MYCOREMEDIATION OF SYNTHETIC DYES: A REVIEW

Abstract

Wastewater containing dyes, originating from industries like textiles, poses a grave environmental threat. Detoxifying these hazardous dyes is essential for environmental compliance. While physicochemical methods exist for dye removal, the harmful potential of chemical breakdown by products is a concern. The review delves into the intricate biochemical processes involved in mycoremediation, highlighting the role of fungal species (enzymes) in the degradation of complex dye molecules. The sustainability and versatility of mycoremediation are explored, alongside limitations like fungal specificity and potential slower kinetics. In conclusion, this chapter underscores mycoremediation's promise as an eco-friendly solution, emphasizing the need for further research and interdisciplinary collaboration to optimize its efficacy in environmental restoration.

Keywords: Dye, Environment, Fungi.

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I. INTRODUCTION

The ingredients that make up the synthetic collars are created in a lab. Metals might also be included in certain synthetic dyes. In 1856, William Henry Perkin developed mauveine (Figure 1), the first synthetic dye to be created by humans. The discovery of mauveine paved the path for the mass production of dyes of varying colours. Since then, many of dyes have been made, and the old natural dyes have been mostly phased out due to the far superior qualities conferred onto the coloured materials (*Buchanan and Rita., 1999*).

Figure 1: Dye Mauveine

(https://i0.wp.com/lilyabsinthe.com/wpcontent/uploads/2015/05/6233293ca7d59e6c175f596742cba93b.jpg?ssl=1)

Synthetic colours still may cause problems for both humans and the environment. People who deal with synthetic colours regularly are at risk of exposure to potentially dangerous chemical substances. Mercury, lead, chromium, copper, sodium chloride, toluene, and benzene are just some of the compounds that may be present in synthetic colours. Toxicity and severe consequences on the human body are possible with prolonged or excessive exposure to such compounds. (*Ali., 2010*).

II. IMPACT OF SYNTHETIC DYES ON THE ENVIRONMENT

Even at low concentrations, dyes have negative impacts on ecosystems. The release of coloured wastewater also includes other very harmful substances, which further exacerbates environmental issues. Dumping colours into water bodies, however, is known to reduce light penetration, raise oxygen consumption (biochemical and chemical), hinder photosynthesis, and stunt plant development. The health risks associated with synthetic dyes are many and serious. (*Ardila et al., 2021*).

Water visibility in the littoral zone is diminished, and sunlight is blocked from reaching the stream bed, due to the discoloration of the wastewater that is produced. Synthetic dyes include several chemicals, some of which are known to cause cancer and genetic mutations in humans, animals, and the environment. Dye effluents and aqueous wastes from the textile industry are both ecologically and aesthetically unpleasant since they persist for a long time and have a high biological oxygen demand (BOD) (*Wang et al., 2007*).

Industrial dyeing includes washing clothes with a dye solution. After dyeing a batch of cloth, vast quantity of water is needed to flush typical synthetic dyes off garments. This wastewater should be treated to remove heavy metals & other harmful compounds before being returned to water systems, sewers, & rivers. However, dumping dye effluent is cheaper than cleaning and reusing industrial unit water. Dye companies worldwide waste millions of tons of dye sewage into waterways. Toxic colours pollute air, water, and soil (*Samanta., 2011, Dawson., 2012*).

III. ROLE OF FUNGI IN DYE DEGRADATION

Due to the limited substrate range of the different degrading bacteria, the dye mineralization efficiency of traditional biological treatment approaches such activated sludge and biofilm systems was rather poor (*Yangn et al., 2009*). The use of so many novel dyes and additives in textile production processes in recent years has also contributed to the decline in efficacy of chemical and biological procedures, which now remove between 22 and 33 percent of colour, respectively (*Ahmad et al., 2015*).

There is evidence that the ligninases, manganese peroxidases, and laccases produced by a number of fungi may remove the colour from azo dyes. Degradation processes have been studied, and genuine mineralization to carbon dioxide has been shown, for several model dyes. In most situations, a reductive breakage of the azo link is the first step in the bacterial metabolism of azo dyes, leading to the synthesis of amines. Some aerobic bacteria have been studied for their ability to thrive on (quite simple) azo chemicals, and these bacteria's reductive mechanisms have been detailed (*Stolz et al., 2001*)**.**

Mawad et al., 2020 examined Anthraquinone and azo dyes are among the most harmful water contaminants. The study used bacteria and fungus to degrade Disperse Blue 65 & Acid Yellow 17 dyes. Pseudomoans aeruginosa and Aspergillus flavus were identified by 16S bacteria & ITS/5.8S rRNA gene sequences. Even at 300 mg/L, the fungal/bacterial consortium degraded dyes better than the strains. Azoreductase, the major catabolic enzyme, may be induced by both dyes by the consortium.

