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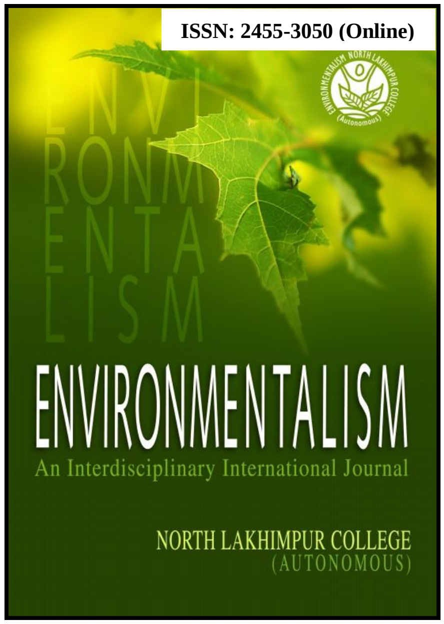

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PHYTOREMEDIATION: A GREEN TECHNOLOGY TO CLEAN UP POLLUTANTS FROM SOIL

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Abstract

Phytoremediation, an emerging clean up technology for contaminated soils, groundwater, and wastewater that is both low-tech and low-cost, is defined as the engineered use of green plants to remove, contain, or render harmless such environmental contaminants as heavy metals, trace elements, organic compounds, and radioactive compounds in soil or water. Contamination of the soil with heavy metal and petroleum hydrocarbon is an alarming situation of the world. De-contamination of the soil particularly with green technology is a great challenge for us. Phytoremediation of the contaminated soil is one of the biological clean up method which has no adverse consequence. It can be defined as the use of plants to accumulate or metabolize toxic compounds contaminating the environment. Plants are able to exclude, accumulate or metabolize toxic inorganic or organic substances. Thereby they contribute significantly to the fate of chemicals and they can be used to remove unwanted compounds from the biosphere. Contaminants can enter the food chain via plants which cause unwanted effects. Plants absorb/exude translocation, store or detoxify inorganic and organic contaminants. However, phytoremediation can used to abate pollutants from soil.

Keywords: Phytoremediation, soil, pollutants

1 Introduction

Phytoremediation is a relatively new technology which makes use of green plants to remove environmental contaminants from soil and groundwater (Basumatary *et al.* 2013). It is possible to use phytoremediation to reach contaminated groundwater 20 feet to 30 feet underground. The use of plants for the removal of xenobiotics from spillage sites, sewage waters, sludge, and polluted areas has become an important experimental and practical approach over the last 15 years (Harrigan 1999). It is advantageous when a low cost solution is needed that can be easily applied to diffuse sources of contamination (Baker, 1970). It can also be used to reduce the leaching of

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contaminants through soils and hence protect the groundwater where guidelines for contaminant levels are more stringent. This technology has also been used to prevent off site migration of contaminants in groundwater.

Research and application of phytoremediation has flourished over the last 15 years. Although phytoremediation may not be the perfect remedial solution that some envisioned when its use at hazardous waste sites was first pioneered, its implementation continues to be appropriate or even preferable at a variety of sites. As the technology matures and its use expands beyond research laboratories and government-funded remediation, site owners and consultants will want comparative data on phytoremediation to determine its appropriateness for a particular site.

Biodegradation of multiple contaminants in the environment is a complex process that has been a source of major concern to environmental biologists and scientist. However recently the concern over the persistence disposition and presence of co-contamination of metals and polycyclic aromatic hydrocarbons in the environment has increased.

2 Mechanisms

Researchers have identified mechanisms by which plants can affect contaminant mass in soil, sediments, and water. Although overlap or similarities can be observed between some of these mechanisms, and the nomenclature varies, this report makes reference to seven phytoremediation mechanisms, each explained in detail below: phytoextraction, phytovolatilization, phytodegradation, rhizodegradation, rhizofiltration phytostabilization, and hydraulic control.

