



Phytoremediation of Heavy Metals from Soil and their Effects on Plant Physiology - A Review

Gouhar Rehman,¹ Juma Muhammad,^{2,*} Muhammad Ilyas,^{2,*} Muhammad Subhanullah,³ Kaleem Ullah,⁴ Muratzhan Massimzhan,⁵ Murat Toktar,^{6,*} Yerkin Bektay,⁸ Medeu Kalybekov,⁹ Alibek Ydyrys^{5,*} and Yryszhan Zhakypbek^{6,8,*}

Abstract

Heavy metals (HMs) are an environmental problem that pollutes water, air, soil, etc. HMs and metalloids are environmental pollutants, particularly cadmium, lead, and arsenic. It is liberated from both the natural and anthropogenic processes. HM group accumulates in the ecosystem through anthropogenic activities, mostly by agriculture and industry processes. When they accumulate to toxic levels in soil, it adversely affects plant and crop productivity. Different plant species were assessed to remediate the soil from HMs. According to the review, the highest bioaccumulation concentration factor (BCF) for *Torilis leptophylla* (L.) Rchb. f. species was 51.52 for Lead (Pb), and the translocation factor (TF) was 17.18 for the *Catharanthus roses* (L.) G. Don species for chromium and bioaccumulation concentration (BAC) was *Catharanthus roseus* (L.) G. Don species was recorded at 83.66 for chromium. The highest levels of BCF and TF for *Polygonum labrum* species were 1.090 and 1.78 for arsenic. Arsenic is the most poisonous element generated by agrochemicals, burning fossil fuels, smelting metals, and pharmaceutical industries. The common effects of arsenic on plants are oxidative stress, decreasing the bioavailability of the essential elements, and morphological change. Cadmium is toxic because it can cause various diseases in plants, like chlorosis, necrosis, and shunted growth. Moreover, it affects the physiological process, reduces carbon fixation, osmotic pressure, and transpiration, and decreases chlorophyll. Pb is one of the critical HMs extensively found in nature in solid waste deposition, slag from mining, firing in shooting ranges, smelting, and automobiles. It is naturally produced from weathering, erosion of rock layers, and ore deposit phenomenon. It reduces the conduction power of the plant stomata, which ultimately affects the transpiration process and reduces the crop yield. Further studies should focus on cost-effective strategies to enhance the phytoremediation of contaminants and the unknown effects of HMs on plants.

Keywords: Desertification; Reclamation; Heavy metals; Bioaccumulation concentration; Translocation factor; Bioaccumulation Concentration.

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1. Introduction

Drylands cover approximately 40-41% of the earth's surface, home to over 2 billion people.^[1] Desertification poses a

significant environmental challenge, potentially impacting about 35% of the planet and affecting roughly 32% of the global population.^[2] This process involves land degradation in arid, semi-arid, and dry sub-humid regions, leading to a decline in vegetation, soil quality, and nutrient levels.^[3]

In Kazakhstan, statistics indicate that desertification and land degradation affect more than 15% of the country's territory, with extreme degradation impacting 180 million hectares of pasture land-of which 27.1 million hectares are severely affected.^[4] An additional 48 million hectares are experiencing medium to low degradation. As a result, crop yields in these areas decline by 2-3 times, protein content in animal feed decreases by 3-6%, and weeds and toxic species increasingly replace beneficial plants. Additionally, the humus layer of the soil is being destroyed, signaling a reduction in soil fertility.^[5]

¹ Department of Environmental Sciences, Shaheed Benazir Bhutto University Sheringal, Dir Upper, Khyber Pakhtunkhwa 18050, Pakistan,

² Department of Environmental Sciences, Shaheed Benazir Bhutto University Wari Campus, Dir Upper, Khyber Pakhtunkhwa 18050, Pakistan.

³ Institute of Urban Environment, Xiamen Chinese Academy of Sciences, Guangdong 361021, China.

⁴ Department of Botany, Government Degree College, Pabbi, Nowshera, Khyber Pakhtunkhwa 18050, Pakistan.

⁵ Biomedical Research Centre, Al-Farabi Kazakh National University, Al-Farabi ave. 71 050040, Kazakhstan.

