Mycoremediation: A Management Tool For Removal of Pollutants From Environment

KEYWORDS: Mycoremediation, Fungus, Decomposers.

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ABSTRACT *Mycoremediation is the process of degrading or removing toxicants from the environment using fungi. Fungi are important decomposers in the natural environment. They create enzymes to degrade the plant polymers cellulose and lignin, two very durable compounds that give plants their structure. Using similar mechanisms, fungi can also break down certain toxic substances. Fungi are known to degrade, or cause to deteriorate, a wide variety of materials and compounds, processes known as mycodegradation and mycodeterioration.*

Introduction

Mycoremediation is a process of using fungi to return an environment (usually soil) contaminated by pollutants to a less contaminated state [1]. Mycoremediation also held promise for removing heavy metals from the land by channeling them to the fruit bodies for removal [2]. Fungi are unique organisms due to their morphological, physiological and genetic features; also they are ubiquitous, able to colonize all matrices (soil, air, water) in natural environments, in which they play key roles in maintaining the ecosystems equilibrium. As a result of adaptation to their environment, fungi developed unique bioremediation properties. Virtually all natural organic compounds can be degraded by one or more fungal species thanks to the production of a variety of enzymes such as amylases, lipases, and proteases that allow them to use substrates as starches, fats, and proteins. A more limited number of species can use pectin, cellulose, and hemicelluloses as carbon sources. Finally, some fungi are the main degraders of natural complex polymers which are resistant to microbial attack, such as keratin, chitin, and lignin. Another advantage of using fungus for biodegradation of pollutant is their easy growing ability in fermenters and thus suitable for large scale production. Also due to its filamentous structure fungal biomass can be separated easily by filtration. In comparison to other organisms, filamentous fungi are less sensitive to variations in nutrients, pH, aeration and temperature.

Classification of fungi on the basis of involvement in remediation process of pollutants can be explained as follows:

- Ligninolytic fungal degradation
- Soil fungal biosorption
- Mycorrhizal fungal degradation

2.1 LIGNOLYTIC FUNGAL DEGRADATION

Many fungal species like *basidiomycetes, ascomycetes* have the potential to degrade lignocellulosic materials present in dead wood, paper and pulp effluents [3]. *Basidiomycetes* species are considered to be a very interesting group of fungi, considered as natural lignocellulose destroyers and include very different ecological groups such as white rot, brown rot, and leaf litter fungi. Polycyclic aromatic hydrocarbons from natural oil deposits are degraded by laccases, a copper containing enzyme found in these *basidiomycetes* [4]. White-rot fungi degrade PVC under aerobic conditions secreting extracellular enzymes which act on the polymers. An edible rot fungus, *Pleurotus pulmonarius* is known for its ability to degrade crude oil [5]. In the following sections we will be focusing on white rot and brown rot fungi.

2.1.1 WHITE ROT FUNGI (WRF)

Fungi causing white rot are represented in all the main groups of the *Basidiomycota* (*Agaricomycotina*), and in some of the *Ascomycota*, namely the *Xylariaceae*. White-rot fungi for lignin degradation have been examined for more than half a century. After the discovery of the extracellular oxidative ligninolytic enzymes of the white-rot fungus *Phanerochaete chrysosporium*, Bumpus *et al.*,1985 [6] proposed the use of this fungus for bioremediation. *P.chrysosporium* was the first fungus to be associated with degradation of organopollutants, because it has been extensively studied as a model microorganism in research on the mechanism of lignin degradation [7].

WRF produces extracellular oxidative enzymes which are able to completely mineralize lignin and carbohydrate components of wood to CO_2 and H_2O. WRF can be used to detoxify or remove various aromatic pollutants and xenobiotics found in contaminated soil [8]. Actually, their ligninolytic enzymes are nonspecific, non-stereo selective, and effective against a broad spectrum of aromatic compounds.

White Rot Fungi produce a battery of lignin degrading enzymes that catalyze oxidation of xenobiotics in addition to their ability to degrade lignin. They consist of peroxidases, laccases, and other enzymes involved in the formation of radicals, ROS and H_2O_2, that cleave the carbon–carbon and carbon–oxygen bonds of the lignin / xenobiotic by means of a free radical mechanism [9].

2.1.2 Pleurotus *ostreatus*

P.ostreatus is an edible species, commonly known as the oyster mushroom [10]. This species is a saprophytic basidiomycete and a natural decomposer because it secretes enzymes and acids that degrade organic polymers [11]. Its great advantage is that large scale production of fungal biomass grown on lignocellulosic substrates has already been developed for human consumption and it is economically feasible because the substrates do not need to be sterilized (pasteurization is sufficient) [7]. The fungal mycelium colonizes natural soil effectively and its temperature requirements are considerably lower than that of

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P.chrysosporium [10], as it is active at 8 °C [12].

2.1.3 Trametes *versicolor*

The basidiomycete *Trametes* (syn. *Coriolus*, *Polyporus*, *Polystictus*) *versicolor* is a very efficient white rot species in nature [43] that was first studied by Dodson *et al*. [13]. This fungus causes rapid white rot invasion of moribund or fallen trees of species such as birch, beech and oak. *T.versicolor* has been used in bioremediation research because of its effective extracellular laccase production and high tolerance to pentachlorophenol.

