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Efficiency of lead, iron, manganese and copper adsorption capacities of submerged aquatic plants in heavy metal pollution for aquaculture

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Abstract At 14 days, the phytotoxicity index revealed that *B. caroliniana* was poisonous to Pb more abundantly than Fe, Mn, and Cu, with Pb values of 6.0 and 1.2 mg.L^{-1}, respectively. *L. adscendens* was more poisonous to Pb than to Fe, Mn, or Cu. Plants were only viable for 4 days at 6.0 mg.L^{-1} doses. *M. crenata* injuries with symptoms typical were shown to have fast toxicity with Pb and Fe at concentrations of 6.0 mg.L^{-1}, resulting in plant mortality within 4 and 6 days, respectively. The toxicity rates of Pb-induced aquatic plants were *B. caroliniana*, *L. adscendens*, and *M. crenata*, all of which had greater cumulative toxicity and death rates than other concentrations. *B. caroliniana* was discovered to be able to absorb Fe after 12 and 36 h of adsorption utilizing three plants. Throughout the 24 h period, *L. adscendens* exhibited the maximum Mn adsorption capacity, while Fe was the heavy metal with the highest mean adsorption over all time periods (12, 24, and 36 h). During the 36-hour period, *M. crenata* showed the highest Cu adsorption capacity. Phytoremediation, to maximize heavy metal adsorption with high efficiency, should be chosen for aquatic plants with the reduction of each heavy metal concentration in mind. The plants employed in the experiment were grown along these common watersheds, are fast growing, and reproduce to further water quality treatment.

Keywords: Phytoremediation, Phytotoxicity, Aquatic plant, Heavy metal, Aquaculture

Introduction

The rapidly increasing aquaculture industry of today aspires to lessen the reliance on natural aquaculture while simultaneously satisfying the rising need for human protein intake (Dauda *et al.*, 2017, Hua *et al.*, 2019). Agriculture chemical pesticides are used in cultivation as well as other forms of human activity that is typical of industrial facilities. That eventually makes its way into natural water sources where it may lead to a buildup of heavy metals including

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lead, copper, iron, and manganese. This leads to an increased concentration of toxic heavy metals in water bodies (Henriksson *et al.*, 2018). Heavy metals provide a significant risk to aquatic life and have an effect on the process of bioaccumulation in aquatic environments (Maruf *et al.*, 2021). Because heavy metals cannot be broken down by naturally occurring processes, some of them will eventually precipitate in aquatic environments and aquatic life (Ebrahimpour *et al.*, 2011). Inadequate treatment has an effect on water supplies, and this results from both the production of agricultural goods and the usage of heavy metal-contaminated chemicals. Industry is a significant contributor to the issue of declining water and soil quality; as a result, it is a crucial element in the problem itself. Heavy metals may be both beneficial and harmful to the living species they come into contact with, including people, aquatic animals and aquatic plants; they have a direct impact on the food chain (Nigussie and Awgchew, 2022). Within the realm of ecotoxicology, the significance of this topic cannot be overstated. Owing to the fact that it may linger in the environment for a long time and has the potential to be harmful to living creatures. There is no known method, either biological or physical, that can break down heavy metals and stay suspended in the water for an indefinite amount of time, posing a hazard to the natural world over the course of many years. Heavy metals may be divided into two categories: essential and non-essential, determined by the functions they perform in living organisms (Bouhadi *et al.*, 2021). In order for plants to carry out the physiological and biochemical processes necessary for their life cycle, essential heavy metals such as copper, iron, manganese, nickel, and zinc are needed; nevertheless, excessive amounts of these elements may be hazardous. Pb, Cd, As, and Hg are examples of non-essential heavy metals that are extremely poisonous and have no recognized purpose in plants (Goyal *et al.*, 2020, Tiwari and Lata, 2018). These metals have the potential to contaminate the environment and have a significant effect on a variety of physiological, biochemical processes in plants, and decrease agricultural production. The food chain is harmful to human health because it allows harmful substances to accumulate in crops, which then accumulate in humans via a process called biological amplification (Ali *et al.*, 2013, Okereafor *et al.*, 2020).

