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SS Ransing
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Krunal Bele
Department of Agricultural Botany, College of Agriculture Nagpur, Dr. PDKV Akola, Maharashtra, India

NP Navnage
Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Kantilal Chande
Department of Agricultural Botany, College of Agriculture Nagpur, Dr. PDKV Akola, Maharashtra, India

Puja Mate
Department of Agricultural Botany, College of Agriculture Nagpur, Dr. PDKV Akola, Maharashtra, India

PR Ramteke
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

PP Wani
Department of Agricultural Botany, College of Agriculture Nagpur, Dr. PDKV Akola, Maharashtra, India

Corresponding Author:
NP Navnage
Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Bioremediation of contaminated soils

SS Ransing, Krunal Bele, NP Navnage, Kantilal Chande, Puja Mate, PR Ramteke and PP Wani

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Abstract
Bioremediation has attracted attention of scientists and biotechnologists for environmental control and it employs biological agents mainly microorganisms like yeast, fungi, algae, or bacteria to treat contaminated soils or water derived in the process applied for treatment of such sites. Microbial bioremediation for in-situ removal of organic pollutants, heavy toxic metals, radionuclides, etc., can be applied successfully. Specific bioremediation technologies can also be developed based on toxicity of contaminants and the site conditions. As a component of bioremediation, application of plants for removal of contaminants from environment, known as phytoremediation, can also be made and hyper accumulator species are capable of accumulating toxic metals about 100 times higher than those typically found in common plants. The paper discusses the different sources of heavy metal which contaminated the soil and water and various techniques for Remediation on Remediatio Remediation of this contaminated soil.

Keywords: Bioremediation, source of pollutants, techniques and mechanism

Introduction

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Shahid, 2017) [8]. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and l and tenure problems. Bioremediation is defined as "The use of biological mechanisms to destroy, transform, or immobilize environmental contaminants in order to protect potential sensitive receptors." Ex *situ* remediation techniques involve removing the soil from the subsurface to treat it. *In situ* remediation techniques involve leaving the soil in its original place and bringing the biological mechanisms to the soil (Rattan *et al.*, 2005) [7]. In the past, thermal, chemical, and physical treatment methods have failed to eliminate the pollution problem because those methods only shift the pollution to a new phase such as air pollution. Bioremediation technology, which leads to degradation of pollutants, may be a lucrative and environmentally beneficial alternative that could produce economic profit (Khan *et al.*, 2008) [6]. Bioremediation manages microorganisms to reduce, eliminate, contain, or transform contaminants present in soils, sediments, water, or air. Over the past several decades, in situ degradation of biologically foreign chemical compounds (solvents, explosives, polycyclic aromatic hydrocarbons, heavy metals, radionuclides, etc.) has been used as a cost-effective alternative to incineration or burial in landfills (Alexander, 1994). An advantage of bioremediation over other methods is that it transforms contaminants instead of simply moving them from one source to another as in the practice of land filling. Also it is relatively low cost compared to other methods of removal (Aziz, *et al.*, 2014) [3]. In a bioremediation process, microorganisms break down contaminants to obtain chemical energy. It involves the manipulation of microorganisms and their metabolic processes (enzymes) to degrade compounds of concern. For example *Phanerochaete chrysosporium* (and several other species) uses a peroxidase enzyme system that acts in concert with H2O2, produced by the fungus, to degrade many recalcitrant organics, especially those with structures similar to lignin, which naturally degrades in soil systems. Degradable contaminants include DDT, lindane, chlordane, TNT, and PCBs. Bacteria and fungi have been shown to break down practically all hydrocarbon contamination in the natural environment. Examples of aerobic bacteria managed for their degradative abilities include Pseudomonas, Alcaligenes, Sphingomonas, Rhodococcus, and Mycobacterium. These bacteria have been reported to degrade pesticides and hydrocarbons, both alkane and polyaromatic compounds (PAHs).

Sources of heavy metals in contaminated soils

Due to the disturbance and acceleration of nature's slowly occurring geochemical cycle of metals by man, most soils of rural and urban environments may accumulate one or more of the heavy metals above defined background values high enough to cause risks to human health, plants, animals, ecosystems, or other media.

1. Fertilizers: Large quantities of fertilizers are regularly added to soils in intensive farming systems to provide adequate N, P, and K for crop growth. The compounds used to supply these elements contain trace amounts of heavy metals (e.g., Cd and Pb) as impurities, which, after continued fertilizer, application may significantly increase their content in the soil.

2. Pesticides: Several common pesticides used fairly extensively in agriculture and horticulture in the past contained substantial concentrations of metals. Examples of such pesticides are copper-containing fungicidal sprays such as *Bordeaux mixture* (copper sulphate) and copper oxychloride.