Decomposition of aromatic polycyclic hydrocarbons, a polychlorinated biphenyl combination, synthetic colours were investigated during this study to examine the effects of Mn-dependent peroxidase (MnP), lignin peroxidase (LPO), & laccase (LAC) in ligninolytic fungi cultivated in liquid medium & soil. Fixed cultures of the high degradative bacterium Irpex lacteus yielded 370-fold & 4-fold more MnP and LAC than immersed cultures. Investigative mycelium of Phanerochaete chrysosporium, & Pleurotus ostreatus growing on straw decomposed anthracene & pyrene in spiked soil, and the amounts of MnP and LAC secreted into the soil were shown to be relevant (*Novotny et al.,2004*).

IV. ENZYMATIC DEGRADATION OF SYNTHETIC DYES

Physical or chemical textile wastewater pretreatment procedures produce toxic sludge, are expensive, energy-intensive, and ecologically inefficient. The degradation of textile dyes by microorganisms presents an environmentally sustainable and potentially profitable alternative to conventional physico-chemical techniques. Microbial enzymes such as laccase and azoreductase present beneficial features including affordability, ease of the extraction

process, suitability for further processing, and mobilization abilities. The use of nanoparticle-microbial enzyme combines has demonstrated the potential to eliminate azo colour contaminants efficiently & expeditiously from textile waste (*Sarkar et al., 2017*).

V. BIOCHEMICAL PROCESSES INVOLVE IN MYCOREMEDIATION

The use of biochemical agents in contamination cleanup is a relatively new scientific method that has shown promise. In the scientific literature, the new bioremediation approach based on fungus is referred to as mycoremediation. *Koul et al., (2021)* focused on a range of substances including heavy metals, polycyclic aromatic hydrocarbons, phenols, chlorinated hydrocarbons, as well as new contaminants such as chemicals that disrupt the endocrine system & pharmaceutical-personal care products. Throughout the chapter, the primary mycoremediation fungal taxa have been highlighted. The biochemical, molecular, and physiochemical elements of mycoremediation (both in the lab and in the field) are important methods.

VI. FUNGAL SPECIES USED IN MYCOREMEDIATION

Mycoremediation in bioremediation is a new technique, yet several scientific papers have been published lately. Mycoremediation uses are shown in Soil spills, in vitro oil pollution, and other tiny spills may also be remedied (*Akpasi et al., 2023*). An ecosystem's nutrient recycling depends on fungi. They can metabolize organic and inorganic contaminants, utilizing them as energy and carbon sources and reducing them to safe quantities. Due to their high ligninolytic activity and mycoremediation performance, two main phyla, Basidiomycota, and Ascomycota, have been intensively studied for their pollutant degrading abilities. Fungal systems degrade polyaromatic hydrocarbons, pharmaceutically active chemicals, heavy metals, synthetic colours, poisons, and radionuclides. These contaminants degrade by bioaccumulation, biosorption, biomineralization, and biotransformation (*Shourie et al., 2022*).

Doratomyces nanus, purpureofuscus, verrucisporus, Myceliophthora thermophila, Phomaeupyrena, and Thermoascus crustaceus degraded biphenyl nuclei with more than seventy efficiencies. Dye is usually stubborn. These colours are harmful to human health. Sweat, light, water, oxidizing agents, and microbial action don't fade textile dyes. 15% of the world's textile dye output (800000 tons/year) is discharged into the process water (*Prakash et al., 2017*).

VII. FACTORS AFFECTING MYCOREMEDIATION

The fungi degradation of different hazardous dyes is influenced by a range of physico-chemical parameters, including but not limited to temperature, supplementation of different carbon & nitrogen sources, dye concentration, electron donor, pH, dye structure, and redox mediator (Fig.2) (*Rajhans et al., 2021*).

