

Decolorization of Textile Dye Effluent by Microbial Bioremediation

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Abstract:

One of the primary sources of environmental contamination is the textile industry, which releases a lot of wastewater that contains dyes. Because textile dye effluents contain complex synthetic colors that are hard to break down, they can have negative effects on the environment and human health when released into natural water bodies. Conventional physical and chemical treatment methods are sometimes expensive and can result in secondary pollutants. Microbial bioremediation has therefore emerged as a practical, economical, and ecologically acceptable method of treating textile dye effluents.

Microbial bioremediation has therefore emerged as a practical, economical, and ecologically acceptable method of treating textile dye effluents. In microbial bioremediation, pigments present in wastewater are removed or broken down by microorganisms such as bacteria, fungi, and algae. These bacteria decolorize textile colors by a number of methods, including biosorption, biodegradation, and enzymatic degradation. Enzymes like azoreductase, laccase, and peroxidase break down complex color molecules into simpler, less dangerous compounds. Microbial species that have shown significant promise for dye decolorization include *Pseudomonas*, *Bacillus*, *Aspergillus*, and *Phanerochaete chrysosporium*. Numerous environmental factors, such as pH, temperature, dye concentration, oxygen availability, and nutrient delivery, affect how well microbial dye degradation works. Both aerobic and anaerobic treatment techniques can successfully decolorize textile effluents. Microbial treatment reduces the toxicity, chemical oxygen demand (COD), and biological oxygen demand (BOD) of wastewater in addition to removing color. Microbial bioremediation is therefore an environmentally beneficial and sustainable way to treat textile dye effluents and is essential for reducing industrial pollution and protecting aquatic habitats. In this scenario, attempts are made to isolate and examine microorganisms that break down dyes.

Keywords: Textile dye, Degradation, Bacteria

Introduction:

Azo dyes are highly recalcitrant, persistent, and toxic compounds, extensively used in the textile industry. The untreated discharge of dye effluents from the textile industry poses severe environmental and health risks (Singh et al.2025).Industrial waste, particularly from the textile and leather industries, is a major contributor to environmental pollution through the release of chemical effluents and dyes. Despite legislative efforts, managing this pollution remains a significant challenge (Sharma et al., 2025). The textile industry is expanding globally and is considered the backbone of the world's largest source of foreign exchange. The development of the textile industry has caused environmental contamination due to its dye waste, which is complex and very difficult to resolve with chemical and physical treatments (Rahayu et al., 2023). Chemical methods can

effectively degrade the dye effluent however they produce more toxic compounds. Biological methods offer an alternative that is more environmentally friendly and produce readily degradable compounds. Dye degrading bacteria can degrade the dyes in the effluent under anaerobic for decolorization followed by aerobic condition to produce readily degradable compounds (Rakhmania et al.2022). Bacterial agents isolated from various sources like dye contaminated soil and textile wastewater have shown to have the ability to effectively decolourise and degrade these dye pollutants leading to improved water quality (Moyo et a.,2022). Untreated wastewater contaminates aquatic bodies by causing eutrophication, change in water color, oxygen depletion which affect aquatic organisms to a great extent (Zafar et al., 2022).

Materials and Methods:

Materials:

Chemicals and Reagents Textile dye effluent sample, Nutrient broth, Nutrient agar, Textile dye effluent samples , Distilled water, pH buffer solution , Synthetic dye Glassware, Conical flasks, Test tubes, Beakers, Petri plates, Pipettes Measuring cylinders Equipment, Incubator Autoclave pH meter Centrifuge Spectrophotometer ,Laminar airflow chamber.

Isolation of Dye Degrading Microorganisms: Microorganisms capable of degrading textile dyes were isolated from contaminated soil or wastewater samples. Serial dilution of the effluent sample was prepared using sterile distilled water. The diluted samples were spread on nutrient agar plates. The plates were incubated at 37 °C for 24–48 hours. Distinct microbial colonies were selected and subcultured to obtain pure cultures.

Screening of Dye Decolorizing Microorganisms: The isolated microorganisms were screened for their ability to decolorize textile dyes. Procedure: Nutrient broth containing a known concentration of textile dye was prepared. The broth was inoculated with isolated microbial cultures. The flasks were incubated at 30–37 °C for 24–72 hours. Decolorization was observed by measuring color reduction visually or using a spectrophotometer.

Decolorization Experiment: To evaluate the dye degradation ability of selected microorganisms: A specific concentration of dye (Reactive blue and Reactive pink) approximately 1 gram were added to nutrient broth. The selected microbial culture was inoculated into the medium. The culture was incubated under suitable conditions (temperature, pH, and aeration). Samples were collected at different time intervals to observe color reduction. Measurement of Dye Decolorization Dye decolorization was measured using a spectrophotometer. After incubation, the culture medium was centrifuged to remove microbial cells. The clear supernatant was collected. to determine optimal conditions for dye degradation: pH: 5–9 Temperature: 2–450 °C. Dye concentration: different concentrations Incubation time: 24–72 hours. Absorbance was measured at the dye's maximum wavelength (λ_{max}).for specific blue dye at 480nm and for specific pink ye it is at 680 nm absorbance was measured by using colorimeter and concentration is calculated by using formula

$$C = A \backslash (\epsilon L)$$

C=concentration

A=absorbance

ϵ =Molar absorptivity

L=Path length

(For specific blue dye=18600 L.Mol⁻¹.cm⁻¹, specific pink=108000 Mol⁻¹.cm⁻¹)

Dye degradation efficiency $= \frac{C_0 - C_e}{C_0} \times 100$

Co=Initial absorbance

Ce=Final absorbance

Data Analysis The results were recorded and analyzed based on the percentage of dye removal. Tables were used to represent the efficiency of microbial decolorization under different experimental conditions. The Pour Plate Method is a microbiological technique used to isolate and count viable

Result:

Gram-positive Shape: Rod-shaped (bacilli). *Bacillus subtilis* bacteria was isolated and identified. Dye degradation capacity of *Bacillus subtilis* was tested for Reactive Blue and Reactive pink its results are shown:

Sr.no	Day	Reactive blue(OD) 480nm	Concentration (mol-1)	Reactive pink(OD) 680nm	Concentration (mol-1)
1	D1	0.36	1.93	1.90	1.75
2	D2	0.34	1.82	1.80	1.66
3	D3	0.33	1.77	1.30	1.20
4	D4	0.28	1.50	1.25	1.15
5	D5	0.19	1.02	1.24	1.14

Conclusion:

Isolated dye degrading bacteria *Bacillus subtilis* degrades Specific blue and specific pink textile dye successfully. The efficiency of degradation of *Bacillus subtilis* for Reactive blue dye is (46%) which is higher than Reactive pink (34%) textile dye.

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