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Article Review: Role of Fungi in Treating Climate and Environment of Pollution

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Abstract : One of the most difficult issues facing humanity in the twenty-first century is climate change and the ensuing environmental degradation. Anthropogenic activities are the primary cause of climate change, which has several facets and leads to global warming and weather variations by increasing greenhouse gas concentrations in the atmosphere. where using fungi's natural metabolic skills to break down and detoxify a variety of contaminants offers a viable and sustainable way to combat environmental degradation. Laccases, peroxidases, and hydrolases are just a few of the many enzymes that fungi possess that enable the breakdown of heavy metals, complex organic compounds, and xenobiotics into less toxic forms. This review sheds light on the possible uses of extremophilic fungi in initiatives to mitigate climate change.

Keywords: Contaminants, Climate Pollution , Fungi , Bioremediation

Introduction

Microorganisms are essential for cleaning soils and surroundings. A promising technique called mycoremediation uses fungi to break down or change toxic materials into less toxic or non-toxic forms. Mycoremediators include a variety of fungal species, such as Rhizopus arrhizus, Phanerochaete chrysosporium, Phanerochaete sordida, Trametes hirsuta, Trametes versicolor, Pleurotus ostreatus, Lentinus tigrinus, and Lentinus edodes (1). Because of their great degree of flexibility and ability to change their shape in reaction to unfavorable or unfavorable circumstances, fungi are extremely successful soil residents (2).

Large-scale production, usage, and application of pesticides, heavy metals, plastic polymers, medicines, and personal care products (PPCPs) are the main causes of emerging pollutants. These substances are made to meet the increasing need for a higher quality of life, health and strategies to guarantee a supply of food and materials for an expanding human population. However, there is frequently significant waste generation associated with their production and use. Mitigation measures do not parallel this. These frequently resistant products/compounds have found their way into and poisoned almost every ecosystem on Earth through groundwater, rivers, air, and ocean circulation (3,4).

The approach currently referred to as bioremediation (5) looks at the fungal destruction of xenobiotics as an efficient way to remove harmful contaminants from the environment.

In order to effectively detoxify contaminated soil and habitats with less chemical, resource, and time inputs, mycoremediation is advised. (6).

Mycelium aims to decompose organic pollutants. Research has shown that fungi are effective in breaking down contaminants like polycyclic aromatic hydrocarbons, PCBs, and oil spills. (7).

Methods

1. *Study Framework*
   - This research uses a literature review approach to explore fungi's potential role in environmental remediation.
   - Primary focus: the mechanisms by which fungi degrade or neutralize pollutants such as heavy metals, organic compounds, and plastics.
2. *Research Questions*
   - What fungal species are most effective in bioremediation?
   - Which enzymes are involved in the degradation process?
   - What conditions optimize fungi-based remediation techniques?
3. *Data Collection*
   - Primary Sources: Peer-reviewed articles, experimental data, and case studies on fungi and bioremediation
   - Secondary Sources: Books, reports, and reviews detailing fungi's roles in ecosystem recovery.
4. *Experimental Validation*
   - Selection of Fungi: Laboratory studies using fungi such as Phanerochaete chrysosporium and Aspergillus niger.
   - Pollutant Targeting: Focus on heavy metals, dyes, plastics, and hydrocarbons.
   - Measurement Metrics: Reduction in pollutant concentration and toxicity.
5. *Biochemical Analysis*
   - Enzyme identification and activity assays for ligninolytic enzymes (laccase, peroxidases) to determine their role in pollutant breakdown.
   - Analysis of by-products to confirm non-toxic degradation.
6. *Data Analysis*
   - Comparative effectiveness of fungal species under varying environmental conditions.
   - Correlation between enzyme activity and pollutant degradation rates.
7. *Limitations and Ethical Considerations*
   - Ethical use of fungal species, including non-invasive collection methods.
   - Consideration of ecological impacts in large-scale remediation applications.

Result and Discussions

Fungi and environmental pollution

Fungi are extremely diverse organisms that play a variety of roles in nature, economy, environmental and food science, and health. Among other things, they are involved in the weathering of soil minerals, the decomposition of organic matrices, and the recycling of substances (8). Over the past two decades, many mycologists have studied the potential of various fungal species to degrade organic compounds. The discovery of the white-rot fungus Phanerochaete chrysosporium has greatly advanced mycoremediation research throughout the world. "Mycoremediation", a combination of "myco" (mushroom) and "remediation" (clean, dissolve, or correct), involves the use of fungi, especially mushrooms, to produce low-tech biomass that can effectively eliminate industrial and environmental pollutants (9).

Fungal & Basic principles of bioremediation

Bioremediation is a creative and optimistic technology that can be used to remove and reduce heavy metals in from contaminated water and soil (10). Bioremediation is considered the most basic and reliable method to eliminate pollutants, especially petroleum and its recalcitrant persistent components, because it is based on the metabolic power ability of microorganisms.

