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REMOVAL OF HEAVY MEALS THROUGH PHYTOREMEDIATION TECHNIQUE

SAURABH DAVE[1] and HARDIK PATHAK[2 *]
[1]Department of Chemistry, JECRC University, Rajasthan, India.
[2]Department of Biotechnology, JECRC University, Rajasthan, India.
* Corresponding author : E-mail: hardikaeshu@gmail.com

Today we are facing several environmental problems including the pollution occur by heavy metals present in soil and water. The present remediation technique of heavy metal removal from contaminated soil is being more cost-effective and fewer side effects than physical and chemical approaches. It has gained attention from scientist as increasing popularity in both academic and practical circles. Phytoremediation is an emerging technology for cleaning up contaminated sites, with several advantages and long term applicability. More than 450 plant species have been identified to have potential for soil and water remediation. The technology involves efficient use of plants for the removal of heavy metals, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural, biological, chemical or physical activities or processes of the plants. A brief review on phytoremediation of heavy metals and its effect on plants have been provided for a wide applicability of phytoremediation.

Keywords: Environmental pollution; Heavy Metal; Phytoremediation.

Introduction

Human evolution has led to immense scientific and technological progress. Global development, however, raises new challenges, especially in the field of environmental protection and conservation[1]. Land and Water are most important natural resources on earth which rely the sustainability of agriculture and the civilization of mankind. Unfortunately, due to human activities they have been subjected to exploitation and severely degraded or polluted.

In the beginning of the industrialization, soil pollution by toxic heavy metals has accelerated dramatically. According to Nriagu (1996)[2] about 90% of the anthropogenic emissions of heavy metals have occurred since 1900 AD; it is now well recognized that human activities involved to a substantial accumulation of heavy metals in soils on a global scale (e.g. 5.6 – 38 x 106 kg Cd yr-1). The pollution includes emission of industrial waste and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, as well as sources like soluble salts (natural and artificial), uses of insecticides/pesticides,[2,3]. Every source is not only a potent source to damage plants, animals and ultimately to human health but also adds heavy metal to soils and waters which affect a serious concern on human health due to their persistence in the environment and carcinogenicity to human beings. They cannot be destroyed biologically but are only transformed from one oxidation state or organic complex to another[4],[5,6]. Therefore, heavy metal pollution posses a great threat to the ecosystems.

Sources of Metal Pollution

Land and water pollution by heavy metals is a worldwide issue. Several activities are sources of heavy metal contamination[7]. Sources of anthropogenic metal contamination include industrial effluents, fuel production, mining, smelting processes, military operations, utilization of agricultural chemicals, small-scale industries (including battery production, metal products, metal smelting and cable coating industries), brick kilns and coal combustion[8]. In Western Europe, 1 400 000 sites were affected by heavy metals[9], of which, over 300 000 were contaminated, and the estimated total number in Europe could be much larger, as pollution problems increasingly occurred in Central and Eastern European countries[10]. One of the prominent sources contributing to increased load of soil contamination is disposal of municipal wastage. These wastes are either dumped on roadsides or used as landfills, and sewage is used for irrigation. These wastes, although useful as a source of nutrients, are also sources of carcinogens and toxic metals. Additional potential sources of heavy metals include irrigation water contaminated by sewage and industrial effluent leading to contaminated soils and vegetables[11].

Heavy metals that have been identified in the polluted environment include As, Cu, Cd, Pb, Cr, Ni, Hg and Zn. The sources of various heavy metals are listed in Table 1.

Table 1: Different Sources of heavy metals

Heavy metals	Sources
As	Semiconductors, petroleum refining, wood preservatives, animal feed additives, coal power plants, herbicides, volcanoes, mining and smelting [2,15]
Cu	Electroplating industry, smelting and refining, mining, biosolids[16]
Cd	Geogenic sources[17], anthropogenic activities [18], metal smelting and refining, fossil fuel burning, application of phosphate fertilizers, sewage sludge[19]
Cr	Electroplating industry, sludge, solid waste, tanneries[20,21,22]
Pb	Mining and smelting of metal liferous ores, burning of leaded gasoline, municipal sewage, industrial wastes enriched in Pb, Paints[19]
Hg	Volcano eruptions, forest fire, emissions from industries producing caustic soda, coal, peat and wood burning[23]
Se	Coal mining, oil refining, combustion of fossil fuels, glass manufacturing industry, chemical synthesis (e.g., varnish, pigment formulation)
Ni	Volcanic eruptions, land fill, forest fire, bubble bursting and gas exchange in ocean, weathering of soils and geological materials[20]

The presence of any metal may vary from site to site, depending upon the source of individual pollutant. Excessive uptake of metals by plants may produce toxicity in human nutrition, and cause acute and chronic diseases. For instance, Cd and Zn can lead to acute gastrointestinal and respiratory damages and acute heart, brain and kidney damages. High concentrations of heavy metals in soil can negatively affect crop growth, as these metals interfere with metabolic functions in plants, including physiological and biochemical processes, inhibition of photosynthesis, and respiration and degeneration of main cell organelles, even leading to death of plants[12]. Soil contamination with heavy metals may also cause changes in the composition of soil microbial community, adversely affecting soil characteristics[13,14].

