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Mycoremediation: A Treatment for Heavy Metal Pollution of Soil

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Abstract: **Heavy metal pollution of soil is one of the most serious matters of concerns in the present day scenario. In agriculture, it has negative effects on both crop quality and yields. Heavy metal accumulation is the result of disposal of concentrated metal wastes by industries. Extensive research has lead to the finding of various processes for treatments of contaminated soils; of which pioneering is Mycoremediation (also called fungal treatment or fungal-based technology) is the application of fungi in remediation of polluted soils and aqueous effluents. The fungi mostly used are wood-rot Basidiomycetes capable of degrading lignin (ligninolytic fungi). Most of these fungi cause white rot of wood, and so they are often called white-rot fungi (WRF). The concept of mycoremediation has come from the primary role of fungi in the ecosystem, which is to decompose. The key to mycoremediation is to determine the right fungal species to target a specific pollutant. Some fungi are hyperaccumulators, capable of absorbing and concentrating heavy metals in the mushroom fruit bodies. The filamentous fungi are known to possess higher adsorption capacities for heavy metal removal. Aquatic fungi have also been found to accumulate heavy metals. Given the present day's circumstances, if techniques, as discussed, are employed, it is possible to give pollution control an all new face by using fungi to sequester or degrade contaminants like heavy metals.**

1. INTRODUCTION

Heavy metal pollution of soil is one of the most serious matters of concerns in the present days. In agriculture, it has negative effects on both crop quality and yields. Heavy metal accumulation is the result of disposal of concentrated metal wastes by industries. Extensive research has lead to the finding of various processes for treatments of contaminated soils; of which pioneering is Mycoremediation (also called *fungal treatment* or *fungal-based technology*), first coined by Paul Stamets [1] [10], is the application of fungi in remediation of polluted soils and aqueous effluents. It is a process of using of making use of fungi to reach a lesser polluted state of environment (usually soils, in this case).

Fungi are important decomposers in the natural environment. They create enzymes to degrade the cellulose and lignin (which give plants their structure) [10]. Similarly, fungi can also break down varioustoxic substances. Adjustments to local soil and water conditions can help in encouragingthe biological activity and the subsequent degradation/ removal of toxic substances through mycoremediation [9].

Organic compounds such as pesticides and petroleum products (in soil) can be degraded using fungi. Like lignin, these compounds are based on hydrocarbons. Enzymes from the fungal mycelia are able to removeatoms (Cl) from larger molecules [9], and then break hydrogen and carbon bond. As a result, mycoremediationis found effective in breaking down some chemicals like chlorinated pesticides, persisting in the environment. Furthermore, bacteria can help to degrade these compounds into final products, which are carbon dioxide (CO_2), water, and methane (CH_4).

Fungi have also proven to be useful in remediation of heavy metals, such as lead (Pb) and cadmium (Cd). Since these metals are already at their simplest state and are not to be degraded any further, fungi can extract them from soil (or water) and accumulate them in their tissues (mycelia or fruiting mushroom bodies). Mushrooms used for such purposes must be treated as hazardous waste after they are used in mycoremediation. [4] [9]. It has been suggested that edible mushrooms can be used formycoremediation tasks but their safety prospects (whether they would be safely edible or not) are to be carefully considered [3]. Though this depends on the nature of the pollutant, but heavy metals pose a greater danger, especially when they get accumulated in the fruiting body of the mushroom, while other organic contaminants might decompose without imparting much toxicity [3].

2. WHY FUNGI?

Fungi can rapidly ramify through substratesdue to presence of***mycelium*** [3].Penetration through *hypha* provides a mechanicalsupport for the chemical breakdown, affected by the secreted enzymes.The large surface area of the *filaments*, maximizes both, mechanical and enzymatic contact with the contaminated environment [4].The extracellular natureof the degradativeenzymes enables fungi to tolerate higher proportions of toxicants than when brought inside the cell.Insoluble compounds that cannot pass through the cell membrane are vulnerable to attack. Fungi are capable of even solubilizing low-rank coal, a complex polymeric substrate, though slowly.During secondary metabolism, relevant enzymes are usually induced by nutritional signalsindependent of the target compound [2]. Their action is independent of the concentration of the substrate and is able to act on chemically diverse substrates.

