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Efficiency comparison of alum and ferric chloride coagulants in removal of dye and organic material from industrial wastewater - a case study

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Coagulation and flocculation are most widely methods used for dye and pollution removal from various wastewaters. The aim of this study is efficiency comparison of inorganic coagulant (Alum and Ferric Cchloride) for treatment of textile factory wastewater. The appropriate coagulant was selected at optimum condition for treatment of textile's factory wastewater by measuring of dye, COD, BOD_5 and TSS parameters. The different pH (4, 5, 6, 7, 8 and 9) was used for determine the optimum pH. Totally, 240 samples were collected and exanimated according the standard methods of wastewater and water tests. Results showed that the ferric chloride has more removal efficiency than alum in removal of COD, TSS and dye. The most removal of COD, TSS and dye using alum was obtained 36, 19 and 68.8% while for ferric chloride was obtained 72, 60 and 98% respectively. The optimum pH 7 and 5 were obtained for alum and ferric chloride respectively. Based on the results, it can be concluded that COD, TSS and dye removal using ferric chloride has higher efficiency than alum. Therefore, application of ferric chloride in the same conditions is preferred than alum.

Keywords: wastewater treatment, textile's wastewater, coagulant, Alum, ferric chloride.

INTRODUCTION

High level pollutants have discharged into the environment at the recent decades due to develop of industrial activities on the one hand and non-compliance with environmental requirements. Accumulation of these organic compounds in the environment poses a serious threat to human health, environment, living organisms and ecosystems (1, 2). The textile industry is one of the oldest industries in the world. This industry from 5000 BC and was recognized when piece of linen clothing was found at Egyptians caves, and was developed with the invention of machines for spinning and weaving after the industrial revolution in England at the eighteenth century. The first man-made fabrics (rayon fibers) were presented to market in the twentieth century (1910). In the recent century, the process of textile factories has been automated and computer-aided work due to technology development. The sewage of different processes units of textile industry has most important environmental issues compared to other waste such as solid waste as well as health and safety is more important. Textile dyeing industry is one of the largest water users that lead to produce the significant amounts of wastewater. This wastewater contains significant amounts of organic dye compounds. Exist of organic dye materials in industrial wastewater cause the irreversible damage to the environment due to decreasing the light penetration into the water and disruption of photosynthesis, reducing the oxygen transfer into the water and the solubility of gases. Also discharge of wastewater into rivers and lakes leads to decreasing water quality (3-7).

Generally, industrial wastewater contaminants include caustic soda, detergents, starch, wax, urea, ammonia, dyes and pigments lifting of biochemical and chemical oxygen demand, suspended solids and toxic substances. Hence, it is necessary the

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treatment of textile dye effluent before discharging into the environment. Biological treatment processes are rarely used for textile wastewater treatment. These processes commonly are effective in biochemical oxygen demand (BOD5) and suspended solids (SS) removal, but are ineffective for the dyes removal from these wastewaters(8), because dye compounds are complex and resistant structures that cause the rate of biodegradation dyes to be slow. The most common method that used for the dyes removal from textile wastewater include physical-chemical methods such as coagulation and flocculation, adsorption, ozonation, reverse osmosis and advanced oxidation are using membrane filters(9-12). Each of these methods has advantages and disadvantages for the dyes removal from wastewater. Coagulation and flocculation processes are used one of the most common and effective method for treatment of effluents dyes (11, 13, and 14).The produce of non-toxic and non-harmful of intermediate products is main advantages of effluents dyes treatment with coagulation and flocculation. Beside, this method is cost effective and is implemented on a large scale (14, 15).In general, coagulation and flocculation is proper method for removal of organic compounds with high weight and larger molecular chains (11, 14 and 16).The aim of this study was to evaluate the effectiveness of alum and ferric chloride coagulants in treatment of one Type of industrial wastewater (textile factory wastewater). For this purpose, the effect of pH and concentration of coagulants are examined.

