Phytoremediation of water contaminated with Copper and cadmium Using *Ceratophyllum demersum*

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Abstract

Copper and cadmium pollution in water is a serious environmental problem because of toxic effects on living organisms and ecosystems, Phytoremediation using aquatic plants is a novel, efficient and low-cost technique for improving wastewater and water quality. The aim of this study was to evaluate the efficiency of *Ceratophyllum demersum* as an ecological solution for the treatment of copper and cadmium contaminated water. To investigate the ability of *Ceratophyllum demersum* to absorb and remove the heavy metals copper (Cu) and cadmium (Cd) from wastewater and reduce their concentrations to environmentally safe level. The absorption capacity of the plant was studied through a laboratory experiment with different copper and cadmium concentrations (0, 5 and 10 ppm). The residual concentrations of copper and cadmium in the water after treatment were determined by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) and removal efficiency and chlorophyll content in the plant were also measured. The results show that the highest removal efficiency was Cu (64.54%) and Cd (59.4%) at 5 ppm, and it decreased to Cu (47.4%) and Cd (43%) at 10 ppm. There was a decrease in chlorophyll content with increase in copper and cadmium concentrations which was 2.16mg/g for Cu and 1.5mg/g for Cd in the non-exposed group, at 5 ppm it was decreased to Cu (2.01mg/g) and Cd (1mg/g) but at 10 ppm it was Cu (1.09mg/g) and Cd (0.9mg/g) respectively. The results indicated that *Ceratophyllum demersum* was efficient in removing copper and cadmium from water but the efficiency was affected by metal concentration.

Keyword: phytoremediation, copper, Cadmium, *Ceratophyllum demersum*.

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Introduction

With the development of industrialization and urbanization, the rapid growth of industries such as metal plating, mining operation, paper manufacturing, fertilizer production, tanneries, batteries and pesticides has resulted in the increasing discharge of heavy metal contaminated wastewater into the environment, especially in developing countries. Heavy metals are not biodegradable like organic pollutants and tend to accumulate in living organisms, and many heavy metal ions are known to be toxic and carcinogenic. Among the toxic heavy metals of concern in the treatment of industrial wastewater are zinc, copper, nickel, mercury, cadmium and lead (Ashraf *et al*., 2019; Fu and Wang, 2011).

Excess copper in water can disrupt aquatic ecosystems, affect microbial communities, and accumulate in organisms, causing potential health risks (Rajeshkumar and Li, 2018; (Bhat and Meril, 2022).Most common removal techniques of both copper and cadmium from the polluted water include chemical precipitation, ion-exchange and membrane filtration but all of them are mostly high-cost, high-energy required and may produce pollutants that disturb environment (Bailey *et al*., 1999; Salt *et al*., 1998).It was found that bioremediation is the most efficient way to reduce the concentrations of copper and cadmium since microorganisms and plants are capable of degrading and transforming metal ions present in water (Dushenkov *et al*., 1995).Several aquatic plants were tested for their ability to remediate copper, and among them, *Ceratophyllum demersum* showed the highest potential to accumulate and absorption copper (Mishra and Tripathi, 2008).This species has advantages such as rapid growth rate, large surface area, and adaptability to different environments, which make it suitable for phytoremediation at a large scale (Ghosh and Singh, 2005).In addition, the efficiency of cadmium and copper removal by plants is influenced by several factors like pH, temperature, initial metal concentration and presence of competing ions (Zeng *et al*., 2017). Research indicates that the optimum pH range is 5.5–7.5 for improving the absorption of copper and cadmium, as extreme pH levels may alter the speciation of the metals and reduce the uptake efficiency (Polechońska *et al*., 2018).

