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PHYTO-REMEDIATION- A SUSTAINABLE TECHNOLOGY TO REMEDIATE HEAVY METAL POLLUTION

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ABSTRACT

Urban sprawl and development due to aspiration for better quality of life, the pressure for intensive agriculture, fast paced industrialization and chaotic anthropogenic activities has increased manifold. These have resulted in environmental pollution, degradation of land and ecological imbalance. The rapid urbanization and industrialization with increasing use various pesticides, micronutrients, which contain essential metals, are resulting into discharge of number of heavy metals. These metals, not being biodegradable, results in bioaccumulation in the environment and causes toxicity. Removal of these metals is generally through physico-chemical reaction which causes generation of large quantity of sludge. Besides, for low concentration of heavy metals it is an economically imprudent method. Bioremediation provides an alternate sustainable option for elimination of metal toxicity from the waste exploiting organism through a variety of processes. Phyto-remediation, a subpart of bioremediation, uses plants and algae for the treatment of the waste. For low to moderate pollutant concentration, phyto-remediation is an energy efficient and cost effective technology which is also aesthetically pleasant. The process of removal depends on the target pollutant and the mechanism.

Keywords: *Industrialization, Anthropogenic, Environmental pollution, Degradation, Bioremediation, Toxicity*

INTRODUCTION

Prior to the dawn of industrialization, the anthropogenic activities were limited in their scope of causing pollution and imbalance in the ecosystem. The large scale imbalance was often due to natural phenomenon and calamity. With the advent of the steam power large scale industrialization took steps in early 19[th] centaury. With the emphasis on the development and increased demand for the consumption anthropogenic activities put pressure on the natural ecosystem and as a result the, the pressure is exerted on limited resources to drive the maximum benefit. This lead to amplified mining and metallurgical activities, emissions, increased utilization of biocides and ferti-nutrients, which added to elevation of metal toxins levels of the ecosystem (Yoon et. al., 2006). The pollution of environment with metal contamixation has been attributed to industrial processes including of metal fabrication, automobile service, chemical works, paper factories, textile manufacturing, tanneries, along with the chemical assisted intensive agriculture and sites of waste dumping (Wong, 2003; Freitas et al., 2004). Heavy metal contamination of soils has become a grave problem in areas of concentrated industrial activity and agriculture. There is no uniform criterion for defining heavy metals, but metals and metalloids having atomic number greater than 20 and density more than 5 g/cm^3 are included in it. Although, these may be essential phyto-nutrients, these can be poisonous for both flora and fauna even at concentrations which are significantly low (Rascio and F. Navari-Izzo, 2011).

The pollution of the environment with heavy metals has become a universal problem. It not only impacts crop yields, soil biomass and fertility, but result into bioaccumulation of metals in the food chain (Gratao et al., 2005; Raj kumar et al., 2009). This is largely owed to pollution of agricultural soils by ever growing application of chemical nutrients and fertilizers, culminating in lasting risk to environmental health (McLaughlin et al., 1999; Wong et al., 2002). Unlike organic pollutants, which degrade naturally over a period, heavy metal persist in environment for a long period of time and are not readily amiable to degradation naturally or by microbial communities (Liu et. al., 2009). Studies have verified that increased levels of heavy metals may manifest in impacts on flora and fauna, including birds and mammals which include stunted growth, behavioral effects, genital deformation, anemia, kidney lesions etc. (Pedersen et al, 2006). Besides, these heavy metals, by way of bioaccumulation through food chain, pose a heightened potential risk to human well being with the soil-crop- human exposure route (Liu et al, 2011). Developing countries requirement for rapid improvement in infrastructure, agriculture and population explosion, coupled with deficient implementation of pollution control systems is resulting into ever increasing in heavy metal contamination of soils [Ji et al., 2000]. Heavy metals infected sites pose a health hazard to plants and

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animals as well as humans. Thus, remediation of such heavy metal polluted is prime requirement for agro-ecological sustainability.

