



A Novel approaches for the Bioremediation of Chromium from Contaminated Soils

A. A. Kamble* P. S. Jadhav, R. K. Aher, N. M Ghangaonkar

Research Centre in Botany, New Arts, Commerce and Science College, Parner – 414 302, India.

PG and Research Centre in Department of Botany Chandmal Tarachand Bora College Shirur. Dist Pune 412 210.

Corresponding author Email: kamble.anuradha12345@gmail.com

ABSTRACT

*The global population's rapid growth has led to increased resource consumption and pollution from the industrial Revolution. Heavy metal contaminations in fertile soils and fresh water are one of the worldwide issues. Contamination in natural resources due to heavy metals is a serious threat to sustainability of ecosystems and human life. Bioremediation techniques include phytoremediation and mycoremediation which are cost effective sustainable and green alternatives to harsh chemical cleanup. Microorganisms play an important role in heavy metal remediation from contaminated resources attributed to its easy operations, without any secondary pollution. This review mainly emphasizes the mechanism of phytoremediation and mycoremediation using endophytes including *Macrophomina phaseolina*, *Fusarium haemaococcum*, *Arcopilus fusiformis*, *Fusarium phaseoliai* from *Portulaca oleracea* L. Some potential fungal endophytes helps to remove chromium from contaminated soils in industrial region of ranjangaon MIDC area.*

Keywords: Bioremediation, Phytoremediation, Endophytes, Heavy metal Chromium.

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INTRODUCTION

The rapid expansion in the global population has resulted in a larger use of natural resources and outlets to meet the population's increased needs for food, energy, and various other essentials. The Industrial Revolution evolved as a way to satisfy these demands; yet, it has also resulted in a significant quantity of persistent pollution in our ecosystems. (46). Pollution in many forms poses substantial difficulties to environmental health. Air pollution, soil contamination, water, plastic, and thermal pollutions are examples of Industrial revolutions. A critical notion is bioremediation, which is using natural processes to address these difficulties, such as the remediation of pollutants like plastic waste and thermal discharges. (61). Soil contamination is referred to the accumulation of persistent harmful substances, salts, chemical compounds, radioactive wastes, or pathogens that have a negative impact on biological systems (38). One critical focus lies on heavy metals, a class of pollutants that resist biodegradation and tend to accumulate within organisms. The toxic nature of heavy metals poses substantial risks to ecosystems. In industries like tannery production, pollutants within effluents inorganic, organic, and toxic compounds, necessitating comprehensive treatment prior to disposal. By doing so, we can effectively prevent the introduction of physical, chemical, and biological pollutants into water bodies, (60). Thus, for effective remediation of such contaminants in the environment, efficient technologies must be deployed to ensure a sustainable ecosystem (29).

Heavy metal pollution has become a global environmental concern due to its harmful effects on human health and ecosystems, with contamination levels differing across regions. Metals such as cadmium (Cd), mercury (Hg), zinc (Zn), chromium (Cr), and lead (Pb) are toxic in nature and can pose significant risks even at low concentrations when present in soil. (53). As an effective remediation technique for contaminated soils, groundwater, and wastewater, phytoremediation has enormous promise. Phytoremediation is considered a cost-effective and highly efficient method for the removal of metals. A study was conducted to evaluate the effectiveness of this technique in eliminating toxic heavy metals from contaminated soil. (44). The concept of phytoremediation – using plants to remove or inactivate pollutants from soils has received increasing attentions in recent years (46). Phytoremediation is an emerging, cost-effective, and environmentally sustainable approach for the remediation of heavy-metal-contaminated

soils, offering significant advantages over conventional physical and chemical methods due to minimal ecological disturbances. Moreover, the technology was likely to be more acceptable to the public than other traditional methods. (54) . The present study also investigated the phytoremediation potential of the plant *Portulaca oleracea*. In addition, the bioaccumulation of the heavy metal chromium in different parts of the plant was analyzed.

