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Distribution of Element in Four Species of Submergent Plant in East Hammar and Al-Chebiyesh Marshes, Iraq

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ABSTRACT

This study assessed the accumulation of heavy metals in aquatic plants from 2008 to 2018, reflecting changes in environmental conditions due to increased industrial activity and pollution. Aquatic plants, crucial for treating pollution and improving water quality, were analyzed in East Hammar and Al-Chebiyesh marshes. The research showed species-specific differences in element accumulation. *Vallisneria spiralis* (2008) and *Ceratophyllum demersum* (2018) accumulated 30 elements each, while *Potamogeton perfoliatus* (2018) also accumulated 30 elements. *Ceratophyllum demersum* (2008), *Potamogeton crispus* (2008 and 2018), and *Potamogeton perfoliatus* (2018) accumulated 29 elements each. *Vallisneria spiralis* (2018) accumulated 27 elements. *Vallisneria spiralis* (2008) recorded the highest concentrations of iron, boron, vanadium, tin, cesium, bismuth, indium, and cerium. The highest titanium concentration was noted in 2018. The highest aluminum accumulation was in *Vallisneria spiralis* (2008). *Potamogeton perfoliatus* accumulated the most barium, strontium, and molybdenum, with concentrations of 2682, 629.7, and 89.9ppm, respectively. *Potamogeton* species consistently accumulated 0.4 ppm of antimony and the highest zinc concentration at 91.8ppm. These findings underscore the distinct element accumulation capabilities of different aquatic plant species.

INTRODUCTION

Wetlands provide a habitat for several unique aquatic plants that help create ecosystems distinct from other systems in the world. The occurrence of aquatic plants is one of the distinguishing characteristics of wetlands, which contain approximately 40% of the total species in the world **(Van der Valk, 2006)**.

Macrophytes can cover large areas and are the dominant primary producers in aquatic environments **(Aravind, 2009; Al-Asadi, 2014)**. The role of submerged aquatic plants is important in improving the function and construction of the aquatic ecosystem through their effective contribution to increasing and supporting biological diversity, being a source of food and shelter for many aquatic organisms such as fish, invertebrates and birds, and providing places for spawning, breeding, and feeding fish, as well as protecting young fish from predators and offering surfaces for plankton adhesion **(Al-Abbawy *et al*., 2013)**. It can also be used as an indicator of nutritive status of water body **(Arts, 2002)**. Moreover, it is being used in the treatment of sewage and industrial waste due to its high ability to absorb nutrients **(Solano *et al*., 2004)**.

Submerged plants are an important indicator of the presence of pollution in any aquatic environment compared to floating or protruding plants since they are completely submerged in the water column, and their roots are attached to the sediments **(Rezania *et al*., 2016)**. Furthermore, growing in polluted water bodies can absorb the toxic substances that enter the food chain and can pose a serious threat to environmental and human health **(Aravind, 2009)**. Essential metals like Mg, Fe, Mn, Zn, Cu, Mo, and Ni are accumulated by plants, while certain plants also collect elements without any necessary biological purpose **(Brankovic *et al*., 2015)**.

Various studies have investigated the heavy metal levels in aquatic plant **(Mahmood, 2008)**. They studied the content of 18 species of aquatic plants of metals (cadmium, cobalt, copper, iron, manganese, nickel, lead and zinc) in some wetlands in southern Iraq, and the results showed that all plant species were distinguished by a high iron absorption compared to the remaining seven trace elements. The results of the analysis of heavy metals in sediments and aquatic plants found in the marshes of southern Iraq (Al-Hawizeh and Al-Hammar) showed that their concentrations were higher in sediments compared to aquatic plants **(Awad *et al*., 2008)**.

The investigation focuses on how the accumulation of certain heavy metals affects the physiological and anatomical characteristics of various *Potamogeton* species. Based on their effectiveness in absorbing metals and unique morphological responses to pollutants, *Potamogeton crispus* and *Potamogeton perfoliatus* can be utilized as bioaccumulators and bioindicators of silver (Ag) and copper (Cu) contamination **(Al-Saadi *et al*., 2013)**.