A study carried out by (Abdulwahid, 2023).included the collection of 15 random polluted water samples and their treatment using *C. demersum* , the study showed that the highest values of Cd removal were obtained on the fifteenth and twelfth day of the aquaculture periods with the lowest concentrations of Cd of 7.9 ± 4.3 µg/L and 31.5 ± 20.2 µg/L, respectively. In contrast, the lowest Cd removal values were observed on the third and sixth days, with the highest Cd concentrations recorded at 86.9 ± 40.8 µg/L and 38.6 ± 19 µg/L, respectively.results indicate that Cd accumulates more in the leaf-like tissues, followed by roots and to a lesser extent in the stem-like parts of these submerged aquatic plants. (Aasim *et al*., 2023) in a recent study exposed in vitro regenerated plants of *C. demersum* (7.5 g/L) to 0, 0.5, 1.0, 2.0 and 4.0 mg/L of cadmium ($CdSO_4.8H_2O$) in water for 24, 72 and 120 h. The results showed significant differences in Cd concentration in water, plant uptake of Cd, bioconcentration factor (BCF) and Cd removal efficiency. Cd uptake and BCF values increased significantly with the duration of exposure. The maximum BCF value (3776.50) was found in plant samples treated with 2 mg/L Cd for 72 hours. Removal efficiency ranged from 93.8% to 98.7% for all Cd concentrations and exposure durations. Therefore, the present study was designed to evaluate the effectiveness of *Ceratophyllum demersum* in removing copper and cadmium from contaminated water under controlled laboratory conditions. In addition, the study examined the influence of different metal concentrations on removal efficiency and assessed changes in chlorophyll content as an indicator of the plant's physiological response to heavy metal exposure.

Materials And Methods

The study was conducted in Health Laboratory, Environmental Health Department, College of Applied Medical Sciences. The *Ceratophyllum demersum* was collected from Husseiniya River (Karbala) and washed with distilled water to remove any impurities or suspended matter.Glass aquarium containing half-strength Hoagland’s nutrient solution was prepared to support plant growth for 30 days before the experiments

Three different concentrations (0,5,10) of (Cu ,Cd) were prepared from standard solution of Copper (II) sulfate pentahydrate ($CuSo_4.5H_2O$), Cadmium (II) sulphate pentahydrate ($CdSo_4.5H_2O$). The concentration of each metal was (5,10 ppm) while the plant without metal treatment were used as a control (0). For each treatment, triplicates were taken. Plastic aquariums of 5 liters capacity were used, which were filled with 2 liters of polluted water. 25 grams of healthy plant was selected and added to containers for 20 days. The laboratory temperature was 25°C, and the illuminance level was 1,000 lux. Completely Randomized Design (CRD) and analysis was done using SPSS software at 0.05 level of significance. The pH of the aquariums was measured using PH meter and was found to be (6.5- 7).

After the experiment, 1 g of Ceratopyllum was taken from each container and ground into a fine pieces in a mortar and pestle. 10 ml of acetone was added to each sample for chlorophyll pigment extraction and spectrophotometer analysis as per (Arnon, 1949)

Total Chlorophyll (mg/L) $= 20.2 \times A645 + 8.02 \times A663$

Water samples were also collected from each container. Three samples were taken from each replicate

The concentration of (Cu, Cd) in treatments water were analyzed using an ICP-OES, Thermo Fisher scientific, Germany to determine the residual concentration of copper (Cu) and Cadmium (Cd) in aqueous solution. Removal of elements was measured by following equation.

$$\text{Removal efficiency \%} = \frac{\text{Initial concentration (mg/l)} - \text{Final concentration (mg/l)}}{\text{Initial concentration (mg/l)}} \times 100$$

