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Original Article

Bioconcentration factor of heavy metals in some aquatic plants in the Shatt al-Arab River and the possibility of using them as bioindicators of heavy metal pollution

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Abstract: This study was conducted to measure the concentration of heavy metals (manganese, copper, zinc, iron, and cadmium) in water and aquatic plants of *Ceratophullum demersum* as a submerged, *Phragmites australis* as an emergent, and *Lemna minor* as a floating aquatic plant to calculate their bioconcentration factor and compare them in aquatic plants to find out proper one as heavy metal bioindicator. Three stations were selected for sampling from the Shatt Al-Arab River, based on the differences in their characteristics in terms of human activities and distribution of aquatic plants. The results showed that *C. demersum* can absorb most of the heavy metals, followed by the *Ph. Australis*. The manganese element was the distinguished element with the highest accumulation rate. Based on the results *C. demersum* can be suggested as a bioindicator of heavy metal pollution in the Shatt Al-Arab River.

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Introduction

Heavy metals have a specific density of more than 5 g/cm^3 (Polle and Schutzendubel, 2002). Their concentration in the environment is low, known as trace elements (Minkoff and Baker, 2001). Heavy metal pollution leads to the destruction of living organisms if they are found in high concentrations (acute), cause congenital malformations, skin infections, reducing fertility, sterility, stunting, or reducing the number of species, at concentrations higher than their normal levels for long-term exposure periods (chronic) (Taobi et al., 2000). Increasing the concentration of heavy metals can destroy cells by replacing some active groups of enzymes, inhibiting their effectiveness, and releasing effective oxygen radicals (ROS) (Scheid et al., 2017). Heavy metals enter the aquatic environment from natural and industrial sources (Singh et al., 2020). They enter the water due to ion exchange or adsorption on the outer surfaces of granules of clay and organic materials or through joint precipitation through rock weathering, as some elements are precipitated and associated with sediments (Karak et al., 2010). The assessment of heavy metals in the aquatic environment is important in controlling pollution because of their ability to move through the food chain or accumulate in the tissues of aquatic organisms (Rekasi et al., 2006; Arkadiusz et al., 2007).

The use of different aquatic organisms as bioindicators of pollution for different types of pollutants, such as heavy metals, is popular, and these organisms are used in many environmental monitoring programs (Duruibe et al., 2007). It also gives a clear picture of the environment that is exposed to stress, such as chemical stress by accumulating some pollutants such as heavy metals, and they help to understand the effects of these elements on their vital activities (Kakar et al., 2010). The accumulation of heavy elements in plant tissues varies according to the types of plants, soil and water's physical and chemical properties, and the specificity of absorption, transfer, and accumulation of elements. Increasing the level of heavy metals within plant tissues leads to their aggregation in different parts of the plants, or

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converting them to other non-toxic forms that can be distributed and used again in metabolic processes (Memon et al., 2001). Many studies used aquatic plants as bioindicators of pollution (Matache et al., 2013; Burada et al., 2014; Hanaf, 2016; Al-Edani et al., 2019).

This study aimed to measure the concentration of heavy metals of manganese, copper, zinc, iron, and cadmium and calculate their bioconcentration factor in *Ceratophullum demersum* as a submerged, *Phragmites australis* as an emergent, and *Lemna minor* as floating aquatic plants and to compare the concentrations of the heavy metals in these aquatic plants to find out their efficiency to remove heavy metals as an indicator of pollution.

Materials and Methods

Sample collection: Three stations were selected to collect samples from the Shatt al-Arab River based on the differences in their characteristics in terms of human activities and their distinction by the presence of aquatic plants, their diversity, and densities. The first station was Al-Sharsh, about 20 km south of Qurna. The second one was on Sindibad Island, about 7-8 km north of Basrah, 36 km away from the first station. The third station was in the Al-Amiya area, near the former fertilizer plant in Abu Al-Khasib located 22.29 km from the second station. Monthly samples of water and aquatic plants were collected from the study stations. For water sample collection, we used 10 L pre-washed plastic bottles. For the aquatic plants, samples were collected by hand, washed with river water to remove suspended substances, and kept in nylon bags until reaching the laboratory.

