TREATMENT OF TEXTILE WASTEWATER BY PHOTO FENTON PROCESS WITH UV LIGHT AND SOLAR RADIATION

Jyoti Katara[1], Prof. (Mrs) Reshma L. Patel[2]
[1]Final year M. Tech. Environmental Engineering,
[2]Associate Professor, Civil Engineering Department,
[1,2]B. V. M. Engineering College, Vallabh Vidyanagar, Gujarat, India

Abstract: This study is aimed at making photo Fenton mode of treatment more approachable to Textile Industries enabling them to reap benefits out of this improvement technology. The research was carried on the untreated waste effluent of textile industry for the removal of COD. About 70-80% COD reduction was obtained without any pre-treatment of the waste effluent at pH 3. The Experimental results shows that maximum COD removal was obtained at 6:1 of COD:H_2O_2 concentration ratio with both the light sources. The different molar concentrations of H_2O_2:Fe^{+2} were considered among which, the efficiency was obtained at 15:1 and 20:1. However, the resultant reaction time for the procedure states that the photo-Fenton treatment can be a useful method for the photo degradation of the organic compounds.

Keywords: Advanced Oxidation Processes, Photo Fenton, Ultraviolet, Solar Radiation, Textile Wastewater

I. INTRODUCTION

Textile mills are the major consumers of water in the world. They utilize an average water of 200m^3/ton of finished goods out of which 90% is appeared as wastewater. These industries are one of the largest groups of industries which causes extreme pollution in terms of quality as well as quantity. Generated wastewaters comprise different effluents coming from different manufacturing unitary operations such as sizing, desizing, scouring, bleaching, dyeing, soaping and softening.
These complex operations, subjected to frequent changes as a result of shifting consumer’s preference, are the cause of the variable volume and the wide diversity of chemical products found in these wastewaters. Though their characteristics depend on the specific operations performed, they commonly present suspended solids, high temperature, unstable pH, high chemical oxygen demand (COD), low biological oxygen demand (BOD) and high colorization.

Textile processes produce multi-component wastewater which is difficult to treat. This wastewater can cause serious environmental problems due to their high color, large amount of suspended solids and high chemical oxygen demand.This wastewater cannot be readily degraded by conventional biological processes (e.g. activated sludge process) because the structure of most commercial dye compounds are generally complex and many dyes are non-biodegradable, this is due to their chemical nature and molecular size.
At present, several methods have been developed to treat textile wastewater but they cannot be used individually because this wastewater has high salinity, color and non-biodegradable organics. The table 1 shows possible treatment of Textile Wastewater and their advantages and disadvantages.

Table 1. Possible treatment of Textile wastewater and their Advantages and Disadvantages

Processes	Advantages	Disadvantages
Biodegradation	Rates of elimination by oxidizable substances about 90%	Low degradability of dyes.
Coagulation-Flocculation	Elimination of insoluble dyes	Production of sludge blocking filter
Adsorption on activated carbon	Suspended solids and organic substances well reduced	Cost of activated carbon
Ozone Treatment	Good decolorization	Less reduction in COD
Electrochemical processes	Capacity of adaptation to different volume and pollution loads	Iron hydroxide sludge

The present study was carried out using a real textile wastewater without any pretreatment from a textile industry located at Vapi, Gujarat, India. The raw wastewater from the unit has COD in the range of 8000-12000 mg/L which is brought under limits by conventional method of treatment. The industry has two different streams of treatment for low COD and high COD wastewater. The treated low COD water is reused back in industry in floor washing and other uses. The extreme diversity of raw materials and production schemes employed by this industry poses problems in assessing effluent characteristics. It is a project based industry which uses multiple dyes and chemicals as per the project allotted. Therefore it is difficult to define pollution control technologies.

Oxidation with Fenton's reagent is an effective method for lowering the concentration of dissolved dyes and organic matters in textile effluent wastewater, this condition results in reduction of color and COD of textile wastewater. Thus the aim of the study was to explore the Photo Fenton to improve the biodegradability of the waste. The two different photo sources were taken as study parameters to find the efficient mode of treatment.

