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Using Medium Pressure Ultraviolet Reactor for Removing Azo Dyes in Textile Wastewater Treatment Plant

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Abstract: This study investigated the destruction of azo dyes in textile effluent using the medium pressure ultraviolet reactor (MPUVR) that emits 254 nm radiation. The effect of parameters such as initial dye concentration and exposure time on the degradation of azo dyes was investigated. The initial concentration of dye was the range of 1-3 mg/L and the exposure time was in the range of 1-15 min. The effectiveness of UV reactor of dyes increased with increasing the exposure time and reduced with increasing the dye concentration. A comparison of the pigment (Black 142), disperse (Yellow 235) and cationic (Blue 3) dyes showed that UV reactor provided the best dye removal after 9 min of UV exposure time.

Key words: Textile wastewater · Medium pressure · Ultraviolet reactor · Azo dye

INTRODUCTION

Effluent of textile industry includes a large variety of contaminants. Main contamination in textile wastewater came from dyeing and finishing processes. These processes require the input of a wide range of chemicals, which generally are organic compounds of complex structure [1-6]. Textile wastewater treatment plants consume large volumes of water and chemical compounds for processing. The chemical reagents used are very different in chemical composition, ranging from inorganic compounds to organic compounds [7-9]. The presence of very low concentrations of dyes in effluent is highly visible and undesirable. Many dyes are difficult to decolorize due to their complex structure [10-12]. There are various methods to classify textile dyes. Common application process classes include: cationic, reactive, disperse and pigment [13-16]. Disperse dyes are applied to hydrophobic fibers such as cellulose acetate, nylon and polyesters. Reactive dyes are also ionic, water-soluble compounds. Pigments are used in a variety of applications; the primary use is in printing inks [16-20].

Photodegradation of azo dyes have been reported for different times by previous authors [21-24]. The purpose of this research was to examine the degradation of azo dyes (Reactive, disperse and pigment) by medium pressure ultraviolet reactor. Photodegradation rates have been performed at different initial concentrations and exposure times. Effects of initial concentrations and exposure times on Photodegradation efficiency were studied.

MATERIALS AND METHODS

The wastewater samples used in this study were effluents from the final clarifier of textile wastewater treatment plant of Tehran city. Three dyes (pigment, disperse and cationic) were obtained from wastewater treatment plant. Performance of all the treatment process by UV reactor was followed by the analysis of dyes at different time intervals, 1 to 15 min. A sample wastewater was obtained as a solution of 3 dyes: 1, 2, 3 mg/L of pigment dye and 1, 2, 3 mg/L of disperse dye and 1, 2, 3 mg/L of cationic dye. After a defined time of irradiation the sample of solution were filtered through a 0.45 membrane filter and analyzed. The dye concentration time data during dye destruction was detected using spectrophotometry. The pH was 6.8-7. Experiments were performed at ambient laboratory temperature 18±20°C. A characteristic of mercury vapor lamp has shown in Table 1. All the analyses were performed according to the procedures outlined in standard methods [21].

The definition of dye degradation percentage (DDP) is as follows:

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Table 1: Arda medium pressure mercury vapor lamp

Lamp type	L (mm)	D (mm)	Area length (mm)	Voltage (V)	Current (Amp)	Life time (h)
MPUV (400w)	120.5	20	72	130+15	3.25	10^4

Note: UV irradiance is calculated in 1 meter from the bulb.

Technical information report from the lamp manufacture, France.

$$DDP = (C_{dye\,1} - C_{dye\,2}) / C_{dye1} \times 100$$

Where DDP (%) is the dye degradation percentage of the reactor,

C_1 is the initial concentration of dye (mg/L),

C_2 is the concentration of dye (mg/L) after reaction for (t) time.

The Potential of using ultraviolet reactor on the degradation of azo dye were analyzed statistically by using SPSS 11.5 and Excel software. The variables were dye, concentration and exposure time. Statistical analysis carried out using One-way ANOVA, Pearson correlation, multiple linear regression.