Sources of metal pollution

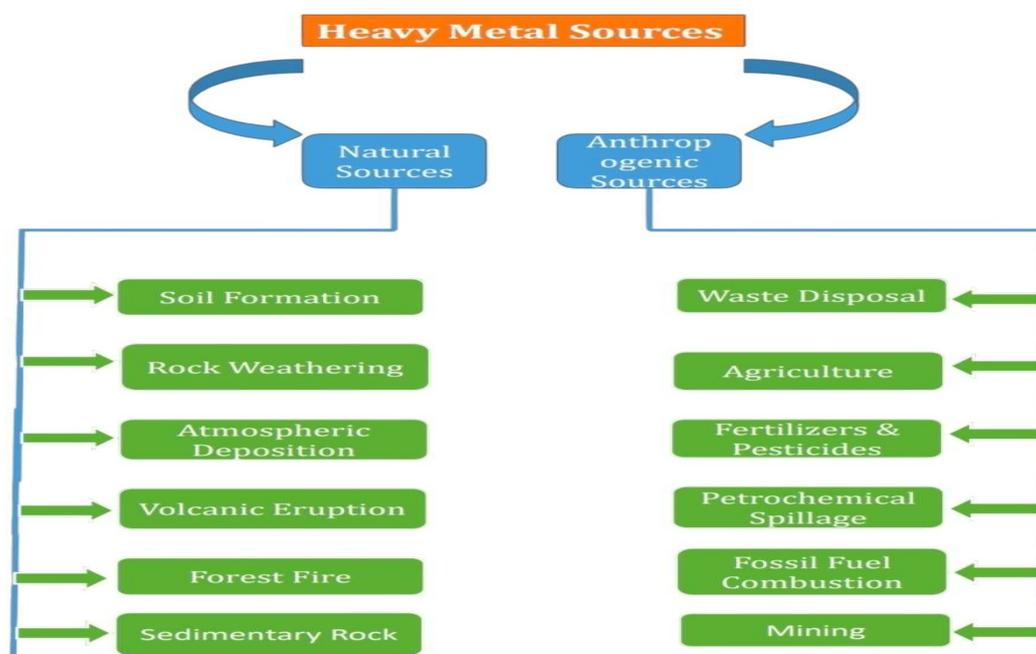


Fig : Different Sources of Heavy Metal

Heavy metals usually exist in the form of carbonates, hydroxides, oxides, sulfides, sulfates, phosphates, silicates, and organic compounds (49) . In WHO (World health organization) Listed 11 heavy metals namely, arsenic, chromium, cadmium, cobalt, copper, manganese, mercury, nickel, lead, tin, titanium. (1). Heavy metal contamination originated from geological and anthropogenic activities. Industrial effluents, fuel production, mining, smelting processes, military operations, use of agricultural chemicals, small-scale industries (such as battery manufacturing, metal products, and cable coating industries), brick, kilns, and coal combustion are some of the sources of anthropogenic metal contamination (4,50). The disposal of municipal waste is one of the main causes of the rising load of soil contamination. While sewage is used for irrigation, these wastes are either disposed of in landfills or on the sides of the road. Although being a valuable source of nutrients, these wastes also contain hazardous metals and toxic chemicals. Other causes may include inappropriate or excessive use of fertilizers, fungicides, and pesticides - which are sometimes restricted. Irrigation of water affected by sewage and industrial effluents, which results in contaminated soils and vegetables, is another potential source of heavy metals (4). Chromium is a naturally occurring element which is found in rocks, plants, animals, and soil. It interact with other elements to generate a variety of compounds (63).

