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# Bioremediation of Dyes in Textile Wastewater

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**Abstract**
Development of industrial activities provides economical benefits but increasing industrial activities also create problems with the removal of wastes. Particularly untreated wastewater of textile industries creates an important environmental problem due to dyes content. High amounts of dyes are toxic for living organisms. There are some physico-chemical methods for removal of dyes but these methods are expensive. Biological treatment methods are relatively cheaper. Bioremediation technologies involve neutralization or removal of pollutants by using organisms. The aim of this study is to review the relevant data about bioremediation of dyes from literature. Some information about decolorization of dyes by microorganisms as bacteria, fungi and algae is given in this paper. Microbial remediation technologies are both inexpensive and efficient technologies for removal of textile dyes.

**Keywords:** Bioremediation, Decolorization, Textile wastewater

## INTRODUCTION

Textile industry releases a high amount of dyeing wastewater to receiving environments [1]. These textile dyes are accumulated in aquatic environments and affect the environment and aquatic life negatively [2]. High concentrations of dyes inhibit photosynthetic microorganisms' activities in rivers or lakes [3]. In addition to this these dyes are accumulated by aquatic organisms and joined the food chain. Dyes have toxic effects in the body of living organisms [4]. For instance dyes cause health problems in mammalians. Treatment of dyeing wastewater is very important. Several treatment technologies are suggested as chemical and physical methods but biological methods are relatively preferred due to inexpensive and eco-friendly nature [5]. Conventional wastewater treatment methods are ineffective because dyes have aromatic structure and resistant to degradative environmental conditions such as light and ozone [6]. Bioremediation is defined as treatment of environment by using organisms. Bioremediation technology involves usage of microorganisms to reduce, eliminate, contain, or transform to benign contaminants present in soils, sediments, water, and air. The aim of this study is to review the data about the usage of bioremediation technologies for decolorization of textile wastewater. This study focuses on decolorization of textile wastewater by using microorganisms such as bacteria, fungi and algae. Also the effect of parameters such as pH, temperature, initial dye concentration and nutrients on microbial dye removal activity is reviewed in this paper.

### Biological Treatments

Conventional wastewater treatment technologies are not sufficient enough because dyes have resistance due to their complex aromatic structure. Biological treatment methods are suggested due to their advantages by some researchers [6], [7] and some advantages of biological wastewater treatment are given in Table 1. Biosorption, bioaccumulation and biodegradation are the mechanisms of biological treatment. Biosorption is introduced as the usage of living or dead biomass for adsorption of pollutants [8]. Bioaccumulation is the accumulation of pollutants in the cell of organisms [9]. Biodegradation is mineralization or degradation of pollutants by enzymatic activities of organisms [10]. All of these mechanisms are used for decolorization of dyes containing in textile wastewater. Variety of factors such as pH, temperature, initial dye concentration and the species of microorganisms affect the decolorization process. In biological treatment technologies variety of living organisms such as algae, bacteria and fungi are used.

**Table 1.** Some advantages of biological wastewater treatment

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|---|
| It is inexpensive due to the usage of the waste biomass in other industries. |
| It is simple. |
| It produces smaller volumes of excess sludge. |
| It can be applied to very different types of effluents |
| It is eco-friendly. |
| It can be applied *in situ* at the contaminated site. |
| Generally there is not observed secondary pollution at the end of the process. |

### Algae for Bioremediation of Textile Dyes

Phytoremediation is defined as usage of algal biomass (macro and micro algae) for removal of pollutants [11]. It is reported that some algae species can able to break down dye molecules into simple compounds [12]. *Spirogyra* sp., commonly available green algae, which was suggested as an effective biomaterial for removal of azo dye reactive yellow 22 by Mohan et al. (2002) [13]. Some algae use dyes as carbon and nitrogen source [14]. *Chlorella pyrenoidosa*, *Chlorella vulgaris* and *Oscillatoria tenuis* are reported as the algae species which can degradate azo dyes by azoreductase enzyme in the literature [12]. A green microalga called

*Cosmarium* sp. is suggested to treat water containing Triphenylmethane dye and Malachite Green dyes [15].

