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by Sanaul Haque

REDUCING PLASTIC POLLUTION BY UTILIZING THE PLASTIC DEGRADING CAPABILITY OF FUNGI IN A NATURAL ENVIRONMENT

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ABSTRACT

Our planet is slowly decaying, pollutions being the very cause of it. Soil and water have been intensely polluted by plastic, which is one of the major problems for our environment. With an attempt to save the earth naturally by reducing plastic pollution, fungi have been researched and tested. The bioremediation technique which uses fungi to clean a contaminated environment is called mycoremediation.

INTRODUCTION

It is the nature which nurtures us but it is us who are destroying it. Environmental pollution is devastating and destructive, causing imbalance in nature and natural phenomenon. Plastic pollution is one of the greatest concern of today's world [1]. Taking hundreds to thousands of years to decompose due to its strong, stable bonds, it is very difficult to solve this problem. Plastic is not something nature recognizes due to its synthetic mixture of chemicals and microbes does not have enzymes strong enough digest it. As plastic is water resistant, it does not absorb much water, making it a hostile environment for microbes to thrive. Thus, a single plastic bag sits in a landfill for ages as everything else rots. Plastic is toxic to living beings. Over time, big chains of plastic might break down into micro or nano plastic which may enter the bloodstream or DNA of living beings causing damage to their biological flow of life [2]. Plastic creates obstacles in the life of aquatic and terrestrial animals, often entangling and suffocating them, leading to their death. The animals may consume plastic thinking it as food resulting in choking or feeling full, ultimately death [3]. Moreover, if plastic enters the basic tropic level of food web, it ultimately reaches the apex, harming an entire web of consumers [4]. And the problem only gets bigger when the amount of managed plastic is far less than the amount produced in a single day. Lifecycle of plastics add to the greenhouse gas emission further contributing to global warming [5].

To conserve nature, we need natural remedies for plastic pollution. This brings us to mycoremediation. 'Myco' comes from the Greek word 'Mykes' which means fungus while 'Remediation' typically means to fix, to clean up. So, using fungi to clean up environmental pollution is basically mycoremediation. Fungi are incredibly versatile, ecologically essential, and biologically unique organisms**.** Structurally, fungi are made up of hyphae, which are long, thread-like filaments that form a network called a mycelium. Unlike plants, fungi cannot perform photosynthesis because they lack chlorophyll; instead, meaning they obtain their food by absorbing nutrients from organic matter. They do this by secreting enzymes that break down complex substances into simpler molecules they can absorb. This mechanism 2 of theirs is what makes them unique. The enzymes secreted from mycelium of different fungi has the ability to break down different kinds of complex pollutants like plastic, making them of wider range as nature's clean up crew. They can also enhance soil health by recycling organic material while breaking down harmful chemicals.

In this study, I aim to explore the use of fungi, specifically mushroom to clean up polluted soil in a natural environment. For carrying out the research successfully, a contaminated site is to be selected. Then based on the type of contaminant present in the soil, the mushroom is selected. We have to bear in mind that a certain type of mushroom can breakdown a specific contaminant which can be a possible challenge. So, a thorough research is to be done beforehand for identifying both the contaminant and mushroom. As the contaminant I aim to degrade is plastic, study on which type mushroom can breakdown which kind of plastic needs to be done first. Then we can proceed to planting mushrooms and supplying necessary nutrient and constant monitoring for successfully carrying out the research.

LITERATURE REVIEW

Mycoremediation still remains bound within laboratory experiments. Researchers found that fungi, especially those that produce lignin-degrading enzymes such as laccase and manganese peroxidase, are very effective at breaking down stubborn organic pollutants like PAHs, pesticides, and synthetic dyes. But the effectiveness of fungi depends on factors like pH, temperature, nutrient availability and presence of heavy metals, which can inhibit fungal growth and enzymatic production [6]. Mycoremediation is being studied as a way to break down microplastics. Fungi such as *Aspergillus* and *Pleurotus* can grow on plastic surfaces and use their enzymes to start breaking the polymer chains [7]. Using agricultural or industrial waste such as straw or sawdust as a growth base for fungi (solid-state fermentation) can reduce the cost of mycoremediation while also helping manage waste [8]. Introduced fungal strains also struggle to survive and stay active in unfamiliar soils because they compete with native microorganisms [9]. Understanding the speed of mycoremediation under different conditions is crucial for assessing whether it can be a practical alternative to conventional treatment methods [10]. Systems biology approaches such as combining genomics, transcriptomics, proteomics and metabolomics are important for fully understanding how fungi react to and break down pollutants [11]. Fungal mycelial networks help shape soil structure and create zones of high microbial activity but contamination can damage these networks. [12] Nonetheless, there is a noticeable absence of data sourced from direct natural experimentation and observation. Tackling this challenge requires planting fungi in a contaminated area and observing it while providing necessary nutrients and keeping them healthy.