Extraction of heavy metals from water samples: According to APHA (2005), a 100 ml sample was taken after shaking the bottle and mixing them well, and 5 ml nitric acid was added. Then, it was heated on a hot plate leaving it to near drying, and 5 ml of nitric acid was added to ensure the sample was digested entirely and left to cool and kept in special containers after being diluted with ion-free distilled water to a specific volume until measurement with a flame atomic absorption spectrophotometer (Unicam SP9 Air Acetylene Pye). The results were expressed in μg/L.

Measurement of heavy metal in aquatic plants: The aquatic plants were washed with tap and distilled water in the lab, respectively. Then, they were dried in an electric oven at 85°C for 24 hours, ground and passed through a laboratory sieve with a mesh of 40, and prepared to measure the heavy metals according to APHA (2005). One g of aquatic plant powder was weighed and placed in25 ml pyrex flasks, then nitric acid (HNO_3) and perchloric acid ($HClO_3$) were added at a ratio of 1:3 and its nozzle was closed with a glass lid. The samples were shaken out, then left for 24 hours under a vacuum, and the flasks were placed in a water bath for an hour to speed up digestion. 2-3 ml of distilled water were added to the samples, then put the beakers on a hot plate at 70°C and left till the volume reached 2 ml. The centrifuge was used to eliminate the sediment, and the volume of the filtrate was completed to 50 ml with distilled water and kept in bottles until examination. Heavy metals were measured using a Flame Atomic Absorption Spectrophotometer, and the result was expressed as μg/g dry weight.

Bioconcentration factor (B.C.F): The bio-concentration factor was calculated according to Kumar et al. (2009) by dividing the total concentration rate of each element in the used tissue (A) by its concentration in water (B), i.e. B.C.F = A/ B. According to the US Environmental Protection Agency (USEPA, 2012), the substance was considered as not bioaccumulative when it is less than 1000, bioaccumulative in less than 1000, and hyper accumulative bioaccumulation when greater than 5000,

Results and Discussions

The use of water for industrial and agricultural purposes is led to its contamination with heavy metals (Al-Asadi et al., 2020). Also, the environmental impact of heavy elements in the water system is related to their distribution between the liquid and solid phases in the water body (Aldoghachi and Altamimi, 2021). Aquatic plants provide proper

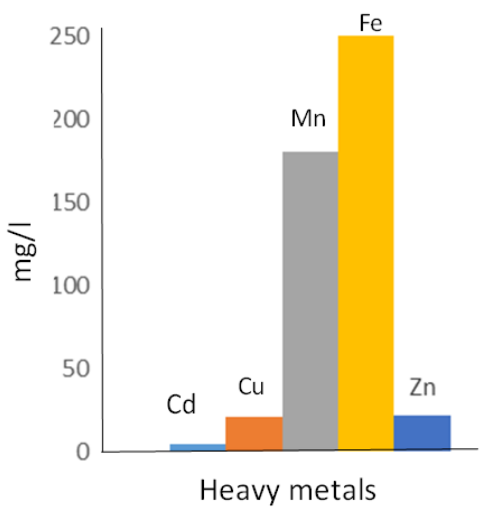

Figure 1. The concentration of heavy elements in water of station 1.

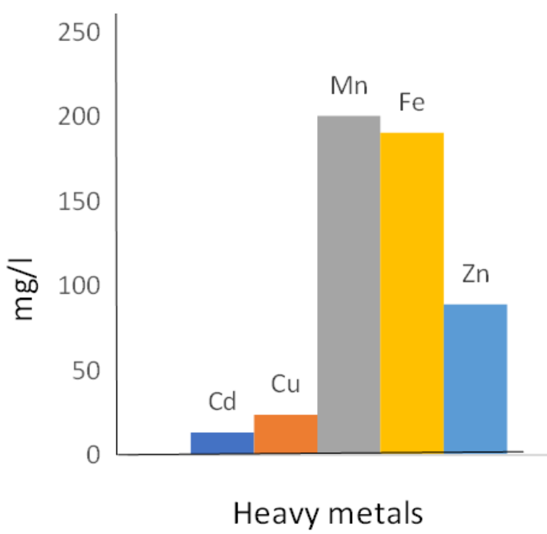

Figure 2. Concentration of heavy elements in water of station 2.