Heavy metal (HM) pollution is a global environmental issue in the present era. The term HM refers to metals and metalloids with atomic numbers above 20 and relative densities greater than 7 g/cm³, as well as toxic effects on biota.^[6,7] Common HMs, such as Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Mercury (Hg), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Tin (Sn), Vanadium (V), and Zinc (Zn), while metalloids are Arsenic (As), Sb and non-metals are Selenium (Se).^[8,9]

HMs originate from natural sources such as weathering of rocks, volcanic eruption, and deposits of ores in the soil, and also librating from anthropogenic sources like industrial processes, smelting, oil refineries, energy production, wastewater treatment, electroplating, mining, and agricultural activities.^[10,11] Some HMs have been documented as essential nutrients to plants like Cu, Fe, Mn, Mo, Ni, and Zn. At the same time, particularly in low concentrations, play a crucial role in plant physiology (ion homeostasis, pigment biosynthesis, photosynthesis, respiration, enzymatic activities, gene regulation, sugar metabolism, nitrogen fixation) although technically not essential. They have toxic effects in high contents such as Co, Cr, Se, and V. Molecularly, responsive gene expression regulates plant development and tolerance against environmental stress. The HM stress activates a high number of genes and many resistance proteins in the plant in order to overcome the stress.^[12]

In large amounts, metallic ions deposition in the ecosystem produces contaminations that seriously threaten animals and plants.^[13] HMs are released into the soil, air, underground, and surface water, causing pollution and affecting the yield and quality of agriculture, fruit, food, medicinal crops, and human health.^[14,15] Exposure to HMs causes damage and alteration in the morphology of plants. It eventually changes the physiology and ecology adaptation, and the plant cannot survive in the natural ecosystem.^[16,17] Long-time exposure to HMs causes some severe kinds of diseases in human beings, such as myocardial infection, high blood pressure, cancer, neurological problems, skin issues, and urinary, reproductive, and respiratory system damage.^[18,19]

In HMs, As, Cd, and Pb are highly toxic to humans.^[20] These are the most common metal contaminants in industrial,

mining, and agricultural areas.^[21,22] Arsenic, cadmium, and lead have no obvious biological function in plant physiology,^[23] but a constant increase of these non-degradability elements in the soil and their causes changes in biogeochemical cycles, microbes communities as well enzymatic activities and in the long run imbalances occur in the ecosystems.^[24] Its enduring removal from the environment or immobilization for an extended period is vital to protect soils and water from contamination.^[25]

In the last era, various strategies have been developed over time to remove HMs from contaminated sites.^[26] These standard methods are surface capping, solidification, soil flushing, electro-kinetic extraction, and vitrification,^[27] but these techniques have a large number of drawbacks such as consumption of high energy, production of toxic slugs, partial removal of HMs, limited to a specific area and high cost.^[28,29] Over the last decade, fast-emerging, environmentally friendly, economically supportive, and alternative to traditional remediation methods have gained more attention; this green technology, known as “Phytoremediation,” is used by plant species to eliminate toxic elements from contaminated environments.^[30]

The use of plants to eliminate or stabilize heavy metals from contaminated soil is known as phytoremediation, and it has become recognized as a viable, environmentally responsible method of reducing the negative impacts of human pollution.^[31,32] The environment has become contaminated with heavy metals due to mining, industrial processes, and agricultural practices.^[33] This poses severe hazards to the health of plants, the quality of the soil, and the integrity of ecosystems. Optimizing phytoremediation efforts requires an understanding of the physiological and anatomical responses of plants to heavy metal exposure.^[34] Because they have evolved to survive in a particular habitat, endemic plants frequently display unique defense mechanisms against heavy metal stress.^[35] Researching these species can reveal important details about the innate survival mechanisms that allow them to flourish in contaminated settings. Researching these species can reveal important details about the innate survival mechanisms that would enable them to thrive in contaminated settings. Furthermore, examining these plants' anatomical features reveals cellular changes such as altered root architecture, vascular tissue organization, and the creation of protective structures. In plants, HMs interfere with several metabolic processes, including photosynthesis, water relations, and nutrient uptake, resulting in reduced plant growth, stunting, and, in some instances, death.^[36] Moreover, the efficiency of phytoremediation can be markedly increased by the use of biostimulators, which are compounds that promote plant growth and resilience.^[37] These substances may improve nutrient uptake, encourage stress tolerance, and encourage root development, all of which would help remove heavy metals from the soil. The phytoremediation efficiency is affected by several key factors such as plant species (floating, emergent and submerged), surrounding climate (temperature

⁶ Department of Mine Surveying and Geodesy, Institute Mining and Metallurgical Institute named after O.A. Baikonurov, Satbayev University, Almaty 050013, Kazakhstan.