Efforts to reduce the amount of heavy metals found in contaminated water and soil have led to the creation of technologies that are user-friendly, eco-friendly, and practical from a financial and logistical perspective. Phytoremediation, according to Emenike *et al.* (2021), is one of the treatment procedures that is both low cost and kind to the environment, and it is used to eliminate contaminants from water and soil. Utilizing a wide range of plant species is a strategy that may be used to cut down on excessive harmful retention and restore regions that have been polluted with different sorts of harmful pollutants, including organic and inorganic substances. It is most often found in soil and bodies of water, and its primary function is to lessen the toxicity that is harmful to both people and the environment (Yang *et al.*, 2022). It is also one of the biological wastewater treatment systems that utilizes the idea of microbial processing to remove toxins that are found in nature. It is essential to make use of the system rather than burying the issue or moving it to another location (Gupta *et al.*, 2012, Liu *et al.*, 2019). Phytoremediation is the process of choosing plant species that are suited to the treatment conditions necessary to remove pollutants from a polluted region. In addition, the plants used for phytoremediation should have a strong and extensive root system (Ali *et al.*, 2013, Verma *et al.*, 2022).

The effectiveness of three aquatic plants, namely *B. caroliniana*, *L. adscendens*, and *M. crenata*, which are all common aquatic plants that can be found in water bodies, was the focus of this research project located in the center of Thailand and have the potential plants to develop well. As a guideline for the management of heavy metal pollutants in natural water sources, it is used to assess the toxicity of test plants and the adsorption of lead (Pb), iron (Fe), copper (Cu), and manganese (Mn).

The research investigated phytoremediation to address the adsorption of heavy metals via the stem, root, and leaves of plants.

Materials and methods

Plant sample collection and plant preparation

Research was conducted in Thailand, along the Nakhon Nayok river in the Muang district of Nakhon Nayok province. The GPS system was used to record the locations of each site that was collected (GPSmap 60CSx, Garmin, US). There were only three submerge species that were gathered in total*:* *Bacopa caroliniana* (14°10'48.82" N, 101°8'39.19" E), *Ludwigia adscendens* (14°10'41.82" N, 101°8.47.88" E), and *Marsilea crenata* (14°10'47.93" N, 101°8.40.71 E).

Plants for testing were prepared. The plants were placed in the cement pond so that they were 80 cm wide and 40 cm high. Before being tested, the plants were acclimated for one week in a plastic container containing 650 mL of water while exposed to sunshine.

Effects of heavy metals on plants

Heavy metals that were analysed in the region, such as lead (Pb), copper (Cu), iron (Fe), and manganese (Mn), which synthesized in distilled water at concentrations of 0, 0.06, 0.12, 0.60, 1.20, and 6.0 mg.L^{-1}. Following the planting of the seeds in the crucibles, which each held 400 cc, the crucibles were removed. Plant abnormalities were seen when healthy plants were grown in a solution containing heavy metals (phytotoxicity). It classified the phytotoxicity of these plants into as follows: 0, which indicates that typical plants do not exhibit any symptoms of being poisonous; 1 indicates that the plant displays aberrant symptoms between 1 and 25% of the time; 2 indicates the specimen of the plant that is exhibited odd symptoms between 26-50%; 3 indicates that the plant displays more than 50% of the aberrant symptoms, although there is still some green tissue present; and 4 indicates that the plant is dead.

From the beginning of the experiment to the end, 14 days of plant changes were tracked and documented. The phytotoxicity index was arrived at by applying the toxicity values to the equation (Chiang *et al*., 2017).

$$\text{Phytotoxicity index} = \frac{\sum \text{(rating no. of plant in the rating)}}{\text{Total no. plant x highest rating}} \text{ x } 100$$

Plant adsorption of heavy metals

All reagents used were nitric acid of analytical grade quality (Suprapur, Merck, Darmstadt, Germany). Ultrapure water obtained from a Milli-Q purifier system (Millipore Corp., Bedford, MA) was used throughout the work.