evidence of water pollution with heavy metals due to their ability to accumulate these elements in their tissues (Coleman et al., 2001). In addition, they grow rapidly and adapt to living in different environments with simple environmental requirements (Dirilgen, 2001). Also, the concentrations of heavy metals in the bodies of plants may differ according to the plant species (Forstner and Wittman, 1981). The current study showed the concentrations of some heavy metals in three aquatic plants in the Shatt Al-Arab, which may give a clear picture of the degree of pollution of the river with heavy metals. Memon et al. (2001) pointed out that the aquatic plants clearly show the river's pollution with heavy metals better than the

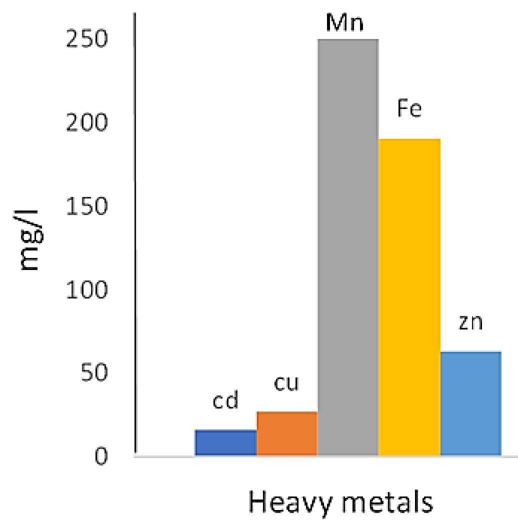

Figure 3. Concentration of heavy elements in water of station 3.

water and sediments. Because aquatic plants are found submerged in the water, prominently or on the cliff, they obtain these elements either by absorbing them from the sediment through their root system or by directly absorbing them (Forstner and Wittmann, 1981; Ekval and Greger, 2002).

The high concentration of heavy metals during the summer and spring is due to the rise in temperatures and increasing the evaporation rates or agricultural activity that increase the load of the fluxes of salts and fertilizers (Alqam, 2002). The concentration of the heavy metals decreased during the autumn and winter, which can be due to the occurrence of rain and increasing water discharge (Hanaf, 2016; Lateef, 2020). The Fe and Mn, followed by Zn had higher concentrations (Figs. 1, 2, 3), and these results agreed with the study of Al-Khuzaie et al. (2020). This may be due to the exposure of the study area to human and agricultural wastewater (Al-Asadi et al., 2019). In addition, the low concentration of heavy metals in river water may be due to the tendency of these elements to accumulate in the bodies of phytoplankton, aquatic plants and other aquatic organisms (Vardanyan et al., 2008; Aldoghachi and Altamimi, 2021), or to adsorb on sediment surfaces (Dhir and Kumar, 2010). Many heavy metals react chemically and physically with other natural substances in the aquatic environment, which changes their oxidative state; thus, they are concentrated,

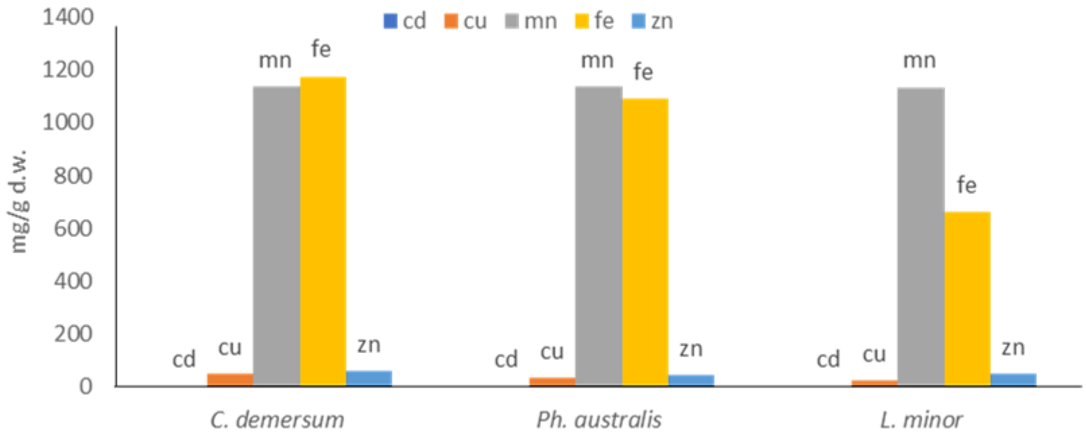

Figure 4. Concentrations of heavy metals in the studied aquatic plants in station 1.

precipitated, or adsorbed on the surfaces of particulate matter (Dube et al., 2001).

