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Phytoremediation potential of common *Asteraceae* weeds: A review

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ABSTRACT

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This review explores the utilization of *Asteraceae* weeds for phytoremediation of polluted soils and water. Key species, such as *Taraxacum officinale*, *Artemisia* spp., and *Helianthus annuus*, are highlighted for their capability to remove heavy metals and organic pollutants. These weeds are promising candidates for large-scale applications due to their environmental tolerance, fast growth, and high biomass production. The review also addresses challenges related to metal toxicity and bioavailability, advocating for advance investigation in genetic engineering and mixed-species systems. Overall, it underscores the *Asteraceae* family's potential in sustainable environmental management.

Keywords: Angiosperms, *Asteraceae*, Heavy metals, Phytoremediation, Pollution.

INTRODUCTION

Heavy metal (HM) load in the environment now poses a substantial danger to global food safety. Contaminated soil is challenging to manage, and heavy metals can straightforwardly come in the food chain through most of the crops, compromising human health (Qin et al. 2021). The rise in soil heavy metal (HM) contamination is linked to irreversible environmental damage from intensified human activities, causing concern within the scientific community. Metals such as nickel (Ni), chromium (Cr), and lead (Pb) are particularly persistent in soil and do not degrade. HMs are classified as either nonessential or essential according to their functions in the natural environment. Although tiny amounts of important HMs are necessary, high levels can be hazardous to human health. Although less important to organisms, unnecessary heavy metals (HMs) can be extremely harmful if they build up in plant cells. Both kinds of heavy metals (HMs) have the potential to adversely impact plant physiology and biochemistry, which could result in lower agricultural yields and health risks for both farmers and consumers.

Rarely detected in substantial concentrations, heavy metals (HMs) build up gradually over time. Even though heavy metals (HMs) are naturally present in the environment, human activity is the main cause of HM contamination. According to Tchounwou et al. (2012), activities including mining for minerals, oil extraction, the use of chemical fertilizers, wastewater discharge, pesticide application, and the burning of fossil fuels all dramatically increase the levels of heavy metals. Numerous remediation techniques are available to mitigate the harm these toxins cause and stop them from spreading into soils, the air, and water. These techniques, which fall into two general categories, mechanical and chemical interventions, include the burning of soil, the creation of electric zones, and the disposal of garbage (Lee et al. 2012).

Chemical treatments, however, come with several disadvantages, including high costs, inadequate control over contaminants, persistent residual chemicals, permanent changes to soil composition, alterations to soil cover, and the risk of secondary contamination. Therefore, developing economical and environmentally sound techniques for effectively restoring HM-contaminated areas is imperative (Čudić et al. 2016). Phytoremediation, which uses plants to reduce soil contamination, is gaining popularity due to its environmental affability, affordability, and impending to immobilize contaminants (Nong et al. 2023).

Phytoremediation is increasingly recognized as a sustainable method for environmental clean-up. This technique leverages high-biomass plants and hyperaccumulators, which are adept at filtering and accumulating heavy metals. Phytoremediation is applied in various contexts, including wastewater treatment (Carlos et al. 2023), wetland reinstatement (Li et al. 2022), and mine rehabilitation (Matakala et al. 2023).

The *Asteraceae* family, the largest plant family, includes species renowned for their adaptability and resilience in challenging conditions, making them well-suited for phytoremediation. This paper explores the mechanisms, effectiveness, and practical applications of *Asteraceae* species in environmental restoration.

MECHANISMS OF PHYTOREMEDIATION

Phytoremediation employs various methods to address environmental contamination, including phytodegradation, rhizofiltration, phytoextraction, phytovolatilization, and phytostabilization (Mocek-pł et al. 2023).

Phytoextraction: In this mechanism, heavy metals are taken up by plants through their roots and moved to their aboveground sections. It provides a long-term solution by harvesting biomass to remove accumulated metals. Phytoextraction, also known as phytoabsorption or phytoaccumulation, can be natural (continuous) or induced by adding external agents to enhance metal uptake and storage (Gerhardt et al. 2017, Rai & Singh 2020, Raza et al. 2020).

Phytostabilization: This technique uses plants to immobilize heavy metals in the soil, reducing their mobility and bioavailability. By utilizing mechanisms like sorption, complexation, and precipitation, phytostabilization prevents contaminants from leaching into groundwater or entering the food chain (Nwoko 2010, Ashraf et al. 2019). It transforms toxic metals into less harmful forms through root exudates and other processes (Gerhardt et al. 2017, Yan et al. 2020).