The concentrations of some heavy metals in the sediments and water of the Euphrates River near the center of the city of Nasiriyah and their accumulation in two types of aquatic plants *Ceratophyllum demersum* and *Phragmites australis* were estimated. It was found that the highest concentrations of the studied elements were found in sediments compared to what was found in water and plants, which had lower concentrations. It was also found that the highest concentration of these elements were accumulated in *C. demersum* plants compared to *P. australis* plants **(Al-Awady *et al*., 2015)**. Concentrations of heavy metals Zn, Pb, Co, Cd, and Ni were estimated in water and sediments and in *Vallisneria spiralis* and *Typha domingensis* at two sites in the Al-Chibayish Marsh - Dhi Qar Governorate - southern Iraq. The study showed that the concentration of heavy metals was the highest in water, followed by sediment, and the lowest in the two plants studied. The highest concentration of the recorded elements was in *T. domingensis* plants compared to *V. spiralis* plants **(Al-Khafaji, 2015)**.

The accumulation of elements Fe, Cd, and Pb in water, sediments, and two aquatic plants, *C. demersum* and *Hydrilla verticillata*, was studied east of the Euphrates River in the Abu Jarak area, located in Babil Governorate - Iraq. It was noted that the studied elements had a higher concentration in *C. demersum* plants compared to *H. verticillata* plants **(Habeeb *et al.*, 2015)**. While **Hanef (2016)** studied the impact of some heavy metals on qualitative and quantitative of producer organisms in the Shatt al-Arab River and explained that *C. demersum* have the highest concentration of the copper, lead, manganese, zinc and cobalt, as the accumulation rates in it were higher than the rest of the studied species.

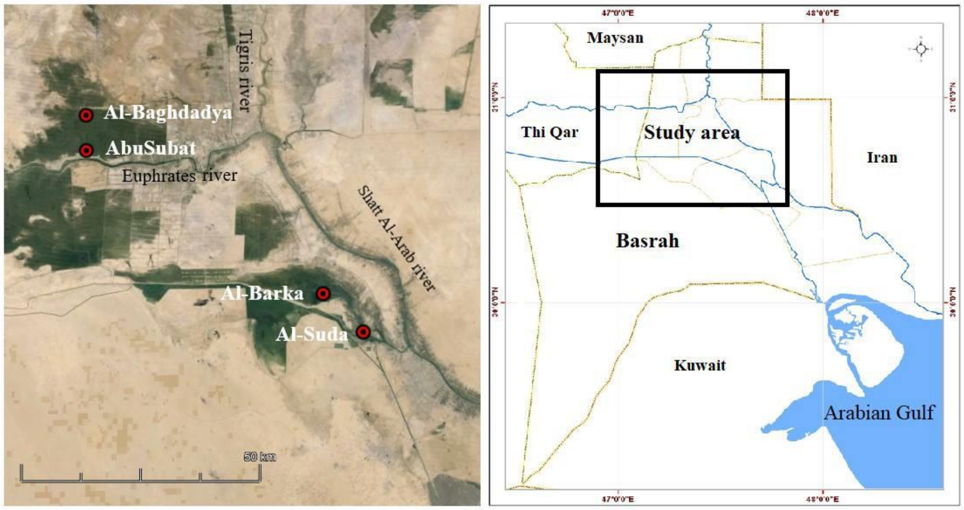
Al-Atbee (2018) determined the concentrations of heavy elements Cr, Ni, Cd, and Pb in their solid and dissolved phases of sediments, water, and four plants: *P. australis*, *Schoenoplectus litoralis*, *T. domingensis* and *C. demersum* in the Al-Chibayish Marsh of Dhi Qar Governorate in southern Iraq. It was noted that the highest concentrations were recorded in the dissolved phase of water and sediments, as for the plants, their order in accumulating the heavy elements studied was as follows: *C. demersum* > *P. australis* > *T. domingensis* > *S. litoralis*. Utilizing SEM/EDX, the elemental composition of *Potamogeton pusillus* leaves that were taken from the Shatt al-Arab River and the al-Hawizeh marshes in southern Iraq were analyzed. The findings indicate that the al-Hawizeh group had greater amounts of F, Na, and Mg **(Al-Saadi *et al*., 2021)**.