The results did not reveal a significant variation in the concentrations of the heavy metals in the different stations, and the reason for this may be due to the similar geological nature of the river (Essa, 1995). The river passes through agricultural lands, and the adjunct lands lead to the addition of these elements into the river water (Al-Khuzaie et al., 2020). The increase in the movement of boats and ships can increase river pollution (Al-Amara, 2001). The loaded oil spilled through the tidal water bodies from the downstream waters of the Shatt al-Arab during the whole year (Aljabri et al., 2016; Al-Asadi et al., 2019).

Based on the results, the order of concentration and abundance of heavy metals in the Shatt Al-Arab waters during the study period was Fe > Mn > Zn > Cu > Cd. Iron is one of the basic elements for most living organisms, and it is usually more abundant in the aquatic environment (Hassan et al., 2008), Also the Shatt Al-Arab sediments contain a high percentage of dark minerals rich in iron, which adds a large proportion of this element to the water during decomposition and dissolution (Albdran et al., 1996).

The results showed that the submerged aquatic plant, *C. demersum* possesses the highest concentration of Cu, Pb, Mn, Zn and Cd, as its accumulation rates were higher than other plants, and this is consistent with findings of Jamnicka et al. (2007). The results also revealed a high concentration of Mn and Zn, indicating that these plants tolerate high levels of these elements. This may be due to the accumulation and storage of these elements within the plant tissues in non-toxic forms, or it has a special mechanism to tolerate high concentrations of elements (Memon et al., 1980), or it absorbs elements in high concentrations and converts them to inert forms in the vacuoles (Peverly, 1988). Aquatic plants that grow near bridges and population areas with heavy traffic may have a major role in increasing the concentrations of some heavy elements in the tissues of aquatic plants, especially zinc (El-Gamal, 2000). Dirilgen (2001) indicated that the elements in natural systems are not prepared for free uptake by the plant but rather in the form of soluble complexes, and this depends on the physical and chemical conditions of the surrounding medium, which makes a strong impact on the processes related to the absorption of elemental ions.

The order of heavy elements in aquatic plants according to their concentration was Mn > Fe > Zn > Cu > Cd. The order of aquatic plants in terms of their concentration of heavy elements was *C. demersum* > *P. australis* > *L. minor* (Figs. 4, 5, 6). The concentrations of heavy metals in aquatic plants have varied, and this may be due to the species of aquatic plants and may be attributed to their tolerance to high concentrations of heavy metals (Memon et al., 2001).

The bioconcentration factor was adopted as a measure to infer the possibility of using aquatic plants and phytoplankton as evidence of pollution. As a result, the rates of bioconcentration in the

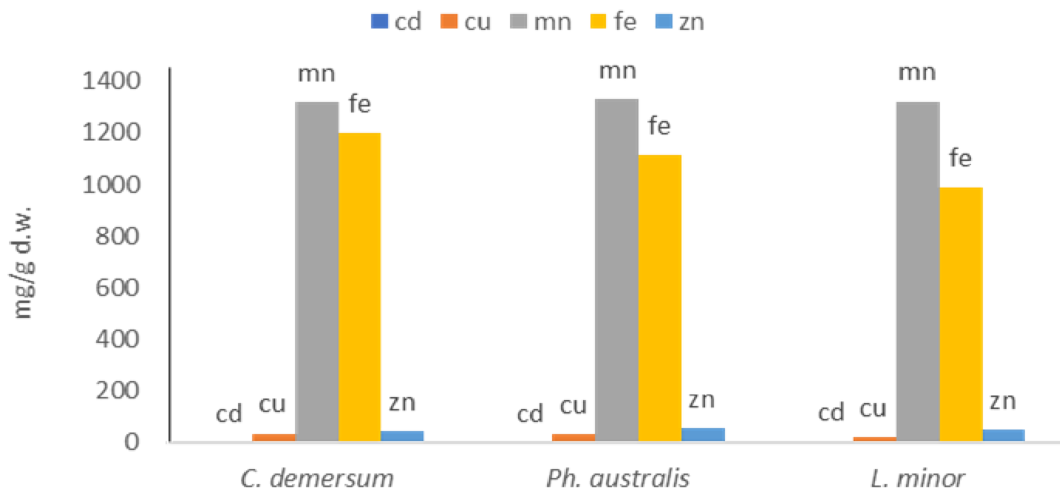

Figure 5. Concentrations of heavy metals in the studied aquatic plants in station 2.

