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3. The Role of Mushrooms Cleaning the Pollutants in The Environment

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Abstract:

People have eaten mushrooms for centuries, because of their rich flavour and high protein content, but mushrooms are so much more than that. Fungi have a unique ability to degrade chemical pollutants such as oil and insecticides, as well as heavy metals and radiation. Fungi can able to filter water, sustaining countless life cycles that are beneficial to ecosystems. Mycoremediation is a remedial technology that uses fungi mycelium (the vegetative component of a fungus) in contaminated soil locations. A mushroom's enzymes are effective at breaking down a wide range of pollutants. This method is about employing fungi's natural capabilities of decomposition to restore and regenerate the land.

3.1 Introduction:

Because of heavy metal pollution, the world's most significant ecological issue is that natural resources like air, water, and soil have become scarce (Kour *et al.*, 2018; Ramya *et al.,* 2018). The governing council of the United Nations environment program issued a treaty in 2001 to stop or reduce the use and production of persistent organic pollutants (POPs). Synthetic organic compound pollution of the environment has grown to be a serious issue on a global scale. Due to their toxic effects on the environment and human health, the United States Environmental Protection Agency (USEPA) has prioritized several classes of chemicals that have been targeted by pollutants. The waste and effluents from homes and agricultural fields are deteriorating in an environment with poor management (Akhtar *et al.,*2020).

These substances include benzene, toluene, ethylbenzene xylene, trinitrotoluene, Penta chlorophenols, polychlorinated biphenyls, 1,1,1-trichloro-2 (4-chlorophenyl) ethane, and polycyclic aromatic hydrocarbons. Polycyclic aromatic hydrocarbons (PAH), which are produced by burning fossil fuels, mining coal, drilling for oil, and burning wood, are recalcitrant environmental pollutants (Lau *et al.*, 2003; Verdin *et al.*, 2004). DDT (dichlorodiphenyltrichloroethane) was one of the first synthetic pesticides that gained widespread use DDT (dichlorodiphenyltrichloroethane) was a wide gain to one of the first synthetic pesticides. DDT has been utilized for pest control in forestry and agriculture all over the world since the 1940s. One of the most widely used organochlorine pesticides was dichloro diphenyl trichloroethane (DDT).

Industries have proliferated like mushrooms around the globe as a result of increased commercialization, polluting the air, water, and soil with toxic chemicals and using excessive amounts of dangerous pesticides and insecticides in agriculture. Oil spills, tank leaks, and wastewater disposal all result in toxic pollutants like hydrocarbons entering the environment. Understanding how pollutants behave in natural settings and developing strategies for reducing or eliminating them are necessary due to the enormous amount of pollutants, their persistence and mobility in natural environments, and their frequent toxicity (O.M. Adedokun *et al.,*2005). To solve the issue, scientists are making a lot of effort.

The practice of bioremediation involves using biological processes to eliminate pollutants from the environment. Significant research in this area has been done with the help of bacteria that can degrade oil spills, like *Pseudomonas putida*. Many environmental researchers are interested in the capacity of fungi to degrade toxic pollutants and hydrocarbons. Fungi are heterotrophs, which means they absorb nutrients to sustain themselves. Exoenzymes, potent hydrolytic enzymes that the fungus secretes, break down food outside the body into simpler compounds that the fungus can absorb and use. The surface area and small volume of fungal hyphae increase the fungus' ability to absorb substances. Due to their capacity to break down organic materials to create extended mycelia networks and the low specificity of their catabolic enzymes, fungi can use pollutants as a growth substrate. They can thus be used in a variety of remediation contexts, some of which involve working with plants. Additionally, edible and/or therapeutic fungi have functions in nature (S.T. Chang *et al.,*1982).

3.2 White Rot Fungi (Mushroom):

Practical considerations include the availability of White rot fungi and the potential benefit of the bioremediation method because of its low cost and eco-friendly nature. Another bioremediation technology is quite different from the well-established white-rot fungi method. (For instance, the systems of bacteria. Due to the fact that most contaminated sites contain a variety of different pollutants, this feature makes using white-rot fungi in bioremediation the most advantageous (Mester *et al.,* 2000).

