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Bioremedition and Phyto–remidiation

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Abstract
Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. There are several different types of phytoremediation mechanisms. With the advance in agriculture and manufacturing industries various hazardous chemicals and compounds are being released which has long term ill effect on the environment. This approach can solve the problem of disposal of radio waste and hence render our environment safe coupled with abundant use of Nuclear energy. Though, some people have also defined Bioremediation as the process which utilize microorganisms or their enzymes to restore the contaminated environment to its original natural state.

Keywords: Bioremedition, Phyto–remidiation, phytoremediation mechanisms

Introduction

The term Bioremediation can be defined as the process to remove pollutants and toxic waste from the environment using Biological agents with less or no side effect to the nature. With the advance in agriculture and manufacturing industries various hazardous chemicals and compounds are being released which has long term ill effect on the environment [1]. Water and soil are most important natural resources that are being polluted by rapid growth of population. To meet this demand, the rapid growth of manufacturing industries and agriculture is necessary which in turn require use of artificial chemicals to enhance rapid and abundant growth of crops and large-scale manufacturing of essential commodities ultimately resulting in accumulation of contaminants, like Chlorine salts, petroleum hydrocarbons, inorganic nitrates, Cr, etc, in our environment [2]. Many microorganisms like bacteria, fungi or yeast act as Bioremediation agents and effectively remove contaminants from water and soil [3]. Some people have also defined Bioremediation as the process which utilize microorganisms or their enzymes to restore the contaminated environment to its original natural state. [2]. However, certain pollutants such as Lead and Cadmium are not efficiently absorbed and processed by the bacteria into environment friendly compounds [4]. These poisonous metals enter the food chain and accumulate in organisms by virtue of Biomagnification. Recently the Biosurfactants have been shown to have a remarkablypositive effect on the efficiency of Bioremediation [5]. Surfactants being amphiphiles deposit at Oil-Water interface and promote the transportation of hydrophobic pollutants into the aqueous phase via solubilisation and micelization [6]. Earlierit was reported that two non-ionic surfactants, Brij30 [Hydrophobic] and $C_{12}E_8$ [Hydrophilic] enhanced the ability of organic degradation of Polycyclic Aromatic Hydrocarbons [PAHs] in contaminated soil [7]. Pseudoallescheria Sp. 18A, an Ascomycetes, have been isolated from soil contaminated by long Chain Aliphatic Hydrocarbons and this fungi was found to have ability to degrade Hydrocarbons as the fungi used these Hydrocarbons as sole source of Carbon. [8]. In another independent study, it was shown that bacteria from the mangrove sediments of Nayband Bay efficiently degrade polycyclic hydrocarbons Fluorene and Phenanthrene from the soil. [9]. As the technological advancement has moved to a new horizon, nuclear energy is being used as cheap and efficient source of energy which results in generation of large amount of nuclear wastes into the environment. [10]. Almost 95% of this radioactive waste is generated by nuclear power plants and this waste has a detrimental effect on the environment even in a very little quantity [11]. The genetic, Physiological and chemical properties of many microorganisms make them suitable agents for bioremediation of radioactive pollutants in groundwater and soil. It has been recently reported that genetically engineered micros can be employed to convert nuclear waste into non-hazardous compounds [10]. This approach can solve the problem of disposal of radio waste and hence render our environment safe coupled with abundant use of Nuclear energy. In another study on water bodies, it was observed that to clean up drainage waters in a cost effective and technically feasible way constructed wetlands can be used as a successful bioremediation tool with high efficacy [12].

Bioremediation is practiced by different methods in accordance to the environmental conditions and the type of pollutant to be tackled. Two basic methods of Bioremediation include:

1. In-situ Bioremediation
2. Ex situ Bioremediation

1. In situ Bioremediation

As the term suggests "In situ Bioremediation" is carried out at the site without removing the water and soil which is to be treated and involves supplementation of soil or water with nutrients, circulating aqueous solutions to stimulate naturally occurring bacteria for degradation of organic pollutants. [2]. Chemotactic ablilities of microorganisms have been reported to be an important for in-situ bioremediation as it enables them to move to the site of contamination using chemotactic ability [2]. Another approach of in-situ bioremediation involves introduction of specific microorganisms to a particular area. These microorganisms accelerate the degradation of contaminants and produce suitable environment to promote growth of other microorganisms which too play vital role in degradation of pollutants. In situ Bioremediation involves:

- Bioventing-This process involves drilling holes around the contaminated site and vacuum is applied at some depth in the soil. On top an increased oxygen supply is kept which is pulled into the soil be vacuum and organic gases are flushed out. This technique has been found productive in removal of petroleum from soil [13].
- Biosparging-This process involves sparging Oxygen into the soil to increase its biological activitywhich in turn promote degradation rate of pollutants in soil. To make the process more cost efficient Hydrogen Peroxide has been used at many sites to increase Oxygen content in soil. [14].
- Bioaugmentation- This process involves introduction of specific microorganisms, with the ability to increase the rate of degradation of contaminants in the soil. It is important to choose the microorganism in accordance to the soil environment to avoid competition between indigenous microorganisms and added biological agent. In 2003, Ruberto *et al*. reported the improvement in the efficiency of bioremediation of hydrocarbon contaminated soil at Antarctica using bioaugmentation with B-2-2 strain [15].

2. Ex Situ Bioremediation

Ex situ bioremediation is the process of removing the soil from the contaminated site and involves many different methods. A specific type of Ex situ bioremediation is Composting which involves mixing the contaminated soil with the compost containing microorganisms having ability to degrade contaminants. These externally administered microorganisms promote the development of indigenous microorganisms in the soil and elevate the temperature ideal for composting. Another heavily practiced ex situ bioremediation is Land Farming which involves removing the polluted soil and spreading it over a field with regular tilling to aerate the soil until the pollutants are degraded. There is one more technique called Biopiles, where composting and land farming are coupled to give better results [2].

