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Review Article

PHYTOREMEDIATION: A GREEN BIO- ENGINEERING TECHNOLOGY FOR CLEANUP THE ENVIRONMENTAL CONTAMINANTS

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ABSTRACT

Environmental bio-engineering technology is a new discipline which integrates living materials mainly plants and micro-organism to address the problems of environmental management and sustainable development. An emerging solution for this problem is phytoremediation, which consists of these uses of plants, usually as a part of reclamation programmes to remove contain inactive or degrade harmful environmental contaminants. Phytoremediaion is a fast developing field and since last ten years lots of field application were initiated all over the world. It includes phytoremediation of organic, inorganic and radionuclides. This sustainable and inexpensive is fast emerging as a viable alternative conventional remediation methods and will be suitable for a developing country like India. In recent years scientist and engineers have started to generate cost effective that include use of plants to clean up the environment. Successful application of phytoremediation however depends upon various factors which must be carefully investigated and properly considered for specific site condition and their potential to use in environmental cleanup. Phytoremediation is a group of technologies that use plants to reduce, degrade, or immobilize environmental toxins, primarily those of anthropogenic origin, with the aim to clean-up contaminated areas. In this review paper, different types of phytoremediation processes and their application for clean-up of metal contaminated sites were reviewed.

INTRODUCTION

Soil is the fundamental foundation of our agricultural resources, food security, global economy and environmental quality (Oh *et al*., 2014). Soil contamination by heavy metals and metalloids has become a serious environmental issue today. A number of metals including chromium, iron, arsenic, zinc, cadmium, mercury and copper are known to significantly compromise the quality of soil and cause adverse effects to human and health and the well-being of other organisms that comes in contact with such soil. Heavy metals are extremely persistent in the environment because they are not biodegradable and may not be broken down by chemical oxidation or through thermal processes; as a result their accumulation readily reaches to toxic levels (Richei, *et al*., 2014). The contamination of soils by heavy metal enhances plant uptake causing their accumulation in different plant. With the development of urbanization and industrialization, soils have become increasingly polluted by heavy metals and organic pollutants, which threaten ecosystems, surface and ground waters, food safety and human health. Hence, there is a great need to develop effective technologies for sustainable management and remediation of the contaminated soils. However, the practical application of phytoremediation has been limited because of its low remediation efficiency. Phytoremediation has been increasingly received attentions over the recent decades, as an emerging and eco-friendly approach that utilizes the natural properties of plants to remediate contaminated soils. By growing plants in the contaminated sites, contaminants in soils will be removed, immobilized, or degraded and the cost is much less expensive than other traditional methods (Oh *et al*., 2014). This review presents the status of phytoremediation technologies with soil heavy metal contamination.

Phytoremediation Technologies

Phytotechnologies are based upon the basic physiological mechanisms taking place in higher plants and associated microorganisms, such as transpiration, photosynthesis, metabolism, and mineral nutrition. Plants dig their roots in soils, sediments and water, and roots can take up organic compounds and inorganic substances; roots can stabilize and bind substances on their external surfaces, and when they interact with microorganisms in the rhizosphere (Marmiroli *et al*., 2006). A promising, relatively new technology for heavy metal contamination sites is the objective in phytoremediation.

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Phytoremediation processes rely on the ability of plants to take up or metabolize pollutant to less toxic substances (Oh *et al*., 2014). There are a number of different forms of phytoremediation, defining these forms is useful to clarify and understand the different processes that occur to a contaminant, their remediation and what should be done for effective phytoremediation. Phytoremediation consists of Different phytoremediation technologies.

Rhizofiltration

It is defined as the use of plants, both terrestrial and aquatic; to absorb, concentrate, and precipitate contaminants from polluted aqueous sources with low contaminant concentration in their roots. This technique is used for cleaning contaminated surface waters or waste waters such as industrial discharge, agricultural runoff, or acid mine drainage by absorption or precipitation of metals onto roots or absorption by roots or other submerged organs of metal tolerant aquatic plants (Mukhopadhyay, 2010).