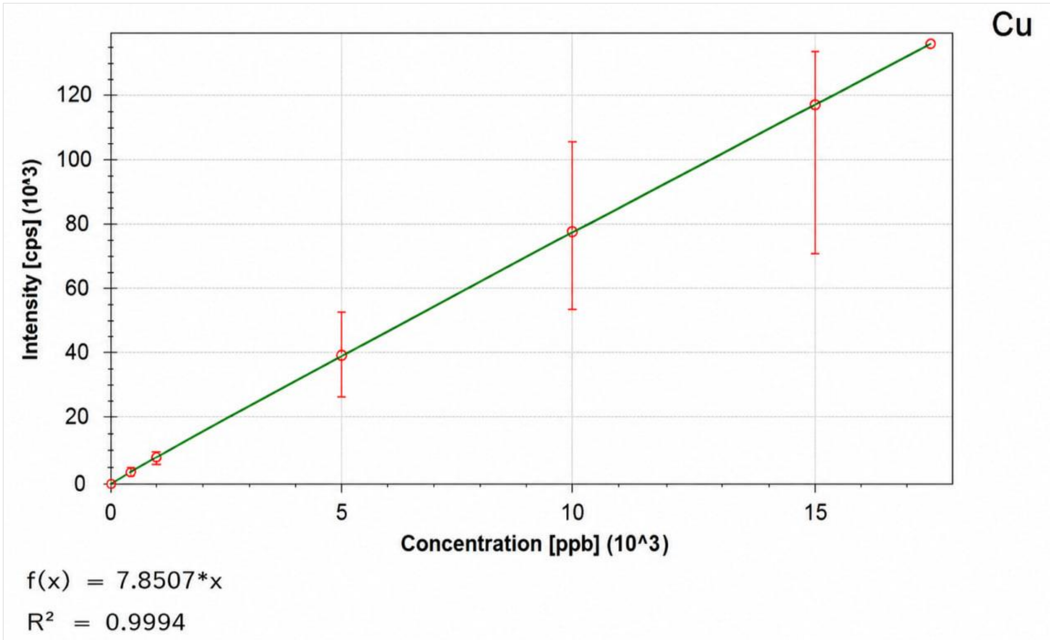

Figure 1: Standard curve of copper.

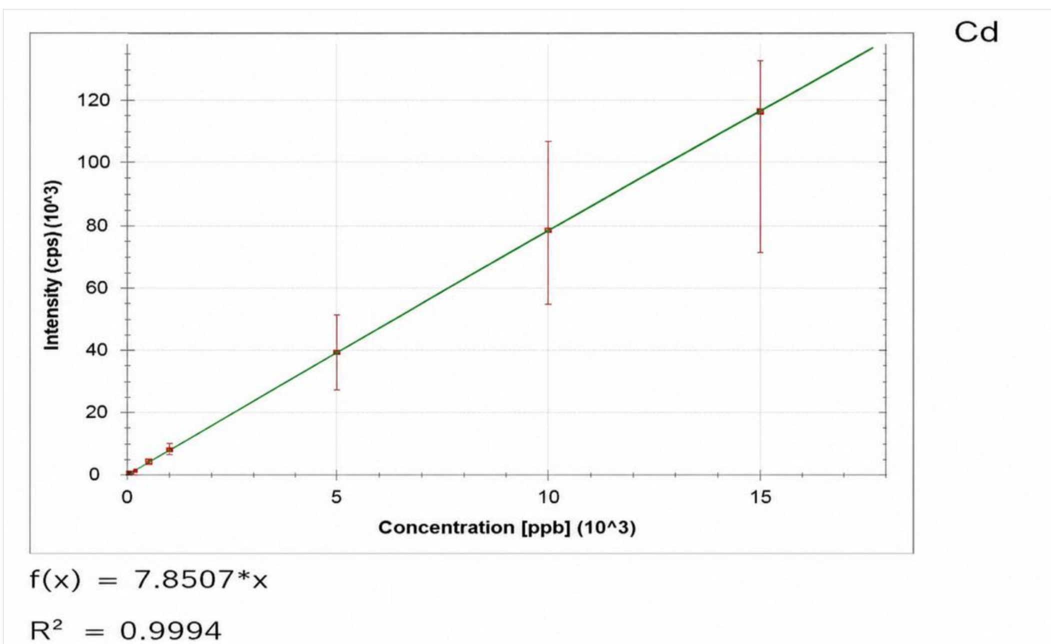

Figure 2: Standard curve of cadmium.

Results

Effect of copper and Cadmium concentration on removal efficiency.

The results in Figure (3,4) showed that the residual copper and cadmium concentration in water decreased after treatment with *Ceratophyllum demersum* at 5 ppm to Cu (1.773) and Cd (2.03) compared to 10 ppm to Cu (5.26) and Cd(5.7).