During the initial experiments it was found that the model pollutant was less degradable at COD:H_2O_2=2:1 and 4:1. Different pH values were also used to acidify the sample, but after several experiments it was found that the optimum pH to perform the experiments was at 3. Hence it was then used throughout the entire process.

II. MATERIALS AND METHOD

Following are the materials and methods used in the present study. It also includes the characterization of the model pollutant.

2.1 The Textile wastewater

The wastewater was obtained from the collection tank of Textile Industry located at Vapi, Gujarat, India. The company is a project based firm, which uses the raw cloth and does the furnishing and printing work of it. There are no fixed chemicals or dyes by the industry as it is based on the type of the work allotted to them. The composite COD of raw wastewater is about 8000–12000 mg/L. At present they are using conventional treatment method for the treatment of wastewater. The general characteristics of the wastewater are mentioned in Table 2.

Table 2. General Characteristics of Wastewater used in current study.

SR. NO.	PARAMETERS	UNIT	VALUE
1	pH	--	12.43
2	Suspended Solids	mg/L	391
3	TDS	mg/L	10240
4	COD	mg/L	9000
5	BOD_5	mg/L	963

(Source: Environmental Engineering Laboratory, BVM Engineering College)

2.2 Experimental methods

Following are the experimental methods and mode of treatment used in the present study.

2.2.1 Photo Fenton treatment

The model pollutant at pH 3.0, without removal of precipitates, was used for Fenton's treatment.COD: H_2O_2 ratio of 2:1, 4:1 and 6:1 were considered. H_2O_2: Fe^{+2} molar ratios of 15:1, 20:1, 25:1 and 30:1 were used in both the procedures. The procedure starts with addition of $FeSO_4.7H_2O$ crystals and then slowly adding H_2O_2 drop wise with stirring. The reaction mixture is then exposed to the light source (here UV light and Solar radiations), where the actual degradation of organic pollutants starts. The reaction was allowed to run for 180minutes. The samples were collected at different time intervals to study the change in the removal efficiency. The time at which samples collected was 90, 120,150 and 180 minutes. After the completion of reaction, pH was adjusted to 9 with NaOH followed by addition of acidic media to adjust pH to 7.0.

2.2.1.1 Photo Fenton Treatment with UV light

The process usually involves the use of low-pressure UV lamps with a principal wavelength of 254nm. Since the maximum absorption of ozone molecules is at 253.7 nm, the light source commonly used is a medium-pressure mercury lamp wrapped in a quartz sleeve that can generate the UV light at wavelength of 200-280.The model pollutant with Fenton's reagent is filled in ultraviolet batch reactor model comprising of two Mercury tubes of 14watts.This experiment was carried out in a reactor of capacity 1000ml as shown in the figure 1. 250 ml volume of the sample was used. The experimental setup was placed on the magnetic stirrer at constant stirring speed and temperature at 25°C.

Following is the batch reactor used for the treatment of wastewater with UV light.

