Bioremediation and Phytoremediation of Contaminated Soils

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Abstract

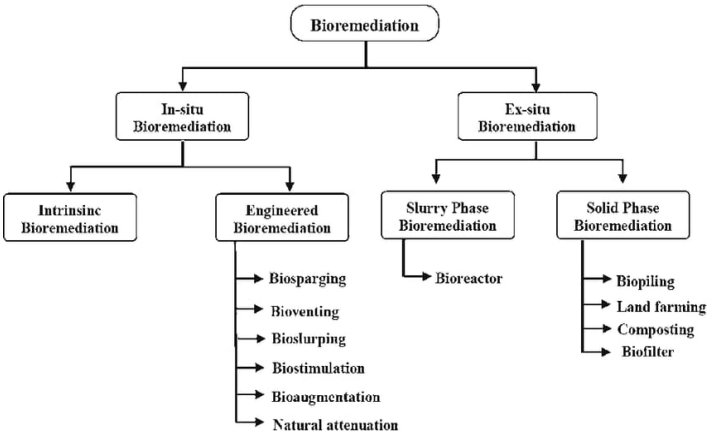
Contamination of soil in recent years has been a major threat to the environment and its management is a significant global issue having importance in agriculture, environment and health. The contamination may be caused by various factors like petroleum products, pesticides, heavy metals and plastics. This manuscript reviews the literatures with emphasis on management of contaminated soils through bioremediation and phytoremediation. Bioremediation employs microorganisms to modify and/or degrade contaminants, while phytoremediation uses plants to remove, contain, and/or change contaminants. The rhizosphere region of the soil is the active zone of remediation. It involves remediation through the activity of plants roots, enzyme produced and the activity of microorganisms.

Introduction

Soil is a complex mixture of minerals, organic material, water, and various lifeforms. In its original state, soil was an uncontaminated substance covering the earth. But humans have intentionally and accidentally poured harmful products onto it in some areas. The risk of contamination is more in urban areas than in rural areas. This is due to various causes such as pesticides, petroleum products, radon, asbestos, lead, chromated copper, arsenate and creosote. Most of them are from industrial sites and due to the excessive use of pesticide and vehicles. People are exposed to contaminants through ingesting soil, absorption through skin, breathing volatiles and dust, eating food grown in contaminated soils and so on. Thus it becomes a serious issue to remediate the contaminants in the soil so as to protect the environment and health of the living organisms. This review addresses recent advances in the remediation of the contaminated soils. Bioremediation and phytoremediation are inexpensive and can be applied in almost all the countries. Developing countries can adopt this technique for the remediation of contaminated soils.

More than 80 countries are affected by land degradation. Of these 36 are situated in Africa (WHO). China stands first in contaminated soil list. The Bengal Delta is one of the most arsenic-polluted areas in the world. Due to India's very rapid economic growth through industrial, agricultural, and mining activities, its soils polluted with trace elements are also significant

Bioremediation



It is branch of biotechnology that uses the living organisms like microorganisms and bacteria to decontaminate the affected area.

Phytoremediation

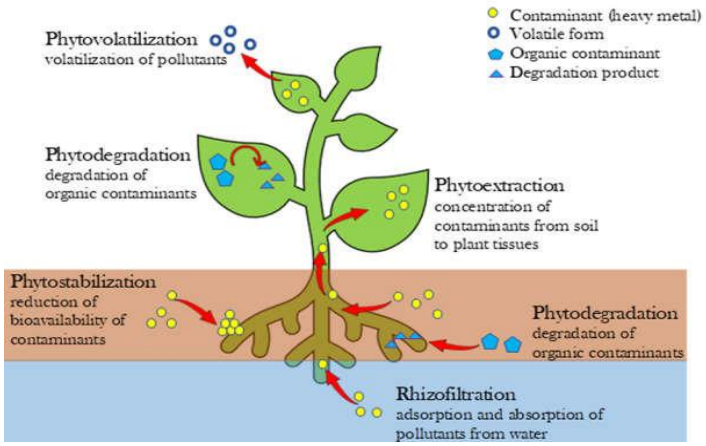


Fig 1 Systematic representation of different phytoremediation approaches by plants under study (Source: Monica *et al.*,2020)

It basically refers to the use of plants and associated microbes to reduce the concentration or toxic effects of contaminants in the environment.

