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**Anbar Journal of Agricultural Sciences**
(University of Anbar – College of Agriculture)

# PHYTOREMEDIATION OF THE HEAVY METALS COPPER, LEAD, CADMIUM, NICKEL AND COBALT USING SOME PLANT SPECIES OF THE ASTERACEAE FAMILY

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**Article info**

**Received:** 2024-03-20
**Accepted:** 2024-06-29
**Published:** 2024-12-31

**DOI-Crossref:**
10.32649/ajas.2024.184465

**Cite as:**
Khalaf, I. M., Hameed, A. T., Talak, A. O., and Nasir, K. M. (2024). Phytoremediation of the heavy metals copper, lead, cadmium, nickel and cobalt using some plant species of the asteraceae family. Anbar Journal of Agricultural Sciences, 22(2): 1019-1032.



**Abstract**

This study explores the complex dynamics of heavy metal accumulation in various plant species of the Asteraceae family, highlighting their role as natural mechanisms for environmental metal remediation. The process depends on soil composition, the bioavailability of heavy metals, and the presence of chelating agents. The research focused on the accumulation of copper, lead, cadmium, nickel, and cobalt in selected plant species. *Sonchus oleraceus* demonstrated notable efficacy in reducing cadmium accumulation, recording the lowest concentration at 0.011 mg/kg. *Launaea nudicaulis* proved to be a promising phytoremediation agent for lead, with the lowest concentration recorded at 7.55 mg/kg. *Bellis perennis* showed strong potential in nickel absorption, with a minimum concentration of 0.32 mg/kg. Global permissible values confirmed the species' effectiveness in phytomediation for cobalt, which achieved the lowest concentration of 0.001 mg/kg. Additionally, statistical analysis at the LSD 5% significance level highlighted notable differences, identifying the species as promising for copper remediation, with a minimum copper concentration of 11.32 mg/kg.

These findings emphasize the diverse capabilities of plants as natural agents in reducing the accumulation and spread of harmful heavy metals in the environment, providing valuable insights for sustainable mitigation of heavy metal pollution. The identified low accumulation values establish these plant species as promising candidates for environmentally friendly and sustainable remediation strategies. This calls for further research and practical implementation in polluted ecosystems. Future studies should delve deeper into understanding the observed differences and verify practical effectiveness these species through field studies and long-term monitoring of metal movement from plants to the environments and their cyclic tendencies.

**Keywords:** Phytoremediation, Heavy metals, Asteraceae, Accumulation patterns pollutant spread.

# المعالجة النباتية للعناصر الثقيلة نحاس والرصاص والكادميوم والنيكل والكوبالت باستخدام بعض الانواع النباتات لعائلة Asteraceae

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## الخلاصة

تتناول هذه الدراسة الديناميكيات المعقدة لتراكم المعادن الثقيلة في أنواع النباتات المتنوعة في العائلة المركبة، والتي تعد من الاليات الطبيعية الفعالة في التخلص من المعادن في البيئة، والتي تعتمد على طبيعة التربة والتوافر الحيوي للمعادن الثقيل، ووجود عوامل مخلبية. ركز البحث على تراكم الكادميوم والنحاس (Cu)، الرصاص (Pb)، والكاميوم (Cd)، النيكل (Ni)، الكوبالت (Co)، في أنواع نباتية مختارة مختلفة. أظهر *Sonchus oleraceus* فعالية ملحوظة في تقليل تراكم الكادميوم، مسجلاً أقل تركيز عند 0.011 ملغم/كغم. واظهر النوع *Launaea nudicaulis* معالجة نباتية واعده للرصاص، حيث تتميز بأقل تركيز مسجل للرصاص يبلغ 7.55 ملغم/كغم، وأُظهر *perennis* Bellis إمكانات قوية لامتصاص النيكل كان فيه الحد الأدنى 0.32 ملغم/كغم. أثبتت القيمة المسموح بها عالميًا فعاليتها في المعالجة النباتية للكوبالت، حيث وصلت تركيزه إلى أدنى قيمة وهي 0.001 ملغم/ كغم. بالإضافة إلى ذلك، اظهر التحليل الاحصائي عند مستوى احتمال LSD 5% فروقا معنوية كنوع واعد لمعالجة النحاس، حيث اظهر أقل تركيز للنحاس عند 11.32 ملغم/كغم.

