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Rhizomediation: An Emerging Clean-Up Technology

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SUMMARY

Rhizoremediation is usually an approach involving microorganisms for the biodegradation of toxic pollutants and contaminants present in the vicinity of plant. Plant roots provide a niche for the microbes to develop at the expense of the root exudates and in get facilitated by removal the pollutants. The harmful pollutants such as: pesticides, herbicides, polycyclic aromatic hydrocarbons (PAHs), chlorobenzoic acid etc. are converted to degradable compounds, while heavy metals such as Zn, Pb, Cu. Cd etc. are transformed from one oxidation state or organic complex to another. There are numerous genera of microbes such as fungi, bacteria, actinomycetes, mycorhizza associated with the rhizomediation process.

INTRODUCTION

In a broad perspective, the term "rhizoremediation" means the removal of the toxic pollutants by the microbes present in the rhizosphere (Segura *et. al.,* 2009). The technique is evolving as an imperative method of eliminating pollutants from contaminated sites by utilizing the combined degradative ability of plants and associated rhizospheric microorganisms (Zhuang *et. al.,* 2007). The rhizospheric microbes enhance the degradation process by producing a wide range of hydrolytic enzymes which aid in the ecorestoration of polluted areas. The success of rhizoremediation primarily depends upon the survival and establishment of plants with rhizospheric microbes. Root exudates, secreted by plants, support a flourishing microbial consortium that assists in rhizoremediation. Moreover, a healthy microbial consortium can be beneficial to the plants by performing numerous plant growth-promoting activities such as phosphate solubilization, siderophore production, N_2 fixation, phytohormones production, and defence against diseases (Lee *et. al.*, 2012).

For example, ACC deaminase-producing bacteria aids in plant's root growth and proliferation in polluted sites (Arshad *et. al.*, 2007). These bacteria have also been reported to play a profound role in enhanced metal tolerance for plants. Enhanced toxic metal tolerance of *Brassica campestris*, *Brassica napus* and nickel hyperaccumulator plant *Thlaspi goesingense* (Idris *et. al.,* 2004) were possibly due to the activity of ACC deaminase-producing rhizobacteria, associated with these plants. Pollutant toxicity, water stress, adverse soil conditions, and nutrient deficiency are typical issues hindering the establishment of vegetation on contaminated sites, which the beneficial microbes tend to overcome. Solubility and availability of contaminants in soil are mostly dependent upon soil properties, i.e., pH, redox potential, mineral composition, clay content, organic matter content etc. Pollutants are mainly adsorbed by organic matter and minerals in the soil, which leads to their entrapment and less bioavailability (Mohan *et. al.*, 2006). However, the enhanced degradation of pollutants by a mutual effort of plants and associated rhizospheric microorganisms has been listed in Table 1.

Table 1. Rhizomediation of Few Degraded Pollutants

Plant species	Microbes associated	Degraded pollutants
Triticum aestivum	*Pseudomonas putida* strains	2,4-D
Hordeum vulgare	*Burkholderia cepacia*	2,4-D
Zea mays	*P. putida*	3-Methylbenzoate
Brassica napus	Cd-resistant rhizospheric bacterial strains	Cd-polluted soil
Beta vulgaris	*P. fluorescens*	Polychlorinated biphenyls (PCBs)
Brassica juncea	*Bacillus subtilis* strain SJ-101	Nickel
Astragalus sinicus	*Mesorhizobium huakuii*	Cd
Populus sp.	Actinomycete *Amycolata* sp. CB1190	1,4-Dioxane

Among the community of rhizospheric microbes, saprotrophic fungi (e.g., species of *Mucor*, *Rhizopus*, *Cunninghamella*, and other *Zygomycota* fungi) use to play a key role in the degradation process employing sugars and other simple soluble nutrients exuded by plant roots. Fungi have a rapid exploitative phase and an extremely competitive ability. Several fungal genera, viz. *Trichoderma*, *Penicillium*, *Fusarium*, *Aspergillus*, etc., have been broadly studied and reported to show tolerance to pollutants such as PCBs, chlorobenzoic acids (CBA), and endosulfan (Pinedo-Rivilla *et. al.*, 2009). Fungi accumulate heavy metals as their cell wall components containing free amino, hydroxyl, and carboxyl groups, which can bind heavy metals very efficiently. Their potential to chelate heavy metals allows them to be used as commercial biosorbents. Mycorrhizal fungi also play an important role in rhizoremediation. These fungi owing to the small diameter of their hyphae can proficiently explore the soil volume and even the small pore spaces which are not accessible for plant roots. They protect the roots from direct interaction with toxic pollutants and augment their degradation, by forming an ectomycorrhizal sheath around roots. Apart from the cell wall components, glomalin proteins formed by mycorrhizal fungi also reported being very efficient in sequestering metals such as Cu, Fe, Cd, Pb, Mn and Zn (Carnejo *et. al.*, 2008).

In addition to fungi, rhizospheric bacterial belonging to diverse genera such as *Bacillus*, *Pseudomonas*, *Arthrobacter*, *Burkholderia*, *Flavobacterium*, *Sphingomonas*, and *Alcaligenes* have been reported to possess the ability to degrade toxic compounds (Mishra *et. al.*, 2017). Similarly, actinomycetes are also explored for the i.e., organochlorine pesticides in the rhizosphere. Actinomycetes can oxidize and dealkylate some highly toxic chemicals e.g., atrazine, aldrin, Endosulfan metolachlor, etc. Moreover, actinomycetes also facilitate soil inoculation due to their rapid mycelial growth, high growth rate, and easy genetic manipulations. Soil microorganisms are also reported to produce biosurfactant compounds that may further enhance the degradation of organic pollutants by increasing their availability to plants. Organic acids, one of the major components of root exudates which usually exists in anionic form i.e., citrate, acetate, malate, oxalate, fumarate which can chelate metal ions and decrease their toxicity for plants and rhizospheric microorganisms (Ling *et. al.*, 2015).

CONCLUSION

The process of rhizoremediation is an arising bio-remediation technique which whenever used well can assist us with getting perfect and green climate by exploiting the common assets in the most ideal manner. Additionally, in the field of agriculture where the aggregation of harmful chemicals and pesticides has prompted the age of desolate land, numerous wellbeing dangers this method can offer an answer for improve biochemical yield, recover those infertile grounds in the most ideal manner. Thus, in a nutshell it can be stated that rhizoremediation can arise as an eco-accommodating clean-up innovation for safeguarding our ecosystem.

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