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Review Article

Review Article on Phytoremediation and Other Remediation Technologies of Soil Contaminated with Heavy Metals

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Abstract

Heavy metal pollution is a serious environmental problem. There are many remediation methods to clean the soil which includes physical methods, chemical methods and biological methods. Physical and chemical methods have many disadvantages and harmful effects but biological methods are now a day's very useful and have many advantages. One of the biological methods is Phytoremediation. It is one of the best methods to clean up the metal contaminants. It inhibits the contaminants of soil and heavy metals which are harmful for plants and for humans. If we are engulfing the food which contains heavy metals cause many harmful diseases which would be fatal and harmful. It is a green technology with good public perception. There are many molecular studies which will improve the efficacy of Phytoremediation. This review presents the status of Phytoremediation technologies with particular emphasis on Phytoextraction, Phytodegradation and Rhizofilteration of soil heavy metal contamination. Unlike organic compounds, metals cannot be degraded, and cleanup usually requires their removal. Most of the conventional remedial technologies are expensive and inhibit the soil fertility; this subsequently causes negative impacts on the ecosystem. So Phytoremediation is one of the cost effective and environmental friendly procedures.

Keywords: Heavy Metals; Phytoremediation; Phytoextraction

Introduction

Soil is the upper layer of earth in which plants grow, a black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles. Soil is the basic environmental elements constituting ecosystem, and the important material basis of human being surviving and developing. Soil contains many harmful contaminants like heavy metals which should be harmful for plants and humans and it should be removed or degraded by different methods. The removal of contaminants, pollutants and other undesirable products from soil sludge's, sediments, surface water and ground water is known as remediation. The soil constitute surface of earth crust. There are different methods to remove the contaminants which include physical, chemical and biological methods. The pollution of water and contamination of soil by heavy metals have become a threat to ecological environment, food safety and agriculture sustainable development [1].

The contamination of soil is a major environmental concern due to dispersal of industrial and urban wastes which is generated by human activities. Contamination may migrate from one place to another by waste disposal, process spillage, smelting and mining of metalliferous ores, sewage sludge application to agricultural soils by dust or other sources which is responsible for the contamination of our ecosystem. Organic and inorganic compounds also causes contamination, which may include heavy metals, combustion reactions, many petroleum products, chemical industries all these produces a waste of heavy metals such as putriscible substances, hazardous wastes, explosives and petroleum products. The

microorganisms which are present in soil can degrade or inhibit the growth of contaminants while heavy metals which are present in soil need more diverse methods. Many metals are necessary for plants growth also but high content of every metal in soil may lead to many diseases. Heavy metals destroy plants growth and its nutritional value [2].

Sources of metal pollution

Geological and anthropogenic activities are the main sources of heavy metal contamination. Anthropogenic activities may include metal contaminations including industrial wastes, production of fuel, mining, smelting processes, military operations, utilization of agricultural chemicals, small-scale industries for example battery production, metal products, metal smelting and cable coating industries), brick kilns and combustion of coal. Municipal waste is also one of the major sources of heavy metal contaminants. Such wastes are further used as landfills while sewage water is used for irrigation purpose. This waste also contains some nutrients which is useful for plants and may also contain some toxic materials. Some other sources of metal contaminants are the use of chemical fertilizers, pesticides and fungicides which are unsafe to use and also banned to some extent, biofertilizers are used in place of it [3,4].

Methods of Remediation

There are different methods to remove the contaminants which include physical, chemical and biological methods.

Physical remediation

Soil replacement method and thermal desorption are the physical remediation methods. The soil replacement means to replace or partly replace the contaminated soil by clean soil. The aim of this method is to dilute the contaminants, may increase the environmental capacity of the soil and to remediate the soil [5].

There are three types of soil replacement:

- **Soil replacement:** The removal of contaminated soil and replacing it with a new soil is known as soil replacement. This method is good for small area contamination.
- **New soil importing:** This method involves by adding clean soil in the contaminated site by covering the surface or by mixing to decrease the polluted concentration.
- **Soil spading:** In this method the contaminated site is dug deeply so that pollutants spread into the deep sites which may achieve the goal of naturally degrading.