تؤكد هذه النتائج على القدرات المتنوعة للنباتات كمعاملات طبيعية تخفض من تراكم وانتشار العناصر الثقيلة الضارة في البيئة، مما يوفر رؤى قيمة للتخفيف المستدام من التلوث بالمعادن الثقيلة في سياقات بيئية متنوعة،

إن قيم التراكم المنخفضة المحددة تضع هذه الأنواع النباتية مرشحات واعدين لاستراتيجيات المعالجة الصديقة للبيئة والمستدامة، مما يستدعي المزيد من البحث والتنفيذ العملي في النظم البيئية الملوثة، وعلية يجب أن تتعمق الدراسات المستقبلية في التوضيحات الآلية للاختلافات الملحوظة والتأكد من الفعالية العملية لهذه الأنواع النباتية من خلال دراسات ميدانية عملية ومراقبة طويلة المدى لتحرك العنصر من النبات الى الطبيعية ودورته فيها.

**كلمات مفتاحية:** المعالجة النباتية، المعادن الثقيلة، العائلة المركبة، أنماط التراكم انتشار الملوثات.

## Introduction

Phytoremediation is a process that utilizes plants to clean polluted environments, leveraging their ability to absorb pollutants from soils, water, and air, and accumulating them in their tissues. Plants can assist in cleaning various types of pollutants, including metals, pesticides, solvents, explosives, crude oil, aromatic hydrocarbons, and leachate fluids from waste dumps (25 and 35). This environmentally friendly method consists of two components: one facilitated by root-colonizing microbes and the other by the plants themselves. This leads to the breakdown of toxic compounds into non-toxic metabolites. Plants can treat various compounds (7). Such as organic compounds, biogenic foreign substances, insecticides, and heavy metals. They offer a sustainable and cost-effective alternative to traditional treatment practices (31 and 36).

Heavy metals, which are non-biodegradable, remain stable in soil for extended periods, posing a long-term threat to the environment. Some heavy metals essential for plant physiological and biochemical processes, become toxic in excessive quantities. Non-essential heavy metals, such as lead, cadmium, and mercury, are highly toxic with no known function in plants, causing environmental pollution and adversely affecting crop physiological and biochemical processes, Microorganisms such as bacteria and fungi isolated from soil show strong biosorption capabilities of metals such as copper, chromium, cadmium, and nickel. In addition, fungi such as *Aspergillus niger* and *Fusarium* spp. demonstrate efficient removal of heavy metals such as arsenic and chromium, displaying their potential in bioremediation (4 and 5). Plants, especially herbaceous perennials, have the ability to absorb ionic compounds from the soil, even at low concentrations, creating a root ecosystem matrix to accumulate heavy metals and modify their biological availability, thus restoring polluted soil and stabilizing soil fertility (12).

The advantages of using phytoremediation include its economic viability when using self-sustaining solar-powered systems, ease of management, low installation and maintenance costs, reduced exposure of pollutants to the environment (19), wide applicability, and easy disposal. It prevents corrosion and filtration of metals by immobilizing heavy metals and reduces the risk of pollutant spread. Additionally, it can improve soil fertility by releasing various organic substances into the soil over decades. Environmental pollution (22), increased industrial activities, emissions from laboratories and vehicles, and the effects of global warming and climate change contribute to increased waste production and reduced agricultural land (11), leading to the accumulation of heavy metals over time (39). Hence, exploring plant-based remediation for the removal, breakdown, and detoxification of hazardous metals from heavy metal-contaminated sites is of significant importance. In response to the toxicity of heavy metals, plants typically employ two defensive strategies: avoidance and tolerance. Through these mechanisms, they effectively regulate cellular concentrations of heavy metals keeping them below threshold levels that could induce toxicity (1 and 37). However, there exists a research gap in studies on plant technologies that address the quantity and quality of elements and the optimal plant species that could serve as a solution for environments contaminated with heavy elements and emissions. There is a need to identify plants that can be employed in treating excessive accumulations and promoting their cultivation in heavily polluted environments. Consequently, this review concentrates on wild plant species from the composite family, which exhibit environmental remediation capabilities for the accumulation of five types of heavy elements, namely Cadmium, Lead, Nickel, Cobalt, and Copper.