Phytodegradation: Also known as phytotransformation, this method breaks down toxic metals into less hazardous forms through plant metabolic processes or rhizodegradation, where plants and microbes work together to alter contaminants (Nwoko 2010, Jan et al. 2014). Enzymes like oxidoreductase and peroxidase play a key role in this process.

Phytofiltration: This approach uses plant roots, shoots, or seedlings to remove contaminants from water or waste sites. Pollutants are absorbed or adsorbed by plants, preventing them from reaching groundwater. Phytofiltration includes rhizofiltration (roots), caulofiltration (shoots), and blastofiltration (seedlings), and can be implemented in situ to reduce costs (Mahajan & Kaushal 2018, Javed et al. 2019).

Phytovolatization: Plants absorb contaminants from the soil and convert them into less volatile forms, which are then released into the atmosphere through the stomata. This method is used for heavy metals like mercury, arsenic, and selenium, as well as organic contaminants. While it reduces pollutant toxicity, it may contribute to air pollution (Morikawa & Erkin 2003, Edwards et al. 2011, Agarwal et al. 2019).

ASTERACEAE SPECIES IN PHYTOREMEDIATION

The *Asteraceae* family, comprising over 1,600 genera and 25,000 species distributed across diverse global ecosystems, is among the largest and most successful flowering plant families (Qi et al. 2011). Nikolić & Stevović (2015) highlight that this family is commonly used in urban environments for the bioremediation of various contaminants, making it a valuable asset for urban green spaces. It has been observed that metal accumulation levels vary significantly among different species of *Asteraceae*.

Sunflower (*Helianthus annuus* L.): Sunflower, an annual plant from the *Asteraceae* family, is a promising candidate for phytoextraction. It grows quickly, produces substantial biomass, and can hyperaccumulate heavy metals in its stems, leaves, and roots (Xiao et al. 2017). Applications: Effective in removing heavy metals such as zinc, cadmium, and lead from contaminated soils (Paulo et al. 2023).

Dandelion (*Taraxacum officinale* F.H. Wigg): Dandelion features a deep root system that enhances its ability to uptake soil-bound contaminants. Applications: Known for extracting heavy metals and hydrocarbons, particularly effective at absorbing cadmium and lead (Kano et al. 2021).

Wormwood (*Artemisia* spp.): Wormwood is recognized for stabilizing metals and degrading organic pollutants. It produces allelopathic chemicals that help break down organic pollutants. Applications: Effective in metal stabilization and organic pollutant degradation (Knudsmark Jessing et al. 2014, Lee et al. 2023).

Groundsel (*Senecio* spp.): Groundsel helps reduce the mobility and bioavailability of heavy metals in contaminated soils. Applications: Utilized in the extraction of heavy metals such as arsenic, lead, and zinc (Bech et al. 2012).

Marigold (*Tagetes* spp.): Marigold species are known for their capability to remove and accumulate heavy metals. Applications: Efficient in removing cadmium (Cd) and nickel (Ni) from polluted soils, with higher biomass in *T. erecta* leading to greater heavy metal accumulation (Madanan et al. 2021, Biswal et al. 2022).

Ragweed (*Ambrosia artemisiifolia* L.): Ragweed is utilized for the phytoremediation of heavy metal affected soil. Applications: Effective in treating soils contaminated with heavy metals (Munazir et al. 2022).

Common Yarrow (*Achillea millefolium* L.): Common Yarrow can accumulate heavy metals such as lead and cadmium. Applications: Used for the extraction of heavy metals from contaminated soils (Antoniadis et al. 2021).

Daisy (*Bellis perennis* L.): Daisy is utilized for removing pollutants, including hydrocarbons and heavy metals. Applications: Effective in the cleanup of hydrocarbon and heavy metal pollutants (Pilon-Smits 2005).

Scentless Chamomile (*Tripleurospermum inodorum* (L.) Sch. Bip.): Scentless Chamomile is used to remediate soils with high arsenic levels. Applications: Effective in treating arsenic-contaminated soils (Tőzsér et al. 2019).

Ox-eye Daisy (*Leucanthemum vulgare* Lam.): Ox-eye Daisy is efficient in the phytoremediation of petroleum hydrocarbon-contaminated soils. Applications: Effective in treating soils polluted with petroleum hydrocarbons (Noori et al. 2018).

Golden Crown beard (*Verbesina encelioides* (Cav.) Benth. & Hook. F. ex A. Gray.): Golden Crown beard is well-documented for its capacity to absorb a few heavy metals, viz., lead (Pb), cadmium (Cd), and zinc (Zn) from polluted soils. Applications: Accumulates these metals in its tissues, decreasing their soil concentration (Naz et al. 2022).

