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Environmental and Human Health
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Review

Microbial Degradation of Micro Plastic and Synthetic Dyes from Waste Water Effluent Using Local Fungal Isolates: A Review

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Received: 4 August 2025; **Revised:** 13 October 2025; **Accepted:** 17 November 2025; **Published:** 12 December 2025

Abstract: Hazardous wastes are produced by the production of textile dyes and different industrial products. It is frequently discovered that the waste produced during the dyes' manufacturing and operation contains both organic and inorganic contaminants such as micro plastic, endangering ecosystems and biodiversity. These contaminates having an adverse effect on the environment. The current review aims to the decolonization and breakdown of azo dyes by fungi, bacteria, yeast, and algae; the physico-chemical treatment does not completely eliminate the concentration of color and dye chemicals. pH, temperature, dye concentration, nitrogen and CO effects, agitation, dye structure, electron donors, and enzymes involved in the microbial decolonization of azo dyes. Micro plastics are widely distributed and a major pollutant in our ecosystem. Micro plastics (MPs) are very small size plastic (<5 mm) present in environment, which comes from industrial, agricultural and household wastes. Plastic particles are more durable due to the presence of plasticizers and chemicals or additives. These plastics pollutants are more resistant to degradation. Inadequate recycling and excessive use of plastics lead to a large amount of waste accumulating in the terrestrial ecosystem, causing a risk to humans and animals. We will concentrate on the decolonization and breakdown of dye compounds into molecules that are safe for the environment. Dyes are resistant to deteriorating environmental elements and contain an aromatic composition. The bioremediation approach uses microorganisms to decrease, remove or transform hazardous materials in soils, sediments, water, and air into safe forms. The purpose of this study is to review data on the use of bioremediation technology for wastewater.

Keywords: Biodegradation; Fungi; Micro Plastic Waste Water; Dye; Decolonization

1. Introduction

Fungi are characterized by their effective enzymatic systems. Fungi offer a viable biodegradation option for microplastics, which can harm the environment. By generating extracellular enzymes such as oxidoreductases and hydrolases that break down polymers into smaller pieces and eventually release water and carbon dioxide, Fungi decompose plastics. include the marine fungus *Alternaria alternata*, which breaks down polystyrene in seawater. There are several species of *Pestalotiopsis*, which can break down plastics even in conditions with low oxygen levels. Although bioremediation may be possible through fungal breakdown.

Wastewater from the dyeing process is released into the environment in large quantities by the textile industry [1]. The ecosystem and aquatic life are adversely affected by the accumulation of textile dyes in aquatic habitats. In rivers or lakes, photosynthetic bacteria are inhibited by high dye concentrations. Furthermore, aquatic creatures acquire these pigments and incorporate them into the food chain. Living things that are poisoned by dyes are

harmful to mammals [2].

Wastewater treatment for dyeing is crucial. Although a number of treatment strategies, including chemical and physical procedures, are recommended, biological methods are generally favored since they are less expensive and more environmentally friendly [3]. Conventional wastewater treatment relies on dyes because of their aromatic nature and resistance to damaging environmental elements like the sun and ozone.

The use of organisms to treat the environment is known as bioremediation. In the bioremediation technique, toxins found in soils, sediments, water, and air are reduced. The purpose of this study is to examine the data pertaining to the decolorization of textile wastewater using bioremediation technology. The decolorization of textile effluent employing microorganisms like bacteria, fungi, and algae is the main topic of this paper. Additionally, the impact of variables on microbial dye removal activity is examined, including pH, temperature, initial dye concentration.

Bacteria were a cheap and effective way. The removal of Enterococcus faecalis YZ 66 was successfully achieved through the adaptation of known strains for the use of dyes and the isolation of effective novel strains, which both boost the efficacy of the bioremediation process, the isolation of new strains, and the modification of well-known strains for the application of dyes, both of which increase the efficacy.

Orange 16 reactive dye, textile azo dyes were successfully decolored by another bacterial strain known as Staphylococcus arlettae strain VN-11 [4]. Temperature, pH, initial dye concentration, and nutrients all have an impact on the microbial decolorization mechanism. These factors are crucial for the growth of microorganisms. The elimination of dyes from wastewater is one of the most significant environmental problems.

The biggest environmental issue is the removal of dyes from wastewater. Textile, leather, paper, printing, plastic, culinary, and other sectors utilize dyes in large amounts to color their good.

The optimal conditions for microbial dye degradation include pH, temperature, as well as environmental factors like oxygen and carbon energy sources. The extensive use of dyes often leads to pollution problems in addition to reducing photosynthesis and light penetration.

