PHYTOREMEDIATION

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ABSTRACT

Our surroundings are filled with a large number of toxicants in different forms. They contaminate water, land and atmosphere where we inhabit. Heavy metal pollution of soil is a significant environmental problem and has its negative impact on human health and agriculture. Soil microorganisms can degrade organic contaminants, while metals need immobilization or physical removal. 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. Thus, metals render the land unsuitable for plant growth and destroy the biodiversity. Green plants are the lungs of nature with unique ability to purify impure air by photosynthesis and remove or minimize heavy metals toxicity from soil and water ecosystem by absorption, accumulation and biotransformation process. Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and / or destroy contaminants in the soil and groundwater. The process of phytoremediation and the plants which are effective to remove certain toxic metals and minerals from soil and water and the advantages and disadvantages of Phytoremediation are briefly reviewed in the present paper.

Key Words: Toxicants, Immobilization, Biotransformation.

1. INTRODUCTION

Since the dawn of the Industrial Revolution, mankind has been introducing numerous hazardous compounds into the environment at an exponential rate. These hazardous pollutants consist of a variety of organic compounds and heavy metals, which pose serious risks to human health. Heavy metals are primarily a concern because they cannot be destroyed by degradation. Frequently, the remediation of contaminated soils, groundwater, and surface water requires the removal of toxic metals from contaminated areas.

There are a number of conventional remediation technologies which are employed to remediate environmental contamination with heavy metals. But a majority of these technologies are costly to implement and cause further disturbance to the already damaged environment. Phytoremediation is evolving as a cost-effective alternative to high-energy, high-cost conventional methods. It is considered to be a "Green Revolution" in the field of innovative cleanup technologies.

2. PHYTOREMEDIATION

Phytoremediation is the use of green plants to clean-up contaminated hazardous waste sites. The idea of using metal-accumulating plants to remove heavy metals and other compounds was first introduced in 1983, but the concept has actually been implemented for the past 300 years on wastewater discharges. The identification of metal hyper accumulator plants capable of accumulating extra- ordinary high metal levels demonstrates that plants have the genetic potential to clean up contaminated soil.

2.1. Various phytoremediation processes

A range of processes mediated by plants or algae are useful in treating environmental problems:

- Phytoextraction: Uptake and concentration of substances from the environment into the plant biomass.
- Phytostabilization: Reducing the mobility of substances in the environment, for example, by limiting the leaching of substances from the soil.
- Phytotransformation: Chemical modification of environmental substances as a direct result of plant metabolism, often resulting in their inactivation, degradation (phytodegradation), or immobilization (phytostabilization).
- Phytostimulation : Enhancement of soil microbial activity for the degradation of contaminants, typically by organisms that associate with roots. This process is also known as rhizosphere *degradation*.
- Phytovolatilization : Removal of substances from soil or water with release into the air, sometimes as a result of phytotransformation to more volatile and / or less polluting substances.
- Rhizofiltration : Filtering water through a mass of roots to remove toxic substances or excess nutrients. The pollutants remain absorbed in or adsorbed to the roots.

Various Phytoremediation Processes are shown in the following diagram:

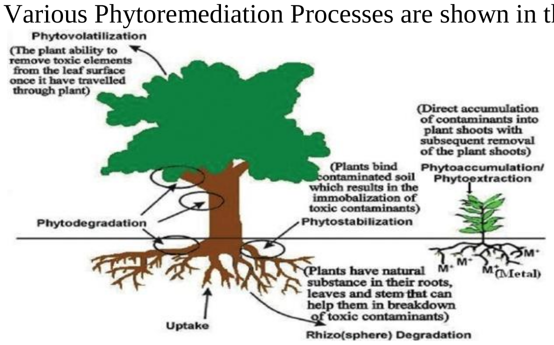

Diagram adopted from Indian J Pharmacol. 2011 May-Jun; 43(3): 246–253. (Ref. 3)

Some of the heavy metals, their sources and effects on human health are given in the following table : (Adopted from International Journal of Scientific and Research Publications, Volume 4, Issue 1, January 2014 – Ref. 2)

2.2. Phytoremediation of Mercury:

2.2.1. Sources of Mercury: - Mercury (Hg), also a naturally-occurring element is a silver-white liquid at room temperature. Due to this property, it is also referred to as kwik, liquid silver, hydrargyrum, and metallic mercury. The most common mineral form of mercury is the non-toxic, insoluble mercuric sulfide or cinnabar (HgS). Naturally occurring Hg is released by degassing of the earth's crust, volcanoes and the evaporation from oceans.

