# Textile Wastewater Treatment: A Critical Review

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***Abstract*— Waste water that is discharged by dye manufacturing and textile finishing industries has become an environmental concern. Textile industry uses various types of synthetic dyes and discharge huge amounts of highly colored wastewater as the uptake of these dyes by fabrics is very poor. This highly colored textile wastewater severely affects photosynthetic function in plant but also has an adverse effect on aquatic life due to low light penetration and oxygen consumption. It may also be lethal to certain forms of marine life due to the occurrence of component metals and chlorine present in the synthetic dyes. Therefore, this textile wastewater need be treated before their discharge. In this article, different treatment methods to treat the textile wastewater have been presented. Treatment methods discussed in this paper involve oxidation methods, physical methods, and biological methods.**

***Index Terms*— Textile wastewater, adsorption, $H_2O_2$, fungi, algae, Bacteria**

## I. INTRODUCTION

Textile industry can be classified into three categories viz., cotton, woolen, and synthetic fibers depending upon the used raw materials. The textile dyeing industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing processes. Wastewater from printing and dyeing units is often rich in color, containing residues of reactive dyes and chemicals, such as complex components, many aerosols, high chroma, high COD and BOD concentration as well as much more hard-degradation materials. The toxic effects of dyestuffs and other organic compounds, as well as acidic and alkaline contaminants, from industrial establishments on the general public are widely accepted. Therefore, in terms of its environmental impact, the textile industry is estimated to use more water than any other industry, globally and almost all wastewater discharged is highly polluted. Average sized textiles mills consume water about 200 L per kg of fabric processed per day [1], [2]. According to the World Bank estimation, textile dyeing and finishing treatment given to a fabric generates around 17 to 20 percent of industrial waste water [2], [3].

In India, the textiles industry consumes around 80% of the total production of 1, 30,000 tons of dyestuff, due to high demand for polyester and cotton, globally [4]. These dyes in wastewater severely affect photosynthetic function in plant. They also have an impact on aquatic life due to low light penetration and oxygen consumption. They may also be lethal to certain forms of marine life due to the occurrence of component metals and chlorine. Suspended particles can choke fish gills and kill them. They also decrease the capacity of algae to make food and oxygen. Dyes are also detected to hinder with certain municipal wastewater treatment operations such as ultraviolet decontamination etc. [5].

Now a day, aromatic and heterocyclic dyes are used in textile industry. The complicated and stable structure of dye is posing a greater difficulty in degradation when present not only in textile wastewater but also in any kind of complex matrix (Ding et al., 2010). Therefore, the main aim of this article is to provide a complete survey about different wet processing steps in cotton textile industry and the cost of methods implemented for the treatment of the dyes in textile wastewater.

This review also explains the critical study of the most generally used methods (chemical, physical and biological) of dye removal from textile industrial effluents.

## II. TEXTILE OPERATIONS

Textile Printing and dyeing processes include pretreatment, dyeing / printing, finishing and other technologies. Pre-treatment includes desizing, scouring, washing, and other processes. Dyeing mainly aims at dissolving the dye in water, which will be transferred to the fabric to produce colored fabric under certain conditions. Printing is a branch of dyeing which generally is defined as 'localized dyeing' i.e. dyeing that is confirmed to a certain portion of the fabric that constitutes the design. It is really a form of dyeing in which the essential reactions involved are the same as those in dyeing. In dyeing, color is applied in the form of solutions, whereas color is applied in the form of a thick paste of the dye in printing. Both natural and synthetic textiles are subjected to a variety of finishing processes. This is done to improve specific properties in the finished fabric and involves the use of a large number of finishing agents for softening, crosslinking, and waterproofing. All of the finishing processes contribute to water pollution. In addition, in different circumstances, the singeing, mercerized, base reduction, and other processes should have been done before dyeing/printing.

In the textile dyeing industry, bleaching is an important process. It has three technologies: sodium hypochlorite bleaching; hydrogen peroxide bleaching and sodium chlorite bleaching. Sodium hypochlorite bleaching and sodium chlorite bleaching are the most commonly used processes. Normal concentration of chlorine dioxide in bleaching effluent is 10-200 mg/L. As chlorine dioxide is a strong oxidant, it is very corrosive and toxic as well. The typical printing and dyeing process is shown in Figure 1.