In this study, the elemental composition of plant species in the submerged plants in the marshes of eastern Al-Hamar and Al-Jubayish was determined.

MATERIALS AND METHODS

1. Study area

The southern Iraqi marshes ranged from 8.000 to 25.000km^2, making them the largest wetland ecosystem in the Middle East **(UNEP, 2004)** and we chose two major marshes in southern Iraq including Al-Chebayish and East Hammar and Four stations in each marsh (Map. 1). To collect submergent macrophytes monthly during 2018 and compare them with those collected in 2008, the study focused on four of the most common aquatic plant species: *Ceratophyllum demersum, Vallisneria spiralis, Potamogeton crispus,* and *Potamogeton perfoliatus*.



Map 1. Study stations: (1) Al-Suda , (2) Al-Barka, (3) AbuSubat, (4) Al-Baghdadya

2. EDX of analysis plant

EDX spectroscopy was conducted at Basrah University/ Science College. The elemental composition of the macrophyte and their potential for monitoring heavy metals was assessed by studying plant uptake. Three duplicates for each sample were collected from the collected 4 species of submergent macrophyte from the Al-Chebayish and East Hammar marshes, and 30 elements were measured in aquatic plant including Al, As, B, Ba, Cd, Ce, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Ti, Tl, V, Zn, Ag, Be, Bi, Cs, Fe, In, Li, and Rb. SEM/EDS data were collected for all samples, measurements and diagnostic features of the species were characterized. Herbarium specimens were prepared and saved in Basrah University Herbarium. Plant species were identified by a light microscope and photographed **(Masson *et al*., 2010)**.

RESULTS AND DISCUSSION

The result of metal composition in plant species explained the difference between submerged species in their ability of element accumulation, the species *V. spiralis* 2008, *C. demersum*, 2018, *P. perfoliatus* 2018 accumulate 30 elements, while *C. demersum*. 2008, *P. crispus* 2008, *P. crispus* 2018, *P. perfoliatus* 2018 accumulate 29 elements, and *V. spiralis* 2018 accumulate 27 elements. This may be due to the different ability of plant species to accumulate elements in their textures, and this may be attributed to ecological factors during sampling time like temperature, pH, salinity which agree with **Demırezen and Aksoy (2004)** and **Al-Mayah and Al-Asadi (2018)**, who stated that the accumulation of elements depends on biotic and abiotic factors, such as temperature and pH.

The highest concentration of Al accumulation was recorded in the *V. spiralis* during 2008 (Fig. 1). This may be due to *V. spiralis* has roots which may represent the initial site of action in submersed macrophytes and wetland plants. Moreover, sediment is likely to be the primary source for Al uptake in aquatic plants **(Genseme & Playle, 1999)** in addition to the fact that the *V. spiralis* has leaves that have a larger area compared to other species. *C. demersum* was the highest species capable of accumulating Mn, as the concentration of the element in its tissues reached 4862ppm during 2018 (Fig. 1). This result agrees with that of **Borisova *et al.* (2016)** who postulated that *C. demersum* leaves have the ability to accumulate manganese. **Rizwan *et al*. (2018)** explained the potentially toxic elements (PTEs) and added that all nutrients are chemically similar. For example, phosphate is chemically similar to arsenic. Therefore, arsenic can be easily absorbed, and in this study, *V. spiralis* observed during 2018 (Fig. 1) had the highest accumulation of As in addition to the fact that *V. spiralis* has roots which help absorb As. Many studies have shown that it enters the root tissues through phosphate transporters **(Meharg & Hartley-Whitaker, 2002)**.

