International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 4 Issue 7, July 2017

ISSN: 2394-4404

Applications Of Bioremediation On Environmental Protection And Restoration

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Abstract: ***Increased industrial and agricultural activity has led to vast quantities at the earth's soil and ground water resources are contaminated with hazardous chemicals. The risk to human and environmental health is rising and studies reveal that these pollutants are contributing to the global epidemic of cancer, and other degenerative diseases. In controlling these risks, the idea of bioremediation has become popular. Bioremediation is a branch of technology which deals with the methods of solving the environmental problems. It is a treatment that has naturally occurring organisms to break down hazardous substances into less toxic or non toxic substances and is cost effective than other technologies used for cleanup of hazardous waste. Bioremediation provides a technology based on use of living organisms like bacteria and fungi to remove pollutants from soil and water. The developed countries like UK, USA, Canada, Australia, Japan and European countries made much progress in using bioremediation. This review focuses on bioremediation techniques/types of living organism used in controlling environmental pollution- inorganic and organic using phytoremediation (plants), mycoremediation (fungi) and rhizoremediation (plant and microbe interaction) in reference to two methods of bioremediation viz., in situ bioremediation and ex situ bioremediation. The present study tries to evaluate how effectively bioremediation is carried out in India.***

Keywords: Bioremediation, phytoremediation, mycoremediation, rhizoremediation, in situ, ex situ

I. INTRODUCTION

The human population is rapidly growing and thus expanding to greater areas, industrial and agricultural activity is growing. This explosion has led to contamination of vast quantities at the earth's soil and ground water resources with hazardous chemicals. A result of this, an inestimable amount of terrestrial and aquatic environments on Earth is contaminated. The risk to human and environmental health is rising and studies reveal that these pollutants are contributing to the global epidemic of cancer, and other degenerative diseases. In controlling these risks, the idea of bioremediation has become popular. Basically bioremediation techniques obliterate pollutants by stimulating the growth of microorganisms, using the contaminants as a food and energy source.

Bioremediation is a branch of technology which deals with the methods of solving the environmental problems. Bioremediation technology has made it possible to decontaminate soil and groundwater and has helped us clean up our oceans after oil spills and other environmental disasters. It is a treatment that has naturally occurring organisms to break down hazardous substances into less toxic or non toxic substances. Bioremediation provides a technology based on use of living organisms like bacteria, microbes, plants and fungi to remove pollutants from soil and water. The scope of environmental bioremediation extends to inorganics viz., Arsenic, Mercury, Chromium, Fluoride, Cyanide, abandoned mines, fly ash disposed sites, engineered phytotreatment technologies, biological permeable barriers; and organics viz., petroleum hydrocarbons, pesticides and explosives.

II. APPROACHES OF BIOREMEDIATION

Depending on the site of application of bioremediation, there are two approaches– in situ and ex situ.

- ✓ *IN SITU* – In situ remediation is the process of treating contaminated waste at its point of -origin. It addresses the use of microorganisms to remove contamination from ground water and soils that remain in place during the cleanup, which is called in situ bioremediation. For example, there may be soil that is contaminated. Rather than remove the soil from its point of origin, it is treated right where it is. The benefit to in situ treatment is that it prevents the spread of contamination during the displacement and transport of the contaminated material.
- ✓ *EX SITU* – Ex situ remediation is a biological process of treating contaminated waste by deliberately transporting to a particular treatment area. To use soil as the example again, the soil may be removed and transported to an area where the bioremediation may be applied. The main advantage to this is it helps to contain and control the bioremediation products, as well as making the area that was contaminated available for use. Under aerobic conditions, specific micro-organisms can utilise organic contaminants such as petroleum hydrocarbon mixtures, polycyclic aromatic hydrocarbons (PAH), phenols, cresols and some pesticides as a source of carbon and energy and degrade them ultimately to carbon dioxide and water.

III. TYPES OF BIOREMEDIATION

On this planet there are number of finest and oldest disaster responders. The process of bioremediation can be carried out by using plants, fungi, microbes, bacteria and archaea as the agents to breakdown the pollutants into less toxic or non toxic substances. The type of remediation depends on the type of contamination and the agent used in degrading the contaminants.

