Review Article

Textile Industry Effluent Treatment Techniques

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Dyes and other chemicals laden wastewater is a main environmental concern for increasing the textile industries in many parts of the world. Textile industries consume different kinds of manmade dyes or other chemicals and release huge extents of highly polluted water into the environment. This excessive dye laden wastewater has great impacts on photosynthetic activity in aquatic plants and animals, for example, fish. It may also affect human health due to the presence of components like heavy metals and chlorine in manmade dyes. Thus, wastewater effluent from textile industries must be treated before discharge into the water body. Treatment technologies observed in this review paper include biological treatment methods (fungi, algae, bacteria, and microbial fuel cells), chemical treatment methods (photocatalytic oxidation, ozone, and Fenton’s process), and physicochemical treatment methods (adsorption, ion exchange, coagulation, and filtration). This review also includes the hybrid treatment methods and their cost per m³ of treated wastewater analysis. There are alternative wastewater treatments systems at different steps of effluent generated from the textile operational unit recommend in this review work.

1. Introduction

Industrialization is the main parameter for the economic growth of a nation and modernization of life. Thus, different large and medium scale industries play a key role in nation’s economic development both in developed and developing countries. The textile industry takes the biggest share due to its ability to create a variety of job opportunities and its integration with different economic sectors both globally and locally. It is the most expanding and emerging sector.

Cotton, woolen, synthetic fibers, synthetic dyes, chemical, and process water are among the major impute raw materials in this industry and all these inputs diversified the economic importance of the textile industry. Based on fibers production, the textile industries can be categorized into two major processes such as dry and wet fabric processes. In dry processing, solid wastes are mainly generated, while liquid wastes are mainly generated in wet processing steps.

Wet fabric processing is including sizing, desizing, scouring, bleaching, mercerizing, dyeing, finishing, and printing. During fiber formation, potable water, different chemicals and dyes consumed and wastewater discharge from wet processing steps depend on the operations. This process is the main source of contaminated water, which is containing dyes and other pollutants because of the more utilization of clean water, dyes, and chemicals in various wet processing unit operations. Discharge of wastewater from the textile industry contains toxic pollutants such as dyes, chrome, NaOH, starch, acid, etc. [1]. Therefore, the textile factories are estimating to consume much potable water and chemicals when compared to other industries and almost all effluents are mostly contaminated. An average textile industry consumes process potable water about two hundred Litter per kilogram of product [2]. Kant [4] reported that estimation of the World Bank dyeing and finishing section is near to 17–20% of industrial wastewater generate. Wastewater, which is containing color discharge into water body,
has a photosynthetic effect on aquatic plants. Particularly, wastewater effluent from printing and dyeing unit operations contains huge chemicals or dyes and their difficult degradation. Type of dyes, applications, and principles of chemical classes are discussed in Table 1 briefly [4]. At present, dyes are mainly aromatic compounds and heterocyclic structures with polar and color-display groups. The structure of dyes is more complicated and stable. Then they are difficult to decompose [2]. In this review work, evaluation of different wet processing steps, various technologies such as biodegradation technologies (fungi, algae, bacteria, and microbial fuel cell), chemical methods (photocatalytic oxidation, ozonation, and Fenton’s process), and physico-chemical methods (adsorption, ion exchange, coagulation, and filtration) of color removal from textile effluents reported by different researches were discussed—as well as treatment cost analysis.

2. Wet Operation Process

Fibers are prepared in the textile industry from different substrates such as wool, cotton, and synthetic materials. Transform fibres into yarn and change the yarn into fabric products and then these fabrics products go through different steps of wet processing unit operation. Steps in wet processing of fabric production are explained in Figure 1 [1].

2.1. Sizing and Desizing Operation Process. In wet processes, during the sizing of fibers, several chemicals are consumed such as starch, enzymes, waxes, and ammonia. The occurrence of starch hampers the diffusion of the dye molecule into the yarn/fabric, which needs the removal of starch proceeding to dyeing and then printing. Removing sizing chemicals from fiber commonly used enzymatic or dilute mineral acid hydrolysis. Converting starch into watersoluble output activity of hydrolysis or oxidation steps is important [4, 6]. The effluent from desizing and sizing unit processes has highly dominant biological oxygen demand (BOD) in the range of 300–450 ppm and a solution of pH that is 4-5 [1].

2.2. Bleaching Operation Process. The bleaching process is one which imparts whiteness by removing the natural coloring matters from fabrics. This process is applicable to obtain bright colors products and white material. Most cellulose fibers are bleached using a variety of oxidizing agents. As a bleaching agent, hypochlorite was used in earlier time. Currently, hypochlorite is substituted by other bleaching agents like H₂O₂ and peracetic acid. Thus, peracetic acid is ecologically friendly and is alternatively used as a bleaching agent [1].