White rot fungi live on woody tissues that are primarily composed of three biopolymers: cellulose, hemicellulose, and lignin. Examining the ecological riches of white rot fungi is necessary to comprehend their capacity to degrade contaminants. Taxonomic classification of fungi that can thoroughly degrade the heterogeneous polyphenolic polymer lignin found in lignocellulosic substrates (Pointing *et al.,* 2001). The term "white rot" describes these fungi attacking wood, leaving the substrate looking bleached as a result of the removal of lignin. Although a few ascomycete genera in the family can also cause white rot decay, basidiomycetes make up the majority of white rot fungi (Eaton *et al.,* 1993).

Lignin is incredibly resilient and gives the plant its strength and structure. It undergoes mineralization in a strictly aerobic setting (Field *et al.,* 1993; Pointing *et al.,* 2001).The significance of lignin biodegradation is the destruct of the matrix, lignin creates which facilitates the bacteria' easier access to cellulose and hemicellulose, the real substrates (Field *et al.,* 1993; Canet *et al.,* 2001). The typical biological solution is to break down biopolymers using highly specific enzymes.

This method is typically very effective because the organism only produces a small amount of this substance. Lignin, which gives the plant strength and structure, is extremely resistant. It is mineralized in an obligate aerobic environment. The physiological significance of lignin biodegradation is the destruction of the matrix it forms, allowing the microorganism better access to the real substrates: hemicellulose and cellulose (Field *et al.,* 1993; Canet *et al.,* 2001). Protein (enzyme) quantity needed to cleave the polymer (Evans *et al.,* 2001). The typical biological solution is to break down biopolymers using highly specific enzymes.

However, because lignin is hydrophobic and highly insoluble, which complicates the catalysis by water-soluble enzymes, the way white rot fungi degrade wood differs (Harvey *et al.,* 2001). Randomly peroxidase-catalyzed polymerization of substituted p-hydroxy-cinnamyl alcohols produces lignin in plants (Field *et al.,* 1993).

This polymer is three-dimensional, with various ether and carbon-carbon bonds connecting its monomers, and its stereoregularity protects it from enzyme attack and the enzymatic degradation of lignin. lignin's chiral carbon which further complicates the situation because it exists in both L and D configurations. Plants cannot absorb or break down lignin because of its large molecular size.

3.3 Role Play of White Rot Fungi Enzymes:

Degrading fungi excrete ligninolytic enzymes into the extracellular environment, where they begin to oxidize substrates (Mester *et al.,* 2000). White rot fungi have developed very generic mechanisms to break down lignin extracellularly as a result (Bar *et al.,* 1994).

The three principal families of lignin-modifying enzymes thought to be involved in the degradation of lignin are laccases, lignin peroxidases, and manganese peroxidases (Reddy *et al.,* 2001). One electron is removed or added to the lignin molecule during the crucial step in the degradation of lignin by laccase the creation of intermediates by ligninolytic peroxidases (LiP and MnP Chemical's ground state (Reddy *et al.,* 2001).

Different enzymes are produced by various white rot fungi species according to their genetic makeup and growth circumstances. Key degrading enzymes include lignin peroxidase (LiP), manganese-dependent peroxidase (MnP), and laccase. The lignin degradation system of enzymes used by this group of fungi serves as the primary mechanism of biodegradation. These enzymes' ability to break down lignin and xenobiotics is well known (Lamar *et al.,* 1992; Vyas *et al.,* 1994). *Lentinula edodes* were DDT degradation in 7 days 29% were degraded and in 28 days 70% were degraded the *Lentinula edodes* (G. Prathima *et al.,*2023).

Environmental science mainly uses GC methods to identify organic pollutants in recent sediments, track the abiotic and biotic transformations of petroleum-type pollutants, and distinguish the oil pollutant from the native organic material of recent sediments.

