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Diksha Bisht
Department of Textile and Apparel Designing, I.C. College of Home Science, Haryana Agricultural University, Hisar, Haryana, India

Nisha Arya
Department of Textile and Apparel Designing, I.C. College of Home Science, Haryana Agricultural University, Hisar, Haryana, India

Shalini Rukhaya
Department of Textile and Apparel Designing, I.C. College of Home Science, Haryana Agricultural University, Hisar, Haryana, India

Arpita Grover
Department of Textile and Apparel Designing, I.C. College of Home Science, Haryana Agricultural University, Hisar, Haryana, India

Corresponding Author
Diksha Bisht
Department of Textile and Apparel Designing, I.C. College of Home Science, Haryana Agricultural University, Hisar, Haryana, India

Treatment and disposal of textile effluents

Diksha Bisht, Nisha Arya, Shalini Rukhaya and Arpita Grover

Abstract
The textile sector is one of the major contributors to the Indian economy because of its high percentage of total export. Large amount of water and various chemicals are utilized by the textile industry during their production process. It is also considered as one of the major contributors of environmental pollution due to the production of huge amount of waste which mainly consists of dye effluent, salts, chemicals and other suspended solids. Due to its high BOD value, untreated textile effluent can induce rapid dissolved oxygen depletion if released directly onto surface water sources. High alkalinity and traces of chromium which is employed in dyes adversely affect the aquatic life and also interfere with the biological treatment processes. The presence of heavy metals and chlorine in synthetic dyes may also have an impact on human health. As a result, wastewater effluent from textile mills must be treated before being discharged into any water body. Biological, chemical, and physicochemical treatment procedures are examples of treatment technologies. The physicochemical and biological characterization of such effluents can be used to determine their quality. Monitoring the wastewater's environmental parameters would enable for a detailed assessment of the effluent treatment plant's performance at any moment and if necessary, suitable adjustments could be implemented to avoid negative effects on the environment.

Keywords: environment, pollution, effluent, dye, chemicals, textile and treatment

1. Introduction
Dye and other chemical-laden wastewater is a major environmental hazard for many countries' growing textile industries. Textile mills use a variety of man-made dyes and other chemicals, and they discharge a large amount of extremely polluted water into the environment. Excess dye-laden effluent has serious consequences for plants, animals, and humans [40]. In many textile industries, there are conventional treatment plants or ETPs (Effluent Treatment Plants), but they generate a high amount of sludge which is toxic and requires proper treatment and disposal. The installation of ETPs is expensive, and many textile manufacturers do not have the financial resources to do so. There are a variety of physical, chemical, and biological strategies that can be used to overcome these limits in a sustainable and cost-effective manner [70]. Sizing, desizing, scouring, bleaching, mercerizing, dyeing, finishing, and printing are all steps of textile processing. It is the primary source of contaminated water output, which may contain harmful pollutants such as dyes, chromium, NaOH, starch, acid, and other contaminants [34]. As a result, textile companies are thought to use a lot of water and chemicals compared to other industries, and nearly all effluents are contaminated. The average textile business uses roughly 200 L of water for every Kg of goods [78]. According to the World Bank, the textile dyeing and finishing industries generate roughly 17–20 percent of wastewater containing colour discharge, which has a negative impact on aquatic plant photosynthesis. Wastewater effluent from printing and dyeing units, in particular, contains large amounts of chemicals or dyes that are difficult to degrade [14].

2. Methods of textile effluent wastewater treatment
Color, biological oxygen demand (BOD), chemical oxygen demand (COD), salt, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS) are all present in high concentrations in the textile effluent (TDS). Because of the presence of dyes and other harmful chemicals that are not easily degradable by standard treatment procedures, wastewater in the dyeing and printing area is more contaminated. Dye-bearing water lowers sunlight penetration, which is necessary for aquatic plant and animal development. The nature of equilibrium is disrupted in the end. To reduce the cost of treating river and groundwater used for drinking and irrigation, the water should be dye-free and free of hazardous contaminants. Textile effluent should therefore be treated before being discharged into the environment.

To eliminate contaminants from textile wastewater, many treatment technologies have been developed, including physical, chemical, biological, and combination technologies [65].