Additionally, some dyes are carcinogenic, mutagenic, or poisonous [5]. Industries became reliant on synthetic dyes made from petrochemicals as a result of the growing demand. Compared to natural dyes, these dyes offer a wide range of color options and are soluble in water, readily absorbed, and color quickly.

Approximately 800,000 t of dyes are currently manufactured each year globally. Many of the dyes produced are used in the textile sector.

Wastewater is released in large quantities during the water-intensive textile production process. Unfortunately, a significant portion of the dyestuff is discharged with the wastewater when dyes from an aqueous dyeing method are not completely exhausted onto the textile fiber [6].

The discharged effluent pollutes land and water, causing significant environmental contamination. It may also alter pH and oxygen levels, be toxic and mutagenic to aquatic plants and animals, and obstruct light penetration. All of which disrupt the aquatic ecology and have effects on human health, including inflammation, lung problems, and immune system disruption, are also associated with the residual dye.

Colored wastewater from the textile industries may contain 10–200 mg/L of dye in addition to a range of other organic and inorganic compounds and additives [7]. In actuality, it's thought that when these dyes are discharged into rivers after wastewater treatment, up to 90% of them stay chemically unchanged. The breakdown of dye molecules is determined by the complexity of their structures.

Based on their chemical composition, they can be classified as acid dyes, azo dyes, basic dyes, disperse dyes, sulfur dyes, pigment dyes. Azo dyes are complex in structure, making up around 70% of the dyes used in the textile industry. Diazotized amine, combined with an amine or phenol and one or more azo groups –N=N– make up azo dyes. They are the most widely used synthetic dyes because they are inexpensive and simple to use [8].

Because microorganisms are adaptable, have dynamic metabolisms, and may include enzyme machinery, using them for biodegradation is convenient. Bioremediation is a non-hazardous, cost-effective, environmentally acceptable, and often more effective method of treating textile waste than conventional methods. The study involved the bioremediation of different concentration of saffron using *Mucor recemoses* (**Figure 1**). This review discusses the process by which microorganisms degrade synthetic colors as well as the separation and screening of bacteria capable of decolorizing textile effluents.

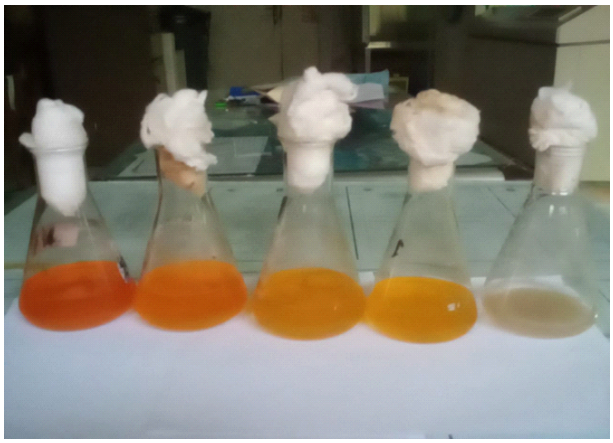

Figure 1. Bioremediation of different concentration of saffron using *M. recemoses*.

The biodegradation of micro plastics in various ecosystems has now been well documented and recent evidence suggests detrimental effects on various biological processes due to this pollution. Accumulation of microplastics in the natural environment is ultimately due to the chemical nature of widely used petroleum-based plastic polymers, which typically are inaccessible to biological processing. One way to mitigate this crisis is adoption of plastics that biodegrade if released into natural environments. In this work, we generated microplastic particles from a bio-based, biodegradable thermoplastic polyurethane (TPU-FC1) and demonstrated their rapid biodegradation via direct visualization and respirometry [9,10].

Furthermore, we isolated multiple bacterial strains capable of using TPU-FC1 as a sole carbon source and characterized their depolymerization products (**Figure 2**). To visualize biodegradation of TPU materials as real-world products we generated TPU-coated cotton fabric and an injection-molded phone case and documented biodegradation by direct visualization and scanning electron microscopy (SEM), both of which indicated clear structural degradation of these materials and significant biofilm formation [11].

(**a**) (**b**)

Figure 2. (**a**) Before treatment with *M. recemoses*; (**b**) After treatment of dye by *M. Recemoses* after 48 h.

2. Dye Degradation Caused by Fungi

The capacity of white-rot fungi to decolorize artificial colors has been thoroughly investigated. They produce a range of extracellular oxidoreductases that degrade lignin and other aromatic compounds. Its structurally nonspecific and nonstereo selective enzyme system consists of laccase, manganese peroxidase (MnP), and lignin peroxidase (LiP). Laccase, which has been extensively studied for the removal of phenol and colors from liquid waste, is produced by Phanerochaete chrysosporium and *Neurospora crassa* [11].

