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Original Research Article

Bioaccumulation of Nickel and Cobalt in the Aquatic Plants *Ceratophyllum submersum & Ceratophyllum demersum*

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Abstract: Aquatic macrophytes play a critical role in the removal and sequestration of heavy metals from contaminated freshwater systems through bioaccumulation and phytoremediation processes. This study examines the capacity of two submerged aquatic plants, Ceratophyllum submersum and Ceratophyllum demersum, to accumulate nickel (Ni) and cobalt (Co) from aqueous environments. The study's findings showed physiological reactions such as lower protein content and a reduction in chlorophyll concentration, which affects photosynthesis. According to the study's findings, heavy metals have an impact on plants' evolutionary states through enzyme alterations, oxidative stress reactions, and pigmentation loss.

Keywords: Accumulation, Aquatic Macrophytes, Heavy Metal, Removal.

INTRODUCTION

Aquatic plants are characterized by their ability to accumulate numerous heavy metals, including nickel and cobalt, as well as other metals such as lead, cadmium, zinc, and iron, when exposed to aqueous solutions (Abdallah, 2012). Studies have demonstrated the ability of aquatic plants to remove nickel from contaminated water with relatively high adsorption efficiency (Lin, *et al*., 2024). In a published study on phytoremediation, C. demersum was used to treat cobalt as part of metal exposure experiments, indicating that this species also absorbs cobalt from solution (Chorom, *et al.,* 2010). General studies on the ability of C. demersum show that the metal content in its tissues varies depending on the type of metal, often following specific enrichment sequences (root > stem), with nickel and cobalt present, but usually at lower levels compared to other major metals such as iron and zinc (Yao, *et al*., 2020).

In some studies, nickel and cobalt were among the least accumulated metals compared to other metals such as iron, zinc, and manganese, but they were still measurable in plant tissues (Kim, *et al*., 2018). Bioaccumulation is not necessarily directly related to plant growth or biomass. Factors such as water chemistry (pH, hardness), metal interactions, and plant physiological responses (oxidative stress, enzymatic defenses) influence the amount of metal that is absorbed and tolerated (Chen, *et al.,* 2015; Zheng, 2022). Both C. demersum and C. submersum can absorb nickel from contaminated water, but Absorption rates and accumulation levels vary depending on the species, environmental conditions, and mineral concentrations (Chorom, *et al.,* 2010).

In studies where nickel accumulation was measured, it tended to be large but less than essential micronutrients such as iron or zinc (Qassim, *et al*., 2024). C. demersum was specifically tested in experiments involving cobalt exposure, demonstrating its ability to absorb cobalt from solutions and its potential to contribute to cobalt removal in controlled environments (Qassim, *et al*., 2025). Cobalt accumulates in the alga C. submersum, but generally to a lesser extent than other metals such as iron and zinc in laboratory bioaccumulation studies (Chen, *et al.,* 2015).

Both species show promising potential as phytoremediators capable of removing traces of metals

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such as nickel and cobalt from polluted aquatic environments; however, bioaccumulation efficiency varies depending on the type and concentration of the metal, the chemical composition of the water, and the plant's functions (Kara, *et al.,* 2015). C. demersum is more widely studied and tends to have a stronger evidence base regarding the uptake of heavy metals, including nickel and cobalt, compared to C. submersum (Abdallah, 2012).

MATERIALS AND METHODS

C. demersum and *C. submersum* were utilized in this study. For each specimen, 250 grams of plant material were accurately weighed and cultivated separately in plastic containers. Each container was filled with ten liters of chlorine-free water, and three concentrations of the target element (10, 20, and 30 mg/L) were applied throughout the experiment (Qassim, *et al*., 2024). Plant samples were collected to analyze protein and chlorophyll content, as well as heavy metal accumulation. Growth was monitored, and data were recorded over a 30-day period. Total chlorophyll content in aquatic plant tissues was quantified using a chlorophyll meter, while protein content was determined via the Bradford assay (Yang, *et al*., 2020; Lu, *et al*., 2024).

