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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.

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.

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 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 2.88×10^6 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^2 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* vertification [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 if plants to suck the heavy metals and also uses the soil microbes for the efficient functioning is refer 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 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. Schwitzguebel 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 volatile 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/Rhizofilteration 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 covert 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 ad 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.

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