2.3. Mercerization Process. In the mercerization process, the caustic soda treatment method is applied to cotton fibers to improve fiber properties such as strength and luster and permanently impart a more affinity for dyes and other finish chemicals. This process also gives cotton fiber increased strength, more absorptive characteristics, and, usually, a high degree of luster, depending on the method applied. Therefore, this process is carried out after bleaching to get a shine and advance dye uptake products. Mainly, the process is done in cotton fabrics treated by using more concentrated NaOH range from 18 to 24% [1].

The fiber is immersing in a solution of sodium hydroxide (caustic soda) for short periods, which is less than four minutes. After being processed, the fiber is washed with water or acid to neutralize the caustic soda. During impregnation of cotton fabric with NaOH, the solution goes through the longitudinal shrinkage in this activity. So, longitudinal shrinkage could be eliminated by holding the fabric under tension or elongating the fabric. Membrane separation techniques or multiple-effect evaporators are commonly used for the recycling of sodium hydroxide for further application [5, 7].

2.4. Dyeing and Printing Operation Process. Dyeing is a process in the textile industry, which involves a combination of either chemical or physical affinity between the fiber and the dye. Dyeing is the process of immersing fabric with a dye solution to bend color in fiber. Auxochrome functional groups like amine, carboxyl, sulphonate, and hydroxyl for bending with fiber, while Chromophore functional groups such as azo (-N=N-), carbonyl (-C=O-), nitro (-N=O-), quinoid in the dyes are responsible for the color [8]. The printing process is carried out using a roller-printing machine. Important reactions carried out in this process are similar to in dying process. In the dying process, dye is applied in a solution form, while in the printing process, dye is applied in a thick paste form to prevent its spread. From the printing process, effluents also contain pollutant components the same as dying.

2.5. Finishing Operation Process. The finishing process in textile industries is used to improve definite characteristics in the fibers. Among these processes including softening, antibacterial, waterproofing, and UV protection imparted to fabric in the finishing process. Effluent from this process also has an important effect on environmental pollution.

3. Textile Effluent Wastewater Treatment Methods

The textile effluent has contained a great amount of color, biological oxygen demand (BOD), chemical oxygen demand (COD), salt, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS). In the dyeing and printing section, effluent has more contamination because of the presence of dyes and different toxic chemicals, which are not easily degradable to conventional treatment methods. Dye-bearing water reduces sunlight penetration that is important for the development of aquatic plants and animals. At the end, the nature of equilibrium is disturbed. To minimize the treatment price of river and groundwater, which is used for drinking and irrigation the purpose, water should be free from any dye or toxic pollutants. Thus,
before discharge into the environment, effluent from textile should be treated. Various treatment technologies have been developed, such as physical, chemical, biological, and combined, to remove pollutants from textile effluent. Figure 2 illustrates effective methods of dye removal from textile industry effluent waste [7].

### 3.1. Physicochemical Method

Different physicochemical methods have been developed, including coagulation, adsorption, filtration, and ion exchange. The coagulation process is a known physicochemical technique designed for the removal of pollutants from textile effluent water. Alum and iron salts are used as a coagulant to enhance the small size particles that make agglomerate (big size) in wastewater. Flocculation-coagulation-based physicochemical technologies are important for the elimination of disperse dyes from effluents. These technologies also have low performance containing reactive and vat dyes in water [1]. Flocculation and Coagulation also have their own limitations because of the low dye removal performance and the huge amount of by-products sludge generation [8]. Sorption technology has significant attraction because of its high removal of dyes from wastewater, containing a variety of dyes. Adsorbent election parameters have great affinity, capability, and desorption basic properties, requiring the selection of adsorbents for the color mitigation process [9]. Commercial activated carbon is an efficient adsorbent for removing dyes due to enough surface area and adsorption capacity. However, high cost and difficulty in its recycling or desorption is a limitation to use it [10]. For adsorption purposes, different investigators have used low-cost adsorbents like bentonite, zeolite, ash, biomass by-products, and resins. Moreover, various researchers tried different biomass wastes used as an adsorbent such as wheat residue, rice husk, modified ginger wastes, etc., for removal of colors from textile effluent wastewater. Using low-cost adsorbents to remove the color from dye containing effluent, the following studies were reported by different researchers. One study applied modified wheat residue (MWR) as adsorbent to remove Reactive Red-24 (RR-24) [11]. Crystal violet (CV) dye was eliminated using modified ginger waste (MGW) [12]. Another study applied activated carbon from empty cotton flower agrowaste to remove Reactive Orange 84 [13]. Dye (Methylene blue and malachite green) was adsorbed by adsorbent (Potato plant waste) [14]. Acid blue 25 (AB25) was adsorbed by adsorbent (activated carbon from waste tea (ACWT)) [15]. Methylene blue was adsorbed by straw based absorbent [16]. Acid orange II was adsorbed by Sugarcane Bagasse Ash [17]. Reactive Blue 49 was adsorbed by Capsicum annuum seeds [18]. Orange-G and Methyl Violet dyes were adsorbed by Bagasse fly ash [19]. Acid Green 25 dye was adsorbed by Activated Prunus Dulcis [20]. Cationic dye was removed by adsorbent (Climoptilolite) [21]. Dye (Congo-red) was removed by adsorbent (Activating natural bentonite) [22]. Cationic and anionic dyes were adsorbed by adsorbent (Smectite rich natural clays) [23]. Methylene Blue (MB) was adsorbed by adsorbent (Date Stones (DS) and Palm-Trees waste (PTW)) [24]. Dye (Reactive Black 5) was adsorbed by bentonite clay [25]. But, their regeneration or desorption, dumping, and high price of the adsorbent and applications of these adsorbents have been limited [26]. Therefore, adsorbents can be used to adsorption method that