Chemical fixation

In this methods chemicals are used which may degrade or inhibits the soil contamination. In chemical fixation the reagents or materials are added in the contaminated soil or using them with heavy metals which makes them insoluble, less toxic matters and also decreases the migration of heavy metals towards water, plants, and other environmental media as a result of which soil is remediated. The conditioning material of soil may include clays, biomaterial, metallic oxides etc. In this method different chemicals are used to immobilize the contaminated site or it may reduce the metal bioavailability through the formation of metal phosphates [6].

Electro kinetic remediation

Electro kinetic remediation is a new remediation technology, in which voltage is applied at the two ends of soil which produces electric field gradient. The pollutants was carried to two poles and then treated with electromigration, elctroosmotic flow or by electrophoresis and then it was treated further. This method is suitable for the low permeability of soil and has advantages of easily install and operate; low cost and not destroy the original nature environment, so can achieve the environmental remediation and protect the original ecotope [7].

Biological remediation

The biological remediation includes Phytoremediation, bioremediation and the combining remediation.

Phytoremediation

Use of living green plants to fix, inhibit or adsorb contaminants and clean the contaminants from soil is known as Phytoremediation. Phytoremediation is a cost effective procedure. In this method we basically use natural products to reduce the contamination, it also remediate the soils, sludges, sediments and contaminated water by organic and inorganic contaminants. This method is very cost effective and ecofriendly and it easily reduces the metal contaminants from soil [8].

Methods of phytoremediation

According to [9] phytoremediation techniques can be subcategorized as phytoextraction, phytodegradation, rhizofiltration, phytostabilization, phytovolatilization and rhizodegradation. Phytoremediation techniques are very effective in the sterilization of the areas that are medium-contaminated and have slight risk.

There are different methods of Phytoremediation:

- Phytodegradation
- Phytostimulation/rhizodegradation
- Phytovolatilization
- Phytoextraction
- Phytostabilization
- Rhizofilteration.

Phytodegradation

Phytodegradation is the process in which we use plants to store, uptake and degrade the contaminants within its tissues. Phytodegradation is also known as phytotransformation in which contaminants are breakdown within the plants by metabolic process which happens in plants, or breakdown of contaminants at the sides of plants by different enzymes which catalyzes or accelerate degradation. There are some organic pollutants which is useful for the plant growth. Such organic compounds are firstly broken down into simpler form and then incorporated within the plant tissues which increase the plant growth [10,11].

Phytostimulation/rhizodegradation

Phytostimulation is also known as rhizodegradation. In this method rhizosphere is associated between the symbiotic soil microbes and plants to degrade the contaminants. This method may also enhance the rhizosphere biodegradation, plant-assisted bioremediation or rhizodegradation is the degradation of contaminants in the soil with enhanced microbial activity in the root zone of the plant also known as rhizosphere [12].

Microbial activity may be stimulated in rhizosphere by several methods

- Compounds like carbohydrates, amino acids, enzymes and acetates exuded by roots containing indigenous microbe population.
- Oxygen is carried by root system to rhizosphere which ensures aerobic transformation.
- Mycorrhizal fungi may degrade organic contaminants which cannot be transformed solely by bacteria due to unique enzymatic pathways
- Root biomass increases the availability of organic carbon
- Increased microbial populations habitat and activity is enhanced by plants.

Phytovolatilization

Phytovolatilization is the ability of plants to uptake the contaminants from the growth matrix and transform or volatilize the contaminants into the atmosphere. In this process contaminants are released in the atmosphere in volatile form through the process of transpiration. This process occurs when plants absorbs water and organic contaminants. When water travels from roots to the leaves along the vascular system of plants which is changed and modified along the way. In this way some of the contaminants move through the plants to the leaves and then volatilizes or evaporated into the atmosphere. This method is primarily used to remove mercury a toxic element, which is converted into less toxic elemental mercury [2].