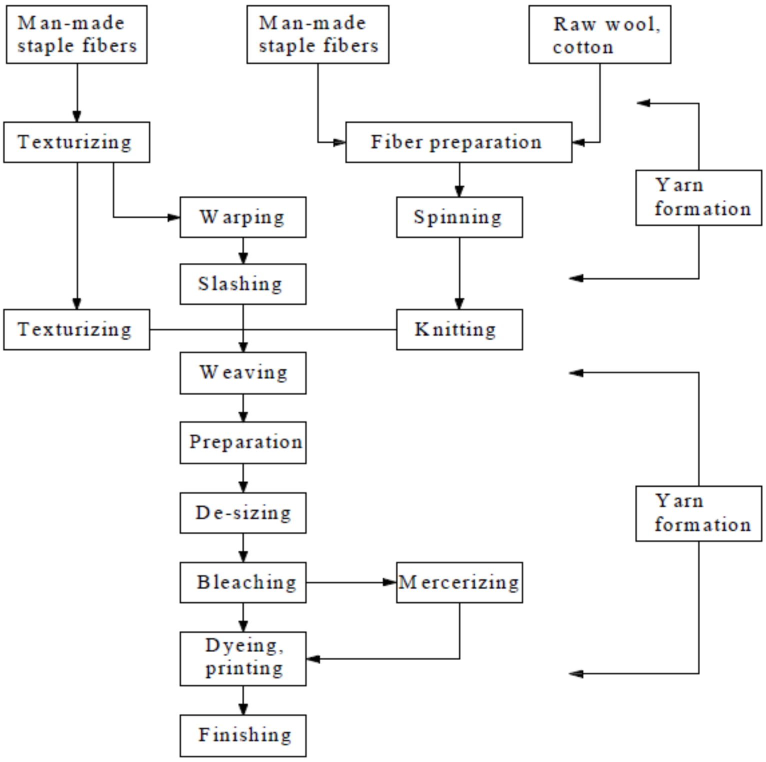


Fig. 1. Various steps involved in processing textile in a cotton mill [6]

## III. THE TEXTILE INDUSTRY STANDARDS FOR WATER POLLUTANTS IN INDIA

As the wastewater is harmful to the environment and people, there are strict requirements for the emission of the wastewater. The standards of the wastewater discharge (Table 1) have far too many parameters due to the variation in the raw materials used, different types of dyes, technology and equipment. These standards are established by the national environmental protection department of Central Pollution Control Board (CPCB) depending upon the local surroundings and environmental safety necessities which are unfixed.

TABLE 1 TEXTILE INDUSTRY STANDARDS FOR WATER POLLUTANTS

| S. No. | Parameters | Standards |
|---|---|---|
| 1 | pH | 6.9 |
| 2 | BOD | 30 ppm |
| 3 | COD | 250 ppm |
| 4 | TDS | 2000 ppm |
| 5 | Sulphide | 2 ppm |
| 6 | Chloride | 500 ppm |
| 7 | Calcium | 75 ppm |
| 8 | Magnesium | 50 ppm |

Source: Paul et al., [7].

For printing and dyeing wastewater, the first consideration is the organic pollutants, color and heavy metal ions. Recently, as the lack of water, the recovery of wastewater should be considered. So the decolorization of the printing and dyeing wastewater increased heavily.

## IV. TEXTILE WASTEWATER TREATMENT PROCESSES

The textile dyeing wastewater has a large amount of complex components with high concentrations of organic, high-color and changing greatly characteristics. The textile wastewater generated from cotton dyeing industry is extremely polluted due to presence of reactive dyes which are not readily amenable to biological treatment. Color water causes scarcity in the light which is essential for the development of the aquatic organisms. As result, it leads to an imbalance in the environment. To reduce the treatment cost of the river water which is used the purpose of drinking; it should not have any color and toxic compounds. Therefore, before discharge of textile wastewater into river, many treatment processes including chemical, biochemical, physical, hybrid treatment processes have been developed to treat it in an economic and efficient way. These technologies are verified to be highly effectual for the treatment of textile wastewater [8].