Plant samples were prepared for analysis by closed-vessel microwave-assisted digestion. Five-hundred milligrams of the plant sample was placed in a polytetrafluoroethylene (PTFE) reactor with 5.0 mL of concentrated nitric acid and 5.0 mL water. When the foam caused by organic matter decomposition disappeared, the vessel was capped and heated following a digestion programme using PerkinElmer Titan MPS (PerkinElmer, MA, USA). The heating procedure consisted of a first step of 5 min to reach 180 °C and a second step of 10 min at 180 °C. After digestion, the samples were diluted to 50 mL with deionized water. The metal contents of the final solution were determined by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

All analyses were performed on a Avio 200 ICP Optical Emission Spectrometer. The wavelengths selected were: Pb (220.353 nm), Mn (257.610

nm), Fe (259.940 nm), and Cu (324.754 nm). The instrument conditions employed for ICP-OES determination were 1500W radio-frequency power, 10.0 $L.min^{-1}$ plasma flow, 0.2 $L.min^{-1}$ auxiliary flow, 0.7 $L.min^{-1}$ nebulizer flow and 1.0 mL min^{-1} sample adsorption rate. The ICP-OES was calibrated with the standard solution for the various elements before analyzing the plant samples**.**

Statistical analysis

For all samples, the analysis was performed in triplicate. Comparisons of mean values and standard deviations (SDs) obtained from any measurements were performed using one-way ANOVA analysis with Fisher's Least Significant Difference (LSD) post hoc tests. The statistical results and significance (P) levels ($P \leq 0.05$) are addressed elsewhere in this article.

Results

Effects of heavy metals on plants

The effects of heavy metals Pb, Fe, Mn, and Cu on the plants *Bacopa caroliniana, Ludwigia adscendens, and Marsilea crenata* were investigated at five different concentrations: 0.06, 0.12, 0.60, 1.20, and 6.00 $mg.L^{-1}$, respectively. Based on the phytotoxicity index and anomalies in plant growth, when *B. caroliniana* plants were exposed to lead for 14 days, they began to exhibit symptoms of abnormality. The plants displayed the symptoms; the leaf tips began to turn yellow before the rest of the leaf and started to wilt until the plant finally passed away. Fe exhibited symptoms of the leaves becoming yellow, losing leaves, and beginning to wither, while Mn showed signals of the leaves turning yellow, beginning to wither, and leaving the leaves on the plant until they are dead. Cu started to exhibit indications of yellowing of the leaves and quickly loses its moisture content. Lead was shown to be more hazardous to plants than iron, manganese, or copper. Only on day 7 did the plants exhibit any signs of life after being exposed to lead at concentrations of 6.0 $mg.L^{-1}$ and 1.2 $mg.L^{-1}$, even though elements Fe, Mn, and Cu in *B. caroliniana* are very resistant to the effects of toxicity (Figure 1A, D, G and J).

Plants of the *L. adscendens* exhibited aberrant symptoms when they are subjected to lead. Symptoms might have been seen in plants. The leaf tips began to turn yellow before the rest of the leaf. Fe exhibit symptoms such as yellowing of the leaves, the shedding of leaves, and the beginning of withering before finally passing away. Mn produced yellowing of the leaves starting at the plant's tips and exhibited indications of quickly wilting until the plant died.

Cu manifested itself physically as symptoms; in particular, some leaves went yellow and eventually fell off completely. The symptoms of lead poisoning were more severe than those caused by toxicity caused by Fe, Mn, or Cu. When the plants were exposed to Pb at a concentration of 6.0 mg.L^{-1}, the plants were only able to live for 4 days. At the same concentration of 6.0, Cu at the same concentration of 6.0 mg.L^{-1}, *L. adscendens* mortality was observed at 14 days. Additionally, when the plants were exposed to Mn and Fe at 6.0 mg.L^{-1}, plant mortality was observed at 8 to 10 days, respectively (Figure 1B, E, H and K).