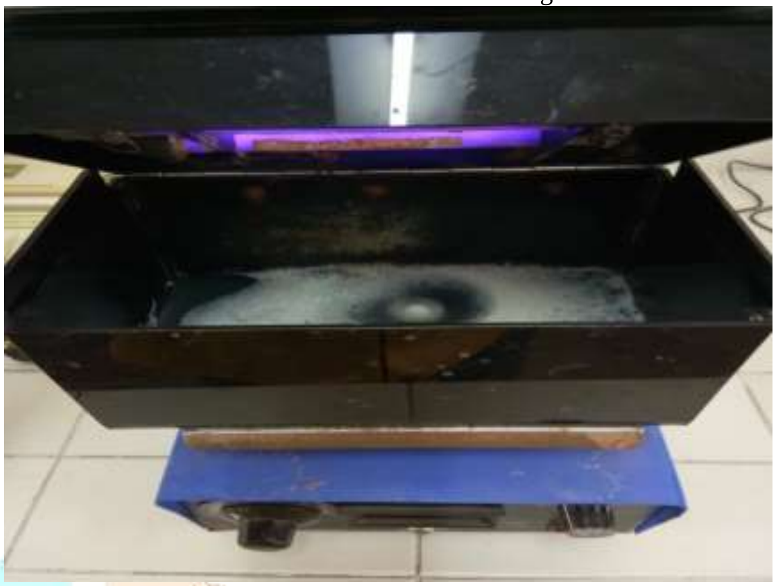

Figure 1: UV Photo Reactor

2.2.1.1 Photo Fenton Treatment Solar Radiation

This experiment was carried out in a glass beaker of capacity 500ml. 250 mL volume of the sample is used. The experimental setup is placed under the sunlight as per the arrangement shown in the Figure 2. The intensity of sunlight was increased by collecting it at a single point using magnifying lens. Additional Ice jacket was created around the reactor to maintain the temperature and ice was added at regular intervals to maintain the temperature at 25°C. The temperature was checked at regular interval of time. The stirring speed was also kept same as that of the Photo Fenton Process with UV Light

Following figure shows the arrangement made for the treatment of wastewater with solar radiations.

Figure 2: Solar Photo Fenton Reactor

2.5 Analytical methods

COD (Closed reflux titrimetric method) were determined as procedure given in Standard Methods (APHA). The secondary parameters like BOD_5, TDS, SS and Chlorides were also determined. The standard method of APHA was taken as reference.

III. RESULTS AND DISCUSSION

This section includes the results drawn from the experimental work

3.1 Photo Fenton's treatment with UV Light & improvement in biodegradability

Table 3 shows change in COD value after Photo Fenton's treatment with UV light. The table includes the data of the maximum COD removal at particular concentration and molar ratio and mentioning the reaction time at which maximum COD removal was obtained. It can be seen from Table 3 that maximum COD reduction obtained in this case is 73%. After achieving Maximum COD reduction (%), the scavenging process of Fe^{+2} takes place in the later stage where COD increases gradually. It is relevant from the results that maximum COD reduction is obtained at COD:H_2O_2= 6:1. Comparative representation of efficiency of COD removal at COD:H_2O_2=6:1 and H_2O_2/Fe^{+2} molar concentrations at 15:1, 20:1,25:1 and 30:1 with UV light is shown in Figure 3.

Table 3: Maximum COD removal at COD/H_2O_2 concentration ratio and H_2O_2:Fe^{+2}molar ratio with respective reaction time. (With UV Light)

Sr No	COD/H_2O_2 concentration ratio	H_2O_2:Fe^{+2}	Maximum COD Removal with UV Light (%)	Reaction time at which Maximum Removal is achieved. (minutes)
1	2:1	15:1	5	90
2		20:1	27	120
3		25:1	54	120
4		30:1	64	90
5	4:1	20:1	39	120
6		25:1	50	90
7		30:1	36	150
8	6:1	15:1	36	120
9		**20:1**	**73**	**90**
10		25:1	23	90
11		30:1	30	90