2.1 Physicochemical Treatment

Coagulation, adsorption, filtration, and ion exchange are some of the physicochemical approaches that have been developed. Coagulation is a well-established physicochemical method for removing contaminants from textile effluent water. Coagulants such as alum and iron salts are used to improve the tiny particles that agglomerate in wastewater. Physicochemical methods based on flocculation-coagulation are critical for the removal of dispersion dyes from effluents. Due to the presence of reactive and vat dyes in water, these methods have a low performance [34]. As a result of low dye removal efficacy and a large number of by-products sludge production, both flocculation and coagulation have their own set of constraints [52]. High removal of colours from wastewater including a range of dyes with the sorption technique has given it a lot of appeal. The colour mitigation procedure necessitates the selection of adsorbents due to their high affinity, capability, and desorption fundamental features [36]. Because of its large surface area and adsorption capability, commercial activated carbon is an effective adsorbent for removing colours. However, the high cost and difficulties of recycling or desorption make it unsuitable for usage [25]. Different researchers have employed low-cost adsorbents such as bentonite, zeolite, ash, biomass by-products, and resins for adsorption. Furthermore, for the removal of colours from textile effluent wastewater, numerous studies explored different biomass wastes utilised as an adsorbent, such as wheat residue, rice husk, modified ginger wastes, and so on. However, their regeneration or desorption, dumping, and adsorbent uses have been limited [29].

Table 1: Inexpensive adsorbents used for removing colors from effluent in different studies

S. No. & Reference	Dye (Pollutant)	Adsorbent used
1. [81]	Reactive Red-24	Modified wheat residue
2. [50]	Crystal violet	Modified ginger waste
3. [18]	Reactive Orange-84	Activated carbon of agro-waste from empty cotton flower
4. [28]	Methylene blue and Malachite green	Potato plant waste
5. [7]	Acid blue 25	Activated carbon from waste tea
6. [80]	Methylene blue	Straw based absorbent
7. [42]	Acid orange II	Sugarcane bagasse ash
8. [1]	Reactive Blue 49	Capsicum annuum seeds
9. [54]	Orange-G and Methyl Violet	Bagasse fly ash
10. [37]	Acid Green 25	Activated *Prunus dulcis*
11. [58]	Cationic dye	Clinoptilolite
12. [76]	Congo-red	Activating natural bentonite
13. [17]	Anionic and Cationic dyes	Natural clays rich in Smectite
14. [12]	Methylene Blue	Date Stones and Palm-Trees waste
15. [3]	Reactive Black 5	Bentonite

As a result, adsorbents can be utilised in adsorption methods with low initial pollutant concentrations or when adsorbents are inexpensive, readily available, and rapidly produced or desorbed. Filtration techniques such as ultrafiltration, nanofiltration, microfiltration, and reverse osmosis have been utilised to remove contaminants from textile effluents. Selection criteria for filter media, as well as their ability to consider temperature and chemical content of textile wastewater, are critical for removal processes. Membrane technologies are used in textile factories to minimise BOD, COD, and colour in effluent wastewater [20]. However, cost of initial investment, membrane clogging, wastes such as water insoluble pigments (example- indigo dye) and starch-applied decolorization membranes all have substantial drawbacks that necessitate further treatment [47]. The ion exchange method is used to remove cation and anion contaminants from wastewater. In the ion exchange process, synthetic resins are commonly used. The ion exchange technique is widely used in the softening of hard water. However, it has only been used to remove dye from water [71]. The advantage of this approach is that no adsorbents are lost. It could be used to remove dyes that are water soluble. However, it is ineffective for water-insoluble dyes such as disperse dyes [75].