Ertuğrul et al (2008) showed that a thermophilic *Phormidium* sp. can decolorize 50- 80% of textile dyes under thermophilic conditions [16]. Algal dye removal ability can be enhanced by stimulating algal growth. For instance, the dye removal activities of *Synechocystis* sp. and *Phormidium* sp. were increased by the addition of tricontanol hormone which was a plant growth regulator [17]. Recently, Preeti and Vena (2017) reported that *Oscillatoria* sp. decolorized 91% of Malachite Green, 75% of Congo Red and 23% of Nigrosin dyes at 0.05% dye concentration [18].

**Bacteria for Bioremediation of Textile Dyes**

Bacteria for biodegradation of azo dyes have been investigated in 1970's, Horitsu et al. (1977) examined that *Bacillus subtilis* was able to degrade azo dyes [19]. The studies on bacterial dye degradation continue from past to present day because biodegradation of textile dyes by bacteria is an efficient and low-cost method. New bacteria for effective biodegradation of dyes are discovered every passing day. The efficiency of bioremediation process is increased by the isolation of effective new strains and adaptation of known strains for utilization of dyes.

Sahasrabudhe and Pathade (2011) investigated that *Enterococcus faecalis YZ* 66 was effectively removed Reactive orange 16 dye [20]. Another bacterial strain called *Staphylococcus arlettae* strain VN -11 decolorized textile azo dyes effectively [21]. Microbial decolorization mechanism is affected by operational parameters as nutrients, pH, initial dye concentration and temperature. These are also important parameters for microbial growth. The efficiency of a biological treatment system is influenced by medium conditions. Bacteria performed maximum dye removal under optimal conditions. Medial pH is a very important parameter for dye removal, the optimal pH for bacterial decolorization process is the range of pH 6- 9 (Table 2).

**Table 2**. The optimal parameters for decolorization activity of different bacterial strains

| Bacterial Strain | Dye | Initial Dye Concentration (mg/L) | pH | Temperature (°C) | Removal Rate (%) | Reference |
|---|---|---|---|---|---|---|
| *Bacillus sp.* | Acid Red 2 | 100 | 6 | 37 | 90 | [35] |
| *Bacillus sp.* | Acid Orange 7 | 100 | 6- 8 | 30 | 99 | [35] |
| *Bacillus sp.* | Remazol Black B | 250 | 8 | 35 | 95 | [36] |
| *Bacillus sp.* | Congo Red | 3000 | 7 | 37 | 100 | [27] |
| *Bacillus subtilis* | Textile Effluent | 150 | 7 | 35 | 63.21 | [28] |
| *Corynebacterium sp.* | Reactive Black 5 | 100 | 7 | 37 | 60 | [37] |
| *Corynebacterium sp.* | Yellow 15 | 100 | 7 | 37 | 76 | [37] |
| *Pseudomonas entomophila* | Reactive Black 5 | - | 5- 9 | 37 | 93 | [38] |
| *Pseudomonas sp. SUK1* | Red BLI | 50 | 6.5- 7 | 30 | 99.28 | [39] |
| *Pseudomonas putida* | Crystal Violet | 200 | 7 | 30 | 50 | [40] |
| *Pseudomonas putida* | Safranin | 200 | 7 | 30 | 30 | [40] |
| *Pseudomonas putida* | Trypan Blue | 100 | 7 | 40 | 80 | [40] |