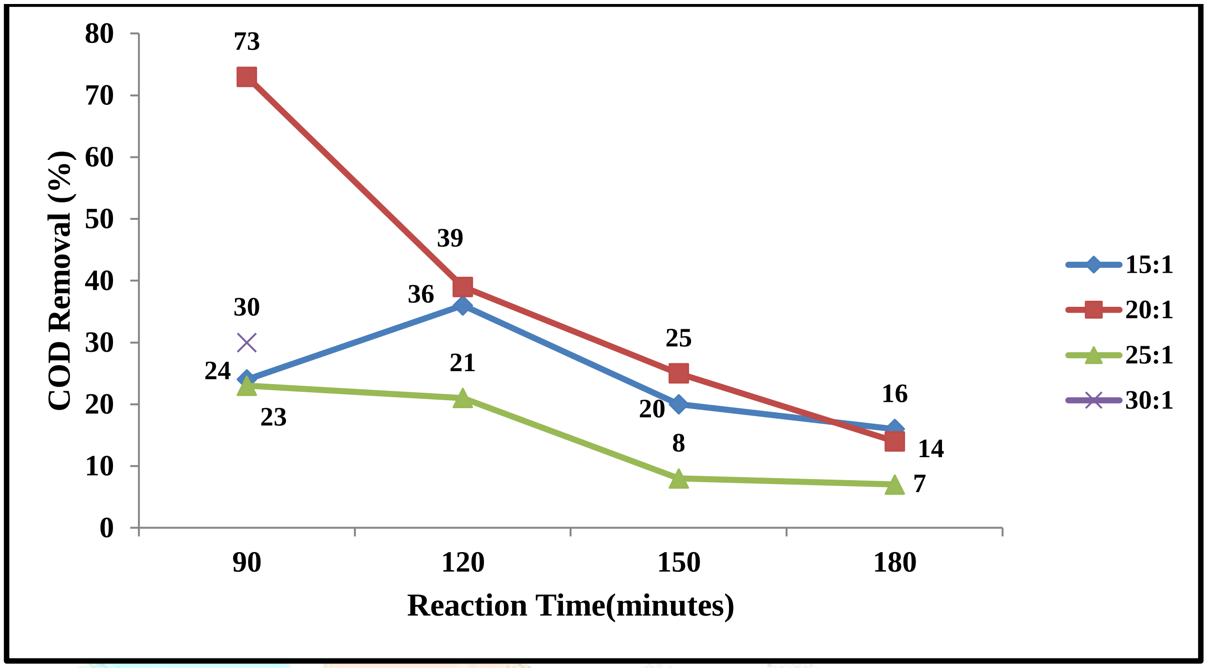

Figure 3: Efficiency of COD Removal at COD:H_2O_2=6:1 at pH=3, H_2O_2:Fe^{+2} Molar ratio 20:1,25:1 and 30:1with UV Light

3.2 Photo Fenton's treatment with Solar radiations & improvement in biodegradability

Table 4 shows change in COD value after Photo Fenton's treatment with Solar Radiation. The table includes the data of the maximum COD removal at particular concentration and molar ratio and mentioning the reaction time at which maximum COD removal was obtained. The results from Table 4 show that COD reduction obtained in this case is 79%. After achieving Maximum COD reduction (%), the scavenging process of Fe^{+2} takes place in the later stage where COD increases gradually. The results depict that maximum COD reduction is obtained at COD:H_2O_2= 6:1.Comparative representation of efficiency of COD removal at COD:H_2O_2=6:1 and H_2O_2/Fe^{+2} molar concentrations at 15:1, 20:1,25:1 and 30:1 with Solar Radiations are shown in the Figure 4.

Table 4: Maximum COD removal at COD/H_2O_2 concentration ratio and H_2O_2:Fe^{+2}molar ratio with respective reaction time(With Solar Radiation)

Sr No	COD/H_2O_2 concentration ratio	H_2O_2:Fe^{+2}	Maximum COD Removal with UV Light (%)	Reaction time at which Maximum Removal is achieved. (minutes)
1	2:1	15:1	8	120
2		20:1	20	150
3		25:1	23	120
4		30:1	55	120
5	4:1	20:1	40	150
6		25:1	41	150
7		30:1	30	150
8	6:1	15:1	79	150
9		**20:1**	30	90
10		25:1	42	150
11		30:1	29	120