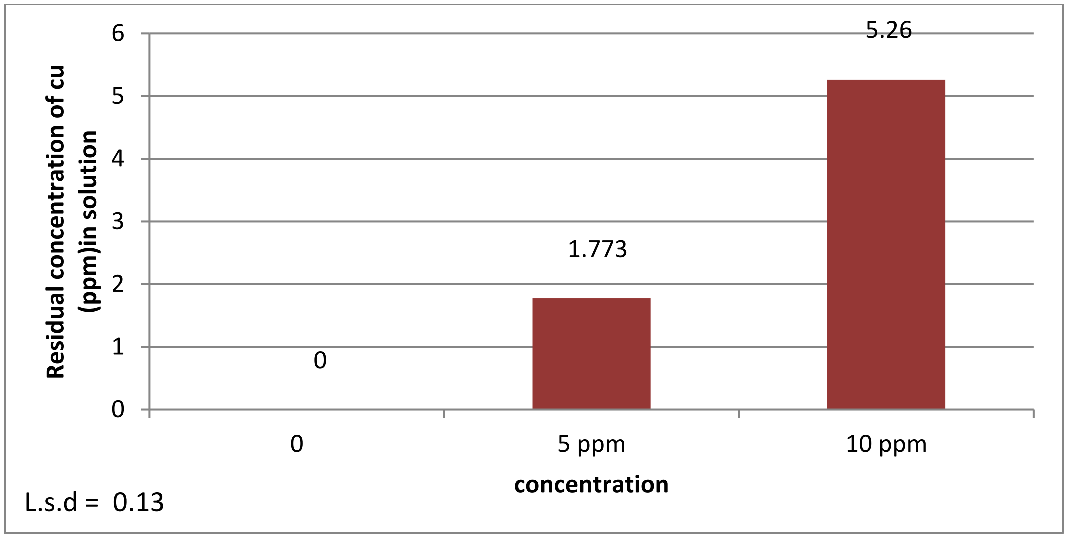

Figure 3: Effect of copper concentration on removal efficiency

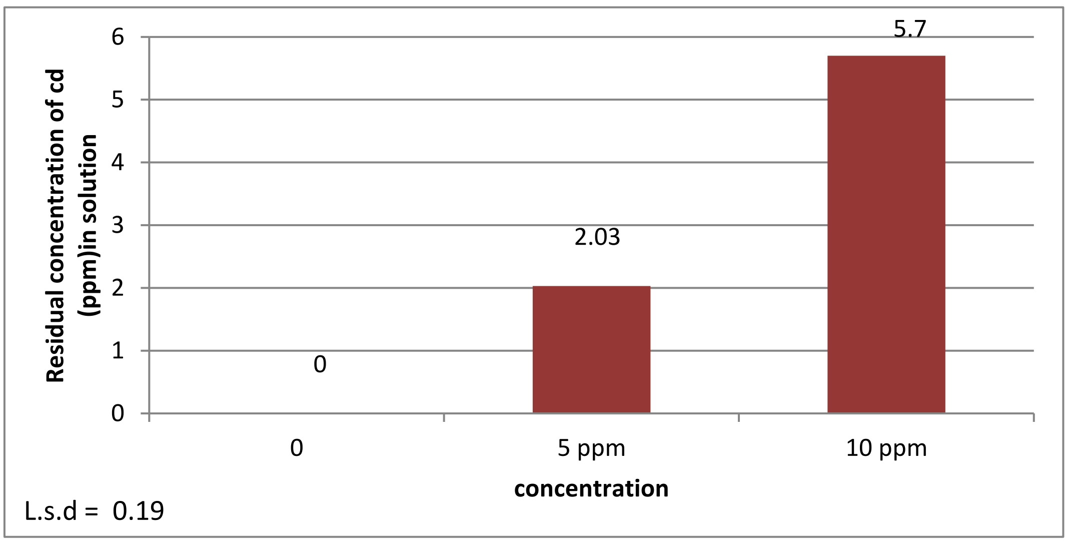

Figure 4: Effect of cadmium concentration on removal efficiency

plant's efficiency in Percentage of removal from water.

The results indicated in Figure (5,6) that the percentage of removal copper and cadmium concentration in water decreased after treatment with *Ceratophyllum demersum*, with the removal efficiency being higher at a concentration of 5 ppm to Cu (64.54%) and Cd (59.4%) compared to 10 ppm to Cu (47.4%) and Cd (43%).

Effect of copper on chlorophyll content

The results in Figure (7,8) clarified that the chlorophyll content of the plant was affected by the increasing copper and cadmium concentration in the medium A slight decrease was observed at 5 ppm to Cu(2.01mg/g), Cd(1mg/g) but at 10 ppm to Cu(1.09mg/g), Cd(0.9mg/g).