### A. Oxidation Methods

These are the most usually used methods of degradation of dyes by chemical means due to its easiness of application. These oxidation technologies can be categorized as advanced oxidation processes and chemical oxidation. These processes have the ability to degrade the toxic initial and their byproduct chemicals, dyes, pesticides, etc. either partly or completely under ambient conditions. Advanced oxidation processes (AOP) are the processes in which hydroxyl radicals are produced in adequate amounts. These hydroxyl radicals are powerful oxidizing agents. These oxidizing agents have an oxidation potential of 2.33 V and shows faster rates of oxidation reactions as compared conventional oxidants such as hydrogen peroxide or potassium permanganate. Hydroxyl radicals react with most dyes with high rate reaction constants [9].

Chemical oxidation methods use oxidizing agents like $O_3$ and $H_2O_2$. Ozone and $H_2O_2$ forms strong non-selective hydroxyl radicals at high pH values. These radicles due to this high oxidation potential can effectively break down the conjugated double bonds of dye chromophores as well as other functional groups such as the complex aromatic rings of dyes. Subsequent formation of smaller non-chromophoric molecules decreases the color of the effluents [10]. These methods are useful for double bonded dye molecules. These oxidizing agents have a low rate of degradation as equated to the AOP processes due to less production of hydroxyl radicals [9]. One major benefit of the ozonation is that ozone can be used in its gaseous state and consequently does not raise the volume of the wastewater and does not result into sludge generation. However, the major disadvantage of using ozone is that it may form toxic byproducts even from biodegradable dyes in wastewater [11].

Degradation of the dye is also possible by the combined treatment of UV light and the $H_2O_2$ due to the production of high concentrations of hydroxyl radicals. This combined method of UV light and the $H_2O_2$ is advantageous for dye-containing textile effluent due to no sludge production and reduction in foul odors. Here, UV light is used to activate the decomposition of $H_2O_2$ into hydroxyl radicals. These hydroxyl radicals cause the chemical oxidation of dye or organic material, mineralizing the same to $CO_2$ and $H_2O$. The parameters such as UV radiation intensity, pH, structure of dye molecule and the dye bath composition need to be optimized to get a more rate of dye removal [12], [13]. Table 2 shows some of the typical applications of oxidation process to the treatment of textile wastewater. It also illustrates the type of oxidation process used for treatment, the dyes and the significant results of the work.

### B. Biological Methods

The biological process removes only the dissolved matter in textile wastewater. The removal efficiency is influenced by the ratio of organic load/dye and the microorganism load, its temperature, and oxygen concentration in the system. On the basis of oxygen requirement, biological methods can be classified into aerobic, anaerobic and anoxic or facultative or a combination of these.

The biological methods for the complete degradation of textile wastewater have benefits such as: (a) eco-friendly, (b) cost competitive, (c) less sludge production, (d) giving non-hazardous metabolites or full mineralization (e) less consumption of water (higher concentration or less dilution requirement) compared to physical/oxidation methods [14].

The efficiency of biological methods for degradation depends on the adaptability of the selected microbes and the activity of enzymes. A wide range of microorganisms such as bacteria, fungi and algae are able to degrade a wide variety of dyes present in the textile wastewater.

#### Fungal Cultures for Degradation of Dyes

A fungal culture has an ability to acclimate its metabolism to changing environmental conditions. This ability is a vital for their existence. Here, intra and extracellular enzymes help in metabolic activity. These enzymes have ability to degrade various dyes present in the textile wastewater. These enzymes are lignin peroxidase (LiP), manganese peroxidase (MnP) and laccase [15], [16]. Mostly, white rot fungal cultures have been used for the removal of azo dyes Current reports on degradation of dyes by fungi are indicated in Table 3.

#### Algae for Degradation Dyes

Algae are omnipresent and are getting an increasing consideration in the area of degradation of textile wastewater. Several species of algae which have been successfully used are reported in Table 4.

### C. Physical Methods

Coagulation - flocculation based physical methods are useful for the decolorisation of wastewater containing disperse dyes. They also have low decolorisation efficiency for the wastewater having reactive and vat dyes. These techniques also limit their use due to the low decolorisation efficiency and large generation of resultant sludge [17], [18].