This helps us better understand the mechanisms by which organic pollutants move between soil, water, and air environments, as well as during experiments on soil bioremediation. In the modern era, it is difficult to imagine an environmental laboratory using GC without at least a gas chromatograph (Wang *et al.,* 1999).

3.4 Bioremediation Properties of Mushrooms:

Fungi and their mycelial "root systems" help ecosystems by ingesting nutrients from the plant matter they decompose and redistributing them to other plants and trees. Fungi's natural function as super-charged decomposers and nutrient dispersers has served as the foundation of nearly all ecosystems. Oxalic acid, one of the enzymes produced by fungi, was thought to be the catalyst for the breakdown of minerals and rock that resulted in the calcium-rich soil that plants grow in (Stamets *et al.*,2016). Fungi are ideal agents to turn to for solutions to the problem of human waste and pollution because they consume difficult-to-breakdown substances. Fungi have been around for billions of years and have adapted to every type of environment imaginable.

Many fungi, for example, have evolved the ability to survive in the absence of sunlight (something plants are not able to do as of yet). As we will see**,** the highly adaptable nature of fungi makes them ideal agents for environmental healing**.**

Through mycoremediation, mushrooms can help to make amends for an environmentally damaged planet by using their natural powers of absorption, decomposition, and adaptation. Mycoremediation is defined as the use of mushrooms (the fruiting body of fungi) to remove waste from the environment (Kulshreshtha *et al.*,2014)."Clean technology" is a popular concept in today's world, where we are becoming more aware of climate change and environmental clean-up. It is an attempt to maximize production while simultaneously reducing waste generation, waste treatment, and waste conversion into some useful form.

3.4.1 Remediation of polluted water with fungi:

Without water, humans cannot survive. Because it hinders development, a lack of access to clean drinking water can keep people in poverty. Currently, 785 million people in the world lack access to clean drinking water. Additionally, 2 billion people lack adequate sanitation, which is highly dependent on access to clean and safe water (Reid *et al.*,2021). A type of bioremediation known as microfiltration uses fungi to break down pollutants in water before they reach larger bodies of water, helping to keep water sources clean.

3.4.2 Removal of Pollutants from the Chicago River of *E. coli:*

It has been demonstrated that the Oyster mushroom *Pleurotus ostreatus* could clean water by removing impurities from both soil and water (Scout *et al.*,2017). In an effort to reduce the pollution that has accumulated in the Chicago River water since the 1700s, one lab-based study looked into mycoremediation. Oyster mushroom mycelia were used to remove 99.25% and 99.74% of *E. coli* from lab-made infected water as well as water directly from the Chicago River over a 96-hour period (Pini *et al.*,2020).

3.4.3 Filtration of Farm Runoff Water:

Fungal filters, a mycelial network that functions as a micro-filtration system and releases enzymes that break down toxic contaminants, are now being used to treat contaminated farm run-off.

3.4.4 Toxic Wildfire Ash is Removed from California Water Supplies:

Wildfires are an environmental problem linked to contaminated water. Co Renewal, a company that specializes in mycoremediation, studied the toxic ash residue left behind by California wildfires in waterways and came up with solutions to clean up both the impacted soil and waterways. Asbestos, lead, arsenic, and plastics were found in dangerous concentrations in the toxic ash from wildfires. Installing hay bales filled with Oyster mushroom mycelium reduces these heavy metals, dangerous Polycyclic aromatic hydrocarbons (PAHs), and TNT.

3.4.5 Remediating polluted soil with fungi:

Industrialization causes heavy metals like lead, cadmium, nickel, chromium, arsenic, selenium, and others to contaminate the soil (Kumar *et al.*,2019). Through plants, animals, or other links in the food chain, toxins that are left to break down in the soil eventually make their way back to us. In the process of biosorption, biological materials serve as toxin absorbents. As was previously mentioned, the *Pleurotus* species, of which Oyster mushrooms are a member, produces a disproportionately large amount of mycelium compared to other species. Which gives it a remarkable capacity to absorb heavy metals and other petroleum wastes from the soil. This amplified.