2.2. Chemical Treatment

Toxic pollutants such as dye, toxic metals and are commonly removed from industrial effluent wastewater using chemical treatment technologies. Advanced oxidation processes and chemical oxidation are two types of chemical treatment techniques. Hydroxyl radicals are produced in large quantities in advanced oxidation processes. Various oxidants, such as Cl, O_3, ClO_2, and H_2O_2 are used to treat wastewater. The purpose of using oxidising chemicals is to target the chromophore. Hydroxyl radicals are extremely potent oxidizers. The majority of colours react quickly with hydroxyl radicals [5]. Inorganic and organic contaminants can also be oxidised by them. Fenton's reagent (reaction between H_2O_2 and Fe^{3+}ions) and photocatalytic oxidation techniques (enhancing semiconductor catalyst using energy source from sunlight) can also be used in AOP procedures. Fenton's reagent chemicals, which are an iron salt, were used to boost oxidation of complex organic contaminants that are resistant to biological degradation (by speeding up H_2O_2 breakdown). The Fenton procedure has the drawback of producing iron sludge as a by-product due to the simultaneous flocculation of the reagent and dye molecules [8]. The technique used oxidising agents such as H_2O_2 and O_3 in the chemical oxidation. The ozonation process is a chemical technique for successfully removing synthetic colours from effluents [24]. The action of the ozone gas breaks the conjugated double bond in azo dyes during the ozonation process, which is responsible for the dyes' hue. The main benefit of the ozonation process is that it may be employed in a gaseous condition, which means there is no change in the volume of the wastewater and no solid waste creation as a by-product. Furthermore, even from biodegradable pigments in effluent water, ozone gas has the potential to create harmful contaminants as a by-product [56]. Another disadvantage of ozonation is its short life of ten minutes in water at pH 7, as well as its high cost [27]. The presence of pH, salts and temperature in wastewater affect the ozonation process' stability. Ozone gas breakdown is accelerated under alkaline conditions (pH > 8.5). As a result, the pH of textile effluent wastewater must be monitored on a regular basis. As UV light stimulates the creation of high quantities of hydroxyl radicals, an integrated treatment procedure of H_2O_2 with UV light to remove colour from wastewater is also feasible [56]. Due to the lack of solid waste formation and foul odour, dye removal from dye-containing wastewater using a combination of UV radiation and H_2O_2 is preferred. UV light is employed to accelerate the breakdown of H_2O_2 into hydroxyl radicals [27]. During the chemical oxidation process, hydroxyl radicals induce organic and inorganic contaminants to mineralize into H_2O and CO_2 products. To achieve a greater rate of dye removal, key operational elements such as UV, pH, dye molecule structure, radiation intensity and dye bath composition must be optimized [72].

Table 2: Combination treatment methods used to remove color from effluent in different studies

S. No. & Reference	Dye (Pollutant)	Treatment methods used
1. [60]	Crystal violet	Under UV irradiation, a nanocomposite based on eggshell as a precursor
2. [23]	Methylene blue	Complex of Zno under solar irradiation
3. [2]	Indigo carmine	Under photocatalytic conditions, silver nanoparticles loaded calcium oxide
4. [57]	Rhodamine	Hybrid H_2O_2, CCl_4, and Fenton's reagent
5. [30]	Azo dye	Combinations of TiO_2/UV/H_2O_2
6. [68]	Reactive Red 120	In the presence of hydrogen peroxide, hydrodynamic cavitation
7. [26]	Yellow Procion, Red Procion and Remazol Brilliant Blue R	Heterogeneous Photocatalytic method

2.3 Biodegradation for removal of dyes from effluent

To eliminate organic substrates from textile effluent wastewater, the biodegradation process is used. Microbes have been used to degrade colours for almost two decades [77]. Microbes degrade dyes in a simple process that requires a complicated mechanism. Microorganisms require certain circumstances and in-depth understanding to flourish in this field [67]. The degradation is affected by the presence of organic materials such as dye and the load of microbes, as well as the temperature, dissolved oxygen content and pH of the system. Biological approaches can be classified as aerobic, anaerobic, anoxic, facultative, or a mix of these. Aerobic processes employ microorganisms to remove contaminants from wastewater in the presence of adequate dissolved oxygen, whereas anaerobic techniques use bacteria without oxygen to remove pollutants from wastewater. Biodegradation has several benefits over physical and chemical techniques, including being environmentally benign, low-cost, low infrastructure and running expenses, low solid wastes, full mineralization into harmless end products, and so on [32]. The effectiveness of the biodegradation process is determined by the microorganisms used and enzyme activity. As a result, an endless number of microbes and enzymes have been identified and tested for dye removal. An important biological aspect of textile wastewater treatment is the separation of potential microorganisms and their utilisation for removal. Various microorganisms such as bacteria, fungus, and algae remove various types of dyes found in textile effluent water.