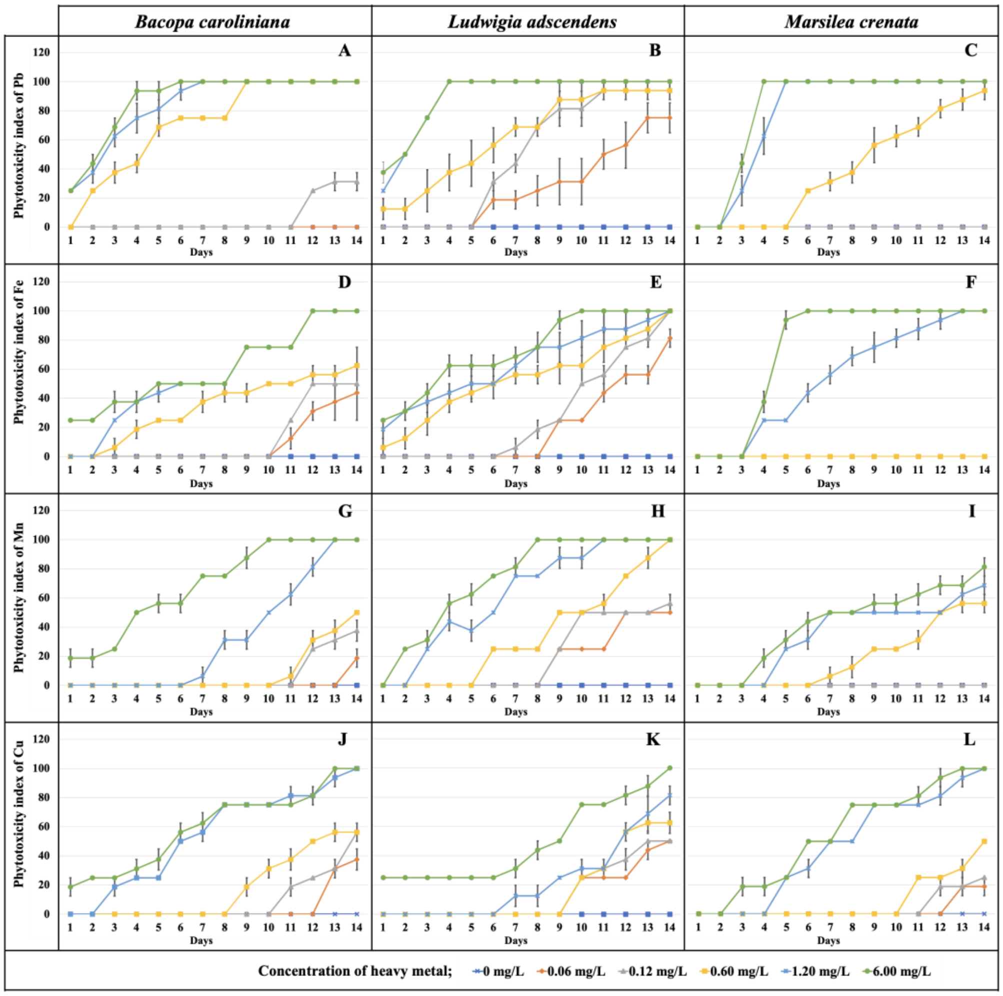

Figure 1. Phytotoxicity index of heavy metals Pb, Fe, Mn, and Cu in *Bacopa caroliniana*, *Ludwigia adscendens*, and *Marsilea crenata* at different concentration

When *M. crenata* plants are exposed to lead, it caused them to develop unusual characteristics. Symptoms might have been seen in plants. The leaf margins were the first part of the leaf to become yellow and gradually become yellow, eventually leading to the leaves falling off and the plant's death. The leaves began to turn yellow from the plant's periphery inward, and the stalks began to bruise and eventually break off before the plant finally died. With Mn, the leaves had a golden-orange coloration with scattered purple dots and withered later. Cu was asymptomatic and some leaves were yellow from the outer edges and stalks were dented, with symptoms emerging with *M. crenata* displaying quick Pb and Fe poisoning. Symptoms included yellowing of some leaves. Because the concentrations were 6.0 mg.L^{-1}, the plants died between 4 and 6 days after being exposed to the solution. In contrast to Mn and Cu, plants exhibited a higher level of toxin resistance when exposed to Pb and Fe (Figure 1C, F, I and L). The toxicity evaluation of the toxicity rates of aquatic plants connected to lead were *B. caroliniana, L. adscendens,* and *M. crenata*. All three of these plants demonstrated toxicity rates with toxic accumulation and death at greater concentrations than other concentrations (Figure 1).