Adsorption approaches have attracted significant attention due to their greater decolorisation efficiency for wastewater containing a variety of dyes. High affinity, capability for the compounds and adsorbent regeneration ability are the main characteristics which need to be considered during the selection of an adsorbent for color removal [19]. Activated carbon is an effective adsorbent for a wide range of dyes. But, its high price and difficulty in its regeneration limits the application for decolorisation [20]. Various adsorbents along with the dye are summarized in Table 5.

TABLE 2 DIFFERENT OXIDATION METHOD FOR DEGRADATION OF DYES.

| S. No. | Author | Type of oxidation process | Conditions | Results |
|---|---|---|---|---|
| 1 | Zuorro and Lavecchia [21] | UV/H2O2 | Azo dye Reactive Green 19 (RG19), Optimum condition of UV radiation 1500 mW cm2 H2O2 and pH conditions (ch ¼ 30 mM, pH ¼ 6.5) | ✓ Complete decolorization in about 20 min.<br>✓ 63% Total organic carbon (TOC) removal in 90 min. |
| 2 | Gupta et al. [22] | Combinations of TiO2/UV/H2O2 | Azo dye Amaranth (AM), Optimum condition of TiO2 (0.16 g/L) and UV radiation of 10 mW/cm2 at wavelength of 254 nm | ✓ The decolorization efficiencies were 17%, 26%, 38% and 64% in the runs UV, UV + H2O2, UV + TiO2 and (UV + TiO2 +H2O2) after approximately.<br>✓ 100 min illumination periods, respectively. |
| 3 | Gogate and Bhosale [23] | Acoustic cavitation (generated using ultra-sonic horn) and hydrodynamic cavitation (generated using single hole orifice) in combination with different chemical oxidants like H2O2, Na2S2O8 and NaOCl, | Orange acid-II (OA-II) and brilliant green (BG) | ✓ In the case of acoustic and hydrodynamic cavitation, degradation was in the range of 50-60% depending on the dye and type of cavitation used.<br>✓ The most effective decolorization of both dye effluent by the combination of hydrodynamic cavitation and chemical oxidation as compared to chemical oxidation and acoustic cavitation based combination. |
| 4 | Mishra and Gogate, [24] | Hydrodynamic cavitational with the presence of H2O2, CCl4 and Fenton's reagent | Rhodamine B (10 ppm) inlet pressure (2.9 e5.8 atm), temperature (30 and 40 C) and pH (2.5-11) H2O2 (10e200 mg/l) | ✓ 99.9% decolorization of Rhodamine using a combination of cavitation and H2O2 as well as a combination of cavitation with Fenton chemistry.<br>✓ 82% degradation by the combination of cavitation with CCl4. |
| 5 | Saharan et al., [25] | Hydrodynamic cavitation using orifice plate, circular venturi and slit venture | Orange-G dye [OG] concentration ranging from 30 to 150 mM pH of 2-13 | ✓ Acidic medium (lower pH) for the degradation of OG using HC.<br>✓ The slit venturi results in to almost 50% greater degradation rate and cavitational yield among all three cavitating devices studied for the same amount of energy delivered. |

TABLE 3 REPORTS ON FUNGAL CULTURES CAPABLE OF DYE DEGRADATION.

| S. No. | Author | Dye | Fungi | Results |
|---|---|---|---|---|
| 1 | Hadibarata et al.,[26] | Naphthalene | White rot fungus Pleurotus eryngii | ✓ Naphthalene degradation by Pleurotus eryngii.<br>✓ Use of naphthalene as carbon source instead of limited carbon source.<br>✓ 1,4-Naphthaquinone, benzoic acid and catechol are metabolites as result of naphthalene biodegradation. |
| 2 | Chen and Yien Ting [27] | Triphenylmethane dyes (Crystal Violet (CV), Methyl Violet (MV), Cotton Blue (CB) and Malachite Green (MG) | Penicillium simplicissimum isolated from indoor wastewater sample | ✓ Decolorisation of 95%, 98% and 82% was observed for Crystal Violet (CV; 100 mg/l), Methyl Violet (MV; 100 mg/l) and Cotton Blue (CB; 50 mg/l), with within 14, 13 and 1 day(s) respectively. |

