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A Review of Phytoremediation

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Abstract

Researchers have explored several low cost treatment technologies for the treatment of wastewaters. Wetland is one of such technologies which is extremely suitable for Indian conditions due to low maintenance requirements and climate that supports high evapo-transpiration. The project has been undertaken to study the efficiency of treatment of waste water by using water hyacinth, of assess the economic return as well as evaluating the various parameters of waste water.

Keywords: Phytoremediation, Heavy metals, Transgenic plants.

1. Introduction

The aquatic plant pond functions as a aerobic pond effectively controls the odor problems of the pond. The environment has been defined in development terms as life supporting system for human existence and survival as well as provider of physical milieu and raw materials required for socio economic progress there for comparatively cheaper and feasible sustainable methods of pollutants removal from it are necessary. One of such methods is phytoremediation which is the use of plant orgin microber green plants and their associated microbioar for the in situ treatment of contaminated soil and wastewater (Sadowsky 1999) with the increasing population in the country the quantity of wasewaters generalled has been increasing beyond the treatment capacities a part from host of industrial effluents and solid wastes in recent years intense efforts are being mode at treatifing the domestic sewage to make the effluents suitable for discharge into the natural waters. Into the natural waters. Technology for treatment of raw sewage involves mechanical chemical and biological processes.

Water pollution is one of the most serious problems of today's civilization. The consumption of water has been doubling on every twenty years but the reduction of this period is expected if today's trends in water use continue (Vealasevic and Djorovic, 1998). These two statements justify people's fear that whole areas of the world will remain without biochemical safe water suitable for drinking and other needs. One can say situation is already alarming if it is known that because of fresh water disposition on Earth only one third of its territory is well provide with water, and if drastic efforts in water protection are not made by year 2025, 2.3 billion people will live in areas with chronic water shortage (WHO, 2005).

Protection of public health is the fundamental purpose of waste treatment. Environmental protection is the second major purpose. It is the responsibility of the engineers, scientists & public officials involved to ensure that waste treatment system achieve this goal.

Health & environmental risk of pollution have became more apparent throughout the world over the past several decades, air, water & soil contaminants can include numerous organic & inorganic substances, such as municipal waste & sewage, various gaseous emissions, fertilizers, pesticides, chemicals, heavy metal and radionuclides, contaminants cause land and groundwater to be unusable. In addition, animals and insects many come in contact with a contaminant, thus introducing a toxic substance into food chain. Because of increased public awareness and concern, environmental regulation have been created to not only prevent pollution, but also to remediate areas.

There are many technologies for wastewater treatment that can help in re-establishing and preserving physical, chemical and biological integrity of water. All of these technologies can be classified in two basic groups.

A. Conventional methods for purification of wastewater (wastewater treatment is carried out by physical, chemical and biological processes) and

B. Alternative methods for purification of wastewater (wastewater treatment is carried out by imitating self-purification process present in natural wetlands.)

Environmental remediation technologies use physical, chemical or biological processes that attempt to eliminate, reduce, isolate for stablize contaminants. Depending on technology used, the process may either take place at the location of contamination (in-situ) or the contaminated soil or water may be removed for ex-situ treatment. Ever remediation technology has certain limitation and disadvantages. It multiple contaminants are involved. It may be reduce the concentrations of pollution to acceptable levels.

In an effort to meet environment regulation of the last three decodes, environmental remediation has development into a multibillion dollar industry. The high cost of many traditional methods is causing many organizations to look to lower cost alternatives. Bioremediation is a commercial remediation technology with a growing market and continuing research.

Today these conventional wastewater treatment facilities fail in satisfying all demands of ecologically aware societies. This is because they; do not hormonize with basic principals of water conservation, do not enable reclamation and reuse of water and nutrients, generate toxic sludge as by product and use chemicals, harmful to environment and people, in the treatment process (Davis for EPA, 2004). So scientist sought for other solutions that will go beyond all problems mentioned above. All of the answers were found in natural wetlands, which then served as model for construction of systems for wastewater purification by aquatic plants.