Remediation of Heavy Metal

Almost all, barring a few cleanup techniques for soil remediation available are energy intensive, expansive, soil disturbing and therefore have limited acceptability in the real world. Conventional techniques of remediation of soil typically employs pneumatic fracturing, solidification/stabilization, vitrification, excavation, removal, washing etc. with chelators or acids (Steele and Pichtel, 1998; Khan et al., 2004; Bhargava et al., 2012). These various types of heavy metal remediation techniques can be classified in two primary groups (a) Physico-chemical (b) Bio remediation

Physico-Chemical Remediation

Physico-chemical remediation means to use of physical and/or chemical methods to control/extract/separate heavy metal contamination. These basically includes

Replacement, containment and isolation of contaminated soil

These methods include addition of large quantity of contaminant free soil to the contaminated site either as envelop to surface or as blending material. In grave distress situations the contaminated soil is altogether removed and replaced with clean soil. Soil isolation refers to techniques such as piling, curtain etc for isolation of contaminant infected soil from the uncontaminated soil, however, for comprehensive remediation other auxiliary engineering measures are required (Zheng et al., 2002).

Electrokinetic remediation

This is a relatively new, economically effective technology based on the creation of direct current potential to form the electric field gradient in electrolytic tank containing the contaminated soil. The potential difference causes electro-migration, electric seepage or electrophoresis forcing transportation of contaminant from contaminated soil to the processing chamber of electrolyte cells and resulting into reduction in the contamination. The method is more suitable for the soils with low permeability (Hanson et al., 1992).

Leaching

The heavy metal contaminated soil is leached with contaminant selective reagents. The contaminating heavy metals are alienated from the soil and recycled from extracting solution.

Adsorption

Adsorption utilizes the fact that a number of metal ions show affinity to fixation and adsorption by various mineral found in clay (bentonite, zeolite, etc.), steel slag, furnace slag, etc (Wang and Zhou, 2004).

Other minor methods

Other lesser employed physico-chemical methods include washing, physical solidification, compounding, heat treatment, chemical admixing, chemical curing, etc.

Bioremediation

Bioremediation is the use of natural and recombinant microorganisms, fungi, algae and plants for the cleanup of environmental pollutants. It is considered as environmentally friendly, cost-effective approach. It relies on enhancement in detoxification and degradation through accumulation in cell and tissues or via transformation by enzymes of metabolic activity to lesser or completely non-toxic compounds. Bioremediation is primarily divided in two categories

Microbial remediation

Microorganisms adapt to its surrounding for survival in its habitat infected with metal toxins, through different mechanisms such as biotransformation, bioaccumulation, biosorption, biomineralization, etc. This adaptation to environment can be gainfully utilised in both ex-situ and in-situ remediation (Berti and Cunningham, 2000; Rulkens et. al., 1997; Salt et.al, 1995, 1997). Microbial remediation is technique of using these microorganism for reduction of toxins through absorption, precipitation, oxidation-reduction, etc . Various metabolites and amino acids excreted by fungi reported to act on heavy metals their resident minerals (Siegel et al. 1986).

Phytoremediation

Some species of algae and plants grow on heavy metal polluted sites. These possess property of accumulation of these pollutants present in soil. The decontamination is effected by harvesting and burning of these plants subject to ripening or enrichment level of the contaminants in the plant.

Phytoremediation

The term phytoremediation is coined from the Greek "phyto" for "plant" and the Latin "remedium" for "to heal again." Phytoremediation is gaining currency as an integrated economically viable and environmentally sustainable technique for dredging and detoxification of dredge, waters and soils contaminated with heavy metal pollution (Clayton 2007). Five important process namely, Rhizofiltration, phytostabilization, phytoextraction,

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phytovolatilization,and phytodegradation encompass Phytoremediation technology (Fulekar et al., 2009; Marques et al., 2009; Chaney *et al.*, 1997).

Phytoextraction

Phytoextration which alternatively termed as phytoaccumulation, is probable best suitable way, without disturbing the fertility and the structure of soil, for isolation and removal of contaminants from the soil (USEPA, 2000). The technique is more employable in the remediation of dispersedly contaminated site having soils with relatively less concentration of pollution (Rulkens et. al., 1997).

Phytoextraction refers to removal of pollutants with sustain cleaning of waste water or soil utilizing plant property of absorption of contaminants through root system and its transportaition to the leaves, stem and branches. There are two primary tactics of phytoextraction first one exploiting natural ability of plant for remediation and second induced or assisted extraction aided with artificially introduced chelating agents (Salt et.al, 1995, 1997).

