

Review on microbial decolourisation of textile dyes

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ABSTRACT

Dye is utilized to impart colour to materials of which it becomes an imperative role in human life. The physical and chemical methods of industrial effluent treatment do not take away the dyes successfully. Recent promising investigates on biological decolourisation of textile effluent has showed that variety of microorganisms and plants accomplished of decolorizing wide range of anionic and cationic dyes. A variety of biological treatment methods are set up to be the top for decolourisation of dye. Biological decolourisation of dye effluent is receiving much consideration due to cost effective and less regeneration by microorganisms such as bacteria, fungi, algae, and plants Current status of biological decolourisation and remediation of dye effluents, and deals with the most deliberate part on the effects of various parameters like pH, temperature and dye concentrations is briefly discussed in this article.

Keywords: Decolourisation, bacteria, algae, fungi.

INTRODUCTION

Colour is a observable pollutant. Colour in effluent has now been considered a pollutant that needs to be treated before discharging it. Industries have shown a significant increase in the use of synthetic complex organic dyes as the colouring material. The global consumption of textiles is currently around 30 million tones with expected growth at 3% per annum. The coloration of this total needs approximately 8×10^5 tons of dyes (Walker G M et. al.,1997) and it is estimated that 10,000 different types of dyes and pigments are produced worldwide annually. Out of which a large number of dyes are azo compounds ($-N=N-$), which are linked by an azo bridge and are used by a wide number of industries (BizunehAdinew, 2012)

Most industries use dyes and pigments to colour their products, which include textile, tannery, food, paper and pulp, printing, carpet and mineral processing industries(Asamudo N.U et.al.,2005).The effluents of these industries are highly coloured and the disposal of these wastes into receiving waters causes damage to the environment (*Mubarak Ali D. A. et. al.*, 2011). They may significantly affect photosynthetic activity in aquatic life due to reduce light penetration and may also be toxic to some aquatic life because of the presence of metals, chlorides, etc. Synthetic textile dyes used each year are lost during manufacture and processing operation and 20% of these dyes enter the environment through effluents that result from the treatment of residual industrial waters(BizunehAdinew, 2012). Colour removal has been the target of great attention in the last few years, not only because of the toxicity of dyes but also due to its visibility.

Various chemical and physical processes, such as ozonation, photo oxidation, electro coagulation, adsorption, activated carbon, membrane filtration and flocculation are applied for colour removal from textile. Such methods are often very costly and although the dyes are removed, accumulation of concentrated sludge creates a disposal problem (Bumpus,J.A., 2004). Due to the financial constraints posed on the treatment of pollutants, they are discarded into the environment and it contributes to about 40% of the total industrial wastewater. There is a need to find alternative biodegradations that are effective in removing dyes from large volumes of effluents and are low in cost such as biological or combination systems.Biological methods are generally considered environment friendly as they can lead tocomplete mineralization of organic pollutants at low cost. Biodegradation is a promising approach for the remediation of synthetic dyes wastewater because of its cost effectiveness, efficiency, and environment friendly nature. It is now known that several microorganisms, including fungi, bacteria, yeasts, and algae, can completely decolorize many dyes(Tripathi A. et. al., 2011).The present work discuss about biological decolourisation of dyes by algae ,bacteria and fungi. And several factors play important roles in dye decolourisation by algae, bacteria and fungi. Among these factors, pH, dye concentrations, and biomass concentrations of biomaterials are quite important

Biological treatment of dyes: Physical and chemical treatment methods such as precipitation, coagulation, adsorption, flocculation, flotation, electrochemical destruction, and mineralization and decolourisation process have some disadvantages such as cost, time, and release of residues (BizunehAdinew, 2012). All these techniques are minimizing the toxicity level not to neutralize the toxicity (Stolz A, 2001). To alternate these techniques, microorganism can be used to completely degrade the dyes, because microorganisms reduce the dyes by secreting enzymes such as laccase, azo reductase, peroxidase, and hydrogenase (Sudha M et. al., 2014). Biological dye elimination is mainly based on microbial biotransformation of dyes. The compact forms of dyes are further mineralized into simpler compounds and are utilized as their energy source. Based on the available literature, the microbial decolourisation of azo dyes is more effective under combined aerobic and anaerobic conditions. A wide range of microorganisms are capable of degrading a variety of azo dyes including bacteria, fungi and yeast. They have developed enzyme systems for the decolourisation and mineralization of azo dyes under certain environmental conditions. Decolourisation of dyes may take place in two ways: either adsorption on the microbial biomass (biosorption) or biodegradation of the dyes by the cells (BizunehAdinew, 2012).