Plant adsorption of heavy metals

The plants *B. caroliniana*, *L. adscendens,* and *M. crenat*a were used in a series of studies comparing their ability to adsorb heavy metals such as Pb, Fe, Mn, and Cu. Throughout the course of the experiment, the data was gathered and recorded at various intervals of 12, 24 and 36 h. Fe adsorption at 12, 24 and 36 h demonstrated that *B. caroliniana* was more effective at adsorbing Fe than the Fe adsorption of *L. adscendens* and *M. crenata,* and this difference was statistically significant at a $P \leq 0.05$. Cu adsorption was discovered at 12 and 36 h, *M. crenata* exhibited a much higher level of adsorption compared to *B. caroliniana* and *L. adscendens*; this difference was statistically significant at $P \leq 0.05$. At 12 and 24 h post-exposure, *M. crenata* was found to have taken in lead. Pb adsorption was shown to be significantly better and statistically different at $P \leq 0.05$ with *B. caroliniana* and *L. adscendens*. However, after 36 h, it was discovered that *L. adscendens* absorbed Pb better than *B. caroliniana* and *M. crenata* by breaking. Mn adsorption after 12 h indicated that M. crenata was better absorbed Mn and statistically different at $P \leq 0.05$ from *B. caroliniana* and *L. adscendens*; however, it was discovered that *M. crenata* was not statistically different in the adsorption of heavy metals after 36 h. If $P \leq 0.05$ and *B. caroliniana* is involved (Figure 2).

In the test for the adsorption of heavy metals, *B. caroliniana* exhibited an excellent capacity for Fe adsorption after both 12 and 36 h. It was discovered that the high Fe adsorption was 78.67 ± 0.36 and 78.92 ± 1.00 mg.kg^{-1}, and these values did not vary at $P \leq 0.05$. According to the results of Cu and Pb adsorption, *B. caroliniana* was heavily adsorbed after 24 h; however, after 36 h, there was a reduction in the amount of Cu element that was present in the plants. They were statistically distinct at a level of $P \leq 0.05$, but the adsorption of manganese increased with increasing time from 12, 24, and 36 h. Mn adsorption rose, and the results were statistically distinct at each time point using a $P \leq 0.05$. At every time interval tested, *B. caroliniana* was able to absorb more iron than lead, manganese, or copper (Figure 2A). When looking at the sorbing at various time intervals, it was discovered that *B. caroliniana* was able to absorb Fe at 12, 24, and 36 h. A statistically significant difference at $P \leq 0.05$ made it more comparable than Cu, Pb, and Mn (Figure 2A).

The test to determine the heavy metal adsorption capacity of *L. adscendens* revealed that the maximum Mn adsorption capacity was 19.0 ± 10.15 mg.kg^{-1}. This value was significantly different at $P \leq 0.05$ than with the other values *L. adscendens* was able to absorb more Fe and Cu at 12, 24, and 36 h increments, and the adsorption capacity was statistically different at $P \leq 0.05$ in Pb adsorption by *L. adscendens* showed that at 36 h, the maximum Pb adsorption was 5.33 ± 0.01 mg.kg^{-1}and was statistically different at $P \leq 0.05$ with the 12 and 24 h time intervals. Pb adsorption by *L. adscendens* as showed in Figure 2B. It was observed that *L. adscendens* was more effective in adsorbing Fe than Cu, Pb, and Mn at 12 and 36 h, and this difference was statistically significant at $P \leq 0.05$. However, Mn adsorption was only detected at 24 h. In a variety of statistical comparisons, it performed much better than other heavy metals with a $P \leq 0.05$. (Figure 2B).

The results of an experiment on the heavy metal adsorption capacity of *M. crenata* showed that the adsorption capacity of Fe and Cu was enhanced at each period of adsorption as well as at each of the 12, 24, and 36 h increments. The difference was statistically significant with a $P \leq 0.05$. Pb adsorption demonstrated that *M. crenata* was substantially adsorbed after 24 h, and when the time period was extended to 36 h, there was a considerable drop in the amount of Cu element found in plants. At a significance level of $P \leq 0.05$, there was a statistically significant difference between the maximal Mn adsorption capacity after 12 h and that at 24 and 36 h of adsorption (Figure 2C). *M. crenata* demonstrated that the adsorption of heavy metals changed over the course of 12, 24, and 36 h. At 12 h, the adsorption of manganese was statistically different at $P \leq 0.05$ when compared to the adsorption of the other heavy metals tested. At 24 h, the adsorption of lead was statistically different at $P \leq 0.05$ when compared to the adsorption of Fe, Cu, and Mn.

