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RESEARCH PAPER

Biological Treatment of Textile Wastewater by Total Aerobic Mixed Bacteria and Comparison with Chemical Fenton Process

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Abstract
Textile effluents are highly colored for synthetic dyes, cause significant water pollution due to high pH, TDS, EC, BOD, and COD content, and are harmful to aquatic species. Among different treatment processes, biological treatment process is considered as a promising approach. In this investigation, a mixed aerobic bacterial consortium was used for the treatment of wastewater. In addition, the fenton process with a normal sand filter was used for treatment and compared with the biological method. The mean values of BOD, COD, TDS, EC, DO, and pH in the raw wastewater indicated that the effluent was highly contaminated according to Bangladesh standard (ECR, 1997). Both the biological treatment process and fenton process separately showed promising removal of pollution load. The aerobic mixed bacterial consortium reduced TDS (66.67%), EC (60%), BOD (91.67%), and COD (85.45%) and fenton process reduced TDS (74.71%), EC (55.11%), BOD (88.33%), and COD (83.63%) compared to the raw effluent bacterial consortium simultaneously degraded dyes and decolorized the wastewater from dark deep green to transparent. Color removal for the mixed aerobic bacterial process after 72 hours of aeration was 58.57% and for the fenton process with a normal sand filter was 80%. BOD and COD removal percentages for aerobic mixed bacterial consortium showed higher removal efficiency than the fenton process with a normal sand filter. Though 92 hours of aeration showed the maximum satisfactory result, aeration time could be reduced to 72 hours which also satisfied the Bangladeshi standard (ECR, 1997).

Keywords: Textile effluents, bioremediation, oxidation process, coagulation-flocculation, microbes.

INTRODUCTION

Textile wastewater causes serious environmental pollution and damage to the aquatic environment. It has been estimated that about 300,000 tons of synthetic dyes are discharged with textile wastewater worldwide every year (Sghaier et al., 2019). Textile wastewater contains different chemicals, such as hydrogen peroxide, acids, alkalis, starch, and surfactant agents (Paul

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et al., 2012). Likewise, it also contains different detergents, surfactants, chlorinated compounds, and toxic organics that added to improve dye adsorption onto the fiber (Prabakar et al., 2018).

Textile effluents are mainly characterized by high pH, TDS, EC, BOD, COD, temperature, organic loads, and low DO content (Tufekci et al., 2007, Meerbergen, et al., 2017). Dyes used in the textile industries can reduce water transparency and oxygen solubility in the surface water body which deteriorates water quality and decreases aesthetic values. Moreover, these dyes are manufactured from aromatic compounds and are also carcinogens (Banat et al., 1996). Widely used azo dyes have adverse effects on the growth of methanogenic bacterial cultures (Hu and Wu, 2001). High COD content in the effluents indicate the presence of toxic agents in such amounts that could be toxic to aquatic biota and to the aquatic ecosystem (Mazumder et al., 2011). If the effluents of any industry e.g., tannery (Shaibur et al., 2022), textile (Babu et al., 2015) or others are discharged directly without proper treatment, it will cause serious environmental pollution which will ultimately change the properties of surface water (Shaibur et al., 2022).

Different physicochemical processes have been applied for the treatment of textile wastewater. The most common processes are adsorption, oxidation, coagulation-flocculation, ozonation, and electrochemical process (Leal et al., 2018; Dotto et al., 2019; Suryawan et al., 2019; Chen et al., 2005), Adsorption and coagulation-flocculation are effective but chemical adsorbents may increase effluent acute toxicity (Castro et al., 2018). Coagulation-flocculation techniques produce large amounts of sludge, which requires safe disposal and further treatment. Ozonation followed by sequencing batch biofilter granular reactor removes surfactant and color at a very satisfactory level (Lotito et al., 2012). The ozonation process can decolorize wastewater to a great extent. Bhad et al., 2022 reported that the pure ozonation process can decolorize 85% of procion blue reactive dye. Moreover, advanced oxidation processes (AOP) and membrane filtration technique produce low sludge volume, as well as cost and energy efficient (Alalewi et al., 2012). This leads to the adoption of advanced oxidation processes (AOP) as attractive options for textile wastewater treatment. But still, it possesses high organic loads in terms of high COD and TOC content, even using a high dose of ozone cannot mineralize organic matter into CO_2 and H_2O at a satisfactory level (Perkowski et al., 1996). These complications can be reduced by using biological methods of treatment.

Bacteria, algae, fungi, and yeasts can disintegrate as well as absorb varieties of synthetic dyes (Ali, 2010). The bacterial strain has the significant capability to degrade textile dye and ultimately decolorize wastewater (Ranga et. al., 2015) though it depends on several factors like initial pH, dye concentration, contact time and temperature (Akar et al., 2008). At neutral pH, bacterial strain from activated sludge can exhibits almost 80% decolorization (Meerbergen et al., 2018). The biological remediation is cost-effective, nonpolluting and low sludges producing process compared to other techniques. It converts synthetic dyes to a comparatively less toxic inorganic compound and produces colorless water (Babu et al., 2015; Wang, et al., 2020).

The breakdown of the complex azo dyes take place in several steps such as the breaking of the azo bonds forming the amines, and then, the catabolism of the aromatic amines to small non-toxic molecules under an aerobic environment. Microorganisms are natural recyclers, converting toxic organic compounds into less toxic metabolic byproducts such as carbon dioxide and water (Meek et al., 2012) and using them as an energy source (Yang et al., 2014). Some bacteria can convert the sulphur-based textile dyes (Sulphur blue 15) to sulphuric acid. (Nguyen et al., 2016).

Different bacteria were identified by many researchers that can degrade different azo-based dyes at a faster rate (Glazer, 1997). For the best result in wastewater treatment plants, all types of organisms that are involved in treating are used together. The choice of choosing organism depends on the local climate and other factors. Local species have a good adaptation capacity to survive in the local environment. In the wastewater treatment plants, three types of bacteria are used to treat the wastewater such as aerobic, anaerobic, and facultative bacteria (Adedayo et al., 2004). The use of bacterial consortia for azo dye degradation produces more effective result over single strains as one bacterial strain of the consortia can perform further degradation of metabolite by another bacteria (Jadhav et al., 2010; Khehra et al., 2005). Moreover, at an industrial scale combination of anaerobic/anoxic/aerobic within a DHS reactor can be a promising treatment method for textile wastewater (Watari et al., 2021).

Recently, the fenton process is considered as an alternative low-cost advanced oxidation treatment process for the removal of persistent dyes from textile wastewater in which H_2O_2 acts as an oxidant agent (Simion et al., 2015; Matira et al., 2015; Masalvad et al., 2021). Chemical Fenton can remove color and COD efficiently (Sozen et al., 2020). Photo-Fenton oxidation and the combination of aerobic sequencing batch reactor reduced COD by 79% and TOC by 75% at pH 2.7 (Blanco et al., 2014).

Different Textile industries separately use Biological or Chemical treatment processes, but their effluents rarely meet the quality standards. To improve the effluent quality of textile wastewater, preliminary or integrated treatment by combining multiple methodologies may bring the expected results with quality standard. To solve the above-mentioned problem, the present study aims to investigate the effectiveness of activated sludge for the treatment of textile wastewater effluent and compare it with the fenton process. Moreover, as limited information is available about microbial community composition and their function in activated sludge (Yang et al., 2014), a detailed analysis was performed which includes characterization of activated sludge and showed the peculiar advantages of the treatment process., In addition, it also tried to find out the specific aeration time of aerobic bacteria to treat the textile effluent efficiently.