Positive outcomes for wastewater treatment can be achieved by employing gel entrapment and adhesion to a matrix [12]. Despite the success, the synthesis of enzymes is inconsistent since white-rot fungi are not normally

present in wastewater. Furthermore, there are several disadvantages to using white-rot fungi, including a long life cycle and a dependence on nutrient limitation.

The lengthy hydraulic retention period needed for full decolonization also limits the decolonization [13].

3. Quantification of Dye Decolonization

After centrifugation at 10,000 rpm for 15 min, it should be ascertained by measuring the absorbance of culture supernatants at the absorbance maxima of the corresponding dyes [14].

Decolonization percentage is calculated as (initial absorbance final absorbance)/initial absorbance × 100. It should be determined by measuring the absorbance of culture supernatants at the appropriate dyes' absorbance maxima following centrifugation at 10,000 rpm for 15 min [15].

Many colors and pigments are toxic and harmful to both aquatic life and humans at the amounts at which they are discharged into receiving water bodies.

To accelerate the dyes' sluggish rate of degradation in wastewater, creative treatment methods were desperately needed. Pleasant to receive water bodies, many colors and pigments are poisonous and dangerous to both humans and aquatic life [16].

Innovative treatment techniques were sorely needed to speed up the slow rate of breakdown of dyes in wastewater.

The application of some bio-sources, such as natural plant components, plays an important role in the treatment of wastewater. Some beneficial microorganisms (yeast, bacteria, and fungi) could can grow on waste water and provide the pollutants a substrate for their growth process. Accordingly, indirect conversion of the waste water to a more usable form for some industrial and agriculture application led to solving the water deficiency problem.

On this account, the application of the biological effects of some kinds of bacteria and fungi was used to degrade the dyestuffs. It was determined that the decolonization of the wastes water samples could be obtained by microorganisms. On the other hand, we can prevent environmental pollution by the degradation of color yields occurring in wastewater. The uniqueness of the proposal research stems from. The uniqueness of the proposal research stems from the new approach to get superior integration management include biological methods of degradation of textile dyes from waste water [17].

This review aims to explain this branch, develop the utilization to be used as applicable to the minimization of contamination and pollution produced from textile dyes in waste water.

Because of its overall influence on the environment, residual dye in wastewater from the textile and synthetic dye manufacturing industries is a global concern. The discharge is highly concentrated in colors and other additives, and it has complex structures. Because colorful clothing is necessary, the dyestuff in the effluent is less susceptible to acids, bases, and oxygen.

As a result, traditional physical and chemical techniques aren't always effective at breaking down the dyes. Certain bacteria that develop in a region where textile effluent is present can use the dyes as a source of carbon, nitrogen, or both. Bioremediation of textile effluent employing these microorganisms has become increasingly popular as a very clean, affordable, and sufficient option.

The contribution of microorganisms to the textile industry and their isolation from textile effluent are the main topics of this review.

4. Microorganisms is a Secondary Focus

Natural materials like flowers, vegetables, wood, roots, insects, etc., were used to extract dyes. However, businesses became reliant on synthetic colors made from petrochemicals due to the growing demand.

Compared to natural dyes, these dyes are more water soluble, readily absorbed, color faster, and offer a wider range of hues. Currently, over 800,000 t of dyes are produced annually throughout the world. The textile industry uses a large number of the dyes produced. The water-intensive textile production process releases a lot of effluent. Unfortunately, a significant amount of the dye is lost with the wastewater when there is insufficient color depletion onto the textile fiber from an aqueous dyeing method [18].

The released wastewater contaminates soil and water, resulting in significant environmental contamination. Additionally, it may change pH and oxygen levels, be poisonous and mutagenic to aquatic plants and animals, and

block light penetration. All of which are detrimental to aquatic ecosystems. The remaining dye is also linked to a number of harmful impacts on human health, including as inflammation, the respiratory system, and immune system disruption.

Colored wastewater from the textile industries may contain 10–200 mg/L of dye in addition to a range of other organic and inorganic compounds and additives [19]. Actually, it's thought that when these hues are discharged into rivers after wastewater treatment, up to 90% of them stay chemically unchanged. The breakdown of dye molecules is determined by the complexity of their structures.

Based on their chemical composition, they can be classified as acid dyes, azo dyes, basic dyes, dispersion dyes, sulfur dyes, pigment dyes, etc. About 70% of the dyes used in the textile industry are azo dyes complex in structure.

They are the most widely used synthetic dye because they are inexpensive and simple to use. Azo dyes and other synthetic colors can be broken down with the use of bacterial techniques.