### Table 1: Type of dyes, their application, and chemical classes [5].

| Types of dyes | Their application | Properties | Chemical classes |
|---------------|-------------------|------------|-----------------|
| Acid dyes     | Nylon, wool, silk, modified acrylics, paper, leather, ink-jet printing, and food | Watersoluble | Azo (including premetallized), anthraquinone, triphenylmethane, azine, xanthene, nitro, and nitroso |
| Basic dyes    | Paper, polyacrylonitrile, modified nylon, modified polyesters, cation dyeable polyethylene terephthalate, and medicine | Watersoluble | Diazahemicyanine, triarylmethane, cyanine, hemicyanin, thiazine, oxazine, and acridine |
| Disperse dyes | Polyester and some amount nylon, cellulose, cellulose acetate, and acrylic fibers | Water insoluble and nonionic dyes | Azo, anthraquinone, styryl, nitro, and benzodifuranone |
| Direct dyes   | Cotton, rayon, paper, leather, and some amount to nylon. | Water soluble and anionic dyes | Polyazo compounds, along with some stilbenes, phthalocyanines, and oxazines |
| Reactive dyes | Cotton and other cellulosic fibers and some extent wool and nylon fibers | Watersoluble | Chromophoric groups such as azo, anthraquinone, triarylmethane, phthalocyanine, formazan, and oxazine |
| Solvent dyes | Plastics, gasoline, lubricants, oils, and waxes | Solvent soluble while water insoluble and nonpolar or little polar | Predominantly azo and anthraquinone, but phthalocyanine and triarylmethane are also used |
| Sulfur dyes   | Cotton and rayon | Water soluble | Anthraquinone (including polycyclic quinones) and indigoids |
| Vat dyes      | Cotton cellulosic fibers and for rayon and wool | Water insoluble | |
has low initial concentration of pollutants or when the adsorbents have less price, is available and is easily generated or desorbed. To eliminate pollutants from the textile effluents, filtration technology such as ultrafiltration (UF), nanofiltration (NF), microfiltration (MF), and reverse osmosis (RO) have been used. Criteria of selection of the filter Medias and their capability to consider the temperature and the chemical contents of textile wastewater are important for the removal techniques. In the textile factory, the purpose of membranes technologies is to reduce BOD, COD, and color from effluent wastewater [27]. However, initial investment cost, clogging of the membrane, generating wastes like water insoluble dyes (for example, indigo dye), and starch applied membranes for decolorization also have significant limitations which are required further treatment [28]. Cation and anion pollutants present in wastewater are removed by applying ion exchange process. Synthetic resins are normally applied in the ion exchange process. For the softening of hard water, the ion exchange process finds extensive use. But, it has been limited for dye removal from water [29]. The advantage of this technology is that there is no loss of adsorbents. It could be applied for the removal of watersoluble dyes. But, it is low efficient for water insoluble dyes like disperse dyes [30].