MATERIAL &METHODS

This study is a cross-sectional study. The samples were collected from sewage of textile factory and were properly transferred to the chemistry laboratory. Optimum pH was adjusted with sodium hydroxide (1N) and sulfuric acid (0.1N) respectively using pH-meter model of Microprocessor 537. At the first step, the pH=6 was selected to determine of appropriate coagulant amount, then coagulant gradually added to the 6 containers of Jar test and experiments were continues until visible flock with appropriate settling was observed. In the second step, after determination of approximate amount of suitable coagulant in previous step, the optimum pH was determined for each individual coagulant using Jar test with pH adjustment at 4, 5, 6, 7, 8 and 9. In the third step, considering the optimal pH obtained at second step, the different amounts of coagulant were added to containers for determine proper dosage of coagulant (2 containers with less than amount coagulant of first step, 1 container with equal amount coagulant of first step and 3 containers with more than amount coagulant of first step) The efficiency removal of dye, COD and BOD_5 were applied as indicators to determine of appropriate coagulant dosage and optimum pH. The tests carried out for both coagulants at least twice in each load. After the addition of coagulant, the samples was transferred to Jar test containers (HACH model) and rapid mixing was conducted for destabilizing particles for one minute at speed of 90 rpm and slow mixing was conducted for create the settling flock for 3 minutes at speed of 30 rpm. After slow mixing, the sample for 15 minutes for sedimentation was kept in stasis. Dye was measured with optical density method at 470 nm using spectrophotometer Varian UV-120-02 models made in America and COD measuring was conducted using COD reactor HACH model with closed reflux method.

Experiments were accomplished thrice and in total 240 samples tested according standard methods for water and wastewater treatment were assessed (17). Used coagulants include Aluminum sulfate ($Al_2(SO_4)_3$) and ferric chloride ($FeCl_3$).

The removal efficiency was calculated as fallow equation:

$$\eta_{Color} = \frac{OD_0 - OD}{OD_0} \times 100 \qquad (1)$$

Where

η_{Color}	Efficiency removal of Dye by coagulants
DO_0	optical density of wastewater before coagulation
DO	optical density of wastewater after coagulation

RESULTS

Table 1 shows the performance compares of alum and ferric chloride coagulant in COD removal of wastewater at optimum pH. Figure 1 shows comparison the COD level after the addition of alum(550 mg/L) and ferric chloride (150 mg/L) and its percentage removal in samples at different pH and different COD of wastewater (1100 and 512 mg/L). Figure 2 shows comparison the COD level after the addition of alum (400 mg/L) and ferric chloride (250 mg/L) and its percentage removal in wastewater samples at different pH and different COD of wastewater (512 and 1280 mg/L). Figure 3 shows the comparison of COD level after the addition of alum (pH =7) and ferric chloride (pH =5) and its percentage removal textile factory wastewater with different COD concentrations in raw wastewater (512 and 1280 mg/L), Figure 4 shows the comparison of TSS level after adding different amounts of alum (pH = 4) and ferric chloride (pH =5) and its percentage removal in textile factory wastewater with different TSS concentrations of raw sewage (240 and 320 mg/L), Figure 5 shows the dye removal at different pH and certain concentration of alum (500 mg/L) and ferric chloride (400 mg/L) and Figure 6 shows the percentage removal of dye with different concentrations of alum (pH=7) and ferric chloride (pH=9).

DISCUSION

The results of other studies conducted by many researchers confirmed that pH is a significant factor in the coagulation and flocculation process. Each coagulant has an optimum pH which in that condition, coagulation and flocculation process for certain dosage of coagulant, the highest efficiency occurs in the shortest time. Therefore, determining of this factor is necessary to ensure the performance of coagulation and flocculation process (18). Thus, it is necessary determine of optimum pH for treatment of textile wastewater factory with alum and ferric chloride coagulant. The results showed that pH has effect on decreasing of COD level in treated wastewater use alum and ferric alum coagulants. So that the highest efficiency of COD and dye removal obtained for alum and ferric chloride coagulants at pH = 7 and pH =5-9 respectively. Alum with different dosage and pH=7 has low efficiency removal of COD even in low concentration (512 mg/L), but with 550 mg/L dosage and pH=7 has highest efficiency removal (36%) in high concentration of raw wastewater COD (1100 mg/L) and with 550 mg/L dosage was obtained highest efficiency removal of dye (75%). Ferric chloride with 150 mg/L and pH=5 has highest efficiency removal in low concentration of raw wastewater COD (68.75%) and with 250 mg/L dosage and pH=5, removal efficiency of COD was obtained 60%. Ferric chloride with 400 mg/L dosage has highest removal efficiency of dye (98%).