RESULTS AND DISCUSSION

The study's findings illustrate the impact of various heavy metal concentrations on the physiological conditions of the aquatic plants under investigation, *C. submersum* and *C. demersum*. Compared to the control group, both species exhibited elevated levels of heavy metals in their tissues by the conclusion of the experiment. Specifically, *C. demersum* demonstrated the highest lead concentration (5.278) as shown in Figure (1) while *C. submersum* exhibited the lowest lead concentration (5.011) relative to the control group. Conversely, Figure (2) indicates that *C. demersum* had the lowest cadmium concentration (1.515), whereas *C. submersum* showed the highest cadmium concentration (2.018) compared to the control group.

These results indicate that these components can be accumulated in the tissues of the aquatic plants that are being studied. They have particular ways of absorbing or tolerating large quantities of these elements, which they then transform into inactive forms inside vacuoles (Abdallah, 2012). Due to species variations, physiological circumstances, and individual reactions to the elements, the concentration of accumulated elements varies among the plants (Liang, *et al*., 2017). By the end of the trial, the study also showed that the aquatic plants' overall chlorophyll content had decreased.

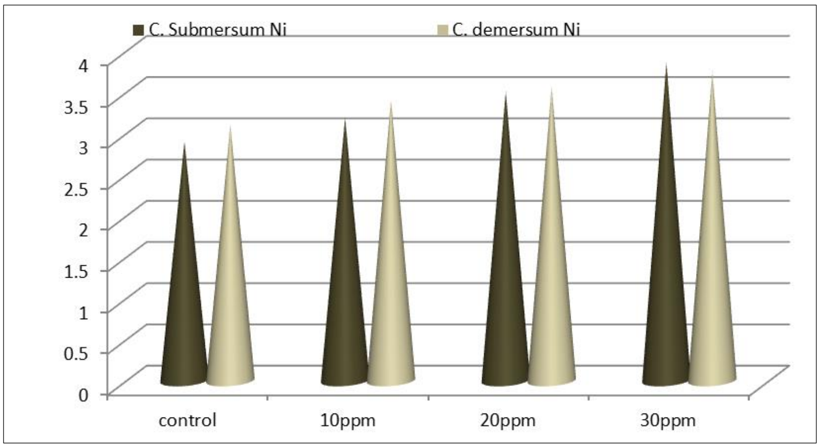

Figure 1: concentrations of (Ni) in *C. submersum and C. demersum* tissue

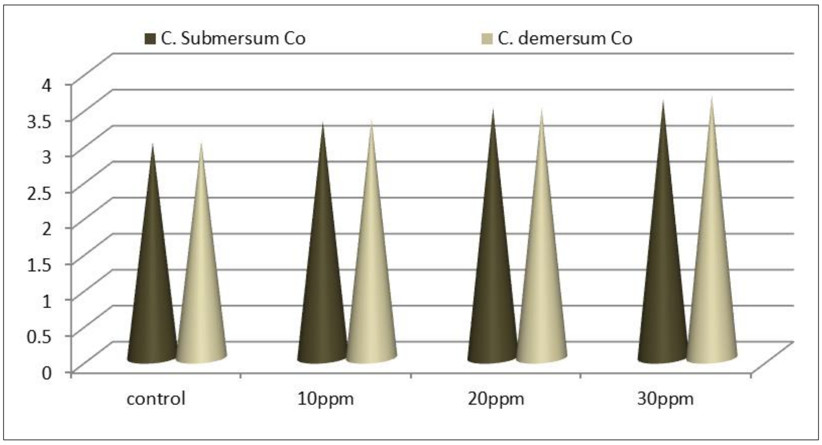

Figure 2: concentrations of (Co) in *C. submersum and C. demersum* tissue

The reduction in chlorophyll content in the aquatic plants as compared to the control group subjected to high quantities of heavy metals is seen in Figure (3), When exposed to lead, the chlorophyll concentration in C. demersum (4.282) was lower than that of C. submersum (4.378), and when exposed to cadmium, the chlorophyll concentration in C. submersum (3.586) was lower than that of C. demersum (3.699), as shown in Figure (4). Because these extremely poisonous chemicals can build up in plant tissues, they are the reason for the low concentration of chlorophyll in experimental plants (Yua, *et al*., 2017).

