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Bioremediation of Heavy Metals Polluted Soil

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Abstract

Soil is the most important component of biosphere. Maintaining soil health and agricultural (crop) productivity is must in the present scenario. Excessive and imbalanced use of chemical fertilizers, contaminated irrigation water increases the level of heavy metal in soil and crop. Heavy metal content in soil above the permissible limit causes serious effect on human health and environmental quality.

Keywords: Heavy Metals; Permissible Limit; Environmental Quality

Abbreviations: HM: Heavy Metals.

Introduction

Injudicious and imbalanced use of agrochemicals lead to heavy metal toxicity and environmental pollution day by day is a big concern not only in India but also in the world. Globalization and rapid industrialization have not only wreaked the havoc on the availability of natural resources but also led to the increment in pollutants. Heavy metals such as lead, nickel, cadmium, copper, cobalt, chromium and mercury are environmental pollutants tend to accumulate in the crops that cause phytotoxicity; thus, downsizing the crop productivity and sooner or later enters the human body through the food chain posing dangerous threats to the environment and human health. HMs belong to group of non-biodegradable, persistent inorganic chemical constituents with the atomic mass over 20 and the density higher than 5 g cm^{-3} that have cytotoxic, genotoxic, and mutagenic effects on humans or animals and plants through influencing and tainting food chains, soil, irrigation or potable water, aquifers, and surrounding atmosphere [1-3].There are two kinds of metals found in soils, which are referred to as essential micronutrients for normal plant growth (Fe, Mn, Zn, Cu, Mg, Mo, and Ni) and nonessential elements with unknown biological and physiological function (Cd, Sb, Cr, Pb, As, Co, Ag, Se, and Hg [4-6]. Both underground and aboveground surfaces of plants are able to receive HMs [7].

Sources of Heavy Metals

Heavy metals derived from geological sources are usually found in forms that are inaccessible to plants. The availability of unique chemical species and their content in the soil are determined by sorption and desorption processes [8]. Anthropogenic pollution, which contributes substantially to the overall heavy metal content of soil [9], is driven by a range of activities such as mining, smelting, and other industrial waste waters as well as vehicle emission. Heavy metal levels in soils and accumulation in plant are mostly caused by anthropogenic activities. The bioavailability of the elements in soil has a major impact on heavy metal accumulation in plants. The use of sewage sludge for agricultural purposes is another practice that leads to increased levels of metal in plants. Because of its high nutrient content, sludge is used in agriculture. However, it is often that sewage sludge is contributor of heavy metals in soils and also changes chemical conditions of soil.

Remediation of Heavy Metal Toxicity

Heavy metal-polluted soils can be ameliorated using a range of technologies. The approaches are divided into in-situ and ex-situ treatment technologies in one classification. In-situ methods involves remediation of heavy metals in its original location. This technique is easy, fast, and produces little waste, but it is only a temporary solution. Ex-situ techniques include removing or excavating soil from a site with low cost of investment and operation. Scientists [10] divides the In-situ remediation strategies into solidification/ Stabilization, Vitrification, soil flushing, electrokinetic extraction and biological treatment. Ex-situ technologies includes solidification/ Stabilization, soil washing, Vitrification and pyrometallurgical separation. Some plants belongs to the Fabaceae, Euphorbiaceae, Asteraceae, Lamiaceae, Scrophulariaceae and brassicaceae [11] can be a viable options for remediation of heavy metal polluted soils. Phytoremediation (In-situ approach that uses vegetation and related microbiota, as well as agronomic methods, to help in metal remediation) is one of the specific bioremediation techniques.

Phytoextraction, phytostabilization, rhizofiltration, and phytovolatization are some of the potentially useful phytoremediation technologies. Hyperaccumulating plants are used in phytoextraction to remove heavy metals from soil by absorption process into roots and shoots of the plant. The aboveground portions were then collected from heavy metal contaminated sites and stored as hazardous waste. Plants are used in phytostabilization technology to limit the mobility and bioavailability of metals in soil. For the removal of heavy metals such as Pb, As, Cr, and Cu, this method uses sorption, precipitation, complexation, or metal balance reduction. While rhizofiltration includes the absorption, accumulation, and precipitation of metals from contaminated areas, as well as aqueous waste streams and groundwater, via the roots of plants. Other phytoremediation methods like phytovolatization (use of plants to volatilize pollutants from their foliage suchas Se and Hg). Another approach for bio-remediation of heavy metals soils includes the use of micro-organisms to detoxify metals by valence transformation, extracellular chemical precipitation or volatilization, etc. Bioremediation of heavy metals polluted soils using micro-orgainsms involves biostimulation, bioaugmentation and bioleaching. Bio-stimulation is in-situ bioremediation process. The growth rate stimulation nutrients and electron donors or acceptors such as acetate, nitrate, ethanol, and sulfate are being used to promote the growth of site-specific indigenous microbes capable of degrading pollutants. Bioaugmentation is the introduction of specific competent micro-organisms to the local microbial population for increasing the metabolic activities needed for remediation while bioleaching involves the use of microbes such as bacteria belongs to the genus Acidiphilium, Acidimicrobium, Ferromicrobium or sulfobacillus and Acidithiobacillus (A. thiooxidans and A. ferrooxidans) in-situ or ex-situ to solubilize heavy metals (Cu, Co, Ni, Zn and U) either by direct processes or as a result of interactions with metabolic products or both [12]. Metal biosorption is also an effective process involving the employment of fungal species like Rhizopus nigricans,Aspergillus vesicolor, Aspergillus niger,Cladosporium resinae, Aureobasidium pullulans and bacterial strains ofShewanella putrfaciens, Psuedomonas aeruginosa, Enterbacter clonacae, Psuedomonas maltophilia and Escherichia coli [13].

Conclusions

Heavy metals because of their bio-accumulation and non-biodegradable nature has become serious threats to the environment and poses problems to the living organisms. So, therefore, it is necessary to carry out the regular monitoring of those areas where heavy metal pollution can occur. Remediation technologies should be applied as soon as possible. This review reveals the role of remedial measures especially bioremediation (Phytoextraction, phytostabilization, rhizofiltration and phytovolatization) and use of microorganisms for heavy metal polluted soil. Further research area needs to be explored by the scientists and researchers for remediation of heavy metal contaminated soil as well as water.

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