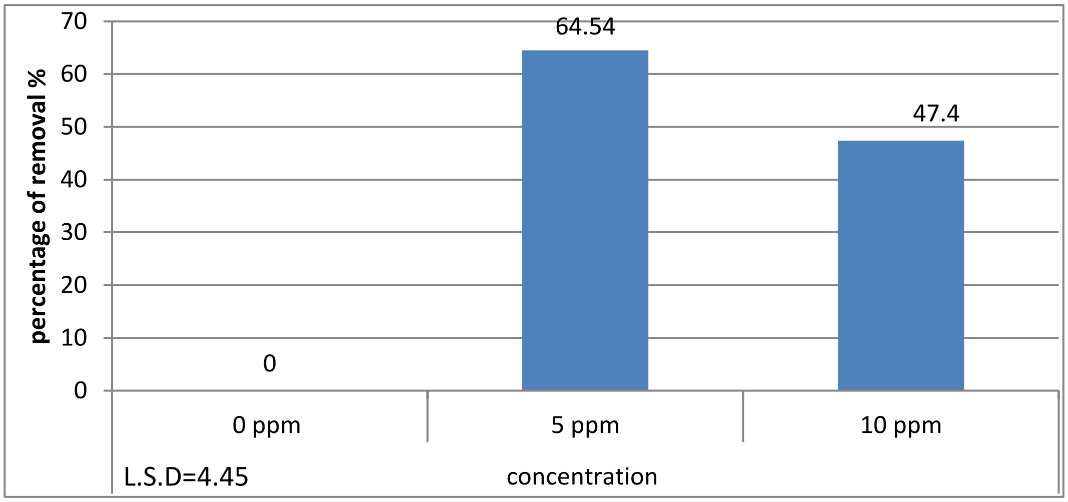

Figure 5: Percentage of removal of Cu from polluted water.

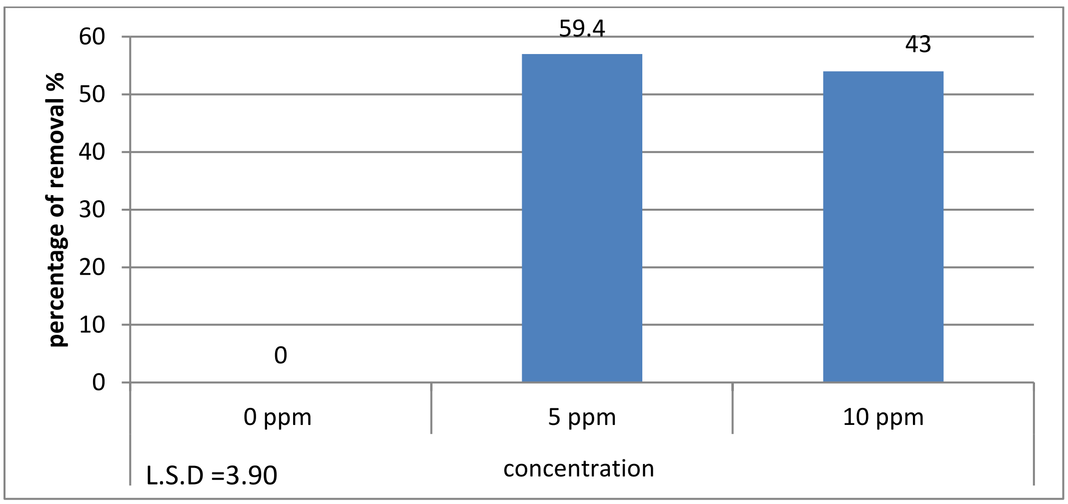

Figure 6: Percentage of removal of Cd from polluted water.

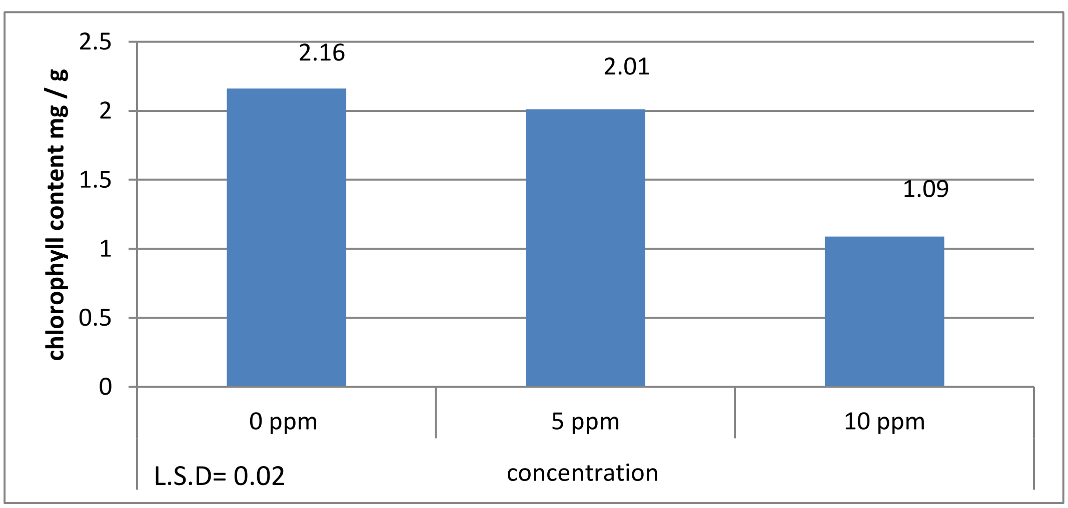

Figure 7: chlorophyll content for Cu treatments.