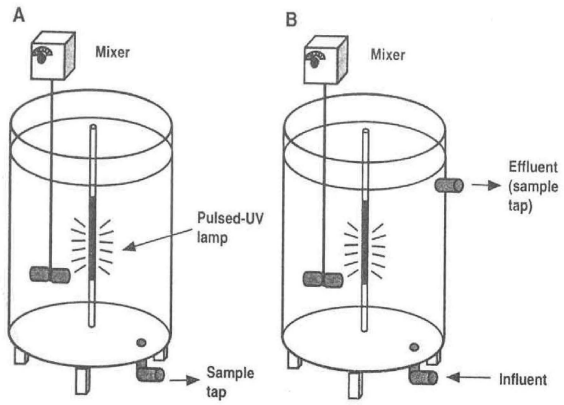

Fig. 1: Ultraviolet reactor

RESULTS AND DISCUSSION

The experiments carried out with UV reactor. Figs. 1 to 3 summarize the result of dyes destruction by UV reactor for pigment, disperse and cationic dyes of textile wastewater plant under 15 different exposure time and 3 different concentration conditions. The percentage of dye destruction at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15 min of exposure time and the degradation of three textile dyes by irradiation were presentated (Figs. 2-4).

Effect of Initial Concentration: Figs. 2 to 4 show the rate of dye removal with time during irradiation at different concentrations. The rate of dye removal is low at the beginning and then increases with time. As can be seen, the decolorization time increases with decreasing initial dye concentration. Figs. 2 to 4 show the effect of different initial dye concentration on the decolorization efficiency. It is seen that the increasing concentration of dye from 1 mg/L to 3 mg/L in the solution reduces the removing dye with UV irradiation.

