PHYTOACCUMULATION OF HEAVY METALS IN MANGROVES AND THEIR REMEDIATION MECHANISM

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Introduction

Mangroves are under increasing heavy metal (HM) pollution pressure from human activities because of the rapid industrialization and urbanization in coastal areas. Mangrove plants are a crucial ecosystem member and appear to be highly tolerant to pollutants by different adaptive strategies. They likely perform as excluder species for non-essential metals and regulators for essential metals, making them excellent candidates for the phytostabilization of heavy metals in intertidal areas. The accumulation and distribution of metal elements in mangrove plants might depend on the metal element levels in forest sediments. Plants have evolved biological detoxification mechanisms to minimize the detrimental effects of HM exposure and their accumulation, including avoidance or exclusion, excretion, and accumulation. The uptake of HMs into roots either occurs by passive diffusion through the cell membrane or by the more common process of active transfer against concentration and/or electrochemical potential gradients mediated by carriers. A metal could also move inside the cell along a concentration gradient through a cation channel in the cell membrane. Mangroves have been regarded as poor accumulators of trace metals. Accumulation occurred at the root level, with restricted transport to aerial portions of the plant. Mangroves could avoid metal uptake. Possible physiological mechanisms responsible for restricted uptake and translocation in plants included cell wall immobilization, complexation with substances such as phytochelatins (PCs), and barriers at the root endodermis.

ARSENIC CONCENTRATION IN SUNDARBANS WETLAND – A CASE STUDIES

The general concern for arsenic in the marine environment is associated with its wide distribution and potential toxicity. Fattorini et al. (2013) studied concentrations and chemical speciation of arsenic in sediments and biota samples from the Indian Sundarbans, the largest continuous mangrove tract formed at the mouth of the Hugli (Ganges) River estuary. Arsenic concentrations in sediments did not exceed 4 ppm, dry weight, with the contribution of inorganic molecules (arsenate and arsenite) ranging from 61.7 to 81.3%. Total As (TAs) concentrations varied from less than 2 to 16 ppm in tissues of bivalves. Sarkar et al. (2017) examined the concentration of total arsenic and individual arsenic species in four soft-bottom benthic marine polychaetous annelids of diverse feeding guilds from the intertidal regions of the Indian Sundarban wetland. The concentration of arsenic (As) in polychaete body tissues exhibited a wide range of variations, suggesting species-specific characteristics and inherent peculiarities in arsenic metabolism. Arsenic was generally present in polychaetes as arsenate (As V, ranges from 0.16 to 0.50 ppm) or arsenite (As III) (from 0.10 to 0.41 ppm) (30–

53% as inorganic As) and dimethylarsinic acid (DMAV < 1–25%).

PHYTOREMEDIATION OF HEAVY METALS

Phytoremediation refers to using plants and associated soil microbes to reduce contaminants' concentrations or toxic effects in the environments". It can be used to remove heavy metals, radionuclides, and organic pollutants (such as polynuclear aromatic hydrocarbons, polychlorinated biphenyls, and pesticides). It is a novel, cost-effective, efficient, environment- and eco-friendly, in situ applicable, and solar-driven remediation strategy. The term "phytoremediation" is a combination of two words: Greek phyto (meaning plant) and Latin remedium (meaning to correct or remove an evil). Green plants have an enormous ability to uptake pollutants from the environment and accomplish their detoxification by various mechanisms.

Phytoremediation technology is a relatively recent technology, with research studies conducted mostly during the last two decades. Techniques of phytoremediation include:

- phytoextraction (or phytoaccumulation),
- phytofiltration,
- phytostabilization,
- phytovolatilization, and
- phytodegradation

PHYTOEXTRACTION

Phytoextraction (also known as phytoaccumulation, phytoabsorption or phytosequestration) is the uptake of contaminants from soil or water by plant roots and their translocation to and accumulation in aboveground biomass i.e., shoots. Metal translocation to shoots is a crucial biochemical process and is desirable in effective phytoextraction because the harvest of root biomass is generally not feasible.

PHYTOFILTRATION

Phytofiltration is the removal of pollutants from contaminated surface waters or wastewaters by plants. Phytofiltration may be rhizofiltration (use of plant roots) or blastofiltration (use of seedlings) or caulofiltration (use of excised plant shoots). In phytofiltration, the contaminants are absorbed or adsorbed, thus minimizing their movement to underground waters.

PHYTOSTABILIZATION

Phytostabilization or phytoimmobilization is using certain plants to stabilize contaminants in contaminated soils. This technique reduces the mobility and bioavailability of pollutants in the environment, thus preventing their migration to groundwater or entry into the food chain. Plants can immobilize heavy metals in soils through sorption by roots, precipitation, complexation or metal valence reduction in the rhizosphere. Metals of different valences vary in toxicity. Plants skillfully convert hazardous metals to a relatively less toxic state by excreting special redox enzymes and decreasing possible metal stress and damage. Phytostabilization limits the accumulation of heavy metals in biota and minimizes their leaching into underground waters. However, phytostabilization is not a permanent solution because the heavy metals remain in the soil; only their movement is limited. It is a management strategy for stabilizing (inactivating) potentially toxic contaminants.