Mercury has a wide variety of uses in industry: medicine, dentistry, batteries, science, and military applications. The burning of fossil fuels and medical waste incineration accounts for more than 80% of all anthropogenic sources. Fifty-five percent of the total consumption of mercury is by chloralkali synthesis (used in electrodes), the wood pulping industry, paint, and electrical equipment. It has been estimated that the global reservoir of atmospheric mercury has increased by a factor of 2 to 5 since the beginning of the industrial revolution. Atmospheric contamination by industry has recently decreased, but mining is still a significant contributor to the contamination of ground and surface waters. The smelting of lead, copper, and zinc ores emits approximately 100 tons globally and 9 tons throughout the US into the atmosphere on an annual basis.

2.2.2. Phytovolatalization of Mercury: - There is some evidence that certain plant species have the ability to extract and accumulate mercury both from the atmospheric and soil sources (Ref. 4) . No plant species with mercury hyper accumulating properties has been identified. Due to this, scientists have been researching the use of genetically engineered plants by inserting bacterial genes specific for detoxifying toxic forms of mercury. Transgenic plants like *Arabidopsis thaliana* L. and tobacco (*Nicotiana tobacum*) containing both the merA and merB bacterial genes have the ability to transform methyl-mercury into elemental mercury, releasing it into the atmosphere through a process termed phytovolatilization.

2.3. Phytoremediation of Lead: Once introduced into the soil matrix, lead is very difficult to remove. The transition metal resides within the upper 6-8 inches of soil where it is strongly bound through the processes of adsorption, ion exchange, precipitation, and complexation with sorbed organic matter. Lead found within the soil can be classified into six general categories: ionic lead dissolved in soil water, exchangeable, carbonate, oxyhydroxide, organic or the precipitated fraction. All of these categories combined make up the total soil lead content (Ref. 4). Water soluble and exchangeable lead are the only fractions readily available for uptake by plants. Oxyhydroxides, organic, carbonate, and precipitated forms of lead are the most strongly bound to the soil.

2.3.1. Sources of Lead: - Among the major sources are lead-based paint, leaded gasoline, lead-contaminated water, manufacturing of lead batteries, rubber products, glass and other lead-containing products, and lead oxide fumes that result when demolishing industrial buildings.

2.3.2. Phytoextraction of Lead: - In natural conditions, lead hyper accumulation has not been documented. However, certain plants have been identified which have the potential to uptake lead. Many of these plants belong to the following families: Brassicaceae, Euphorbiaceae, Asteraceae, Lamiaceae, and Scrophulariaceae. *Brassica juncea,* commonly called Indian Mustard, has been found to have a good ability to transport lead from the roots to the shoots, which is an important characteristic for the phytoextraction of lead. Some calculations indicate that *Brassica juncea* is capable of removing 1,550kg of lead per acre.

2.4. Phytoremediation of Arsenic:

2.4.1. Sources of Arsenic:- Organic arsenic compounds are mainly used as pesticides, primarily on cotton plants, while inorganic arsenic is primarily used to preserve wood. Once arsenic is released in the environment it cannot be destroyed, and many arsenic compounds dissolve in water. Arsenic has also shown up in drinking water, especially among well water, and long-term exposure to arsenic in drinking water has been linked to cancer of the bladder, lungs, and skin, and kidney, nasal passages, liver and prostate.