Because microorganisms are adaptable, have dynamic metabolisms, and may include enzyme machinery, using them for biodegradation is convenient. Bioremediation is a non-hazardous, cost-effective, environmentally acceptable, and often more effective method of treating textile waste than conventional methods. This review discusses the process by which microorganisms degrade synthetic colors as well as the separation and screening of bacteria capable of decolorizing textile effluents.

4.1. Microorganisms for Dye Removal from Textile Wastewater

Textile wastewater can be treated using a variety of physical or chemical techniques (**Figure 3**). Using microorganisms or microbial enzymes, or doing so in conjunction with a physicochemical technique, provides a more economically viable outcome. In addition to ensuring a non-toxic approach, the employment of microbes may decolorize extremely complicated synthetic dyes.

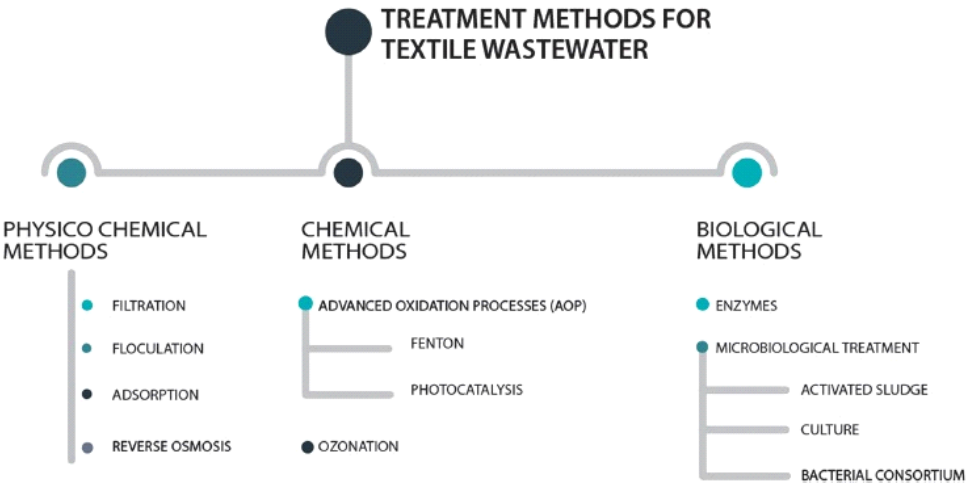

Figure 3. Techniques for removing dyes from textile wastewater.

The activity and the ability of microorganisms impact the effectiveness of the dyestuff treatment. There are two primary methods that microorganisms decolorize textile dyes: either by adsorption on microbial biomass or by the dyes' biodegradation by the cells or enzymes. The use of biomass is particularly advantageous if the effluent is highly toxic and does not support the growth and maintenance of microbial cells.

Bacteria, microalgae, and fungi are examples of adsorbents, and the adsorption process does not break down the color into smaller pieces. Unlike biosorption, biodegradation disrupts and frequently completely breaks down the original dye structure. Biodegradation is therefore the most sensible choice.

4.2. Degradation of Dyes by Fungi

The mineralization of synthetic hues has been extensively studied in relation to white-rot fungus. They produce a range of extracellular oxidoreductases that degrade lignin and related aromatic compounds. Its structurally

nonspecific and nonstereoselective enzyme system consists of laccase, manganese peroxidase (MnP), and lignin peroxidase (LiP). Laccase, which has been extensively studied for the removal of phenol and colors from liquid waste, is produced by Phanerochaete chrysosporium and Neurospora crassa [19].

Aspergillus ochraceus, Trametes versicolor, and others have also received a lot of attention. Positive outcomes for wastewater treatment can be achieved by employing gel entrapment and adhesion to a matrix.

Despite the success, the synthesis of enzymes is inconsistent since white-rot fungus are not normally present in wastewater. Additionally, utilizing white-rot fungi has certain drawbacks, such as a lengthy growth cycle and a reliance on nutrient limitation.

4.3. Degradation of Dyes by Yeasts

Azoreductases, which catalyze the reductive cleavage of azo groups (–N=N–), are responsible for the biological decolorization of azo dyes by yeasts. Candida oleophila and Candida zeylanoides are two examples of these yeasts. These strains produce the appropriate amines through azo bond reduction, which causes decolonization. A study of the enzymes that Saccharomyces cerevisiae MTCC 463 uses to biodegrade methyl red revealed varying degrees of laccase, lignin peroxidase, NADH-DCIP reductase, azoreductase, tyrosinase, and aminopyrine N-demethylase. According to studies, oxidative enzymes such laccase and lignin peroxidase may help break down these molecules into aliphatic amines. Furthermore, S. cerevisiae cells have shown bioaccumulation of reactive textile dyes (Remazol Blue, Remazol Red (RB) and Black B) during molasses development. The capacity of certain ascomycete yeast species, such as Candida tropical is, *Debaryomyces polymorphus*, and *Issatchenkia occidentalis*, to decolorize azo dyes has been studied. *Galactomyces geotrichum* MTCC 1360 has the ability to decolorize azo and reactive high exhaust textile dyes. Trichosporon beigelii has been shown to be able to completely eradicate Navy blue HER [20].