3.2. Chemical Treatment Methods. Chemical treatment technologies are commonly applied to remove toxic pollutants like dye, toxic metals, and odor from industry effluent wastewater. Chemical treatment techniques can be categorized into advanced oxidation processes (AOP) and chemical oxidation. In advanced oxidation processes (AOP), efficient amounts of hydroxyl radicals are generated. For wastewater treatment, various oxidants such as Cl, O₃, ClO₂, and H₂O₂ are applied. Applications of oxidizing agents are for attacking the Chromophore imparts. Hydroxyl radicals are powerful oxidizing agents. Most dyes react with hydroxyl radicals at a high reaction rate [31]. They are also able to oxidize with inorganic and organic pollutants. AOP processes can also be involved Fenton’s reagent (reaction between Fe³⁺ ions and H₂O₂) and photocatalytic oxidation methods (use of energy source from sunlight for enhancing semiconductor catalyst). Applied Fenton’s reagent chemicals that are an iron salt to enhance oxidation of complex organic pollutants (by accelerating H₂O₂ decomposition), which are resistant to biological degradation. The disadvantage of the Fenton process is the production of the iron sludge as a by-product because of the combined flocculation of the reagent and dye molecules [32]. In the chemical oxidation, the process applied oxidizing agents like O₃ and H₂O₂. The ozonation process is a chemical method and is used in the removal of synthetic dyes from effluents effectively [33]. In the ozonation process, the activity of the ozone gas breaks the conjugated double bond in azo dyes, which is responsible for giving color to the dyes. The major advantage of the ozonation method is that ozone can be used in a gaseous state and no change in the volume of the wastewater and there are no solid waste generation as by-products. In addition, the main limitation of using ozone gas is that it may produce toxic pollutants as by-products even from biodegradable dyes in effluent water [34]. Another limitation of the ozonation method is the short half-life of ten min in water at pH 7 and the high cost [35]. The stability of the ozonation process depends on the presence of pH, salts, and the temperature in wastewater. Under the alkaline condition (pH > 8.5), ozone gas decomposition is faster. Therefore, the pH of textile effluent wastewater needs continuous monitoring. The integrated treatment process of H₂O₂ with UV light to remove the color from wastewater is also possible because UV light enhances the production of high concentrations of hydroxyl radicals [34]. Advantageous dye removal from dye containing wastewater by the combination process of UV light and the H₂O₂ is preferable due to having no solid waste generation and bad smell. Here, we enhance the decomposition of H₂O₂ into hydroxyl radicals.
used to UV light [36]. Organic and inorganic pollutants are mineralizing into CO₂ and H₂O products caused by hydroxyl radicals during the chemical oxidation process. The main operational factors such as UV radiation intensity, pH, the structure of dye molecule, and the dye bath composition must be optimized to get a higher rate of dye removal [37]. Crystal violet (CV) dye was removed from water by applying (Pd@CaO) nanocomposite adsorbent based on eggshell as a precursor under sunlight irradiation [38]. Applying Co (II) complex@ZnO under solar irradiation to remove Methylene blue was investigated [39]. A novel composite silver nanoparticles loaded calcium oxide under photocatalytic conditions that was used as an adsorbent for the removal of indigo carmine dye was studied [40]. Applying combination treatment methods, the following researches were investigated by different researchers. Hybrid H₂O₂, CCl₄, and Fenton’s reagent for removal of Rhodamine dye from water was studied [41]. Combinations of TiO₂/UV/H₂O₂ for azo dye removal [42], and for removal of Reactive Red 120 dye (RR120), type of oxidation process (Hydrodynamic cavi-
tation in the presence of hydrogen peroxide) and outcome (at low pH the result was the higher degradation) were investigated. Moreover, the addition of H₂O₂ increases the degradation rate because of additional hydroxyl radicals produced for the explanation of dye. There was no further enhancement in the removal of dyes after the optimum concentration of H₂O₂ [43]. Remazol Brilliant Blue R, Red Procion, and Yellow Procion were removed by the Heterogeneous Photocatalytic method [44]. Pollutants (cotton-textile dyeing wastewater), type of oxidation process (advanced oxidation processes), and outcome (at 60 mg catalyst loading, 85.5% mineralization, and 98.5% decolorization) were achieved in the solar-photo-Fenton process. While, integrating the biological method with solar-photo-Fenton reaction process, the amount of photo energy (0.5 kJ/UV/L) and H₂O₂ (7.5 mM) is required to attain the COD below 250 mg/L [37]. Pollutant (Textile dye bath effluent), type of oxidation process (H₂O₂/UV, UV, and O₃), and outcome (on the application of H₂O₂/UV on biotreated dye bath effluent, 98% of decolorization was achieved. Application of AOPs following the biotreatment has surpassed the biodegradability) [45]. In general, photocatalytic degradation of dye can be explained in equations (1)–(5) [46]. Table 2 illustrates photocatalytic and other chemical methods for dye degradation.

\[
\text{photocatalyst} + h\nu \rightarrow h\nu B^+ + eCB \tag{1}
\]
\[
O_2 + eCB \rightarrow \cdot O_2 (\text{superoxideradical}) \tag{2}
\]
\[
H_2O + h\nu B^+ \rightarrow (\text{hydroxylradical}) + H^+ \tag{3}
\]
\[
O_2 + \text{pollutant} \rightarrow \text{intermediate and H}_2O + CO_2 \tag{4}
\]
\[
OH + \text{pollutants} \rightarrow \text{intermediate and H}_2O + CO_2 \tag{5}
\]

3.3. Biodegradation Process. The biodegradation process is applied to remove the organic substrates in the textile effluent wastewater. The degradation of colors started almost two decades ago using microbes [53]. The degradation of man-made dyes by microbes is easy to process while it involves a complex mechanism. For the growth of microorganisms, suitable conditions and depth knowledge are required [54]. The degradation performance is depending on the presence of organic matter like dye and load of microorganisms, the temperature of waste, pH of waste, and concentration of dissolved oxygen in the system. Aerobic, anaerobic, and anoxic or facultative or a combination can be categorized as biological methods. Anaerobic process uses microorganisms to remove the pollutants in wastewater presence of sufficient dissolved oxygen while using microorganisms without oxygen to remove pollutants from wastewater known as anaerobic methods. Compared to physical and chemical methods, biodegradation process have the following advantages such as being eco-friendly, low-cost, low infrastructure, and operating costs, low solid wastes, complete mineralization into nontoxic end products, etc. [55].