Effect of cadmium on chlorophyll content.

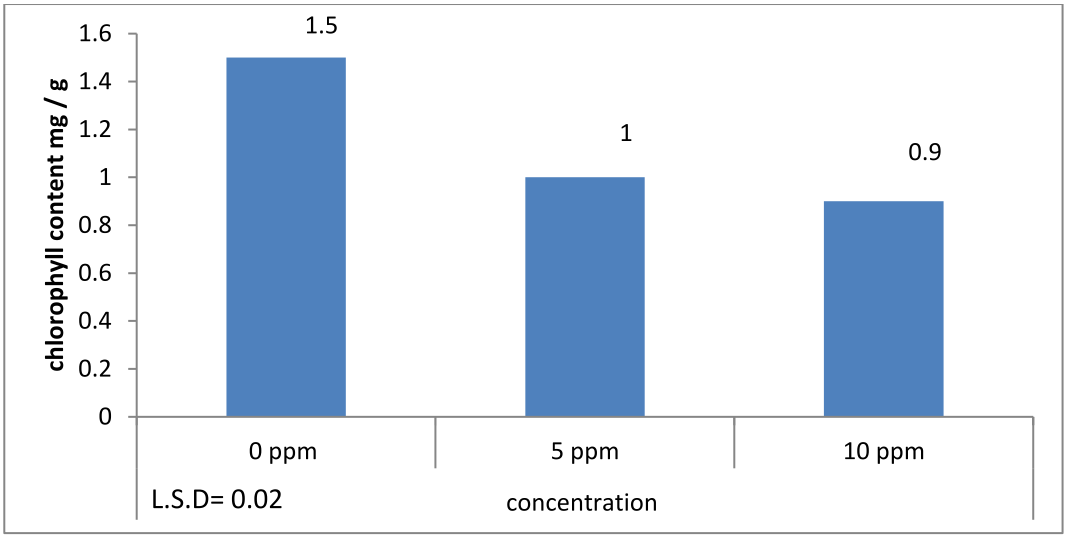

Figure 8: chlorophyll content for Cd treatments.

Discussion

Aquatic plants are essential for the recycling of nutrients and heavy metals in various aquatic ecosystems since they help remove heavy metals and other pollutants from the water (Dushenkov *et al.*, 1995).*Ceratophyllum demersum* is one of the most important of these plants, as it is used in water quality studies to monitor heavy metals and other pollutants present in sediments and water. It is also capable of accumulating pollutants at higher levels than their concentration in the surrounding environment (Mishra and Tripathi, 2008).

The results indicate that the plant can absorb copper most effectively at low concentrations, whereas, at higher concentrations, its ability to absorb decreases due to the possible saturation of copper absorption sites or copper toxicity (Ghosh and Singh, 2005).These results agree well with the previous studies indicating that aquatic plants showed higher absorption ability at low concentrations, but at high concentrations, they may experience some stress that inhibits their vital processes (Zeng *et al.*, 2017).The chlorophyll content of the plant was influenced by an increase in concentrations of copper and cadmium in the medium. A slight decrease was observed at 5ppmto Cu (2.01mg/g), Cd (1mg/g) but at 10ppm to Cu (1.09mg/g), Cd (0.9mg/g), the decrease was significant to indicate that copper and cadmium had begun to exhibit toxic effects which inhibited photosynthesis (El-Khodaryand Al-Homaid, 2021). This is in agreement with previous studies that have shown that heavy metals such as copper, cadmium may interfere with chlorophyll synthesis in plants by disrupting vital physiological processes such as the absorption of essential elements or by generating free radicals that damage plant cells (Xie *et al.*, 2021).In addition, it was found that the removal of copper and cadmium was influenced by some factors, such as the copper and cadmium concentration in the medium. The increased concentration of copper and cadmium led to the increased amount of these metals taken up by plants, while the percentage of copper and cadmium removed decreased with the increased concentration, which suggests that plants have a certain level of metal uptake beyond which the removal rate decreases (Ranjan *et al.*, 2020).These results are consistent with other studies that confirmed that absorption efficiency depends on the concentration of the heavy metal in the medium, where absorption is effective initially but decreases at higher concentrations due to the saturation of binding sites or the toxic effects on the plant (Liao and Zhang, 2019; Ostroumov and Shestakova, 2009).

