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Potential of *Trichoderma sp.* in Bioremediation: A Review

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Abstract—*Environment pollution and accumulation of pollutants is a matter of global concern as it may lead to disasters. Environmental awareness has resulted in development of regulatory measures that aim to protect the environment from future contamination and exploitation. Bioremediation is a cost effective and nature friendly biotechnology that is powered by microbial enzymes. A large number of enzymes from bacteria, fungi, and plants have been reported to be involved in the biodegradation of toxic organic pollutants. In particular the bio-removal of pollutants carried out by fungi serves as an economical means of treating effluents and the polluted water areas charged with toxic metallic ions. Trichoderma species are known for degradation of pollutants and hence play a useful role in ecosystem management. Vast diversity in Trichoderma spp. seem to have perspective for use in sustainable agriculture and biofuel crops using tools and technique of modern plant biology. The present review describes the role of Trichoderma sp. in bioremediation, i.e. facilitating metal stress tolerance and hyperaccumulation of toxicants for plant tissue protection and hence enhanced nutrient availability and efficiency. Further research is needed to evaluate the long-term effects of Trichoderma on metal behaviour in the heterogeneous system under field conditions, developing advanced bioprocess technology to reduce the toxicity of the pollutants and also to obtain novel useful substances.*

Keywords : *Bioremediation, Trichoderma, pollutants, biodegradation*

1. INTRODUCTION:

Environmental pollution is a global issue, wherein heavy metal and organic contaminants continue to be major pollutants (Xiezhi *et al.*, 2005). Flora and fauna are adversely affected by existence of pollutants, which also lead to contamination in growundwater through leaching. Consequentially, performance and quality of products reduces, which poses danger to human health (Khosravi *et al.*, 2009). In addition, plant growth has been restricted due to presence of contaminants in soil, causing environmental stress (Khosravi *et al.*, 2009, Mohsenzade *et al.*, 2012). Toxic effects of these pollutants and compounds cause detrimental effects on gastrointestinal, respiratory and nervous systems, may also lead to cell necrosis in exposed organs (Saberi *et al.*, 2010). These pollutants, once accumulated in soil and water, enter the food chain and thus put all flora and fauna at risk. Metal toxicity appears in metabolic processes like nitrogen fixation, nitrogen reduction, irregularities on enzyme synthesis etc (Nwuche *et al.*, 2008).

2. BIOREMEDIATION BY FUNGI:

Bioremediation is defined as microorganism mediated transformation or degradation of contaminants into nonhazardous or less-hazardous substances, which employs micro organisms like bacteria, fungi, algae and plants. Bioremediation technology uses microorganisms to reduce, eliminate, contain, or transform to benign contaminants present in soils, sediments, water, and air. Bioremediation is described as the use of microorganisms to destroy or immobilize waste materials. Bioremediation is based on the principle of enzymatic attack of microbes on pollutants and their conversion into less harmful products. Application of bioremediation involves the manipulation of environmental parameters for faster growth of microbes and hence, quick degradation of pollutants. Control of such metal pollutants is being made possible through use of micro organisms currently, like bacteria, fungi, yeasts and algae, which are considered important as agents of bioremediation (Pradhan *et al.*, 2007). Micro organisms are known to immobilize these metal ions by linking them with their cell walls (Vankar *et al.*, 2008). Thus, microorganisms in soil aid in absorption of plant nutrients, increase the performance of plants, and, consequently, improve the physical and chemical properties of contaminated soil. Their presence in the rhizosphere of plants can intensify the phytoremediation process by enhancing phytostimulation or rhizodegradation (Cao *et al.*, 2008, Kavamura *et al.*, 2010).

Fungi are known to function together with bacteria and an array of microorganisms, they are capable of handling breaking down some of the largest molecules present in nature (Fernandez-Luqueno *et al.* 2010). Some fungi exude extracellular enzymes which allow for digestion of energy sources in their surroundings and further diffusion of these molecules through the substrate towards the fungus (Mai *et al.*

2004). Fungi possess these decomposing abilities to deal with the array of naturally-occurring compounds that serve as potential carbon sources. Hydrocarbon pollutants have similar or analogous molecular structures which enable the fungi to act on them as well (Fernandez Luqueno *et al.* 2010). Fungi attack plastic polymers as well; these come in a wide range of structures as lignin and are acted upon by different fungi species for different polymers. This decomposing ability is perhaps even more impressive than PAH decomposition. Fungi have been found to be effective in degradation of PAHs as well as bioremediation of toxic metals as well, which are commonly found in the same polluted sites and can reduce the effectiveness of some degradive microorganisms. Hong *et al.* (2009) surveyed gas station soil and found strains of *Fusarium* and *Hypocrea* that could degrade one carcinogenic high weight PAH, pyrene, as well as uptake copper and zinc.

