Journal of Community Health Research. 2014; 3(1):31-38.

Original Article

Treatment of Synthetic Textile Wastewater by Combination of Coagulation/Flocculation Process and Electron Beam Irradiation

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Received: 12/10/2013 **Accepted:** 3/2/2014

Abstract

Introduction: Textile wastewaters are heavily polluted with dyes and chemicals and have a broad range of pH, high COD concentration and suspended particles. In this study, the efficiency of color and turbidity removal from synthetic textile wastewaters were investigated by a combined process of coagulation/ flocculation and electron beam irradiation.

Materials and Methods: The experiments have been done on model dye solution samples, which were prepared from ten dyes supplied from Yazd Baff factory. Aluminum sulphate was employed as coagulant. Then samples were irradiated by electron beam accelerator at different doses. Absorption spectra of the samples were measured using UV-Vis spectrophotometer. The pH and turbidity values of the solutions were measured by a pH meter and turbidimeter.

Results: According to results, the degree of decoloration and turbidity removal of synthetic dye solutions increased when the alum concentration increased and reached 64% and 90% respectively at 112 ppm of alum. After irradiation, it is observed that absorbance decreased rapidly at 540 nm by increasing the radiation dose because of macromolecules degradation and then it decreased slowly to a degree of decoloration of 95% at 3 kGy. The level of pH decreased by irradiation and then changed very slowly or remained constant with increasing irradiation dose.

Conclusion: The results indicate that a combination of coagulation/ flocculation and irradiation is so effective for turbidity removal and decoloration. Coagulation process eliminates suspended particles from disperse dyes effectively, while destruction of soluble dye molecules happens by irradiation, which considerably increases decoloration efficiency.

Keywords: Textile wastewater; Coagulation/flocculation; E-Beam Irradiation; Decoloration

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Introduction

Textile dyeing processes are among the most environmentally unfriendly industrial processes, because they produce colored wastewaters that are heavily polluted with dyes, alkali, acid, salt, textile auxiliaries and suspended particles [1, 2].

Due to the limitation of the water resources, there are many studies on developing new methods to reuse wastewater. Since biological treatment is insufficient to remove the color, the application of specific treatments is required. There are different techniques to achieve color removal, among them the most used are: Activated carbon adsorption, membrane filtration, coagulation-flocculation process, treatment with ozone and electrochemical oxidation [3-5].

In the textile industry, the choice of more effective and less expensive treatment processes or their combinations depends on the dyestuffs and dyeing methods used during the production [1]. Coagulation/flocculation is a relatively simple physical-chemical technique that may be employed successfully for the treatment of water and wastewater. Aluminum sulphate ($Al_2(SO_4)_3$), ferric chloride ($FeCl_3$) and other metal salts were commonly used as coagulants [6,7]. Surfactants and dyes with high molecular weights are removed by coagulation/flocculation processes followed by the sedimentation, flotation and filtration [1].

Colloidal particles, which are present in water and wastewater, generally have negative charges. They repel each other due to the charges and remain suspended in water and wastewater for a long time. The objective of coagulation is to destabilize the suspension by coating the negatively charged surface of colloidal particles with positively charged species. When a coagulant such as aluminum salt is added to wastewater, a series of soluble hydrolysis species are formed that have positive or negative charges depending on the wastewater pH. The positively charged hydrolysis species can be absorbed onto the surface of colloidal particles and destabilize the stable colloidal particles. This mechanism is called charge neutralization[7]. The main advantage of this method is decoloration of the waste stream due to the removal of dye molecules from effluent, and not due to a partial decomposition of dyes, which can lead to an even more potentially harmful and toxic aromatic compound [1, 8, 9].

Advanced oxidation processes (AOPs) are based on the generation of hydroxyl radicals in water, which are highly oxidative, while non-selective oxidants are able to oxidize organic compounds particularly unsaturated organic compounds such as azo dyes [10, 11]. Ionizing Radiation of wastewater as an advanced oxidation process creates three short-life intermediates: hydroxyl radical ($^{\bullet}OH$), hydrated electron (e_{aq}^-) and hydrogen atom ($H^{\bullet}$). It is considered that hydroxyl radical has the major role in degradation of the dye chromophore [2, 11,12]. At sufficiently high absorbed doses, these transformation can result in complete decomposition of the organic pollutants in the wastewater. Also, efficiency of the process are notably influenced by irradiation conditions and wastewater compositions [13-16].