Bacterial decolourisation: The bacterial reduction of the dye is usually nonspecific and bacterial decolourisation is normally faster (McMullan G et. al., 2001). A wide range of aerobic and anaerobic bacteria such as *Pseudomonas putida* (Tripathi A. et. al., 2011), *Bacillus sp.* (Abraham C.I et. al., 2014), *Pseudomonas putida* (Wei Wang et. al., 2012), *Bacillus subtilis* (Milikli G et. al., 2012), *Pseudomonas spp.* (Shah MP et. al., 2013), *Bacillus subtilis* SPR42 (Baljeet Singh Saharan et. al., 2011), *Tsukamurella sp.* J8025 (Wen-Tung Wu et. al., 2012), *Geobacillus stearothermophilus* UCP 986 (Norma S. et. al., 2010), *P. fluorescens* and *Corynebacterium* (Saleh M Al- Garni et. al., 2013), *Georgenia sp.* CC-NMPT-T3 (Madhuri Sahasrabudhe et. al., 2013), *Bacillus cereus* (Vidhyakalarani R et. al., 2013) have been extensively reported as degraders of dyes. Bacterial decolourisation is effective to decolorize both azo and anthraquinone dyes. And it will result in the production of biogas. But sometimes it will result only low decolourisation rates. (Bumpus, J.A., 2004)

For the effective decolourisation of dye it requires specific oxygen catalyzed enzymes and requires additional carbon and energy sources (Tony Hadibarata et. al., 2013). Some strains of aerobic use azo dyes as sole source of carbon and nitrogen: others only reduce the azo group by special oxygen-tolerant azo reductases. A number of research groups investigated the ability of bacteria in metabolism of azo dyes. Azo dyes are not readily metabolized under aerobic condition, and as a result of metabolic pathways it degraded into intermediate compounds but not mineralized. It can be completely degraded under coupled aerobic-anaerobic degradation (Sudha M et. al., 2014). In an anaerobic condition, the azo bond undergoes cleavage to generate aromatic amines and it was mineralized by nonspecific enzymes through ring cleavage under aerobic condition. Therefore, coupled anaerobic treatment followed by aerobic treatment can be an efficient degradation method of azo dyes (Feigel B J et. al., 1993, Mubarak Ali D. A et. al., 2011) have described bacterial strains which display a good growth in aerobic or agitation culture, but color removal was obtained with a high efficiency in anoxic or anaerobic culture. Mixed bacterial culture can give a better degradation rate than the individual strain (Walker G M et. al., 1997).

Fungal decolourisation: The most widely explored fungi in consider to dye degradation are the ligninolytic fungi (Bumpus, 2004). Apart from this, *Schizophyllum commune* IBL-062 (Muhammad Asgher et. al., 2013), *Aspergillus allhabadii* (30), *A. niger* (30), *A. sulphurous* (Namdhari B S et. al., 2012), *P. eryngii* F032 (Tony Hadibarata et. al., 2013), White-rot fungi (*pleurotus florida*) (Krishnaveni M, 2011) have been report which are competent of decolourisation of dyes. Large literature exists regarding the potential of these fungi is to oxidize phenolic, nonphenolic, soluble and nonsoluble dyes (Padmanaban V C et. al., 2013). White-rot fungi produces lignin peroxidase, manganese peroxidase and laccase that degrades many aromatic compounds due to their nonspecific enzyme systems (Toh, Y C et. al., 2013).

Steady operation of unremitting fungal bioreactors for the treatment of synthetic dye solutions have been achieved, application of white-rot fungi for the removal of dyes from textile wastewaters faces many problems such as large volumes produced, the nature of synthetic dyes, and control of biomass (Stolz A, 2001). In the previous type, the cells create enzymes such as laccase, Manganese peroxidase and lignin peroxidase to mineralize the dyes (Reghukumar C et. Al., 1996, Fu Y et. al., 2001). Lignin peroxidase act a key role in the degradation of azo dyes using *P. chrysosporium* (Ollikka P et. al., 1993).

Table.1.Recent reports on bacteria capable of dye decolourisation.