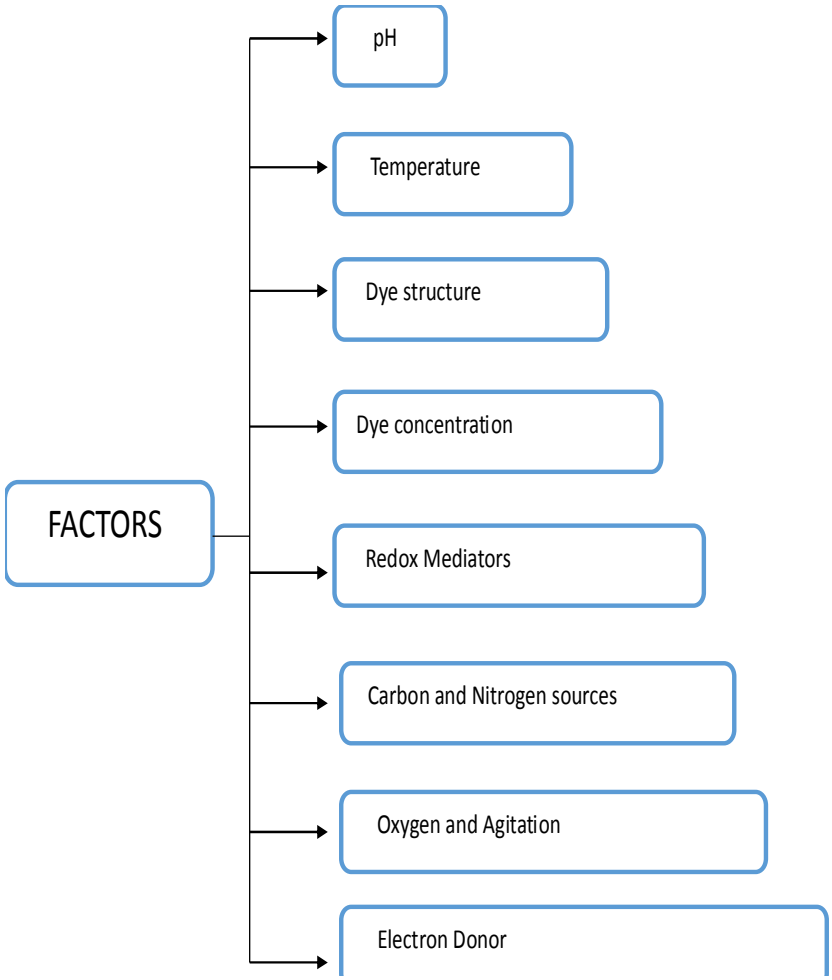

Figure 2: Factor Affecting Mycoremediation

1. **pH of Medium:** The medium's pH affects dye decolorization/degradation. Colour removal is best at neutral or somewhat acid pH (*Hefnavy et al., 2017*). Coriolopsis sp. degraded Ponceau 2R dye faster at pH 4.5 than at pH 5.0 *(Cheng et al., 2016).* During azo dye breakdown, the fungus generated acid, according to the scientists. *Aspergillus niger* and *Aspergillus flavus* breakdown dye as red in pH range of 3.1–6 (*Verma et al., 2019*).

2. **Temperature:** Various fungi need various temperatures to work well, hence temperature directly affects fungal decolorization/degradation. Ganoderma cupreum AG-1 decolorized azo dye reactive violet 1 better at lower incubation temperatures as 28–31°Celsius (*Ameen et al., 2021*). The best temp. level for dyes degradation by an Aspergillus strain was 33–37°Celsius (*Ameen et al., 2021*). However, fungal strains' enzymatic activity and polymeric dye decolorization were enhanced at 60–70°C (*Btanquez et al., 2019*).

3. **Structures & Amounts of Dyes:** Dye degradation capability is significantly influenced by structure and concentration. Dye-degrading fungi's enzymes may not detect low dye concentration. High dye concentrations are harmful to fungus and block enzyme active sites, affecting dye breakdown. Decolorizing dyes with a structure & low weight is also straightforward. However, high-molecular-weight, complex-structured dyes decolorize

slowly (*Li et al., 2019*). The increase in dye levels avoids dye degradation & decolorization (*Liu et al., 2017*).

4. **Carbon and Nitrogen Sources:** Dye wastewater decolorization improved using carbon supply. When rice bran was added to other carbon sources, *Phanerochaete chrysosporium* decolored synthetic textile dye effluent by 89.2% (*Kiran et al., 2019*). According *to Sweety et al. 2017,* the optimal N2 sources for fungi (*Trichoderma virens, Talaromyces stipitatus, and A. niger*) azo dye degradation was 1.7 percent & 0.4 percent ammonium sulphate & sodium nitrate.

5. **Redox Mediators (RMs):** The redox potential affects RM stimulation. Thus, electron shuttling molecule only work as redox mediator for azo dye decrease if it decreases reaction active energy. In a prior work, Trametes versicolor degraded Rhodamine B using seven RMs: vanillin, vanillic acid,4-nitrophenol, veratyl alcohol, (*Khammuang & Sarnthima, 2009*). ABTS decolorized Rhodamine B by more than 83 percent in 50 h, compared to 23 percent without the mediator.

