Mangalayatan Journal of Scientific and Industrial Research

Man. J. Sci. Ind. Res.
Volume 1 (1) (2024), 24108

Review Article

Review on Microbial Degradation of Reactive Textile Dyes using Soil-Derived Bacteria

Shreshtha Upadhyay* and Kritika Singh[2]

Mangalayatan University, Aligarh (India), [2] K.R. Mangalam University, Sohna

*Corresponding author:shrestth899@gmail.com

Abstract

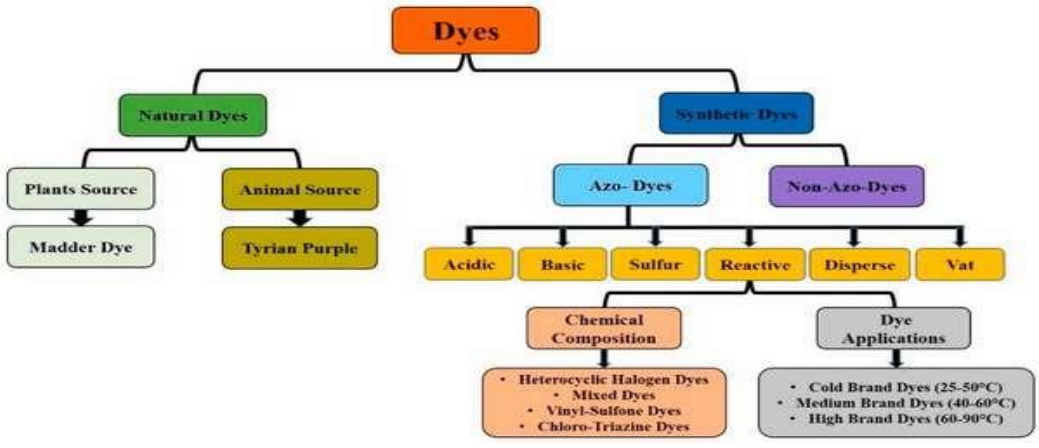
Reactive dyes are widely used in the textile industry but contribute significantly to environmental pollution due to their persistence and toxicity. This study explores the isolation, characterization, and application of soil-derived bacteria for degrading reactive dyes, such as reactive blue, reactive red, and reactive yellow. Soil samples collected from sites near textile industries in Ahmedabad, Gujarat, were subjected to microbiological and analytical processes, including enrichment culture techniques, spectrophotometric analysis, and Thin Layer Chromatography (TLC). The findings revealed the potential of indigenous bacterial strains in bioremediation, with variations in decolorization efficiency observed for each dye. This review provides a comprehensive analysis of microbial mechanisms, methods, and potential applications in sustainable pollution management.

Keywords: *Spectrophotometric Analysis, Textile Dyes, Thin Layer Chromatography, Bioremediation.*

1. Introduction

1.1 Overview of Textile Industry Pollution

The textile industry significantly contributes to economic development worldwide but is a major source of water pollution. Reactive dyes, commonly used for their vibrant and long-lasting properties, are resistant to degradation under natural conditions, making them persistent pollutants in wastewater.



Received: 26 Oct. 2024; Accepted: 15 Nov. 2024

1.2 **Microbial Bioremediation as a Sustainable Solution**

Microbial bioremediation offers an eco-friendly alternative to chemical methods for wastewater treatment. Bacteria, fungi, and algae can metabolize and decompose complex dye molecules, utilizing them as carbon or energy sources. Among these, bacterial degradation has garnered significant attention due to its efficiency and adaptability. The current study aims to isolate and characterize indigenous bacterial strains from textile industry soils. Evaluate their dye-degrading potential through spectrophotometric and chromatographic analyses and investigate their suitability for bioremediation applications.

2. METHODOLOGY

3.1 Sample Collection and Preparation

Soil samples were collected from five different locations near textile dyeing industries in Ahmedabad, Gujarat. Samples were taken from a depth of 10–15 cm using sterile tools and stored in sterile containers. These samples were transported to the laboratory for further analysis.

3.2 Isolation of Dye-Degrading Bacteria

3.2.1 Preparation of Enrichment Media

Enrichment media were prepared by adding reactive dyes (200 mg/L) to nutrient broth. This step aimed to select and enhance the growth of dye-tolerant bacterial species from the soil samples.

3.2.2 Sub-Culturing of Media

The enriched media were incubated at 37°C for 72 hours with intermittent shaking (120 rpm). Sub-culturing was performed by transferring aliquots into fresh enrichment media, ensuring the dominance of dye-degrading bacteria.

3.2.3 Isolation of Bacterial Strains

Serial dilution of enriched samples was conducted, and aliquots were plated on nutrient agar supplemented with reactive dyes. Plates were incubated at 37°C for 24–48 hours.

3.2.4 Isolation of Pure Bacterial Colonies

Distinct bacterial colonies with different morphologies were picked and streaked onto fresh nutrient agar plates for further purification.

3.3 Characterization of Isolated Bacteria

3.3.1 Morphological Characterization

3.3.1.1 Colony Morphology: Colony size, shape, color, margin, and elevation were recorded.

3.3.1.2 Cell Morphology: Gram staining and microscopic observations were used to classify bacteria as Gram-positive or Gram-negative.

3.4 Analytical Methods

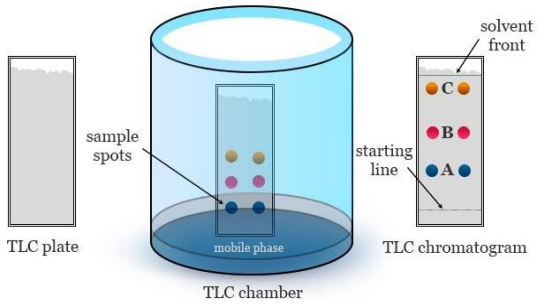
3.4.1 Spectrophotometric Analysis

Decolorization efficiency was quantified using a UV-Visible spectrophotometer by measuring absorbance at the maximum wavelength (λmax\lambda_{\text{max}}λmax) for each dye.

