

Original Research Article

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Role of Fungi in Bioremediation of Paper Effluent

Anupriya Parthasarathy¹ and B. Shanmuga Priya²

¹Department of Microbiology, Annai Violet Arts and Science College, Ambattur, Chennai, Tamil Nadu, India

²Department of Biotechnology, Vivekandha College of Arts and Women, Elayampalam, Namakkal, Tamil Nadu, India

**Corresponding author*

ABSTRACT

The paper industry is one of the major water-intensive industries and generates considerable quantities of wastewater during its manufacturing processes. Paper effluent may contain dyes, chemicals, salts, heavy metals and organic matter, which can adversely affect aquatic ecosystems and human health when discharged without adequate treatment. Conventional physical and chemical treatment methods may be associated with high costs, incomplete removal of pollutants and secondary pollution. Bioremediation using microorganisms provides an environmentally friendly approach for reducing pollutants present in industrial effluents. Marine fungi are increasingly recognized as promising bioremediation agents because they possess diverse enzymatic systems capable of transforming complex organic pollutants. Enzymes such as laccase, lignin peroxidase, manganese peroxidase and other oxido reductases can degrade or modify recalcitrant compounds present in paper and pulp wastewater. Marine fungi may also tolerate variations in salinity, pH and other environmental conditions, making them suitable candidates for the treatment of industrial effluents. Their ability to utilize organic pollutants as carbon or energy sources can contribute to the reduction of colour, chemical oxygen demand and other contaminants in wastewater. Therefore, the isolation and screening of indigenous marine fungi from coastal environments may provide potential strains for the biological treatment of paper industry effluent. Studying their decolourization and pollutant-removal capabilities can help identify efficient fungal strains for future bioremediation applications. The use of marine fungal microorganisms offers a sustainable and eco-friendly alternative to conventional treatment methods and may contribute to the development of cost-effective wastewater management strategies for the paper industry.

Keywords

Mycoremediation, Lignolytic Enzymes, White-Rot Fungi, Decolorization, Pulp and Paper Effluent

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Introduction

The pulp and paper manufacturing process involves several stages, including raw material preparation, pulping, bleaching, washing, chemical treatment and

paper formation. During these processes, various organic and inorganic substances are released into wastewater. The composition of the effluent may vary depending on the raw materials used, manufacturing process, bleaching methods and chemicals employed. Some compounds

present in paper industry effluent are resistant to natural degradation and may persist in the environment if they are not effectively treated. Therefore, the development of efficient and environmentally sustainable treatment methods is an important area of research.

Conventional methods used for industrial wastewater treatment include physical, chemical and biological approaches. Physical and chemical methods such as coagulation, precipitation, adsorption and oxidation can reduce pollutants; however, they may require considerable amounts of chemicals and energy and can sometimes generate secondary waste. Biological treatment has therefore received considerable attention because microorganisms can utilize or transform several pollutants under suitable environmental conditions. Among microorganisms, fungi have attracted particular interest due to their extensive metabolic capabilities and ability to produce extracellular enzymes.

Fungi are naturally involved in the decomposition of complex organic materials in terrestrial and aquatic environments. Their filamentous growth enables them to colonize substrates efficiently and interact with a large surface area of contaminated material. Fungal organisms can produce extracellular enzymes such as laccase, lignin peroxidase, manganese peroxidase and other oxidative enzymes, which are involved in the breakdown of lignin and other structurally complex compounds. These enzymatic activities can also contribute to the transformation of certain dyes and other recalcitrant substances present in industrial wastewater.

Species belonging to the genera *Trichoderma* and *Aspergillus* have been investigated for their ability to produce hydrolytic and oxidative enzymes and for their potential applications in environmental biotechnology. *Trichoderma* species are widely distributed in soil and organic environments and are known for their diverse enzymatic activities. Similarly, *Aspergillus* species possess considerable metabolic versatility and have been reported to interact with and transform a variety of organic compounds. Their ability to grow under different environmental conditions makes them potential candidates for biological wastewater treatment.