4.4. Dye Degradation by Plants and Algae

Studies have shown that photosynthetic organisms like cyanobacteria and algae can use an induced form of azoreductase to degrade azo dyes. Algae are most frequently used in bio sorption. Azo dyes can be broken down by several species of Chlorella and Oscillatoria into their aromatic amines, which can subsequently broken down into CO_2 or simpler organic molecules [21].

The method, also known as phytoremediation, has several advantages, one of which is the decreased need for nitrogen supplies. *Brassica juncea*, *Sorghum vulgare*, and Phaseolus mungo have all proven successful in decolorizing textile effluents to 79%, 57%, and 53%, respectively. *Blumea malcommi* and *Tagetes patula* have also shown promising results in the literature. However, there are a number of drawbacks, including the space required for the treatment to function and the impact of pollution on plants.

4.5. Bacterial Dye Degradation

Bacterial oxidoreductive enzymes are primarily responsible for the degradation of synthetic hues. Because of their dynamic metabolism, bacteria are able to employ the complex xenobiotic compounds of the dyestuff as a substrate. During the process, they are converted to simpler metabolites. The advantage of obtaining microorganisms from real wastewater disposal sites is that the enzymes that help break down.

4.5.1. Pure Bacterial Cultures

Beginning in the 1970s, Bacillus cereus, Bacillus subtilis, and Aeromonas hydrophila were recognized as promising remediators based on multiple studies. The structurally complex synthetic dyes and other compounds present in textile effluents reduce dissolved oxygen concentrations when released into water bodies, creating anoxic conditions that are dangerous to most living organisms. In recent studies, Proteus mirabilis, Pseudomonas luteola, and Pseudomonas sp. cultures have shown promising results for azo dye degradation in anoxic conditions [22].

4.5.2. Mixed Bacterial Cultures

It can be difficult and time-consuming to isolate pure microorganisms from textile wastewater. Furthermore, it is challenging for a pure bacterial culture to achieve total decolorization. Mixed bacterial cultures produce better.

Toxic aromatic amines can be effectively broken down by them. However, the procedure and the results are

difficult to understand because these results are difficult to replicate and because mixed cultures do not give a precise picture of the dye metabolism [23].

5. Bacterial Methods for Decomposition of Dyestuff

Bacteria's oxidases aid in the breakdown of synthetic colors. Azoreductase is essential for decolonization of azo dyes because it breaks down azo bon Mono- and dioxygenases catalyze the transfer of oxygen from O_2 into the aromatic ring of organic compounds.

It has been investigated whether certain bacteria can break down dyes in an aerobic environment. The incorporation of oxygen from O_2 into the aromatic ring of organic molecules is catalyzed by mono- and dioxygenase enzymes under aerobic circumstances [24]. Azoreductases, which are catalyzed by oxygen, assist certain aerobic bacteria degrade azo compounds.

5.1. Decolourization under Anaerobic Conditions

Bacteria's breakdown of synthetic dyes is the enzyme azoreductase works in anaerobic environments to decompose azo dyes. Nicotinamide adenine dinucleotide and flavin adenine dinucleotide (FADH) are the reducing agents.

Both aerobic and anaerobic processes break down the intermediates created during the process. According to research, since aerobic respiration NADH's electron transport to azo bonds. Oxygen may prevent the electron transfer from NADH to azo bonds. Alternatively, nonspecific extracellular interactions between reduced chemicals produced by the anaerobic biomass could be the cause of decolonization. Methanogens and both acid genic and methanogenic bacteria cause decolonization in anaerobic environments. Depending on the dye structure and the carbon supply, it is a generic process. Although the bacteria that cause decolonization can develop aerobically, decolonization can only occur in anaerobic conditions. Dye decolonization reactions frequently show first-order kinetics with respect to dye concentration. There have also been reports of zero-order kinetics [25].

5.2. Decolourization under Anoxic Conditions

Anaerobic environments have no oxygen at all. In contrast, there is less than 0.5 mg/L of dissolved oxygen in anoxic environments. These function in environments similar to those of aerobic treatments. More electrons are carried by nicotinamide adenine dinucleotide phosphate. Anoxic decolonization of different colors has been demonstrated to benefit from mixed aerobic and facultative anaerobic bacterial populations [26]. This raises the cost because it calls for complicated organic sources like peptone and yeast extract.