Bacteria	Dye	Percentage of removal	Experimental conditions	Time of contact	Reference
<i>Pseudomonas putida</i>	Acid Orange 10	90%	Static condition, pH 7.0, temperature of 37 °C	24 hrs	Tripathi, 2011
<i>Bacillus sp.</i>	Acid Orange 7	73%	Temperature 37°C	3 days	Abraham, 2014
<i>Pseudomonas putida</i>	Acid green 25 and acid red 18	91-97%	Optimum temperature 35°C and pH 3	3 hrs	Wei Wang, 2012
<i>Bacillus subtilis</i>	Azo dyes	92 %	pH 6-10 temperature 10°C-40°C addition of carbon sources	12 hrs	Milikli G, 2012
<i>Bacillus subtilis</i> SPR42	congo red dye	94 %	Temperature 37°C pH 8.5	24 hrs	Baljeet Singh Saharan, 2011
<i>Bacillus</i>	Blue 2B	60 %	temperature 40°C and pH 7	48 h	Bhoosreddy, 2014
<i>Pseudomonas spp.</i>	methyl orange	84	dye concentrations (50–200 mg/l), pH (6–10) and temperatures (30–40°C)	4 day	Shah, 2013
<i>Tsukamurella</i> sp. J8025	methyl orange	98%	Temperature 30 °C	48 hrs	Wen-Tung Wu, 2012
<i>Geobacillus stearothermophilus</i> UCP 986	Reactive Azo Dye Orange II	96–98%	Temperature 50°C	24 hrs	Norma S, 2010
<i>P. fluorescens</i> and <i>Corynebacterium</i>	Crystal Violet	100%	Plackett-burman and Box-Behnken statistical experimental designs	58 hrs	Saleh M Al-Garni, 2013
<i>Georgenia</i> sp. CC-NMPT-T3	Reactive Orange 16,	94.2%	pH 6-8 temperature 28±2°C - 45°C.	8 h	Madhuri Sahasrabudhe, 2013
<i>Bacillus cereus</i>	Reactive Blue 19	52-95%	-	-	Vidhyakalrani, 2013

Table.2.Recent reports on fungi capable of dye decolourisation.

Fungi	dye	Percentage of removal	Experimental conditions	Time of contact	Reference
White-rot fungi (<i>pleurotus florida</i>)	crystal violet	100%	pH 5.5 temperature 37°C	24 hrs	Krishnav, 2011
	Orange G	100%			
	malachite green	90%			
<i>Schizophyllum commune</i> IBL-06	Solar brilliant red 80	84.8%	pH 4.5 and Temperature 30°C.	7 days	Muhammad Asgher, 2013
<i>Aspergillus allhabadii</i> ,	Reactive Blue MR,	95.13±0.11%	Temperature 25±2°C	10 days	Namdhari, 2012
<i>A. niger</i>		83.14±0.19%			
<i>A. sulphureus</i>		93.01±0.25%			
<i>P. eryngii</i> F032	Reactive Black 5	93.57%	pH 3 and temperature 40 °C,	72 hrs	Tony Hadibarata, 2013

Algal decolourization: Algae have been found to be potential biosorbents because of their availability in both fresh and saltwater (Wen-Tung Wu et. al., 2012). The biosorption capacity of algae is attributed to their relatively high surface area and high binding affinity. Cell wall properties of algae play a major role in biosorption; electrostatic attraction and complexation are known to take place during algal biosorption. Functional groups such

as hydroxyl, carboxylate, amino and phosphate found on the algal cell surface are considered to be responsible for sequestration of contaminants from wastewater (Asha Srinivasan, 2010).

Colour removal by algae was due to three intrinsically different mechanisms of assimilative utilization of chromophores for production of algal biomass, CO₂ and H₂O transformation of coloured molecules to non-coloured molecules, and adsorption of chromophores on algal biomass. Report of algae capable of degrading azo dyes, through an induced form of an azo reductase showed good colour removal (Anjaneyulu, 2005). Several species of *Chlorella* and *oscillatoria* were capable of degrading azo dyes to their aromatic amines and in further metabolizing the aromatic amines to simple organic compounds or CO₂. Some were even capable of utilizing a few azo dyes as their sole source of carbon and nitrogen (Wen-Tung Wu, 2012).

Table.3.Recent reports on algae capable of dye decolourisation.

