PAKISTAN BIOMEDICAL JOURNAL
https://www.pakistanbmj.com/journal/index.php/pbmj/index
Volume 5, Issue 10 (October 2022)

Review Article

Microbial Degradation of Industrially Important Textile Dyes

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ARTICLE INFO

Key Words:
Microbial Degradation of Industrially Important Textile Dyes

How to Cite:
Farhan, M. (2022). Microbial Degradation of Industrially Important Textile Dyes: Microbial Degradation of Industrially Important Textile Dyes. Pakistan BioMedical Journal, 5(10). https://doi.org/10.54393/pbmj.v5i10.809

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Received Date: 15th October, 2022
Acceptance Date: 24th October, 2022
Published Date: 31st October, 2022

ABSTRACT

The high demand for dyes in the paper, cosmetic, clothing, leather, and food industries drives up the use of dyes as a result of industrialization. As a result, wastewater production from dye manufacturing activities will rise. The presence of dyes and their structural compounds in wastewater from industrial sources place humans, animals and plants lives at risk. Synthetic dyes are more challenging to decolorize because they are more resistant to chemical and physical remediation than natural dyes. Microbial degradation has been investigated and checked mainly to speed up dye degradation. This paper discusses types of textile dyes and its biodegradation from a scientific and technological standpoint. It also compiles data on the factors that influence dye(s) biodegradation, the role of microbial species in the dye(s) degradation process, and future research directions in this field.

INTRODUCTION

Dyes are high in demand for use in different industries, i.e., food, cosmetic, leather, paint and textiles. They can be classified into 25 different types based on their chemical configuration of the chromophore [1]. Textile dyes are made up of thousands of different dyes that are used to stain a wide range of fabrics. Dye intermediates are dyes precursors and can be made from raw materials like naphthalene and through a variety of chemical reactions [2]. Discharge of effluents from urban and industrial areas leads to water pollution. Pollution has a detrimental effect on the atmosphere and poses health risks to all living things on the earth [3]. The structure and application of dyes can be used to classify them. It is difficult to eliminate dyes using traditional methods due to their high solubility in water [4]. Textile dye produces colors, causing creative harm as well as preventing light diffusion in the water, resulting in a decrease in dissolved oxygen levels and affecting aquatic life's photosynthesis rate [5]. Biological treatment has a number of advantages, including being a convenient, low-cost, and environmentally friendly procedure. Microorganisms which are vast in number are easy to manipulate and hence require little planning [6]. Dye processing, among the numerous operations of dye industries, is the primary cause of environmental contamination due to the release of toxic dye into water bodies. Algae, yeast, bacteria, and fungi are among the microorganisms that may mineralize or decolorize various dyes [7]. Due to synergistic metabolic action, it has been documented that a mixed microbial culture can achieve efficient dye degradation [8]. In the field of bioremediation, genetic engineering has made a major impact. The degradation of dye is influenced by factors such as pH, temperature, dye structure, soluble salts, heavy metals, nutrients, and so on [9]. The aim of this study is to broaden the spectrum of dye biodegradation. It covers dye forms, dye intermediates, and dye effects. It also goes over

DOI: https://doi.org/10.54393/pbmj.v5i10.809

different techniques that can be helpful in degrading dyes and describes factors that affect the biodegradation of dye.

1.0 Types of Textile Dyes

Textile dyes are categorized based on their chemical structure; few are listed below:

1.1 Azoic Dyes

A million tons of azo dyes are produced globally each year, according to estimates. There are actually over 2,000 substantially different azo dyes in use, and they come in a range of shapes and sizes. [10]. Azo dyes are the most common form of synthetic dye. Azo dyes account for roughly 70% of all dyes used in industry. Many factors contribute to the phenomenal success of azo dyes, including the flexibility of the condensation reactions, the extensive options for structural variations and tolerance to the requirements of the dyes in many applications [11].

1.2 Reactive Dyes

Reactive dyes are known by their ability to form covalent bond with their substrates during the dyeing process. On cotton, they give a wide variety of colors with exceptional light and deep cleaning. As a result of these characteristics, this dye class is considered to be on the higher end of the market. To dye cellulose, reactive dyes are used, and an increasing amount is used on wool and nylon [12].

