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Bio Remedial Potential for the Treatment of Contaminated Soils

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ABSTRACT

As anthropogenic activities rise over the world, representing an environmental threat, soil contamination and treatment of polluted areas have become a worldwide concern. Bioremediation is a sustainable technique that could be a cost-effective mitigating solution for heavy metal-polluted soil regeneration. Due to the difficulties in determining the optimum bioremediation methodology for each type of pollutant and the lack of literature on soil bioremediation, we reviewed the main in-situ type, their current properties, applications, and techniques, plants, and microbe's efficiency for treatment of contaminated soil. In this review, we describe the deeper knowledge of the in-situ types of bioremediation and their different pollutant accumulation mechanisms.

Keywords: *Bioremediation, Bioventing, Bioaugmentation, Phytoremediation.*

INTRODUCTION

The abundance of pollutants in the environment has expanded dramatically in recent decades as a result of the expansion of industry and urbanization, raising serious concerns around the world (Suman et al., 2018; & Ashraf et al., 2019). Persistent hazardous substances, radioactive wastes, salts, chemical compounds, or pathogens that have a negative impact on biological processes accumulate in the soil are referred to as soil contamination (Mareddy et al., 2017). As a result, higher quantities of harmful substances in the soil, primarily as a result of heavy metals, petroleum derivatives, and pesticides have an impact on ecosystem balance and human health (Palansooriya et al., 2020). When a pollutant penetrates the soil, it can be absorbed, carried away by runoff and wind, or leached by infiltration water, which flows through the lower layers and into groundwater. Air pollutants, agricultural residues, irrigation, byproducts, accidental oil spills, floods, poor waste and sewage management, hydrocarbon deposition, and heavy metals are all major sources of soil pollution (Laborczi et al., 2020).

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Bioremediation has recently received a lot of attention since they are environmentally beneficial, can swiftly remove a variety of toxins, and are substantially less expensive than conventional approaches (Ashraf et al., 2019). This approach consists of natural mechanisms that are capable of effectively biodegrading a wide range of contaminants, like persistent pollutants; as a result, it can be a viable and successful method for soil pollution mitigation.

Preliminary environmental analysis, soil composition, type of pollutant, microbes, and plant species will be used to determine the most appropriate and viable remediation strategy (Azubuike et al., 2016). The characterization of the polluted site, on the other hand, is the first step toward successful cleanup. The efficacy of bioslurping, bioventing, biosparging, bioaugmentation, phytoremediation, and its mechanisms for soil treatment will be discussed in the next sections based on these considerations.

1. Bioslurping

Bioslurping, also known as multiphase extraction, combines soil vapor extraction, improved vacuum pumping, and bioventing to conduct indirect O_2 supply and improve pollutant degradation in groundwater and soil (Azubuike et al., 2016). It's a good approach to get rid of light non-aqueous phase liquids (LNAPLs), which are water-insoluble and lower in density pollutants that float in the water table. It functions similarly to a tube that slurps LNAPLs from a tank and transports contaminants upwards. Following their removal from the surface, bioventing is used to biodegrade contaminants (Kumar et al., 2018). The bioslurping tube begins to remove vapors from the unsaturated area when the fluid level in the good drops owing to the vacuum extraction of LNAPLs. The transport of soil gases is aided by steam extraction, which improves aeration and aerobic decomposition. After all, toxins have been removed, the facility can also be used for typical bioventing to complete bioremediation (Kim et al., 2014). At greater depth it is impossible for the vacuum pump to extract LNAPLs, So, the bioslurping system can be installed only if the contaminants are 7m below the soil surface.

2. Bioventing

Bioventing is the process that provides oxygen for increasing microbial activity, controlled airflow stimulation, and ultimately improve bioremediation (Brown et al., 2015). The pollutants that are more harmless for the environment, normally for achieving transformation humidity and nutrients are added for the improvement of remediation (Höhener & Ponsin, 2014).