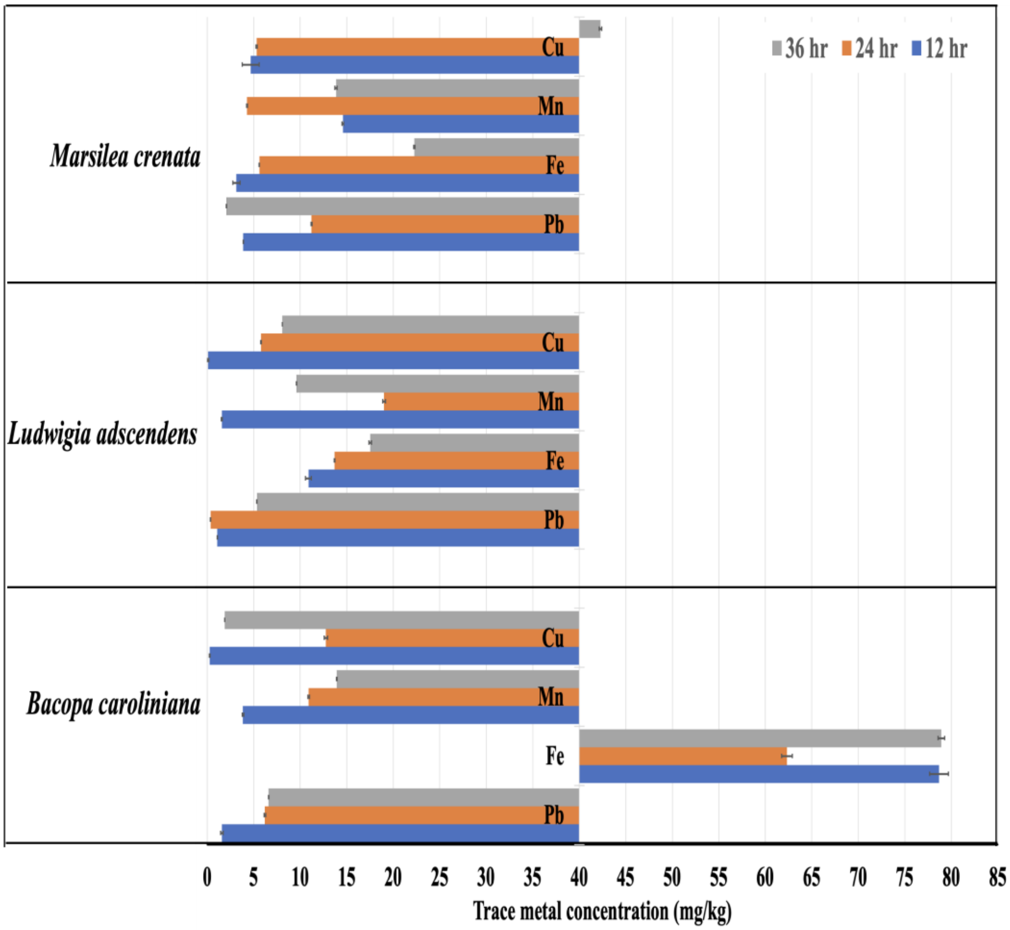

Figure 2. Capacity of *Bacopa caroliniana, Ludwigia adscendens,* and *Marsilea crenata* to adsorb Pb, Fe, Mn, and Cu

