

## Phytoremediation: An Environmental Friendly Technique - A Review

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### Abstract

Phytoremediation technology is a cost effective and environmentally and ecologically friendly as it utilizes plants natural ability to suck the pollutant present in the soil. There are many plants having this natural ability to up take the heavy metals and organic pollutants from air, soil and water. There are different subsets of phytoremediation; the most effectively used ones are (a) phytofiltration (b) phytoextraction (c) phytostabilization (d) phytovolatilization. In the present review, current knowledge about the phytoremediation and its techniques are discussed.

**Keywords:** Phytoremediation; Phytoextraction; Phytofiltration; Phytovolatilization; Environmental pollution

### Introduction

Heavy metals are excessively contributing towards the Environmental pollution all over the world. There is a major release of heavy metal from the extraction of ores for mineral and then their processing for their use in different areas leads to the pollution as the heavy metals are highly mobile in the environment that is the main reason of their presence in environment. The occurrence of heavy metal is becoming much more severe because of the increase in the industrialization and severe disruption of natural biogeochemical cycles. Heavy metals are non-biodegradable elements and they tend to accumulate in the environment for longer run as compared to those of organic substances. Their accumulation in the soils and water bodies leads to the threatening effects on the human health as they are more likely to enter the food chain. Heavy metals have the capacity to bio accumulate in the tissues of human body, they also have the ability to bio-magnify by reaching in to higher trophic level from lower trophic level. They also cause the decrease in microbial activity by causing toxicological changes in the microbes of soils [1]. Heavy metals are divided in two categories on the basis of their role in the biological system one are essential heavy metals and other are non-essential heavy metals. Essential are those, which are required by living organisms in smaller amount but have a significant role in the biochemical and physiological functioning of living organisms as well. Some essential heavy metals are Fe, Mn, Cu, Ni and Zn [2,3] whereas the non-essential ones are not required by the body for any such functioning and the examples of them are Pb, Cd, Cr, Hg and As Cr [4-10]. Heavy metals have the tendency to interfere with the normal functioning of human body and they are very harmful for living systems above certain limits.

### Sources of heavy metals in the environment

Heavy metals can enter into the environment from both natural and anthropogenic sources. The natural processes that contribute towards heavy metals releases are volcanic activity, weathering processes of minerals and erosion. Whereas the anthropogenic activities concerning with heavy metals are mining processes, electroplating, smelting use of fertilizers and pesticides especially phosphate and also the use of biosolids in agriculture, discharge from industries, dumping of sludge, and deposition of heavy metals through atmospheric processes [11-15]. Table 1 gives anthropogenic sources of selected heavy metals in the environment.

### Harmful effects of heavy metals on human health

Heavy metals have the ability to affect the human health on great levels. They are posing adverse impact on the quality of health as they can access the food chain through soil and water because of

Heavy metals	Sources	References
Pb	Aerial emission from combustion of leaded petrol, battery manufacture, herbicides and Insecticides	[14,61]
As	Pesticides and wood preservatives	[61]
Cr	Tanneries, steel industries, fly ash	[53]
Ni	Industrial effluents, kitchen appliances, surgical instruments, steel alloys, automobile batteries	[60]
Hg	Release from Au-Ag mining and coal combustion, medical waste	[14,16,58]
Cd	Paints and pigments, plastic stabilizers, electroplating, incineration of cadmium-containing plastics, phosphate fertilizers	[57,59]
Cu	Pesticides, fertilizers	[53]

Table 1: Anthropogenic sources of specific heavy metals in the environment.

the contamination of these environments through the natural and anthropogenic activities. Heavy metals and metalloids have the tendency to cause harmful toxicological effects even if enter in very small amount [16-18]. They have the capacity to cause oxidative stress as they produce free radicals [19], increased production of very reactive oxygen species refer to as oxidative stress which can increase the antioxidants in the inside the cell and results in damage or death of the cell [20,21]. Besides, they also have the ability to replace the enzymes or attach in place of enzymes causing their normal function to disrupt [22]. The most harmful heavy metals of all are Cd, Hg, As, Zn, Cr, Pb, Sn and Cu because they are more toxic [23,24]. Many of metals in them are non-essential and some of them are essential heavy metals but are trace elements. Different health issues are more likely to be concerned with the heavy metals accumulation and it also depends on their oxidation state and concentration.