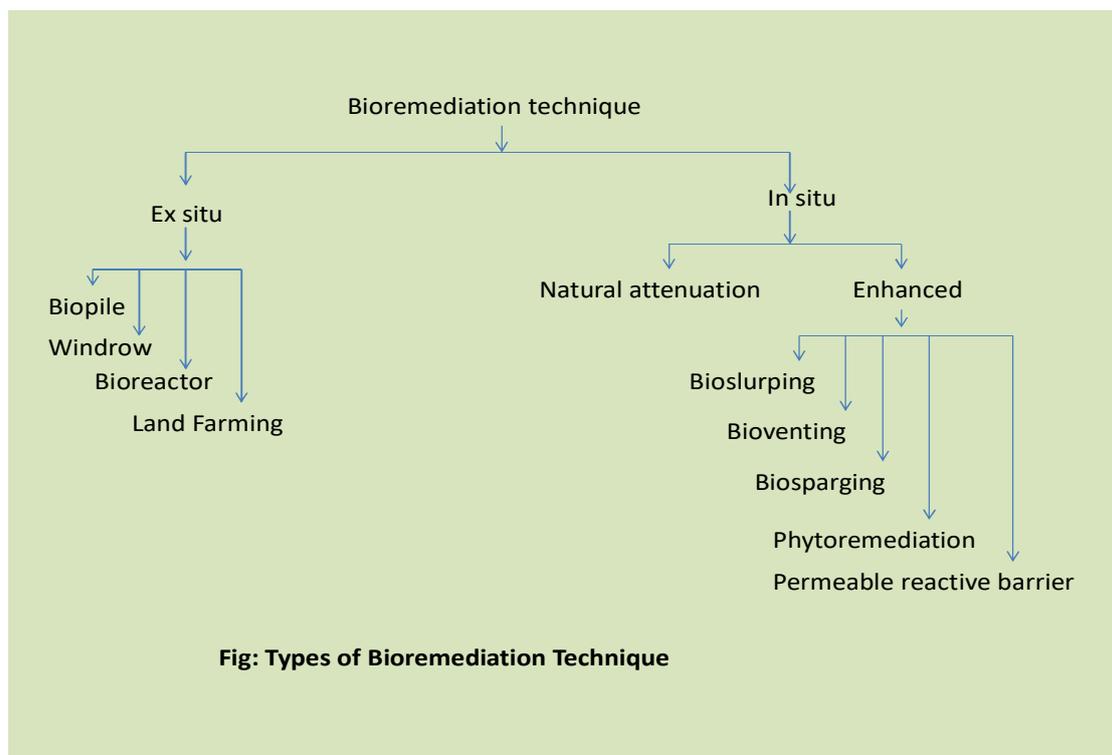
CHROMIUM

Chromium is a toxic substance, and excess Cr in the body causes skin diseases, respiratory, kidney and liver. In the environment, Cr is often found in valences of 3 and 6. Chromium in trivalent form is less hazardous than hexavalent chromium, but when Cr (III) coincides the oxidant, Cr (III) has same toxic properties as Cr (VI). The hexavalent chromium is more soluble and mobile in water. The substance is more dangerous because of its high toxicity, its mutagenic nature can cause carcinogenic effects to living organisms including microorganisms (55). Cr (VI) is classified by the World Health Organization as a human carcinogen, and it is known to cause damage to respiratory tract tissues, kidneys, liver, and skin (3).

TYPES OF BIOREMEDIATIONS

Bioremediation involves a range of treatment methods and technologies designed to remove or neutralize environmental contaminants. The cleanup process can be carried out through different biological approaches, including microbial remediation, phytoremediation, phytoremediation, and mycoremediation.

Key strategies used in bioremediation include biostimulation, natural attenuation, bioaugmentation, bioventing, and biopiling (5).



PHYTOREMEDIATION

The word is derived from the Latin suffix "remedium," which refers to cleanup or restore, and the Greek word "phyto," which indicates plant (13). The term even includes a wide range of plant-based remedies that clean polluted environments using either naturally occurring or genetically modified plants (20). Though the concept was first brought forth in 1983, it has been utilized for the past 300 years to eliminate heavy metals and other elements from wastewater discharges (26,9). According to several studies Phytoremediation is a new, cost-efficient, and environment friendly remedial treatment that is accepted by the people and the environment (55,48,44,41). Phytoremediation is also referred as green remediation, botano-remediation, agro-remediation, or vegetative remediation, is seen as a green remediation technique that is appealing to the general population. It eliminates, immobilizes, or detoxifies heavy metals from the soil and water using plants and associated microbiota, soil supplements, and agricultural techniques (62,24,13). It is costly to use traditional physicochemical techniques that are developed for small and highly contaminated areas to detoxify massive amounts of heavy metal-affected soil. In recent years, a growing interest is seen in the phytoremediation and the utilization of plants to eliminate or inactivate contaminants from soils (45).

Table 1 : Examples of plants widely used and studied in bioremediation of Chromium.

Plants	Heavy metal uptake (mg/Kg)	References
<i>Brassica napus</i>	9	34
<i>Cystus ladanifer</i>	2667	47
<i>Tagetes minuta</i>	111-411	2
<i>Rumex hastatus</i>	26-848	2
<i>Raphanus sativus</i>	5	10
<i>Bryophyllum pinnatum</i>	32.48±3.21	19
<i>Portulaca oleracea</i>	150	3

TYPES OF PHYTOREMEDIATION

Phytoextraction/phytoaccumulation: Involves the uptake of contaminants by plant roots followed by their translocation and accumulation in aboveground tissues, such as stems and leaves, which can be harvested for contaminant removal (21).

Phytodegradation: in this process, the plant takes up the contaminant through its roots from the contaminant is trans-located and the aerial portions of the plant. The difference between phytoextraction and phyto-degradation is that in the latter the contaminant is converted to a less toxic form during translocation to the aerial portions of the plant (4).