Fungal treatment can involve different mechanisms, including biodegradation, biosorption, bioaccumulation and enzymatic transformation. In biosorption, pollutants may become associated with the fungal cell wall, whereas enzymatic degradation can chemically transform

complex compounds into simpler substances. These mechanisms may operate individually or simultaneously depending on the fungal species and the characteristics of the effluent. Factors such as pH, temperature, nutrient availability, incubation period and pollutant concentration can influence fungal growth and treatment efficiency.

Decolourisation is an important parameter in evaluating the effectiveness of fungal treatment because visible colour in industrial effluent is often associated with complex organic compounds and dyes. A reduction in colour can indicate the adsorption or transformation of coloured compounds by fungal biomass or extracellular enzymes. However, colour removal alone does not necessarily confirm complete detoxification; therefore, additional parameters such as COD, BOD, pH and other relevant physicochemical characteristics can provide a more comprehensive assessment of treatment efficiency.

The isolation and screening of naturally occurring fungi from environmental sources can help identify strains with useful bioremediation properties. Indigenous fungal isolates may be better adapted to local environmental conditions and may therefore have potential for application in wastewater treatment. Screening selected isolates for growth, enzyme production and effluent decolourisation can provide preliminary information about their bioremediation capability.

Thus, the present study emphasizes the isolation, identification and evaluation of fungal isolates, particularly *Trichoderma* and *Aspergillus* species, for their potential role in the treatment and decolourisation of industrial effluent. The study aims to explore fungal-based treatment as a sustainable biological approach and to provide preliminary evidence for the possible application of these microorganisms in industrial wastewater management.

Materials and Methods

Collection of Effluent

The study presentation describes collection of highly coloured effluent from a unit located in Bhavani, Erode. The concentrated solution obtained from the rinsing step was collected in a 10-L airtight plastic container. The effluent was filtered through ordinary filter paper to remove large suspended particles and stored at $4 \pm 1^\circ\text{C}$ until further analysis.

Sterilization

Glassware was initially washed with detergent and thoroughly rinsed with distilled water. The glassware was then sterilized in a hot-air oven at 120°C for 1–5 hours. Inoculations were performed using flame-sterilized loops, and the experimental work was carried out under strict aseptic conditions.

Isolation of Marine Fungi

Marine fungal species were isolated from a seawater sample collected from Thiruchendur. The water samples were subjected to serial dilution and inoculated onto sterile Potato Dextrose Agar (PDA). The fungal colonies obtained were identified using Lactophenol Cotton Blue staining. Stock cultures of the isolated fungal species were preserved on agar slants at 4°C.

Preparation of Fungal Inoculum

A standard fungal inoculum was prepared by subculturing a single colony of the respective fungus from the stock culture into 125-mL conical flasks containing 10 mL of PDA medium. The cultures were incubated at 30°C in a rotary incubator shaker at 200 rpm for three days.

Introduction of Fungi into Effluent

Filtered effluent was transferred into 500-mL conical flasks. A 10-mL aliquot of each fungal culture was inoculated into the effluent medium. Raw effluent without fungal inoculum was maintained as the control.

The flasks were incubated at $30 \pm 2^\circ\text{C}$ for 10 days under static conditions. Shaking was provided for one hour at two-day intervals using a mechanical shaker.

Evaluation of Bioremediation

The efficiency of fungal treatment was evaluated by monitoring changes in physicochemical parameters including pH, BOD, COD, total suspended solids (TSS), and effluent colour/decolourisation efficiency. The presentation also describes monitoring of fungal growth and enzyme activity during the treatment process.

Results and Discussion

Isolation of Marine Fungi

The study resulted in the isolation of fungal species including *Trichoderma harzianum* and *Aspergillus flavus*. These fungi were used for effluent treatment.

Changes in Physicochemical Characteristics

The physicochemical characteristics of the raw effluent and fungal-treated effluent are presented in Table 1.