⁷ Department of Soil Ecology, Kazakh Research Institute of Soil Science and Agrochemistry named after U.U. Usmanov, Al-Farabi Ave. 75, Almaty 050060, Kazakhstan.

⁸ Department of Metallurgy and mineral Processing, Satbayev University, Almaty 050000, Kazakhstan,

⁹ Faculty of Forestry and Land Resources, Kazakh National Agrarian Research University, Abay ave. 8 050040, Kazakhstan.

*Email: juma@sbbu.edu.pk (J. Muhammad), sirfilyas@yahoo.com (M. Ilyas), y.zhakypbek@satbayev.university (Y. Zhakypbek), Alibek.ydyrys@kaznu.edu.kz (A. Ydyrys)

of about 27 °C with sufficient sunlight and water), and environmental conditions (appropriate amount of sodium chloride, nutrients and chelating agents at pH of 5 to 6).^[38]

The primary goal is to provide an overview of the most recent developments in phytoremediation techniques, including methods to increase the bioavailability, tolerance, and accumulation of HMs. The use of genetic engineering to enhance plant performance during phytoremediation is also highlighted in this paper. This review also serves as the theoretical and conceptual foundation for the authors' research on the desertification of the Caspian Sea.

2. Search strategy

The digital libraries were searched using a number of keywords associated with HMs and their effects on health. We looked through the following libraries for research-related studies:

- Web of Science (webofknowledge.com/)
- Google Scholar (<https://scholar.google.com/>.)
- SpringerLink (<http://www.springer.com/in/>.)
- ScienceDirect (<http://www.sciencedirect.com>.)
- US National Library of Medicine National Institute of Health (PubMed) (<https://www.ncbi.nlm.nih.gov/pubmed/>.)

The keywords for the search were chosen by the authors in collaboration with four additional study participants, academics working in the field. Among these terms are "HMs," "wastewater," and "health impacts". With simply the keyword "water contamination with HMs" in the search, the majority of the papers were located. Other keyword strings created using Boolean "AND" and "OR" were also used to make sure that no relevant publication was missed. The paper selection was completed in three steps. These steps are as follows: the first step is to remove duplicate and redundant papers; the next step is to read the research paper's keywords, abstract, and title. The last step is to read the full text of the research paper. Finally, two steps of inclusion and exclusion criteria were applied.

3. Phytoremediation

The remediation of polluted soil has been a major issue in recent times. Several efforts were made to develop different techniques for the restoration of contaminated soil, such as drilling contaminants, adding chemical regenerators, pumping contaminants, and physical stabilization by adding non-toxic materials,^[39,40] improving the soil's physical and chemical traits by using mineral tailings, such as steel slag, zeolite, limestone, and fly-ash,^[41] excavation, soil washing, and chelate extraction. These technological methods are appropriate for heavily contaminated sites. Still, they reduce soil quality and are an arduous process,^[42-44] destroying the soil fertility and reducing the yield production of crops.^[45] These conventional methods have some adverse effects on the environment, like producing toxic slugs, requiring energy, partial removal of contaminants, and being limited to specific areas.^[46] Table 1 provides an overview of the many plants utilized for this purpose.

Chelation of metals in the cytosol by high-affinity ligands is potentially a fundamental mechanism of HMs detoxification and tolerance. Potential ligands include amino acids, organic acids, and two classes of peptides, phytochelatins and metallothioneins.