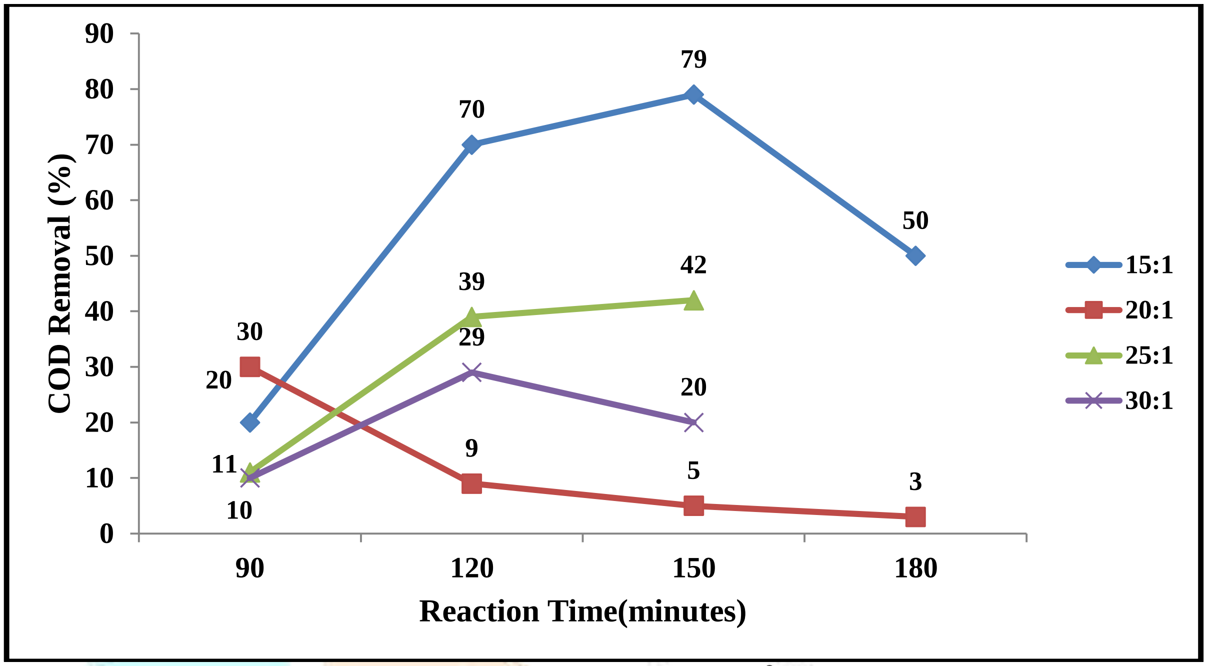

Figure 4: Efficiency of COD Removal at COD:H_2O_2=6:1 at pH=3, H_2O_2:Fe^{+2} Molar ratio 15:1, 20:1,25:1 and 30:1with Solar Radiation

3.3 Comparison of efficiency of COD Removal using UV Light and Solar Radiations

Table 5 shows the data of maximum COD removal with UV Light and Solar radiations at respective reaction time. Maximum Reduction was obtained at COD:H_2O_2=6:1 in both the cases so the data of different H_2O_2:Fe^{+2} molar concentration are mentioned in the table 5. The result indicates that maximum result is achieved in less time in case of UV Light than that of Solar Radiation. The average reaction time for maximum removal of COD is 90 minutes in Photo Fenton process with UV Light whereas 150 minutes in Photo Fenton process with Solar radiation. Efficiency of COD Removal with UV Light and Solar Radiation at respective H_2O_2:Fe^{+2} molar concentrations are shown in Figure 5.

Table 5: Comparison of efficiency of COD Removal using UV Light and Solar Radiations with reaction time.

Sr No	H_2O_2:Fe^{+2}	Maximum COD Removal with UV Light (%)	Reaction time at which Maximum Removal is achieved. (minutes)	Maximum COD Removal with Solar radiation (%)	Reaction time at which Maximum Removal is achieved. (minutes)
1	15:1	36	120	79	150
2	20:1	73	90	30	90
3	25:1	23	90	42	150
4	30:1	30	90	29	120