The results show that fungal treatment resulted in changes in the physicochemical characteristics of the effluent. Both fungal treatments reduced pH, BOD, COD and suspended solids compared with the raw effluent. The values reported in the presentation show a greater reduction with *T. harzianum*.

Decolourisation Efficiency

The fungal isolates demonstrated different levels of decolourisation during the treatment period. According to the presentation, *Trichoderma harzianum* showed progressive improvement in decolourisation, with reported efficiencies of approximately 49%, 60%, 85% and 80% at the different observation points represented in the presentation. *Aspergillus flavus* showed decolourisation efficiencies of approximately 28%, 48%, 64% and 60% at the corresponding observation points.

The maximum reported decolourisation efficiency was 85% for *T. harzianum*, whereas the maximum reported efficiency for *A. flavus* was 64%.

The presentation reports that *T. harzianum* achieved approximately 85% decolourisation at 72 hours. Further increase in incubation period did not produce a significant additional effect on decolourisation efficiency.

The present study demonstrates the potential of fungi as biological agents for the treatment of coloured industrial effluent. The fungal isolates used in the study, *Trichoderma harzianum* and *Aspergillus flavus*, were capable of reducing several physicochemical parameters of the effluent.

Table.1 Physicochemical characteristics of raw and fungal-treated effluent.

S. No.	Parameter	Raw Effluent	<i>T. harzianum</i>	<i>A. flavus</i>
1	pH	10.0	7.5	7.8
2	BOD	29.5	13.2	15.1
3	COD	365	120	241
4	TSS	1800	600	750

Table.2 Reported decolourisation efficiency of fungal isolates.

Fungal isolate	Maximum reported decolourisation efficiency
<i>Trichoderma harzianum</i>	85%
<i>Aspergillus flavus</i>	64%

The raw effluent was alkaline, with a pH of 10. Following fungal treatment, the pH decreased to 7.5 with *T. harzianum* and 7.8 with *A. flavus*. This indicates that fungal treatment was associated with a reduction in the alkalinity of the effluent. BOD and COD are important indicators of the organic pollution load of wastewater. In the present study, BOD decreased from 29.5 in the raw effluent to 13.2 after treatment with *T. harzianum* and 15.1 after treatment with *A. flavus*. Similarly, COD decreased from 365 in the raw effluent to 120 with *T. harzianum* and 241 with *A. flavus*.

Total suspended solids also decreased following fungal treatment. TSS was reduced from 1800 in the raw effluent to 600 after treatment with *T. harzianum* and 750 after treatment with *A. flavus*.

The most notable observation was the decolourisation of the effluent. *T. harzianum* showed a maximum decolourisation efficiency of 85%, while *A. flavus* showed a maximum efficiency of 64%. The presentation attributes the decolourisation process partly to fungal biomass and enzyme activity.

The higher decolourisation efficiency observed with *T. harzianum* indicates that this isolate had a greater capacity for colour reduction under the conditions used in this study. The presentation also indicates that fungal biomass increased with increasing incubation time and that biomass plays an important role in dye degradation through increased enzyme activity.

The study therefore demonstrates that fungal treatment can contribute to the reduction of colour and selected pollution parameters in industrial effluent.

Limitations

- The source presentation does not provide replicate numbers, statistical tests, standard deviations or significance values for the physicochemical and decolourisation measurements.
- The presentation uses both paper effluent and textile effluent terminology, and the exact industrial source should be confirmed before submission.
- The presentation does not provide a complete reference list; therefore, a validated bibliography should be added before journal submission.
- The study evaluates a limited number of fungal isolates and selected physicochemical parameters. Further work would be required to establish broader treatment performance.

In conclusion, the present study demonstrates that fungal isolates can be used as potential biological agents for the treatment and decolourisation of industrial effluent.

Among the fungal isolates investigated, *Trichoderma harzianum* showed greater bioremediation potential than *Aspergillus flavus*. Treatment with *T. harzianum* resulted in considerable reductions in pH, BOD, COD and total suspended solids. The fungus also achieved a maximum reported decolourisation efficiency of 85%.