Phytovolatilization: The uptake of contaminants by plants and their subsequent release into the atmosphere in volatile form Phyto-volatilization (30) occurs as growing trees and other plants take up water as well as organic and inorganic contaminants. Some of these contaminants can pass through the plant leaves and Vaporize into the atmosphere at comparatively low concentrations (35). Juncea efficiently accumulates mercury in its tissues and can volatilize certain mercury species, while some *Helianthus species* similarly absorb mercury and convert it into volatile forms that are released through their leaves. In addition, *Stanleya pinnata* (Prince's plume), a selenium-hyperaccumulating plant native to North America, can accumulate high concentrations of selenium in its tissues and subsequently volatilize selenium compounds into the atmosphere as part of its detoxification strategy. (27)

Phytostimulation: Degradation of contaminants by plants facilitated by microorganisms in the rhizosphere (12).

Phytostabilization: Phytostabilization is defined as (1) Immobilization of a contaminant in soil through absorption and accumulation by root, adsorption onto roots, or precipitation within the root zone of plants, and (2) The use of plants and plants roots to prevent contaminant migration via wind and water erosion, leaching and soil dispersion (7)

Table 2: PLANT SPECIES WHICH CAN ACCUMULATE HEAVY METALS

Plants	Category	Contaminated area	Heavy Metals	References
<i>Cicer arietinum L (chickpea)</i>	Phytoaccumulators	Soil	Cr, Cd, Pb, Cu	59
<i>Eichhornia crassipes L. (Water hyacinth)</i>	Phytoaccumulators	Water	Cr, As, Zn, Cs, Co	25
<i>Jatropha curcas L. (Purging nut, physic nut)</i>	Phytoaccumulators	Soil	Al, Fe, Cu, Cr, As, Zn, Hg, Mn	6
<i>Pistia stratiotes L. (water lettuce)</i>	Phytoaccumulators	Water	Cr, As, Cd	28
<i>Pisum sativum L. (pea)</i>	Phytoaccumulators	Soil	Cr, As, Pb, Cu, Zn, Fe, Cd, Ni,	52
<i>Spinacia oleracea L. (spinach)</i>	Phytoaccumulators	Soil	Cd, Cu, Fe, Ni, Pb, Zn, Cr	58
<i>Brassica juncea, sunflower (Helianthus spp.)</i>	Phytovolatilization	Soil	Mercury	27
<i>Brassica juncea (Brassicaceae)</i>	Phytoextraction		Cr, Cu, Cd, Ni, Zn, and Pb	33
<i>Portulaca oleracea</i>	hyperaccumulation	Soil	Cu, Ni, Hg, and Pb	18

Portulaca oleracea:

Portulaca oleracea is a succulent plant belonging to the *Portulacaceae* family, derived from the mediterranean region, that grows nicely across the world, from australia and north america to India. The plant is a self-compatible annual weed that can grow up to 40 cm tall and grows rapidly. It generally grows along the ground with taproots, alternate leaves, and smooth stems which help to tolerate dry conditions and poor soils (3). The *Portulaca* plant act as hyperaccumulators of Cd and Cr in irrigated areas near to an industrial area in India. Heavy metal uptake by plants generally impact variety of biochemical and physiological pathways, limiting plant growth and often causing cell death (56,54) Monitoring the translocation of heavy metals in the soil and plant sections (shoot and root) of *Portulaca oleracea* L. which grows in cultivated lands at certain industrial areas in Dakahlia District, Northern Nile Delta, Egypt. (31,34) Stated that plants were harvested and plant samples were prepared for the evaluation of physical parameters (plant height, fresh and dry weight) and chemicals properties. Atomic Absorption Spectrophotometer (AAS) was used to measure Chromium concentrations in soil and plant samples . The Results showed that while plant height, fresh weight, and dry weight increase at low concentrations, they reduced at high chromium contamination levels.

MYCOREMEDIATION

Endophytic microorganisms, including fungi and bacteria, colonize internal plant tissues asymptotically, neutral associations without causing harm to the host plant or to themselves. (42) Stated that they are predominantly localized within specific plant tissues, including vascular bundles, apoplastic regions,

cortical root tissues, dead cortical cells, and developing buds (42). Endophyte-assisted phytoremediation was shown to be a potential technique for in situ remediation of contaminated soils, and many endophytes have been discovered to be resistant to heavy metals and capable of degrading into organic pollutants. Heavy-metal-resistant endophytes can improve plant development, reduce metal phytotoxicity, and influence metal transport and accumulation in plants during heavy metal phytoremediation (22). Eight endophytic fungi were isolated from *purslane* (collected from Hohhot, Inner Mongolia, China), and they were belonged to the genera *Penicillium* (isolates K, N, P, M, and I), *Chaetomium* (isolate J), *Fusarium* (isolate H), and *Petriella* (isolate O). The results of the isolates on the host were examined to establish the framework for future research and development of *Portulaca* resources, Moreover, the endophytic fungus significantly affects the growth of purslane (64).