5.3. Decolourization under Aerobic Conditions

The majority of bacteria that break down colors in aerobic environments need another carbon source since they are unable to use the dye as a carbon source. Azo compounds are the only carbon source that very few bacteria can live on. These bacteria, such *as Pigmentiphaga kullae* K24 and *Xenophilus azovorans* KF 46, may cleave –N=N– bonds and use amines to proliferate.

Because they have oxidoreductive enzymes, ae Aerobic Decolonization. Since they cannot use the dye as a carbon source, most bacteria that degrade color in aerobic settings require another carbon source. The sole carbon source that very few bacteria can survive on is azo compounds. These bacteria, like Xenophilus azovorans KF 46 and *Pigmentiphaga kullae* K24, may cleave –N=N– bonds and use amines to multiply. Due to their oxidoreductive enzymes, robic bacteria can split color molecules either symmetrically or asymmetrically. Additionally, they might cause hydroxylation, desulfonation, deamination, etc. Anaerobic bacteria can thus degrade various color structures.

6. Isolation and Screening of Bacteria That Degrade Textile Dyes

The sample, dietary requirements, and targeted colors can all influence the method selected for bacterial isolation. The recommended storage temperature for experimental dyes is room temperature. One gram of each powder color is dissolved in one hundred milliliters of autoclaved distilled water to create 1% stock solutions, which are then filtered. Samples may be gathered from appropriate locations for the disposal of textile waste [27]. The development and selection of decolonization-capable bacteria is the next stage. For this stage, a number of approaches

might be used. The most fundamental and widely applied approaches are covered in this work.

7. Enrichment Culture of Sample

Using this method, the sample is grown in a nutrient medium that has been treated with the experimental dye. Which media should be utilized depends on the bacteria's growth requirements in the sample. A 1% dye concentration added to nutritional broth can support the growth of several bacteria. Bushnell Haas (BH) medium consisting of KH_2PO_4 0.1%, K_2HPO_4 0.1%, $MgSO_4 \cdot 7H_2O$ 0.02%, $CaCl_2 \cdot 2H_2O$ 0.002%, NH_4Cl 0.1%, NH_4NO_3 0.1%, NaCl 0.01%, and $FeCl_3$–$6H_2O$ 0.005% at pH 7 can be used [28].

Mineral salts medium (MSM) containing Na_2HPO_4 (3.6 g), $(NH_4)_2SO_4$ (1.0 g), KH_2PO_4 (1.0 g), $MgSO_4$ (1.0 g), Fe(NH_4) citrate (0.01 g), $CaCl_2 \cdot 2H_2O$ (0.10 g), and 10.0 mL of trace element solution per liter can also be used [28]. To enrich dye decolorizing microorganisms, the effluent sample and dye mixture must be added to a conical flask with suitable media and incubated under suitable conditions (e.g., 37 °C, 100–150 rpm). The media needs to be supplemented with glucose, yeast extract, etc. if the microorganisms in the sample are unable to use the dye as a carbon source. At predefined intervals (e.g., 6 h) after the incubation, the solution is checked for decolonization. When a sample exhibits positive findings for a particular dye, the results for individual colonies are confirmed using the plate method on a screening medium.

8. Biological Treatment Using Different Microbial Groups

Biological treatment using a consortium of different microbial groups, such as bacteria-fungi, and microalgae-bacteria recently became a popular choice for the effective treatment of municipal and industrial wastewater due to their offering several advantages, though it also has some limitations [29]. Therefore, a combination of treatment techniques could be far more advantageous than a single technique for effectively removing contaminants, including dyes, from textile wastewater. Some studies have reported that combined physicochemical and biological treatment techniques have also been used to treat textile dye wastewater. As illustrated in **Table 1**, the different treatment approaches have distinct advantages and disadvantages in various aspects such as technical, economic, efficiency, and environmentally friendly.

Table 1. Biological treatment using different microbial groups [18,19].