2.1.4 Brown-Rot Fungi (BRF)

Brown rot is a kind of wood decay caused exclusively by Basidiomycota, namely Agaricomycetes. This class encompasses BRF belongs to the Agaricales, Hymenochaetales, Gloeophyllales, and Polyporales. Interestingly, only 6% of all the known wood decay fungi are now known to cause a brown rot and are almost exclusively associated with conifers [14]. BRF degrade cellulose and hemicelluloses present in wood after only a partial modification of lignin (demethylation, partial oxidation, and depolymerization). Because of the preferential degradation of polymers, the decayed wood loses its inherent strength.

2.2 SOIL FUNGI

Many soil residing fungal species such as *Mucor sp, Aspergillus carbonaruius, Aspergillus niger, Rhizopus sp, Saccharomyces cerevisiae, Botrytis cinerea, Neurospora crossa, Phanerochaete chrysosporium and Lentinus sajor-caju* have been extensively studied for heavy metal biosorption [15]. Saccharomyces cerevisiae was found to be the efficient bio-absorbent of heavy metals like Pb, Au, Co, Cu [16].

Current research indicates that *Saccharomyces cerevisae* is able to absorb even 92% of Pb (II), 100% of copper (II) and 68% Mo ions from the solution within first hour of experiment. It also possesses high adsorption efficiency against Cd (II) and Co (II) ions [17].

On the other hand, *Loddermyces elongisporus* is capable of removing up to 81% of Cu(II) ions and is tolerant to high concentrations of other ions [18]. *Aspergillus niger* viable biomass removes nickel ions from the solution in very high rate, and its dead cells can remove about 75% arsenic (V) and 95% of arsenic (V) ions from the solution [19 & 20]. Akhtar *et al*., [21] found the Ni tolerance of different species was in order of Aspergillus> Pithyum> Curvularia while for Cu and Cd, the order was Aspergillus> Curvularia>Pithyum. The metal tolerance among filamentous fungi was observed in order of Cd >Cu >Ni [21].

Studies have shown the considerable potential of Penicillium strains as a naturally, abundant and cheap source for heavy metal environmental reduction. Recently, the high potential of P. simplicissimmum to remove Cd (II), Zn (II) and Pb (II) from aqueous solutions was reported [22]. Their efficiency as adsorbents depends on the capacity, affinity and specificity including physic-chemical nature. *Penicillium* strains, as soil fungi, showed ability to produce extracellular enzymes and metabolize hydrocarbons. The capacity of *Penicillium* strains to produce cellulose, mannanase and pectinase indicated that these strains should be able to use several agricultural wastes. Some of these strains are not only able to oxidize, but also mineralize hydrocarbons such as phenol, halogenated compounds and poly aromatic hydrocarbons (PAH). Metabolism of PAHs by *Penicillium* strains involves cytochrome P_{450} monooxygenase enzyme systems. The first steps of PAH oxidation result in the formation of monophenols, diphenols,dihydroidols, and quinines. In a second step, water-soluble conjugates such as sulphates and O-methyl conjugates, which are detoxification products, can be formed.

2.3 MYCORRHIZAL FUNGI

Mycorrhizal fungi, growing as a symbiont encourage degradation of organic contaminants in soil [23]. The fungal partner captures nitrogen (N), phosphorus (P), and other nutrients from the soil environment and exchanges them with the plant partner for photosynthetically derived carbon (C) compounds that feeds fungal metabolism. Several types of mycorrhizal associations have been classified according to the fungus involved and the resulting structures produced by the root–fungus association: ectomycorrhizas (ECM), ericoid mycorrhizas (ERM), ectendomycorrhizae, arbuscular mycorrhizae (AM), arbutoid mycorrhizae (ARM), monotropoid mycorrhizae, and orchid mycorrhizae.

Plants that grow on heavily polluted soils are known as mycotrophic. ECM, ERM, and VAM fungi can increase plant tolerance to heavy metals at toxic concentrations. This is due to the accumulation of metals in extrametrical hyphae and extrahyphal slime. This leads to the immobilization of metals in or near roots and decreases uptake to shoots. Increased levels of metal tolerance to plants are not known in all mycorrhizal associations, due to differences in influence on plant metal tolerance. ECM fungi may be useful as bioindicators of pollution [24 & 25]. The capability to degrade POPs of mycorrhizal fungi, and especially of ECM and ERM fungi, seems mainly related to the production of polyphenol oxidases (e.g., laccase, catechol oxidase, and tyrosinase) and peroxidases.

In conclusion, the majority of mycorrhizal fungi appear to be able to degrade a range of contaminants. To date only a limited number of mycorrhizal fungal taxa (and only single isolates of each) have been investigated with respect to their abilities to degrade organic pollutants.

3. CONCLUSION

The anthropogenic sources emit high amounts of toxic, heavy metals into water, air and soil. The traditional methods of removing them are usually costly and ineffective. Biosorption of pollutants on biomass appears to be a very useful and cheap method. It also allows recovering metals from sorbents by using basic and cheap chemical methods that are not so harmful for the environment. Further cost reduction can be performed by using the spillage biomass from biotechnological industry. Researches show that even complex mixtures of polluting heavy metals can be easily treated by use of biomass absorbents. As the whole industry tends to become more "green", the bioremediation is the natural way of dealing with heavy metal polluted wastewater.

Mycoremediation may play a direct role in biodegradation of complex organic substrates via enzymatic catabolism. However most fungi have been examined in isolation from an ecosystem context, thereby excluding interactions among the different organisms and the soil environment. Thus further efforts are needed to better understand how the soil ecosystem works as a whole; a better knowledge of complexity of this heterogeneous environment, and of the interactions between the different organisms present, will make it possible to formulate more effective bioremediation strategies.

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