| | | | | |
|---|---|---|---|---|
| | | | | ✓ 54% decolorization was observed for Malachite Green (MG; 100 mg/l) for after 14 days. ✓ Biodegradation of Triphenylmethane dyes was due to Lignin peroxidase and NADH-DCIP reductase activities using 2 g/l biomass and 100 ppm dye. |
| 3 | Benghazi et al.,[28] | Remazol Brilliant Blue R (RBBR) and Acid Red 299 (NY1) | Aspergillus niger | ✓ Recombinant and native laccases showed similar decoloris-ation (40 -60%) for Remazol Brilliant Blue R within 200 min. ✓ In case of Acid Red 299 (NY1), recombinant laccases (30% decolorisation) showed faster decolorisation as compared to native laccases (13% decolorisation) within 40 min. |
| 4 | Kulkarni et al.,[29] | Disperse dye Solvent Red 24 | Lichen Permelia perlata | ✓ Laccase and Manganese peroxidase was responsible for Biorans formation. ✓ 100% decolorisation was observed within 24 h under pH and temperature of 8 and 50 C, respectively. ✓ metabolites obtained after biotrasformation were naphthalen phenyldiazene and -1- D30yldiazene, naphthalene, 1-(2-methylphenyl)-2-D30 diphenyldiazene |

TABLE 4 REPORTS ON ALGAE FOR DYE REMOVAL

| S.No. | Author | Dye | Algae | Mechanism |
|---|---|---|---|---|
| 1 | Kousha et al., [30] | Acid orange II (AO7) dye | Brown alga, Stoechospermumma ginatum | Adsorption |
| 2 | Khataee et al., [31] | Triphenylmethane dye, Malachite Green (MG) | Xanthophyta alga, Vaucheria species | Adsorption |
| 3 | Khataee et al., [32] | C.I. Basic Red 46 (BR46) | Green macroalga Enteromorpha sp. | Biodegradation |
| 4 | Meng et al.,[33] | Acid red 27 (AR27) | Shewanella algae (SAL) | Biodegradation |

TABLE 5 VARIOUS ADSORBENT FOR ADSORPTION OF DYE.

| S. No. | Author | Dye | Adsorbent |
|---|---|---|---|
| 1 | Zhong et al., [34] | Anionic dye (Reactive red-24, RR-24) | Modified wheat residue (MWR) |
| 2 | Tunali Akar et al., [35] | Reactive Blue 49 | Capsicum annuum seeds |
| 3 | Elkady et al., [36] | C.I. Remazol reactive red 198 | Immobilized eggshell with a polymer mixture of alginate and polyvinyl alcohol |
| 4 | Kumar and Ahmad, [37] | Crystal violet (CV) dye | Treated ginger waste (TGW) |
| 5 | Moussavi and Khosravi, [38] | Methylene blue (MB) | Pistachio hull powder (PHP) |
| 6 | Kara et al., [39] | Reactive dye (RR45), | Symphoricarpusalbus, Modified with sodium diethylithio carbamate |
| 7 | Sumanjit et al. [40] | Dye basic blue 9 (BB9) | Ground nut shells charcoal (GNC), and Eichhornia charcoal (EC) |

## V. CONCLUSIONS

Aim of the Wastewater Treatment Plants in textile industry is to implement technologies giving minimum or zero water pollution. These wastewater treatment plants in textile industry are the most accepted approaches towards reaching environmental safety. Yet, no particular treatment methodology is appropriate or universally adoptable for all kinds of textile effluents. Hence, the treatment of textile wastewater is done by a combination of several methods, which contain physical, chemical and biological method depending on the type and quantum of pollution load. This review has discussed several methods that can be adopted to treat the dye in textile wastewater and to reduce the pollution load. Physical and oxidation methods are effective for the degradation of dye in textile wastewater only if the textile effluent volume is small.

Wastewater treatment plants utilizing biological methods, rather than chemical methods claim that their preference is due to low production of inorganic sludge, low working costs and complete mineralization/stabilization of dye in biological method. Normally, textile wastewater parameters after biological treatment are not in compliance with the textile wastewater discharge standards. So to meet wastewater discharge and to reduce the effect of toxic or inhibitory compounds on bacteria, firstly, recalcitrant organic compounds and dyes should be oxidized by chemical oxidation or advanced oxidation method to convert it to biodegradable constituents before subjecting the wastewater to bacterial treatment is preferred. The researches on pollution control for the textile industry should also focus on quantitative description of combination processes instead of only qualitative discussion.

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