Percent decolorization was calculated using the formula:

Decolorization Efficiency (%)=Initial Absorbance - Final AbsorbanceInitial Absorbance×100 \ Initial Absorbance

3.4.2 Chromatographic Analysis



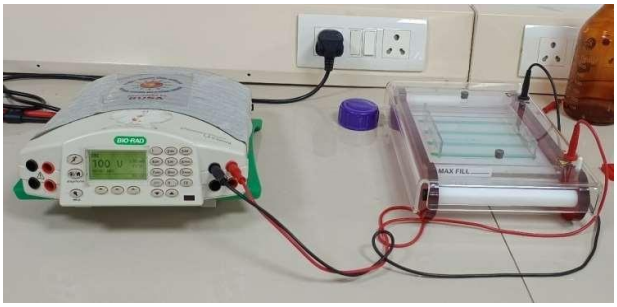
TLC was performed using silica gel plates as the stationary phase. Dye degradation products were separated, and Rf values were calculated to confirm dye breakdown.

3.5 Molecular Characterization

3.5.1 DNA Extraction

Genomic DNA was extracted using the phenol-chloroform method. The quality and concentration of DNA were assessed using a nanodrop spectrophotometer.

3.5.2 Agarose Gel Electrophoresis



Extracted DNA was subjected to agarose gel electrophoresis to verify its integrity and purity.

3.5.3 Polymerase Chain Reaction (PCR)

PCR amplification of the 16S rRNA gene was performed to identify bacterial isolates at the molecular level. Sequencing results were compared with databases using BLAST for taxonomic identification.

4. RESULTS AND DISCUSSION

4.1 Efficiency of Dye Degradation

The isolated bacterial strains exhibited varying levels of decolorization efficiency:

- **Reactive Blue:** Sample 2 showed the highest decolorization (16.51%) on the 7th day.
- **Reactive Red:** Sample 1 demonstrated a maximum decolorization of 19.66% on the 7th day.
- **Reactive Yellow:** Sample 1 achieved 15.89% decolorization on the 6th day.

These results indicate the specificity of bacterial enzymatic systems toward different dye molecules.

4.2 Analysis of Degradation Products

Spectrophotometric data revealed reductions in absorbance at characteristic wavelengths, confirming dye degradation. TLC analysis further supported this, with altered Rf values suggesting the formation of new compounds.

4.3 Mechanisms of Dye Degradation

The bacterial degradation process primarily involves enzymatic pathways such as:

- **Oxidative Enzymes:** Laccase, peroxidase, and tyrosinase.
- **Reductive Enzymes:** Azo-reductases, which cleave azo bonds.

These pathways break chromophoric structures into simpler, less toxic metabolites, facilitating mineralization.

5. FUTURE PROSPECTS

1. **Metabolic Engineering:** Enhancing bacterial degradation efficiency through genetic modifications.
2. **Consortia Development:** Utilizing mixed bacterial cultures for synergistic effects.
3. **Industrial Applications:** Scaling up microbial treatment in textile effluent plants.
4. **Environmental Assessments:** Evaluating microbial-treated wastewater for ecological safety.

6. CONCLUSION

This study highlights the potential of indigenous soil bacteria for degrading reactive dyes in textile effluents. The methodologies employed and the results obtained provide a foundation for advancing bioremediation technologies. The combination of microbiological, analytical, and molecular techniques paves the way for sustainable pollution mitigation strategies.

References

1. Ali, H. (2010). Biodegradation of synthetic dyes: A review. *Water, Air, & Soil Pollution*, 213(1-4), 251-273.
2. Forgacs, E., et al. (2004). Biological degradation of dyes: A review. *Environmental International*, 30(7), 953-971.
3. Jadhav, J. P., et al. (2008). Decolorization of azo dye methyl red by Saccharomyces cerevisiae MTCC 463. *Chemosphere*, 68(2), 394-400.
4. Khan, S., et al. (2013). Bacterial decolorization and degradation of azo dyes: A review. *Journal of Applied Microbiology*, 115(5), 1413-1427.

5. Kumar, A., et al. (2012). Decolorization and biodegradation of reactive dye by a bacterial strain isolated from a contaminated site. *Environmental Science and Pollution Research*, 19(6), 2073-2079.

6. Pandey, A., et al. (2007). Review on microbial decolorization of textile effluents. *Journal of Environmental Management*, 86(4), 688-697.

7. Puvaneswari, N., et al. (2006). Impact of synthetic dyes on environmental pollution and their biodegradation. *Bioremediation Journal*, 10(1), 3-9.

8. Rai, H. S., et al. (2005). Removal of dyes from the effluent of textile and dyestuff manufacturing industry: A review of emerging techniques. *Dyes and Pigments*, 66(1), 75-90.

9. Saratale, R. G., et al. (2011). Decolorization and degradation of synthetic dyes by fungal isolates. *Biotechnology Advances*, 29(6), 802-810.

10. Shah, M. P., et al. (2013). Microbial degradation of textile dyes through indigenous bacterial strains. *Bioremediation Journal*, 17(3), 178-184.

11. Tamura, K., et al. (2011). MEGA5: Molecular Evolutionary Genetics Analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Molecular Biology and Evolution*, 28(10), 2731-2739.

12. Vasudevan, D., et al. (2020). Bioremediation of textile dyes: Current status and future prospects. *Bioresource Technology Reports*, 12, 100584.