This high energy electron beam has been reported by researchers to be effective for removal of colored water containing various dyes such as direct, reactive and disperse [2, 11, 12]. From economic point of view, a combination of radiation and conventional methods, such as coagulation is the most promising [17].

In this study, the efficiency of color and turbidity removal from synthetic textile wastewater samples were investigated by a combined process of coagulation/ flocculation and electron beam irradiation.

Materials and Methods

The experiments have been done on model dye solution samples, prepared from ten dyes according to table 1 that were supplied from Yazd Baff textile factory. Aluminum sulphate ($Al_2(SO_4)_3.18\ H_2O$) was purchased from Merck Company. Absorption spectra of the samples were measured using UV-Vis spectrophotometer (Perkin Elmer, Lambda 25 model). The pH and turbidity values of the solutions were measured by a Metrohm 827 model pH meter and 2100AN turbidimeter (Hach Company). Samples were irradiated by 10 MeV electron beam of Rhodotron TT200 accelerator in Yazd Radiation Application Research School. The synthetic dyeing wastewater was prepared by adding 10 mg of ten different dyes (table 1) to 1 L of distilled water to obtain 100mg/L concentration of dye solution. The coagulation experiments were carried out in a conventional jar-test apparatus. Varying doses of alum were placed in beakers. The initial rapid mixing stage took place for 1 min at 120 rpm, followed by a slow stage for 20 min at 20 rpm. Then the sludge was left to settle for 30 min. After the settling period, the supernatant was withdrawn from the beakers and used for analysis of UV-Vis, turbidity and pH. After determination of the optimum amount of alum, samples were irradiated by electron beam at different doses of 1, 3 and 6 kGy. The degree of decoloration and turbidity removal of samples were calculated as follows:

Decoloration (%) = $\frac{(A_0\text{-}A_i)\times 100}{A_0}$, A_0 and A_i are the absorbance at λ_{max} of the samples before and after the treatment. Turbidity removal (%) = $\frac{(T_0\text{-}T_i)\times 100}{T_0}$, T_0 and T_i are the turbidity value of the samples before and after treatment. All the experiments were performed at ambient temperature of 25 ^{0}C.

Table 1: Dyes were supplied from Yazd Baff factory for preparation of synthetic textile wastewater

No.	Reactive	Disperse	Direct	Sulphur
1	Remazol navy blue GG	Ariaperse yellow 4GWL	Direct fast blue B2R	Sulphur black B
2	Remazol black B	Allilon red 3BRL	EV direct red BWS	-
3	Indofix red MERB	Dianix classic black SEG	AMBO direct yellow RL	-

Results

The absorption spectra of synthetic wastewater after coagulation with different amounts of aluminum sulphate are shown in fig.1. Absorption at 540 nm was selected as an index to estimate the decoloration efficiency. It can be seen that characteristic peak value decreased with increasing alum dosage. The results of decoloration efficiency and turbidity removal versus different amounts of Alum are presented in figs. 2 and 3. According to these figures, the degree of decoloration and turbidity removal of synthetic dye solutions increased when the alum concentration increased and reached 64% and 90% respectively at 112 ppm of alum. The changes in pH values of wastewater versus different amounts of alum are shown in fig. 4. After coagulation process, the pH decreased sharply.

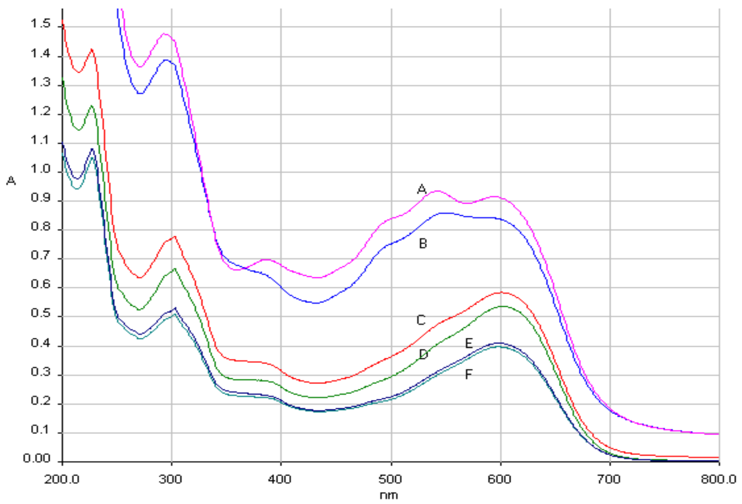

Figure 1: Changes of absorption spectra of synthetic wastewater after coagulation with different amount of coagulant(**A**: Initial wastewater, **B**: alum 12 ppm, **C**: alum 37 ppm, **D**: alum 62 ppm, **E**: alum 112 ppm, **F**: alum 187 ppm)