The strong acidic or alkaline environments decreased color removal activity of bacterial strains. For instance, *Enterobacter agglomerans* showed maximum Methyl Red removal at pH 7-9 [22]. *Pseudomonas sp.* SUK1 removed 99.28% of Red BLI at pH 6.5- 7 [23]. Acid blue 113 was removed at pH 7-8 by *Bacillus subtilis* maximally [24]. Temperature is another important parameter for dye removal of bacteria. The optimal temperature for decolorization is reported as 30- 40 °C (Table 2). Temperature effects the production of bacterial enzymes for removal of dyes and increasing temperature rate results in augmentation of decolorization. On the other hand higher temperature rates, which cause denaturation of cellular enzymes or are harmful to cell viability, decreased dye removal activity. Guo et al. 2007, examined the effect of the temperature range of 20 to 50 °C on decolorization of Anthraquinone by bacteria and maximum dye removal determined as 95% at 50 °C [25]. *Bacillus fusiformis* kmk 5 removed Orange 10 and Disperse Blue 79 at 37 °C maximally [26]. Gopinath et al. 2009 showed that azoreductase enzyme of *Bacillus sp.* was responsible for removal of Congo Red and optimal temperature for dye removal was 37 °C [27]. Initial dye concentration also affects the dye removal performance of bacterial strains due to the toxic impact of dye. Sivaraj et al 2011 reported that while the initial dye concentration of textile effluent was increased from 150 to 300 mg/L the decolorization rates were decreased from 72% to 55% [28]. Decolorization rates of Acid Red 113 by halo tolerant bacterial strains called *Pseudomonas aeruginosa* and *Bacillus flexus* were decreased from 87% to 60% and 84% to 57% while dye concentration increased from 25 to 100 mg/L, respectively [29]. The nutrient content of medium affects the decolorization activity because the higher amount of suitable nutrients significantly enhance bacterial growth. For instance, *Pseudomonas aeruginosa* and *Brevibacillus choshinensis* showed maximum decolorization activity in the presence of 10% glucose and were reported as effective bacterial strains for bioremediation of textile effluents [30]. Joshi et al (2008) revealed that dye removal performance of bacterial consortium was better in the medium contained yeast extract or combination of yeast extract and glucose than in the medium contained only glucose, peptone or starch [31]. Microorganisms use aromatic dye molecules as nutrient or energy sources in the bioremediation process [32]. Recent studies focused on the usage of bacterial consortium for bioremediation technologies [33]. Patowary et al. (2016) reported that bioremediation needed the cooperation of more than a single species because individual strains can degrade

limited range of pollutants [34].

**Fungi for Bioremediation of Textile Dyes**

Fungal bioremediation is described as mycoremediation and is an important point in wastewater treatment technologies from the past to present [41]. Glenn and Gold (1983) studied the first research about the effective degradation of dyes by white rot fungi called *Phanerochaete chrysosporium* [42]. Usage of fungi mostly white rot fungi for the treatment of wastewater was extensively studied [43]. Banat et al. (1996) proved that fungi were suitable for treatment of dye containing textile effluents [44]. The usage of fungi in wastewater treatment technologies has some advantages such as fungi can produce extracellular enzymes in order to solubilizes the insoluble substrates and fungi have a good physical and enzymatic contact with their environment because of their increased cell to surface ratio. Also extracellular fungal enzymes provide an advantage to tolerate toxic compounds at high concentrations [6]. Some fungal species produce ligninolytic enzymes named lignin peroxidases (LiP), manganese dependent peroxidases (MnP) in order to degrade pollutants such as lignin and dyes [45].

Fungal dye decolorization capacity is affected by several conditions such as nutrients, pH, temperature and initial dye concentration. The carbon source is an important nutrition for fungi. The optimal parameters for decolorization activity of different fungal strains are changed according to the properties of fungal species (Table 3).