Table 3: List of potential endophytic fungi involved in the bioremediations of different heavy metals

Sr.No	Fungal endophytes	Host plant	Metals	References
1.	<i>flavus Aspergillus fumigatus</i> , <i>A. Rhizopus sp.</i> , <i>Penicillium radicum</i> , <i>Fusarium</i>	Healthy plant	Cr +6, strains were able to carry out intra- and extramycelial reduction of Cr-VI to Cr-III	8
2.	<i>Chaetomium cupreum</i>	<i>Miscanthus sinensis Andersson</i>	Al tolerance via inducing chlorogenic acid production and producing oosporein	23
3.	<i>Fusarium sp.</i> <i>Colletotrichum sp.</i>	<i>Shorea robusta</i> <i>Terminalia bellirica</i>	Lead, chromium, copper, and zinc	32
4.	<i>Lasiodiplodia sp.</i>	<i>Portulaca oleracea</i>	Cd, Pb, Zn Deng <i>et al.</i>	15
5.	<i>Pestalotiopsis Sp.</i>	<i>Nypa fruticans</i>	Copper, lead, zinc, and Chromium	11
6.	<i>Aspergillus foetidus</i>	Healthy plant	Chromium	39
7.	<i>Mucor sp. CBRF59</i> <i>Brassica</i>	<i>Brassica chinensis</i>	Cd and Pb Deng <i>et al.</i>	16

CONCLUSION

The review underscores the importance of continued research and development in the field of bioremediation of heavy metals and in particular of chromium. Emphasizing the need for interdisciplinary approaches and collaboration to address the complexities of heavy metal contamination. The integration of these novel methods holds the promise of more efficient, sustainable, and cost-effective remediation solutions, ultimately contributing to the protection of environmental and human health.

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CONFLICT OF INTEREST

Authors declare no conflict of interest.

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REFERENCES

- Albert, L. (2015). Gestión de los productos químicos. *En: México Tóxico. XXI Siglo veintiuno editores, México*, 21-37.
- Ali H, Khan E, Sajad MA (2013) Phytoremediation of heavy metals- concepts and Applications. *Chemosphere* 91:869-881.
- Alyazouri, A., Jewsbury, R., Tayim, H., Humphreys, P., & Al-Sayah, M. H. (2020). Uptake of chromium by portulaca oleracea from soil: Effects of organic content, pH, and sulphate concentration. *Applied and environmental soil science*, 2020(1), 3620726.
- Ansari Z. A., and Sharma P. (2017). A Review on Phytoremediation by Alternanthera Philoxeroides. *International Conference on Innovative Research In Science, Technology and Management*. Modi Institute of Management and Technology, Dabari, Khota, Rajasthan. 978-983-86171-20-7.
- Azubuike, C. C., Chikere, C. B., & Okpokwasili, G. C. (2016). Bioremediation techniques—classification based on site of application: principles, advantages, limitations and prospects. *World Journal of Microbiology and Biotechnology*, 32(11), 180.