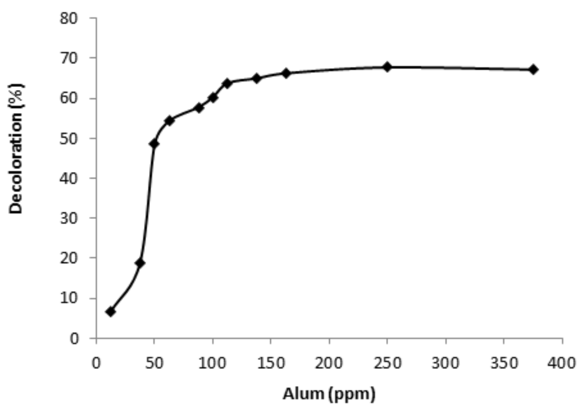

Figure 2: Decoloration of synthetic wastewater versus different amounts of alum at ambient temperature

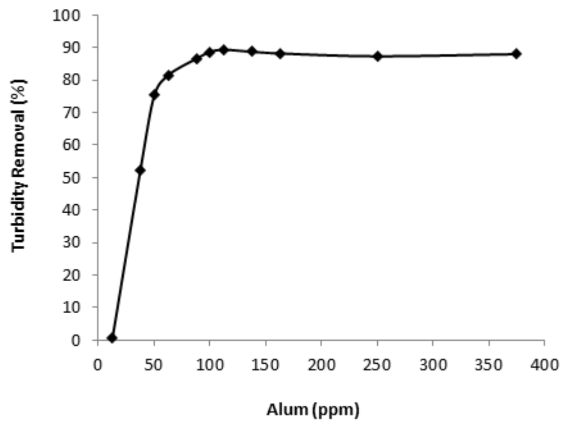

Figure 3: Turbidity removal of synthetic wastewater versus different amounts of alum

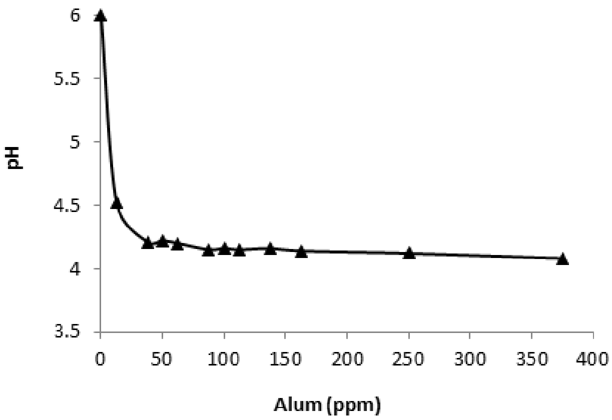

Figure 4: Changes of pH value in synthetic wastewater after Coagulation with different amounts of alum.

At the next stage, treated synthetic wastewater with optimum amount of alum (112 ppm), was irradiated by 10 MeV electron beam at doses of 1, 3 and 6 kGy. After irradiation, decoloration efficiency, variation of pH and absorption spectra has been shown in figs. 5- 7. It is observed that absorbance at 540 nm decreased rapidly by irradiation, because of macromolecules degradation and then decreased slowly with increasing the absorbed dose and degree of decoloration reached to 95%. Experimental results showed that the amount of pH decreased by irradiation and then changed very slowly or remained constant with increasing irradiation dose.