Discussion

The beneficial effects of *B. caroliniana, L. adscendens, and M. crenata* on the metal uptake of Pb, Fe, Cu, and Mn by symptomatic and plant toxicity tests showed that when exposed to heavy metals, *B. caroliniana*, *L. adscendens*, and *M. crenata* showed different symptoms depending on the type of metal. These tests were conducted on *B. caroliniana*, *L. adscendens*, and *M. crenat*. This is a preliminary evaluation to determine whether or not there is pollution from heavy metals in natural water sources that can be utilized for aquaculture by analyzing the reactions of plants to heavy metals and looking for irregularities in plant growth caused by heavy metals that are still present in the environment It was discovered that the qualities that are present in plants altered according to the color change that occurs due to the destruction of chlorophyll. This change is referred to as chlorosis. Necroses, another symptom shown by the plant, may also be traced back to vascular malfunction, the same dysfunction that causes wilting in plants. *B. caroliniana*, *L. adscendens* and *M. crenata* may demonstrate comparable Pb toxicity: The tips of the leaves begin to turn yellow, and the leaves eventually blight, dry up, fall off, and die. When plants are subjected to lead concentrations in excess of what they are able to tolerate, the results may include stunted growth, chlorosis, and blackening of the roots. When plants are subjected to lead concentrations in excess of what they are able to tolerate, the results may include stunted growth (Aziz *et al.*, 2015). When *Marsilea crenata* was used in high toxicity manganese pollution, it was discovered that the plant exhibited strong symptoms, including reduced root elongation and an inhibition of seed germination (Zulfiqar *et al.*, 2019). The leaves have a yellow-orange coloration to scattered purple dots. It is a peculiar symptom that only plants exhibit. Brown patches that develop between the leaf veins may be seen on leaves that have been poisoned by manganese and crinkle leaf (Agrios, 2005), and Mn was also discovered to absorb manganese better throughout the day length as a protein component of plant pigments (Alejandro *et al.*, 2020). This finding was made in relation to manganese absorption. Leaves on plants that were evaluated for Fe toxicity and found to be poisonous to *B. caroliniana*, *L. adscendens*, and *M. crenata* became yellow, and the leaves were discarded. In addition, the process of seed germination, root elongation, and stem elongation are all negatively impacted when plants are subjected to an excessive amount of Fe. This is because an excessive amount of Fe is toxic to plants. The toxicity of Cu obtained by plants with a lack of chlorophyll causes growth to stall at the root level, and the roots do not become elongated or branched (Kumar *et al.*, 2021, Mir *et al.*, 2021).

At concentrations of up to 6.00 mg.L^{-1}, the responses of *B. caroliniana, L. adscendens,* and *M. crenata* displayed fast wilting to plant death. Because of contamination, higher plant responses to lead were seen in *B. caroliniana*, *L. adscendens*, and *M. crenata* than in response to iron, manganese, or copper (Benzarti *et al.*, 2008). This was due to the fact that higher plant responses to lead were observed. The mechanism that causes plants to give out oxygen in order to defend themselves result in a poor utilization of nutrients with both a decrease in photosynthesis and an increase in mortality result in a significant decrease in crop output. The early phases of plant development are affected by the manifestations of plants that have been poisoned with lead. In the event that nutrient and water absorption is an issue (Zulfiqar *et al.*, 2019), then lead-contaminated soil is a very soluble and plants are no able to absorb it. As a direct consequence of this, Pb-contaminated crops often had shoots with concentrations of less than 50 mg Pb.g^{-1} (Cunningham *et al.*, 1995), and the majority of water sources and groundwater were polluted (Nigussie and Awgchew, 2022). Submerged plants that are both terrestrial and aquatic and have a fuzzy root system are able to utilise lead-contaminated plants. Rhizo-filtration, even in minute levels, may be used to remove lead (Nigussie and Awgchew, 2022). Submerge plants with high rates of development were used for the heavy metal absorption test by *B. caroliniana, L. adscendens,* and *M. crenata*. Potential of selected plant has a density that has growth characteristics comparable to *Typha angustifolia L.*, as well as a good ability to treat heavy metals and fast absorb heavy metals owing to direct contact with the medium. Moreover, it has a density that has the ability to treat heavy metals. The roots of most plants are able to adsorb and store toxins and transport them to concentrate in above-ground portions, such as stems and leaves, to assist in lowering the level of toxicity in plants by spreading to other regions. It is possible for lessen the quantity of heavy metal pollution in water thanks to the processes of plants (Qian *et al.*, 1999).