6. B. L. Masocha and O. Dikinya (2023) *Jatropha Curcas* L. Biomass Yield and Leaf Nutrient Content Response to Incorporated Poultry Litter and Its Biochar in Sandy-Loam Soil, *Commun. Soil Sci. Plant Anal.*, vol. 54, no. 14, pp. 1896–1909.
7. Berti, W. R., & Cunningham, S. D. (2000). Phytostabilization of metals. *Phytoremediation of toxic metals: using plants to clean up the environment*. Wiley, New York, 71-88.
8. Bibi S, Hussain A, Hamayun M et al (2018) Bioremediation of hexavalent chromium by endophytic fungi; safe and improved production of *Lactuca sativa* L. *Chemosphere* 211:653–663
9. Blaylock. M. (2008). Phytoremediation of contaminated soil and water: field demonstration of phytoremediation of lead contaminated soils. *Lewis Publishers*, Boca Raton, FL.
10. Chen. Y. H, Li X. D and Shen. Z. G. (2004) Leaching and uptake of heavy metals by ten different species of plants during an EDTA assisted phytoextraction process. *Chemosphere* 57, 187-196.
11. Choo, Jenny, Nuraini Binti Mohd Sabri, Daniel Tan, Aazani Mujahid, and Moritz Müller.(2015) "Heavy metal resistant endophytic fungi isolated from *Nypa fruticans* in Kuching Wetland National Park." *Ocean Science Journal* 50, no. 2 : 445-453.
12. Cluis. C. (2004) Junk-greedy Greens: Phytoremediation as a new option for soil decontamination. *BioTeach J*, 2(6), 1-67.
13. Cunningham, S. D., & Ow, D. W. (1996). Promises and prospects of phytoremediation. *Plant physiology*, 110(3), 715.
14. Deng Z, Cao L, Huang H et al (2011) Characterization of Cd- and Pb-resistant fungal endophyte *Mucor* sp. CBRF59 isolated from rapes (*Brassica chinensis*) in a metal-contaminated soil. *J Hazard Mater* 185(2-3):717–724.
15. Deng Z, Zhang R, Shi Y et al (2014) Characterization of Cd-, Pb-, Zn-resistant endophytic *Lasiodiplodia* sp. MXSF31 from metal accumulating *Portulaca oleracea* and its potential in promoting the growth of rape in metal-contaminated soils. *Environ Sci Pollut Res* 21:2346–2357.
16. Deng, Z., Cao, L., Huang, H., Jiang, X., Wang, W., Shi, Y., & Zhang, R. (2011). Characterization of Cd- and Pb-resistant fungal endophyte *Mucor* sp. CBRF59 isolated from rapes (*Brassica chinensis*) in a metal-contaminated soil. *Journal of Hazardous Materials*, 185(2-3), 717-724.
17. Deng, Z., Zhang, R., Shi, Y., Hu, L. A., Tan, H., & Cao, L. (2014). Characterization of Cd-, Pb-, Zn-resistant endophytic *Lasiodiplodia* sp. MXSF31 from metal accumulating *Portulaca oleracea* and its potential in promoting the growth of rape in metal-contaminated soils. *Environmental Science and Pollution Research*, 21(3), 2346-2357.
18. Dwivedi, S., Mishra, A., Kumar, A., Tripathi, P., Dave, R., Dixit, G., ... & Tripathi, R. D. (2012). Bioremediation potential of genus *Portulaca* L. collected from industrial areas in Vadodara, Gujarat, India. *Clean Technologies and Environmental Policy*, 14(2), 223-228.
19. Ekwumemgbo, P. A., Eddy, N. O., & Omoniyi, I. K. (2013). Decontamination of heavy metals in polluted soil by phytoremediation using *Bryophyllum pinnatum*. In *E3S Web of Conferences* (Vol. 1, p. 13004). EDP Sciences.
20. Flathman, P. E., & Lanza, G. R. (1998). Phytoremediation: current views on an emerging green technology. *Journal of soil contamination*, 7(4), 415-432.
21. Ghosh, M., & Singh, S. P. (2005). A review on phytoremediation of heavy metals and utilization of its by products. *Asian J Energy Environ*, 6(4), 18.
22. Hai-Yan. Li., Da-Qiao Wwi., Mi Shen & Zuo-Ping Z. (2012). Endophytes and their role in phytoremediation. *An international Journal of Mycology*.1560-2745 Vol. 54.
23. Haruma T., Yamaji K., Ogawa K (2019). Root endophytic *Chaetomium cupreum* chemically enhances aluminium tolerance in *Miscanthus sinensis* via increasing the aluminium detoxicants, chlorogenic acid and oosporein. *PLoS One* 14(2):e0212644.
24. Helmisaari. H. S., Salemaa. M., Derome. J., Kiikkila. O., Uhlig. C, Nieminen. T. M. (2007). Remediation of heavy metal-contaminated forest soil using recycled organic matter and native woody plants. *J. Environ. Qual.* 36: 1145–1153.
25. Ibezim-Ezeani, M. U., & Ihunwo, O. C. (2020). Assessment of Pb, Cd, Cr and Ni in water and water hyacinth (*Eichhornia crassipes*) plant from Woji Creek, Rivers State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 24(4), 719-727.
26. Karami. A., Shamsuddin. Z. H. (2010). Phytoremediation of heavy metals with several efficiency enhancer methods. *Afr. J. Biotechnol.* 9(25): 3689-3698.
27. Kharwade, M. A. M., Gharpinde, M. H. T., Vyawahare, M. A. D., Kamde, M. S. P., Thakre, M. U. I., & Zade, M. J. P. (2020). Remediation of contaminated soil using indian mustard through phytoremediation technique.
28. Kumar, V., Singh, J., & Kumar, P. (2019). Heavy metal uptake by water lettuce (*Pistia stratiotes* L.) from paper mill effluent (PME): experimental and prediction modeling studies. *Environmental Science and Pollution Research*, 26(14), 14400-14413.
29. Kummerer. K., Dionysiou. D. D., Olsson. O., Fatta-Kassino. D., (2019). Reducing aquatic micropollutants-increasing the focus on input prevention and integrated emission management. *Sci. Total Environ.* 652, 836–850.
30. Kushwaha P., Kashyap. P. L. (2021). A Revive of Advances in Bioremediation of Heavy Metals by Microbes and plants. *Journal of Natural Resource Conservation and Management* Vol.2, No.1 pp 65-80.
31. Maha M., Elshamy, Y. M. Heikal, Giuliano B. (2019). Phytoremediation Efficiency of *L. Naturally Growing* in some Industrial Sites, *Portulaca oleracea* Dakahlia District, *Egypt, Chemosphere*.
32. Mahish, P. K., Shukla, R. V., & Choubey, A. (2017). Effect of heavy metals and xenobiotic compound on the growth of some endophytic fungi isolated from Achanakmar, Amarkantak biosphere reserve India. *Int Res J Environ Sci*, 6(1), 35-40.
33. Mang, K. C., & Ntushelo, K. (2019). Phytoextraction and phytostabilisation approaches of heavy metal remediation in acid mine drainage with case studies: a review. *Applied Ecology & Environmental Research*, 17(3).