## Materials and Methods

Phytoremediation experiment: Plant samples were collected directly from various regions in Central Iraq, including areas in Anbar and Baghdad provinces, characterized by residential and human activity in the spring, summer, and fall of 2022. A total of 21 mature plant samples were collected, identified, and classified in the herbarium of the College of Science, University of Baghdad. The plants were air-dried and stored in triplicate for each specie. Branches and leaves from the plant samples were taken, cleaned, dried in an oven at 70°C for 48 hours, and then ground using an electric grinder. The ground samples (1 g) were weighed and placed in digestion tubes, labeled with the plant sample number. Wet digestion was performed by adding 10 mL of concentrated sulfuric acid and 3 mL of perchloric acid. The digestion tubes were placed in a digestion apparatus, heated at 90°C for 45 minutes until a clear solution was obtained. The solution was allowed to cool, and the digested solution diluted to 25 mL with distilled water and mixed well. The elemental concentrations were determined using an Atomic Absorption Spectrophotometer following the method outlined (26).

## Results and Discussion

Copper Accumulations in the Plant Species: The results of copper estimation in the studied species showed variability in accumulation values (in Figure 1), with the highest concentration 73 mg/kg was observed in the *A. subulatus*, species followed by *L. laciniatus* 71 mg/kg, and lowest concentration was found in *S. marianum* 12 mg/kg. The average copper content across all plants was 48.6 mg/kg. There were statistically significant differences among the studied species, with copper concentrations ranging from 5 to 40 mg/kg (20).

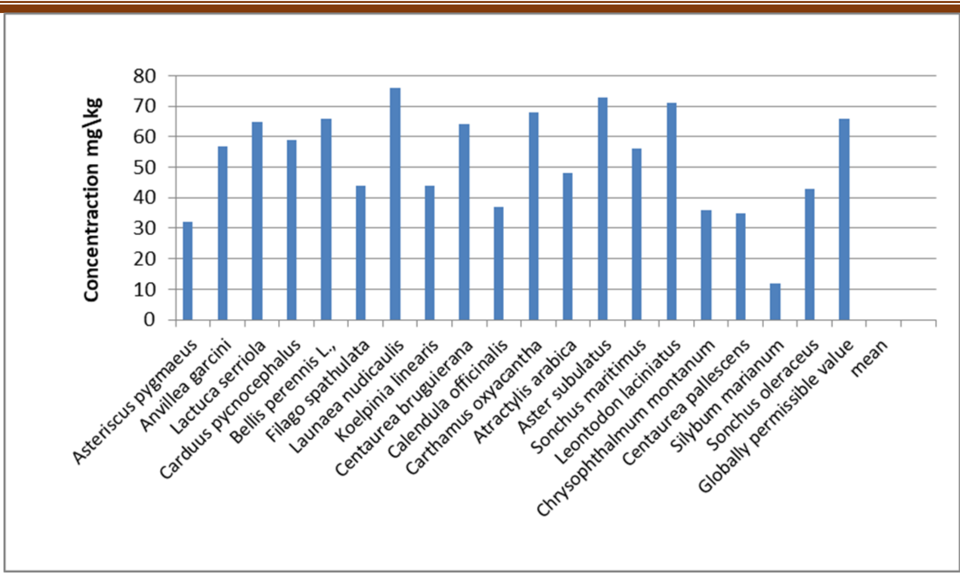


**Figure 1: Levels of the heavy metal copper in plant species. (LSD 5%= 0.012).**

Industrial and mining activities contribute to increased copper content in ecosystems, which is also added to the soil through various human activities, including copper smelting processes (23). Small plants tend to have higher copper concentrations, which decrease as the plant matures. While copper is an essential element for plants and crucial for their growth, high concentrations can impact physiological processes such as respiration and photosynthesis (34 and 40).