2.4.2. Phytoextraction of Arsenic:- Researchers in Florida discovered that ferns are growing in soil contaminated with arsenic at an abandoned lumber yard. The ferns had been soaking up arsenic from the soil through their roots and storing it in their fronds. The Florida discovery marked the first time a plant had been found to naturally take up arsenic in high concentrations. The fronds of *Pteris vittata*, or brake fern, can be clipped or the entire plant can be dug up and disposed of safely, a process that was patented by the Florida group in 2001. Phytofiltration involves the use of plants to remove toxic compounds from water. Two arsenic hyper accumulators, *Pteris cretica* cv *Mayii* (Moonlight fern) and *Pteris vittata* (Chinese brake fern) are identified by applying the above process.

2.5. Phytoremediation of Cadmium:

2.5.1. Sources of Cadmium: - Cadmium, a naturally occurring metal, can be found in food, water and cigarette smoke. It is a known human carcinogen that appears to act in two ways: it harms DNA directly and disturbs a DNA repair system that helps to prevent cancer.

2.5.2. Phytoextraction of Cadmium: - *Solanum nigrum* (Solanaceae) has a potential application for phytoextraction of Cd from contaminated soils. *S. nigrum* can accumulate Cd from soils where the concentrations are relatively low, and thus it has application for use of slightly to moderately Cd-contaminated soil.

A fast growing weed plant *Physalis minima* Linn. is used for the removal of Cadmium from the contaminated soils (Ref. 5). Crop plants like maize may also be indicated as potential phytoremediant of Cd.

2.6. Phytoremediation of Chromium:

2.6.1. Sources of Chromium: - Chromium present in the atmosphere originates from anthropogenic sources which account for 60-70%, as well as from natural sources which account for the remaining 30-40%. The main human activities contributing to the chromium increase in the atmosphere are: metallurgical industries, refractory brick production, electroplating, combustion of fuels and production of chromium chemicals, mainly chromates and dichromates, pigments, chromium trioxide and other. The cement industry, production of phosphoric acid in a thermal process, and combustion of refuse and sludge are other potential sources of atmospheric chromium. The main natural sources are volcanic eruptions and erosion of soils and rocks, airborne sea salt particles and smoke from forest wildfires.

2.6.2. Phytoextraction of Chromium:- The findings indicated that family Cruciferae (*Brassica campestri* L.- raya) was most tolerant to Cr toxicity, followed by Chenopodiacea (*Spinacia oleracea* L.- spinach) and Leguminosae (*Trigonella foenumgraecum* L.- fenugreek). Because raya removed the highest amount of Cr from soil, it could be used for pytoremediation of mildly Cr- contaminated soils. A fast growing weed plant *Physalis minima* Linn. is also used for the removal of Chromium from the contaminated soils (Ref. 5).

2.7. Advantages of Phytoremediation

- A significant advantage of phytoremediation is that a variety of organic and inorganic compounds are amenable to the phytoremediation process.
- Phytoremediation can be used either as an in situ or ex situ application. In situ applications are frequently-considered because it minimizes disturbance of the soil and surrounding environment and reduce the spread of contamination via air and waterborne wastes.
- It is a green technology and when properly implemented is both environmentally friendly and aesthetically pleasing to the public.
- Phytoremediation does not require expensive equipment or highly-specialized personnel, and it is relatively easy to implement.
- It is capable of permanently treating a wide range of contaminants in a wide range of environments.
- The greatest advantage of phytoremediation is its low cost compared to conventional clean-up technologies.

2.8. Disadvantages and Limitations of Phytoremediation

- It is restricted to the rooting depth of remediative plants.
- Remediation with plants is a lengthy process, thus it may take several years or longer to clean up a hazardous waste site, and the contamination may still not be fully remediated.
- The use of invasive, nonnative species can affect biodiversity.
- The consumption of contaminated plants by wildlife is also a remarkable concern.
- Harvested plant biomass produced from the process of phytoextraction may be classified as hazardous waste, therefore subject to proper handling and disposal.
- Unfavorable climate can limit plant growth and phytomass production, thus decreases process efficiency.

2.9. Conclusion:

Phytoremediation is considered to be an innovative technology. By increasing our knowledge and understanding – this method will provide a cost-effective, environmentally friendly alternative to conventional cleanup methods. Researches are still going on - on this aspect. Let us hope more number of plants with phytoremediation ability be identified in the years to come.

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