3.4.6 Remediation of Diesel-contaminated land:

The one that had been sporulated with Oyster mushroom spores, had turned what had once been a contaminated wasteland into a thriving ecosystem and had biodegraded the most dangerous oil of all the plots. This experiment decreased the soil's PAH count, or the quantity of these frequently carcinogenic aromatic hydrocarbons, from 10,000 parts per million (ppm) to less than 200 ppm, in just eight weeks (Stamets *et al.*,2016).

3.4.7 Degradation of Plastics and Other Humans:

There would be an enormous amount of non-biodegradable plastic waste on the planet even if we stopped making plastic products right away. About 242 million tons of plastic waste was released onto the earth in 2016. Several Kingdom Fungal species, including *Pleurotus ostreatus* (Oyster Mushroom) (Kulshreshtha *et al.*,2014; Da Luz *et al.*,2013), *Trametes Versicolor* (Turkey Tail), (Jang *et al.*,2009) and *Lentinula edodes* (Shiitake) have been identified as having the ability to degrade plastics and PAHs (Tsujiyama *et al.*,2013).

3.5 Conclusion:

Mushroom is a tremendous boon to the idea of using this for the bioremediation process as a real-world solution. The cultivation of edible mushrooms on agricultural and industrial wastes may thus be a value-added process capable of converting these discharges, otherwise considered wastes, into foods and feeds. Besides producing nutritious mushrooms, it reduces the genotoxicity and toxicity of mushroom species. Bioremediation through mushroom cultivation will alleviate two of the world’s major problems i.e., waste accumulation and the production of proteinaceous food simultaneously.

Thus, there is a need for further research on the exploitation of the potential of mushrooms as bioremediation tools and their safety aspects for consumption as a product.

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3.7 References:

1. Kour, J., Chauhan, PK, Dulta K. (2018). Isolation, characterization, and identification of microorganisms from distillery effluent contaminated soil and ex-situ bioremediation of contaminated soil. Biological Forum – An International Journal, 10(1): 101-110.
2. Ramya, R., Boominathan M. (2018). Bioremediation of heavy metal using growing cells in industrial effluent. *International Journal of Theoretical & Applied Sciences*, 10(1),100-105.
3. Akhtar, N., Amin-ul, Mannan M. (2020). Mycoremediation: Expunging environmental pollutants. Biotechnology Reports, 26, -00452.
4. Lau, KL, Tsang Y, Y SW, Chiu SW. (2003). Use of spent mushroom compost to bioremediate PAH- contaminated samples. Chemosphere,52,1539-46.
5. Verdin, AA, Sahraoui L-HR, Durand R. (2004). Degradation of benzo(a)pyrene by mitosporic fungi and extracellular oxidative enzymes. Int Biodeterior Biodegr,53, 65-70.
6. O.M. Adedokun, A.E. Ataga. (2005). “Effects of Crude Oil and Oil Products on Growth of Some Edible Mushrooms”. Journal of Applied Sciences & Environmental Management, Vol 10 No. 2 pp. 91-93.
7. S. T. Chang, P. G. Miles (1982). “Introduction to mushroom science”. In Tropical Mushrooms-Biological Nature and Cultivation Methods, S. T. Chang and T. H. Quimio, the Chinese University Press, Hong Kong, pp. 3-10.
8. Barr D, Aust S. (1994). Mechanisms white rot fungi use to degrade pollutants. Environmental Science Technology; 28 (2): 78-87.
9. Canet, R., Birnstingl J., Malcolm D, Lopez-Real J, Beck A. (2001). Biodegradation of polycyclic aromatic hydrocarbons (PAHs) by native microflora and combinations of white-rot fungi in a coal-tar contaminated soil. Bioresource Technology; 76: 113-117.
10. Eaton, R. and Hale M. (1993) Wood, decay, pests, and prevention. Chapman and Hall, London.
11. Evans, C. Hedger J. (2001). Degradation of cell wall polymers. In Fungi in bioremediation. Gadd G. Ed Cambridge University Press. Cambridge, U.K.
12. Field, J., Jong E., Feijo-Costa G. and Bont J. (1993). Screening for ligninolytic fungi applicable to the biodegradation of xenobiotics. Trends in Biotechnology; 11: 44-49.
13. Harvey, P. Thurston C. (2001). The biochemistry of ligninolytic fungi. In: Gadd G. (Ed.) Fungi in bioremediation. Cambridge University Press. Cambridge, U.K.
14. Mester, T., Tien M. (2000). Oxidation mechanism of ligninolytic enzymes involved in the degradation of environmental pollutants. International Biodeterioration & Biodegradation; 46: 51-59.
15. Pointing, S. (2001). Feasibility of bioremediation by white-rot fungi. Applied Microbiology and Biotechnology; 57: 20-33.