1.3 Sulphur Dyes

Sulfurization involves variety of reactions such as formation of ring, oxidation and reduction processes and substitution. Sulfur dyes possess undeniable role in the dyeing of silk, paper as well as on leathers. Among all synthetic dyes, Sulphur dyes are cheap and acquire perfect washing ability of light fastness, but they do face a severe drawback due to dullest color spectrum of all synthetic dyestuffs. The majority of these dyes are made by thionation of various aromatic intermediates, and their structures are extremely complex [13].

2.0 Toxicity of Textile Dyes

The textile industry is a multi-dollar industry that accounts for 7 percent of total of global exports and employs millions and billions of people around the world [14]. The textile industry poses negative impacts due to its environmental consequences [15]. Sludge of textile elevates issues as it is containing excess quantities of organic matter, presence of undesirable structures, certain heavy metals and pathogenic microorganisms [14]. Textile dye color not only deteriorates the functionality of aquatic environment, but it also prohibits light from getting through, resulting in a reduction in photosynthetic activity and depleted oxygen levels, impacting the entire aquatic biota [16]. The presence of such compounds poses harmful impact on the diversity of bacteria present in soil as well as on the growth of plants [17]. Since heavy metal cations have negative charges, they can be assimilated by fish gills until released in the aquatic environment, causing them to accumulate in some tissues. As a result, they can enter human organs through the food chain, causing a variety of diseases [18]. Furthermore, oxidative stress caused by chromium in textile dyes is another issue associated with recalcitrant behavior, causing significant harm to plant growth and development, especially photosynthesis and CO_2 assimilation [19]. As a result, it is critical to employ treatment methods aimed at ensuring the environment's long-term viability for future generations. Physical-chemical methods, while efficient, are associated with the inconvenient disposal of sludge as well as high costs for electricity, inputs, and operation [17]. For the treatment of textile effluents, biodegradation is proposed as the most cost-effective option [20].

3.0 Biological Degradation of Textile Dyes

Bacteria, algae, filamentous fungi and yeasts are the microorganisms that can be employed and has the excellent potential for bioremediation. They can degrade the toxic components present in the sludge, water, waste or convert them into less toxic form [21]. Microbes can be isolated from wild, from the clothing effluents capable for biodegrading dyes [22]. Another method that could be employed is the multiplication of desired gene responsible for biodegradation in to its suitable vector to enhance the degradation capacity [23].

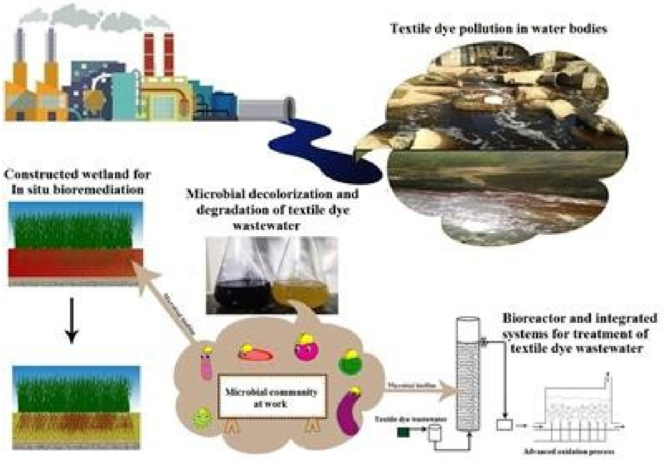

Figure 1: Mechanism of textile dye degradation

3.1 Mechanism of Degradation of Dyes using Bacterial Strains

Aerobic, anaerobic and facultative anaerobic are the conditions that are required by microorganisms for the degradation of azo dyes. Azo reductase degrades azo dyes, though it still contains potentially toxic components. These intermediate compounds can then be degraded aerobically or anaerobically [24]. Congo red, a diazo dye is a

DOI: https://doi.org/10.54393/pbmj.v5i10.809

water-soluble organic compound. The use of Congo red, on the other hand, has long been discontinued, owing to its carcinogenic properties. In a recent study reported by Kishor *et al.* [25] detoxification of Congo red dye from industrial effluents by a novel strain, *Bacillus cohnni* (RKS9) was investigated. Another method which could be employed is the use of immobilized cells rather than free cells which has proved more effective in degradation. On immobilizing the bacteria on alginate beads of calcium, efficiency of bacteria degrading the dye was improved as per the study conducted by Unnikrishnan *et al.* [26].