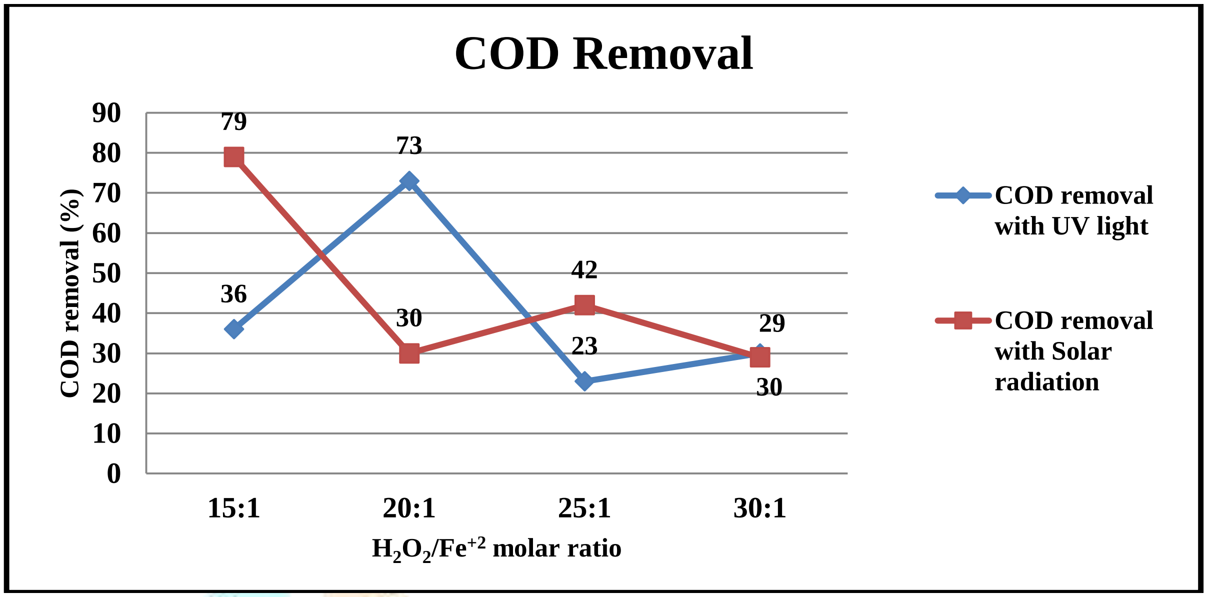

Figure 5: Efficiency of COD Removal at COD:H_2O_2=6:1 at pH=3, with UV Light and Solar Radiation

IV. CONCLUSION

The textile effluent water is playing a major role in polluting the water stream. Hence a need of proper treatment method is important to reduce the pollution level. The characteristics of the wastewater depicted that its bio-degradability was 0.1 which makes it suitable for Advanced Oxidation process. Hence treatment of textile wastewater was done with Advanced Oxidation process due to its non bio-degradable nature. Photo Fenton treatment was given to the wastewater with or without any pre-treatment. H_2O_2 is differently connected in light of the fact that it has no vaporous release or chemical residues as found with other chemical oxidants.
The COD:H_2O_2 molar ratio used in the study were 2:1, 4:1 and 6:1 from which maximum removal was obtained at 6:1.The Photo Fenton's treatment with both the light sources can achieve up to 70% removal of COD at H_2O_2:Fe^{+2} molar concentration of 20:1 (for UV Light) and 15:1(for Solar Radiation).The Photo Fenton process with Solar Radiation can be used to reap out the maximum benefits. This method can prove as a low cost high efficiency treatment method.

V. ACKNOWLEDGMENT

The Author thankfully acknowledges to Prof. (Dr.) Indrajit Patel, Principal, B.V.M. Engineering College, VallabhVidyanagar, Gujarat, India for their motivational support to carry out this research.

REFERENCES

[1] Advanced Oxidation Processes (AOP) For Water and Wastewater Treatment Contents', *Ultrasound*

[2] Andreozzi, R, 'Advanced Oxidation Processes (AOP) for Water Purification and Recovery', *Catalysis Today*, 53 (1999), 51–59 <https://doi.org/10.1016/S0920-5861(99)00102-9>

[3] Barbusiński, K., 'The Modified Fenton Process for Decolorization of Dye Wastewater', *Polish Journal of Environmental Studies*, 14 (2005), 281–85 <https://doi.org/10.1021/ar50088a003>

[4] Brillas, Enric, 'A Review on the Degradation of Organic Pollutants in Waters by UV Photoelectro-Fenton and Solar Photoelectro-Fenton', *Journal of the Brazilian Chemical Society*, 25 (2014), 393–417 <https://doi.org/10.5935/0103-5053.20130257>

[5] Chun, Hu, Wang Yizhong, and Tang Hongxiao, 'Destruction of Phenol Aqueous Solution by Photocatalysis or Direct Photolysis', *Chemosphere*, 41 (2000), 1205–9 <https://doi.org/10.1016/S0045-6535(99)00539-1>