3. Biosolids and Manures: The application of numerous biosolids (e.g., livestock manures, composts, and municipal sewage sludge) to land inadvertently leads to the accumulation of heavy metals such as As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Mo, Zn, Tl, Sb, and so forth, in the soil. Metals added to soils in applications of biosolids can be leached downwards through the soil profile and can have the potential to contaminate groundwater.

4. Metal Mining and Milling Processes and Industrial Wastes: Mining and milling of metal ores coupled with industries have bequeathed many countries, the legacy of wide distribution of metal contaminants in soil. During mining, tailings (heavier and larger particles settled at the bottom of the flotation cell during mining) are directly discharged into natural depressions, including onsite wetlands resulting in elevated concentrations.

5. Air-Borne Sources: Airborne sources of metals include stack or duct emissions of air, gas, or vapor streams, and fugitive emissions such as dust from storage areas or waste piles. Metals from airborne sources are generally released as particulates contained in the gas stream. Some metals such as As, Cd, and Pb can also volatilize during high-temperature processing (Chen *et al.*, 2013) [4].

Different techniques for decontamination of heavy metals present in soil

1. Traditional Remediation of Contaminated Soil
2. Management of Contaminated Soil:
   a) Increasing the soil pH to 6.5 or higher.
   b) Draining wet soils.
   c) Applying phosphate.
   d) Carefully selecting plants for use on meta contaminated soil
3. Bioremedation
4. Phytoextraction

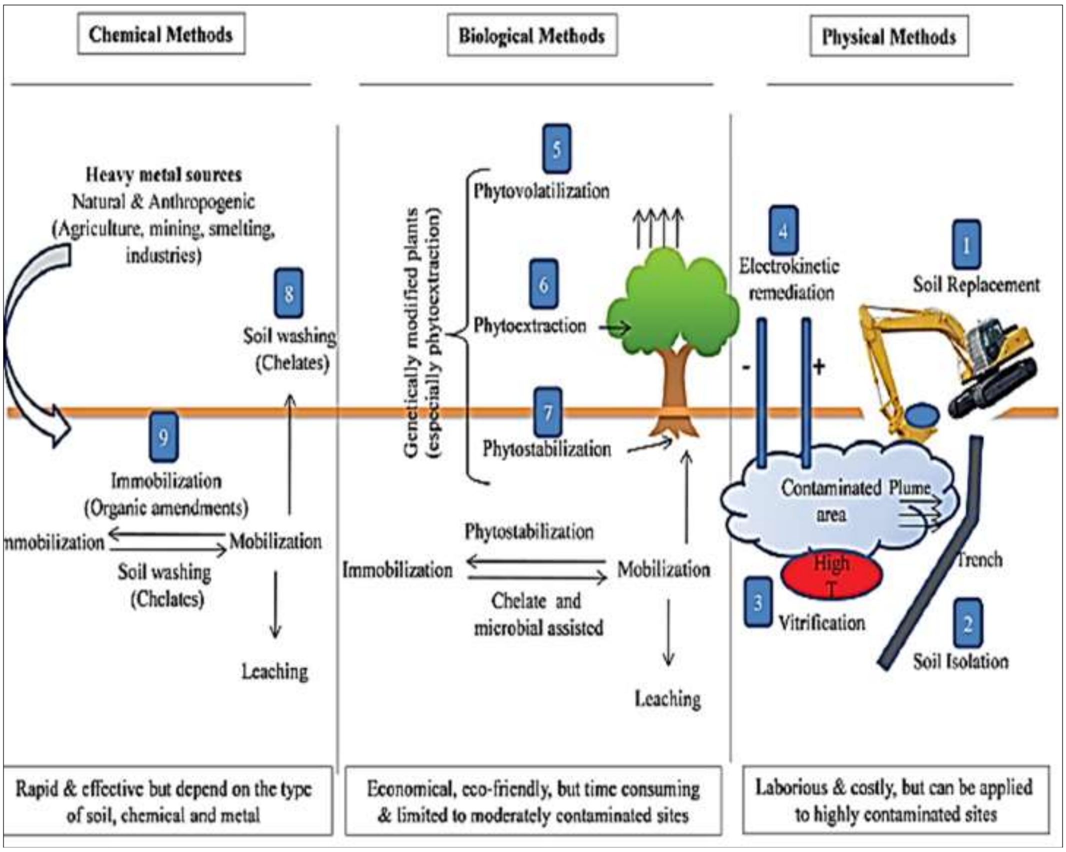

Fig 1: Method of remediation of contaminated soil (Khalid *et al.*, 2016) [5]

How Does Bioremediation Work?
Bioremediation depends on the biological processes of microorganism, one of which metabolism.