Different sources of soil contamination and their remediation

Bioremediation and phytoremediation of pesticide contaminated soils

The production and application of pesticides has a long history because of the many benefits associated with their use. Pesticides, including organophosphates and organochlorines, have been used worldwide in crop production over the past few decades. Although they are beneficial economically, they cause adverse impacts on the environment and human health (Briceño *et al*., 2018). Apart from pesticides being used on a large scale there are obsolete (outdated, banned) pesticides being used in certain countries. These pesticides need to be processed to reduce their toxicity. FAO estimates that the quantity of obsolete and unwanted pesticides is about 500,000 tones. (Sidhu *et al*., 2019) reviewed the toxicity of organophosphate pesticides on plants and animals in multifarious terrestrial and aquatic ecosystems, including inhibition of various enzyme activities.

Table 1 List of microorganisms with the genes that degrade pesticides

Name of Bacteria	Name of Genes
	BACTERIA
Sphingomonas spp.	linA, linB
Pseudomonas diminuta	Opd
Alteromonas spp.	opaA
A. radiobacter	opdA
Nocardia sp	adpB
Escherichia coli	pepA
Pseudomonas monteilli	hocA
Burkholderia caryophilli	pehA
Bacillus cereus	Phn
Burkholderia sp. JBA3.	ophB
Stenotrophomonas sp. SMSP-1.	ophC2
Lactobacillus brevis	OpdB
Arthrobacter sp. scl-2.	Mh
Ochrobactrum sp. Yw28, *Rhizobium radiobacter*	Mpd
Arthrobacter sp	Oph
Arthrobacter sp. L1 (2006)	Mph
Burkholderia cepacia	MpdB
Enterobacter sp.	opdE
X. autotropphicus	dhlA
Sphingomonas paucimobilis	linB
Bacillus spp.	ALDH
Bacillus spp.	Est
	FUNGI
Aspargillus niger	A-opd

(Source: Gangola *et al*., 2019)

They also summarized the genes and enzymes involved in their degradations. Based on 337 measurements of reductive dechlorination and methanogenesis production (Cheng *et al*., 2022**),** accelerated methanogenesis occurs simultaneously with the accelerated reductive removal of chlorinated organic contaminants including organochlorine pesticides**.** Huang *et al*., 2018 have reviewed microbial degradation of pesticide residues by both natural and recombinant microorganisms. Liu *et al*., 2019 have reviewed recent progress with genetically engineered organisms that have been prepared to improve biodegradation of pesticides.

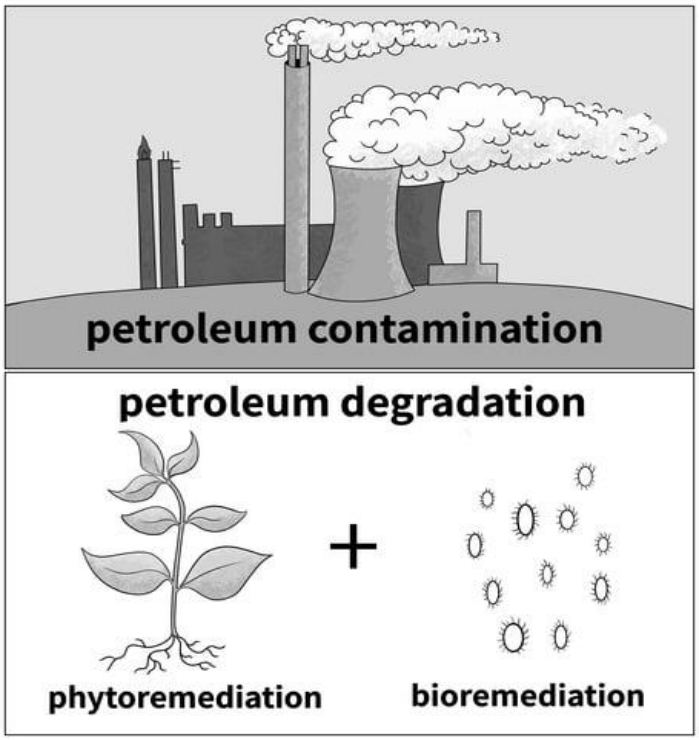
In the process of bioremediation, the insitu bioremediation has shown a rapid progress. It involves phytoremediation, bioremediation by indigenous microorganisms and bioaugumentation. To date, many microbes capable of degrading organic pesticides have been isolated. Among them, *Streptomyces*, one of the most common degraders, can efficiently degrade pesticides including diuron (*S. albidoflavus*), cypermethrin (*Streptomyces sp.* HU-S-01) and chlordane (*Streptomyces sp.* A5) in aquatic, soil and slurries systems (Briceño *et al*., 2018).