(Fig. 1). Microorganisms are an important part of heavy metal bioremediation (11)

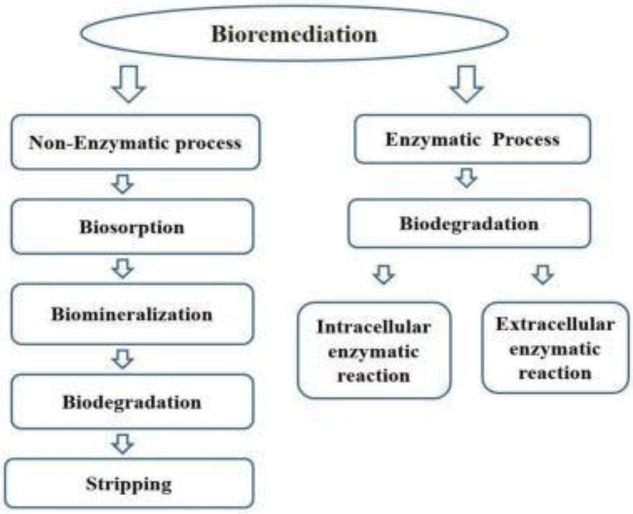

Fig. 1. Bioremediation mechanism

Biological Interventions Based on Fungi for Sustainable Environments

Fungi possess the remarkable capability to break down organic matter, a crucial skill that facilitates the creation of environmentally sustainable technologies (Figure 2). Numerous organic materials, including wood, paper, and textiles, can be biodegraded by the diverse fungi found on our planet. This decomposition process plays a vital role in the natural cycling of nutrients within ecosystems, making it possible to incorporate it into waste management and recycling strategies to lessen the environmental impact of waste. For nearly a century, mushrooms have been utilized in biotechnology. Materials derived from mycelium can serve as substitutes for textiles, leather, and even specific polymers. By transitioning from petroleum-based materials to those derived from mycelium, we could significantly mitigate plastic pollution. In laboratory settings, researchers have also identified and employed fungi capable of degrading plastics. Additionally, research indicates that enzymes sourced from basidiomycetes can effectively break down plastics (12, 13, 14).

In recent years, researchers from many fields have been working together to develop composite materials from agricultural and forestry waste.

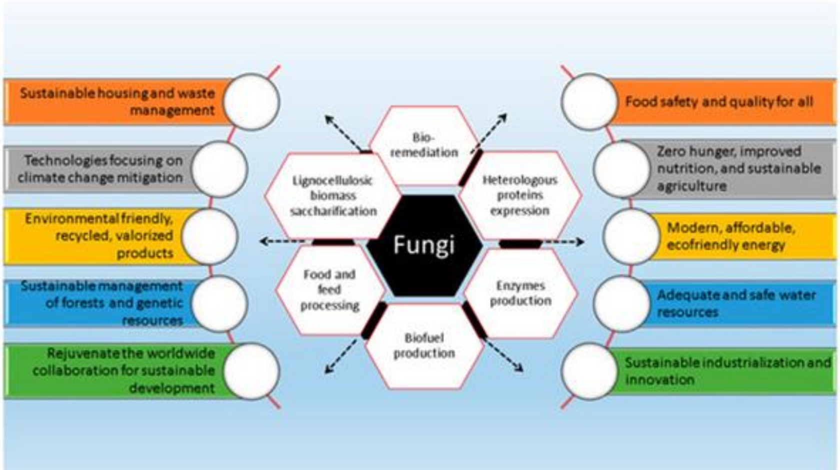

Figure 2. Biotechnological applications of fungi and their contribution to United Nations' sustainable development goals.

Mycoremediation

Mycoremediation is the process which utilizes fungi to eliminate poisons from various environmental components, either alive or dead (15).Mycoremediation is a cheap procedure that doesn't create any hazardous waste. The effectiveness of mycoremediation is dependent on the selection and use of an appropriate fungus species for the target heavy metal or other pollutant. This can be a viable and cost-effective answer to the problem of soil and water contamination (16).

Mycoremediation is a bioremediation process that uses fungi to eliminate harmful compounds; it can be performed in the presence of both filamentous fungi (molds) and macrofungi (mushrooms). As a result, mycoremediation can be used as a biological instrument for pollutant degradation, transformation, or immobilization (17).

Bioremediation of different pollutants using fungi

A. Bioremediation of heavy metals

Fungi like *Trichoderma harzianum* and *Aspergillus niger* play a significant role in the bioremediation of heavy metals, primarily because they can secrete organic acids that chelate these metals, aiding in their extraction. *A. niger*, for instance, generates citric acid, which effectively solubilizes metals such as lead and cadmium, transforming them into less harmful forms that can be immobilized or precipitated from the environment. Under laboratory conditions, *A. niger* has demonstrated the capability to decrease cadmium concentration by as much as 87% within a span of 14 days. (18,19).