Treatment Approaches	Pros	Cons
Bioremediation		
Bacteria	Effective organic matter decomposition, nutrient removal, low operational costs, versatile in various treatment systems, reduced chemical use, scalable and adaptable.	Slow start-up time, risk of system failure, high maintenance requirements, odor, and gas emission.
Fungi	Degradation of complex organic pollutants, less sludge production, symbiosis with other organisms	Less efficient for basic nutrient removal, tend to grow more slowly, and are not as widely adopted or understood in large-scale wastewater treatment
Algae	Nutrient removal, energy efficiency, biomass production, carbon sequestration, oxygen production, low-cost treatment.	Large space requirement, operational complexity, slow growth rate, harvesting challenges, sensitivity to environmental conditions, and risk of contamination.
Yeast	Effective for certain types of organic waste and toxic metals, offers rapid growth and high resilience to harsh conditions and, the production of valuable by-products.	Less efficient at nutrient removal and complex pollutant degradation, require energy-intensive cultivation and biomass management, sludge production.
Consortium	Synergistic action, improved process efficiency, broad environmental tolerance	The complexity of management, competition for resources, and process control challenges.
Physicochemical		
Adsorption	Effective, cheap, and commonly used method.	Cost of regeneration, high cost of adsorbents.
Coagulation-flocculation	Complete removal of dye, simplicity, and low capital cost.	Produce highly toxic sludge, handling, and disposal problems, and removal depends on dye structure.
Ion exchange	No loss of sorbents during regeneration, solvent reclamation is possible, and dyes can be effectively removed.	Not effective for dispersing dyes, expensive technology, and organic solvents.
Electrodialysis	The system is very robust, efficient, and easily controllable.	The sacrificial anode requires to be replaced periodically, needs continuous monitoring and maintenance, and costs electricity.
Membrane	Removal of all dye types, appreciable resistance to temperature, good chemical resistance, and excellent color removal.	A limited lifetime before membrane fouling occurs, Concentrated sludge production, is costlier, and suitable for low volume of treatment.
Advanced oxidation	Efficient removal of dyes, able to remove non-biodegradable compounds.	High costs for reagents, energy consumption, sludge production, and toxic by-products
Flotation	Low cost, shorter hydraulic retention time.	Subsequent treatments are required to improve the removal efficiency.

9. Biodegradation of Dyes Using a Single Isolate

Recently, several studies have been conducted on color removal using single isolates (**Table 2**). Examples include *Acinetobacter baumannii* (JC359), *Bacillus cohnni* (RKS9M), *Pseudomonas stutzeri* (SPM-), *Klebsiella vari* and *Acinetobacter baum* [30].

Table 2. Some of the potential microorganisms used for the biodegradation of textile dyes [18,19].

Isolates	Isolated from	Type of Dye Used	Culturing Time (h)	Culturing Condition	Dye Concentration (mg/L)	Optimal PH and Temprature (°C)	COD/BOD Removal Efficiency (%)	Color Removal Efficiency (%)
Acinetobacter baumannii	-	Reactive black 5 (RB5), Reactive red 120 (RR120), and Reactive Blue 19 (RB19)	48	Anaerobic	500	7 & 37	-	98.8 = RB5, 96 = RR120 96.2 = RB19
Bacillus cohnni	Textile wastewater & sludge	Congo red	48	Anaerobic and aerobic	100	7.2 & 32	77.35/86.02	93.87
Bacillus albus	Textile wastewater and sludge	Methylene blue	6	-	100	7 & 30	83.87	99.27
Klebsiella pneumoniae	Textile wastewater	disperse blue-284	24	Anaerobic and aerobic	200	7 & 37	-	95
Pseudomonas stutzeri	Textile wastewater	Procion Red	20	microaerophilic	50	8 & 32	90/85	98
Klebsiella variicola	Soil samples	Acid Blue 113	72	Anaerobic	100	8 & 35	-	93.43
Acinetobacter baumannii strain	-	Reactive Blue 221 and Reactive Black 5	48	Aerobic	500	9 &45	-	90 for RB221, 87 for RB-5
Isolates	Textile wastewater	Seven different dyes	216	Anaerobic	50 µL of dye in 100 mL media	7 & 30	89.173 to 93.93 by different isolates	73.73 to 92
Isolates	Soil samples	a mixture of azo dyes	96	-	200	-	89 (mixed isolates)	55.9 ± 3.1 to 87.6 ± 3.1
Halomonas sp.	Soda lake	Reactive Red 184	96	Anaerobic and anoxic	150	10.4 & 25	97.5	98

9.1. Serial Dilution of Sample

Soil impacted by the effluent or textile effluent may be the sample collected from a site that was polluted. The sample should be diluted using sterile distilled water or sterile saline solution. Next, spread or streak each dilution over nutrient agar plates for a full day at the proper temperature. Following the isolation of pure colonies, the isolates' capacity to decolorize colors on media supplemented with dyes must.