In short, Bioremediation is the technique where natural degradation process is induced or enhanced to clean the pollution from the environment. It is need of the time to understand the relation between the microorganisms and their environment so as to make this cleaning process more efficient and effective.

Phytoremediation

Phytoremediation is a method that uses different types of plants to remove, transfer, stabilize and/or destroy contaminants in the soil and groundwater. Several types of phytoremediation mechanisms are present. They are as follows:

1. Rhizosphere biodegradation- In this, the plant releases natural substances through its roots, supplying nutrients to microorganisms in the soil. The microorganisms enhance biological degradation.
2. Phyto-stabilization- Chemical compounds produced by the plant immobilize contaminants, rather than degrade them.
3. Phyto-accumulation [phyto-extraction] - Plant roots absorbs the contaminants along with other nutrients and water. The contaminant mass is not destroyed but ends up in the plant shoots and leaves. This method is used primarily for wastes containing metals. At one demonstration site, water-soluble metals are taken up by plant species selected for their ability to take up large quantities of lead [Pb]. The metals are stored in the plants aerial shoots, which are harvested and either smelted for potential metal recycling/recovery or are disposed of as a hazardous waste. As a general rule, readily bioavailable metals for plant uptake include cadmium, nickel, zinc, arsenic, selenium, and copper. Moderately bioavailable metals are cobalt, manganese, and iron. Lead, chromium, and uranium are not very bioavailable. Lead can be made much more bioavailable by the addition of chelating agents to soils. Similarly, the availability of uranium and radio-cesium 137 can be enhanced using citric acid and ammonium nitrate, respectively.
4. Hydroponic Systems for Treating Water Streams [Rhizofiltration]- Rhizofiltration is similar to phyto-accumulation, but the plants used for clean-up are raised in greenhouses with their roots in water. This system can be used for ex-situ groundwater treatment. That is, groundwater is pumped to the surface to irrigate these plants. Typically hydroponic systems utilize an artificial soil medium, such as sand mixed with perlite or vermiculite. As the roots become saturated with contaminants, they are harvested and disposed of.
5. Phyto-volatilization- Plants take up water containing organic contaminants and release the contaminants into the air through their leaves.
6. Phyto-degradation- Plants actually metabolize and destroy contaminants within plant tissues.
7. Hydraulic Control- Trees indirectly remediate by controlling groundwater movement. Trees act as natural pumps, when their roots reach down towards the water table and establish a dense root mass. This takes up large quantities of water. A poplar tree, for example, pulls out of the ground 30 gallons of water per day, and a cottonwood can absorb up to 350 gallons per day.

As the advance in industrialization, the extraction of metal ores has increased at a rapid rate. This has resulted in release of these metals into the environment. Metals are non-biodegredable and therefore accumulate into the environment and pose a risk to the environment and human health. In soil, these heavy metals may accumulate in microorganisms and result in the decrease in their number and pollutant degradation ability [16]. With each passing year the concentration of these heavy metals keep on increasing in the soil resulting in an alarming threat to the environment and human health [17]. Different physical, chemical and biological processes have been carried on to remove the heavy metals from soil which include in situ vitrification, landfill, soil washing, and stabilization of electro-kinetic systems [18]. A recently developed approach is phytodesalination which involves removal of salt from the soil by the use of halophytes and that soil can be later used to grow crops and other beneficial plants [19]. Recently it was reported that in comparison to Glycophytic plants, Halophytes have better adaptation to resist and grow in soil containing heavy metals [20]. Heavy metals can be removed efficiently with the use of plants which harvest multiple times in a single growth season and have higher efficiency of Phytoremediation [21]. Accumulation of heavy metals from soil into the tissues of the plants is indicated by Bioconcentration Factor, which is expressed as target metal concentration in plant tissue divided by its concentration in soil. [22]. Aquatic macrophytes have direct contact with the contaminated water and remove pollutants from the water with higher efficiency than terrestrial plants [23]. It has been reported that Pistia stratiotes is very effective phytoremediator plant of Mn polluted water and can grow at a very rapid rate across the water bodies [24]. It was observed that Azolla is better pytoremediator plant by virtue of its short doubling time, Nitrogen Fixation and tolerance to accumulation of large variety of metals. Phytoremediation process is a slow process which requires a long time or removal of contaminants and it is applicable to soils contaminated with low levels of pollutants as plant growth is not possible in heavily contaminated soil [25] It was observed that Phragmitesaustralis could absorb ^{238}U from soil and translocated it to shoot. Similar phenomenon was found in Eichhorniacrassipes which has phytoremedative action against radioactive ^{137}Cs and ^{60}Co [26] Recently in China, the Boron-Doped Diamond anode was used for treatment of bio treated coking wastewater containing very high organic and inorganic pollutants [27]. Wild reeds which are grown at contaminated sites have shown to accumulate more metals into tissues in comparison to the Reeds grown at non-contaminated sites and thus have better efficiency to remediate the soils contaminated by Acid Mine Drainage [AMD] [28] In a recent study, 26 cultivars of wheat, naked oats, husk oats and barley were screened for their phyto-remediational potential for Strontium and among all the tests, only Neimengkeyimai-1, a naked oat cultivar showed promising results for Sr accumulation [29].

Conclusion

Bioremidiation is a process where natural degradation rates are enhanced through stimulation of indigenous microorganism. It is an effective ecological and economically effective alternative for reclamation. Different site specific properties such as geology, soil properties along with contaminant/pollutant specific studied must be considered before progressing toward bioremediation.

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