DEGRADATION OF A TEXTILE REACTIVE AZO DYE BY A COUPLED CHEMICAL-BIOLOGICAL PROCESS– COMPUTATIONAL ANALYSIS

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Abstract

Water pollution poses serious threats to both the environment and the organisms that depend on their environment for survival. Due to the toxicity from dyes in textile wastewater, there is a dire need for the development of innovative and efficient treatment technologies. In this study treatability studies, using a combined treatment method of combined biological and chemical processes. Advanced Oxidation Processes (AOPs) were studied extensively for the treatment of reactive azo dye. Moreover, to check the practical applicability of AOPs, they were optimized for treatment of textile industry wastewater.

1.0. INTRODUCTION

Photo-Fenton and photocatalytic processes were used as AOPs. Fenton and photo-Fenton processes provide an oxidation that is capable of remediating wide range of organic pollutants. One drawback of these processes is that they require acidic pH to prevent precipitation of iron. But in case of photo-Fenton process this is compensated by the regeneration of ferrous ions from ferric ions because of sunlight. That's why, this process showed more efficiency for dye degradation as compared to Fenton process. The operating parameters such as pH and initial concentrations of oxidants (H_2O_2, Fe^{2+} and TiO_2) were optimized for 2 h treatment process.At the optimal conditions, pH =2.9, H_2O_2 = 952.32 mg/L and Fe^{2+} = 358.66 mg/L the % degradation of dye in Fenton process was 68.68%. On the other hand, % degradation of dye obtainedusing photo Fenton process at the optimal conditions, pH=2.95, H_2O_2 = 1282.22 mg/L, Fe^{2+} = 371.82 mg/L was 75.9%.

Photocatalytic process uses TiO_2 as catalyst to generate OH* radicals from air. In this study, optimized conditions are derived for degradation of reactive azo dye and, significant results were obtained. At TiO_2 = 169.2 mg L^{-1} and pH=5.48, 73.70% degradation was reported in the duration of 2 h.

Using sludge from Sewage treatment plant and optimized conditions of different chemical processes, the textile wastewater (2 L) was treated in a combined biological-chemical treatment process. The biological treatment was done for 24 h and chemical treatment was done for 2 h.Maximum COD removal of 93 % for textile wastewater was reported in biochemical treatment in which photocatalytic treatment was used. For other processes, the treatment efficiency was also significant such as: For Fenton treatment= 77 % and for Photofenton treatment = 88 %. Therefore, a combined treatment process using biological and chemical process can prove to be a promising technology for the treatment of textile wastewater.

2.0. LITERATURE REVIEW

Water is one of the basic necessities of the life and therefore humanity should be more concerned about its depletion as compared to that of oil or money. Water level in all its sources whether it is ground or surface is depleting at high rate and it is projected that by the year 2030 water will be major political and social issue among the developed countries. Therefore, priority should be given to the storage, efficient usage and recycling of the water. Industries of many developing countries generate a lot of waste water which is disposed into the fields and remains wasted. Therefore, efficient treatment technologies need to be developed to treat the waste water and reuse it.

Global usage of fresh water in different sectors such: industries, agricultural, domestic etc., introduce a lot of toxic chemicals in the water. These toxic chemicals are not easily degradable and they stay in the water system for a long time. Disposal of untreated water in the water bodies and lands affect the living beings as well. These toxic chemicals are ingested by fishes and also absorbed by plants. In this way, these toxic chemicals become part of our food chain and living beings also come in contact with these toxic chemicals. Therefore, treatment of wastewater has become a global concern.

3.0. OBJECTIVES

1. Evaluation of AOPs for the treatment of the azo dye contaminated water

2. Evaluation of the bio-compatibilty (biodegradability) of the photochemically pretreated solution.

3. Proposition of a general strategy to develop combined photochemical and biological system for the treatment of azo contaminated water and textile industry waste water.

4. Evaluation of the performance of coupled chemical-biological treatment system at lab scale for treatment of azo contaminated water and textile industry waste water.