The results indicate that *Trichoderma* has potential for the biological treatment of coloured industrial effluent. The study therefore supports the use of fungal bioremediation as an environmentally friendly approach

for reducing pollution associated with industrial wastewater.

The presentation specifically concludes that *Trichoderma* was efficient in decolourising the effluent and useful for the decolourisation of paper-mill effluent.

Future Scope

- Optimization of pH, temperature and incubation period.
- Optimization of fungal biomass concentration.
- Detailed study of fungal enzymes involved in colour removal.
- Evaluation of ligninolytic enzymes such as laccase, manganese peroxidase and lignin peroxidase.
- Assessment of heavy-metal and phenolic compound removal.
- Evaluation of the toxicity of treated effluent.
- Comparison of individual fungal isolates and mixed fungal cultures.
- Evaluation of the treated effluent against relevant environmental discharge standards.

Acknowledgments

The source presentation does not provide an acknowledgments statement. This section should be completed with the appropriate institutional, laboratory and technical support details before submission.

Conflict of interest

The source presentation does not provide a conflict-of-interest statement. An appropriate declaration should be added by the author before submission.

Author Contributions

P. Anu Priya: study conception, experimental work, data compilation and manuscript preparation. This contribution statement is formatted from the supplied paper context and should be confirmed by the author before submission.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

- Esmaeeli, A., Sarrafzadeh, M.-H., & Zeighami, S. (2023). A comprehensive review on pulp and paper industries wastewater treatment advances. *Industrial & Engineering Chemistry Research*, 62(21), 8119–8145. <https://doi.org/10.1021/acs.iecr.2c04393>
- Hubbe, M. A., Metts, J. R., Hermosilla, C., Blanco, M. A., Yerushalmi, L., Lindholm-Lehto, P., Khodaparast, Z., Kamali, M., & Elliott, A. (2016). Wastewater treatment and reclamation: A review of pulp and paper industry practices and opportunities. *BioResources*, 11(3), 7953–8091.
- Kansal, A., Siddiqui, N., & Gautam, A. (2011). Wastewater treatment of pulp and paper industry: A review. *Journal of Environmental Science & Engineering*, 53(2), 203–218.
- Patel, H., & Dudhagara, P. (2021). Trends and strategies in the effluent treatment of pulp and paper industries: A review highlighting reactor options. *Environmental Science and Pollution Research*.
- Raghukumar, C. (2000). Fungi from marine habitats: An application in bioremediation. *Mycological Research*, 104(10), 1222–1226. <https://doi.org/10.1017/S095375620000294X>

- Raghukumar, C., Chandramohan, D., Michel, F. C., Jr., & Redd, C. A. (1996). Degradation of lignin and decolorization of paper mill bleach plant effluent (BPE) by marine fungi. *Biotechnology Letters*, 18, 105–106.
- Raghukumar, C., D'Souza-Ticlo, D., & Verma, A. K. (2008). Treatment of colored effluents with lignin-degrading enzymes: An emerging role of marine-derived fungi. *Critical Reviews in Microbiology*, 34(3–4), 189–206. <https://doi.org/10.1080/10408410802526044>
- Rodríguez Couto, S., & Toca Herrera, J. L. (2006). Industrial and biotechnological applications of laccases: A review. *Biotechnology Advances*, 24(5), 500–513.
- Thompson, G., Swain, J., Kay, M., & Forster, C. F. (2001). The treatment of pulp and paper mill effluent: A review. *Bioresource Technology*, 77(3), 275–286. [https://doi.org/10.1016/S0960-8524\(00\)00060-2](https://doi.org/10.1016/S0960-8524(00)00060-2)
- Unuofin, J. O., & Njobeh, P. B. (2018). Laccases from marine organisms and their applications in the biodegradation of toxic and environmental pollutants: A review. *Environmental Science and Pollution Research*.

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