One of the primary roles of fungi in the ecosystem is to decompose, performed by mycelium. The mycelium secretes extracellular enzymes and acids that breakdown lignin and cellulose, the two main building blocks of plant fiber [8]. The key to mycoremediation is determining the right fungi species to target a specific contaminant [2].Some mushroom species are known to degrade several of these, while others are more selective.

The effectiveness of White rot fungi (WRS) in degrading a wide range of organic molecules is due to the release of extra-cellular lignin-modifying enzymes in them. They have low substrate specificity, so they can act upon various molecules similar to lignin [8]. Enzymes used in derading lignin are: Lignin-peroxidase (LiP), manganese peroxidase (MnP), various H_2O_2 producing enzymes and laccase[2] [8]. With the addition of carbon sources such as straw, sawdust and corn cob at contaminated sites, the degradation processes can be altered [1].

3. FEASIBILITY OF THE MYCOREMEDIATION TOOL

Many of mushrooms species from the forest area of Bucegi Mountains, consumed by the native population were reported to absorb concentrations of heavy metals [7]. From all the edible species, eight mushrooms were chosen, some of which considered edible and some not. Heavy metal concentration in the fruiting body of mushrooms were found to be different from one species to another and showed mean values of 11.94 mg/kg for Ti, 1.07 mg/kg for Sr, 1163.86 mg/kg for Bi and 17.49 mg/kg for Mn. The bioconversion factor of heavy metals representedthe level of metal concentrations in mushroom bodies, correlated with the metallic element in the soil on which the fungus grew, and was knownto have the highest values in *Marasmiusoreades* species for bismuth and titanium [7].

Hypholomacapnoides was found to have the highest concentrations of Ti, Sr and Mn, as compared to others. *Marasmiusoreades* species also hadcrucial values of bioconversion factors of Bi andTi in the fruiting body. Between the Ti, Sr, Bi, and Mn concentrations in the soil and theirs bioconversion factor in the fruiting body of mushrooms was a medium and low degree of correlation, with statistical significance difference ($p < 0.001$, and $p < 0.0001$).

O.D. Asiriuwa, J.U. Ikhuoria and E.G. Ilori[6] did studies in which mycoremediationwas used to assess the bioaccumulation potential of heavy metals- Cd, Zn, Cu and Pd, by mushroom for heavy metal contaminated soils. Results obtained revealed that mushrooms can effectively bioaccumulate heavy metals from metal-contaminated soil. Minimum and maximum concentration of Cu accumulation by mushroom was 10.60 and 41.80 mg/kg, respectively, with no amendment level,giving highest Cu accumulation concentration= 41.80 mg/kg. The bioaccumulation potential of Cd was the least. Cd concentration ranged from 3.90 to 17.90 mg/kg. It was observed that the amount of metal accumulation in the mushroom decreased with increase in amount of poultry dropping added to the soil. The study focusing on the bioaccumulation potential of heavy metals by WRF revealed the efficiency of WRF in remediating metal contaminated soil. The uptake of the heavy metals by the fungi was also found to have a relationship with concentration amendment added to the metal-contaminated soil [6]; which is of particular importance to mushroom pickers and consumers.

D. Damodaran, K. V. Shetty and B. R. Mohan [5] report the heavy metal remediation potential of *Galerinavittiformis*from *Strophariacea*family. This particular species was found to be effectively removing heavy metals- Cu, Cd, Cr, Pb and Zn, from the contaminated soils of Dakshina Kannada District, Karnataka, India, within a time period of 30 days. Both biological and chemical chelators at 1, 5 and 10 mmol/kg concentrations were found to increase the mycoremediation potential of the mushroom. The fruiting bodies of *G. vittiformis*were reported to accumulate higher concentrations of all the metals in consideration than in its mycelia. The efficiency of the process could be enhanced by addition of chelators like citric acid and gallic acid.

4. CONCLUSION

As discussed above, by the understanding of the mentioned studies, it can be concluded that several species of fungi/mushroom have been proven effective as mycoremediation tools. Studies have revealed that mushrooms can bioaccumulate heavy metals from metal contaminated soils. *Galerinavittiformis*has been found to efficiently remove heavy metals (Cu, Cd, Cr, Pb and Zn). *Marasmiusoreades* species has been found to accumulate heavy concentrations of bismuth and titanium. Also, *Hypholomacapnoides*, had the highest concentrations of Ti, Sr and Mn.

There is a need of even more extensive research and its implementation in this field, because mycoremediation is that tool which can give pollution control an all new face to sequester or degrade contaminants like heavy metals.

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