5. Evaluation of the effects of UV in enhancement of treatment of dye contaminated water.

4.0.STATISTICAL ANALYSIS

For Photofenton treatment

$X_3 = 76 + 1.25\,Y_1 + 0.50Y_2 - 4.75Y_3 - 1.5Y_1Y_2 + 0.00Y_1Y_3 + 1.50Y_2Y_3 - 6\,Y_1^2 - 3.5Y_2^2 - 5Y_3^2$ $X_4 = 60 - 2.81Y_1 - 0.94Y_2 + 12.50Y_3 + 1.87\,Y_1Y_2 + 1.25Y_1Y_3 - 3.75Y_2Y_3 + 16.56Y_1^2 + 9.06Y_2^2 + 12.19Y_3^2$

Where, $X_{1,3}$ = % degradation; $X_{2,4}$ = COD

Y_1 = $FeSO_4.H_2O$ concentration; Y_2 = H_2O_2 concentration; Y_3 = pH

Table 4.1: Experimental and predicted responses from the Box-Behnken designed experiments for Photofenton treatment

Variables										
	pH		H_2O_2		$FeSO_4,7H_2O$		Experimental		Predicted	
S.No.	Coded values	Actual values	Coded values	Actual values	Coded values	Actual values	Responses		Responses	
				mg/L		mg/L	X_3	X_4	X_3	X_4
1	0	4	0	500	0	600	76	60	61.12	82.75
2	0	4	-1	1000	+1	400	67	87.5	53.62	70.75
3	+1	2	+1	1000	0	600	60	105	52.38	67.25

4	0	4	0	1000	0	400	76	60	41.88	54.25
5	0	6	0	1000	0	600	76	60	55.87	73.5
6	-1	6	0	1500	+1	400	70	75	49.37	60.5
7	0	4	+1	1000	-1	400	69	80	51.63	64.5
8	0	2	+1	1000	+1	200	70	75	40.13	52.5
9	-1	4	-1	500	0	200	70	75	55.99	71.76
10	+1	4	0	1500	+1	200	63	92.5	43.75	56.26
11	+1	6	0	500	-1	400	62	95	47.25	63.76
12	0	4	0	1500	0	600	76	60	39.01	47.26
13	-1	2	0	1500	-1	400	75	62.5	61	83
14	0	4	-1	1000	-1	400	60	100	61	83
15	+1	6	-1	1000	0	200	61	97.5	61	83
16	0	4	0	1000	0	400	76	60	61	83
17	-1	2	+1	500	0	400	69	77.5	61	83

Table 4.2: Maximum values of responses at optimum condition in photo Fenton treatment

S.No.	Control Parameters	Symbolic representation	Maximum values for Responses
			% degradation (X_3 = 75.99)
1	$FeSO_4.H_2O$	Y_1	371.82
2	H_2O_2	Y_2	1282.22
3	pH	Y_3	2.95