METHODOLOGY

Fungi are natural decomposers, and exploring their potential will help use to fight plastic pollution. Some fungi produce powerful enzymes such as laccases, peroxidases, and esterases, that can break apart the tough chemical structures of certain plastics. These enzymes cut long plastic polymer chains into smaller pieces, which other soil microbes can then further degrade. The following steps need to be applied to utilize fungi to clean plastic contaminated soil.

1. **Defining the Project's Goals:**

Before starting, it is important to set a clear plan. The first step is to identify the specific type of plastic to target—such as polyethylene (PE), polypropylene (PP), or microplastics. Each plastic has a different chemical structure, which affects the choice of fungi and the overall treatment strategy.

The next step is deciding whether to treat the soil on-site (in-situ) or remove it for treatment elsewhere (ex-situ). In-situ treatment is usually cheaper but slower and offers less control over conditions. Ex-situ treatment, such as using bioreactors or specially built compost piles, allows better control but is more expensive and harder to manage.

2. **Assessing the Site and the Plastic:**

Understanding the contaminated site is critical for success. This includes mapping the spread of plastic pollution both above and below the surface. It is also important to examine soil properties—such as texture, pH, moisture, and nutrient levels—and check for other contaminants like heavy metals that might limit fungal growth.

Accurately measuring the amount of plastic in the soil is essential. This involves identifying particle sizes, from large pieces to microplastics, and using tools like Fourier-transform infrared (FTIR) or Raman spectroscopy to confirm the plastic type. Checking the soil's existing microbial community also provides a useful baseline for tracking the project's progress.

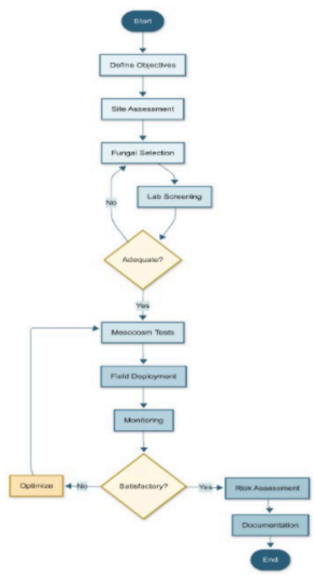

Figure 1: Flowchart Diagram of the Methodology

3. **Selecting the Right Fungi:**

The next step is to identify the most promising fungal candidates. A good starting point is fungi already found in plastic-polluted areas, such as landfills or industrial sites, since they may have naturally adapted to breaking down plastics.

Several species have shown potential in laboratory studies, including *Pleurotus ostreatus* (oyster mushroom), *Aspergillus niger*, and different types of *Penicillium* and *Trichoderma*. However, plastic-degrading ability can vary even within the same species. Using a combination of different fungi, or pairing fungi with bacteria, can sometimes improve plastic breakdown.

4. **Screening Fungi in the Lab:**

After selecting potential fungal candidates, they need to be tested in the laboratory through a step-by-step screening process.

- Initial Screening**:** Start with "clear-zone" assays. Fungi are placed on petri dishes containing plastic-based media. Those that can break down the plastic form a clear halo around their colonies.
- Enzyme Activity**:** Promising fungi are then tested for their production of plastic-degrading enzymes.
- Testing on Plastic Samples**:** The best candidates are incubated with actual plastic under controlled conditions. Success is measured by observing weight loss, chemical changes using FTIR, and smaller plastic molecules. The most conclusive evidence is the release of carbon dioxide, showing the fungi are truly metabolizing the plastic.

5. **Scaling Up to Mesocosms**:

Before applying fungi in the field, it is useful to run a trial in a mesocosm, a controlled outdoor experiment that simulates natural conditions on a smaller scale. This helps fine-tune the process, including the best way to introduce fungi to the soil and the ideal nutrient levels to support their growth and plastic-degrading activity.

6. **Deploying the Fungi in the Field**:

When ready, the selected fungi are introduced to the contaminated site. The method depends on the type of pollution: for surface contamination, fungi can be mixed into the topsoil, while deeper pollution may require more involved approaches, like setting up treatment beds.

7. **Monitoring Progress**:

It is important to regularly track the progress of the mycoremediation project. This includes taking soil samples to measure reductions in plastic content. Additionally, monitoring the health of the soil and surrounding ecosystem helps ensure that introducing the fungi does not cause unintended harm.

8. **Risk Assessment and Regulations**:

Before introducing non-native fungi into the environment, local regulations must be followed. It is preferable to use fungi native to the area whenever possible. A careful risk assessment should also be done to evaluate any potential negative effects on the local ecosystem.

CONCLUSION

To address the growing effect of plastic pollution, mycoremediation can be a better and natural alternative to the current treatments applied for the degradation of plastics. For that, the research and application of mycoremediation in natural environments is extremely necessary. Following the steps of methodology, a successful experimentation in a natural environment can be conducted. This will help us to understand what affects fungal growth, the rate and result of the process. Furthermore, due to being a completely natural method, mycoremediation is far more suitable for sustainability.

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