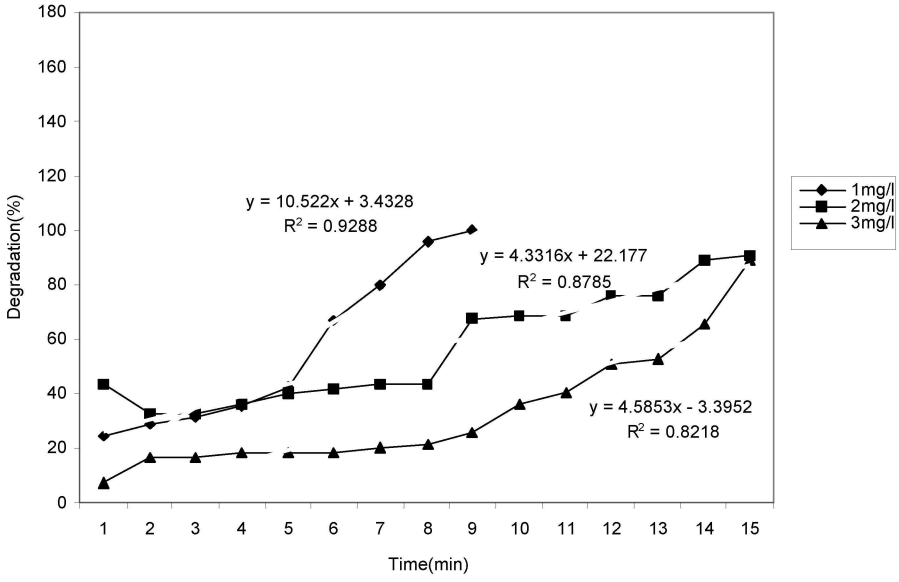

Fig. 2: Degradation percentage of pigment dye during varying exposure times

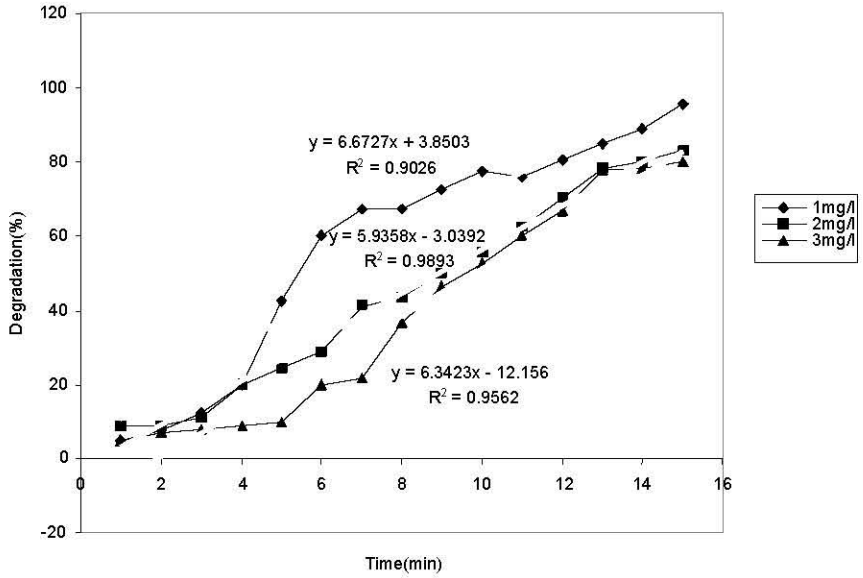

Fig. 3: Degradation percentage of disperse dye during varying exposure times

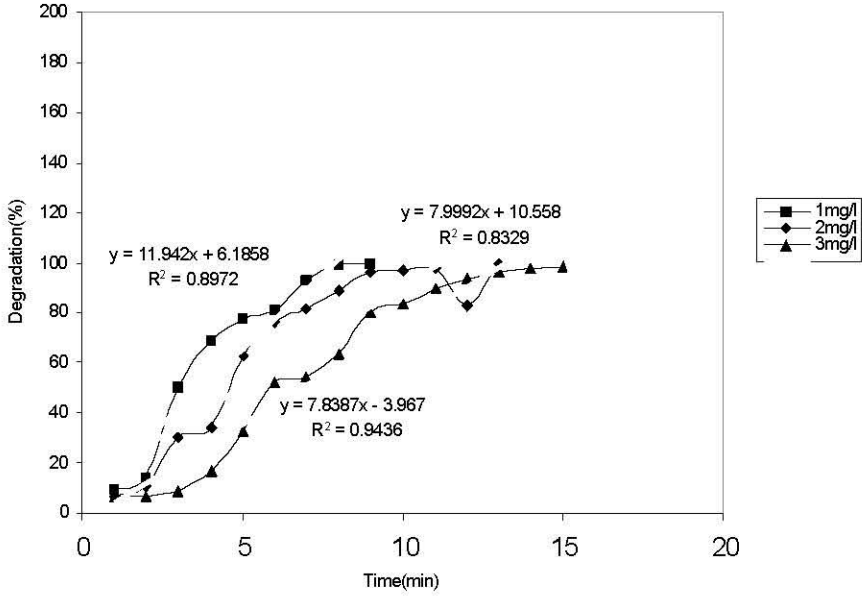

Fig. 4: Degradation percentage of cationic dye during varying exposure times

When increasing the dye concentration up to 3 mg/L, a decrease in percentage yield of the dye destruction was observed, as expected as shown in Pearson correlation test presented in Table 1 (P value= 0.02, r= -0.211). Post-hoc test (Table 2) show that the ultraviolet irradiation treatment on decolorization for 1 mg/L is more effective than the 3 mg/L (P value= 0.024). On the other hand, the mean difference is significant at the 0.05 level.

Shen and Wang indicate that degradation ratios of dye decreased rapidly as their initial concentration increase. Akbal [23] indicated that at higher initial dye concentration decreased the light penetration and thus decreased the rate of degradation. This is in agreement with our study. Also, the decrease of degradation is that photolysis of dyes proceeds through the production of OH radicals and oxidation by the photogenerated holes [24]. Al-Kdasi *et al.* [25] recorded when initial concentration increases, the production of hydroxyl radicals decreases.

Effect of Exposure Time: The degradation rates of azo dyes (pigment and cationic) solutions (Figs.2 and 4) were much higher when compared to the disperse dye solution (Fig.3). On the other hand, it is clearly to show that at

Table 2: One-way test

	Sum of squares	df	Mean square	F	Sig.
Regression	6661.056	2	3330.528	3.713	0.027
Residual	105850.352	118	897.037		
Total	112511.409	120			

Table 3: Post-hoc test (Multiple Comparisons)

					95% Confidence Interval	
(I) Time(min)	(J) Time(min)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
1.00	2.00	.8309	6.55249	.899	-12.1448	13.8066
	3.00	-15.6411(*)	6.87351	.025	-29.2525	-2.0296
2.00	1.00	-.8309	6.55249	.899	-13.8066	12.1448
	3.00	-16.4719(*)	6.64668	.015	-29.6342	-3.3097
3.00	1.00	15.6411(*)	6.87351	.025	2.0296	29.2525
	2.00	16.4719(*)	6.64668	.015	3.3097	29.6342

* The mean difference is significant at the.05 level

Table 4: Pearson correlation test

Parameter		Concentration	Exposure time	Degradation
Concentration	Correlation coefficient	1	.150	-.211(*)
	Sig. (2-tailed)	.	.100	.020
Exposure time	Correlation coefficient	.150	1	.786(**)
Sig. (2-tailed)		.100	.	.000
Degradation	Correlation coefficient	-.211(*)	.786(**)	1
	Sig. (2-tailed)	.020	.000	.