Algae	Dye	Percentage of removal	Experimental conditions	Time of contact	Reference
<i>Cosmarium sp.</i>	Malachite Green	92.4%	Temperature 5 to 45 °C	24 hours	Daneshvar,2005
Green algae	Monazo and diazo dyes	68%	Temperature 25 °C	2 days	Hanan Hafez Omar, 2008
<i>Lyngbya sp.</i> BDU 9001 with coir pith	textile dye	73%	pH 7 and the temperature 29°C	15 days	Henciya,2013
Algal biomass	malachite green	85%	pH 4 to 6 temperature 50°C	45 min	Swapnali M Gajare, 2012
Green algae	indigo	89.3%	pH 8, temperature 25°C and salinity at 15 g L ⁻¹	5 days	ElisangelA F
	direct blue	79%			
	remazol brilliant orange	75.3%			
	crystal violet	72.5%			

Factors affecting biodegradation of dyes: Ecosystems are active environments with variable abiotic conditions, like pH, temperature, presence of oxygen, metals, salts, etc. Optimization of such abiotic conditions will greatly help in the development of industrial-scale bioreactors for bioremediation.

1. pH: In general, fungi show better decolourisation and biodegradation activities at acidic or neutral pH whereas bacteria at neutral or basic pH. The pH plays a major upshot on the efficiency of dye decolourisation, and the optimal pH for colour removal was 6-10. (Palanivelan Ramachandran et. al., 2013) Adaptation of microorganisms to varying pH enhances the process of effluent treatment. The optimum pH for color removal was neutral to slightly alkaline and the colour removal was decreased rapidly at strongly acid or alkaline pH values. Almost all fungal dye decolourisation studies showed that higher dye removal rate take place in acidic pH range. Altering the pH within a range of 7-9.5 have a very little effect on dye reduction process (Palanivelan Ramachandran et. al., 2013).

2. Temperature: Temperature is an important environmental factor and the biodegradation activities of microorganisms are affected by changes in temperature. The rate of colour removal increases with increasing initial temperature (Palanivelan Ramachandran et. al., 2013). The ambient temperature for colour removal for bacteria was 35-45°C. the degradation activities of the microorganisms decrease because of slow growth, decreased reproduction rate and deactivation of enzymes responsible for degradation (BizunehAdinew, 2012).

3. Initial dye concentration: The effect of dye concentration strongly influences the rate of dye removal and also impacts the toxicity of dye molecule. Percentage of decolourisation increased with increase in time irrespective of initial dye concentration for bacteria. The decolourisation of dye decreases with increasing dye concentration. Growth of fungi was affected by the presence of high concentration of dye. (Kapdan I K et. al., 2002) reported the maximum dye stuff turquoise blue G, phthalocyanin dye) concentration tolerated by *C.versicolor* was 1200mg/l. Decolouriation efficiency was high if dyestuff concentrations were 100-250mg/l (in 3-5 days) and nearly 700-

1200mg/l (9 days). It indicates decolorization of dye decreases with increasing dye concentration. (Parshetti G et. al., 2007)

4. Effect of Nutrients: Nutrients plays an significant role in dye decolourisation process, superior amount of nutrients significantly influences the growth of micro-organism and boost the degradation of dyes in aqueous solution. *Pseudomonas* sp. BSP-4 isolated from azo dye contaminated soil capable to decolourise azo dye black E by utilizing it as nitrogen source up to 300 ppm in 36 hours (Sudhakar P et. al., 2002) Nutrient constituent in the medium have noticeable effect on colour removal along with natural supplements had a positive impact on dye decolourisation for fungi *Aspergillusfumigatus*XC6 supplemented with the a range of carbon and nitrogen sources particularly ammonium sulphate had significant effect on effluent colour reduction (Jinqi L et. al., 1992).

CONCLUSION

Economical removal of colour from effluents remains an important problem although a number of successful systems have evolved employing various physico-chemical and biological processes. These effluents mostly comprises of chemical or synthetic compounds which can severely affect the biotic life of the environment and cause several health hazards to mankind indirectly. Biodegradation of synthetic dyes using various fungi, bacteria and algae is becoming a potential approach for the treatment of dye wastewaters. With the increasing production of synthetic chemicals and their ultimate release into the environment, the natural microbial populations are unable to decompose them in due course of time.

To develop a low cost and low-technological bioprocess for the treatment of dye waste waters. Industries to be treat their wastewaters before discharging into the environment. The application of microbes is simple and can be readily modified according to the character of the dye. An understanding and knowledge of biodegradation are helpful in pollution abatement and the production of bio friendly and environment friendly products like biodiesel, bioethanol, bio pesticides, biopolymers, etc. The biodegradation abilities of microorganisms can be enhanced by gradually exposing them to higher concentrations of synthetic organic chemicals. Microorganisms exposed to higher levels of pollutants evolve mechanisms and pathways for degrading them.

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