4. Green Technology for HMs Removal

Phytoremediation is a green technology in which plants remove and degrade the contamination in the soil and water. It is cost-effective, environmentally friendly, socially acceptable, and less technical. The plants metabolize, assimilate, or adsorb hazardous material in the soil to remove HMs and degrade other toxic contaminants from the soil and water.^[47,48] Phytoremediation technology uses native plant species, which is more beneficial than ex-situ techniques.^[49,50]

Plants that accumulate high concentrations of metals are sometimes referred to as "hyper accumulators". The term was first used to describe those plants that uptake and collect more than 1000 µg metal g⁻¹ dry mass.^[51] Generally, these plants have dense root systems, high tolerance, fast growth, and more adaptability to stressed environments. Such types of plants are known as hyper-accumulative plants. They translocate, aggregate, osmo-regulate, and immobilize the contamination from the polluted area.^[52-54]

5. Phytoremediation through Rhizofiltration in Plant

Phytoremediation contains many subsets, such as phytostabilization, phytovolatilization, and biofiltration (Fig. 1).^[55,56] It involves phytoextraction, and phytodegradation has recently been used to remediate metals and organic contaminants in the soil.^[57] Phytoextraction is the phenomenon in which the plant absorbs the HMs from soil or water along with another nutrient in solution form, transfers into the upper biomass, and accumulates in the harvestable part. Phytostabilization immobilizes the contaminants in the root via absorption of the root or precipitation in the rhizosphere. Phytovolatilization is the process in which the plant absorbs the contaminants through the root and moves upward in the xylem, then converts it into a volatile compound, which is released into the atmosphere. Rhizofiltration can absorb or precipitates inorganic and organic contaminants through roots and around root zone.^[58]

Hyperaccumulator plants in the desert and semi-desert regions perform several different functions in improving the environmental functions of the environment, along with cleaning the soil from heavy metals: 1) absorbing heavy metals from the soil into the tissues of the roots, stems, and leaves (Fig. 2); 2) restoration of soil fertility (improving the biological activity of the soil; improving the physical properties of the soil, improving the chemical properties of the soil; enriching the soil with organic matter; influencing the processes of new soil formation); 3) improve food safety; 4) improve human and animal safety; 5) improve environmental biodiversity; 6) reduction of carbon dioxide and dust emissions into the environment; 7) formation of a