MATERIALS AND METHODS

Sample collection

Wastewater samples were collected from a renowned Textile Dyeing and Printing Industries limited located at Savar Upazilla in Dhaka, Bangladesh. The samples were collected in a plastic sample bottle of 5 liters capacity. Firstly, sample bottles were washed with 20% HNO_3 solutions and finally rinsed with de-ionized water (Tasneem et al., 2021). After labeling the sample bottles were transported to the "Water Research Center" laboratory at Jahangirnagar University, Savar, Dhaka, Bangladesh where the samples were preserved at 4^0C in the refrigerator for further analysis. This research was designed into two processes, the biological treatment process and the chemical fenton process.

Biological treatment process

Activated sludge also collected from the same industry which contained huge aerobic microbes. Activated sludge containing aerobic bacteria used in this experiment to degrade dye and reduce the dye concentration for the treatment of textile wastewater. Activated sludge was used because it would be a great source of active microbes which may get nutrients from dyes and organic materials (Shade et al., 2012). Furthermore, activated sludge is more effective for

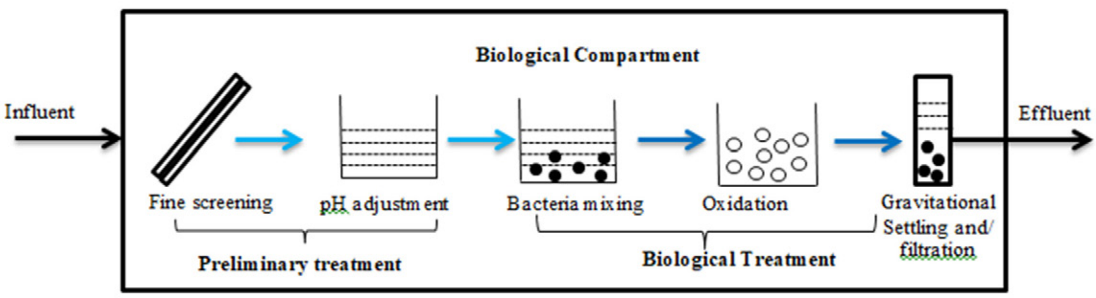

Fig. 1. Sketch of the lab-scale biological treatment plant.

COD reduction (Anastasi et al., 2012). Bacteria were collected, isolated and identified from the activated sludge (Ishak et al., 2011; McKinney and Weichlein, 1953). Incubator used to grow and maintain microbial cultures or cell cultures. Two air diffusers were used for continuous aeration of activated sludge. The ratio of wastewater and activated sludge used in this treatment process was 1: 0.6 (McKinney and Weichlein, 1953).

For the biological treatment process, physicochemical parameters were measured periodically after every 12-hour interval to find out the effective aeration time for the treatment of textile wastewater.

Chemical treatment process

For the chemical treatment process, raw textile effluent was treated with the fenton process and then filtered with a normal sand filter. Sand needed to clean with water and dried under the Sun. The jar test method was applied and firstly, pH of raw wastewater was adjusted to pH 2. In a 500 ml jar, 10 ml of $FeSO_4$ in ppm was applied and 3 ml of 30% concentrated hydrogen peroxide (conc. H_2O_2) was slowly added. Fenton process produces hydroxyl radical, a very strong oxidizing agent while ferrous ion reacts with hydrogen peroxide. This hydroxyl radical reacts with different contaminants (Kang et al., 2002). Further Hydroxyl radical can also react with hydrogen peroxide.

$$Fe^{2+} + {\cdot}OH \rightarrow OH^{\cdot} + Fe^{3+} \quad (1)$$

$$OH^{\cdot} + \text{Toxic Organics} \rightarrow \text{Detoxified products} \quad (2)$$

$${\cdot}OH + H_2O_2 \rightarrow H_2O^{\cdot} + H_2O^{+} \quad (3)$$

This solution was mixed for 5 minutes with a stirrer and kept it 30 minutes for settlement. Then raw wastewater sample was filtered through the normal sand filter. After collecting filtered water, different physico-chemical parameters were measured. Color of the raw effluent was observed by naked eye and absorbance is measured by colorimetric method using UV-visible Spectrometer (200nm-1000nm wavelength). Color removal percentage was calculated by equation (4)

$$\textbf{Color removal}\ \% = (1 - Abs_f/Abs_0) \times 100 \quad (4)$$

Where, Abs_f is the UV-absorbance of the treated dye and Abs_0 is the UV absorbance of the untreated dye (Berkessa et al., 2020)

Physico-chemical parameter

Physico-chemical parameter such as, EC and Salinity of wastewater was measured by conductivity meter. (HANNA Instrument, HI- 8033), Turbidity was measured by turbidity meter (Microprocessor Turbidity Meter, HANNA Instrument: HI93703). The results were expressed in term of Formazin turbidity units (FTU). The pH of wastewater was measured by pH meter Ecoscan Ion Meter (Model No.6). TDS was determined by using TDS Meter (HANNA.HI 8734 instrument). DO content of effluent samples were determined by using DO meter.

BOD and COD analysis

BOD (mg/L) was determined by 5-days incubation (20 ℃) method. The sample was filled in an airtight bottle and incubated at 20 ℃ temperature for 5 days. The dissolved oxygen (DO) content of the sample is determined before and after five days of incubation at 20 °C and the BOD is calculated from the difference between initial and final DO. BOD removal efficiency was measured by equation (5).

$$\text{Removal of BOD \%} = (1\text{-}BOD_f/BOD_o) \quad (5)$$

Where, BOD_f is the chemical oxygen demand of the treated dye and BOD_o is the chemical oxygen demand of the untreated dye (Hossain et al., 2020).

COD (mg/L) was determined by gravimetric method and titrimetric method. COD removal efficiency was measured by equation (6)

$$\text{Removal of COD \%} = (1\text{-}COD_f/COD_o) \quad (6)$$

Where, COD_f is the chemical oxygen demand of the treated dye and COD_o is the chemical oxygen demand of the untreated dye (Buthiyappan et al., 2019).

Isolation and identification of heterotrophic aerobic bacteria

To isolate aerobic heterotrophic bacteria 40 ml aliquot of well-shaken mixed liquor activated sludge sample was centrifuged at 10,000 rpm and the residue suspended in a beaker. Serial dilution of the suspension was made, and 1 ml of each dilution was spread on individual sterile agar plates (Pike et al., 1972). Using the serial dilution method, the sample was diluted to 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4} times. MacCon key agar was used to isolate gram negative bacteria (Allen, 2005; Elazhary et al., 1973) and nutrient agar for mix culture (Carrillo et al., 1996). Further gram staining was done for rapid distinction of gram positive and negative bacteria (Gregersen, 1978). After incubation for 5 days at 20^0C colonies were selected for identification. Physical characteristics of the colonies, i.e., size, odor, texture and color were observed (Lotter et al., 1985). A set of biochemical tests were done for bacterial identification and physio-morphological culture traits were determined as suggested by Bergey's Manual of Systematic Bacteriology, Volume 1 and 2 (Krieg and Holt, 1984; Sneath et al., 1986). Bacterial population numbers were expressed as a percentage of total number of colonies (CFU) that grew. For biological treatment, pH of raw wastewater was adjusted with concentrated hydrochloric acid to pH 7 as it results in the highest bacterial degradation capability (Holkar et al., 2016) and bacterial consortium was optimized with pH and temperature (Lalnunhlimi and Krishnaswamy, 2016).