34. Marchiol L., Sacco P., Assolari S and Zerbi G (2004). Reclamation of polluted soil: phytoremediation potential of crop-related Brassica species. *Water Air Soil Pollut.* 158,345-356.
35. Mueller, B., Rock, S., Gowswami, D., & Ensley, D. (1999). Phytoremediation decision tree. *Prepared by-Interstate Technology and Regulatory Cooperation Work Group*, 1-36.
36. Muhammad, S., Shah, M.1 T., Khan, S., Saddique, U., Gul, N., Khan, M. U., ... & Naz, A. (2013). Wild plant assessment for heavy metal phytoremediation potential along the mafic and ultramafic terrain in northern Pakistan. *BioMed research international*, 2013(1), 194765.
37. Nusrat E., Rab N., Sajjad A., Muhammad M. K., and Junaid H. (2016). Phytoremediation of Chromium-Contaminated Soil by an Ornamental Plant, Vinca (*Vinca rosea* L.) *Journal of Environmental Agricultural Sciences*. 7: 29-34.
38. Okrent D. (1999). On intergenerational equity and its clash with intragenerational equity and on the need for policies to guide the regulation of disposal of wastes and other activities posing very long-term risks. *Risk Analysis*, 19(5), 877-901.
39. Prasenjit, B., & Sumathi, S. (2005). Uptake of chromium by *Aspergillus foetidus*. *Journal of Material Cycles and Waste Management*, 7(2), 88-92
40. Ramakrishna, A., & Roshchina, V. V. (Eds.). (2018). *Neurotransmitters in plants: perspectives and applications*. CRC Press.
41. Revathi, K., Haribabu, T. E., & Sudha, P. N. (2011). Phytoremediation of chromium contaminated soil using Sorghum plant. *International Journal of Environmental Sciences*, 2(2), 429-441.
42. Roshchina V. V. (2012). *The Excretory Function of Higher Plants*; Springer Science & Business Media: Cham, Switzerland.
43. Rout, M. E. (2014). The plant microbiome. In *Advances in botanical research* (Vol. 69, pp. 279-309). Academic Press.
44. Saier Jr, M. H., & Trevors, J. T. (2010). Phytoremediation. *Water, Air, and Soil Pollution*, 205(Suppl 1), 61-63.
45. Salt D. E., Smith. R. D., Raskin. I. (1998). Phytoremediation. *Annu Rev Plant Physiol Plant Mol Biol* 49: 643-668.
46. Sardrood, B. P., Goltapeh, E. M., & Varma, A. (2012). An introduction to bioremediation. In *Fungi as bioremediators* (pp. 3-27). Berlin, Heidelberg: Springer Berlin Heidelberg.
47. Scragg, A. H. (2005). *Environmental biotechnology* (No. Ed. 2, pp. 456-pp). New York: OXFORD university press.
48. Singh, B., Yadav, C. M. (2009). Effect of soybean straw on voluntary intake, nutrient utilization and rate of passage in sheep and goats. *Indian J. Small Rum.*, 15 (2): 262-265
49. Singh, R., Gautam, N., Mishra, A., & Gupta, R. (2011). Heavy metals and living systems: An overview. *Indian journal of pharmacology*, 43(3), 246-253.
50. Singh, R., Singh, S., Parihar, P., Singh, V. P., & Prasad, S. M. (2015). Arsenic contamination, consequences and remediation techniques: a review. *Ecotoxicology and environmental safety*, 112, 247-270.
51. Singh. A., Eapen. S., Fulekar. M. H. (2009). Potential of *Medicago sativa* for uptake of cadmium from contaminated environment. *Romanian Biotechnology Letters*. 14: 4164-4169.