According to the findings of this research, *B. caroliniana*, *L. adscendens,* and *M. crenata* all showed distinct levels of adsorption effectiveness for lead, iron, copper, and manganese, as well as varying levels of adsorption duration for *M. crenata*. First to be efficiently absorbed was Mn at 12 h, then Fe at 36 h, then Cu at 36 h, and finally Pb at 36 h. When working in an aqueous medium, one may get better absorption. This is due to the crucial part that light plays in the process of photosynthesis in plants. The capacity to remove heavy metals showed signs of deterioration. In comparison to plants that were exposed to light (Afroze and Sen, 2018), the behavior of various plants was significantly different throughout the distinct processes of Fe, Cu, and Mn adsorption. Metal cations each have their own unique valence, yet their structures are quite similar (Pinto *et al.*, 2014, Yang *et al.*, 2022). The majority of plants absorb poisons via their roots, and these toxins are then carried to the above-ground parts of the plant, such as the stems and leaves, where they concentrate. This helps minimize the toxicity of the plant overall by distributing it over its many components. It is feasible for it to reduce the quantity of heavy metal contamination in water due to the processes of plants (Emenike *et al.*, 2021).

The absorption of heavy metals by plants *L. adscendens* was found to have the maximum Mn adsorption capacity throughout the period of 24 h and varied from the time periods of 12 and 36 h, which may have been because of the heavy metal treatment plants (phytoremediation) and the primary removal of heavy metals from the environment by plants, which occurs as a result of adsorption and operates as phytoremediation. To finish the process, potential of selected plants might present itself in a variety of ways, such as the vegetative fixation process known as phytostabilization. When plants take in toxins, those toxins either become less mobile or are converted into a form that other living things cannot utilise. Pb, As, Cd, Cr, Cu, and Zn are all treated by this procedure (Bouhadi *et al.*, 2021). This method has the benefit of doing away with the need of removing dangerous materials, and it also achieves a high level of success when applied to both groundwater and surface water resources (Jadia and Fulekar, 2008).

Additionally, the roots of plants have the ability to take in or filter out contaminants. In the event that the pollutant is present as a solution that has been polluted with water, the only part of the plant that collects pollutants is the root system. Filtering at the root level is another name for it. Pb, Cd, Cu, Ni, Zn, and Cr may all be removed from agricultural water by the process of rhizofiltration. This process can also be used to remediate acid mine drainage (Bouhadi *et al.*, 2021, Mahar *et al.*, 2016, Verma *et al.*, 2022). However, the use of phytoremediation to adsorp heavy metals and the biologics of the plants can be employed to both contribute significantly to the restriction that exists. The management of treated plants is another issue that has to be addressed (Zhao and McGrath, 2009) because of the size of their roots. This is except in certain close vicinities to the surface of the soil and water when plants are able to remove pollutants. The root size of the plant has to be of adequate length in order for it to be able to treat toxins deep into the rock (Bouhadi *et al.*, 2021, Padmavathiamma and Li, 2007). In addition to the capability of plants to absorb heavy metals, it is applicable to the treatment of metallurgical waste in water that has been polluted by fisheries owing to low costs that may be found in natural settings. Alternatively, some species are considered to be weeds because of how rapidly they reproduce. It is more likely to be found along the water's edge. When purified, it may be used to remove heavy metals from natural water sources so that they can be utilized in fisheries. In addition, it would have a beneficial impact on the method of aquaculture by ensuring animal safety.

Water contamination and shortages have imposed a substantial cost on the environment. Rising industry and urbanization have exacerbated the heavy metals problem. Heavy metals are one of these harmful compounds that can readily accumulate in the environment. It is difficult to remove heavy metals from wastewater because they exist in several chemical forms. The majority of metals are not biodegradable and can easily move across multiple trophic levels to accumulate permanently. Generally speaking, these conventional procedures for the remediation of heavy metals are expensive and time-consuming. Treatment technologies require substantial capital expenditures and pose the issue of sludge disposal. The phytoremediation of heavy metal-polluted wastewater demands an ecologically acceptable, low-maintenance, cost-effective treatment technique and fishery management.

Heavy metal removal studies found that the submerged plant performed admirably in removing the selected heavy metals, implying that they could be considered viable options for wastewater treatment. The implementation of novel approaches in aquaculture and fisheries management can improve future chances for the use of aquatic macrophytes in phytoremediation capability of aquatic species and fisheries management.

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