Figures were analyzed and produced by using "R programming language (R.4.0.5)" software.

RESULTS AND DISCUSSION

Biological treatment process

Microbial Characterization

To identify microorganisms, unknown microbes were compared with known similar microbes. The morphological and physiological characteristics of the cultures were examined by observing the size, odor, texture, and color of colonies. The collected activated sludge contained mostly gram-negative genera. The result (table 1) showed that the activated sludge mainly comprised the genera of *Bacillus*, *Thiobacillus, Alcaligens, Acinetobacter, Achromobacter, Citrobacter, Flavobacterium, Micrococcus, Pseudomonas, Nitrosomonas* and *Nitrobacter*. The only gram-positive bacterium was from the genus *Micrococcus*. A total 108 of non-identical aerobic heterotrophic bacterial colonies were isolated from the activated sludge and identified based on their phenotypic properties. *Pseudomonas* was the most dominated (27%) species and Flavobacterium, the second dominated (21%) species found from activated sludge sample. More than 95% of bacteria were gram negative.

The obtained result of bacterial identification is consistent with several previously published research reports (Snaidr et al., 1997, Wagner et al., 1994, Wang et al., 2010).

Table 1. Identification of heterotrophic bacteria from the activated sludge.

Genus	Gram staining	Shape	% Of Total Isolates (CFU/mL)
Bacillus	Negative	Rod	16%
Thiobacillus	Negative	Rod	8%
Alcaligens	Negative	Rod	5%
Acinetobacter,	Negative	Coccobacillary	11%
Achromobacter	Negative	Straight rods	4%
Citrobacter	Negative	Rod	3%
Flavobacterium	Negative	Rod	21%
Pseudomonas,	Negative	Rod	27%
Nitrosomonas	Negative	Rod	2%
Nitrobacter	Negative	Rod/Pear shaped	1%
Micrococcus	Positive	Coccus	2%

Table 2. Changes of different physico-chemical parameters of wastewater after 36, 48, 72, 84 and 96 hours of biological treatment.

Parameters	Effluent quality standards, ECR 1997	Pretreatment values	Post-treatment parameters in hours					
			36 h	48 h	60 h	72 h	82 h	96 h
pH	6.5-9	10.4	7	6.9	6.8	6.7	6.8	6.7
DO (mg/L)	4.5-8	1.8	5.8	6.1	6.7	6.7	6.8	6.8
TDS (mg/L)	2100	870	400	380	320	320	300	290
EC (µs/cm)	1200	2250	1660	1210	980	980	930	900
BOD (mg/L)	50	600	400	180	50	50	50	50
COD (mg/L)	200	1100	570	280	170	170	170	160

Treatment performance of microbial sludge

Table 2 summarizes the characteristics of raw Textile wastewater which reveals the potential biological treatment options of the wastewater. The ratio of BOD and COD (BOD/COD) at 0.54 also suggests the potentiality of biological treatment options. Table 3 shows the pollution load removal efficiency in percentage after every 12 hours aeration interval. Figure 2 shows the changes in pH of the wastewater. pH was adjusted to 7 from 10.4 by adding concentrated Hydrochloric acid (HCl) as the neutral pH is a favorable condition for bacterial survival. Besides, high oxygen concentration from continuous aeration influenced pH conditions and maintained the value almost at a neutral level. Figure 3 shows the changes of dissolved oxygen (DO) content. The initial DO of raw wastewater was 1.8 which indicates highly deficit of dissolved oxygen that reveals the necessity of treatment. Finally, DO content increases to 6.8mg/L after 96 hours of continuous aeration which is higher than the ECR,1997 standard (4.5 mg/L). As oxygen concentration was increased with continuous aeration, DO content of effluent water increased with extended treatment duration. Figure 4 demonstrates changes in the TDS values. TDS of raw wastewater was 870 mg/L which finally reaches to 290 mg/L after 96 hours of aeration.

Table 3. Treatment efficiency in percentage after different time hours

Parameters	Removal Efficiency After Treatment					
	36 hours	48 hours	60 hours	72 hours	84 hours	96 hours
pH	32.69%	33.65%	34.61%	35.57%	34.61%	35.57%
TDS (mg/L)	54.02%	56.32%	59.77%	59.77%	65.51%	66.67%
EC (µs/cm)	26.23%	46.23%	49.78%	56.45%	58.67%	60%
BOD (mg/L)	33.34%	70%	80%	91.67%	91.67%	91.67%
COD (mg/L)	48.18%	74.54%	83.63%	84.54%	84.54%	85.45%

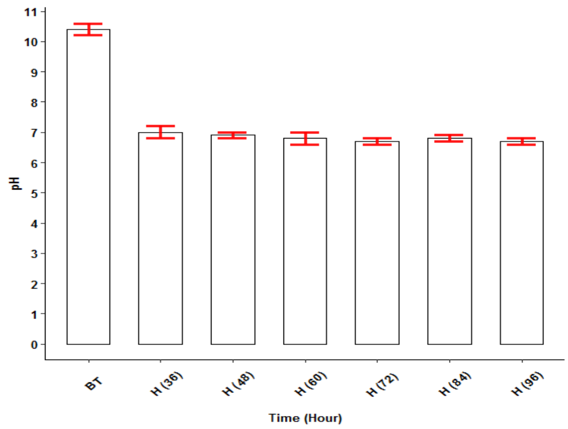

Fig. 2. pH value (Mean ± Standard deviation) of wastewater before treatment (BT) and after treatment in different hours.

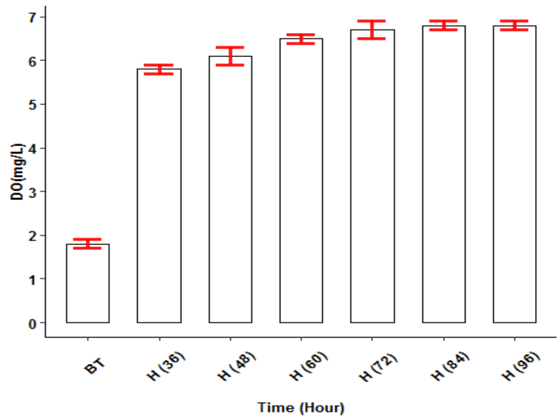

Fig. 3. DO value (Mean ± Standard deviation) of wastewater before treatment (BT) and after treatment in different hours.

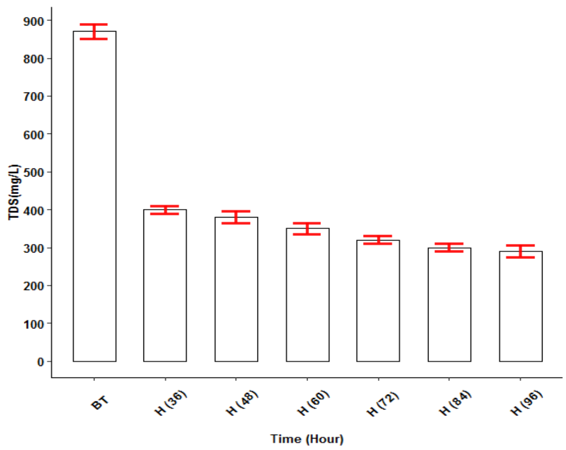

Fig. 4. TDS value (Mean ± Standard deviation) of wastewater before treatment (BT) and after treatment in different hours.