16. Reddy, C., Mathew Z. (2001). Bioremediation potential of white rot fungi. In. Gadd G. (Eds.) Fungi in bioremediation. Cambridge University Press. Cambridge, U.K.
17. Lamar, RT. (1992). The role of fungal lignin-degrading enzymes in xenobiotic degradation. Biotechnology,3, 261-266.
18. Vyas, BRM., Bukowski S., Sasek VM., Matuchas M. (1994). Degradation of anthracene by selected white-rot fungi. FEMS MicrobiolEcology,14, 65-70.
19. Prathima, G. Vidya Prabhakar K. (2023). Environmental Bioremediation of DDT-Contaminated Soil by Using the Mushroom Extract of *L. edodes*. Current Trends in Biotechnology and Pharmacy Vol. 17 (1) 603 - 608, Jan 2023, ISSN 0973-8916 (Print), 2230-7303 (Online)10.5530/ctbp.2023.1.
20. Wang ZD, Ingas M, Page D. (1999). Oil Spill Identification. J f Chromatograph.,843: 369–411.
21. Stamets, P. (2016). *How Mushrooms Can Clean Up Radioactive Contamination – An 8 Step Plan.* Permaculture magazine.
22. Kulshreshtha, S, Mathur N, Bhatnagar P. (2014). Mushrooms as a product and their role in mycoremediation. *AMB Express*.4:29. Published 2014 Apr 1. doi:10.1186/s13568-014-0029-8.
23. Reid, K. (2021). *Global water crisis: Facts, FAQs, and how to help*. World Vision.
24. Smout, B. (2017). *Oyster mushroom (Pleurotus ostreatus) water filter for removal of sediments and atrazine*. Warren Wilson College.
25. Pini, A.K., Geddes, P. (2020). Fungi Are Capable of Mycoremediation of River Water Contaminated by *E. coli*. *Water Air Soil Pollut* 231, 83. *Mycoremediation Services*. MycoLogic.(n.d.)
26. Kumar, A. (2019). Fungal Phytoremediation of Heavy Metal-Contaminated Resources: Current Scenario and Future Prospects. In: Yadav A., Singh S., Mishra S., Gupta A. (eds) Recent Advancement in White Biotechnology Through Fungi. Fungal Biology. Springer, Cham.
27. Jang, K.Y, Cho S.M, Seok S.J, Kong W.S, Kim G.H, Sung J.M. (2009). Screening of the biodegradable function of indigenoulingo-degrading mushrooms using dyes. *Mycobiology.* 4:53–61. doi: 10.4489/MYCO.2009.37.1.053
28. Da Luz, J.M.R., Paes S.A., Nunes M.D., da Silva M.C.S., Kasuya M.C.M. (2013). Degradation of Oxo-Biodegradable Plastic by *Pleurotus ostreatus*. *PLoS ONE.* 4(8):69386.
29. Tsujiyama S., Muraoka T. (2013). Takada N. Biodegradation of 2,4-dichlorophenol by shiitake mushroom (*Lentinula edodes*) using vanillin as an activator. *Biotechnol Lett.* 4:1079–1083.1.