[6] Dehghani, Mansooreh, Esmaeel Shahsavani, Mahdi Farzadkia, and Mohammad Samaei, 'Optimizing Photo-Fenton like Process for the Removal of Diesel Fuel from the Aqueous Phase', *Journal of Environmental Health Science and Engineering*, 12 (2014), 87 <https://doi.org/10.1186/2052-336X-12-87>

[7] Ebrahiem, Ebrahiem E., Mohammednoor N. Al-Maghrabi, and Ahmed R. Mobarki, 'Removal of Organic Pollutants from Industrial Wastewater by Applying Photo-Fenton Oxidation Technology', *Arabian Journal of Chemistry*, 10 (2017), S1674–79 <https://doi.org/10.1016/j.arabjc.2013.06.012>

[8] Esplugas, Santiago, Jaime Gimenez, Sandra Contreras, Esther Pascual, and Miguel Rodriguez, 'Comparison of Different Advanced Oxidation Processes for Phenol Degradation', *Water Research*, 36 (2002), 1034–42 <https://doi.org/10.1016/S0043-1354(01)00301-3>

[9] Ganesan, R, and K Thanasekaran, 'Decolourisation of Textile Dyeing Wastewater by Modified Solar Photo-Fenton Oxidation', *Int. J. Environ. Sci.*, 1 (2011), 1168–76 <https://doi.org/10.6088/ijes.00106020011>

[10] Hassaan, Mohamed A, and Ahmed El Nemr, 'Advanced Oxidation Processes for Textile Wastewater Treatment', *International Journal of Photochemistry and Photobiology*, 2 (2017), 85–93 <https://doi.org/10.11648/j.ijpp.20170203.13>

[11] Kang, Shyh Fang, Chih Hsiang Liao, and Shei T. Po, 'Decolorization of Textile Wastewater by Photo-Fenton Oxidation Technology', *Chemosphere*, 41 (2000), 1287–94 <https://doi.org/10.1016/S0045-6535(99)00524-X>

[12] Kehinde, FagbenroOluwakemi, and Hamidi Abdul Aziz, 'Textile Waste Water and the Advanced Oxidative Treatment Process, an Overview', *International Journal of Innovative Research in Science, Engineering and Technology*, 3 (2014), 15310–17 <https://doi.org/10.15680/IJIRSET.2014.0308034>

[13] Kos, Lech, Karina Michalska, and Jan Perkowski, 'Textile Wastewater Treatment by the Fenton Method', *Fibres and Textiles in Eastern Europe*, 81 (2010), 105–9

[14] Lodha, Bharat, and Sanjeev Chaudhari, 'Optimization of Fenton-Biological Treatment Scheme for the Treatment of Aqueous Dye Solutions', *Journal of Hazardous Materials*, 148 (2007), 459–66 <https://doi.org/10.1016/j.jhazmat.2007.02.061>

[15] Matavos-aramyan, Sina, and Mohsen Moussavi, 'Advances in Fenton and Fenton Based Oxidation Processes for Industrial Effluent Contaminants Control-A Review', *International Journal of Environmental Science & Natural Resources*, 2 (2017), 1–18 <https://doi.org/10.19080/IJESNR.2017.02.555594>

[16] Mazille, F., T. Schoettl, A. Lopez, and C. Pulgarin, 'Physico-Chemical Properties and Photo-Reactivity Relationship for Para-Substituted Phenols in Photo-Assisted Fenton System', *Journal of Photochemistry and Photobiology A: Chemistry*, 210 (2010), 193–99 <https://doi.org/10.1016/j.jphotochem.2009.12.015>

[17] Mehta, Mehali, and Swati Parekh, 'Applicability of Fenton Process for Treatment of Industrial Effluents : A Review', *International Journal of Engineering Research and Application*, 4 (2014), 26–29

[18] Meric, Sureyya, Giusy Lofrano, and Vincenzo Belgiorno, 'Treatment of Reactive Dyes and Textile Finishing Wastewater Using Fenton's Oxidation for Reuse', *International Journal of Environment and Pollution*, 23 (2005), 248–58