3. ROLE OF ENZYMES IN BIOREMEDIATION:

Oxidoreductase constitute an important class of enzymes that are involved in humification of phenolic substances produced from decomposition of lignin in soil. They are also capable of detoxification of xenobiotics such as phenolics or anilinic compounds through polymerization or copolymerization with other substrates (Park *et al.*, 2006). Activity of fungi is seen due to action of extracellular oxidoreductase enzymes, like laccase, manganese peroxidase and lignin peroxidase, released from fungal mycelium. Fungi are more efficient in reaching soil pollutants as compared to bacteria (Rubilar *et al.*, 2008). An important group of ubiquitous oxidoreductase enzymes that have displayed potential for biotechnological and bioremediation applications are laccases. Pollutants are degraded by specific oxygenases, which mediate dehalogenation reactions of halogenated methanes, ethanes and ethylenes along with multifunctional enzymes. Extracellular enzyme activity is a key step in degradation and utilization of organic polymers, since only compounds with molecular mass lower than 600 daltons can pass through cell pores (Vasileva-Tonkova & Galabova, 2003). Hydrolytic enzymes disrupt major chemical bonds in the toxic molecules and results in the reduction of their toxicity. This mechanism is effective for the biodegradation of oil spill and organophosphate and carbamate insecticides. The most useful indicator for testing hydrocarbon degradation in soil is lipase activity. Though it’s production cost is high, lipase enzyme plays very important role in food, chemical, detergent manufacture, cosmetic and paper making industries, (Sharma *et al.*, 2011).

4. *TRICHODERMA SP.* AS AGENT OF BIOREMEDIATION:

One of the most potent group of fungi used widely for bioremediation is *Trichoderma sp.* In addition, they are known to enhance plant growth and development. The genus *Trichoderma,* most common occurrence, with the potential for colonisation in diverse habitats. *Trichoderma* is a genetically diverse genus, filamentous in nature with agricultural and medicinal importance. (Ahamed and Vermette 2009; Contreras-Cornejo *et al.* 2009; Lorito *et al.* 2010). Being a potent biocontrol agent, plant growth promoter, helps in improvement of soil fertility, disease suppression and composting (Contreras-Cornejo *et al.* 2009; Lorito *et al.* 2010). *Trichoderma sp.* is a producer of organic acids such as gluconic acid, fumaric acid, and citric acid, which decrease soil pH and allow phosphate dissolution, as well as dissolution of macro- and micronutrients such as iron, manganese, and magnesium, which are necessary for plant metabolism. *Trichoderma sp* is characterised by it’s ability to modify the rhizosphere microflora of plants through the intensive colonisation of roots, and with strong fungi that are aggressive against pathogens (Ociepa, 2011; Brotman *et al.*, 2010) (Fig. 1). Also, it has wide applications in enzyme production, paper, pulp and food industry (Ahamed and Vermette 2008; Singh and Singh 2009), as well as in remediation of soil and water pollution pollution (Ezzi and Lynch 2005) and biofilm preparation in the field of nanotechnology (Vahabi *et al.* 2011). *Trichoderma* exhibits resistance to many agrochemicals, thus it is used as a tool for integrated pest management. Also, it is a potent producer of hydrolytic and industrially important enzymes, like amylase from T harzianum (Harman *et al.* 2004a), cellulases from T reesei (Ahamed and Vermette 2009) 1,3 bglucanases from T. harzianum, T. koningii (Monteiro and Ulhoa 2006), and chitinases from T. aureoviridae and T. harzianum (Sandhya *et al.* 2004) is well established. *Trichoderma* sp. are found to be highly resistant to a wide range of toxicants viz, heavy metals, organometallis compounds, tannery effluents, and harmful chemicals like cyanide (CN) (Ezzi and Lynch 2005). This makes them an important fungal genus to be explored as a genetic resource to employ in bioremediation of toxic pollutants.