### Cleanup of heavy metal-contaminated soils

The increase in the concentration of heavy metals in the environment has been reported after every passing year [25]. Different cases of heavy metal pollution have been reported, a total  $2.88 \times 10^6$  ha area of land has been disturbed because of the mining activities in China and adding to that another 46700 ha has also been destroyed on annual basis due to the same purpose [26]. These disturbed lands are incapable

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of producing vegetation and favor more soil erosion and pollution. Other cases reported in Netherlands and Belgium where almost 700 km<sup>2</sup> area of the region is polluted by the deposition of heavy metals from the atmosphere, heavy metals are Zn, Pb and Cd [27]. Because of these issues the need of the hour is to cope up with these challenges lessen the impact of this pollution on the ecosystems. The cleanup of these pollutants is reported to be a challenging job because of their costliness and the techniques required for that are very complex as well [28]. Different types of chemical physical and biological approaches have been used for the cleanup. There are many conventional methods for this purpose that are soil incineration, soil washing, solidification, soil washing, soil flushing, excavation and landfill, stabilization of electro-kinetic systems, *in situ* verification [14,29]. The methods with physical and chemical techniques have various limitations as they are not really cost effective, require more labor, leads to the disturbance in the microflora of the soil and leads to irreversible changes in the properties of soil. Chemical techniques are not really trustable as they lead to the formation of secondary pollutants some way or the other. So, it is the need of the hour to execute a cost-effective approach which is side by side environment friendly and efficient method for the remedy of heavy metals. Phytoremediation is that novel approach which is a green solution as compared to other solutions.

### Phytoremediation - green solution

A technique which uses plants for the uptake of heavy metal contaminants from the soil by using abilities of plants to suck the heavy metals and also uses the soil microbes for the efficient functioning is referred to as phytoremediation [30]. This technique can be used for the removal of heavy metals from the soil and besides that it can also be used for the removal of other environmental pollutants like organic pollutants that includes poly chlorinated biphenyls (PCBs), poly aromatic hydrocarbons (PAHs) and pesticides. This approach is novel, cost effective, ecofriendly and good for environment as well [31-42].

### Techniques of phytoremediation

Different techniques have been introduced to exploit the potential of plants for the removal of hazardous compounds from contaminated water and soil. Schwitzgubel has explained different technological subsets of phytoremediation [43]:

- **Phytoextraction (Phytoaccumulation):** Removal of pollutants using the plants having the ability to accumulate pollutants from the soil and store them in their shoots so that they can be harvested.
- **Phytotransformation:** It is the phenomenon in which the complex organic molecules are converted into the simpler one by degrading them and the simpler one can then be incorporated in the tissues of plants.
- **Phytostimulation:** This process includes the stimulation of enzymes present in the rhizosphere which can lead to the bioremediation using microbes or fungal degradation by releasing exudates.
- **Phytovolatilization:** In this the plants take up the pollutants and then they can volatilize from the surface of the leaves.
- **Phytodegradation:** In this technique, there is the use of enzymes for the breakdown of harmful organic pollutants like herbicides or trichloroethylene. This can happen both inside or outside the plants as the plants can also secrete the enzymes outside.
- **Phytorhizofiltration:** It is the inhibition of organic pollutants

from mixing into the water streams or groundwater using roots for filtration purpose as they can absorb or adsorb the pollutants.

- **Phytostabilization:** This technique involves the prevention of mobility of organic pollutants into the soil thus reducing its bioavailability and stops them from entering into the food chain.

In this review, four major sub-sets, namely, Phytoextraction, Phytostabilization, Phytovolatilization and Phyto/Rhizofiltration will be discussed further.

**Phytoextraction:** In Phytoextraction, also known as phytoabsorption phytosequestration, or phytoaccumulation, the contaminants are being up taken by the plant roots from the contaminated soil and water and then they are then being accumulated in the biomass above the ground as in shoots [44-46]. Whereas, the transfer of metals into the shoots is not a very easy process, it is mainly required for the effective phytoextraction, because if metal store in roots then it will not a very feasible process to deal with the biomass [47,48].