[19] Pérez, Montserrat, Francesc Torrades, Xavier Domènech, and José Peral, 'Fenton and Photo-Fenton Oxidation of Textile Effluents', *Water Research*, 36 (2002), 2703–10 <https://doi.org/10.1016/S0043-1354(01)00506-1>

[20] Prajisha, V P, K J Sosamony, and P A Solomon, 'Treatment Of Textile Wastewater Using Solar Photofenton Process', 6 (2016), 39–43

[21] Punzi, Marisa, *Treatment of Textile Wastewater by Combining Biological Processes and Advanced Oxidation*, 2015

[22] Rabelo, M. D., C. R. Bellato, C. M. Silva, R. B. Ruy, C. A. B. da Silva, and W. G. Nunes, ‘Application of Photo-Fenton Process for the Treatment of Kraft Pulp Mill Effluent’, *Advances in Chemical Engineering and Science*, 4 (2014), 483–90 <https://doi.org/10.4236/aces.2014.44050>

[23] Ramachandran, Ganesan, and Thanasekaran Kumarasamy, ‘Degradation of Textile Dyeing Wastewater by a Modified Solar Photo-Fenton Process Using Steel Scrap/H2O2’, *Clean - Soil, Air, Water*, 41 (2013), 267–74 <https://doi.org/10.1002/clen.201100462>

[24] Review, A, ‘Advanced Oxidation Processes for Treatment of Textile and Dye Wastewater : A Review’, 4 (2011), 271–75

[25] Rodrigues, Carmen S D, Luis M. Madeira, and Rui A R Boaventura, ‘Optimization and Economic Analysis of Textile Wastewater Treatment by Photo-Fenton Process under Artificial and Simulated Solar Radiation’, *Industrial and Engineering Chemistry Research*, 52 (2013), 13313–24 <https://doi.org/10.1021/ie401301h>

[26] Rodríguez, Miguel, ‘Fenton and UV-Vis Based Advanced Oxidation Processes in Wastewater Treatment: Degradation, Mineralization and Biodegradability Enhancement’, *Department D’Enginyeria Quimica I Metal·lurgia*, 2003, 296 <http://diposit.ub.edu/dspace/handle/2445/35398>

[27] Sahunin, Chantanapha, Jittima Kaewboran, and Mall Hunsom, ‘Treatment of Textile Dyeing Wastewater by Photo Oxidation Using UV/H 2O2/Fe2+ Reagents’, *ScienceAsia*, 32 (2006), 181–86 <https://doi.org/10.2306/scienceasia1513-1874.2006.32.181>

[28] Starling, M C, L A S Castro, R B P Marcelino, C C Amorim, Universidade Federal, and De Minas Gerais, ‘Textile Wastewater Treatment Ferrioxalate Reuse After Photo- Using Fe (Ii) and’, 1–8

[29] Tony, Maha a., and Zeinab Bedri, ‘Experimental Design of Photo-Fenton Reactions for the Treatment of Car Wash Wastewater Effluents by Response Surface Methodological Analysis’, *Advances in Environmental Chemistry*, 2014 (2014), 1–8 <https://doi.org/10.1155/2014/958134>

AUTHORS’ BIOGRAPHY

Jyoti Katara received her Bachelor of Engineering degree in Environment Engineering from the Government Engineering Collage, Gujarat Technological University in 2015. At present, she is final year student of Master's Degree in Environmental Engineering from Birla Vishvakarma Mahavidyalaya, Gujarat Technological University.

Prof. Reshma L. Patel received her Bachelor of Engineering degree in Civil Engineering from the Birla Vishvakarma Mahavidyalaya, Sardar Patel University in 1991. In 1993 she received her Master's Degree in Civil (Environmental) Engineering from Birla Vishvakarma Mahavidyalaya, Sardar Patel University. She joined Birla Vishvakarma Mahavidyalaya Engineering College as a faculty in 1994, where she is Associate Professor of Civil Engineering Department with a total experience of 22 Years in the field of Research, Designing and education. She is guiding M.E. (Environmental Engineering) Thesis work in the field of Civil/ Environmental Engineering. She has published many papers in National/ International Conferences and International Journals.