5. ROLE OF *TRICHODERMA SP.* IN BIOREMEDIATION:

Many studies and reports have signified the role of *Trichoderma* in bioremediation and environmental clean up. Based on our bibliographical studies there is few report about Cd accumulation ability of *Trichoderma* species. The biomass of soil fungi including *Trichoderma* plays an important role in the bioremediation of contaminated soils and can be applied in integrated pest management and phytoremediation. Moreover, it can remove and concentrate the various ions, such as Pb, Cd, Cu, Zn, and Ni, and sorption was widely recognised as the main mechanism of uptake (Yazdani *et al.*, 2009, Srivastava *et al.*, 2011). Asha Sahu *et al.*, (2012) concluded that T. viride can be successfully used for bioremediation of cadmium and lead from aqueous media. Therefore, bio-removal carried out by these fungi could serve as an economical mean of treating effluents and the polluted water areas charged with toxic metallic ions. Hence, it was concluded that T. viride has affinity to tolerate high concentration of applied heavy metals.

Pentachlorophenol (PCP) is a widespread, persistent environmental contaminant that has been, and in some developing countries still is one of the extensively used fungicides and pesticides,. It was reported by Ngieng *et al.*, 2014 that *Trichoderma* sp are capable of biodegradation of PCP. Certain species of *Trichoderma* have been reported to tolerate and accumulate several heavy metals such as copper, zinc, cadmium, and arsenic in laboratory conditions (Errasquin and Vazquez 2003; Zeng *et al.* 2010). *T. asperellum* and *T. viride* were reported to remove arsenic from liquid media through biovolatilization (Srivastava *et al.* 2011). *Trichoderma* spp. increase uptake of nitrates and other ions in root region and in the process also facilitates uptake of various toxic metals and metalloids thus assisting in phytoextraction activities (Cao *et al.* 2008). *Trichoderma* atroviridae is reported to influence uptake and translocation of Ni, Zn, and Cd in Brassica juncea, while *T. harzianum* was reported to promote growth of crack willow (Salix fragilis) in metal-contaminated soil (Adams *et al.* 2007). It is reported that *T. harzianum* strains can detoxify potassium cyanide and promote root growth of arsenic hyperaccumulating fern Pteris vittata (Lynch and Moffat 2005). Combined application of AM fungi and *T. harzianum* increased the tolerance and accumulation of Eucalyptus globulus to high concentrations of aluminum and arsenic in soil (Arriagada *et al.* 2009). The potential of *Trichoderma* to stimulate the growth of trees in heavy metal-contaminated soil has been investigated and its role in revegetation and stabilization has also been demonstrated (Adams *et al.* 2007; Arriagada *et al.* 2009). Mechanisms that *Trichoderma* apply in facilitating metal stress tolerance in plants is attributed to enhanced root biomass production, hyperaccumulation of toxicants in plant tissues protection against oxidative damage in plants, and enhanced nutrient availability and efficiency (Arriagada *et al.*,2009; Mastouri *et al.,* 2010). Argumedo-Delira *et al.* (2012) reported tolerance of 11 *Trichoderma* isolates to crude oil (COil), naphthalene (NAPH), phenanthrene (PHE), and benzo[a]pyrene (B[a]P) using in vitro systems. Fungi including *Trichoderma* are becoming recognized for their ability to efficiently biodegrade toxic contaminants (Cao *et al.* 2008). The fungi are effective because of an extracellular enzyme system that catalyzes reactions that can degrade aromatic toxic compounds. They are capable of degrading various chemicals, including pesticide residues in soil like chlordane, lindane, and DDT, which make them useful for the remediation of pesticide-contaminated sites (Ezzi and Lynch, 2005). In integrated plant protection strategies, *Trichoderma* strains can be combined with pesticides containing metal ions and chemicals. Role of *Trichoderma* sp. in bioremediation of pollutants has been summarized in Table 1.

6. CONCLUSION:

There have been numerous technologies for environemental clean up, each having its advantages and limitations for the treatment of specific contaminants. Bioremediation by use of micro organisms is an innovative approach having a potential to alleviate numerous environmental pollution problems. Owing to its presence and role in contaminated sites, the application of the fungi in bioremediation is well known. The diverse genus *Trichoderma* is is tolerant to a range of recalcitrant pollutants including heavy metals, pesticides, and polyaromatic hydrocarbons. Hence, it can be successfully applied and developed for bioremediation of environmental contaminants

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