Petroleum hydrocarbons

Petroleum hydrocarbons consist of a complex mixture of different organic contaminants, including alkanes, cycloalkanes, aromatic hydrocarbons, and other organic contaminants. Harindintwali *et al*., 2022 reviewed the syntrophy of bacteria and archaea during the anaerobic degradation of hydrocarbons, especially with the methanogenic process as its final step. They highlighted that syntrophic bacteria with different metabolic capabilities can cooperate with methanogenic archaea to biodegrade hydrocarbons.

All phytoremediation mechanisms can be used for petroleum-polluted territories, but the main ones are phyto and rhizodegradation and phytovolatilization. Rhizodegradation is the combined action of plant roots and microbes. Microbes degrade the hydrocarbons present in soil through various enzymatic activity whereas plants support the growth of microorganisms. The plants rhizosphere has more microorganisms due to the action of root exudates released by the plants. The quantity and type of root exudates depend upon the plant species and environmental factors such as

temperature ,pH, moisture etc.,an experiment to prove the satisfactory effects *of Festuca arundinacea* plants on soil contaminated with Pb, Cd, Ni and TPH was shown (Steliga and Kluk, 2020).



(Source: Stepanova *et al.,* 2022)

Heavy metals

Among all the pollutants heavy metals is of more concern due to their high toxicity. These metals are present in trace amounts. They are toxic even at low concentration. Metals like arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, zinc and selenium are highly toxic in low concentration. These contaminants being pollutants in soil, water and other resources enter the human body through food, water, air or absorption through skin when they come in contact with humans. Heavy metal resistance system in many bacteria is based on efflux. Two groups of efflux system have been recognized in gram negative bacteria which are chemiosmotic pumps. Detoxfication of lead can also be achieved through sequestration. In *streptococcus thermophilus* strain 4134, two genes (cadCSt and cadASt) were confirmed to constitute in cadmium/zinc resistance.

Certain plants associated with plant growth promoting bacteria are involved in remediation of toxic heavy metals. Plants interact with heavy metals through various ways. They can be

1. Phytoextraction is the translocation of metals from contaminated soils to the ground surface via the root system of plants.
2. Phytostabilization is the use of certain plants to reduce the mobility and bioavailabilty of soil/water contaminants.
3. Phytodegradation is the transformation or breakdown of metal contaminants by plant metabolic pathways following uptake from soils.
4. Phytovolatilization is the use of plants to extract metal contaminants and then convert into volatile forms that are released to the atmosphere.
5. Rhizofiltration involves the absorption, concentration and the precipitation of metal contaminants from water or aquatic or land plants.

Some plant species have been identified as hyper accumulators since they are able to absorb heavy metals and accumulate abnormally high levels. These plants include *Pteris vittata, Sedum plumbizincicola, Thlaspi caerulescens, Alyssum serpyllifolium, Phytolacca americana* and *Solanum nigrum* (Chen *et al.,* 2014).

Conclusion

This review shows bioremediation and phytoremediation of various contaminants. This highlights the plants and microorganisms involved in the remediation process. This article clears that most of the researchers suggest that microbes-based remediation methods are found to be eco-friendly and recommended for various contaminated sites. These approaches are environment friendly and low-cost technology that can be adopted easily in various countries of the world. Extensive research is needed in providing more efficient strains of microorganisms and plant species for the remediation process.

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