Phytoextraction

Phytoextraction is also the process of Phytoremediation in which plants are used to transfer, absorbs or store toxic contaminants from soil matrix into the tissues of roots and shoot. Phytoextraction is a process of Phytoremediation in which plants are used to degrade contaminants, mostly heavy metals from soil and water which may be harmful for other organisms. Phytoextraction can also be performed by those plants that can uptake low level of pollutants but due to the high growth rate and biomass production may remove the contaminants from soil [13]. When the plants used in this method are compared to other plants, it can be observed that they can accumulate contaminant elements 100 times more. In this method *Brassicacea, Euphorbiacea, Asteraceae, Lamiaceae* and *Scrophulariaceae* and 400 other types are identified which can accumulate heavy metals [14].

Rhizofilteration

Rhizofilteration comes from the word rhizo means roots and filtration means to filter. Rhizofilteration involves the use of roots to store or uptake the contaminants from aqueous growth matrix or to filter the contaminants from groundwater, surface water and wastewater through roots to degrade the contaminants. Contaminated water contains many toxic substances like heavy metals which are very harmful to human health and causes many fatal diseases such contaminants must be removed so that living organisms should be get rid of all these contaminants [15]. This method provides an opportunity for the use of terrestrial and aquatic plants. It is also used in basins, tanks, and ponds besides natural environment [16,17].

Phytostabilization

Phytostabilization basically reduces the flexibility or mobility of heavy metals in soil. This method immobilizes the metals into the soil matrix which may reduce the bioavailability of soil. Immobilization of metals may be done by decreasing dust which may be blown by wind, by reducing soil erosion, and by minimizing the solubility of the contaminants or bioavailability to food chain. By adding soil amendments, like organic matter, alkalizing agents, phosphates and biosolids which reduces the solubility of metals in soil and minimize leaching to ground water [18]. Generally contaminants' transportation by wind, water erosion, washing out or soil dissemination can be prevented. In a system which is closely related to the plant's root environment microbiology and chemistry, the plant is able to modify the contaminant factor's form into non-resoluble or non-transported in water [19].

Impact of phytoremediation

Heavy metals are toxic materials which have harmful impact on plants and other living organisms. There are three strategies of plants for growth on the metal contaminated soil [16,20].

Metal excluders

Metal excluder stops or prevents metal from entering the aerial parts and it maintains low and constant metal concentration over a broad range of metal concentration in soil and they restrict metal in their roots. Plants may change permeability of its membrane; it may changes the metal binding capacity of cell walls or by exuding more chelating substances [21,22].

Metal indicators

Metal indicators are the species that actively gather metal in their aerial tissues and it generally reflects the metal level in soil. They tolerate existing concentration level of metals by producing intracellular metal binding compounds which is known as chelators, or it may alter sectionalize pattern by storing metals in non sensitive parts [23].

Metal accumulator plant species

Metal accumulator plant species is also known as hyperaccumulator such species can concentrate metal in their aerial parts, to levels far exceeding than soil. Hyper accumulator absorbs high level of contaminants like heavy metals in their roots, shoots or leaves. Many researchers have identified hyperaccumulator species by collecting plants from different sources where soil contains more amounts of heavy metals. About 400 hyperaccumulator species are known from 22 families. The *brassicaceae* family contains a large number of hyperaccumulating species which contains wide range of metals, these includes 87 species from 11 genera [24,25].

Conclusion

Land pollution and soil pollution contains heavy metals and it is a major environmental concern. Metals and other inorganic compounds are the widespread form of contaminants which is found in waste water, sludges, ground water, sediments etc. and the aqueous medium causes many harmful diseases. Phytoremediation is one of the cost effective and ecofriendly methods which use green plants to remediate degrade or inhibit the heavy metal contaminants by different methods. This method stabilizes the environment. Harvesting the plants shoots can permanently remove the contaminants from soil. Phytoremediation does not have devastating impact on the fertility of soil and the structure like some of the technologies have such as acid extraction and soil washing. Phytoremediation is one of the best methods which are more active and invasive remedial methods.

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