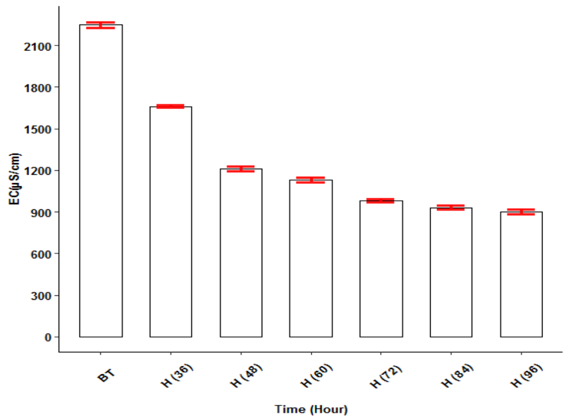

Fig. 5. EC value (Mean ± Standard deviation) of wastewater before treatment (BT) and after treatment in different hours.

Aerobic bacteria removed 66.67% of TDS from raw wastewater. Activated sludge increase biodegradability and based on this mechanism aerobic bacteria from activated sludge at high oxygen content increased the effectiveness of TDS removal. Figure 5 indicates the changes in electrical conductivity (EC) of raw wastewater from 2250 µs/cm to 900 µs/cm after 96 hours of aeration. Finally, biological treatment process removed 60% of EC from the wastewater. In

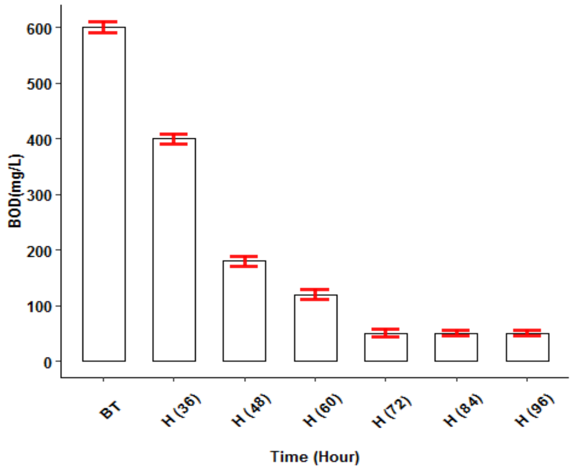

Fig. 6. BOD value (Mean ± Standard deviation) of wastewater before treatment (BT) and after treatment in different hours.

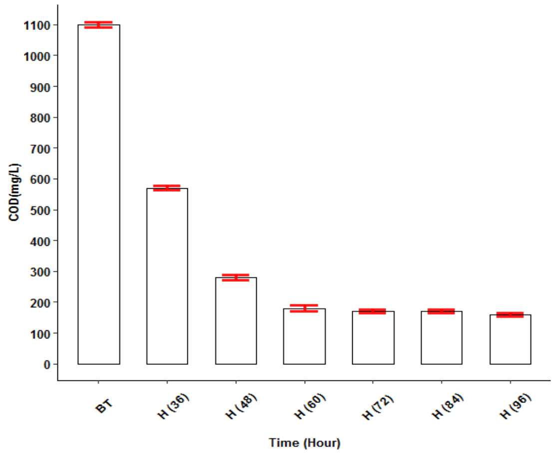

Fig. 7. COD value (Mean ± Standard deviation) of wastewater before treatment (BT) and after treatment in different hours.

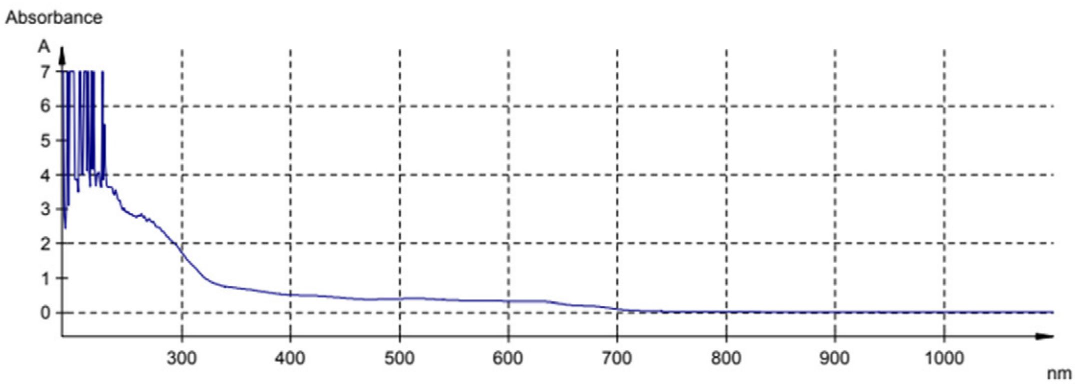

Fig. 8. UV absorbance spectra of dye color of raw effluent.

figure 6, the changes in BOD values were represented. The initial BOD value of raw wastewater was 600 mg/L which clearly indicates the high pollution phenomenon of the textile effluent. After 96 hours of aeration finally it reached to 50 mg/L. BOD value after 72 hours of aeration also fulfilled the standard quality of ECR, 1997. This method showed 91.67% of BOD removal efficiency both for 72 hours and 96 hours of aeration time. Increasing biomass with a higher aeration time enhances organic matter degradation (Malik et al., 2021). In this experiment, more microorganisms in the aeration box were also responsible for the removal of organic material which ultimately reduced BOD. In figure 7, the COD value of wastewater is plotted. The COD value of raw wastewater (1100mg/L) was higher than the BOD value (600 mg/L). In every 6 hours interval COD value decreased and reached to 160 mg/L which indicated the higher pollution load removal efficiency of activated sludge. In this aeration time, aerobic bacteria showed 85.54% of COD removal efficiency. Food to microorganisms (F/M) ratio also plays a vital role in organic load removal. Increasing F/M ratio decrease COD removal (Mirbagheri et al., 2014). In this experiment, at a fixed size of aeration box with no additional influent made constant amount of organic substrate and increased microorganisms lower the F/M ratio causing high COD removal. Figure 9 shows the changes in UV-absorbance value after 72 hours aeration of raw wastewater. By solving equation 4, 58.57% of color removal of wastewater was achieved

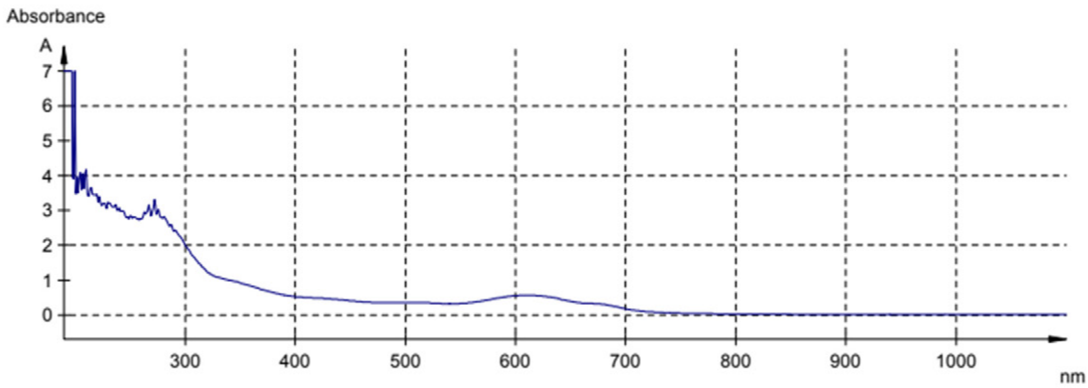

Fig. 9. UV absorbance spectra of dye color of effluent after 72-hour aeration.