**Phytostabilization:** Phytostabilization is also known as phytoimmobilization, in this technique, the contaminants are immobilized in the soil by using different plants having the ability to stabilize the pollutants [49]. By using this technique, the mobility of the contaminants will be reduced which lead to the reduction of bioavailability of these pollutants. This then help in reducing the migration of pollutants into the groundwater and preventing their ability to enter into the food chain [50]. In this process, heavy metals are immobilized by their sorption into the roots, reducing their valence number and then making them complex and immobilize in the rhizosphere [14,23,45]. Metals having different valences also tend to have different toxicity. By releasing redox enzymes, several plants convert different hazardous metals into a relatively less toxic state and leads to the decrease of metal stress and its damages. To instance, Chromium (VI) is converted into Chromium (III), as Cr (III) is less toxic and have less mobility in the soil. In the process of phytostabilization, the contaminants are not really removed from the soil but their movement in the soil and leaching down the groundwater can be minimized. So, it cannot be claimed that this is the permanent solution for the removal of contaminants from the soil but it can aid other different processes and can be used to manage the pollutants [51].

**Phytovolatilization:** It is the technique in which the pollutants are up taken by the plants from the soil, and then converted into the volatile form and then released in the atmosphere. Phytostabilization can be used for organic pollutants and other heavy metals like Se and Hg. But as explained earlier, it transfers the pollutants into the atmosphere, from one medium to another, and does not remove the pollutants permanently. The pollutants from the atmosphere can also be re deposited into the soil after some time [52]. So, because of this it is a controversial method for remedies.

**Rhizo/Phytofiltration:** Phytofiltration is used to inhibit the organic pollutants in waste water and surface water from mixing into the water streams or groundwater using plants for filtration purpose as they can absorb or adsorb the pollutants [53]. The process phytofiltration can also be rhizofiltration in which plant roots are used and can be blastofiltration in which seedlings can be utilized or caulofiltration (the use of excised plant shoots) [54]. Due to phytofiltration, the movement of contaminants in the soil minimized [55-62].

### Conclusion

Heavy metals are said to be persistent in the environment leading

to cause pollution by entering into groundwater and food chain. They cannot be degraded in the environment so there is a need to develop a proper remedial plan for their removal from the environment. Plants are being used for the betterment of the effected soils in several areas by the scientists. The use of plants for the removal of contaminants from the soil is phytoremediation, a green solution for the problem of heavy metals. This is the fast, innovative, emerging, ecofriendly and cost effective alternate to the conventional remedial method. Further research is obligatory to observe the economic and ecological competences of Phytoremediation.