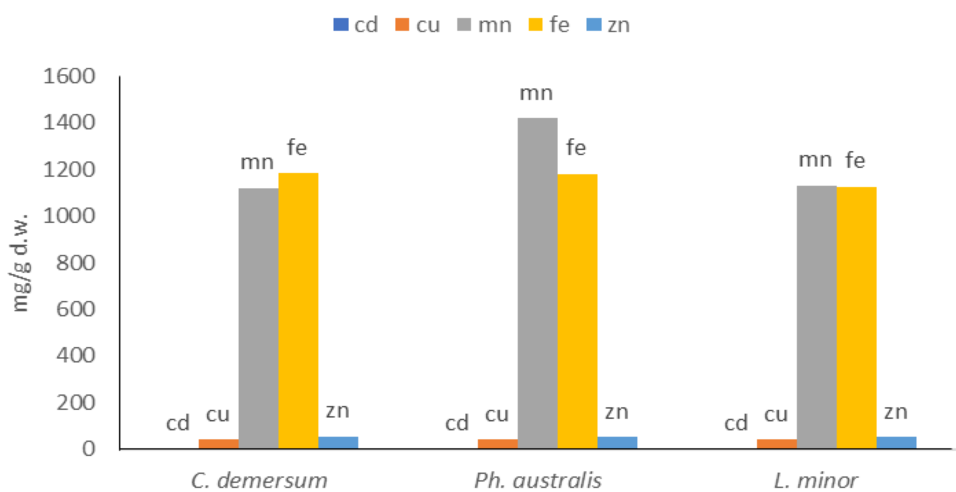

Figure 6. Concentrations of heavy metals in the studied aquatic plants in station 3.

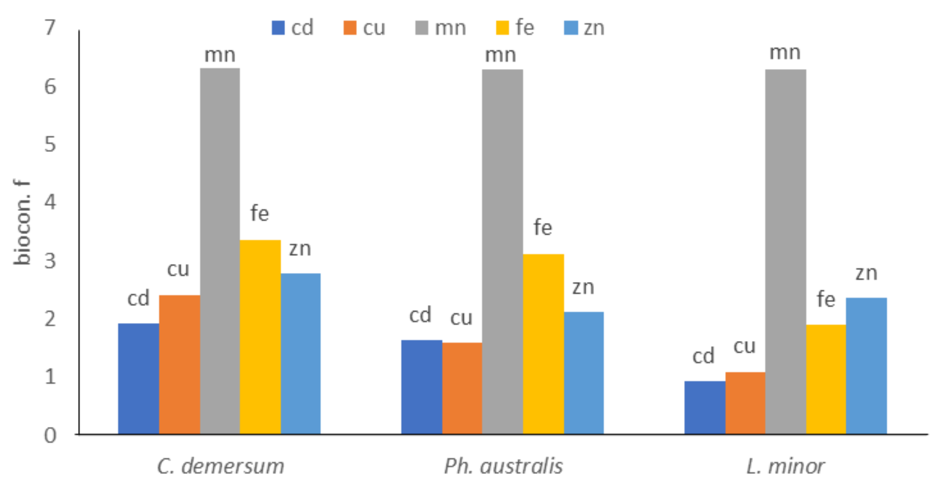

Figure 7. Bioconcentration factor of heavy metals in the studied aquatic plants in station 1.