These compounds prevent the manufacture of chlorophyll by blocking the enzymes that produce it, including Porphobilinogen deaminase, which forms porphyrin, and aminolevulinic acid dehydratase. Because heavy metals block the enzymes involved in the production of carotene and chlorophyll, higher concentrations of these metals in plant tissues result in a decrease in the amount of chlorophyll. Certain enzymes aid in the production of chlorophyll, as noted by Mohammed, *et al., (*2024).

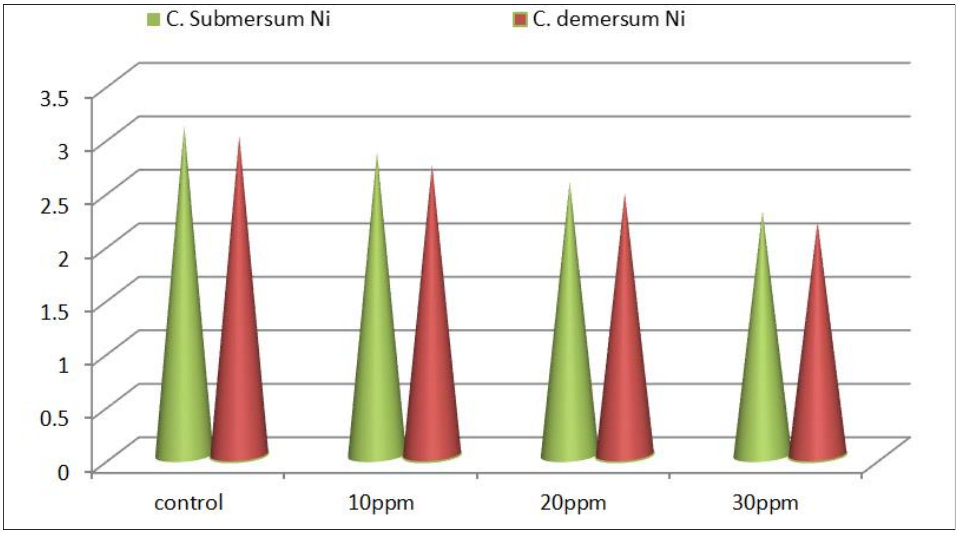

Figure 3: Effect concentrations of (Ni) on chlorophyll in *C. submersum and C. demersum.*

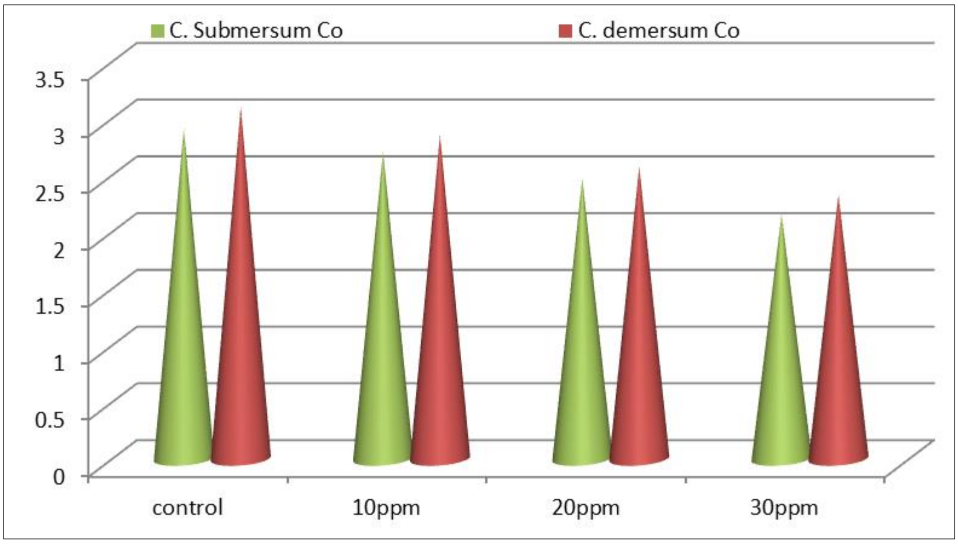

Figure 4: Effect concentrations of (Co) on chlorophyll in *C. submersum and C. demersum.*