Borisova *et al*. (2016) found that the amount of nickel accumulation in submerged plants is higher than its concentration in water at the study sites. The presence of this element inside the plant is related to its physiological role in the plant metabolism, such as *C. demersum* in 2008 which recorded the maximum value of nickel collected in its tissues in this study (Fig. 2). The current result agrees with those of **Al-Awady *et al*. (2015)**, **Hanef (2016)**, **Zaki *et al*. (2016)** and **Al-Atbee (2018)** since they found the concentrations of element in this species was more than their concentrations in other aquatic plants.

The result explains that *V. spiralis* in 2008 recorded the highest concentration of Ce, B, V, Sn, Fe, Bi, In, and Cs, respectively (Figs. 1, 2, 5, 6, 7) and the largest value of Ti (Fig.4) documented during 2018. This is due to the fact that *V. spiralis* was one of submergent macrophyte with an ability to remove heavy metals from water and sediments **(Keskinkan *et al*., 2003; Saygıde˘ger & Do˘gan, 2004)**. Additionally *V. spiralis* is a freshwater plant that has submerged, linear, strap- or tape-shaped leaves that can grow up to 10mm wide and 100cm or longer when grouped in a basal rosette. It also has small stems, horizontal runners, and fibrous roots **(Lowden, 1982)**, which make up the majority of the metal intake. Heavy metals are taken up via the cuticle's passive mobility. Minerals are drawn inward by the polyglalacturonic acid of the cell wall and the negatively charged cutin and pectin polymers of the cuticle. The movement of positively charged metal ions is caused by this increased charged density inside **(Prasad, 2005)**.

Ali *et al*. (2013) discuss how, in addition to the presence of nutrients that plants need, many non-essential heavy elements accumulate within their tissues, for example, cadmium. Our results showed that plant species differed in their ability to accumulate cadmium in their tissues, and the highest ability was in *V. spiralis* (Fig. 3).

The results indicated that the highest concentrations of accumulated elemental Mercury (Hg) were found in *Potamogeton crispus* with 1.9ppm and *Ceratophyllum demersum* with 1.8ppm during 2008 (Fig. 3). This is likely due to their presence as rooted submergent plants in polluted water, as discussed by **Ali (1999)**. These plants have demonstrated an ability to accumulate significant amounts of mercury in a concentration-duration dependent manner, as highlighted by **Ali *et al.* (2000)**. This characteristic suggests their potential utility in phytoremediation efforts aimed at mercury-polluted water bodies.

According to **Idaszkin *et al*. (2014)**, given the physiological barrier that prevents some metals from moving to the plant's aboveground sections, certain metals are mostly collected in the root, whereas other metals can move easily to the stem and leaves, and this finding matches the results of the present study, as the submerged plant varied in their capacity to collect Cr in their tissues. The highest concentrations were recorded in *V. spiralis* 2008, *C. demersum* 2018, *P. crispus* 2018, respectively (Fig. 3). It was distinguished from the results that the two species *P. crispus* recorded the highest Cu values accumulated during 2018 (Fig. 3). This may be ascribed to the strong resistance to stress brought on by pollution, and its ability to absorb nutrients is often used in wetland restoration **(Jin *et al*., 1994; Xu *et al*., 2015)**. As noted by **Lu *et al.* (2012)**, *Potamogeton crispus* is among the few species capable of thriving in nutrient-rich Chinese lakes. In contrast, *Potamogeton perfoliatus* demonstrated the highest capability among species studied to accumulate barium (Ba), molybdenum (Mo), strontium (Sr), and silver (Ag), with concentrations in its tissues reaching 2682, 629.7, 89.9, and 2.6ppm, respectively (Figs. 2, 5, 6). Additionally, the genus *Potamogeton* consistently accumulated antimony (Sb) at a level of 0.4ppm across its species (Fig. 4). These characteristics make them significant as biological indicators in the Iraqi marshes, where they are prevalent and capable of accumulating substantial amounts of elements, as noted by **Matache *et al.* (2013)** and **Al-Asadi *et al.* (2022)**. The results showed that all the submerged species recorded the same concentrations of thallium element (Tl) during 2008 and 2018, while the device did not detect its concentration in *V. spiralis* 2018 (Fig. 2).