5.0. RESULTS OF OPTIMIZATION

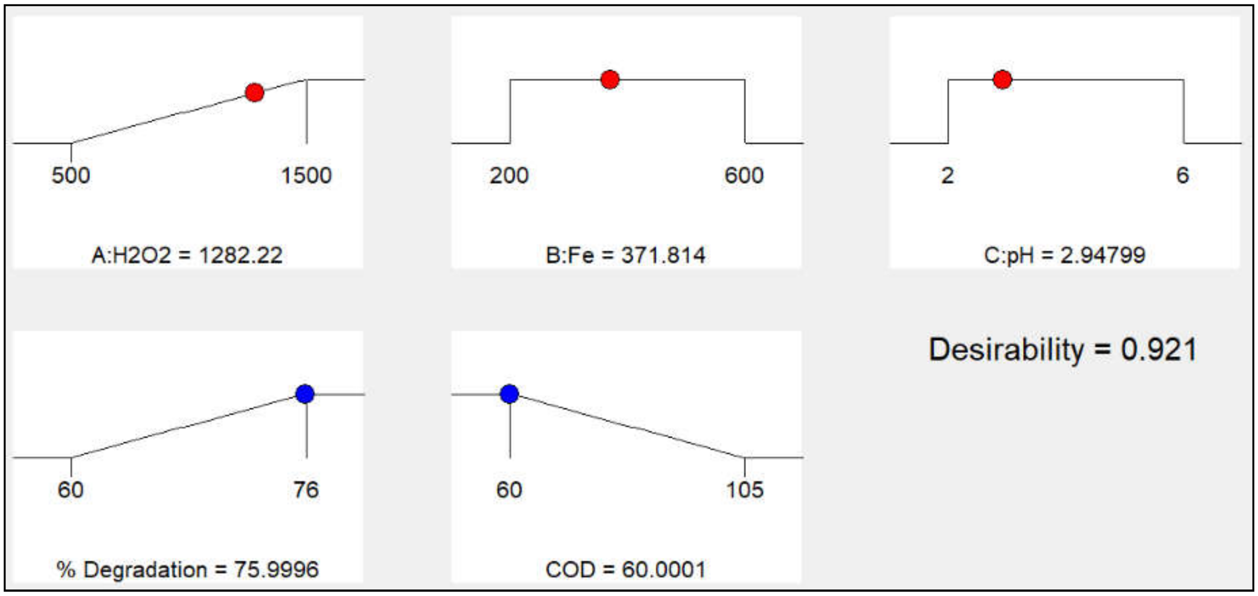

Fig 5.1: Results of optimization for Photofenton treatment

5.1. Effects of H_2O_2 concentration in Fenton and Photofenton treatment

Figure 5.1 (a, b, c, d) and 4.8 (a, b, c, d)shows the % degradation and COD removal of reactive azo dye solution with increasing concentrations of H_2O_2.

From the results, it can be interpreted that up to certain concentration of H_2O_2, the COD removal and % degradation increased with increase in concentration of H_2O_2. Beyond this concentration of H_2O_2 increase in COD degradation is only marginal, in case of Fenton process. In case of photo Fenton process, the COD degradation increases with the increase in H_2O_2 concentration. Therefore, 952 mg/L of H_2O_2 concentration was chosen as the optimal concentration for Fenton process whereas the optimum concentration in case of photo Fenton processes was 1282 mg/L. At these optimal concentrations of H_2O_2, about 75.99% of % degradation was reported in case of photo Fenton process respectively.

5.2. Effects of FeSO4.7H2O concentration in Fenton and Photofenton treatment

Figure 5.1. (a, b, e, f) and Figure 4.8 (a, b, e, f) shows the % degradation and COD removal of reactive azo dye solution with increasing concentrations of Fe^{2+}.

In case of Fenton process, initially by increasing concentration of Fe^{2+} up to 358.66 mg/L, the COD degradation rate increased, beyond which decrease was reported. On the other hand, in case of photo Fenton process, COD degradation was highest (75.99%) at 371.82 mg/L of Fe^{2+} after which it showed a decreasing trend. Therefore, keeping in mind the economical factors of any operation/project, based on this study, the optimal concentrations of Fe^{2+} 371.82 mg/L for photo Fenton process, respectively, could be proposed.

6.0. CONCLUSIONS

Literature survey revealed that effluent of textile industries contaminate the water bodies and affect our ecosystem. Therefore, to eliminate such pollutants AOPs such as: Fenton, photo-Fenton and photocatalytic processes, have been investigated for the degradation of reactive azo dye. Present study also investigated the use of the multivariate statistical approach for optimizing the process parameters to achieve maximum degradation of reactive azo dye.

The observations of these investigations clearly demonstrated the importance of choosing the optimum degradation parameters to obtain a high degradation rate, which is essential for any practical application of these processes. Practical applicability of Fenton and photo-Fenton processes is proved by the effective COD reduction of textile industry wastewater.

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