6. **Agitation and Oxygen:** Aeration/oxygen supply depends on agitation. Reductive enzyme activity is thought to increase in anaerobic conditions (*Khan et al., 2012*). Utilizing same pH & temperature, agitation reduced decolorization percentages. The reaction of medium's agitation hindered decolorization (*Bettin et al., 2019*). However, *Kaushik and Malik 2009)* found that agitation boosted decolorization in fungal dye remediation trials.

VIII. ADVANTAGES OF MYCOREMEDIATION

1. **Mycoremediation in Cleaning Environment:** Bioremediation uses biological resources to breakdown hazardous/toxic pollutants into non-hazardous/nontoxic compounds and maintain a cleaner environment. Fungi degrade or remove contaminants from the environment in mycoremediation. Decomposers like fungi are vital. Fungi can break down polycyclic aromatic hydrocarbons, chlorinated aromatic chemicals, dyes, nitroaromatics, insecticides, and more. Fungi break down harmful hydrocarbon chains and complicated hydrocarbons into digestible forms (*Vijaya., 2018*).

2. **Mycoremediation for Petrol Contaminated Soils:** Certain fungal species are particularly resistant to contamination and capable of removing pollutants from soil. Alternata *fungal strains, aspergillus flavus, curvularia lunata, fusarium solani, mucor racemosum, penicillium notatum,* and *ulocladium atrum* were identified from contaminated gasoline and are utilized to degrade synthetic colours found in petroleum.

Dickson et al., (2019) concluded that for optimal utilization of mycoremediation of petroleum-contaminated soils, ideal environmental, edaphic, and climatic factors of a typical contaminated site must be incorporated into the approach from first principles. The study focused on the identification of chemicals and substrates used in mycoremediation for the purpose of remediating soils polluted with petroleum. Several strategies to address the challenges associated with mycoremediation in the context of petroleum-contaminated soils. The findings of research indicated that to achieve optimal mycoremediation of soils contaminated with petroleum, is essential to include the

relevant environmental, edaphic, and climatic attributes specific to a typical polluted site right from the outset.

3. **Mycoremediation in Agriculture:** Waste removal and treatment do not appear to remedy environmental deterioration and soil depletion. Thus, sustainable development requires alternate contamination remediation methods. Mycoremediation is recommended to detoxify contaminated soil and environment with fewer chemicals, energy, and time. To achieve agricultural sustainability, fungi as mycoremediators require substantial research (*Purohit et al., 2018*).

IX. LIMITATIONS OF MYCOREMEDIATION

However, mycoremediation is not without its limitations. One key challenge is the specificity of fungal strains for particular dye types. Different dyes require distinct enzymatic activities for breakdown, and not all fungi possess the necessary enzymes. Therefore, selecting the appropriate fungal species or strain for effective dye degradation becomes crucial, and extensive research is needed to identify suitable candidates (*Dutta et al., 2022*).

Additionally, mycoremediation may have slower kinetics compared to some physicochemical methods. The degradation process by fungi can be influenced by various factors, including environmental conditions (temperature, pH, humidity), nutrient availability, and the concentration of pollutants (*Danouche et al., 2021*). Consequently, the timeline for achieving significant dye removal may be longer, especially in situations with unfavorable conditions.

Furthermore, the scalability of mycoremediation can be a limitation in large-scale applications. Fungal growth and activity might be influenced by factors that are challenging to control in real-world settings (*Steffen et al., 2011*). This can impact the overall efficiency and reliability of the remediation process, potentially necessitating supplementary methods or longer treatment durations.

In conclusion, mycoremediation offers a promising approach to address synthetic dye pollution due to its effectiveness, versatility, and sustainability. Nevertheless, it is essential to carefully consider its limitations, such as fungal specificity, kinetics, and scalability, when implementing mycoremediation strategies for the removal of synthetic dyes. Balancing its advantages with these challenges will be crucial for maximizing its potential in mitigating dye pollution and promoting environmental health.

X. CONCLUSION

As we conclude this chapter, it becomes evident that mycoremediation offers a promising avenue for addressing synthetic dye pollution, presenting a compelling alternative to traditional remediation methods. By carefully weighing its advantages and limitations, we can chart a course towards a more sustainable future, where the intricate synergy between fungi and contaminants unlocks innovative solutions to pressing environmental concerns. Embracing mycoremediation calls for a balance between scientific exploration and practical application, an endeavor that holds the potential to reshape relationship with both synthetic dyes and the ecosystems they impact.

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