Table 4. Changes of parameters and removal efficiency after Fenton process with sand filter technique. (F= Fenton process, SF= Sand filter)

Parameters	Raw effluents	After Treatment (F+SF)	Effluent quality standard [Bangladesh Standards, ECR,1997]	Removal efficiency (%)
pH	10.4	4.5	6.5-9	-
DO (mg/L)	1.8	6.19	4.5-8	-
TDS (mg/L)	870	220	2100	74.71%
EC (µs/cm)	2250	1010	1200	55.11%
BOD (mg/L)	600	70	50	88.33%
COD (mg/L)	1100	180	200	83.63%

which is 21.43% less than the fenton process with a normal sand filter (figure 10). Previous research also showed that the color removal efficiency of the fenton process is higher than the activated sludge process (Bae et al., 2015). Naked eyes observation also showed that treated wastewater turned transparent from the deep dark green color of raw wastewater (figure 11).

Treatment performance of Fenton process.

Treatment efficiency was satisfactory and different physico-chemical parameters such as Color, EC, TDS, pH, DO, BOD, COD, were observed which were within recommended level of Bangladesh standard.

Fenton is considered as a promising treatment technique for pollutant removal of Textile wastewater as it can remove almost all parts of organic matter by both oxidation and coagulation methods. In this experiment, treatment performance of the fenton process with sand filter technique was appraised by measuring several parameters of textile effluent like TDS, EC, BOD, COD and color removal. This technique removes 74.71% TDS, 55.11% EC, 88.33% BOD, 83.63% COD and finally 80% of wastewater color. pH value of wastewater influences the redox potential (Yang et al., 2009). Therefore, pH adjustment was necessary in this experiment. The mechanism of fenton process reveals that Fe^{2+} with oxygen in aerobic condition produces OH^- which can break some part of unbiodegradable substances into small molecules and consequently these transfer to biodegradable substances (Su et al., 2011). Thus, this process reduced BOD and COD values in wastewater. Kang et al., (2002) also reported that fenton coagulation reduce COD as Fe^{2+} and Fe^{3+} both are coagulant.

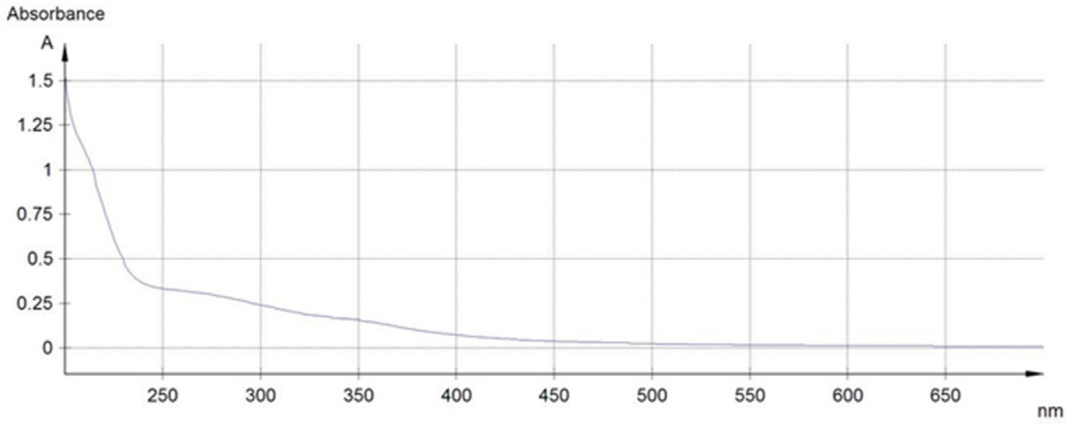

Fig.10. UV absorbance spectra of dye color of effluent after Fenton process and normal sand filtration.

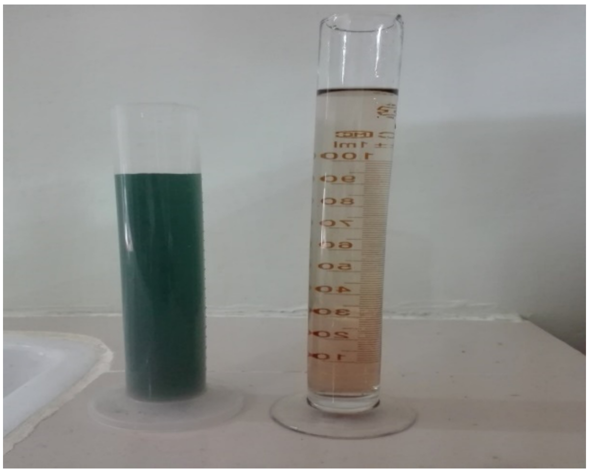

Fig.11. Color of raw and treated wastewater after 72 hours of aeration.

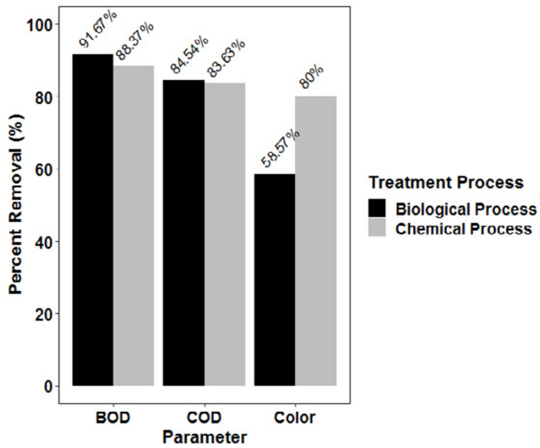

Fig.12. Comparison of biological and chemical treatment process for BOD, COD and Color removal.

Comparison of the biological and chemical treatment process

TDS removal of the biological treatment process was 8.04% less than the fenton process. For the fenton process TDS removal was 74.71%, whereas for the biological treatment process it was 66.67%. But for other parameters such as EC, BOD and COD removal, biological treatment efficiency was more than the fenton process with normal sand filter though both processes satisfied the Bangladesh Standards, ECR, 1997. Color removal for the biological process was 58.57 % after 72 hours of aeration whereas, for the fenton process with normal sand filtration technique it was 80% which is 21.43% higher than the biological process (Figure 12). Though the biological process is time-consuming, it is an environmentally friendly method and consumed no chemicals except Hydrochloric acid for pH correction thus it is considered a cost-effective method of wastewater treatment. This aerobic mixed bacterial treatment method possesses higher color removal efficiency than many other biological treatment methods which is represented in table 5. It is assumed that high toxicity removal is possible if this biological process is combined with an adsorbent filter (Badawi et al., 2021). Application of the fenton process as a biological post-treatment could eliminate the non-biodegradable part of textile wastewater more effectively (Blanco et al., 2012). Moreover, coupling of fenton process with the biological treatment method could perform better to achieve the goal of reusing the wastewater in agricultural site.