ADVANTAGES OF *ASTERACEAE* IN PHYTOREMEDIATION

Asteraceae plants offer several advantages for phytoremediation owing to their high biomass production, adaptability, and ability to hyperaccumulate heavy metals (Table 1). Many species in this family, such as *Taraxacum officinale* (dandelion) and *Helianthus annuus* (sunflower), produce substantial biomass, enhancing their capacity to uptake and store large amounts of contaminants (Ali et al. 2013). These plants are adaptable to a wide range of environmental circumstances, which makes them appropriate for a variety of remedial applications (Robinson et al. 2003). Members of the *Asteraceae* family are also well-known for their capacity to remove heavy metals from contaminated soil, including lead, cadmium, and zinc (Lone et al. 2008). Additionally, they have the capacity for phytostabilization, which aids in stabilizing pollutants in the soil and halts their erosive or leaching spread.

CHALLENGES AND LIMITATIONS

Despite their benefits, *Asteraceae* plants face several challenges in phytoremediation. The process can be slow, often taking years or even centuries to fully remediate contaminated sites, especially for metals with deep or extensive contamination. The effectiveness of phytoremediation can be limited by root growth depth, which may not reach the full extent of the polluted area (Shen et al. 2022). Moreover, high metal concentrations can inhibit plant growth and reduce remediation efficiency (Ali et al. 2013). Contaminant bioavailability also poses a challenge, as firmly bound metal ions in the soil can be difficult to release. There is also a risk of food chain contamination if the remediation process is not well-managed (Ramamurthy & Memarian 2012, Li et al. 2022). Finally, seasonal growth patterns can affect the overall effectiveness

Table 1: Species used in Heavy metals extraction.

S. No.	Common Name	Botanical name	Extracted heavy Metals	References
1.	Sunflower	*Helianthus annuus* L.	Pb, Cd, Zn	Xiao et al. (2017), Paulo et al. (2023)
2.	Dandelion	*Taraxacum officinale* F.H. Wigg.	Pb, Cd	Kano et al. (2021)
3.	Wormwood	*Artemisia vulgaris* L.	Organic pollutants, Heavy metals	Knudsmark Jessing et al. (2014), Lee et al. (2023)
4.	Groundsel	*Senecio vulgaris* L.	As, Pb, Zn	Bech et al. (2012)
5.	Marigold	*Tagetes erecta* L.	Cd, Ni	Madanan et al. (2021), Biswal et al. (2022)
6.	Ragweed	*Ambrosia artemisiifolia* L.	As, Cd, Cr, Cu, Mn, Ni, Pb	Munazir et al. (2022)
7.	Common Yarrow	*Achillea millefolium* L.	Cd, Pb	Antoniadis et al. (2021)
8.	Daisy	*Bellis perennis* L.	Hydrocarbons, Heavy metals	Pilon-Smits E. (2005)
9.	Scentless Chamomile	*Tripleurospermum inodorum* (L.) Sch. Bip.	As	Tőzsér et al. (2019)
10.	Ox-eye Daisy	*Leucanthemum vulgare* Lam.	Petroleum hydrocarbons	Noori et al. (2018)
11.	Golden crown beard	*Verbesina encelioides* (Cav.) Benth. & Hook. F. ex A. Gray.	Cd, Pb, Zn.	Naz et al. (2022)

of remediation, as plant growth and, consequently, contaminant removal may be slower during non-growing seasons.

FUTURE PERSPECTIVES

To enhance the effectiveness of phytoremediation, future research should prioritize several key areas. Genetic engineering offers the potential to develop plant varieties with improved abilities to uptake and tolerate heavy metals, which could significantly boost remediation efficiency. Additionally, creating mixed-species systems could leverage synergistic effects, where different plant species complement each other's strengths, potentially leading to more effective contaminant removal. Conducting field trials is essential for assessing the usefulness and efficacy of various methods in actual use. Furthermore, understanding the long-term ecological impacts and sustainability of using *Asteraceae* plants in phytoremediation is essential to ensure that these methods do not inadvertently cause adverse effects on ecosystems.

CONCLUSION

Heavy metal contamination poses severe risks to the health of humans, animals, aquatic life, and plants. Phytoremediation offers a promising solution due to its low-tech, environmentally friendly, and socially and economically acceptable nature. The *Asteraceae* family stands out as a particularly effective choice for phytoremediation due to its extensive diversity and adaptability. With continued research and field testing, *Asteraceae* species have the potential to play a crucial role in long-term environmental rehabilitation efforts, providing a sustainable method for mitigating heavy metal pollution and restoring ecological balance.

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