Al-Khafaji *et al*. (2016) indicated in their study the possibility of using the *C. demersum* as a good indicator for the accumulation of trace elements including cobalt since we found in our current study that the highest level of Co was documented in *C. demersum* during 2018 (Fig. 4). This may be due to the nature of the plant that have the capacity to absorb this element from surrounding water and sediments, and the surface area of the plant branches that twigs over several other species **(Zaki *et al*., 2016)**.

P. perfoliatus in 2018 verified the highest value for Pb concentration (Fig.4) collected in its tissues since *P. perfoliatus* is the most effective accumulator of trace elements including lead **(Matache *et al*., 2013)**. The results explain that the *P. perfoliatus* 2018 recorded the high concentration of Se which reach 113ppm (Fig. 5). The reason may be due to that selenite is chemically analogous sulphate, therefore, the former can be readily absorbed **(Rizwan *et al*., 2018)**. Most studies have shown that Se shows a high affinity for sulfate transporters **(Shibagaki *et al*., 2002)**. Species of the genus *Potamogeton* recorded the highest values of Zn, and the highest values (91.8ppm) were accumulated in the tissues of the species *P. perfoliatus* during the 2018 (Fig. 5). This is because Zn is an element necessary for the good functioning of living organisms, but its excess is harmful. It is one of the more portable metals within the environment and is actively taken up roots. Elevated concentrations of Zn can be an indicator of industrial pollution in rivers **(Skorbiłowicz *et al*. 2016)**.

The results indicated that species such as *Vallisneria spiralis* in 2008, *Ceratophyllum demersum* in 2018, and *Potamogeton perfoliatus* in 2018 recorded the same concentration of beryllium (Be), while this element was not detected in other species (Fig. 7). *Ceratophyllum demersum* in 2018 showed elevated concentrations of both lithium (Li) and rubidium (Rb). This phenomenon may be attributed to the plant's structure, as *C. demersum* lacks roots but possesses finely divided leaves that resemble roots. This structural feature increases the plant's surface area to volume ratio, enhancing its ability to absorb heavy metals from the water column, as discussed by **Li *et al.* (2015)**. Further details are exhibited in Fig. (8).