52. Slima, D. F., & Ahmed, D. A. E. A. (2020). Trace metals accumulated in pea plant (*Pisum sativum* L.) as a result of irrigation with wastewater. *Journal of Soil Science and Plant Nutrition*, 20(4), 2749-2760.
53. Suman, J., Uhlik, O., Viktorova, J., & Macek, T. (2018). Phytoextraction of heavy metals: a promising tool for clean-up of polluted environment? *Frontiers in plant science*, 9, 1476.
54. Sushmita N. (2020). Heavy metal accumulation in *Portulaca*. *Journal of Pharmacognosy and Phytochemistry*, 2018; 7(3).
55. Taufikurahman, T., Pradisa, M. A. S., Amalia, S. G., & Hutahaean, G. E. M. (2019, August). Phytoremediation of chromium (Cr) using *Typha angustifolia* L., *Canna indica* L. and *Hydrocotyle umbellata* L. in surface flow system of constructed wetland. In IOP conference series: Earth and environmental science (Vol. 308, No. 1, p. 012020). IOP Publishing.
56. Tiwari, K. K., Dwivedi, S., Mishra, S., Srivastava, S., Tripathi, R. D., Singh, N. K., & Chakraborty, S. (2008). Phytoremediation efficiency of *Portulaca tuberosa* Rox and *Portulaca oleracea* L. naturally growing in an industrial effluent irrigated area in Vadodra, Gujrat, India. *Environmental Monitoring and Assessment*, 147(1-3), 15-22.
57. Turan, M., & Esringü, A. (2007). Phytoremediation based on canola (*Brassica napus* L.) and Indian mustard (*Brassica juncea* L.) planted on spiked soil by aliquot amount of Cd, Cu, Pb, and Zn. *Plant, Soil and Environment*, 53(1), 7-15.
58. Ugulu, I., Bibi, S., Khan, Z. I., Ahmad, K., Munir, M., & Malik, I. S. (2022). Potentially toxic metal accumulation in spinach (*Spinacia oleracea* L.) irrigated with industrial wastewater and health risk assessment from consumption. *Bulletin of Environmental Contamination and Toxicology*, 109(6), 1117-1125.
59. Upadhyay, S. K., Ahmad, M., Srivastava, A. K., Abhilash, P. C., & Sharma, B. (2021). Optimization of eco-friendly novel amendments for sustainable utilization of Fly ash based on growth performance, hormones, antioxidant, and heavy metal translocation in chickpea (*Cicer arietinum* L.) plant. *Chemosphere*, 267, 129216.
60. Verma, J. P., & Jaiswal, D. K. (2016). Book review: advances in biodegradation and bioremediation of industrial waste, *front. Microbiol*, 6.
61. Vidali, M. (2001). Bioremediation. an overview. *Pure and applied chemistry*, 73(7), 1163-1172.
62. Vyslouzilova, M., Tlustos, P., Szakova, J., Pavlikova, D. (2003). As, Cd, Pb and Zn uptake by *Salix* spp. Clones grown in soils enriched by high loads of these elements. *Plant Soil Environ*. 49: 191-196.
63. Wilbur S., Abadin H., Fay M., Yu D., Tencza B, Ingerman L., Klotzbach J., James S., Toxicological Profile for Chromium. Atlanta (GA): Agency for Toxic Substances and Disease Registry (US); 2012 Sep. PMID: 24049864

64. Zhang, Y., Wan, Y., Tie, Y., Zhang, B., Wang, R., & Wang, G. (2019). Isolation and Characterization of Endophytic Fungi from Purslane and the Effects of Isolates on the Growth of the Host. *Advances in Microbiology*, 9(5), 438-453.

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