*Correlation is significant at the 0.05 levels (2-tailed)

**Correlation is significant at the 0.01 levels (2-tailed)

Table 5: Multiple Linear Regression test * (coefficients)

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	33.771	4.603		7.337	.000
Concentration	-12.901	1.857	-.337	-6.946	.000
Exposure time	6.093	.354	.836	17.233	.000

* Linear regression equation:

Degradation = 33.771 - 12.901 concentration + 6.093 exposure time

Table 6: Coefficient of determination

R	R Square	Adjusted R Square	Std. Error of the Estimate
.853(a)	0.728	0.724	16.09401

lower exposure time (9 min) resulted in complete degradation and thus, high dye removal (100%) efficiencies were obtained. Experiments show that the longer exposure time the more advantageous for disperse dye removal where dye removal at 15 min was 95.65% (1 mg/L), 83.33% (2 mg/L), 80.00% (3 mg/L) as shown in Fig.2. For pigment dye solution, reaching 90.74% (2 mg/L), 89.10% (3 mg/L) as shown in Fig. 3. For cationic dye solution, reaching 98.40% (3 mg/L) as shown in Fig. 4.

The complete destruction of pigment and cationic dyes (100%) was obtained in case of concentration of 1 mg/L. In case of pigment dye concentration equal to 1, 2 and 3 mg/L, the rates of pigment dye destruction after 9 min, 15 min and 15 min were 100%, 90.74% and 89.10%, respectively (Fig.2). In case of dye concentration equal to 1 mg/L, 2 mg/L and 3 mg/L, the rates of disperse dye destruction after 15 min of irradiation were 95.65%, 83.33% and 80.00%, respectively (Fig.3). Also, the rates of cationic dye destruction after 9 min, 13 min and 15 min of irradiation were 100%, 100% and 98.40%, respectively (Fig.4).

Shyh- Fang *et al.* [26] reported that the longer exposure times the more advantageous for dye removal where dye degradation at 10 min was only 9% of removal after 2 h. Kos *et al.* [27] expressed that degradation of dyes reached 0 to 60% depending on time of irradiation.

Also, the obtained results from our study were supported by Lio *et al.* [28] Mozia *et al.* [29] Namboodri *et al.* [30], Shu *et al.* [31] and Yang *et al.* [32].

Data Analysis: Using One- way ANOVA (Table 2) authors found statistically significant differences in azo dyes (df=2, F=3.713 and P value=0.027). This table shows that the significance levels obtained for the statistical analysis that authors used. Post-hoc test (Table 3) show that the pigment and cationic dyes were more easily decolorized than disperse dye (P value=0.025 and P value=0.015, respectively). On the other hand, the mean difference is significant at the 0.05 level. The statistical study using Pearson correlation test showed that when increasing the exposure time, an increase in removal percentage, as shown in Table 4 (P value < 0.001, r= 0.786). On the other hand, correlation is significant at the 0.05 level and correlation is significant at the 0.01 level. Also, the linear relationships equations are as follows (Table 5):

$$\text{Degradation} = 33.771 - 12.901\ \text{Concentration} + 6.093\ \text{Exposure time}$$

The statistical analysis using multiple regression shows that there were linear relationships between degradation percentage, exposure time and concentration as shown Table 6.According to Table 6 coefficient of determination (R^2) is equal to 0.728.

The UV reactor with medium pressure UV lamp was investigated for degradation of dye from textile effluent. From the results of this study and others from the literature, one could claim that the UV degradation reactor of textile effluent could be employed as a powerful technique for the destruction of dye of this industry. The decolorization of azo dyes such as pigment, disperse and cationic by medium pressure ultraviolet lamp in a batch reactor was found to be an effective method for textile dyeing wastewater treatment. In this study, the parameters monitored were; initial dye concentration and exposure time. These parameters have a considerable effect on the rate of removing dye by r batch reactor. The conclusions derived from this research are:

- UV treatments evaluated during this research decolorized the pigment, disperse and cationic dyes of the wastewater treatment plant effluent to varying degrees. This study show that efficacy of the UV irradiation was dependent on the initial dye concentration and exposure time.
- The effectiveness of UV reactor for degradation of dyes decreased with increasing the initial dye concentration and increased with increasing the exposure time. But an optimum time for complete decolorization was obtained after 15 min.
- The pigment and cationic dye solutions (1 mg/L) are rapidly decolorized by UV reactor (9 min, 100%), but the disperse dye solution (1 mg/L) is more resistant to the UV irradiation (9 min, 72.50%). Also, UV irradiation (3 mg/L) will ensure inadequate destruction for three dyes.

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