Excessive copper accumulation in plant tissues can have harmful effects on plant health and the ecosystem. Monitoring its levels in different plant species is crucial for understanding their potential role in phytoremediation of copper and assessing the safety of these plants for human consumption and environmental pollution (38). C Comparisons of copper accumulation in different plant species reveal differences in their ability to accumulate this heavy metal. The environmental implications of this results, especially regarding the potential use of these plants in phytoremediation efforts, are of utmost importance. Additionally, data should be assessed in the context of internationally defined permissible values, which serve as benchmarks to determine whether copper levels in these plants fall within acceptable limits for human consumption and environmental safety (13 and 21). The globally accepted permissible value is 66 mg/kg, which acts as a reference point for this purpose. Plants with copper concentrations below this limit can be considered safe for consumption and may have potential applications in phytoremediation. On the contrary, species exceeding this value may require further research and pose risks to the environment and human health.

Lead Accumulations in the Plant Species: Figure 2 shows the levels of lead concentration in the studied plant species. The lowest concentration, 7.55 mg/kg, was observed in the plant L. nudicaulis. Some plants exhibited lead accumulation exceeding the globally permissible value of 12.6 mg/kg, such as L. laciniatus 14.9 mg/kg, S. oleraceus 13.65 mg/kg, and A. cancellata 14.87 mg/kg, the average accumulation rate across all species was 10.811 mg/kg. The increased accumulation of lead in these plant species may be attributed to the high consumption of fuel, elevated lead emissions into the air and soil, and proximity to coal manufacturing sites. Lead, being a non-essential mineral for plant growth, is a significant chemical pollutant in the environment and a toxic element for humans. Studies indicate the ability of plants to absorb lead from the air through stomata and the plant's green parts.

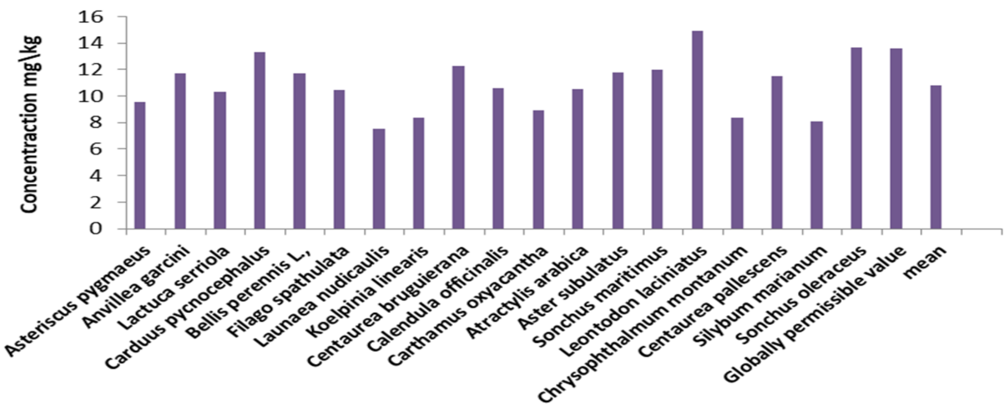


**Figure 2: Levels of the heavy metal Lead in plant species. (LSD 5%= 0.0043).**

Minute dust particles deposited on the plant's leaf surface, along with acidic compounds, interact with certain components of the cuticle, facilitating the spread of heavy elements to leaf tissues, affecting plant growth and the health of humans and animals (43).

In simpler terms, the water and spinach samples were contaminated with cadmium and lead at levels that unsafe for human consumption. The levels of Cadmium, and Lead levels were also high in the samples. The levels of these metals decreased in the following order: lead > chromium > cadmium > nickel > zinc > copper > iron. There was a significant increase in the concentration of lead in species growing in densely populated areas that experience heavy traffic, such as the city center, and this is related to the chemical composition and metabolic efficiency that enables the plant to accumulate various elements in its tissues (16). This indicates the ability of some plants to absorb and accumulate lead in their tissues when its concentration increases in their environment in alignment with the findings of this study (14). High lead concentration in the soil can reduce plant productivity and hinder their physiological processes such as photosynthesis, cell division, and water absorption, resulting in toxic symptoms such as wilting of old leaves, leaf and root deformities, and stunted plant growth (18).