Table1 Phytoremediation includes the following processes and mechanisms of contaminant removal

S.No.	Process	Mechanism	Contaminant
1	Rhizofiltration	Accumulation	Organics/Inorganics
2	Phytostabilisation	Complexation	Inorganics
3	Phytoextraction	Hyper-accumulation	Inorganics
4	Phytovolatilization	Volatilisation by leaves	Organics/Inorganics
5	Phytodegradation	Degradation in plant	Organics

Phytostabilisation

It is mostly used for the remediation of soil, sediment and sludges and depends on roots ability to limit contaminant mobility and bioavalability in the soil. Phytostabilisation can occur through the sorption, precipitation, complexation, or metal valence reduction (Ghosh and Singh, 2005). Plants with high transpiration rates, such as grasses, sedges, forage plants and reeds are useful for phytostabilization by decreasing the amount of ground water migrating away from the site carrying contaminants. Combining these plants with hardy, perennial, dense rooted or deep rooting trees (popular, cottonwoods) can be an effective combination (Mukhopadhyay, 2010).

Phytoextraction

Phytoextaction involves the use of plants that has the ability to concentrate the heavy metal in their shoot tissue, to remediate contaminated lands. Usually, the shoot biomasses are harvested for disposal in special site or are burnt to recover the metal (Islam *et al*., 2007). It is also known as phytoaccumulation, phytoabsorption and phytosequestration. Phytoextraction can be divided into two categories: continuous and induced (Salt *et al*., 1998). Continuous phytoextraction requires the use of plants that accumulate particularly high levels of the toxic contaminants throughout their lifetime (hyperaccumulators), while induced phytoextraction approaches enhance toxin accumulation at a single time point by addition of accelerants or chelators to the soil (Mukhopadhyay, 2010).

Phytovolatilization

Phytovolatilization involves the use of plants to take up contaminants from the soil, transforming them into volatile form and transpiring them into the atmosphere.

Phytovolatilization occurs as growing trees and other plants take up water and the organic and inorganic contaminants. Some of these contaminants can pass through the plants to the leaves and volatilize into the atmosphere at comparatively low concentrations (Ghosh and Singh, 2005). It involves the use of plants to take up contaminants from the soil transforming them into volatile form and transpiring them into the atmosphere. Selenium (Se) is a special case of a metal that is taken up by plants and volatilized (Mukhopadhyay, 2010).

Phytodegradation

In phytoremediation of organics, plant metabolism contributes to the contaminant reduction by transformation, break down, stabilisation or volatilising contaminant compounds from soil and groundwater. Organic contaminants are degraded (metabolized) or mineralized inside plant cells by specific enzymes that include nitroreductases (degradation of nitroaromatic compounds), dehalogenases (degradation of chlorinated solvents and pesticides) and laccases (degradation of anilines) (Paulo *et al*., 2014). Rhizodegradation is the breakdown or organics in the soil through microbial activity of the root zone (rhizosphere). Enhanced rhizosphere degradation uses plants to stimulate the rhizosphere microbial community to degrade organic contaminants (Kirk *et al*., 2005).

Role of Phytoremediation

A major environmental concern due to dispersal of industrial and urban wastes generated by human activities is the contamination of soil. Controlled and uncontrolled disposal of waste, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for the migration of contaminants into non-contaminated sites as dust or leach ate and contribute towards contamination of our ecosystem. Although many metals are essential, all metals are toxic at higher concentrations, because they cause oxidative stress by formation of free radicals. Another reason why metals may be toxic is that they can replace essential metals in pigments or enzymes disrupting their function.