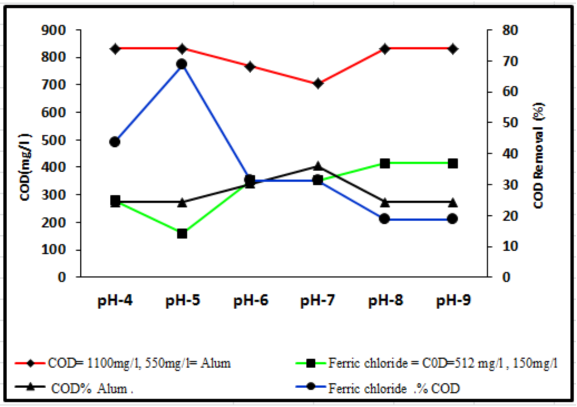

Fig. 1. Comparison of COD level after the addition of alum (550 mg/L) and ferric chloride (150 mg/L) and its percentage removal in samples at different pH and different COD of wastewater (1100 and 512 mg/L).

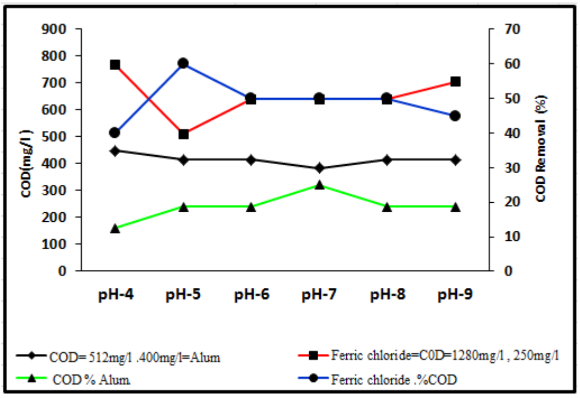

Fig. 2. Comparison of COD level after the addition of alum(400 mg/L) and ferric chloride (250 mg/L) and its percentage removal in wastewater samples at different pH and different COD of wastewater (512 and 1280 mg/L).

Table 1. The comparsion COD level and its removal percentage in different pH, alum= 550 mg/L and ferric chloride =150 mg/L in different COD of raw sewage (512 and 1100 mg/L).

	Parameters				
Coagulants	Range of raw sewage COD (mg/l)	Range of sewage COD after Jar test (mg/l)	Optimum pH	Consumed coagulant (mg/l)	Efficiency removal of COD (%)
Alum	512 -1100	384 - 704	7	400 - 550	25 - 36
Ferric chloride	512 -1280	160 - 641	5	150 - 250	60 – 68.75

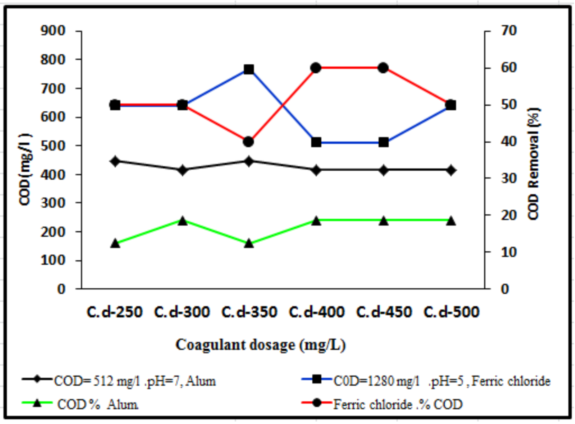

Fig. 3. Comparison of COD level after the addition of alum (pH =7) and ferric chloride (pH =5) and its percentage removal textile factory wastewater with different COD concentrations in raw wastewater (512 and 1280 mg/L).

