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11. Mycoremediation: An Eco-Friendly Approach for Sustainable Development

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11.1 Information:

An approach of mycoremediation is to clean up hazardous toxic substances from soils, groundwater and surface water by Appling biological organism. Bioremediation can be defined *as the efficient use of plants and microbs to remove, detoxify or immobilise environmental contaminants in a growth matrix (soil, water or sediments) through the natural biological, chemical or physical activities and processes of the plants and its associate rhizospheric* microorganism (Jadia and Fulekar (2009).

Fungi are unique organisms equipped with remarkable metabolic and absorption capabilities that can take up nutrients or contaminants selectively from the growth matrix of soil. When fungi used for bioremediation, it is some time called as mycoremediation or mycorestoration.

Mycoremediation is the use of fungi/mushrooms mycelia as tools to repair or restore the weakened or damaged environment. Mushroom mycelia can produce a group of complex extracellular enzymes which can degrade and utilize the lignocellulosic wastes in order to reduce pollution. It has been revealed recently that mushroom mycelia can play a significant role in the restoration of damaged environments.

Saprotrophic, endophytic, mycorrhizal, or even parasitic fungi/mushrooms can be used in mycorestoration, which can be performed in four different ways: mycofiltration (using mycelia to filter water), mycoforestry (using mycelia to restore forests), mycoremediation (using mycelia to eliminate toxic waste, and mycopesticides (using mycelia to control insect pests). These methods represent the potential to create the clean ecosystem, where no damage will be left after fungal implementation (Stamets 2005). It is done by several ways such as-

11.2 Mushroom Cultivation:

Large scale agriculture release huge bulk of agriculture wastes as by-products. India produces about 350 million tonnes of agricultural waste per annum and a major part of it is burnt on field called as stubble burning. This traditional stubble burning practice contribute the emission of greenhouse gases (CO_2, N_2O, CH_4), air pollutants (CO, NH_3, NOx, SO_2, NMHC, volatile organic compounds), particulates matter and smoke thereby poisoning threat to human health (Jain *et al.* 2014). Fungal mycelia produce a group of complex extracellular enzymes that are used for decomposing lignocellulosic agro wastes for restoration of damaged environment with extraction of valuable industrial and pharmaceutical important chemicals and mushroom as nutrient rich food through the process of mycorestoration. Mycorestoration is defined as the use of fungi to prevent, reduce, repair, restore and ameliorate the negative impacts of chemical and biological pollutants.

11.3 Reclamation of Soil:

Addition of spent mushroom substrate (after harvesting of mushroom as crop through the process of mushroom cultivation technology) in soil will help to improve soil health by improving its texture, water holding capacity, nutrient status and increase organic carbon content. The phosphorus and potassium requirements of crop plants can be fulfilled by addition spent mushroom substrate into the soil.

11.4 Agriculture

One of the main uses of spent substrate is as organic fertilizer and soil conditioner in agriculture and horticulture. It serves as supplier of both organic matter, which improves soil structure and as a source of macro and micro elements for plants nutrition. The spent mushroom substrate being rich in N, P and K acts as a good growing medium for vegetables such as cucumber, tomato, broccoli, tulip, cauliflower, pepper, spinach, etc.

11.5 Plant Disease Management:

The actinomycetes, bacteria and fungi inhabiting in the spent mushroom substrate does not only play a role in its further decomposition but also exert some antagonism to the soil borne pathogens. The organic amendment of soil with spent mushroom substrate helps in restricting the root knot infestation of tomato plant by *Meloidogyne incognita*. The extract from spent mushroom substrate also inhibits the conidial germination of *Venturia inaequalis* a causal agent of apple scab; *Cochliobolus carborum* causing disease on maize and *Sphaeropsis sapinea* causing disease on red pine.

11.6 Animal Feed and Fodder:

Mushroom spent substrate obtained after oyster mushroom cultivation can be reused further as cattle feed. Cellulose made available after oyster mushroom cultivation can act as energy source for animals as they have sufficient quantity of enzymes and microbes in rumen, which can degrade it further. The spent oyster mushroom can substitute about 30% of the total feed and fodder without affecting the growth of animals.

11.7 Biogas and Casing Material Production:

As indicated above, spent substrate obtained after oyster mushroom cultivation can be utilized as cattle feed, that generate cattle manure/dung can be used for producing biogas, and the sludge accumulated in biogas tank can be used as casing material for button mushroom cultivation.

11.8 Bioremediation:

In the area of environmental technology, harnessing of fungi in bioremediation of industrial effluents contaminated with heavy metals and other toxic substances is a major new development. Fungi have the ability to absorb heavy metals on their surface because of the charge on their cell walls. They are also able to bind metals because of their ability to produce certain metal binding peptides and proteins. They are also able to degrade complex carbon compounds such as pesticides by virtue of an array of enzymes they normally possess. This phenomenon of clean up contaminant from environment by using fungi is called as bioremediation or phytoremediation or mycoremediation. Fungi as potential treatment of contaminants began in 1985 when the white rot species *Phanerochaete chrysosporium* was discovered as strong potential for bioremediation in pesticides, PAHs, dioxins, carbon tetrachloride, and many other pollutants. Among fungal systems, *P. chrysosporium* has become the model for bioremediation. Other notable species of white rot fungi include *Pleurotus ostreatus* and *Trametes versicolor*. Some potential fungal species with heavy metal tolerance (.i.e. absorbed without its any harm used for bioremediation) are listed in Table 11.1.

Table 11.1: Fungal species with its heavy metal tolerance

Category	Scientific Name	Heavy Metal Tolerance .I.E. Absorbed Without Its Any Harm
Fungal species	*Phanerochaete chrysosporium*	Ni(II), Pb(II)
	Aspergillus niger	Cd
	Aspergillus fumigatus	Ur(VI)
	Aspergillus terreus	Cu
	Penicillium chrysogenum	Au
Yeast species	*Saccharomyces cerevisiae*	Uranium, Cd, Methyl mercury and Hg (II)
	Kluyveromyces fragilis	Cd

11.9 References:

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2. Stamets P. 2005. Mycelium Running: How Mushrooms Can Help Save the World. Ten Speed Press, Berkeley, California.
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