Cadmium Accumulation in the Plant Species: Figure 3 presents the results of cadmium estimation for the examined plant species, S. oleraceus had the lowest concentration, at 0.011 mg/kg. In contrast, S. marianum recorded 0.75 mg/kg, and C. pallescens showed an accumulation value of 0.193 mg/kg, surpassing the globally permissible limit 0.01. Significant differences were observed among the studied species, with an overall accumulation rate of 0.126 mg/kg in all species.

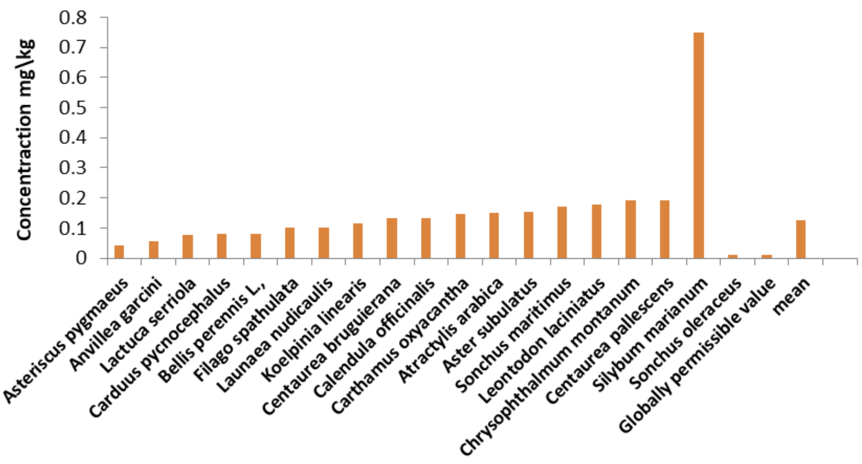


**Figure 3: Levels of the heavy metal cadmium in plant species. (LSD 5%= 0.011).**

The proximity of some species to pollution sources may contribute to increased cadmium accumulation (29). Factories, public roads, chemical and organic fertilizers, municipal waste, and sewage are major sources of cadmium pollution, in addition to atmospheric deposits in industrial areas (17). Cadmium affects cellular metabolic processes by reducing hydrolytic enzyme activity, starch movement, seed germination, and root growth inhibition. These are common symptoms of cadmium toxicity, intensifying with higher concentrations, affecting photosynthesis, cell wall construction, and seed germination (44).

Plants can be employed as a treatment for cadmium through accumulation various mechanisms. Among them is Root Vacuole Sequestration, which is proven to be the primary process restricting the transfer of cadmium to shoots and seeds. By isolating cadmium in root vacuoles (3), plants can prevent its transfer to other parts, reducing overall accumulation. Soil amendment is another strategy where non-organic amendments like phosphorus and silicon can reduce the bioavailability of cadmium to plants. Phosphorus forms insoluble complexes with cadmium, reducing plant uptake, while silicon mitigates cadmium-induced damage by altering water and nutrient uptake (8, 10 and 42).

Asteraceae plants were observed to have higher quantities of heavy metals compared to those of the Poaceae family. Specifically, the Asteraceae family exhibited primary accumulation of zinc and cadmium in the aboveground parts, while the Poaceae family tends to accumulate them in the root system. Investigating the fundamental mechanisms behind this phenomenon is important for the development of efficient phytoremediation strategies (9). Specific plant species, such as R. communis, have shown effectiveness in reducing cadmium accumulation in the soil. Studies have identified its potential for phytoremediation and soil purification in areas rich in cadmium and lead (41). These approaches collectively offer potential strategies to reduce cadmium accumulation in plants, providing insights into environmentally friendly practices for soil remediation.

Nickel accumulations in the Plant Species: Figure 4, compares of nickel accumulation in wild plant species with globally permissible values. The highest nickel accumulation was observed in *L. nudicaulis*, reaching 3.65 mg/kg, while the lowest was 0.89 mg/kg in *C. pycnocephalus*. The overall accumulation rate averaged 3.405 mg\kg. The variation in nickel accumulation depends on the plant species and their role in the metal's detoxification