Table 5. Comparison of treatment efficiency with previous research.

Treatment methods	BOD removal (%)	COD removal (%)	Color removal efficiency (%)	Reference
Conventional Activated Sludge	--------	57%	37%	Nawaz and Ahsan 2014
Activated sludge with bentonite, activated clay and macrosorb.	--------	80-90%	36%	Pala and Takot 2002
Aerobic activated sludge process (Without ozone pretreatment)	28.6%	32.0%	30%	Suryawan et al., 2019
Activated Sludge process sequencing batch reactor	--------	80.71%	--------	Mirbolooki et al 2017
Sequencing batch bio-filter granular reactor.	--------	82.10%	52.50%	Lotito et al 2014
Biological process, sequencing batch reactor	--------	83.3%	35.5%	Fongsatitkul et al 2004
Activated sludge		68%	34.30%	Anastasi et al 2012
Aerobic mixed bacteria with 72 hours aeration.	91.67%	84.54%	58.57%	This study
Fenton oxidation process	--------	68%	24%	Nawaz and Ahsan 2014
Fenton process with normal sand filter	88.33%	83.63%	80%	This study

From table 2, the changes of the parameters after the biological treatment process were satisfactory enough. The value of pH, DO, EC, TDS, BOD and COD after 72 hours of aeration was 6.7, 6.7mg/L, 980µs/cm, 320mg/L, 70mg/L, 150mg/L which all were within the recommended level by DoE. From these results, it is clear that for physicochemical treatment of textile wastewater by aerobic mixed bacteria the aeration time of 72 hours is efficient. The present study demonstrates that such an approach is indeed possible because bacterial isolates from sludge possesses the ability to degrade synthetic dyes. This biological treatment method of textile wastewater also can reduce the cost of chemicals as this is a method of using no chemicals except hydrochloric or sulphuric acid for correction of sample pH. Fenton process with normal sand filter also gave attractive results. COD removal for the fenton process was 83.63% whereas biological treatment efficiency was maximum 85.45%. Thus, mixed bacterial culture produces better performances than the fenton process. The performance of the fenton process could be increased if an adsorbent filter is used rather than a normal sand filter (Hossain et al., 2020).

Table 5 represents the efficiency of the present research which clearly reflects the better performance for both biological and chemical process of the present study than many others previous research. Higher performance of pollution load removal by biological treatment process was possible for some pretreatment such as pH adjustment and using mixed aerobic bacteria rather than single isolates with continuous longer aeration period.

In this study textile water was treated to reduce physicochemical parameters in terms of TDS, BOD, COD, Color, pH, EC and wanted to bring them within the standard limit recommended by Department of Environment (DoE), Bangladesh. That is why the present study gave emphasized on the reduction of color and other physicochemical parameters such as TDS, BOD, COD, pH, EC and toxicity was not investigated. This is the limitation of this work. In future research, toxicity testing should be examined after biological treatment to remove further toxic molecules as Punzi et al., (2015) reported that using advance oxidation process like photo fenton process after biological treatment can effectively remove toxicity.

CONCLUSION

Textile wastewater treatment by aerobic mixed bacteria and the fenton process was the major goal of this current research. At the same time, the comparative analysis between biological and chemical processes was presented. The biological treatment process showed excellent removal efficiency for BOD, COD, EC and TDS. Although the biological treatment process showed high efficiency after 96 hours of aeration,72 hours of aeration time also satisfied the Bangladesh Standards, ECR, 1997. And it was good enough for both color treatment and different physico-chemical parameter treatment, as at this time all the physico-chemical parameters remained within standard level recommended by DoE. The biological treatment was also cost effective as it reduced the cost of different chemicals. Both biological process and the fenton process remove color from deep dark green to a transparent level. Fenton process with normal sand filter also showed promising removal efficiency and it exceeded the efficiency of biological process for TDS removal. But for other parameters such as EC, BOD, and COD bacterial process showed the higher efficiency. In the present study, textile wastewater was treated to keep it within the recommended standard. This research was a step towards the future improvement of our knowledge about the combined textile wastewater treatment technology's efficiency of biological and chemical process. In future research combining these two experiments with some further development can achieve SDG's 14th goal of conserving life below water and zero waste generation.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

Alalewi, A. and Cuiling, J. (2012). Bacterial influence on textile wastewater decolorization. J. Environ. Prot. 3, 889.

Adedayo, O., Javadpour, S., Taylor, C., Anderson, W. A. and Moo-Young, M. (2004). Decolourization and detoxification of methyl red by aerobic bacteria from a wastewater treatment plant. W. J. Microbiol. Biotechnol., 20(6), 545-550.

Akar, T., Ozcan, A. S., Tunali, S. and Ozcan, A. (2008). Biosorption of a textile dye (Acid Blue 40) by cone biomass of Thuja orientalis: estimation of equilibrium, thermodynamic and kinetic parameters. Bioresourc. Technol., 99(8), 3057-3065.

Allen, M. E. (2005). MacConkey agar plates protocols. American Soci. Microbio., 30, 1-4.

Ali, I. (2010). The quest for active carbon adsorbent substitutes: inexpensive adsorbents for toxic metal ions removal from wastewater. Separat. and Purifica. Review., 39(3-4), 95-171.

Anastasi, A., Spina, F., Romagnolo, A., Tigini, V., Prigione, V. and Varese, G. C. (2012). Integrated fungal biomass and activated sludge treatment for textile wastewaters bioremediation. Bioresour. Technol., 123, 106-111.

Babu, S. S., Mohandass, C., Vijayaraj, A. S. and Dhale, M. A. (2015). Detoxification and color removal of Congo Red by a novel Dietzia sp. (DTS26)–a microcosm approach. Ecotox. Environ. Safe., 114, 52-60.

Badawi, A. K. and Zaher, K. (2021). Hybrid treatment system for real textile wastewater remediation based on coagulation/flocculation, adsorption and filtration processes: Performance and economic evaluation. J. Water Process. Eng. 40, 101963.

Bae, W., Won, H., Hwang, B., de Toledo, R. A., Chung, J., Kwon, K. and Shim, H. (2015). Characterization of refractory matters in dyeing wastewater during a full-scale Fenton process following pure oxygen activated sludge treatment. J. Hazard. Mater., 287, 421-428.

Banat, I. M., Nigam, P., Singh, D. and Marchant, R. (1996). Microbial decolorization of textile-dye-containing effluents: a review. Bioresour. Technol. 58:217-227

Bhad, R. M., Das, A., and Kodape, S. M. (2022). Ozonation of Procion Blue Reactive Dye and it's Kinetics Study. Pollution, 8(2), 529-541.

Berkessa, Y. W., Yan, B., Li, T., Jegatheesan, V.and Zhang, Y. (2020). Treatment of anthraquinone dye textile wastewater using anaerobic dynamic membrane bioreactor: Performance and microbial dynamics. Chemosphere, 238, 124539.

Blanco, J., Torrades, F., De la Varga, M., and García-Montaño, J. (2012). Fenton and biological-Fenton coupled processes for textile wastewater treatment and reuse. Desalination, 286, 394-399.

Blanco, J., Torrades, F., Morón, M., Brouta-Agnésa, M. and García-Montaño, J. (2014). Photo-Fenton and sequencing batch reactor coupled to photo-Fenton processes for textile wastewater reclamation: feasibility of reuse in dyeing processes. Chem. Eng. J. 240, 469-475.