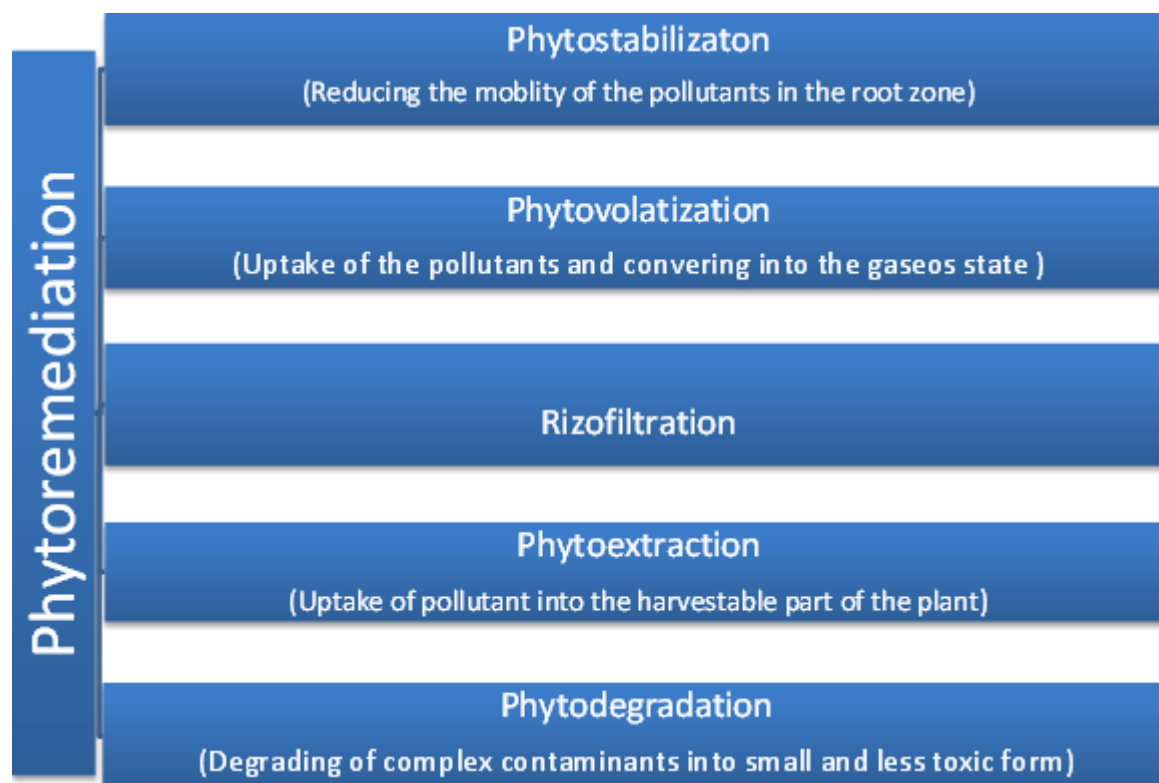


Fig. 1 shows a different method that is used for the absorption of HMs.

microclimate in the desert and semi-desert conditions; 8) reducing global warming.

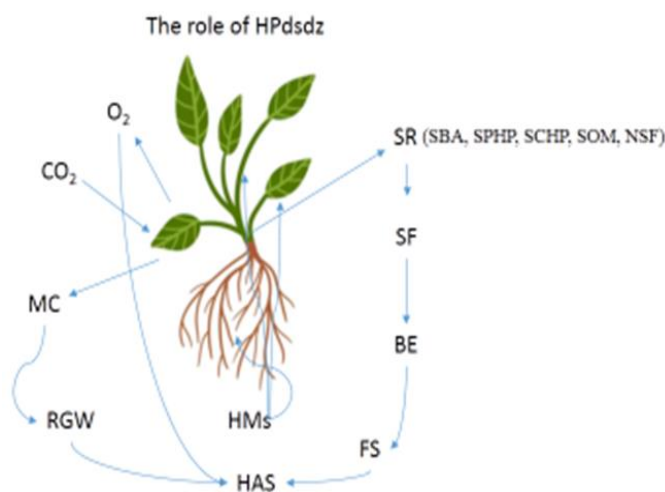


Fig. 2 The role of hyperaccumulating plants of the desert and semi-desert zone – HPdsdz. hyperaccumulating plants of the desert and semi-desert zone – HPdsdz, Soil reclamation – SR, Soil biological activity – SBA, Soil physical properties – SPHP, Soil chemical properties – SCHP, Soil organic matter – SOM, New soil formation – NSF, soil fertility – SF Biodiversity of ecosystems – BE, Food safety – FS, Human and animal safety – HAS, Microclimate – MC, Reducing global warming – RGW.

It is because majority of the HMs build-up in the soil system, and are absorbed by plants mainly via root system. In addition to plant roots, the aerial organs of plants such as leaves, fruits and flowers can also absorb heavy metals.

6. HMs remediation through protein in plant

Plants have a special kind of protein known as transporter protein, which binds the HMs to absorb from the soil or water, but in some plants, the contaminants are directly attached from the aquatic environment through water uptake, triggering adsorption and leading to aerial part and accumulation. Hyper-accumulating plants have the remarkable ability to cope with the HMs in their tissues.^[59,60] This technology is used in remediation projects in many developing countries because it is easy to implement and ten times cheaper than engineering-based remediation.^[61]

7. Origin of Arsenic

Arsenic (As) is a toxic metalloid with carcinogenicity and teratogenicity that naturally occurs in different oxidation states, organic and inorganic, which are interconvertible to each other.^[72,73] Generally, arsenic occurs in the earth's crust in two common forms such as As (III) and As (V). Based on occurrence, it is the 20th element found in anaerobic and aerobic environments all over the world.^[74,75] Arsenic also presents in elemental forms such as arsenic (0) and arsine (−3), while Monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA) is the organic form of arsenic found in paddy fields.^[76]

Arsenic inter into the environment, both from natural processes such as weathering of minerals which are rich in (As) as well as from volcanic eruption and from anthropogenic activities like fossil fuel burning, smelting of metals, pharmaceutical industries, agrochemicals, animal feed additives, and wood preservatives.^[77] About 568 minerals,

Table 1. List of some plant species used in the phytoremediation of different soil contaminants.