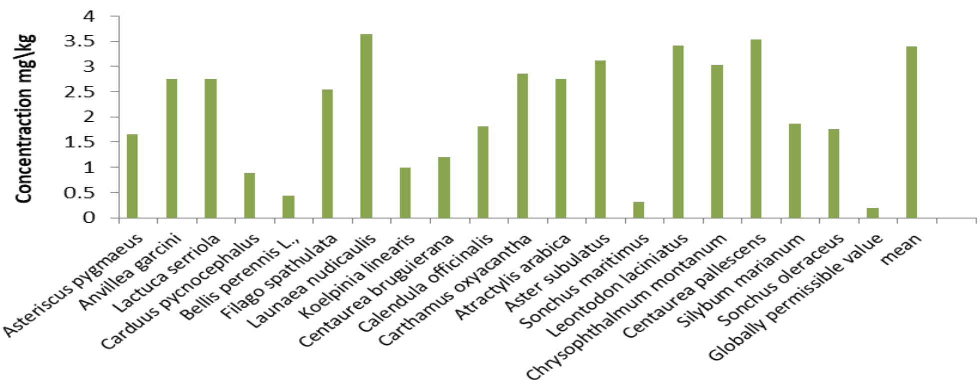


**Figure 4: Levels of the heavy metal nickel in plant species. (LSD 5%= 0.005).**

Nickel is an essential nutrient for plant growth, with its only known biochemical function in plants, residing in the active site of the urease enzyme, containing a binuclear nickel center (32). the nickel requirements of plants are exceedingly low, and nickel deficiency is rare. Some plants exhibit the ability to excessively accumulate nickel, meaning they can accumulate high levels in their tissues without experiencing toxicity. These are called hyperaccumulators and can be utilized in phytoremediation to remove pollutants from the soil (6). The mechanisms behind excessive nickel accumulation in plants are not fully understood, but enhanced uptakes of Ni2+ cation from the soil might be driven by high expressions of nickel transporters. Nickel accumulation in plants can lead to the formation of metal-binding compounds called phytochelatins (33). Certain plants, such as N. tabacum L and T. japonicum, accumulate nickel and form vital means of response to nickel stress, nickel toxicity can harm plants by interfering with various physiological functions, including enzyme activity, root development, and photosynthesis. At low levels, nickel treatment can enhance the morphological parameters of plants, but higher levels can induce oxidative stress and alter growth patterns. The easiest and most effective strategy to correct severe nickel deficiency in plants is foliar spraying with a diluted solution of NiSO4 or any other water-soluble nickel fertilizer. This can help alleviate nickel deficiency symptoms, such as leaf necrosis, and promote healthy plant growth (24 and 30).

Cobalt Accumulation in the Plant Species: Figure 5 compares cobalt accumulations in various wild plant species against globally permissible values. The highest accumulation was observed in *L. serriola* at 0.992 mg/kg, exceeding the global threshold of 0.532 mg/kg. *S. maritimus* exhibited the lowest at 0.210 mg/kg, well below the permissible limit. *L. serriola* was the only plant species surpassing the global threshold, indicating potential phytomediation efficacy in cobalt-contaminated environments, with an overall accumulation rate of 0.57 mg\kg in the studied species. Understanding cross-species variations in metal accumulation is crucial. Other species, such as *C. bruguierana* and *A. subulatus*, demonstrated moderate cobalt accumulation capacities.