In addition to lowering the metals' toxicity and bioavailability, this process stops them from migrating further into the environment. Fungi's capacity for heavy metal detoxification is further enhanced by their ability to bind heavy metals to their cell walls using functional groups such as carboxyl, amino, and hydroxyl groups (20).

The overall effectiveness of remediation can be increased by the mycelial network of fungi's ability to simultaneously degrade organic pollutants and immobilize heavy metals. (21).

B. Bioremediation of dyes

Through enzymatic action, fungi such as *Pleurotus ostreatus* and *Trametes versicolor* are known to decolorize and destroy synthetic dyes. Lactase and manganese peroxidase are two examples of enzymes that break down the intricate structures of dyes, rendering them non-toxic. *T. versicolor*, for example, can break down 90% of Reactive Black 5 dye in just 7 days. (22).

Advantages of fungal bioremediation

Because of their special biological and ecological traits, fungi have a number of clear benefits over bacteria in the bioremediation of contaminants. Because of these benefits, fungi are very useful for addressing a variety of pollutants in a range of environmental settings.

A. Adaptability to extreme conditions

Due to their high degree of adaptability, fungi can flourish in environments with extreme pH, temperature, and moisture levels where bacterial activity may be restricted. Fungi such as *Aspergillus niger* and *Penicillium chrysogenum*, for example, can thrive in alkaline conditions with a pH of up to 11 and in extremely acidic conditions with a pH as low as 2 (23). Because of their versatility, fungus can thrive in settings that are unsuitable for many bacteria, like alkaline industrial waste locations or acidic mine drainage sites.

B. Enzymatic diversity and efficiency

Numerous enzymes found in fungi are capable of breaking down a broad spectrum of contaminants. These include ligninolytic enzymes that may break down complex organic compounds, such as lactases, peroxidases, and oxidoreductases. For instance, lignin and a variety of xenobiotic substances, including as polycyclic aromatic hydrocarbons (PAHs) and chlorinated phenols, can be broken down by extracellular enzymes produced by white-rot fungus such as Phanerochaete chrysosporium (24).Because of their diverse range of enzymes, fungus are able to break down difficult-to-break down contaminants that bacteria cannot.

C. Versatility in bioremediation applications

Fungi are versatile and can be used in various bioremediation applications, including soil, water, and air decontamination. They are effective in both in situ and ex situ remediation strategies. In situ applications involve the direct treatment of contaminated sites, where fungi are introduced to degrade pollutants on site. Ex situ applications involve the removal of contaminated material to a controlled environment for treatment. For instance, fungi have been used successfully in bioreactors to treat wastewater contaminated with dyes and heavy metals, achieving significant reductions in pollutant concentrations (25).

D. Symbiotic relationships

Fungi often form symbiotic relationships with plants, which can further enhance bioremediation processes. Mycorrhizal fungi, for example, associate with plant roots and facilitate the uptake and translocation of nutrients, including degraded pollutants. This symbiosis not only supports the health and growth of plants in contaminated soils but also enhances the overall efficiency of the bioremediation process by extending the degradation capabilities of the fungi through the root network of the plants (26).

Precipitation reactions

Fungi can induce precipitation reactions by converting soluble metal ions into insoluble forms. For instance, fungi can secrete organic acids that react with metal ions to form metal oxalates or phosphates, which precipitate out of solution. *Aspergillus niger* has been documented to facilitate the precipitation of lead as lead oxalate, effectively removing it from contaminated media (25).

Enzymatic degradation

Fungi secrete a variety of enzymes, including laccase and manganese peroxidase, which can degrade complex organic pollutants. These enzymes break down the molecular structures of pollutants such as polycyclic aromatic hydrocarbons (PAHs) and synthetic dyes into simpler, less harmful compounds. For example, Phanerochaete chrysosporium secretes ligninolytic enzymes that degrade lignin and PAHs through oxidative cleavage, leading to significant reductions in pollutant concentrations (26,27).

Conclusion

An inventive and ecologically conscious approach to environmental cleanup is provided by fungal bioremediation, particularly Mycoremediation. When it comes to understanding their mechanisms and cleaning up contaminated locations, fungi have demonstrated a tremendous deal of promise and potential. Mycoremediation is a flexible, economical, and ecologically benign method of eliminating a range of pollutants, including pesticides, heavy metals, hydrocarbons, and more, by utilizing the unique metabolic abilities of certain fungi. Fungi's ability to transform complicated contaminants into simpler, less dangerous forms or into components that are easier for other species to break down shows how effective this method is. The fungi's adaptability and resistance in a range of environmental circumstances further supports mycoremediation's potential wide use.

Mycoremediation has great potential, but there are still a few obstacles to overcome, such as differences in effectiveness depending on the environmental conditions, the pollutants being treated, and the type of fungal species used. In the end, mycoremediation is an inventive, long-term, and developing approach with tremendous potential for environmental restoration, providing hope for the cleanup of polluted sites while reducing ecological damage. Mycoremediation has the potential to significantly contribute to the mitigation of environmental pollution and the promotion of healthier, more balanced ecosystems.

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