Metal Toxicity

All plants have the ability to accumulate "essential" nutrients (Ca, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Se, V and Zn) from the soil. Plants need different concentrations of these nutrients for growth and development. This ability also allows plants to accumulate other "non-essential" metals (Al, As, Au, Cd, Cr, Hg, Pb, Pd, Pt, Sb, Te, Tl and U) which have no known biological function [24,25,26]. Moreover, metals cannot be broken down and when concentrations inside the plant cells accumulate above threshold or optimal levels, it can cause direct toxicity by damaging cell structure (due to oxidative stress caused by reactive oxygen species) and inhibit a number of cytoplasmic enzymes[27]. In addition, it can cause indirect toxic effects by replacing essential nutrients at cation exchange sites in plants[24]. Baker (1981)[25] proposed that some plants have a capability to tolerate the presence of large amounts of heavy metals in their environment by the following three ways: 1. Exclusion, transport of metals is restricted and constant metal concentrations are maintained in the shoot over a wide range of soil levels.

2. Inclution, shoot metal concentrations reflect those in the soil solution in a linear relationship.

3. Bioccumulation, metals are accumulated in the roots and upper plant parts at both high andlow soil concentrations.

Prajapati et al., 2012[28] investigated that aquatic macrophytes, *Pistia stratiotes*, may be used for phytoremediation of water bodies polluted with heavy metals, Cr and Co in a sustainable way.

Excessive metals in human nutrition can be toxic and can cause acute and chronic diseases[12]. Zn is an essential trace nutrient to all high plants and animals. Zinc is required in a large number of enzymes[29] and plays an essential role in DNA transcription. Zinc toxicity often leads to leaf chlorosis[30]. Zn majorly absorbed by *Brassicaceae* family and is in the genus Thlapsi.

Technologies for Removal of Heavy Metals

The term phytoremediation (phyto = plant and remediation = correct evil) is relatively new, coined term in 1991. Phytoremediation term has been used widely since its inception, with a variety of specific meanings Soil constitutes the weathered surface to the earth's crusts which is mixed with organic material and in which microorganism live and plant grow. Soil consists of the inorganic materials, organic materials, air and water in loosely packed soil particles; plant roots and small organisms including bacteria, fungi etc. The mineral components vary according to a particular set of climatic conditions. Soil properties play a significant role in determining plant growth as well as in community development. Soil water holding capacity is controlled by its structure and texture. The soil moisture content has great bearing in controlling solute movement, salt solubility, chemical reactions and microbiological activities and ultimately the bioavailability of the metal ions. It directly connected with the clay percentage of any soil structure. The pinnacle performance is achieved under a set of most favorable conditions. The cleaning of contaminated soils from heavy metals is the most difficult task, particularly on a largescale. Phytoremediation involves phytoextraction[31,] rhizofiltration[32], phytostablization[3]and phytotransformation /phytodegradation[34]. Aquatic macrophytes *Pistia stratiotes* L. has been extensively used for phytoremediation[35,36]. *Pistia stratiotes was* used in laboratory experiments for the removal of several heavy metals (Fe, Cu, Zn, Mn, Cr, and Pb) resulting from anthropogenic activity[37]. Several methods have been adopted for the cleaning of these harmful metals which may be physico chemical or biological.

In physicochemical approach excavation and burial of the soil at a hazardous waste site, fixation/inactivation (chemical processing of the soil to immobilize the metals), leaching by using acid solutions or proprietary leachants to adsorb and leach the metals from soil followed by the return of clean soil residue to the site[33], precipitation or flocculation followed by sedimentation, ion exchange, reverse osmosis and microfiltration[38]. The physicochemical approaches are generally costly and have side effects[3, 38].

Biological approaches include: (1) utilization of microorganisms to detoxify the metals by, extracellular, or volatilization [by enzymatically, valence transformation, chemical precipitation etc], (2) use of special type of plants species to decontaminate soil or water by inactivating metals in the rhizosphere or translocating them into the aerial parts of the plants. This approach is called phytoremediation, which is considered as a new and highly promising technology for the reclamation of polluted sites and cheaper than physicochemical approaches [5,38].

Advantages and Disadvantages

Phytoremediation technique is a cost effective technique and it is the most acceptable approach towards the removal of heavy metals. The major advantages of the heavy metal adsorption technology by biomass are its effectiveness in reducing the concentration of heavy metal ions to very low levels and the use of inexpensive biosorbent materials[39]. Phytoremediation as possibly the cleanest and cheapest technology can be employed in the remediation of selected hazardous sites[40]. Phytoremediation encompasses a number of different methods that can lead to contaminant degradation[41]. Phytoremediation is regarded as a new approach for the cleanup of contaminated soils, water, and ambient air[42]. Phytoremediation research can also contribute to the improvement of poor soils such as those with high aluminum or salt levels[43]. It is applicable to a range of toxic metals and radionuclides, minimal environmental disturbance, elimination of secondary air or water-borne wastes, and public acceptance[44]. Phytoextraction is considered as an environmentally eco friendly method to remove metals from economically valorized in the form of bioenergy. The use of metal-accumulating bioenergy crops might be suitable for this purpose.

Among them are being time consuming method, the amount of produced biomass, the root depth, soil c hemistry and the level of contamination, the age of plant, the contaminant concentration, the impacts of contaminated vegetation, and climatic condition. The intermediates formed from those organic and inorganic contaminants may be cytotoxic to plants[45]. Phytoremediation is also limited by the growth rate of the plants. More time may be required to phytoremediate a site as compared with other more traditional cleanup technologies. Excavation and disposal or incineration takes weeks to months to accomplish, while phytoextraction or degradation may need several years. Therefore, for sites that pose acute risks for human and other ecological receptors, phytoremediation may not be the remediation technique of choice[40,45]. Phytoremediation might be best suited for remote areas where human contact is limited or where soil contamination does not require an immediate response[39].

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