PHYTOVOLATILIZATION

Phytovolatilization is plants' uptake of pollutants from soil, their conversion to volatile form and subsequent release into the atmosphere. This technique can be used for organic pollutants and heavy metals like Hg and Se. However, its use is limited because it does not remove the pollutant completely; only it is transferred from one segment (soil) to another (atmosphere) from where it can be redeposited. Phytovolatilization is the most controversial of phytoremediation technologies.

PHYTODEGRADATION

Phytodegradation is the degradation of organic pollutants by plants with the help of enzymes such as dehalogenase and oxygenase; it is not dependent on rhizospheric microorganisms. Plants can accumulate organic xenobiotics from polluted environments and detoxify them through their metabolic activities. From this point of view, green plants can be regarded as "Green Liver" for the biosphere. Phytodegradation is limited to removing organic pollutants only because heavy metals are non-biodegradable. Recently, scientists have shown interest in studying the phytodegradation of various organic pollutants, including synthetic herbicides and insecticides. Some studies have reported using genetically modified plants (e.g., transgenic poplars) for this purpose.

PHYTOSTIMULATION

Phytostimulation is a process in which some natural matter is secreted by plants from the roots or else as food for the microorganisms living in symbiotic ecological relation to them. These microbes get stimulated and degrade the contaminants present in soil or water. This process can also be called the biological degradation of pollutants through the symbiotic ecological relationship of plants and microorganisms.

Table 1. Phytoremediation definitions and their descriptions

Technique	Description
Phytoextraction	Accumulation of pollutants in harvestable biomass i.e., shoots
Phytofiltration	Sequestration of pollutants from contaminated waters by plants
Phytostabilization	Limiting the mobility and bioavailability of pollutants in soil by plant roots
Phytovolatilization	Conversion of pollutants to volatile form and their
Phytodegradation	Degradation of organic xenobiotics by plant enzymes within plant tissues
Rhizodegradation	Degradation of organic xenobiotics in the rhizosphere by rhizospheric microorganisms
Phytodesalination	Removal of excess salts from saline soils by halophytes

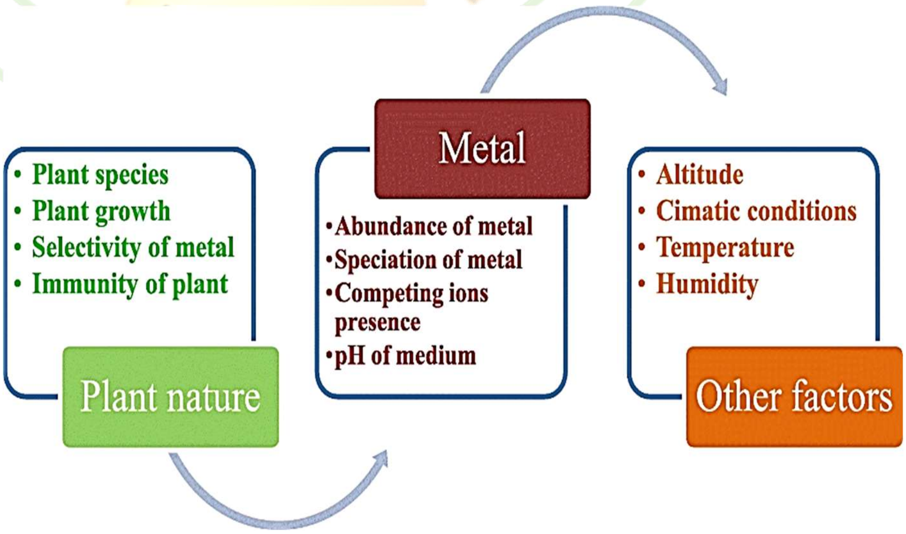

Figure 1. shows the factor affecting phytoremediation

ADVANTAGES AND DISADVANTAGES OF PHYTOREMEDIATION

- It can be highly specific and also non-specific.
- Less expensive than excavation or incineration processes
- If mineralization occurs gets complete degradation and clean up
- It does not transfer contaminants from one environment to another
- It uses a natural process
- Good public acceptance
- Process is simple
- It does not use any dangerous chemicals

Although phytoremediation is a promising approach for the remediation of heavy metal-contaminated soils, it also suffers from some limitations.

- A long time is required for clean-up.
- Phytoremediation efficiency of most metal hyperaccumulators is usually limited by their slow growth rate and low biomass.
- Difficulty in the mobilization of the more tightly bound fraction of metal ions from soil i.e., limited bioavailability of the contaminants in the soil.
- It applies to sites with low to moderate metal contamination levels because plant growth is not sustained in heavily polluted soils.
- There is a risk of food chain contamination in mismanagement and lack of proper maintenance.

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