- ✓ *Phytoremediation:* Phytoremediation is based on the concept of saving the nature using the nature. This technique directly uses living green plants for in situ purpose. It is an alternative or complimentary technology that can be used along with or, in some cases in place of mechanical conventional clean-up technologies that require high expenditure and high energy inputs. It runs with solar energy, hence ecologically friendly. Phytoremediation is most useful at sites with shallow, low levels of contamination but treats wide varieties of contaminants. Phytoremediation removes, degrades and detoxifies contaminants located in the soil, sediments, groundwater, surface water, and even the atmosphere. Phytoremediation uses plants to bind, extract, and clean up pollutants such as pesticides, petroleum hydrocarbons, metals, and chlorinated solvents. The Table 1 gives the most commonly used plants in Phytoremediation and the corresponding contaminant

Type of Plant	Contaminants
Indian Mustard	Copper, Lead and Mercury
Willow (Salix species)	Most heavy metals
Poplar Tree	Nitrate
Sunflower	Copper, Zinc, Lead Nitrates
Indian grass	Crude oil, Pesticides residues
Ferns	Arsenic and other heavy metals
Hyacinth	Copper, Lead

Table 1

Mycoremediation: Fungi feature among Nature's most vigorous agents for the decomposition of waste matter, and is an essential component of the soil food web, providing nourishment for the other biota that live in the soil. Mycoremediation, a form of bioremediation, is the process of using fungi to degrade or sequester contaminants in the environment. Stimulating microbial and enzyme activity, mycelium reduces toxins in-situ. Some fungi are hyperaccumulators, capable of absorbing and concentrating heavy metals in the mushroom fruit bodies. Mycoremediaiton can be used in oil spills, chemical toxins and hydro cleanup. A few of the common fungi used in remediation, and some of the contaminants they work on are given in Table 2. There are many factors that affect the rate and ability for mushrooms to break down toxins, the first of which is the physical nature of the hydrocarbons. Generally, contaminants that are molecularly simpler are easier to break down than more complicated ones. Low temperatures slow the process and warm temperatures speed it up. Fungi prefer a pH of 4 to 5 that is they prefer a pH which is slightly more acid than a neutral pH which is 7. Oxygen is also essential to fungal metabolism. The initial step of hydrocarbon degrading involves adding oxygen to the hydrocarbon, and so a lack of oxygen in the environment slows the process.

Type of Fungi	Contaminants
Shaggy Mane	Arsenic, Cadmium, Mercury
Elm Oyster	Dioxins, Wood Preservatives
Phoenix Oyster	TNT, Cadmium, Mercury, Copper
Pearl Oyster	PCB's, PAH's, Cadmium, Mercury, Dioxins
King Oyster	Toxins, Agent Orange
Shitake	PAH's, PCB's, PCP,s
Turkey Tail	PAH's, TNT, Organophosphates, Mercury
Button Mushrooms	Cadmium
King Stropharia	E-coli and other biological contaminants

Table 2

- ✓ *Rhizoremediation:* Rhizoremediation is a useful plant-microbe interaction and a cost effective bioremediation process. Rhizosphere is a black box of bioremediation. The rhizosphere is a zone of predominantly commensal and mutualistic interactions between plants and microbes. These microbes have access to root exudates, which serve as the food for the microbes. Plant roots provide a large surface, on which microbes can proliferate, can be transported through the soil in terms of both spreading and depth and root provides nutrients and through its soil penetration, facilitates oxygen exchange allowing the proliferation of aerobic microorganisms. This is more suitable in-situ bioremediation. Table 3 gives the combination of plant and the microbe in action and the corresponding metal contaminants that can be detoxified.