**Table 3.** The optimal parameters for decolorization activity of different fungal strains

| Fungal Strain | Dye | Initial Dye Concentration (mg/L) | pH | Temperature (ºC) | Removal Rate (%) | Reference |
|---|---|---|---|---|---|---|
| *Aspergillus tamari* | Coomasie Brilliant Blue | - | 5 | 30 | 93 | [52] |
| *Aspergillus tamari* | Bromophenol Blue | - | 5 | 28 | 100 | [52] |
| *Aspergillus tamari* | Malachite Green | - | 5 | 28 | 91 | [52] |
| *Coriolopsis sp.* | Orange G | - | 4.5 | 35 | 60 | [53] |
| *Marasmius cladopyllus* | Remazol Brilliant Blue R | 200 | 5.5 | 22 | 97 | [54] |
| *Penicillium purpurogenum* | Coomasie Brilliant Blue | - | 5 | 28 | 91 | [52] |
| *Penicillium purpurogenum* | Bromophenol Blue | - | 5 | 28 | 92 | [52] |
| *Penicillium purpurogenum* | Malachite Green | - | 5 | 28 | 52 | [52] |
| *Perreniporia tephropora MUCL47500* | Methyl Orange | 300 | 5.5 | 30 | 92.03 | [55] |
| *Perreniporia tephropora MUCL47500* | Reactive Blue | 300 | 5.5 | 30 | 95.18 | [55] |
| *Rhizopus arrhizus* | Reactive Red | 100 | 3 | 30 | 100 | [56] |
| *Rhizopus arrhizus* | Reactive Black | 100 | 3 | 30 | 100 | [56] |
| *Rhizopus arrhizus* | Remazol Blue | 100 | 3 | 30 | 71.83 | [56] |
| *Rhizopus arrhizus* | Methylene Blue | 100 | 6 | 30 | 92.5 | [56] |
| *Trametes villosa* | Drimaren Brilliant Blue | 20 | 5.5 | 28 | 85 | [57] |

Kapdan et al. (2000) investigated the effect of different carbon sources such as glucose, starch, fructose and molasses on Everzol Turquoise Blue g dye decolorization of *Coriolus versicolor* and showed that glucose was the most usable carbon source for fungi [46]. Kaushik and Malik (2009) reported that the nitrogen content of media organized the fungal enzyme production for decolorization [6]. The effect of different nitrogen sources as ammonium chloride, malt extract and peptone on poly R-478 decolorization activity of *Letinus edodes* was examined by Hatvani and Mecs (2002) and the fungus showed the most effective decolorization rate in the presence of malt extract [47]. Temperature is another important parameter for decolorization activity and most of the studies recommended higher temperatures for dye removal of fungal species [6]. The Bromophenol Blue dye decolorization of *Rhizopus stolonifer* was increased by increasing temperature from 35 to 55 °C [48]. Most of the fungal strains performed maximum decolorization activity between 22 to 35°C (Table 3).The impact of pH is also important for fungal decolorization by influencing the chemical nature of fungal surface and dye molecules. Especially the pH of the environment affects the charge of the fungal surface due to altering the functional groups and the electrochemical interactions between charged dye molecules and fungal surface occur. For instance, *Rhizopus arrhizus* performed maximum decolorization capacity at pH 2 because the fungal cell surface became positive in an acidic environment and the anionic dye molecules were adsorbed on the fungal surface due to electrostatic interactions [49]. In addition to this the cationic dye Methylene Blue removal by *Fomes fomentarius* and *Phellinus igniarius* was increased while the pH value increased from 3 to 11 because in higher pH values the fungal surfaces' electro negativity increased and the negative charged fungal biomasses interacted with the positively charged dye ions [50]. In dye biodegradation process the importance of environmental pH is related with the fungal growth due to the fungal surface for dye sorption and also metabolically active fungal cell number is increased. *Coriolus versicolor* showed maximum decolorization (99%) at pH 4.5 which was also optimum pH for the fungal growth [46]. Optimal pH for *Aspergillus versicolor* growth was 6 and the fungus decolorized Remazol Blue at pH 6 maximally [51]. Most of the studies showed that fungal strains showed maximum dye removal activity at pH values 4.5 - 5.5 (Table 3) which was also optimum pH for fungal growth.

## CONCLUSION

This study focuses on decolorization of textile dyes by the means of bioremediation. Algae, bacteria and fungi are the effective biomaterials for bioremediation of dyes in textile wastewater. Environmental conditions have an important role in the removal of dyes. In addition to this the chemical properties of dye molecules and biochemical nature of organisms affect the decolorization process. Especially the enzymes of the organisms play an important role in biodegradation of dye molecules.

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