Based on these results, *Ceratophyllum demersum* can be considered a promising option for treating copper and cadmium-polluted water at moderate concentrations. However, its efficiency may be affected at higher concentrations, which necessitates the study of other factors such as the pH effect, the presence of organic materials that may enhance absorption, and the possibility of incorporating other plants to increase the removal efficiency (Ghosh and Singh, 2005;. Xie *et al.*, 2021).

conclusion

The results obtained in this study show how effective the use of Ceratophyllum demersum as a biological approach can be used to eliminate copper and cadimum ions from contaminated water. It has been revealed that the plant is capable of absorbing large amounts of copper and cadimum, especially at low concentration levels, with the maximum rate of removal of 64.54% and 59.4% for 5 ppm copper and cadimum, respectively. However, the efficiency of the plant's activity decreases with an increase in concentration of these elements.

References

Aasim, M., Ali, S. A., Aydin, S., Bakhsh, A., Sogukpinar, C., Karatas, M., Khawar, K. M., and Aydin, M. E. (2023). Artificial intelligence-based approaches to evaluate and optimize phytoremediation potential of in vitro regenerated aquatic macrophyte Ceratophyllum demersum L. Environ. Sci. Pollut. Res., 30, 12232–12245.

Abdulwahid, K. D. (2023). Phytoremediation of cadmium pollutants in wastewater by using Ceratophyllum demersum L. as an aquatic macrophyte. Water Conserv. Manag., 7(2), 83–88.

Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. Plant Physiol., 24(1), 1–15.

Ashraf, S., Ali, Q., Zahir, Z. A., Ashraf, S., and Asghar, H. N. (2019). Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. Ecotoxicol. Environ. Saf., 174, 714–727. https://doi.org/10.1016/j.ecoenv.2019.02.068

Bailey, S. E., Olin, T. J., Bricka, R. M., and Adrian, D. D. (1999). A review of potentially low-cost sorbents for heavy metals. Water Res., 33(11), 2469–2479.

Bhat, F. A., and Meril, D. (2022). Dynamic landscape of ichthyofaunal diversity in India: Discoveries and exploration (2009–2022).

Dushenkov, V., Kumar, P. B. A. N., Motto, H., and Raskin, I. (1995). Rhizofiltration: The use of plants to remove heavy metals from aqueous streams. Environ. Sci. Technol., 29(5), 1239–1245.

El-Khodary, S. A., and Al-Homaid, A. (2021). Phytoremediation potential of Ceratophyllum demersum for copper removal from contaminated water. Egypt. J. Aquat. Biol. Fish., 25(4), 167–182.

Fu, F., and Wang, Q. (2011). Removal of heavy metals from wastewaters: A review. J. Environ. Manage., 92(3), 407–418.

Ghosh, M., and Singh, S. P. (2005). A review on phytoremediation of heavy metals and utilization of its byproducts. Appl. Ecol. Environ. Res., 3(1), 1–18.

Liao, Q., and Zhang, T. (2019). Efficiency of Ceratophyllum demersum in the removal of copper from contaminated aquatic ecosystems. Environ. Toxicol. Chem., 38(5), 1032–1040.

Mishra, V. K., and Tripathi, B. D. (2008). Concurrent removal and accumulation of heavy metals by three aquatic macrophytes. Bioresour. Technol., 99(15), 7091–7097.

Ostroumov, S. A., and Shestakova, T. V. (2009). Decreasing the measurable concentrations of Cu, Zn, Cd, and Pb in the water of the experimental systems containing Ceratophyllum demersum: The phytoremediation potential. Dokl. Biol. Sci., 428, 444–447.

Polechońska, L., Klink, A., Dambiec, M., and Rudecki, A. (2018). Evaluation of Ceratophyllum demersum as the accumulative bioindicator for trace metals. Ecological Indicators, 93, 274-281.