## References

1. Khan S, Hesham AEL, Qiao M, Rehman S, He JZ (2010) Effects of Cd and Pb on soil microbial community structure and activities. *Environ Sci Pollut Res* 17: 288-296.
2. Göhre V, Paszkowski U (2006) Contribution of the arbuscular mycorrhizal symbiosis to heavy metal phytoremediation. *Planta* 223: 1115-1122.
3. Cempel M, Nikel G (2006) Nickel: a review of its sources and environmental toxicology. *Pol J Environ Stud* 15: 375-382.
4. Cobbett C (2003) Heavy metals and plants-model systems and hyperaccumulators. *New Phytol* 159: 289-293.
5. Mertz W (1981) The essential trace elements. *Science* 213: 1332-1338.
6. Peng K, Luo C, Chen Y, Wang G, Li X (2009) Cadmium and other metal uptake by *Lobelia chinensis* and *Solanum nigrum* from contaminated soils. *Bull Environ Contam Toxicol* 83: 260-264.
7. Kärenlampi S, Schat H, Vangronsveld J, Verkleij J, van der Lelie D (2000) Genetic engineering in the improvement of plants for phytoremediation of metal polluted soils. *Environ Pollut* 107: 225-231.
8. Sánchez-Chardi A, Ribeiro CAO, Nadal J (2009) Metals in liver and kidneys and the effects of chronic exposure to pyrite mine pollution in the shrew *Crocidura russula* inhabiting the protected wetland of Doñana. *Chemosphere* 76: 387-394.
9. Suzuki N, Koizumi N, Sano H (2001) Screening of cadmium-responsive genes in *Arabidopsis thaliana*. *Plant Cell Environ* 24: 1177-1188.
10. Dabonne S, Koffi B, Kouadio E, Koffi A, Due E (2010) Traditional utensils: Potential sources of poisoning by heavy metals. *Br J Pharm Toxicol* 1: 90-92.
11. Sabiha-Javied S, Mehmood T, Tufai M, Irfan N (2009) Heavy metal pollution from phosphate rock used for the production of fertilizer in Pakistan. *Microchem J* 91: 94-99.
12. Modaihsh A, Al-Swailem M, Mahjoub M (2004) Heavy metal contents of commercial inorganic fertilizer used in the Kingdom of Saudi Arabia. *Agri Mar Sci* 9: 21-25.
13. Fulekar M, Singh A, Bhaduri AM (2009) Genetic engineering strategies for enhancing phytoremediation of heavy metals. *Afr J Biotechnol* 8: 529-535.
14. Wuana RA, Okieimen FE (2011) Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. *ISRN Ecology*, pp: 1-20.
15. Chehregani A, Malayeri BE (2007) Removal of heavy metals by native accumulator plants. *Int J Agri Biol* 9: 462-465.
16. Memon AR, Schröder P (2009) Implications of metal accumulation mechanisms to phytoremediation. *Environ Sci Pollut Res* 16: 162-175.
17. Arora M, Kiran B, Rani S, Rani A, Kaur B, et al. (2008) Heavy metal accumulation in vegetables irrigated with water from different sources. *Food Chem* 111: 811-815.
18. Kara Y (2005) Bioaccumulation of Cu, Zn and Ni from the wastewater by treated *Nasturtium officinale*. *Int J Environ Sci Technol* 2: 63-67.
19. Mudipalli A (2008) Metals (micro nutrients or toxicants) and global health. *Indian J Med Res* 128: 331-334.
20. Krystofova O, Shestivska V, Galiova M, Novotny K, Kaiser J, et al. (2009) Sunflower plants as bio indicators of environmental pollution with lead (II) ions. *Sensors* 9: 5040-5058.
21. Das K, Das S, Dhundasi S (2008) Nickel, its adverse health effects and oxidative stress. *Indian J Med Res* 128: 412-425.
22. Malayeri BE, Chehregani A, Yousefi N, Lorestani B (2008) Identification of the hyper accumulator plants in copper and iron mine in Iran. *Pak J Biol Sci* 11: 490-492.
23. Ghosh S (2010) Wetland macrophytes as toxic metal accumulators. *Int J Environ Sci* 1: 523-528.
24. Wright RT (2007) *Environmental Science. Toward a Sustainable Future*. Prentice Hall of India, New Delhi, India.
25. Govindasamy C, Arulpriya M, Ruban P, Francisca LJ, Ilayaraja A (2011) Concentration of heavy metals in seagrasses tissue of the Palk Strait, Bay of Bengal. *Int J Environ Sci* 2: 145-153.
26. Xia HP (2004) Ecological rehabilitation and phytoremediation with four grasses in oil shale mined land. *Chemosphere* 54: 345-353.
27. Meers E, Slycken SV, Adriaensen K, Ruttens A, Vangronsveld J, et al. (2010) The use of bio-energy crops (*Zea mays*) for 'phytoremediation' of heavy metals on moderately contaminated soils: a field experiment. *Chemosphere* 78: 35-41.
28. Barceló J, Poschenrieder C (2003) Phytoremediation: principles and perspectives. *Contrib Sci* 2: 333-344.
29. Sheoran V, Sheoran A, Poonia P (2011) Role of hyperaccumulators in phytoextraction of metals from contaminated mining sites: a review. *Crit Rev Environ Sci Technol* 41: 168-214.
30. Greipsson S (2011) Phytoremediation. *Nat Educ Knowl* 3: 10.
31. Clemens S (2001) Developing tools for phytoremediation: towards a molecular understanding of plant metal tolerance and accumulation. *Int J Occup Med Environ Health* 14: 235-239.
32. Suresh B, Ravishankar GA (2004) Phytoremediation-A novel and promising approach for environmental clean-up. *Crit Rev Biotechnol* 24: 97-124.
33. LeDuc DL, Terry N (2005) Phytoremediation of toxic trace elements in soil and water. *J Ind Microbiol Biotechnol* 32: 514-520.
34. Odjegba VJ, Fasidi IO (2007) Phytoremediation of heavy metals by *Eichhornia crassipes*. *Environmentalist* 27: 349-355.
35. Turan M, Esringu 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 Environ* 53: 7-15.
36. Lone MI, He Z, Stoffella PJ, Yang X (2008) Phytoremediation of heavy metal polluted soils and water: progresses and perspectives. *J Zhejiang Univ* 9: 210-220.
37. Kawahigashi H (2009) Transgenic plants for phytoremediation of herbicides. *Curr Opin Biotechnol* 20: 225-230.
38. Saier MH, Trevors JT (2010) Phytoremediation. *Water Air Soil Pollut* 205: 61-63.
39. Kalve S, Sarangi BK, Pandey RA, Chakrabarti T (2011) Arsenic and chromium hyperaccumulation by an ecotype of *Pteris vittata*-prospective for phytoextraction from contaminated water and soil. *Curr Sci* 100: 888-894.
40. Sarma H (2011) Metal hyperaccumulation in plants: a review focusing on phytoremediation technology. *J Environ Sci Technol* 4: 118-138.
41. Singh A, Prasad SM (2011) Reduction of heavy metal load in food chain: technology assessment. *Rev Environ Sci Biotechnol* 10: 199-214.
42. Vithanage M, Dabrowska BB, Mukherjee B, Sandhi A, Bhattacharya P (2012) Arsenic uptake by plants and possible phytoremediation applications: a brief overview. *Environ Chem Lett* 10: 217-224.
43. Schwitzguebel JP (2000) Potential of phytoremediation, an emerging green technology. *Ecosystem service and sustainable watershed management in Science* 9: 210-220.
44. Rafati M, Khorasani N, Moattar F, Shirvany A, Moraghebi F, et al. (2011) Phytoremediation potential of *Populus alba* and *Morus alba* for cadmium, chromium and nickel absorption from polluted soil. *Int J Environ Res* 5: 961-970.
45. Yoon J, Cao X, Zhou Q, Ma LQ (2006) Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. *Sci Total Environ* 368: 456-464.
46. Sekara A, Poniedzialek M, Ciura J, Jedrzczyk E (2005) Cadmium and lead accumulation and distribution in the organs of nine crops: implications for phytoremediation. *Pol J Environ Stud* 14: 509-516.