Buthiyappan, A., Gopalan, J. and Raman, A. A. (2019). Synthesis of iron oxides impregnated green adsorbent from sugarcane bagasse: Characterization and evaluation of adsorption efficiency. Journal of environmental management., 249:109323.

Carrillo, P. G., Mardaraz, C., Pitta-Alvarez, S. I. and Giulietti, A. M. (1996). Isolation and selection of biosurfactant- producing bacteria. J. Microbiol. Biotechnol., 12(1), 82-84.

Castro, M., Nogueira, V., Lopes, I., Vieira, M. N., Rocha-Santos, T. and Pereira, R. (2018). Treatment of a textile effluent by adsorption with cork granules and titanium dioxide nanomaterial. J. Environ. Sci. Health C, 53(6), 524-536

Chen, X., Shen, Z., Zhu, X., Fan, Y. and Wang, W. (2005). Advanced treatment of textile wastewater for reuse using electrochemical oxidation and membrane filtration. Water S.A., 31(1), 127-132.

Dotto, J., Fagundes-Klen, M. R., Veit, M. T., Palacio, S. M. and Bergamasco, R. (2019). Performance of different coagulants in the coagulation/flocculation process of textile wastewater. Journal of Cleaner Production, 208, 656-665.

Elazhary, M. A. S. Y., Saheb, S. A., Roy, R. S. and Lagacé, A. (1973). A simple procedure for the preliminary identification of aerobic gram-negative intestinal bacteria with special reference to the Enterobacteriaceae. Can. J. Comp. Med, 37(1), 43.

Environmental Conservation Rules (ECR), Department of Environment. Ministry of Environment and Forest. People's Republic of Bangladesh; 1997.

Fongsatitkul, P., Elefsiniotis, P., Yamasmit, A. and Yamasmit, N. (2004). Use of sequencing batch reactors and Fenton's reagent to treat a wastewater from a textile industry. Biochem. Eng. J., 21(3), 213-220.

Glazer, A.N. (1997). Microbial Biotechnology WH freeman and Company New York. 54—58.

Gregersen, T. (1978). Rapid method for distinction of Gram-negative from Gram-positive bacteria. European journal of applied microbiology and biotechnology, 5(2), 123-127.

Holkar, C. R., Jadhav, A. J., Pinjari, D. V., Mahamuni, N. M. and Pandit, A. B. (2016). A critical review on textile wastewater treatments: possible approaches. J. Environ. Manage., 182, 351-366.
Hossain, M. S., Sarker, P., Rahaman, M. S. and Uddin, M. K. (2020). Integrated Performance of Fenton Process and Filtration (Activated Charcoal and Sand) for Textile Wastewater Treatment. Curr. J. Appl. Sci. Technol., 21-31.
Hu T. L. and Wu, S. C. (2001). Assessment of the effect of azo dye RP2B on the growth of a nitrogen fixing cyanobacterium Anabaena sp. Biores Technol 77:93–95.
Ishak, W. W., Jamek, S., Jalanni, N. A., and Jamaludin, N. M. (2011). Isolation and Identification of Bacteria from Activated Sludge and Compostfor Municipal Solid Waste Treatment System. Int. Proc. Chem. Biol. Environ. Eng., 24, 450-454.
Jadhav, J. P., Kalyani, D. C., Telke, A. A., Phugare, S. S. and Govindwar, S. P. (2010). Evaluation of the efficacy of a bacterial consortium for the removal of color, reduction of heavy metals, and toxicity from textile dye effluent. Bioresourc. Technol., 101(1), 165-173.
Kang, S. F., Liao, C. H., and Chen, M. C. (2002). Pre-oxidation and coagulation of textile wastewater by the Fenton process. Chemosphere, 46(6), 923-928.
Khehra, M. S., Saini, H. S., Sharma, D. K., Chadha, B. S., and Chimni, S. S. (2005). Decolorization of various azo dyes by bacterial consortium. Dyes pigm., 67(1), 55-61.
Krieg, N. R. and J. G. Holt. (1984). Bergey's manual of systematic bacteriology. Vol. 1. The Williams and Wilkins Co., Baltimore.
Lalnunhlimi, S. and Krishnaswamy, V. (2016). Decolorization of azo dyes (Direct Blue 151 and Direct Red 31) by moderately alkaliphilic bacterial consortium. Brazilia. J. Microbiol., 47(1), 39-46.
Leal, T. W., Lourenco, L. A., Scheibe, A. S., De Souza, S. M. G. U., and De Souza, A. A. U. (2018). Textile wastewater treatment using low-cost adsorbent aiming the water reuse in dyeing process. Journal of Environmental Chemical Engineering, 6(2), 2705-2712
Lotito, A.M., Fratino, U., Bergna, G. andDi Iaconi, C., 2012. Integrated biological and ozone treatment of printing textile wastewater. Chem. Eng. J. 195-196, 261-269.
Lotito, A. M., De Sanctis, M., Di Iaconi, C. and Bergna, G. (2014). Textile wastewater treatment: Aerobic granular sludge vs activated sludge systems. Water Res., 54, 337-346.
Lotter, L. H. and Murphy, M. (1985). The identification of heterotrophic bacteria in an activated sludge plant with particular reference to polyphosphate accumulation. Water SA, 11(4), 179-184.
Malik, A., Hussain, M., Uddin, F., Raza, W., Hussain, S., Habiba, U. E. and Ajmal, Z. (2021). Investigation of textile dyeing effluent using activated sludge system to assess the removal efficiency. Water Environ. Res, *93*(12), 2931-2940.
Masalvad, S. K. S., and Sakare, P. K. (2021). Application of photo Fenton process for treatment of textile Congo-red dye solution. Mater. Today: Proc.: Proceedings, 46, 5291-5297.
Matira, E. M., Chen, T. C., Lu, M. C., and Dalida, M. L. P. (2015). Degradation of dimethyl sulfoxide through fluidized-bed Fenton process. J. Hazard. Mater., 300, 218-226.
Mazumder, D. (2011). Process evaluation and treatability study of wastewater in a textile dyeing industry. Int. J. Ener. Environ., 2(6).
McKinney, R. E., and Weichlein, R. G. (1953). Isolation of floc-producing bacteria from activated sludge. J. Appl. Microbiol, 1(5), 259-261.
Meek, D. W., Hoang, C. K., Malone, R. W., Kanwar, R. S., Fox, G. A., Guzman, J. A., and Shipitalo, M. J. (2012). Rational polynomial functions for modeling E. coli and bromide breakthrough. Transac. of ASABE, 55(5), 1821-1826.
Meerbergen, K., Willems, K. A., Dewil, R., Van Impe, J., Appels, L., and Lievens, B. (2018). Isolation and screening of bacterial isolates from wastewater treatment plants to decolorize azo dyes. J. Biosci. Bioeng., 125(4), 448-456.
Meerbergen, K., Van Geel, M., Waud, M., Willems, K. A., Dewil, R., Van Impe, J. and Lievens, B. (2017). Assessing the composition of microbial communities in textile wastewater treatment plants in comparison with municipal wastewater treatment plants. MicrobiologyOpen, 6(1), e00413.
Mirbagheri, S. A., Ebrahimi, M. and Mohammadi, M. (2014). Optimization method for the treatment of Tehran petroleum refinery wastewater using activated sludge contact stabilization process. Desalination Water Treat, 52(1-3), 156-163.
Mirbolooki, H., Amirnezhad, R. and Pendashteh, A. R. (2017). Treatment of high saline textile wastewater by activated sludge microorganisms. J. Appl. Res. Technol. 15(2), 167-172.
Nawaz, M. S. and Ahsan, M. (2014). Comparison of physico-chemical, advanced oxidation and biological