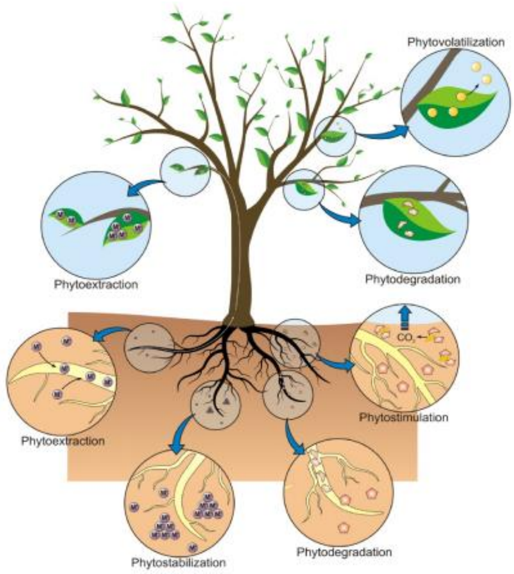

Table 2 Advantages and disadvantages of phytoremediation

Table 2 Advantages and disadvanges of phytoremediotion

No	Advantages	Disadvantages
1	Amendable to a variety of organic and inorganic compounds	Restricted to sites with shallow contamination within rooting zone of remediative plants.
2	Uses solar energy and is low cost	Still under development and therefore not accepted by many regulatory agencies
3	High acceptance by the public	Metal concentrations in the soil can be toxic and lethal to plants
4	Reduces the amount of waste to be landfilled (up to 95%), can be furtherutilized as bio-ore of heavy metals.	Harvested plant biomass from phytoextraction may be classified as a hazardous waste hence disposal should be proper.
5	In Situ applications decrease spread of contaminant via air and water.	Climatic conditions are a limiting Factor
6	Does not require expensive equipment or highly specialized personnel.	Introduction of nonnative species may affect biodiversity
7	In large scale applications the potential energy stored can be utilized to generate thermal energy.	Consumption/utilization of contaminated plant biomass is a cause of concern.
8	In Situ / Ex Situ Application possiblewith effluent/soil substrate respectively.	May take up to several years to remediate a contaminated site.
9	The harvested biomass can be economically valuable	The area to be decontaminated must be large enough to allow application of cultivation techniques

Thus, metals render the land unsuitable for plant growth and destroy the biodiversity (Ghosh and Singh, 2005). When categorizing plants that can grow in the presence of toxic elements, the terms "metal excluder", "metal indicator", and "metal accumulator" are used. Metal excluders prevent metal from entering their aerial parts or maintain low and constant metal concentration over a broad range of metal concentration in soil; they mainly restrict metal in their roots. The plant may alter its membrane permeability, change metal binding capacity of cell walls, or exclude more chelating substances (Lasat, 2000). A metal indicator species is one that actively accumulates metal in their aerial tissues and generally reflects metal level in soil. They tolerate the existing concentration level of metals by producing intracellular metal binding compounds (chelators), or alter metal compartmentalization pattern by storing metals in non-sensitive parts (Ghosh and Singh, 2005). Indicator species have been used for mine prospecting to find new ore bodies. Metal accumulators can concentrate metal in their aerial parts, to levels far exceeding than soil. By definition, hyperaccumulators are herbaceous or woody plants that accumulate and tolerate without visible symptoms a hundred times or greater metal concentrations in shoots than those usually found in non-accumulators. Baker and Brooks (1989) established 0.1% as the minimum threshold tissue concentrations for plants considered Co, Cu, Cr, Pb or Ni hyperaccumulators, while for Zn or Mn the threshold is 1%. For cadmium and other rare metals, it is 0.01% by dry weight. Hyperaccumulators are found in 45 different families, with the highest occurrence among the Brassicaceae (Mukhopadhyay 2010). In phytoremediation technology, multiple metals contaminated soil and water requires specific metal hyperaccumulator species and therefore requires a wide range of research prior to the application. Now a days this technology is receiving considerable attention for cleanup of soil contaminated with heavy metals (Khanam, 2011).The advantages and disadvantages have been discussed in Table 2.

CONCLUSION

Phytoremediation is considered to be an innovative technology and hopefully by increasing our knowledge and understanding of this intricate cleanup method it will provide a cost effective, environment friendly alternative to conventional cleanup methods. Such plants have the advantage of accumulating and degrading components of such contaminants. Phytoremediation can be an income generating technology especially if metal removed from the soil can be used as bio-ore to extract useable metal. i.ephytomining and energy generated through biomass burning. It is also low impact cleanup technology applicable in both developed and developing countries. Several comprehensive reviews have been published, summarizing many important aspects of this novel green technology.

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