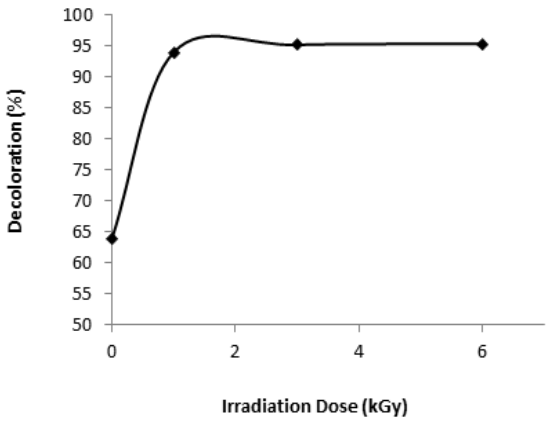

Figure 5: Decoloration of synthetic wastewater versus absorbed dose

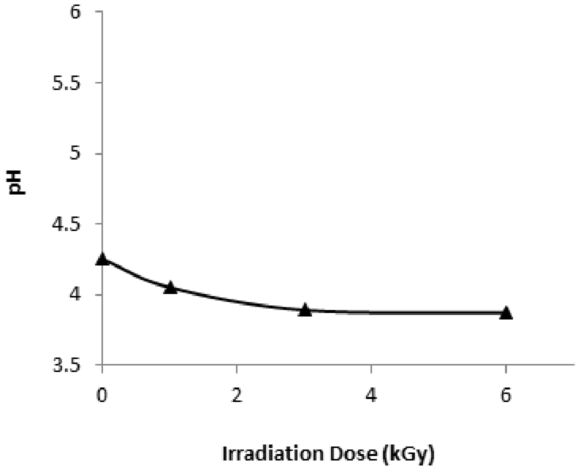

Figure 6: Changes of pH value of synthetic wastewater versus absorbed dose

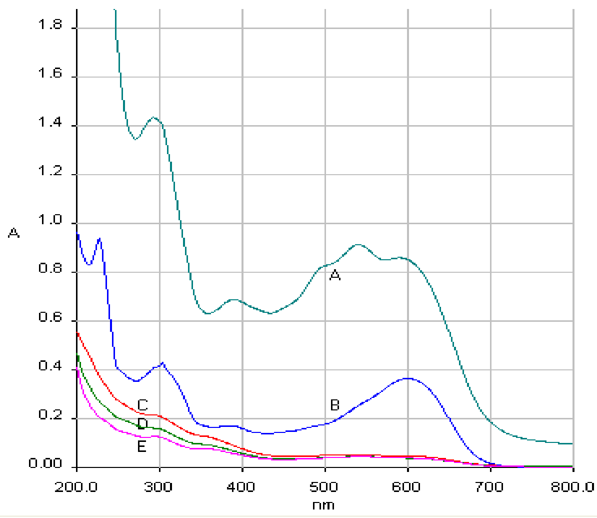

Figure 7: Absorption spectra of synthetic wastewater before and after irradiation

(**A:** initial synthetic wastewater, **B:** after coagulation in optimum condition, **C:** after irradiation at 1 kGy, **D:** after irradiation at 3 kGy, **E:** after irradiation at 6 kGy)

Discussion

Low solubility of disperse dyes increase suspending particles and turbidity in synthetic textile wastewater samples. Coagulation process eliminates suspended particles effectively.

According to figures 2 and 3, decoloration efficiency and turbidity removal increases by increasing the amount of alum and these efficiencies are the most values, %64 and %90 respectively at 112 ppm.

Noticeably, it cannot be observed further color and turbidity reduction when further increase of the alum dosage, which can be explained by the charge neutralization theory.

When alum is added to the dye solution, $Al^{3+}_{(aq)}$ and its hydrolyzed products interact with negative colloids and neutralize their charges, it results in the colloids destabilization. Over the appropriate dosage, the colloids can absorb the cations and become positively charged, hence, may be stable again as a result of electrical repulsion [7].

In irradiation treatment, as it can be seen in fig. 7, characteristic peak values decreased rapidly with increasing absorbed dose from 0 to 1 kGy and then decreased slowly with increasing absorbed dose.

In all cases, the pH decreased sharply after the first irradiation dose of 1 kGy. Thereafter, the pH values changed very slowly or remained constant with increasing irradiation dose. This suggests that at the beginning of the irradiation, big dye molecules were broken down to middle and smaller organic compounds such as formic acid, acetic acid and other benzoide compounds. If the dye solutions continue to be irradiated by electron beam, the interim compounds react with active species like hydroxyl radicals to be degraded further to inorganic products and pH decreases more remarkably [2, 18- 21].

Conclusion

The above results indicate that a combination of coagulation/flocculation and irradiation of 10 MeV electron beam is so effective for turbidity removal and decoloration. Coagulation process eliminates suspended particles from disperse dyes effectively, while destruction of soluble dye molecules happens by irradiation that considerably increases decoloration efficiency.

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