The prime factors for candidate suitable plant species are ability of roots to suck in high concentration of heavy metals, translocation of these to shoot biomass and production of biomass in large quantity. Other factors effecting suitability of plant for extraction are metal selectivity, rate of growth, resilience to disease etc. (Cunningham and Ow, 1996; Baker et. al., 1994). Recycling of the pollutants can be effected by recycling of polluted biomass (Brooks et. al., 1998).

Phytostabilisation

It is generally refers to the stabilization of contaminant in soil and primarily employed in remediation of dredges and soils (USEPS, 2000; Mueller et. al. 1999). The employability of the species is decided on the basis of ability of plant roots in restriction of contaminant mobility and its bioavailibilty. The primary mechanism is to reduce the rate of percolation, thwart erosion of soil and restrain noxious metal transportation to neighborhood. Plants with high density of roots restrict erosion and promote soil stabilization. It is more employable where accelerated immobilization is required with preservation of the ground and surface water quality. Frequent monitoring requirement due to contaminant stabilized in the soil, without removal, is major constraint of the method.

Phytodegradation

Phytodegradation is dissociation of complex molecules suck up by the plant in simpler products which than are stored in plant parts (Chaudhry et. al., 1998). In this, metabolic action in photosynthesis breakdown, transform and stabilize the contaminants adsorbed by plants effecting the reduction of contamination in soil and/or ground water.

Phytovolatilization

Phytovolatilization is process wherein the soil contaminants are transformed into volatile compounds by the plants and evapo-transpired. The mechanism of this contaminant transportation and volatilization occurs at very moderate concentration (Mueller et. al., 1999).

Rhizofiltration

The utilization of dense root mass of plant for filtering, concentrating and precipitation of contaminants in polluted liquid media is Rhizofiltration. It can be gainfully employed for the partial treatment of sewage, industrial waste water as well as of mine and agriculture drainage. The rhizofiltration can advantageously be used in both ex-situ and in-situ applications. Besides, the technique has been reported to promise in containment and treatment of metals like Cd, Zn, Cu, Ni, Pb etc, through retention of these within plant root zone (Mueller et. al., 1999; USEPA, 2000).

Sustainable phytoremediation

Phytoremediation turns out to be valuable for the reason that it primarily depends on abundantly available solar radiation for accelerate remediation and preserve characteristics and structure of the soil (Zhuang et al., 2007), Bioavailability and metal sequestration potential of the plant are prime factors governing efficacy of phytoremediation. It has been observed, more often than not, that the plants promising enhanced capacity of metal extraction yield low biomass and show sluggish (Denton, 2007). Only a few of plant species are found to be beneficial for promoting sustainable functional ecosystem and are also suitable for remediation, among the naturally occurring species of plant, reported from the sites which are contaminated. Family Cruciferae of plant kingdom and genus Brassica, Alyssums and Thlaspi has accounted for majority of more than 400 plant species reported in aiding phytoremediation (Xin et al., 2003). In addition to suitability for phytoremediation, it is desirable that these species ought to maintain succession and are perpetual, with value to the society by yielding products and services.

Major body of research has been on the species observed to be in different climatic and ecological zone. Introducing such species in alien environment has socio economic issues and environmental challenge. The more sustainable holistic system for phytoremediation of metal contaminated sites is employing suitable naturally occurring species which either have very sparse or nil food chain contact, yet provide socio-economic benefit (like essential oils, fuel biomass, biodiesel etc)

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For achieving sustainable phytoremediation it is imperative that locally occurring species of marketable crops like fragrant plants or biomass producing plants or species having social and ecological importance are employed. The oils derived from such grown aromatic plants are free from risk of metal contamination (Khajanchi et al., 2013).

CONCLUSION

Phytoremediation is a fast developing field with initiations all reported from all over world. In case of countries, such as India, which are not so developed, phytoremediation is an economic and sustainable option vis-à-vis conventional technique of remediation. Knowledge of suitable plants in phytoremediation is particularly limited in India. Naturally occurring perennial plant species with good metal uptake ability, either fast growing with high biomass or with economic product value are required for ensuring environmental, economic and social sustainability.

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