Metal	Associated Plant	Microbial action in rhizosphere aiding metal uptake
Zn	*Thlaspi Caerulescens*	Bacterially mediated dissolution of Zn from non labile phase
Ni	*Alyssum murale*	Bacterial Ni solubilisation
	Brassica campestris Lycopersicon Esculentum	*Kluyvera ascorbata* SUD165 Siderophore production and ACC deaminase activity
Se	*Brassica juncea L*	Bacteria volatilizes Se into nontoxic forms, such as dimethylselenide
As	*Pteris vittata*	Mycorrhizae increased the amount of P transporters at hyphae level for As uptake Phenolic defense system (formation of thiol like glutatuhione)
Cu	*Elsholtzia splendens*	Dissolution of Cu by addition of rhizobacterial strain MS12 and ampicillin 0.1mg/g
Cd	*Trifolium repens*	Coinoculation of *Brevibacillus* sp. and AM fungus
	Brassica napus	Cadmium resistant bacterial strains inoculated to plants. (Indole acetic acid as auxin produced by the isolates for tolerance)
	Arabidopsis sinicus	Inoculation of recombinant *Mesorhizobium huakuii* subsp. rengei B3
Multi-metals	*Zea mays*	Inoculation of *Brevibacterium haloterans*
		Mycorrhizae bound metals to organic matter and increases uptake
		Inoculation of Engineered Rhizobacteria (*Pseudomonas putida* 06909 with metal binding peptide EC20)
TCE and Heavy metals	*Helianthus annus*	EC20, was introduced into rhizobacteria *Pseudomonas* strain Pb2-1 and *Rhizobium* strain10320D

Table 3

IV. FACTORS AFFECTING BIOREMEDIATION:

The rate at which microorganisms degrade the contaminants is influenced by the specific contaminants present, their concentrations, the oxygen supply, moisture, temperature, pH levels, nutrient supply, bio-augmentation and metabolism.

V. MERITS AND LIMITATIONS OF BIOREMEDIATION

Bioremediation is a cost effective treatment of polluted sites, completely breakdown the contaminant, uses solar power, and is a natural way of treating polluted environment and protecting the same.

Bioremediation is a long term process. In bioremediation it is difficult to determine whether the contaminants have been destroyed. Highly chlorinated compounds have very low biodegradability, some compounds may be broken down into more toxic by-products (e.g., TCE to vinyl chloride) or PAHs to less degradable PAHs (carcinogens)., prior to selection of a particular bioremediation technique, extensive research is required for isolation and optimization of optimal microbes.

VI. ALTERNATIVES TO BIOREMEDIATION

There are conventional methods of annihilating pollutants viz., burning/incineration, land filling, dumping and burial as alternate methods to bioremediation. But these methods may again pollute the sites. Also these methods are more expensive than bioremediation techniques; hence bioremediation is cost effective and safer technology than other technologies used for cleanup of hazardous waste.

VII. BIOREMEDIATION IN INDIA

The Ministry of Environment and Forests (MoEF) is responsible for protecting the nation’s environment and biodiversity. To carry out this, bioremediation and other techniques of environment protection and remediation are being adopted. Progress has been made in applying microorganisms to the restoration of polluted soil through bioremediation processes. The degradation has led to intensive experimentation, aiming at identifying the most promising techniques. Many research institutes and universities are having expertise in bioremediation techniques, to name a few – NGRI, IICT, CRIDA, IICT, OU, UoH, JNTU, IARI, IISC, ILS. The techniques of phytoremediation, phyto covers, microbial remediaiton, rhizoremdiation are used in many affected areas.

VIII. CONCLUSION

Bioremediation requires prior selection of a particular bioremediation technique. Extensive research is required for isolation and optimization of optimal microbes. Proper care need to be taken in administering a suitable technique/s of bioremediation. The application of microorganisms to enhance the fertility of soil conditions and removing the soil contaminations through bioremediation technology is extensively used in Europe and USA. However, the application of bioremediation technology in the restoration of ecosystem and soil management used in India is less compared to Europe and USA. Hence, we need extensive research programs to increase the capabilities of bioremediation to deep, extensive, subsurface contamination due to chlorinated hydrocarbons and complex mixed wastes, including soils and groundwater.

Besides that, The American Academy of Microbiology (AAM) has concluded that enough knowledge is now available for field trials of bioremediation technology for organic compounds and further they emphasized that research is needed for the following classes of environmental pollutants: metals, metalloids, radionuclides and complex polycyclic hydrocarbons. The on-going microbial genomics studies will deliver more robust technologies for the bioremediation of metal – contaminated waters and land. Exciting developments in the use of microorganisms for the recycling of metal waste, with the formation of novel biominerals with unique properties are also predicted in the near future.

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