Plant	HMs	BCF	TF	BAC	References
Cnicus benedictus Linn	Cadmium	2.06	5.26	10.87	
Parthenium hysterophorus L.	-	7.83	1.78	14.00	
Xanthium strumarium L.	-	7.672	1.107	8.497	Naz <i>et al.</i> (2022) ^[62]
Chenopodium album L.	-	12.82	0.69	8.89	
Ptero cypsela laciniata		0.04	0.09	-	Zhong <i>et al.</i> (2019) ^[63]
Lolium perenne L.	-	1.26	2.51	-	Zhang <i>et al.</i> (2019) ^[64]
Allium griffithianum Boiss.	Lead	3.45	5.39	18.58	
Torilis leptophylla (L.) Rchb.f.	-	51.52	0.47	23.94	Muhammad <i>et al.</i> (2019) ^[65]
Catharanthu sroseus (L.) G. Don	-	6.18	1.96	12.1	
Pteris vittata	Chromium	0.156	0.704	1.602	
Populus nigra	-	0.054	0.0549	0.781	
Xanthium strumarium	-	0.0380	0.968	0.288	Khan <i>et al.</i> (2023) ^[66]
Verbascum Thapsus	-	0.0806	0.940	1.399	
Allium griffithianum Boiss.	-	7.39	29.91	221.14	
Torilis leptophylla (L.) Rchb.f	-	36.98	0.89	32.92	
Catharanthus roseus (L.) G. Don	-	4.87	17.18	83.66	
Asplenium dalhousiae Hook.	-	5.25	1.82	9.57	Sajad <i>et al.</i> (2020) ^[67]
Artemisia japonica Thunb.	-	1.84	2.34	4.32	
Verbena officinalis L.	-	43.19	0.12	5.04	
Urtica pilulifera L.	-	49.62	0.48	23.56	
Zinnia elegans L.		2.821	1.524	-	Panda <i>et al.</i> (2020) ^[68]
Athyrium schimperi	-	0.2	-	0.6	
Berberis lycium	-	0.1	-	3.4	Sajad <i>et al.</i> (2018) ^[69]
Lantana camara	Arsenic	0.45	1.03	-	
Polygonum glabrum	-	1.090	1.78	-	Deepa <i>et al.</i> (2015) ^[70]
Corrigiola Telephiiifolia	-	1.54	0.52	-	
Cyperus Exaltatus	-	0.45	0.61	-	Onyia <i>et al.</i> (2020) ^[71]
Nymphaea Maculata	-	0.14	0.23	-	

“As,” critically exist in natural conditions. These are the rock-forming minerals. In urban areas, the atmospheric concentration of As in Air is $0.02 \mu\text{g m}^{-3}$, while their concentrations vary from region to region and soil to soil, ranging from 0.1 to 40 mg kg^{-1} . In seawater, its concentration

is reported as less than $2 \mu\text{g L}^{-1}$, and in freshwater, their concentration is recorded from 0.15 to $0.45 \mu\text{g L}^{-1}$.^[78-81]

More than 70 countries were affected by arsenic through the contamination of groundwater.^[82,83] Pollution is increasing worldwide due to anthropogenic activities and affecting

farmland; it changes soil fertility, degrading the ecosystem, reducing crop yield, and contaminating the food chain.^[84,85]

8. Effects of arsenic on plant physiology

Arsenic has been declared the most toxic substance by the Agency for Toxic Substances and Disease Registry (ATSDR) and kept on the Substance Priority List-2019 (ATSDR 2019). It has an unknown biological function, but its presence in elevated amounts in soil or irrigation water affects plant physiology and human health by entering the food chain.^[86]

9. Effects of arsenic on plant morphology

Arsenic produces harmful effects on plant morphology, like chlorosis, cell death, disturbances in mineral homeostasis, epinasty, necrosis, reduced biomass, and stunted growth.^[87] Toxicity liberates free radicals in the cells of plants, altering their cellular metabolism and function. It also changes the growth rate, physiochemical properties, and molecular function of the plant through oxidative eruption. The oxidation states control the As biogeochemical behavior between soil and plant, whereas the toxicity, bioavailability, and mobility.^[88] Arsenic brings an epigenetic change in some plant species, such as *Pteris cretica* Albo-lineata, when exposed to 100 mg/kg⁻¹ and reduces their ethylation at cytosine (5 mC).^[89]