2.3.1 Algal Treatment

Algae can be either macro or micro and are found in different water bodies. The sun provides energy for them to produce food. Macroalgae are visible like little plants growing in water commonly known as seaweed and phytoplankton. On the contrary, a microscope is used to detect microalgae as one won't be able to notice microalgae in the water with their eyes. Color is removed from textile effluent water using algae via three separate processes: dyes ingested by algae, dyes converted to noncolored products utilising enzymes and chromophores absorbed into the surface of algae. Biosorption and biodegradation are two distinct processes. The biosorption process involves dye molecules migrating from the solution phase to the solid phase (adsorbent), whereas the biodegradation process involves enzymes breaking dye molecules' bonds, allowing the dye molecule to be converted into various by-products [34]. High amounts of sodium chloride and various humic acids azo dye (such as Acid Red 27) given to *Shewanella* algae for decolorization are found in wastewater. This research found mediated elimination of Acid Red 27 results in the formation of fewer phototoxic aromatic amines. The best parameters for the degradation of Basic Red 46 from wastewater were evaluated, including a temperature of 25 °C, a dye starting concentration of 15 mg/L, a dosage of algae of 2 g and reaction duration of 5 hours utilising a green macroalga such as *Enteromorphasp* [45]. As a result, it can be concluded that algae play an important role in the adsorption and breakdown of colours in wastewater. In addition, an alternative biosorption technique employing algal waste for colour should be used instead of commercial activated carbon [49].

Table 3: Algal species used to remove color from effluent in different studies

S. No. & Reference	Dye (Pollutant)	Algal species
1. [43]	Malachite green	Green macroalgae - *Cladophora*
2. [46]	Acid orange II	Brown alga- *Stoechospermum marginatum*
3. [44]	Triphenylmethane, malachite green	*Xanthophyta, Vaucheria*
3. [11]	Reactive Azo Yellow 22	*Spirogyra*
3. [21]	Malachite green	Microalgae - *Cosmarium*

2.3.2. Bacterial Treatment
Researchers began investigating dye removal using an anaerobic environment by bacteria twenty years ago, utilizing azo-reductase enzymes under anaerobic circumstances for the removal of primarily azo colours due to the reductive breakdown of azo double bonds [59]. The necessity of breaking (-N=N-) azo bonds resulted in a product that was perhaps colourless and toxic-intermediates, which were then handled using anaerobic or aerobic procedures [63]. *Enterobacter* sp. Bacterial culture was used to remove Reactive Blue 19 dye from water [35]. A bacterium culture of microbial *Consortium* was used to remove Reactive Orange 16 dye from water. *Proteus mirabilis* bacterium culture was utilised to remove Reactive Blue 13 (RB13) dye from water [51]. Reactive Blue 13 dye was eliminated from water using bacterial culture of *Proteus mirabilis* [62].

2.3.3. Fungal Treatment
Fungal metabolism may be adapted to the changing environmental circumstances, which is necessary for their survival. As a result, the action of metabolism is supported by external and intracellular enzymes. The textile effluent water digested by enzymes has a variety of hues. Fungal cultures appear to be a favorable condition for removing colours from textile effluent water due to enzymes. Enzymes such as lignin peroxidase, manganese peroxidase, and laccase aid in the breakdown of dyes [6, 19].

Table 4: Fungus used to remove color from effluent in different studies

S. No. & Reference	Dye (Pollutant)	Fungal culture used
1. [48]	Azo dyes	White rots
	Solvent Red 24	Lichen Permeliaperlata
2. [13]	Remazol Brilliant Blue R and Acid Red 299	Aspergillus Niger
3. [31]	Naphthalene dye	White-rot fungus Pleurotuseryngii

However, the extended growing phase, the need for nitrogen-restrictive conditions, unpredictable enzyme production, and large reactor size are all disadvantages of employing white-rot fungus to remove colours from wastewater [4]**.** When using fungus alone, the system becomes unstable, and after 20 to 30 days, bacteria will begin to emerge, and the fungi will no longer be dominant in the system, reducing the removal of dyes in the system [39].

2.4 Microbial Fuel Cell Treatment (MFC)
A microbial fuel cell converts chemical potential energy (organic molecules available in wastewater) into electricity through a biological process [38]. Various electrode materials, configurations and membrane materials, i.e. anode and cathode, microbial community and textile effluent wastewater including azo dyes, have been reported by certain studies for electricity production utilising MFC technology [41]. However, the cathode (Platinum) and anode materials (carbon cloth and carbon paper) are both expensive and delicate. Structures made of nanotubes boost power and stability while lowering charge transfer resistance [55]. Internal resistance can be reduced by using various metals such as Cu, Ni, Si and TiO_2. As a result, combining carbon composites with low-cost electrocatalysts such as Cu and TiO_2 has led in a viable anode material. Recent research concentrated on cathode components and the utilisation of carbon nanofibers or nanotubes to improve surface efficiency. Co_3O_4/ nanocarbon composite material was investigated and found similar to Pt/C in terms of power density, Columbic efficiency and current at reduction peak [73].