3.2 Mechanism of Degradation of Dyes using Fungal Strains

Filamentous fungi are found in respective ecological niches, such as soil, organic waste and living plants [27]. Fungal systems are the best option for treating colored and metallic effluents. These fungi can degrade a wide range of organic compounds because their ligninolytic enzymes, such as lignin peroxidase (LiP), manganese peroxidase (MnP), and laccase, are relatively nonspecific [28].

A strain of fungus reported to be novel, *Peroneutypa scoparia*, was demonstrated for the degradation of a dye, Acid Red 197 for the first time. The enzyme showed promise as a cost-effective and viable product, as well as a safe and environmentally friendly dye decolorization process as reported by Pandi *et al.* [29].

3.3 Mechanism of Degradation of Dyes using Algal Strains

Photosynthetic species, such as cyanobacteria and algae, have a wide range and algae has been found to degrade variety of azo dyes due to an enzyme present, azoreductase [30]. Removal of the dye color by algae is based on three distinct mechanisms: assimilative utilization of chromophores for algal biomass processing, CO_2 and H_2O transformation of colored molecules to non-colored molecules, and chromophores adsorption on algal biomass. *Chlorella pyrenoidosa*, *Chlorella vulgaris*, and *Oscillateria tenuis* have been confirmed to biodegrade and decolorize more than 30 azo compounds, with the azo dyes decomposed into simpler aromatic amines [31]. The microbial tool Brevibacillus laterosporus was used to decolorize the disperse dye Disperse Red 54. (DR54). B. laterosporus was tested under ideal conditions (pH 7, 40°C), within 48 hours, laterosporus had fully decolored DR54 (at 50 mg L^{-1}) as reported by Kurade *et al.* [32].

4.0 Factors Affecting Microbial Degradation of Textile Dyes

Dye industrial wastewater contains a variety of azo dyes as well as other structurally distinct dyes. Metals, salts, and other compounds have been documented to make dye degradation more difficult, as well as being toxic to bacterial growth [33]. Water quality is influenced by many factors, some of them are listed below:

4.1 pH

An essential factor in the management of effluent and waste is pH. The use of dyes and salts decide the pH of a solution. It might be acidic, alkaline or neutral. Rate of degradation of dyes is also affected by pH. Degradation can be enhanced by adjusting the pH of the effluent and selecting the microbial strain that can grow at the pH of the effluent [34].

4.2 Temperature

Mineralization, diffusion, and chemical reactions that increase the pH of water are all influenced by the temperature of the water. If bacteria are present in wastewater, high temperatures can kill them or prevent them from growing. Giving bacterial cultures an optimal temperature, which is normally 30-40°C for most bacteria, accelerates dye degradation [35].

4.3 Dye Concentration and Dye Structure

Dye concentration and dye composition have an effect on dye degradation and decolorization. Low dye concentrations may have gone undetected by enzymes generated by dye-degrading bacteria. High dye concentrations, on the other hand, are toxic to bacteria and can prevent dye degradation by blocking enzyme active sites. Dyes with a low molecular weight and a basic structure, on the other hand, are simple to decolorize. Dyes with a large molecular weight and a complex structure, on the other hand, take a long time to decolorize [34].

CONCLUSIONS

Dye industry wastewater that is not properly treated and discharged into the atmosphere has a detrimental impact on the water and soil system. This necessitates the creation of environmentally safe methods for remediating the effluent's toxic chemical compounds. Biological treatments have the ability to be more beneficial than physical and chemical treatments. Microbial organisms with dye degradation capabilities have been used to illustrate biological wastewater treatment. In this regard, the use of such organisms could be beneficial in improving the efficiency of the degradation process. Another significant factor that may offer future benefits is the integration of technologies. Dye degradation of industrial wastewater requires the development of advanced technologies and materials.

Conflicts of Interest

The author declare no conflict of interest.

Source of Funding

The author received no financial support for the research, authorship and/or publication of this article

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