3. Biosparging

In biosparging, the air is delivered into the soil to encourage microorganisms to degrade organic matter. In contrast to bioventing, the air is supplied into the saturated area, forcing volatile contaminants to flow upward. The efficiency of biosparging is determined by soil permeability, which impacts both the availability of pollutants to microorganisms and the biodegradability of pollutants (Godheja et al., 2019). Mineral oils, naphthalene's and BTEX can be degraded by aerobic bacteria. While the deeper layer of groundwater and soil is usually anaerobic. Oxygen is introduced into the soil and groundwater via injection filters to support the development of aerobic microorganisms. The bacteria's capacity to break down pollutants is boosted by this direct oxygen source (da Silva et al., 2020).

4. Bioaugmentation and Biostimulation

Bioaugmentation is the addition of previously selected indigenous or genetically engineered microbes to the autochthonous microflora of a contaminated area in order to support oil breakdown. When the natural microorganisms are unable to break down the contaminants, this approach is particularly effective (Woźniak-Karczewska et al., 2019). Further research is needed for bioaugmentation to improve its applications (Dzionek et al., 2016). With the addition of growth stimulants such as phosphorus and nitrogen, native microorganisms are stimulated to proliferate in biostimulation. When natural microorganisms are unable to perform efficient remediation under normal conditions, they must be stimulated by the addition of nutrients, oxygen, or other oxidizing agents. Injection wells are commonly used to apply stimulating agents underground (Zeneli et al., 2019). Nutrient availability is a limiting element for biodegradation in most severely hydrocarbon-contaminated coastal systems (Roy et al., 2018). The fundamental advantage of this technology is that it uses autochthonous microorganisms that are well adapted and widely spread in the environment. Similarly, when the geology of the site is complex, it can become a limiting factor (Speight, 2016). The distinctions between these two processes are highlighted, particularly in terms of the inclusion of selected species and the existence of indigenous microbes (da Silva et al., 2020).

5. Phytoremediation

Phytoremediation is the process of using plants in contaminated areas to encourage physical, chemical, biochemical, and biological interactions that reduce pollutant toxicity (Godheja et al., 2019). Plants absorb ionic substances from the soil through their root system, even at low concentrations. Plants extend their root systems into the soil matrix, generating a rhizosphere ecosystem that accumulates heavy metals and adjusts their bioavailability, allowing damaged soil to be reclaimed and soil fertility to be restored (DalCorso et al., 2019). Various methods, including biodegradation, vaporization, and filtering, are used depending on the type of pollutant.

Phytoremediation has a number of advantages, including (i) phytoremediation is cost-effective since it is a solar-powered autotrophic system that is simple to operate and maintain, (ii) It is environmentally and ecologically benefici al, because it limits pollutants exposure to the environment and ecosystem, (iii) applicability: used on a big size field and is readily disposed of, (iv) by stabilizing heavy metals and reducing erosion and metal leaching, it minimizes the risk of contaminants spreading, (v) It can aid soil fertility by releasing a wide range of organic compounds (Jacob et al., 2018). Plants interact with contaminants in a variety of ways during phytoremediation (Favas et al., 2014).

5.1. Phytoextraction

This technique includes the pollutant being removed from the soil and accumulating in a plant component (e.g., root, stem, or leaf) (Sidhu et al., 2018). Phytoextraction has been the most popular phytoremediation approach for removing metalloids and heavy metals from contaminated soil in recent years (Sarwar et al., 2020). There are a several processes involved in heavy metal phytoextraction: (I) Heavy metal mobilization in the rhizosphere, (ii) HMs uptake by plant roots, (iii) HMs ion translocation from roots to aerial portions of the plant, (iv) HMs ion compartmentation and sequestration in plant tissues (Ali et al., 2013).