10. Adoptability of plants toward arsenic effects

Plants adopted them to reduce toxicity through different mechanisms, such as Ca-calmodulin, hormones, ROS-signaling, and Mitogen-Activated Protein Kinase (MAPK). In plant leaves, specialized pores in the epidermis cell known as stomata are responsible for different functions such as respiration, photosynthesis, and transpiration. It also plays a role in adapting plants to environmental stress as they contact the plant with the external environment.^[90,91] It affects the plant stomata conductance properties, chlorophyll content, transpiration, oxidative stress, and protein synthesis.^[92] Increased levels of Arsenic in plants bring some physiological and morphological changes such as oxidative phosphorylation and adenosine triphosphate, Ethylene production, cell membrane damage, delayed root hair growth, chlorophyll content reduction, abscission in plant leaves, increased oxidative stress weaken the protein synthesis and transpiration efficiency.^[93,94]

11. Origin of Cadmium

Cadmium (Cd) was discovered by F. Stromeyer in Göttingen, Germany, in 1817. It is a squashy metal colored like silvery-white powder belonging to the toxic (HMs) group and naturally occurs about 0.2 mg/kg in soil. Its biological persistence half-life in the human body is 16 to 30 years. According to FAO/WHO, an adult's recommended tolerable cadmium intake is approximately 0.4-0.5 mg/week (60-70 µg per day). Its accumulation ratio in the human body is about 1.8 ppm in the bones, 0.14 to 3.2 ppm in muscle, while in blood is 0.0052 ppm. Cadmium accumulates in the ecosystem through

different anthropogenic activities, mainly by agriculture and industry processes.^[95] Cd resists in the soil for up to 1 to 3 years and near-shore sediments for 2 years, whereas seawater can stay over 7000 years.^[96]

12. Effects of Cadmium on plant physiology

Cadmium is a highly toxic element in nature that causes different diseases in plants, such as chlorosis, necrosis, and stunted growth.^[97] Cadmium is the primary substitute for calcium (Ca), having an equal charge, the same ionic radius, and chemical characteristics.^[98] Cadmium reduces carbon fixation, osmotic pressure, and transpiration, and decreases chlorophyll content and photosynthetic activity.^[99] During biogeochemical cycles, HMs can be enriched in plants, thus causing damage to the stomata morphology; physiological and metabolic processes such as Cd can reduce stomata conductance and reduction in carbon dioxide uptake.^[100] Cd has a highly lethal effect on plants and is a more dynamic substance that accumulates in different parts of plants.^[101] In mustard plants, Cd increases the concentration of intercellular CO₂, which increases the stomata pore size and conductance power, leading to an effect on the process of photosynthesis.^[102] Cd concentration produces a negative effect on the vascular bundle of the plant, reducing the uptake of water and its transport, as well as the absorption of mineral nutrients from the soil to the plant body.^[103] Cd changes the permeability of the plasma membrane, causing a reduction of water content in the plant tissue.^[104] Control over Cd uptake and accumulation in the plant is complicated due to the fact that a large number of essential elements like Cu, Fe, Mn, and Zn facilitate it.^[105] The toxicity of Cd is measured twenty times greater than that of other HMs.^[106] According to the Environmental Protection Agency (EPA), the Standard maximum level of containment of Cd concentration is 0.05 mg/Kg.^[107] Overproduction of reaction oxygen species (ROS) in plants due to cadmium causes some severe effects, such as a reduction in the growth in the roots of plants by up to 73%, while in *Triticum aestivum*, overproduction of ROS (up to 116 %).^[108]