47. Tangahu BV, Abdullah SRS, Basri H, Idris M, Anuar N (2011) A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *Int J Chem Eng* 2011: 31.
48. Zacchini M, Pietrini F, Mugnozza GS, Iori V, Pietrosanti L, et al. (2009) Metal tolerance, accumulation and translocation in poplar and willow clones treated with cadmium in hydroponics. *Water Air Soil Pollut* 197: 23-34.
49. Singh S (2012) Phytoremediation: a sustainable alternative for environmental challenges. *Int J Gr Herb Chem* 1: 133-139.
50. Erakhrumen AA (2007) Phytoremediation: an environmentally sound technology for pollution prevention, control and remediation in developing countries. *Edu Res Rev* 2: 151-156.
51. Vangronsveld J, Herzig R, Weyens N, Boulet J, Adriaensen K, et al. (2009) Phytoremediation of contaminated soils and groundwater: lessons from the field. *Environ Sci Pollut Res* 16: 765-794.
52. Padmavathamma PK, Li LY (2007) Phytoremediation technology: hyper accumulation metals in plants. *Water Air Soil Pollut* 184: 105-126.
53. Khan MA, Ahmad I, Rahman IU (2007) Effect of environmental pollution on heavy metals content of *Withania somnifera*. *J Chin Chem Soc* 54: 339-343.
54. Mesjasz-Przybyłowicz J, Nakonieczny M, Migula P, Augustyniak M, Tarnawska M, et al. (2004) Uptake of cadmium, lead, nickel and zinc from soil and water solutions by the nickel hyperaccumulator *Berkheya coddii*. *Acta Biol Cracov Bot* 46: 75-85.
55. Memon AR, Aktoprakligil D, Ozdemir A, Vertii A (2001) Heavy metal accumulation and detoxification mechanisms in plants. *Turk J Bot* 25: 111-121.
56. Mukhopadhyay S, Maiti SK (2010) Phytoremediation of metal enriched mine waste: a review. *Global J Environ Res* 4: 135-150.
57. Pulford I, Watson C (2003) Phytoremediation of heavy metal-contaminated land by trees-a review. *Environ Int* 29: 529-540.
58. Rodrigues S, Henriques B, Reis A, Duarte A, Pereira E, et al. (2012) Hg transfer from contaminated soils to plants and animals. *Environ Chem Lett* 10: 61-67.
59. Salem HM, Eweida EA, Farag A (2000) Heavy Metals in Drinking Water and their Environmental Impact on Human Health. Cairo University, Egypt, pp: 542-556.
60. Tariq M, Ali M, Shah Z (2006) Characteristics of industrial effluents and their possible impacts on quality of underground water. *Soil Environ* 25: 64-69.
61. Thangavel P, Subbhuraam C (2004) Phytoextraction: role of hyperaccumulators in metal contaminated soils. *Proc Indian Natl Sci Acad* 70: 109-130.
62. Sakai Y, Ma Y, Xu C, Wu H, Zhu W, et al. (2012) Phytodesalination of a salt affected soil with four halophytes in China. *J Arid Land Stud* 22: 17-20.

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