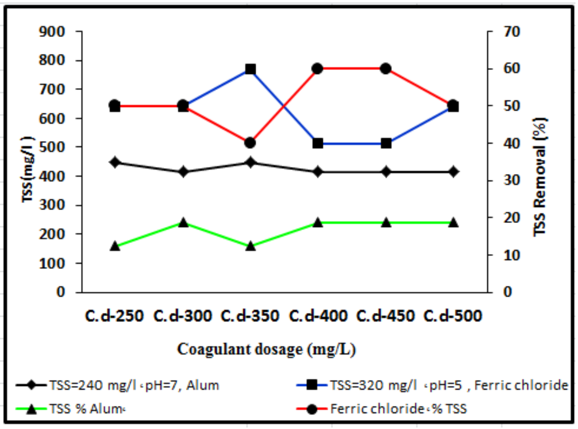

Fig. 4. Comparison of TSS level after adding different amounts of alum (pH = 4) and ferric chloride (pH =5) and its removal in textile factory wastewater with different TSS concentrations of raw sewage (240 and 320 mg/L).

Considering the results, ferric chloride with 150 and 250 mg/L was recommended for low and high concentration of COD respectively. This coagulant was selected for treatment of textile wastewater. The comparison of these results with results obtained from dye and COD removal using magnesium carbonate, PAC and combined treatment of textile wastewater using coagulation and oxidation with fenton (19-21). Indicated that ferric chloride has more efficiency removal than magnesium carbonate. Also, Jonaidy and Azizi (2008) reported that ferric chloride has best efficiency removal of dye than alum which confirms the results of this study (22).

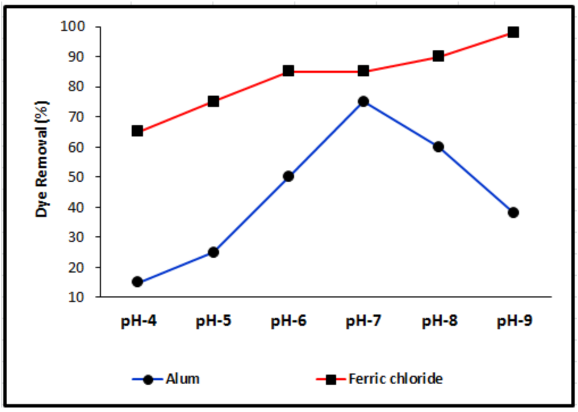

Fig. 5. The dye removal at different pH and constant concentration of alum (500 mg/L) and ferric chloride (400 mg/L).

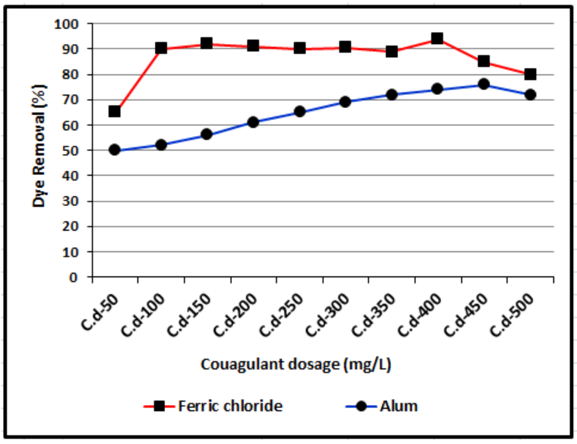

Fig. 6. The dye removal with different concentrations of alum (pH=7) and ferric chloride (pH=9).

CONCLUSION

Based on the findings, pH is effective parameters in terms of coagulation and flocculation process and it can be concluded that using ferric chloride to removal of COD, TSS and color of textile factory's wastewater had higher efficiency than alum and therefore its application in the same conditions than alum is preferred.

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