If adequate mixing catalysts can be done, carbon nanofibers might match or even outperform the Pt/C electrode in terms of efficiency. As a result, further work has to be done to improve the performance of carbon nanofiber-based cathodes for Microbial fuel cells by using more effective and low-cost catalysts [35]. As a result, low-cost catalysts including cobalt, manganese dioxide, iron and others offer a viable cathode material for nanofiber composites. MFC is heavily reliant on membrane materials for commercial uses, which must have good selectivity, low resistance, and cheap cost with long-term stability. Membranes are used in MFC to guarantee that ions are transferred from one area to another. The thick sheets of membranes such as Aromatic Sulphonic Acid sulfonated poly (sulfones and ether ketones) were utilised with highly ionic conductivities (1 S/cm) linked to liquid potassium hydroxide and phosphoric acid [8]. Furthermore, power generation has been done by producing porous materials such as clay pots or ceramics to lower internal resistance [22]. The performance of MFC is harmed by lowering microbial activity and chemical potential [33]. As a result, it is feasible to generate five times the amount of energy required to clean textile effluent from wastewater [79].

2.5 Combination of Chemical and Biological Treatment
Chemical treatment methods may not always achieve 100% removal of specific dye molecules in textile effluent water and the technology may be costly due to the additional energy requirement, such as UV light and chemical reagents i.e. H_2O_2, oxidizers and Fe^{3+} [15]. Likewise, end results representative of genuine textile effluent wastewater may not always be produced by biological treatment approaches. Some water-soluble substrates and dye molecules from the textile industry are challenging to handle with biological approaches alone at various stages of wet processing [61]. It is crucial to reduce the use of chemicals, energy, and operational costs to as little as possible. Different combinations of chemical oxidation and biological treatment strategies have been documented in literature. For the elimination of COD and TOC from textile effluent wastewater, chemical treatment was combined with biological treatment techniques [16]. A high level of surfactant and colour removal is achieved when biological treatment is combined with chemical treatment methods (ozonation followed by batch biofilter granular reactor sequencing), [53]. Textile effluent wastewater was also treated using a combination of biological and chemical approaches to eliminate Reactive Red-120 [64]. The removal of AR18 azo dye from textile effluents using a combination of biological and chemical treatment approaches (SBR and improved Fenton process as posttreatment) has been described [9]. The removal of dyes i.e. Reactive Black 5, Remazol Red RR and Reactive Red 180 from water has been reported using a combination biological and chemical treatment technique [74]. Integrated biological and chemical treatment approaches have been used to remove colours such

as the reactive azo dyes Yellow Reactron 4GL, Navy Blue Intracon USB Ultra and Red Intracon CD3SR [69]. Some researches were reported on treatment of wastewater with H_2O_2 [15], photo-Fenton [16], and ozonation [53]. To remove biodegradable pollutants from wastewater effluents from textiles, a biological approach was used as a pretreatment and to remove non-biodegradable pollutants, an advanced oxidation process was used as a posttreatment, as described by [10]. The kind of contaminants in wastewater, the quality of output, and the cost of technology all influence the integration of one or more chemical processes with other technologies such as biological processes [66].

3. Conclusion

Waste originated from the textile industry mainly comprised of water-based effluent from various operations. The textile industry generates a large volume of waste water that contains a variety of chemicals used in dyeing, printing and finishing processes and many dyes, resulting in a lot of colour in the waste water. The effluent generated in various steps or processes exceeds the standard, making it highly contaminated and hazardous. Conventional techniques of effluent treatment not only include high cost but also produces huge amount of sludge which require proper disposal treatment. These techniques concentrate the dye molecules and convert it into sludge and this sludge is disposed from the industries without any treatment and is responsible for causing pollution. So, to replace these conventional techniques which results in generation of huge amount of sludge, is to move towards the sustainable techniques which not only utilize cheap waste material for treating effluent but also produce little amount of sludge. And, also gives advantages such as low cost, high colour removal efficiency and reduced sludge production. Thus, different measures which can be adopted to treat the waste water discharged from textile chemical processing industries to protect and safeguard environment from possible pollution problem has been the focus point of many recent investigations. Depending on the amount and type of pollutant loading, textile industry wastewater treatment facilities are properly built by integrating several technologies, such as physical with chemical, biological with chemical, and physical with biological approaches.

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