13. Origin of Lead

Pb is one of the most common HMs, having less biological function in nature, but is a significant environmental threat. Lead and its compound persist in the soil for a long period, and it is very difficult to degrade them into the sample form, so it becomes part of the food chain through the uptake of the plant, affecting the plant as well as other living organisms. It is extensively found in nature in anthropogenic sources such as deposition in solid waste, slag from mining,^[109,110] firing in shooting ranges, smelting, and automobiles. Still, naturally, Pb occurs in the crust of the earth in some minerals forms such as Cerussite (PbCO₃), galena (PbS), pyromorphite (Pb₅(PO₄)Cl₃), and anglesite (PbSO₄). Cerussite and galena are the main sources of the Pb contamination of soil, while pyromorphite and anglesite cause less Pb pollution. Pb is also present in numerous forms like ionic form, hydroxides, oxides, Pb (II),

and complexes of oxyanion, in which Pb (II) and Pb-hydroxy complexes are the most stable forms in the environment. It also liberates the ecosystem through weathering, erosion of rock layers, and ore deposit phenomenon.^[111-113] Annually alone, the USA's military shooting ranges contributed (70,000 metric tons of Pb bullets) to the environment.^[114] About 10% of toxic waste is formed by Pb metal out of all other HMs. A study reported that the Pb pollution index in the soil ranges from 400 to 800 mg kg⁻¹, and it may reach 1000 mg kg⁻¹ in the recent past industrial activities.^[110] In the process of smelting, many Pb metals are liberating to the soil ecosystem in the ionic form, which is absorbed by the plants and subsequently transferred into the food chain.^[115,116]

14. Effects of lead on the plant physiology

Pb contaminations in the Soil are absorbed by the plant and accumulate in their roots and stems.^[117] When moved from soil to the plant body, minimal amounts of Pb ions are translucent into the stem and aerial parts of the plant, whereas a significant amount remains concentrated in the root portion.^[118] The rising level of Pb in plants has a negative effect on the physiological process of the plant, affects the biogeochemical cycle, and reduces the soil's organic matter.^[119] When the Pb level increases significantly, such as more than 300 mg kg⁻¹ in the soil, it adversely affects the diversity of the microbial community, more specifically reducing soil microbial biomass carbon (C) and nitrogen (N) levels and catalase activity but increasing inverse phenomenon in the soil ecosystem.^[120] The active ions of the Pb produce toxic effects on the plant tissue and alter the normal function of the plant, damaging the process of photosynthesis and plant growth seed germination as well as reducing the absorption of other essential minerals.^[121] In wheat plants, lead reduces the conduction power of the stomata, which ultimately affects the transpiration process and reduces the yield of the crop (Kanwaet *al.*, 2020).^[122] Investigated the response of *Hypnea*, ryegrass (*Lolium*) exposed to 500 µM stress of Pb, it was observed that the carotene, chlorophyll a, and chlorophyll b levels and the photosynthesis rates were significantly decreased as compared to the control plant by the rate of 52.9 and 39.4%, respectively as also reduce the rate of the net photosynthesis (Pn) and transpiration rates.^[123,124] Pb can transfer from soil to plants and then accumulate in the food chain, indirectly affecting human health and especially causing more serious impacts on children's health.^[125,126] Pb accumulates in the food chain and affects human health, particularly children.^[127]

15. Limitations

The first limitation of this research study is that the search was carried out in only a few but the most widely referenced libraries. Several libraries were skipped during the search process. This decision was made to focus on only those papers that were published in high-quality peer-reviewed journals and conference venues to get justifiable results.

16. Conclusions and perspectives

Due to human activities, the concentration of HMs was increasing day by day. The high level of HMs, *i.e.*, Cd, Pb, Cr, and As in the ecosystem can affect all living organisms. Different plant species uptake HMs and play an important role in cleaning the environment. BCF, TF, and BAC are examples of cost-effective green technology. The review indicates that the species of *Catharanthus roseus* (L.) G. Don for Cr had the highest BAC, TF for Cr, and BCF for *Torilis leptophylla* (L.) Rchb.f. species. The highest BCF and TF levels for arsenic in *Polygonum glabrum* species. By synthesizing these findings, the review underscores the potential of specific plant species in phytoremediation efforts within the context of desertification in the Caspian Sea region. The future of phytoremediation is still in the research and development phase, and there are many technical barriers, which need to be addressed. Both agronomic management practices and plant genetic abilities need to be optimized to develop commercially useful practices.

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Conflict of Interest

There is no conflict of interest.

Supporting Information

Not applicable.

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