techniques for the textile wastewater treatment. Alex. Eng. J., 53(3), 717-722.
Nguyen, T. A., Fu, C. C., and Juang, R. S. (2016). Biosorption and biodegradation of a sulfur dye in high strength dyeing wastewater by Acidithiobacillus thiooxidans. J. Environ. Manage., 182, 265-271.
Pala, A., and Tokat, E. (2002). Color removal from cotton textile industry wastewater in an activated sludge system with various additives. Water Res., 36(11), 2920-2925.
Patil, A. D. and Raut, P. D. (2014). Treatment of textile wastewater by Fenton's process as an Advanced Oxidation Process. J. Environ. Sci.Toxicol. and Food Technol., 8, 29-32.
Paul, S.A., Chavan, S.K. and Khambe, S.D., (2012.) Studies on characterization of textile industrial wastewater in solapur city. Int. J. Chem. Sci. 10, 635-642.
Perkowski, J., Kos, L., and Ledakowicz, S. (1996). Application of ozone in textile wastewater treatment. Ozone Sci Eng. 18, 73-85
Pike, E. B., Carrington, E. G. and Ashburner, P. A. (1972). An evaluation of procedures for enumerating bacteria in activated sludge. J. Appl. Microbiol., 35(2), 309-321.
Prabakar, J., John, J., Arumugham, I. M., Kumar, R. P. and Srisakthi, D. (2018). Comparative evaluation of retention, cariostatic effect and discoloration of conventional and hydrophilic sealants-A single blinded randomized split mouth clinical trial. Contemp. Clin. Dent., 9(Suppl 2), S233.
Punzi, M., Anbalagan, A., Börner, R. A., Svensson, B. M., Jonstrup, M., & Mattiasson, B. (2015). Degradation of a textile azo dye using biological treatment followed by photo-Fenton oxidation: evaluation of toxicity and microbial community structure. Chem. Eng. J., 270, 290-299.
Ranga,P., Saharan, B.S. and Sharma, D. (2015). Bacterial degradation and decolorization of textile dyes by newly isolated Lysobacter sp. Afr. J. Microbiol. Res. *9*(14), 979-987.A
Sghaier, I., Guembri, M., Chouchane, H., Mosbah, A., Ouzari, H. I., Jaouani, A. and Neifar, M. (2019). Recent advances in textile wastewater treatment using microbial consortia. J. Text. Eng. Fash. Technol., 5(3), 134-146.
Shade, A., Peter, H., Allison, S. D., Baho, D., Berga, M., Bürgmann, H. and Handelsman, J. (2012). Fundamentals of microbial community resistance and resilience. Front. microbiol,, 3, 417.
Shaibur MR, Tanzia FKS, Nishi S, Nahar N, Parvin S, Adjadeh TA (2022): Removal of Cr (VI) and Cu (II) from tannery effluent with water hyacinth and arum shoot powders: A study from Jashore, Bangladesh. J Hazard. Mater. Advance. 7(2022). doi: https://doi.org/10.1016/j.hazadv.2022.100102.
Simion, V. A., Cretescu, I., Lutic, D., Luca, C., and Poulios, I. (2015). Enhancing the Fenton process by UV light applied in textile wastewater treatment. Environ Eng Manag J, 14(3).
Sneath, P.H. A., N. S. Mair, M. E.Sharpe, and J. G. Holt. 1986. Bergey's manual of systematic bacteriology. Vol. 2. The Williams & Wilkins Co., Baltimore.
Snaidr, J., Amann, R., Huber, I., Ludwig, W., and Schleifer, K. H. (1997). Phylogenetic analysis and in situ identification of bacteria in activated sludge. Appl. Environ. Microbiol., 63(7), 2884-2896.
Sozen, S., Olmez-Hanci, T., Hooshmand, M., and Orhon, D. (2020). Fenton oxidation for effective removal of color and organic matter from denim cotton wastewater without biological treatment. Environ. Chem. Lett., 18(1), 207-213.
Su, C. C., Pukdee-Asa, M., Ratanatamskul, C., and Lu, M. C. (2011). Effect of operating parameters on the decolorization and oxidation of textile wastewater by the fluidized-bed Fenton process. Sep. Purif. Technol., *83*, 100-105.
Suryawan, I., Siregar, M. J., Prajati, G., and Afifah, A. S. (2019). Integrated ozone and anoxic-aerobic activated sludge reactor for endek (Balinese textile) wastewater treatment. Journal of Ecological Engineering, 20(7).
Tasneem, A., Sarker, P., Akter, S., Mouna, S. S. P., Rahaman, M. S., Mohinuzzaman, M., and Kabir, M. M. (2021). Textile wastewater treatment by combination of chemical and phytoremediation processes. Pollution, 7(1), 43-54.
Tüfekci, N., Sivri, N., and Toroz, İ. (2007). Pollutants of textile industry wastewater and assessment of its discharge limits by water quality standards. Turk. J. Fish. Aquat. Sci, *7*(2), 97-103.
Wagner, M., Amann, R., Kämpfer, P., Assmus, B., Hartmann, A., Hutzler, P., and Schleifer, K. H. (1994). Identification and in situ detection of gram-negative filamentous bacteria in activated sludge. Syst. Appl. Microbiol., 17(3), 405-417.
Wang, X., Wen, X., Criddle, C., Wells, G., Zhang, J., and Zhao, Y. (2010). Community analysis of ammonia-oxidizing bacteria in activated sludge of eight wastewater treatment systems. J. Environ. Sci., 22(4), 627-634.
Wang, Y., Wang, H., Wang, X., Xiao, Y., Zhou, Y., Su, X., and Sun, F. (2020). Resuscitation, isolation and

immobilization of bacterial species for efficient textile wastewater treatment: a critical review and update. Sci. Total Environ., 730, 139034.
Watari, T., Hata, Y., Hirakata, Y., Nguyet, P. N., Nguyen, T. H., Maki, S. and Yamaguch, T. (2021). Performance evaluation of down-flow hanging sponge reactor for direct treatment of actual textile wastewater; Effect of effluent recirculation to performance and microbial community. J. Water Process. Eng., 39, 101724.
Yang, X., Xue, Y., and Wang, W. (2009). Mechanism, kinetics and application studies on enhanced activated sludge by interior microelectrolysis. Bioresour. Technol, 100(2), 649-653.
Yang, H. Y., Jia, R. B., Chen, B., and Li, L. (2014). Degradation of recalcitrant aliphatic and aromatic hydrocarbons by a dioxin-degrader Rhodococcus sp. strain p52. Environ. Sci. Pollu. Res., 21(18), 11086-11093.
Yang, Q., Wang, J., Han, X., Xu, Y., Liu, D., Hao, H. and Qi, S. (2014). Analysis of the bacterial community in a full-scale printing and dyeing wastewater treatment system based on T-RFLP and 454 pyrosequencing. Biotechnol. Bioprocess Eng., 19(1), 191-200.