2.1 Phytoextraction

The first phytoremediation patent applied for in the United States related to phytoextraction (McCutcheon 2003). Phytoextraction refers to the ability of plants to remove metals and other compounds from the subsurface and translocate them to the leaves or other plant tissues. The plants may then need to be harvested and removed from the site. Even if the harvested plants must be land filled, the mass phytoextraction is usually limited to metals and other inorganic compounds in soil or sediment.

2.2 Phytovolatilization

Phytovolatilization also involves contaminants being taken up into the body of the plant, but then the contaminant, a volatile form there, or a volatile degradation product is transpired with water vapor from leaves. Phytovolatilization may also entail the diffusion of contaminants from the stems or other plant parts that the contaminant travels through before reaching the leaves (McCutcheon 2003). Phytovolatilization can occur with contaminants present in soil, sediments, or water and has been found to occur with volatile organic compounds, including trichloroethene, as well as inorganic chemicals that have volatile forms, such as selenium, mercury, and arsenic .

2.3 Phytodegradation

When the phytodegradation mechanism is at work, contaminants are broken down after they have been taken up by the plant. As with phytoextraction and phytovolatilization, plant uptake generally occurs only when the contaminants' solubility and hydrophobicity fall into a certain acceptable range. Phytodegradation has been observed to remediate some organic contaminants, such as chlorinated solvents, herbicides, and munitions, and it can address contaminants in soil, sediments, or groundwater.

2.4 Rhizodegradation

Rhizodegradation refers to the breakdown of contaminants within the plant root zone, or rhizosphere. Rhizodegradation is believed to be carried out by bacteria or other microorganisms whose numbers typically flourish in the rhizosphere. Studies have documented up to 100 times as many microorganisms in rhizosphere soil as in soil outside the rhizosphere (McCutcheon 2003). Microorganisms may be so prevalent in the rhizosphere because the plant exudes sugars, amino acids, enzymes, and other compounds that can stimulate bacterial growth. The roots also provide additional surface area for microbes to grow on and a pathway for oxygen transfer from the environment. The localized nature of rhizodegradation means that it is primarily useful in contaminated soil, and it has been investigated and found to have at least some success in treating a wide variety of mostly organic chemicals, including petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), chlorinated solvents, pesticides, polychlorinated biphenyls (PCBs), and benzene, toluene, ethylbenzene, and xylenes (BTEX).

2.5 Rhizofiltration

In the rhizofiltration process, contaminants are also taken up by the plant and removed from the site when the plant is harvested; however, in this case, the contaminant is removed from the dissolved phase and concentrated in the root system. Rhizofiltration is typically exploited in groundwater (either in situ or extracted), surface water, or wastewater for removal of metals or other inorganic compounds.

2.6 Phytostabilization

Phytostabilization takes advantage of the changes that the presence of the plant induces in soil chemistry and environment. These changes in soil chemistry may induce adsorption of contaminants onto the plant roots or soil or cause metals precipitation onto the plant root. The physical presence of the plants may also reduce contaminant mobility by reducing the potential for water and wind erosion. Phytostabilization has been successful in addressing metals and other inorganic contaminants in soil and sediments.

2.7 Hydraulic control

Phytoremediation projects employing hydraulic control generally use phreatophytic trees and plants that have the ability to transpire large volumes of water and thereby affect the existing water balance at the site (McCutcheon 2003). The increased transpiration reduces infiltration of precipitation or increases transpiration of groundwater, thus reducing contaminant migration from the site in groundwater plumes. Hydraulic control can therefore be used to address a wide range of contaminants in soil, sediment, or groundwater.

The success of phytoremediation at a given site cannot always be attributed to just one of these mechanisms because a combination of mechanisms may be at work.