Rajeshkumar, S., and Li, X. (2018). Bioaccumulation of heavy metals in fish species from the Meiliang Bay, Taihu Lake, China. Toxicol. Rep., 5, 288–295.

Ranjan, R., Singh, S. P., and Yadav, A. K. (2020). Copper accumulation and detoxification mechanisms in aquatic plants: A review on phytoremediation of copper by Ceratophyllum species. Sci. Total Environ., 740, 139913.

Salt, D. E., Smith, R. D., and Raskin, I. (1998). Phytoremediation. Annu. Rev. Plant Physiol. Plant Mol. Biol., 49, 643–668.

Xie, S. S., Zhang, C., and Wu, Q. L. (2021). Role of Ceratophyllum demersum in phytoremediation of copper from contaminated water. Sci. Total Environ., 760, 143322.

Zeng, X., Xu, Y., Boeckx, P., and Wang, C. (2017). Influence of pH on copper uptake and accumulation in wetland plants: A case study with Typha latifolia. Chemosphere, 180, 196–203.

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المعالجة النباتية للمياه الملوثة بالنحاس والكادميوم باستخدام نبات الشمبلان (*Ceratophyllum demersum*)

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المستخلص

يُعد تلوث المياه بالنحاس والكادميوم من المشكلات البيئية الخطيرة، نظرًا لما تسببه هذه العناصر من تأثيرات سامة في الكائنات الحية والأنظمة البيئية. وتُعد المعالجة النباتية (Phytoremediation) باستخدام النباتات المائية تقنية بيئية حديثة وفعّالة ومنخفضة التكلفة لتحسين جودة المياه ومعالجة مياه الصرف الصحي. هدفت هذه الدراسة إلى تقييم كفاءة نبات الشمبلان *Ceratophyllum demersum* بوصفه حلًا بيئيًا لمعالجة المياه الملوثة بالنحاس والكادميوم، ودراسة قدرته على امتصاص وإزالة عنصري النحاس (Cu) والكادميوم (Cd) من المياه الملوثة وخفض تراكيزهما إلى مستويات آمنة بيئيًا. تمت دراسة قدرة النبات على الامتصاص من خلال تجربة مختبرية باستخدام تراكيز مختلفة من النحاس والكادميوم، وهي 0 و5 و10 جزء بالمليون (ppm) وبعد المعالجة بالنبات، تم تحديد التراكيز المتبقية من النحاس والكادميوم في المياه باستخدام جهاز مطياف البلازما المقترنة حثيًا – الانبعاث البصري (ICP-OES) كما تم حساب كفاءة إزالة كل من النحاس والكادميوم، إلى جانب قياس محتوى الكلوروفيل في النبات لتقييم تأثير التعرض للمعادن في حالته الفسيولوجية. أظهرت النتائج أن أعلى كفاءة لإزالة النحاس والكادميوم تحققت عند تركيز ppm5، إذ بلغت كفاءة إزالة النحاس 64.54% والكادميوم 59.4%. بينما انخفضت كفاءة الإزالة عند زيادة التركيز إلى ppm10، لتصل إلى 47.4% للنحاس و43% للكادميوم.كما أظهرت النتائج انخفاضًا في محتوى الكلوروفيل مع زيادة تراكيز النحاس والكادميوم. فقد بلغ محتوى الكلوروفيل في المجموعة غير المعرضة للمعادن 2.16 ملغم/غم للنحاس و1.5 ملغم/غم للكادميوم، ثم انخفض عند التعرض لتركيز 5 ppm إلى 2.01 ملغم/غم للنحاس و1 ملغم/غم للكادميوم. وعند تركيز ppm10، انخفض محتوى الكلوروفيل إلى 1.09 ملغم/غم للنحاس و0.9 ملغم/غم للكادميوم، على التوالي.وعليه تؤكد هذه النتائج إلى أن نبات الشمبلان *Ceratophyllum demersum* يمتلك قدرة ملحوظة على إزالة النحاس والكادميوم من المياه، مما يجعله خيارًا بيئيًا واعدًا في مجال المعالجة النباتية للمياه الملوثة. ومع ذلك، فقد تأثرت كفاءة الإزالة بتركيز المعادن، إذ انخفضت كفاءة النبات في إزالة النحاس والكادميوم مع زيادة تركيزهما في المياه.

الكلمات المفتاحية: المعالجة النباتية، النحاس، الكادميوم، الشمبلان.