C. demersum were higher than *P. australis* and *L. minor* for all the studied elements (Figs. 7, 8, 9), therefore, *C. demursum* can be considered as a biological index for heavy elements in the aquatic environment (Hanaf, 2016). The concentration factor increases when there is an increase in the

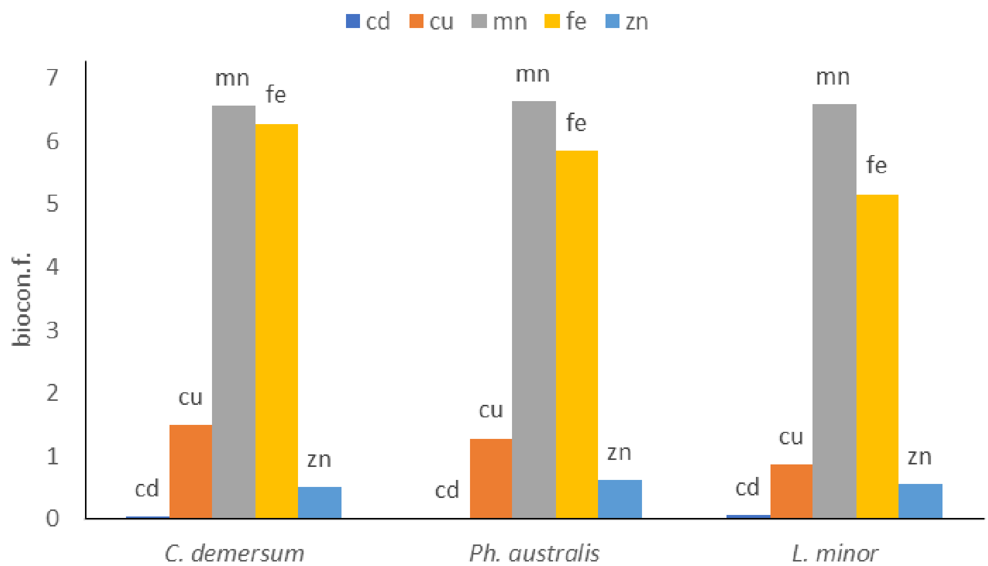

Figure 8. Bioconcentration factor of heavy metals in the studied aquatic plants in station 2.

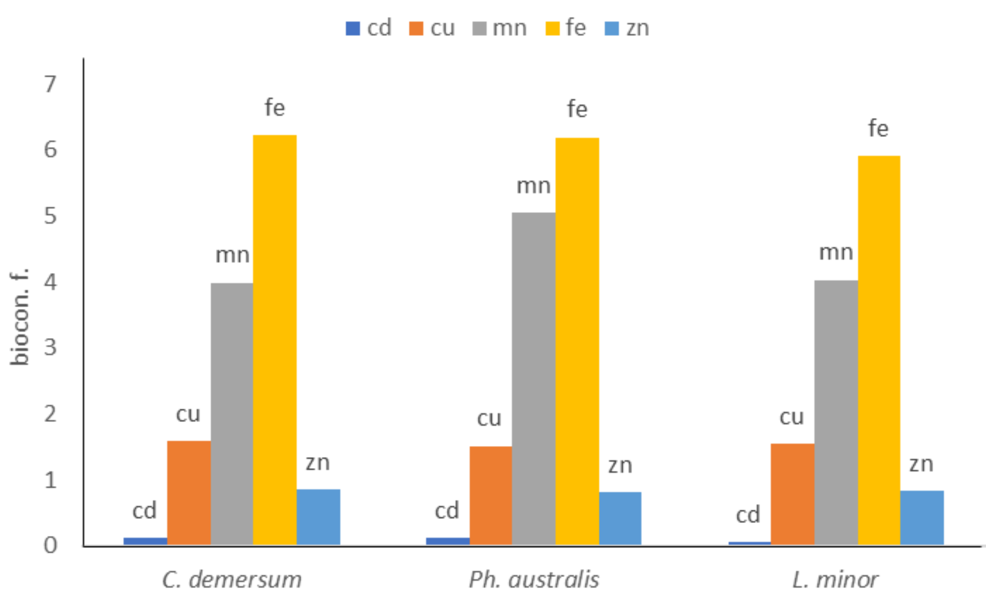

Figure 9. Bioconcentration factor of heavy metals in the studied aquatic plants in station 3.

concentrations and decreases when the concentrations of the elements decline. The *C. demursum* can accumulate heavy metals inside its bodies in larger quantities Athbi et al. (2018). In line with our findings, Al-Khafaji and Al-Awady (2014) showed the possibility of *C. demursum* and *P. australis* removing some heavy metals from the aquatic environment.

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