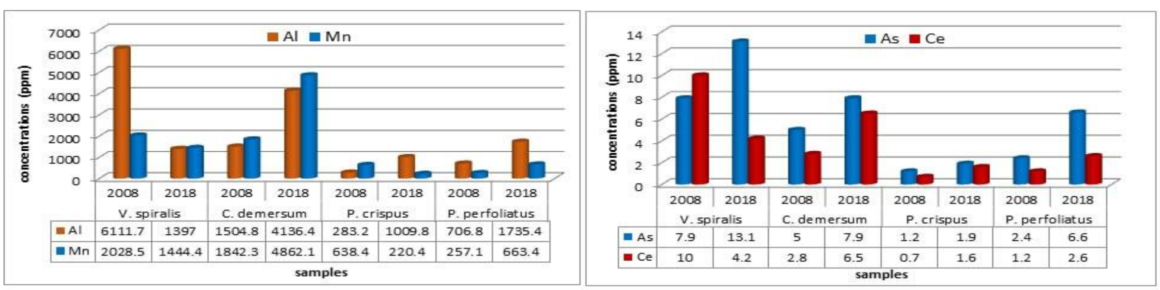


Fig. 1. Al, Mn, As and Ce concentration accumulated in plants species

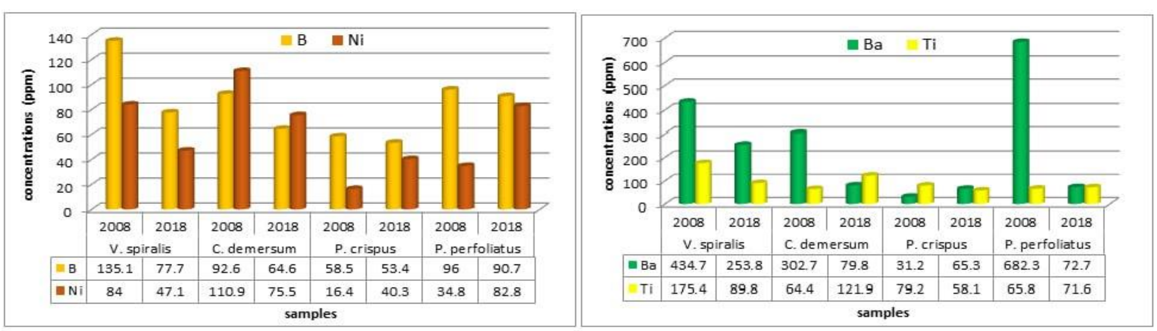


Fig. 2. B, Ni, Ba and Ti concentration accumulated in plant species

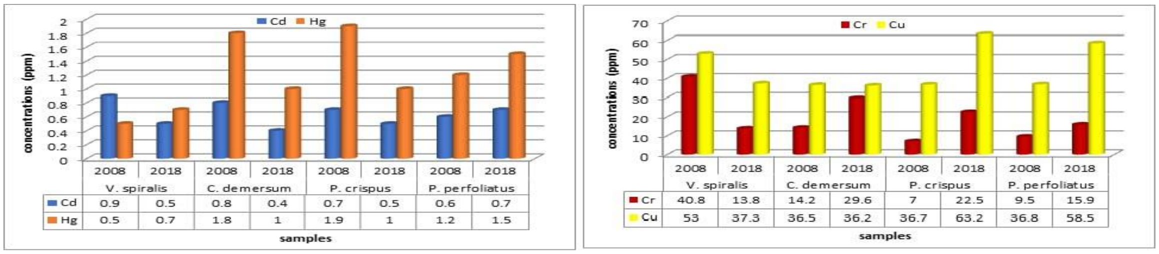


Fig. 3. Cd, Hg, Cr and Cu concentration accumulated in plants species

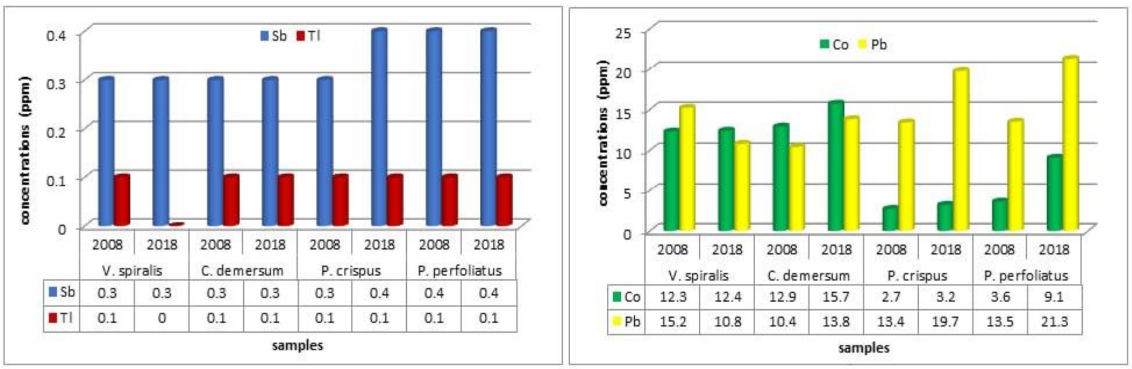


Fig. 4. Sb, Tl, Co and Pb concentration accumulated in plant species

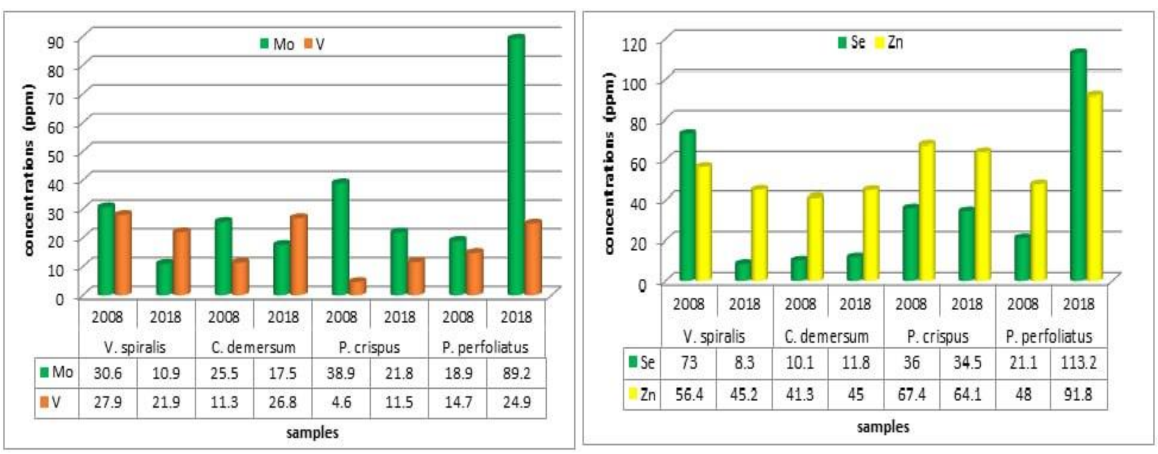