3 Benefits of Phytoremediation

Numerous benefits of phytoremediation have been established or hypothesized:

- Phytoremediation can be less invasive and destructive than other technologies.
- Studies have indicated that implementing phytoremediation may result in a cost savings of 50 to 80 percent over traditional technologies

- Phytoremediation may provide habitat to animals, promote biodiversity, and help speed the restoration of ecosystems that were previously disrupted by human activity at a site.
- Phytoremediation installations can improve the aesthetics of brownfields or other contaminated sites.
- Phytoremediation may promote better air or water quality in the vicinity of the site
- Vegetation may help reduce erosion by wind or water.
- Planted trees may also provide shade to buildings, helping to decrease energy consumption.
- Forests and other vegetation serve as a carbon sink to help sequester carbon emitted from other sources.

4 Limitations of Phytoremediation

Phytoremediation is not universally appropriate or successful; some important limitations must be noted:

- Extremely high contaminant concentrations may not allow plants to grow or survive; phytoremediation is likely to be more effective or reasonable for lower concentrations of contaminants.
- For remediation to be successful, contamination must generally be shallow enough that plant roots can reach the contaminants, or contamination must be brought to the plant
- Phytoextraction techniques can cause contaminants to accumulate in plant tissues, which could cause ecological exposure issues or require harvesting
- Phytovolatilization may remove contaminants from the subsurface, but might then cause increased airborne exposure.
- If non-native species are selected for phytoremediation, the consequences of introducing them to the ecosystem may be unknown or unexpected.
- The time required to achieve the remedial goals may be longer with phytoremediation than with other treatment technologies. Phytoremediation can require several growing seasons for a tree stand to be established and for contaminant concentrations to be reduced.

5 Implementation of Phytoremediation

As should be apparent from the benefits and drawbacks to phytoremediation listed above, the success of phytoremediation at a given site is dependent on a large number of factors, including contaminant types, concentrations, and depths; contaminated media; selection of appropriate vegetation; plant growth and survival; and site climate (USEPA 2006). As with all remediation projects, a thorough feasibility study and analysis of remedial options is typically warranted before selection of phytoremediation as the final remedy. Once phytoremediation has been selected, greenhouse studies, pilot testing, or even field demonstrations may be required before a full-scale system can be installed. Careful consideration should be given to plant selection, operation and maintenance requirements (including fertilization and irrigation), and performance monitoring to ensure that the remedy is effective.

6 Plant processes involved in phytoremediation

Phytoremediation takes advantage of the natural processes of plants. These processes include water and chemical uptake, metabolism within the plant, exudate release into the soil that leads to contaminant loss and the physical and biochemical impacts of plant roots. Growth of plants depends on photosynthesis in which water and carbon dioxide are converted into carbohydrates and oxygen, using the energy from sunlight. Roots are effective in extracting water held in soil, even water held at relatively high matric and osmotic negative water potentials; extraction is followed by upward transport through the xylem. Transpiration occurs primarily at the stomata with additional transpiration at the lenticels. Nutrient uptake pathways can take up contaminants that are similar in chemical form of behavior to the nutrients. Cadmium can be subject to plant uptake due to its similarity to the plant nutrients calcium and zinc. Arsenic might be taken up by the plants due to similarities to the plant nutrient phosphate. For uptake into a plant, a chemical must be in solution, either in ground water or in the soil solution. Water is absorbed from the soil solution into the outer tissue of the root. Contaminants in the water can move through the epidermis through the casparian strip, and then through the epidermis where they can be sorbed bound and metabolized.

The uptake and translocation of organic compounds is dependent on their hydrophobicity, solubility and polarity and molecular weight. Briggs et al., 1992*;* found that translocation of non-ionized compounds to shoot was optimum for intermediate polarity compounds that were moderately hydrophobic, with less translocation for more polar compounds. More hydrophobic compounds are more strongly bound to the root surfaces or partition into root solids, resulting in less translocation within the plant.

7 Conclusion

Pollutants can be polished by using plants to bring the soil to its original condition. There are different mechanisms and processes with the help of which phytoremediation can be implemented to abate the pollution from environment. Even though it is a slow process it has many advantages as it is a green technology rather than the physical and chemical methods.

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