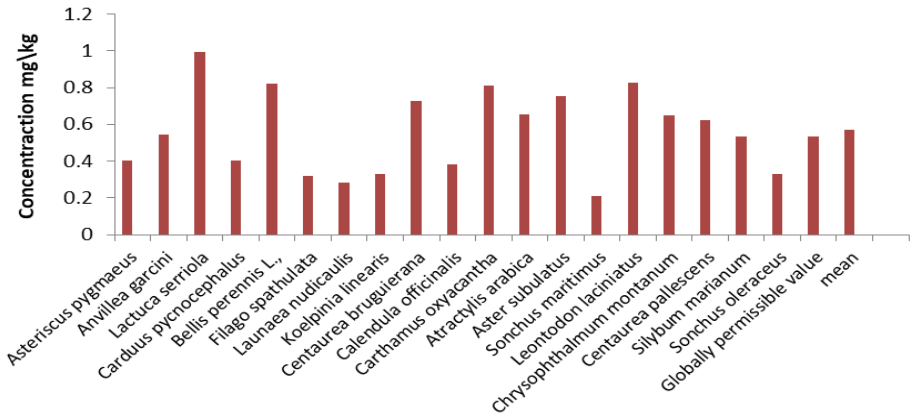


**Figure 5: Levels of the heavy metal cobalt in plant species. (LSD 5%= 0.010).**

Cobalt is an essential micronutrient crucial for plant growth and ranges from 15 to 30 mg/kg in the earth's crust. It has a pivotal role in nitrogen fixation, enzymatic activation, and vitamin B12 synthesis. Excessive cobalt accumulation in plants is relatively rare compared to other metals such as nickel and copper. The study highlights Glochidion cf. sericeum's simultaneous excessive accumulation of nickel and cobalt, suggesting potential shared physiological pathways (13 and 40).

The practical applications of cobalt-accumulating plants in phytomining, extracting valuable metals from soil, are limited due to dose-dependent accumulation properties (34). However, field experiments on cobalt-contaminated waste may be justified due to its relatively high metal value. In enhanced phytoremediation studies, genetically modified plants like AfSSB demonstrated increased cobalt accumulation (38), indicating potential applications for engineered plants in cobalt treatment. Cobalt mobility in soil and plant accumulation can be influenced by various factors, including soil chemical properties and experimental manipulations (2). Understanding these factors is vital for developing effective cobalt phytoremediation strategies (9 and 21). Variations in cobalt accumulation can be attributed to species-specific traits or cobalt concentrations available in the plant environment. Further research is needed to establish a comprehensive understanding and applications, such as the feasibility of using these plant species for cobalt phytoremediation or the environmental effects of elevated cobalt levels. Some studies shown that plants from this Asteraceae family, such as milk thistle and chrysanthemum morifolium ramat, have a protective effect against various toxic chemical agents, including aluminium, copper, Cadmium and lead. Other studies have investigated the biochemical responses of plants of this family to toxic heavy metals and organic pollutants, which represent the main targets of phytoremediatio. In addition, some plants from the Asteraceae family have been found to have antioxidant, detoxifying, and anti-cancer properties (15, 27 and 28).

## Conclusions

This study provides important insights into copper, lead, nickel, cobalt, and cadmium accumulation patterns in various plant species. Adhering to internationally permissible values is imperative to assess the safety and environmental impact of these plants. *L. nudicaulis* display relative tolerance with low accumulation of nickel, lead, and cadmium, while *S. maritimus* exhibit low accumulation values for cobalt and cadmium. Nevertheless, heavy metal tolerance is contingent on environmental conditions and genetic factors, necessitating further research to determine the most effective phytoremediation plant under specific conditions. Each plant species demonstrates unique heavy metal accumulation characteristics. *L. serriola* shows the highest cobalt accumulation, while *S. maritimus* has the lowest. Some species surpass globally permissible levels, particularly in lead measurements. The highest cadmium accumulation occurs in *S. marianum*, and nickel concentration is notable in *K. Lineris* ,*A. cancellata* exhibits the highest lead absorption. However, additional studies are necessary to validate these observations and understand the physiological effects on plants, especially when exceeding globally permissible values. The observed variations in accumulation capacity may be attributed to species-specific traits, such as root structure, soil-plant interactions, and metabolic capabilities, these results underscore the significance of these species in understanding plant-metal interactions on an environmental scale, offering potential roles in phytoremediation in specific contexts. Caution is warranted due to potential human health effects from consuming plants exceeding globally permissible concentrations of heavy metals.

**Supplementary Materials:**

No Supplementary Materials.

**Author Contributions:**

Author Ashwaq Talib Hameed; methodology, writing—original draft preparation, other authors writing—review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding:**

This research received no external funding.

**Institutional Review Board Statement:**

The study was conducted following the protocol authorized by the Head of the Ethics Committee, University of Anbar, Iraq Republic.

**Informed Consent Statement:**

No Informed Consent Statement.

**Data Availability Statement:**

No Data Availability Statement.

**Conflicts of Interest:**

The authors declare no conflict of interest.

**Acknowledgments:**

The authors will like to Acknowledge Officials in Central Consulting Laboratory at the College of Agriculture, University of Anbar.

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