Fig. 5. Mo, V, Se and Zn concentration accumulated in plant species

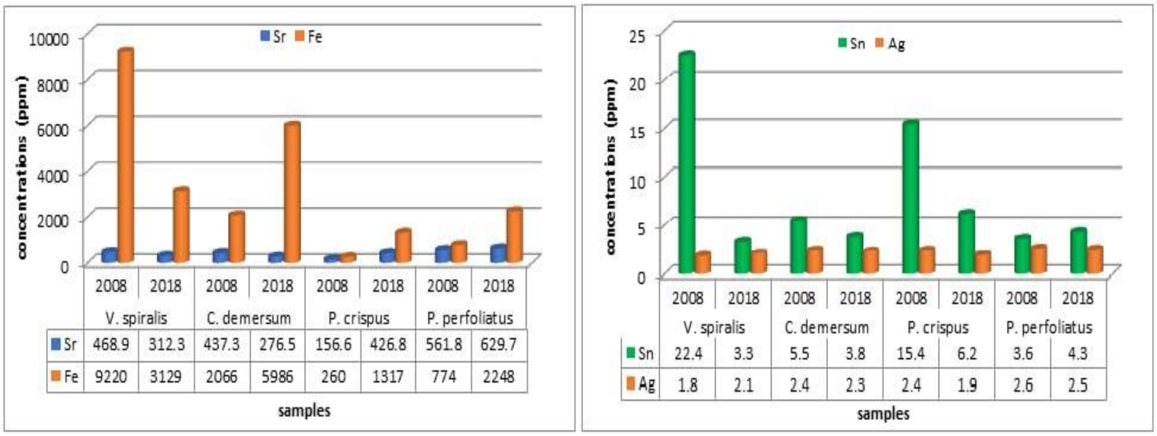


Fig. 6. Sr, Fe, Sn and Ag concentration accumulated in plant species

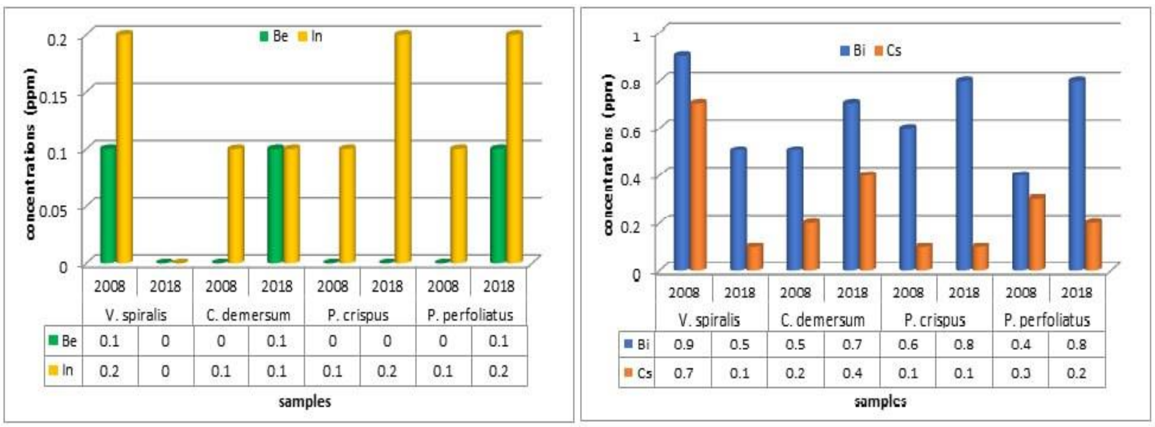


Fig. 7. Be, In, Bi and Cs concentration accumulated in plant species

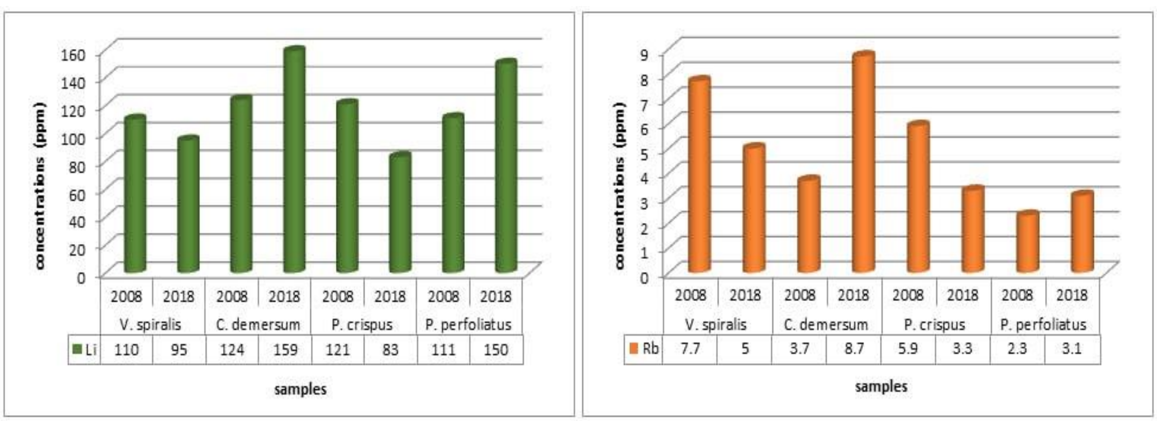


Fig. 8. Li and Rb concentration accumulated in plant species

CONCLUSION

The study observed differences in the accumulation of heavy elements among aquatic plants, noting that plants collected in 2018 exhibited higher levels of pollutant accumulation compared to those collected in 2008. Among the most commonly accumulated elements in aquatic plants were aluminum (Al), cadmium (Cd), and iron (Fe). These findings highlight the variability in pollutant uptake by aquatic plant species over time, reflecting changes in environmental conditions and pollution levels.

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