Phytoremediation uses plants to cleanup contaminated soil and groundwater, taking advantages of plants natural abilities to take up, accumulate and /or degrade constituents of their soil and water environments.

Phytoremediation is an emerging technology based on the use of green plants to remove, contain, inactivate or destroy harmful environmental pollutants. Like any other new approach, phytoremediation will only be accepted if its success is demonstrated. The key factor is low cost and aesthetic aspects, making it suitable to remediate large contaminated sites in populated areas.

Phytoremediation is an eco-friendly approach for remediation of contaminated soil and water using plants. Phytoremediation is comparised of two components, one by the root colonizing microbes and the other by plants. Themselves, which degrades the toxic compounds to farther non-toxic metabolites various compounds, uiz. Organic compounds, xenibiotics, pesticides and heavy metals are among the contaminants that can be effectively remediated by plants. They exhibit various enzymatic activities for degradation of xenobiotics viz. dehalogenation, denitrification leading to breakdown of complex compounds to simple and non-toxic products. Plant and alage also have the ability to hyper accumulation various heavy metals by the action of phytochelatins and metallothioneins farming complex with heavy metals and translocate them into vacuoles. Due to the low cost of the technique, the low disturbance of an in-situ treatment, a high probability of public acceptance and the fact that it is easy to handle, phytoremediation has a strong potential as a natural, solar energy driven remediation approach for the treatment of sits, groiundwater and wastewater contaminated with heavy metals, organic xenobiotics and radio nuclides.

2. History of Phytoremediation

The basic idea that plants can be used for environmental remediation is quite old. However, it was not until 1948, that some Italian researchers first reported nickel hyperaccumulation in the Italian serpentine plant Alyssum bertolonii. This finding was all but forgotten unitl 1977, when researcher Robert Brooks, of Massey University in New Zealand, made similar observations. This time, the concept caught on. Extensive researches on the use of semi-aquatic plants (or ecosystems as a whole) for treating radionuclide-contaminated waters were initiated in Russia at the dawn of the nuclear ara. The knowledge that aquatic or semi-aquatic vascular plants such as, water hyacinth (Eichhornia crassipes), pennywarth (Hydrocotyle umbellate), duckweed (Lemna minor), and water velvet (Azolla pinnata), can take up Pb, Cu, Cd, Fe and Hg from contaminated solutions existed for a long time. This ability is currently utilized in many wetlands, which may be effective in removing some heavy metals as well as organics from water.

Phytoremediation, popularly known as 'green clean' is a novel strategy for the removal of toxic contaminants from the environment by using plants. This concept is increasingly being adopted, as it is a cost effective and user-friendly alternative to traditional methods of treatment. Toxic metal pollution in water and soil is a major environmental problems and cost conventional remediation approaches do not provide acceptable solutions. Rapid growth in population and massive industrilization in recent years has resulted in pollution of the biosphere with toxic metals.

Phytoremediation is emerging technology that uses various plants to degrade, extract, contain or immobilize contaminants from soil and water. This technology has been receiving attention lately as an innovative cost effective alternative to the more established treatment methods used at hazardous waste sites.

In India, aquatic vascular plants like Hydrilla verticillata, Spirodela polyrrhiza, Bacopa monnierii, Phragmites karka and Scirpuslacustris have been used to treat chromim-contaminated effluent and sludge from leather tanning industries.

Application of phytoremediation for the clean up of industrial wastes contaminated with toxic metals is another important area that has blossomed in recent years. Certain plants translocate metals from their surrounding and accumulate them in their above ground parts at high concentrations. Thus, they can be harvested and removed from the site. Two routes are currently being explored to develop metal accumulating plants; genetic engineering and, the selective breeding of naturally occurring hyperaccumulator-plants.

A. Phytoremediation

The basic idea that plants can be used for environmental remediation is certainly very old and cannot be traced to any particular source. However, a series of fascinating scientific discoveries combined with interdisciplinary research approaches have led to the developmental technology called phytoremediation.