9.2. Quantification of Dye Decolourization

After centrifugation at 10,000 rpm for 15 min, the absorbance of culture supernatants at the absorbance maxima of the corresponding dyes should be measured to determine decolonization [30]. Decolonization percentage is calculated. The absorbance of culture supernatants at the absorbance maxima following 15 min of centrifugation at 10,000 rpm absorbance minus starting absorbance)/initial absorbance × 100.

10. Screening for Enzymes

It is necessary to make a screening media enhanced with 0.01% experimental dye. The screening medium's well (about 5 mm) should be filled with around 10 µL of supernatant. Zone sizes need to be measured after a 24-h incubation period under ideal conditions. Purification and additional testing of the crude enzyme in the supernatant are necessary for successful outcomes [31].

11. Factors Affecting Bacteria's Decolonization Performance

In addition to physical, chemical, and biological processes, the biodegradation of synthetic dyes and other chemicals in textile effluent depends on a number of environmental factors.

11.1. Structure of Dye

Color fading is more common in dyes with simpler structures and lower molecular weights. It has been demonstrated that oxidation is influenced by the type of substituents on the aromatic ring. Research indicates that whereas electron-withdrawing chloro, fluoro, and nitro substituents stop oxidation, electron-donating methyl and methoxy substituents promote a compound's enzymatic breakdown.

11.2. Dye Concentration

According to a study, as the dye concentration rises, the decolonization rate progressively decreases. The reason for this could be that dyes are toxic to bacteria. Two more possible explanations are inadequate cell to dye ratios and dye molecules with different shapes that inhibit the active sites of azoreductase.

Because plastic naturally degrades at a very slow rate, plastic trash builds up in all areas of the ecosystem [32, 33]. Plastics are resistant to biodegradation because of their hydrophobicity, high molecular weight, and long chain polymer structure. Indeed, it can take up to a millennium for certain plastics to break down. The rapid accumulation of plastic in natural ecosystems can be attributed to these phenomena. Therefore, creating an effective method to quicken plastic decomposition is crucial to preventing this yearly buildup.

The scientific community has offered a number of natural answers that have been partially demonstrated through experimentation. These techniques include irradiation with gamma rays, chemical and thermal degradation, photo-degradation (degraded by light), and biodegradation (degraded by biological additions or microbes).

11.3. Carbon and Nitrogen Sources

Generally speaking, most bacteria cannot use colors as a source of nitrogen or carbon for growth. These bacterial cultures require a source of complex organic compounds such as peptone, yeast extract, or a combination of the two in order to break down [34].

11.4. pH and temperature

At ideal pH, the rate of decolorization is higher; It is lower at pH values that are more acidic or alkaline. Tolerance to high pH is essential since most textile industry processes take place in alkaline conditions. 6.0 to 10.0 is frequently the optimal range.

Denaturation of azoreductases can be linked to extremely high temperatures. It has been found that raising the temperature within a specific range (optimum) speeds up the decolorization process. The rate is significantly reduced when the temperature is raised further.

Different types of microorganisms decolorize colors in aerobic, facultative anaerobic, and anaerobic environments. Reductive enzyme activities, which are higher in anoxic settings for those working under anaerobic conditions, break down the structure of the synthetic dyes. Dissolved oxygen is believed to impede the breakdown of azo dyes because both molecules serve as electron acceptors and oxygen is a much stronger oxidant [35]. They are cheap, don't produce a lot of sludge, and don't harm the environment.

12. Conclusions

The organisms in the soil and water of the impacted area are poisoned by the complex structural of dyes. In order for the industries' effluents to be released into water bodies with little environmental damage, they require a practical and economical way to treat them. The effluent can be broken down by microorganisms and enzymes since they don't create a lot of sludge, don't harm the environment, and are cheap. Microbial and enzymatic wastewater breakdown is a good choice.

This review has examined a number of lab-based study findings based on existing literature studies. However, it is necessary to generate comparative information about the industrial performance of isolated microorganisms.

To maximize decolonization by isolated bacterial strains, all parameters must be optimized.

The successful lab tests using newly identified bacteria may eventually be expanded for usage in businesses. Experiments should be used to determine the decolonization rate as well as the toxicity levels in treated effluent. Based on the positive laboratory results, efforts should then be undertaken to scale up and employ bacterial decolonization techniques in real industrial effluents.

Additionally, the latest advancements in proteomics and genomics may enhance the efficacy of bacterial or enzymatic treatments of textile effluent. Because of all the positive study findings and recent developments, it is expected that microbiological treatment will take the lead in eliminating dangerous compounds, micro plastic and colors from textile effluent.

Funding

This work received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data used in this study are available from the corresponding author upon reasonable request.

Acknowledgments

The authors extended deep thanks for the NRC for continuous technical support.

Conflicts of Interest

The authors declare no conflict of interest.

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