Aquatic plants exposed to levels of heavy metals had lower protein concentrations than the control group, as seen in Figure 3. When C. demersum was exposed to lead, its chlorophyll concentration (2.409) was lower than that of C. submersum (2.417), and when C. submersum was subjected to cadmium, its chlorophyll concentration (1.698) was lower than that of C. demersum (2.395), as shown in Figure (2b). According to this explanation, the proportion of protein in plant tissues is decreased because protein is used by the tissues to perform essential functions or metabolic processes that balance the amount present of these components (Zheng, 2022). As exposure continues until the experiment's conclusion, this proportion falls (Mohammed, *et al.,* 2024).

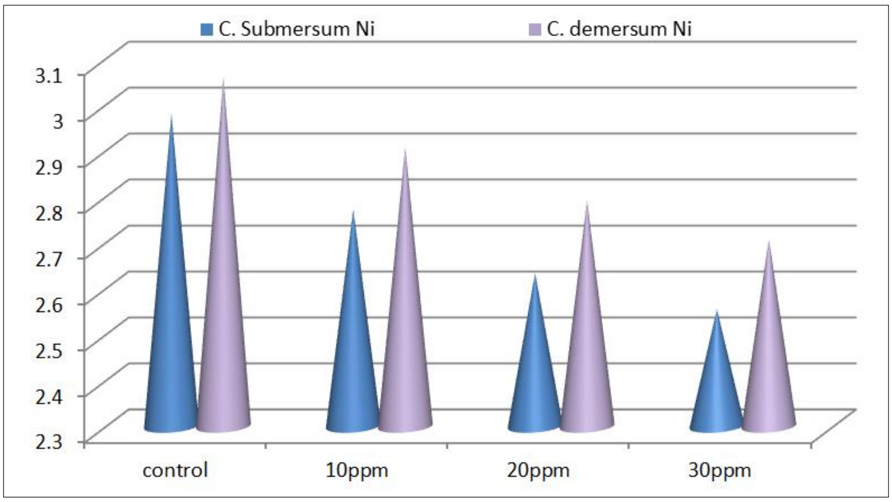

Figure 5: Effect concentrations of (Ni) protein content in *C. submersum and C. demersum.*

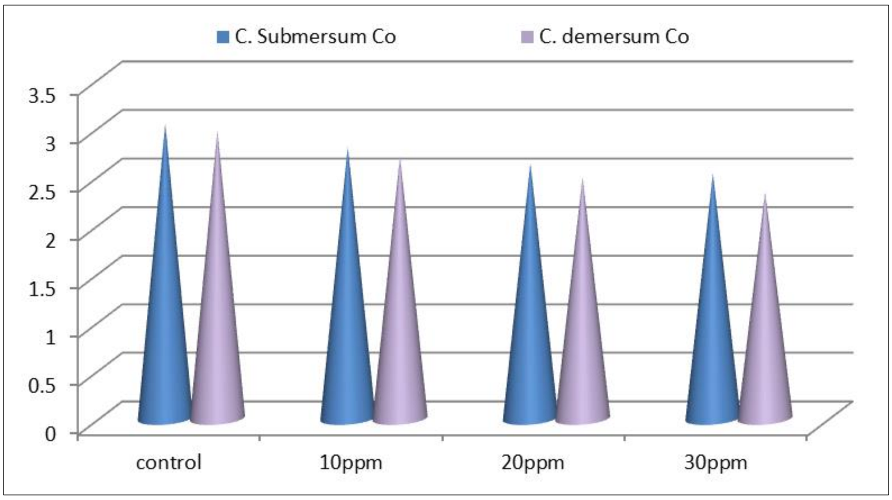

Figure 6: Effect concentrations of (Co) on protein content in *C. submersum and C. demersum..*

CONCLUSION

Although this needs to be confirmed by focused experiments, C. submersum and C. demersum have been shown to have the capacity to bioaccumulation heavy metals and to have physiological effects such as pigment loss, oxidative stress responses, or enzyme alterations to Ni and Co exposure, such as decreased photosynthesis, oxidative stress, lowered protein content, and activation of antioxidant defenses.

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Conflict of Interest: The authors have no conflict of interest.

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