At present time, phytoremediation is an emerging technology and there is till a significant need to stimulate the development and evaluate the potential of plant biotechnology for the removal of organic pollutants and toxic metals from wastewater and contaminated sites depending on the particular situation including the type and degree of pollution, different remediation strategies can be requested. Delivering a cheap flexible and safe biological treatment that is applicable to specific contaminated sites and wastewater is a relatively recent focus. Phytroemediation is expected to be a significant leap forward, as compared to classical bioremediation techniques, base on the use of microorganisms only.

The term phytoremediation (phyto = plant & remediation = correct evil) is relatively new, coined in 1991. Basic information for what is now called phytoremediation comes from a variety of research areas including constructed wetlands, oil spills and agricultural plant accumulation of heavy metals. The term has been used widely since its inception, with a variety of specific meanings. The generic term phytoremediation consists of the Greek Pretix Phyto (Plant) attached to the Latin roof Remedium (to correct or remove an evil) {Cunningham et. Al. 1996}. Phytoremediation describes the treatment of environmental problems through the use of plants.

All the plants extract necessary nutrients, including metals, from their soil and water environments. Some plants, called hypreaccumulators, have the ability to store large amounts of metals, even some metals that do not appear to be required for plant functioning. In addition, plants can take up various organic chemicals from environmental media and degrade of otherwise process them for use in their physiological processes.

There are few basic types of phytoremediation techniques 1) Rhizofiltration, a water remediation technique involving the uptake of contaminants by plant roots (ii) phytoextraction, a soil technique involving uptake from soil, (III) phytotransformation, applicable to both soil and water, involving the degradation of contaminants through the plant metabolism, (iv) phytostimulation or plant assisted bioremediation also used for both soil and water, which involves the stimulation of microbial biodegradation through activities of plants in the root zone and (v) phytostabilization, using plant to reduce the mobility and migration potential of contaminants in soil.

The application of phytoremediation can either be achieved through the use of already existing plants in their natural habit, for example, natural wetlands or as artificial marshes or swamps knows as constructed wetlands cultivated ad designed to emulate the capability of natural wetlands to remove sediments and pollutants from anthropogenic discharge such as wastewater sewage treatment, reclamation of land after mining, storm water and other disturbances to the environment.

Phytoremediation can be used in combination with other clean up approaches as a ‘finishing’ or ‘polishing’ step. Some phytoremediation applications are slower than mechanical and chemical methods and are limited to the depths that are within the reach of the plant roots.

Major advantages reported for phytoremediation as compared to traditional remediation technologies include the possibility of generating less secondary wastes, minimal associated environmental disturbance, and the ability to leave sols in place and in a usable condition following treatment. Cited disadvantage include the long lengths of time required (usually several growing seasons), depth limitation (3 feet for soil and 10 feet for groundwater), and the possibility of contaminant entrance into the plant material.

B. Mechanism of Phytoremediation

There are several ways by which plants clean up or remediate contaminated sites. The uptake of contaminants in plant occurs primarily through the root system, in which the principal mechanisms for preventing toxicity are found. The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth along with other non-essential contaminants (Y in Ougang 2002).

Phytoremediation mechanism can be classified based on the contaminant late : degradation, extraction, containment, or a combination of these. Phytoremediation applications can also be classified base on the mechanisms involved, such mechanisms include extraction of contaminants from soil or groundwater or surface water, concentration of contaminants in plant tissue, degradation of contaminants by various biotic or a biotic processes, volatilization or transpiration of volatile contaminants from plants to the air, immobilization of contaminants in the root zone, hydraulic control of contaminated groundwater (plume control) and control of runoff, erosion and infiltration by vegetative covers.

2.1 Degradation

Plants may enhance degradation in the rhizosphere (root zone of influence). Microbial counts in rhizosphere soils can be 1 to 2 orders of magnitude greater than in non rhizosphere soils, It is not known whether this is due to microbial or fungal symbiosis with the plant, plant exudates including enzymes or other physical / chemical effects in the root zone. There are, however, measurable effects on certain contaminants in the root zone of planted areas.