5.2. Phytodegradation

When a contaminant is absorbed by a plant, it is transformed into a less harmful form. Phytodegradation is a process that occurs when this type of alteration occurs on the plant's surface (Park et al., 2011). Plants generate enzymes such as dehalogenase and oxygenase. These enzymes aid in the catalysis of the decomposition process. Specific enzymes break down, mineralize, or metabolize organic contaminants inside plant cells. Laccases (degradation of anilines), nitro-reductases, and dehalogenases are a few of these enzymes. These enzymatic systems can be found in plants like Myriophyllum spicatum and Populus spp. According to Rylott & Bruce, (2009) plant metabolism causes the chemical change of ambient chemicals, which frequently results in degradation (phytodegradation), inactivation, or immobilization (phytostabilization). In the case of organic contamination, Industrial chemicals, explosives, insecticides, solvents, and other xenobiotic substances are rendered harmless by the metabolism of certain plants, such as Canna (Kvesitadze et al., 2006).

5.3. Phyto volatilization

The pollutant is extracted from the soil and converted into a volatile chemical, which the plant then releases into the atmosphere. The phytovolatilization approach is based on a plant's ability to absorb and volatilize certain metals. Hg, Se, As, and other elements from the periodic table's groups IIB, VIA, and VA can be absorbed by the roots, transformed into harmless forms, and then released into the atmospheric air. The same method can be used to measure the absorbance of organic substances (Pilon-Smits & LeDuc, 2009). When compared to other phytoremediation procedures, phytovolatilization has the advantage of removing heavy metal contaminants from the site and dispersing them as gaseous molecules without the requirement for plant harvesting and disposal. Similarly, selenium can be taken by *Astragalus bisulcatus* and *Stanleya pinnata*, as well as transgenic *Arabidopsis haliana* plants (containing bacterial genes). Meanwhile, *Liriodendron tulipifera*, *Brassica napus*, and *Nicotiana tabacum* can absorb Hg. The same method can be used to measure the absorbance of organic substances (Pilon-Smits & LeDuc, 2009).

5.4. Phyto stimulation:

This is the process of increasing soil microbial activity to aid in the breakdown of pollutants. Organisms linked with plant roots are responsible for pollution breakdown in this way. Exudates are chemicals released by plant roots that can speed up the breakdown of contaminants. Phyto stimulation is the term used when microorganisms assist in the breakdown process (Borriss, 2020). The use of phyto stimulation is restricted to organic contaminants (Prasad, 2003). The microbial population in the rhizosphere is varied due to the varying geographical distribution of nutrients. However, the genus *Pseudomonas spp* is the most common organism, and it is linked to roots (Ali et al., 2013).

5.5. Phyto stabilization

This method involves immobilizing contaminants in the soil, preventing erosive processes, and allowing for the interaction of contaminants with hummus and lignin (Shackira & Puthur, 2019). The major goal is to prevent contaminants from mobilizing and limiting their presence in soluble form, as well as preventing their diffusion into the soil. According to Ali et al., (2013), plants from the genera *Haumaniastrum*, *Alyssum*, *Eragrostis*, *Ascolepis*, and *Gladiolus* are cultivated for this purpose. HM's such as Zn, Cd, Cu, U, As, Pb, and Se can also be absorbed by these trees of this genera.

CONCLUSION

Bioremediation is an essential form of "green bioengineering." It uses a variety of techniques, including green plants and bacteria, to remove toxins from the environment. Highly toxic compounds from polluted soil can be accumulated, absorbed, tolerated, transferred, digested, degraded, and stabilized using this biotechnology. The application of a soil bioremediation methodology depends on a variety of parameters, including the location and kind of contamination, the objectives, predicted efficiency, cost-effectiveness, and duration of the treatment, as well as public acceptance. Bioremediation is important because it is effective in removing harmful organic aromatic pollutants, heavy metals, polycyclic aromatic hydrocarbons (PAHs), landfill leachates, pesticides, and herbicide contamination. Bioaugmentation, biostimulation, and phytoremediation are the most commonly utilized in-situ bioremediation techniques, however, the combined use of different biotechniques should be considered, as it boosts the efficiency of remediation while minimizing the individual limitations of each. Furthermore, well-designed bioremediation initiatives can open up new markets and make it easier to manage contaminated soils, allowing for the integration of long-term socio-economic activity.

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