The efficiency of the biodegradation process depends on the selection of microorganisms and the activity of enzymes. Therefore, the presence of an infinite amount of microorganisms and enzymes have been isolated and tried for the removal of dyes. The isolation of potential microorganisms and their use for removal is an important biological aspect of textile effluent treatment. Different types of dyes present in the textile effluent water are removed by various microorganisms like bacteria, fungi, and algae.

3.3.1. Fungal for Removal of Dyes. A fungal has the ability to adapt its metabolism to change environmental conditions. This ability is essential for their existence. Therefore, extracellular and intraenzyme supports the activity of metabolism. Different colors are present in the textile effluent water degraded by enzymes. Because of enzymes, fungal cultures seem to be a suitable condition to remove dyes from textile effluent water. Lignin peroxidase (LiP), manganese peroxidase (MnP), and laccase are enzymes that help the degradation of dyes [56, 57]. The degradation of dyes from textile effluent has been mostly done using white-rot fungi and Phanerochaete Chrysosporium [58]. White rots fungal cultures are able to degrade azo dyes. Disperse dye Solvent Red 24 was removed by fungi culture (Lichen Permelia perlata) [59]. Remazol Brilliant Blue R (RBBR) and Acid Red 299 (NY1) were eliminated by fungi culture (Aspergillus Niger) [60]. Naphthalene dye was removed by applied fungi culture (white-rot fungus Pleurotus eryngii) [61]. However, limitations of using white-rot fungi to remove dyes from wastewater are the long growth phase, the requirement of nitrogen restrictive conditions, unreliable enzyme production, and big reactor size [62]. Using fungi alone, the system is in an unstable condition and after certain days that are from 20 to 30, bacteria will start developing and the fungi
will no longer dominate in the system and reduce the removal of the dyes in the system [63].

3.3.2. Algae for Removal of Dyes. Algae are either microorganisms or macroorganisms like vegetables or plants. Algae are commonly living in the river, sea, and lakes or ponds. The sun is the source of energy for all algae to make food. Macroalgae are commonly called seaweed and phytoplankton. Therefore, we think of a small plant or vegetables that live in the water body. Microalgae are too small that we will be unable to see them in the water with our eyes. They are detected under a microscope.

Algae are available everywhere and important microorganisms for removal dyes from textile effluent water. Removal of color by using algae occurs through three different processes like those in which dyes are consumed by algae for their growth, conversion of dyes to noncolored products using enzymes, and chromophores sorption onto the surface of algae. Biodegradation and biosorption processes are different activities. The dye molecules are moving from the solution phase to the solid phase (adsorbent), which is known as the biosorption process, while when enzymes are breaking bonds of dye molecules, and then the dye molecule can be transformed into other by-products, this is known as the biodegradation process [1]. In wastewater, there are high concentrations of sodium chloride and different humic acids azo dye (like acid red 27) applied to Shewanella algae (SAL) for decolorization. This study indicated mediated removal of acid red 27 outcomes into less phototoxic aromatic amines. For degradation of Basic Red 46 from wastewater, optimum conditions were investigated such as temperature is 25°C, dye initial concentration is 15 mg/L, a dose of algae 2 g, and reaction time is 5 h using the green macroalga like Enteromorpha sp [64]. Therefore, algae have a significant role in the removal of dyes in wastewater by adsorption or degradation methods. In addition, instead of commercial activated carbon using algae waste for color, remove alternative biosorption process [65].

Removal of malachite green (MG) applied algae (that is, Green macroalga Cladophora species), with mechanisms of degradation (Biodegradation) investigated by [66]. Mitigation of Acid orange II (AO7) dye from water applied algae (that is, a Brown alga, Stoechospermummarginatum), with mechanisms of degradation (Adsorption) [67], elimination of dyes (Triphenylmethane dye, malachite green (MG) applied algae (that is Xanthophyta alga, Vaucheria species) Mechanisms of degradation (Adsorption) [68]. Removal of malachite green dye applied algae (Marine alga), Mechanisms of degradation (Adsorption) [69]. Removal of Reactive Yellow 22 (azo) applied algae (Spirogryaspecies), Mechanisms of degradation (Biodegradation process) [70]. Mitigation of MalachiteGreen dye applied algae (Microalgae Cosmarium sp) Mechanisms of degradation (Biodegradation) [71].