Another possible mechanisms for contaminant degradation are metabolism within the plant. Some plants may be able to taken in toxic compounds and in the process of metabolizing the available nutrients, detoxify them. Trichloroethylene (TCE) is possibly degraded in popular trees and the carbon used for issue growth while the chloride is expelled through the roots.

2.2 Extraction

Phytoextraction or phytomining, is the process of planting a crop of a species that is known to accumulate contaminants in the shoots and leaves of the plants and then harvesting the crop and removing the contaminant from the site. Unlike the destructive degradation mechanisms, this technique fields a mass of plant and contaminants (typically metals) that must be transported for disposal or recycling. This is a concentration technology that leaves a much smaller mass to be disposed of when compared to excavation and land-filling.

Volatization or transpiration through plants into the atmosphere is another possible mechanism for removing contaminants from the soil or water of a site. At is often raised as a concern in response to a proposed phytoremediation project, but has not been shown to be an actual pathway for many contaminants. Mercury (Hg) has been shown to move though a plant and into the air in a plant that was genetically altered to allow it to do so.

2.3 Containment & Immobilization

Containment using plants binds the contaminants to the soil, renders them non-bioavailable or immobilizes them by removing the means of transport.

Hydraulic control is another from of containment ground water containment plume control may be achieved by water consumption, using plants to increase the evaporation and transpiration from a site some species of plants use tremendous quantities of water, and can extend roots to draw from the saturated zone.

Vegetative cover (evapotranspiration or water balance cover) systems are another remediation application utilizing the natural mechanism of plants for minimizing infiltrating water. Originally proposed in arid and semi-arid regions vegetative covers are currently being evaluated for all geographic regions.

Depending on the phytroemediation technology selected, contaminates may be contained and left in place, removed or volatilized.

Table – 2.1 Summarizes the methods of contaminant control for each phytoremediation technology.

Table – 2.1 Summary of Phytoremediation Technologies and Method of Contaminant Control.

Method	Destruction	Extraction/Uptake	Containment
Phytoextraction (concentration)		√	
Rhizofiltration		√	
Phytostabilization		√	
Rhizordegradation	√		
Phytodegradation	√		
Phytovolatilization Plume control		√	
Vegetative cover	**√a**		**√b**
Riparian corridors	√	√	√

a – Phytoremediationtoremdiation Cover
b- Evaportanspiration Cover

Plants function in phytoremediation in two ways, the major one being facilitation of favorable condition for microbial degradation, specifically by plant root colonizing microbes and the second aspect is plant root itself, providing a simple and inexpensive means of accessing contaminants existing in subsurface soil and water.

Plants act as hosts to aerobic and anaerobic micro-organisms, supplying them with both physical habital and chemical building blocks plant roots and shoots increase microbial activity in their direct environmental by providing additional colon sable surface area. Increasing readily-degradable carbon substrates by organic exudates and lactates and by decomposition of part of their mass and creating temporally and spatially varying oxygen regimes.

Plant roots cause changes at the soil-root interface as they release organic and inorganic exudates in the rhizosphere. These roots exudates affect the number and activity of microorganisms, the aggregation & stability of the soil particles around the root, and the vailability of the contaminants. Root exudates by themselves can increase or decrease (immobilize) the availability of the contaminants in the root zone of the plants through changes in soil characteristics, release of organic substances, changes in chemical composition and or increase in plant assisted microbial activity.

Upon absorption into root, the chemical migrates through roots xylem and via sap eventually reaches leaves. Reactive chemicals may be degraded in this journey and some may be bound in root membranes chemicals sprayed or deposited on leaves may diffuse into the plant through cuticle and stomata. Extent of absorption is dependent on leaf age, thickness of cuticle and chemical concentration, which may affect respiratory and photosynthesis mechanisms.

Lynch (1982) reported that the soil associated with plant root (rhizosphere) supports 10-100 times more micro-organisms per gram than unplanted soil, de to supply of carbon-containing compounds exuded by plant roots, plants can maintain aerobic conditions in the rhizosphere, leading to microbial degradation. In the second aspect of phytoremediation, plants that are metabolically active degrade the pollutants.

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