores, benthic invertebrates, and migratory birds that feed in the Iraqi marshes; hence, it would be important to continuously monitor the dynamics of heavy metals in the marshes for the purpose of conserving their habitats [30].

## 5 CONCLUSIONS

The aim of this study was to evaluate the level of heavy metal pollution in southern marshes (Iraq) through surface water and the sediment samples of three macro-aquatic plants (Ceratophyllum demersum, Parundo donax and Phragmites australis). Vanadium, cobalt, copper and lead concentrations of surface water have not exceeded drinking water standards (Class II), but there were localized concentrations of these constituents that were higher than normal concentrations in sediment samples. The bioaccumulation of the metals was found to be different and variable depending on the species, as the highest uptake was obtained for the majority of the metals for the submerged C. demersum species (especially for Ti, Cr, V and Pb). All aquatic species in general and submerged plants in particular have great potential in phytoremediation process and can be used as significant bioindicator to monitor heavy metal in marsh environment.

## STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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### *Disclosure of conflict of interest*

The author declares no conflict of interest.

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