3.3.3. Bacteria for Removal of Dyes. Investigation of dye removal using an anaerobic environment by bacteria started twenty years ago [72], applying azo-reductase enzymes under anaerobic conditions for removal of mostly azo dyes because of the reductive breakage of azo double bonds. The importance of azo bonds (-N=N-) breaking results in a product of possibly colorless and toxic-intermediates results, which are further treated by anaerobic or aerobic techniques [73]. Recently, using single bacterium culture like Alcaligenes faecalis PMS-1 has been developed for biodegradation of dyes from textile effluent wastewater [74], Enterobacter sp. EC3 [53], Aeromonas hydrophilia [75]. A previous report stated that the degradation of colors from textile effluent is facilitated by single bacterium culture and their results are shortened. Acid orange 7 and acid orange 8 dyes were removed from water by applying bacteria culture (MI2) [76]. Removal of Blue Beaktiv from wastewater was applied using bacteria culture (Novel microbial consortia “Bx”) [77]. Removal of Reactive Blue 19 dye from water was applied using bacteria culture (Enterobacter sp. F NCIM 5545) [78].
To remove Reactive Orange 16 (RO16) dye from water, bacteria culture (microbial consortium DAS) was applied [79]. To eliminate Reactive Blue 13 (RB13) dye from water, bacteria culture (Proteus mirabilis LAG) was used [80]. To remove malachite green, Crystal violet and Brilliant green dyes were applied bacteria culture (Kurthia sp) [81]. Operational factors affect the degradation of dyes by bacteria, such as dissolved oxygen, temperature, pH of a solution, initial extents of color, dye structure, and nitrogen sources, redox mediator and the amount of electron donor. Therefore, to obtain efficient output and rapid bacterial degradation, it is important to determine the consequence and every design factor on the biodegradation reactor.

3.4. Textile Effluent Wastewater Treated by Microbial Fuel Cell (MFC). Microbial fuel cell is a biological process that changes chemical potential energy (available organic compounds in wastewater) into electricity [82].

At its objective, the MFC is a fuel cell, which changes chemical potential energy into electrical power applying oxidation-reduction reactions methods. In the MFC process, the microorganisms oxidize different organic substrates of water in the anode chamber to generate electrons or protons that transfer to the cathode chamber to consume oxygen.

In an anode, anaerobic respiring bacteria can efficiently degrade organic matter into carbon dioxide as the product, while electrons and protons generated. The advantages to implementing wastewater treatment to make MFCs includes the direct conversion of organic materials into electrical energy, less excess activated sludge compared to other processes technologies, insensitive to operation environment, even at low temperatures, without any gas treatment, without any energy input for aeration, and a widespread application in locations with insufficient electrical infrastructures. Limitation: Microbial fuel cells are not applied in big scale industries because of the less power generation and high investment cost. For the previous study, various researches have been explored to increase the energy generation from MFCs.

Some investigations have reported different configurations, electrode materials, and membrane materials, that is, cathodes and anodes, microbial community, and textile effluent wastewater containing azo dyes used for electricity generation using MFC technology [83]. However, materials used as anode (carbon paper and carbon cloth) and cathode or (Platinum) are high prices and fragile. Therefore, microbial fuel cells with high power generated, fewer price electrode or membrane materials, and better scale-up should be designed for treating wastewater. In recent years, modified or activated carbon nanofibers have been used as an anode. However, the limitations are that these materials have a great internal resistance that could be large pore size or film formation. For further improved power production, this restriction should be avoided in the future. Nanotubes structures improve power and stability and reduce charge transfer resistance. Multiwall carbon nanotubes coating on granular carbon electrodes was applied. Most carbon materials are used for anodes made up [84, 85]. Using different metals such as Ni, Cu, TiO2, and Si can reduce internal resistivity. Therefore, the use of carbon composites material along with low-cost electrocatalyst substances like Cu and TiO2 have a promising anode material made up while further detailed investigation are required to be applied in this way. Recent research focused on cathode parts and for applying nanofibers or nanotubes of carbon to enhance surface efficiency. Song et al. [86] reported that Co3O4/nanocarbon composite material was examined, which has the same performance of Pt/C in all aspects such as power density, current at reduction peak, and Columbic efficiency.

If suitable mixing catalysts are obtained, nanofibers of carbon could be expected to fit the efficiency of the Pt/C electrode or even greater performance. Therefore, more effort needs to be worked to increase the performance of carbon nanofiber-based cathode by the use of more effective and low-cost catalysts for Microbial fuel cells [78]. Thus, low-cost catalysts such as cobalt, iron, manganese dioxide, etc., have a promising cathode material to use of nanofiber composites. However, more effort needs to be made in this way. For commercial purposes, MFC is highly dependent on membrane materials, which have high selectivity, less resistance, and low-cost with stability for long time. Applications of membranes in MFC to ensure the transfer of ions from one region to the other region. Highly ionic conductivities (1 S/cm) related to liquid potassium hydroxide and phosphoric acid have been used along with the thick sheets of membranes such as Aromatic Sulphonic Acid sulfonated poly (sulfones) and sulfonated poly (ether ketones) [32]. In addition, power generation has also been achieved by making materials like earthen pot or ceramic high porous to reduce internal resistance [87]. It will be a main design of MFC if low-cost membranes like those mentioned above can affect proton transfer in available other cations because of size variation. The selectivity of ideas still has no changes. Cation substrates available in textile effluent wastewater like Mg2+, K+, NH4+, Na+, and Ca2+ are able to transfer the Nafion membrane-like protons. An accumulation of cation species is produced in the cathode chamber, causing an increase in the pH in the previous chamber and a decrease in the pH in the anodic chamber. As an outcome of this activity, MFCs performance is reduced by reducing the chemical potential and decreasing the activity of microorganisms [88]. Therefore, it is possible to produce power from wastewater which is five times more than the power consumed to treat the textile effluent [89].