Microbial Metabolism
Metabolism refers to all chemical reaction that happen in cell or organism. Metabolic process fall into two types, that are as follow

1) Anabolism – Building up
In anabolism, Chemical taken up by the microorganism are used to build various cell parts. Carbon and nitrogen are the basic chemical in the protein, sugar, and nucleic acid

2) Catabolism- Breaking Down
Catabolism allow microorganism to gain energy from the chemicals available in the environment. Although most microorganism are exposed to light and to chemical energy sources, most relay on chemicals for their energy. When chemical breakdown energy release. Microorganism use this energy to carry out cellular function, such as those involved in anabolism.

Types of bioremediation
In situ bioremediation
The goal of aerobic in situ bioremediation is to supply oxygen and nutrients to the microorganisms in the soil and does not require excavation or removal of contaminated soils (U.S. EPA (1996) [9]. In situ techniques can vary in the way they supply oxygen to the organisms that degrade the contaminants. Two such methods are bioventing and injection of hydrogen peroxide. Remediation can take years to reach cleanup goals.

Biosparging
Biosparging involves the injection of air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of contaminants by naturally occurring bacteria.

Bioaugmentation
Bioremediation frequently involves the addition of microorganisms indigenous or exogenous to the contaminated sites.

Bioventing
Bioventing systems deliver air from the atmosphere into the soil above the water table through injection wells where contamination is located. Nutrients, nitrogen, and phosphorus may be added to increase the growth rate of the microorganisms. It involves supplying amount of oxygen necessary for the biodegradation and nutrients through wells to contaminated soil to stimulate the indigenous bacteria. Bioventing employs low air flow rates. Bioventing is effective in removing petroleum hydrocarbons, aromatic hydrocarbons, and non-volatile hydraulic oils

Soil biopiles
Biopiles are a hybrid of land farming and composting use for treatment of surface contaminatin with petroleum hydrocarbons they are a refined version of land farming that tend control physical losses of the contaminants by leaching and volatilization. Biopiles provide a favorable environment for indigenous aerobic and anaerobic microorganisms.

Injection of hydrogen peroxide
This process delivers oxygen by circulating hydrogen peroxide through contaminated soils to stimulate the activity of indigenous microbial populations.

Ex-Situ bioremediation
Ex situ techniques require excavation and treatment of the contaminated soil.

Liquid slurry phase
Contaminated soil is combined with water and other additives in a bioreactor and mixed to keep indigenous microorganisms in contact with the contaminants.

Solid phase
Solid-phase bioremediation treats soils in aboveground treatment areas equipped with collection systems to prevent contaminants from escaping.

Composting
Contaminated soil is combined with nonhazardous organic components such as manure or agricultural wastes. The presence of organic materials supports the development of a rich microbial population and elevated temperature characteristic of composting.

Land farming
Contaminated soil is excavated Spread over a prepared bed which is periodically tilled until pollutants are degraded.

Bioreactor
Containment vessel used to create solid, liquid and gas phases. Mixing condition to increase the bioremediation rate of soil bound and water soluble pollutants.
Several factors influence the success of bioremediation and should be considered on a site-by-site basis. Factors include the existence of a microbial population capable of degrading the contaminant, availability of contaminants in the microbial populations, the type of contaminant, its concentration, and environmental factors such as soil type, temperature, pH, the presence of oxygen, or other electron acceptors and nutrients. Although microorganisms are present in contaminated soils, they are not necessarily present in the numbers required for intrinsic bioremediation (Aislabie *et al*., 1997) [1].

Table 1: Environmental Conditions Influencing Biodegradation (Adapted from Vidali, 2001) [10]

Parameter	Condition required for microbial activity	Optimum for soil degradation
Soil moisture	25-38 % OF WHC	30-90%
Soil pH	5.5-5.8	6.5-8.0
Oxygen content	Minimum 10% air filled pores	10-40%
Nutrient content	N and P	C/N/P: 100:10:1
Temperature (^{0}C)	15-45	20-30
Heavy metals	<2000 ppm	700 ppm

Conclusions
Bioremediation provides a technique for cleaning up pollution by enhancing the natural biodegradation processes. So by developing an understanding of microbial communities and their response to the natural environment and pollutants, expanding the knowledge of the genetics of the microbes to increase capabilities to degrade pollutants, conducting field trials of new bioremediation techniques which are cost effective, and dedicating sites which are set aside for long

term research purpose, these opportunities offer potential for significant advances. Despite the high potential for bioremediation as an effective technology, its use is limited by the depth of understanding of biodegradation processes and inexperience in managing these processes in the field. This includes aspects of cometabolism, inoculation, evolution of biodegradation capabilities, monitoring and process control, measures of effectiveness, and genetic engineering.

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