3.5. Hybrid or Combination of Biological and Chemical Oxidation Treatment Methods. Biological treatment methods do not constantly give final outcomes of real textile effluent wastewater. Some of the dye molecules and other watersoluble substances from the textile industry at different steps of wet processing is difficult to treat by biological methods alone [90]. In chemical treatment methods, 100% removal of certain dye molecules in textile effluent water is not always possible and maybe the price technology is expensive because additional energy is required like UV radiation and chemical reagents like Fe2+, H2O2, and
oxidizers [91]. Thus, the only alternative methods for 100% removal use biological treatment methods as a pretreatment and chemical oxidation as a posttreatment or vice versa to change possibly. Depending on the components in the textile effluent wastewater, the advantage of the pretreatment method is used for the partial oxidation process of the nonbiodegradable pollutants like dye molecules and other toxic substances to get biodegradable substrates. To minimize chemicals, energy, and operating costs is important to process. Various combinations treatment methods, biological with chemical oxidation, have been reported in the literature. Biological treatment was integrated with chemical treatment methods for the removal of COD and TOC from textile effluent wastewater [92]. When biological treatment is integrated with chemical treatment methods (Ozonation followed by sequencing batch biofilter granular reactor (SBBGR)), the outcome is high surfactant and color removal [93]. Biological and chemical treatment methods integrated to remove Reactive Red-120 (RR-120) were also reported from textile effluent wastewater [94]. Biological and chemical treatment methods integrated (SBR and enhanced Fenton process as posttreatment) to remove azo dye AR18 from textile effluents have been reported [95]. Hybrid biological and chemical treatment methods to remove Reactive Red 180, Reactive Black 5, and Remazol Red RR dyes from water have been reported by [96]. Removal of different dyes such as the reactive azo dyes Red Intracon CD-3SR, Yellow Reactron 4GL, and Navy Blue Intracon US-B Ultra with integrated biological and chemical treatment methods have also been reported [97]. Some researches were reported by H2O2 [91], photo-Fenton [92], and ozonation [93]. Therefore, the chemical treatment method is used as a post- or pretreatment. For removing the bio-degradable pollutants in wastewater effluents from textile applied biological method as pretreatment and to remove nonbiodegradable pollutants, the posttreatment was applied using advanced oxidation process (AOP) reported by Basha et al. [98]. The integration of one or more chemical processes with other technologies like biological processes depends on the type of pollutants in wastewater, quality of output, and the price of technology. When the chemical treatment method is used as a pre- or postprocesses in hybrid steps, sometimes its result is less and even difficult to the characteristics of the real effluent from textile [99]. To know the impact of the working environments such as contact time, initial concentration of oxidant, type of catalyst, PH of the solution, and on the real effluent temperature characteristics in the pretreatment steps, a systematic approach is required. Final goals of combination technology of chemical and biological treatment methods as pre- or posttreatment in order to reduce investment costs and to obtain the quality output. When compared to the whole investment cost of biological process effluent treatment plant (ETP) integrated with chemical oxidation is 70–80% lower or (0.33–0.5 USD/m^3) of treated wastewater [100]. Therefore, an appropriate technique should be integrated to obtain the best technology to treat wastewater effluents from the textile industry, environmental friend, and with the best overall commercial applicable.

3.6. Cost of Textile Effluent Wastewater Treatment Methods.
In recent years, the studies on pollution of water control mechanism for the textile factories are widely attention on only quality analysis techniques. Most researchers are not having a quantifiable explanation for pollution of water control method cost for textile effluent wastewater to explain with the help of cost visibility. Therefore, economic visibility and cost analysis are also important to give attention to wastewater treatment methods. Technologies for water pollution-control mechanism, the type of textile factory, and regional distribution are all main impacts that influence cost analysis [101]. This part focused on previous investigation to explain the cost analysis for pollution-control methods from the textile effluent. In Table 3, wastewater treatment methods and treatment cost analysis are illustrated. Table 3 shows the cost explanation for some treatment methods. The investigations indicated that integrated microfilter (MF)-nanofilter (NF)-advanced oxidation process based on treatment has fewer costs as compared to other treatment methods. For future, there is a requirement to investigate research which will be based on the price analysis of treatment methods such as photocatalyst, advanced oxidation processes (AOP), integrated treatment methods like biological with chemical, biological with physical and chemical with physical and MFC used for real wastewater effluent from industry for example textile. To reduce unnecessary wastage of power and consumable chemicals and to get the lower operating price in an integrated process to remove organic pollutants like dye, the degradation percentage should be minimum in the pretreatment or posttreatment steps [109]. To reduce the prices of treatment process, first, cost-intensive technologies should be selected or these technologies substituted by low-cost or efficient treatment methods. For example, catalysts recycle and use the H2O2 effluent from the bleaching process. Figure 3 recommends the various processing parts, which require to be followed for a possible selection of integration of integrated chemical and biological treatment methods for textile effluent wastewater. The price of all integration technologies and their environmental effect obtained after the treatment process should be compared with each other. Therefore, the integration process have fewer prices and too low toxicity products obtained; thus, this technology should be used to treat dyes the textile effluent wastewater. Figure 3 illustrates important biological and chemical treatment ways, which should be applied to the wastewater treatment process in the textile industry. The diagram also shows different conditions, depending on the pollutants in the textile effluent wastewater that might combine.
Table 3: Cost of technologies and treatments of wastewater effluent in textile.

| Technology for treatment of textile effluent | Treatment cost (US$/m³) | Reference |
|--------------------------------------------|-------------------------|-----------|
| Chemical and ion exchange process          | 3.5 US$/m³              | [102]     |
| Biologically pretreated textile wastewater followed by chemical treatment methods (Fe₃⁺/H₂O₂) | 0.57 US$/m³             | [103]     |
| Electro-Fenton                             | 3.13 US$/m³             | [104]     |
| Integrated                                 | EC + F (1.65 US$/m³)     | [105]     |
| Electrocoagulation, H₂O₂/Fe²⁺/UV with adsorption | EC + PF (2.3 US$/m³)    |           |
| Electrocoagulation                         | Fe electrode (1.562 US$/m³) |           |
| Hybrid photo-Fenton and membrane (MF-NF-AOP and MF-AOP-NF) | MF-NF-AOP (0.421 US$/m³), MF-AOP-NF (0.736 US$/m³) | [107]     |
| Hybrid photo-Fenton and membrane (MF-NF-AOP and MF-AOP-NF) | H₂O₂/UV-Vis/Fe²⁺ (100 mg·L⁻¹ H₂O₂/4 mg·L⁻¹ Fe²⁺) (0.91 US$/m³) |           |
| Photocatalytic processes under UV and visible light sources | H₂O₂/UV-Vis/Fe³⁺ (100 mg·L⁻¹ H₂O₂/20 mg·L⁻¹ Fe³⁺/80 mg·L⁻¹ H₂C₂O₄) (1.07 US$/m³) | [108]     |
| Photocatalytic processes under UV and visible light sources | H₂O₂/UV (100 mg·L⁻¹ H₂O₂) (2.24 US$/m³) |           |

Figure 3: System for integrating chemical oxidation with biological process for wastewater treatment from textile effluent [1].
4. Conclusions

The aim of this review work was to design appropriate wastewater treatment technologies, which are removing effluents from the wastewater of textile factories to mitigate water pollution. Concerning environment, accepted technology must be applied for the treatment of textile industry effluent. Various technologies have been observed to remove dyes from water in the textile factories in this review paper. Thus, in the textile industry, wastewater treatment plants are well designed by integration of various technologies, such as physical with chemical, biological with chemical, and physical with biological methods depending on the type and amount of pollutant loading. Due to the cost and clogging, effect membrane filtration method limits applying dye removal while adsorption method is preferable. Due to the low generation of by-products like solid wastes, low-working costs, and complete mineralization of dyes, the biological treatment method is better than the chemical treatment process. To reduce the load on microbial and get quality output, chemical method pretreatment was important before adding the wastewater to the microbial treatment process. In recent years, more researchers or workers should give attention to the kinetic research to remove pollutants and modelling of bioreactor for the integrated technologies of chemical oxidation or advanced oxidation process (AOP) as a pre- or posttreatment of separated pollutants effluents from each step in wet processing system before or after sending to biological treatment methods. The benefit of the research associated with fewer cost materials for MFC will have positive results in the textile factories effluent waste treatment plant through MFC technology, mini-mization of energy consumption, and extracting energy from wastewater. The studies on the control of pollution mechanisms in any industry like textile should pay attention to cost analysis descriptions of integrated processes instead of only qualitative research.

Therefore, in the future, it is important to have works that will try to pay attention to the removal of pollutants like dyes with a combination of chemical and biological treatment methods. Such a type of study may increase the biodegradability pollutants, which are effluent from textile factories carrying watersoluble dyes consumed for the printing and dying process.

Data Availability

The information can be obtained from the authors upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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