

Colour and COD Removal in Textile Effluents using Coagulation Flocculation

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ABSTRACT: There are various techniques for the treatment of textile effluent and coagulation- flocculation is one of the most widely used technique. Present study mainly focuses on comparing the treatment efficiency of Polyaluminium chloride (PACl)with respect to ferroussulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$)and Ferric Chloride ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$) when used for treating textile Effluent. The parameters used in determining the treatment efficiency weredecolourisation and COD reduction for synthetic as well as real textile wastewater containing reactive and disperse dyes. PACl was found to be the most effective coagulant in terms of decolourisation as well as COD reduction. It gave decolourisation and COD reduction efficiency of more than 95 and 75%, respectively, in case of disperse dyes. However, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ was producing the minimum sludge for synthetic wastewater. PACl was found to be the bestcoagulant for the decolourisation and COD reduction of textile effluent.

KEYWORDS: coagulation, textile effluent, PACl,colour removal, ferrous sulphate.

I. INTRODUCTION

The textile industry is a very discreet and broad manufacturing sector. Textile industries remodel fibres into yarn; transform the yarn into fabrics or related products, and dye and finish these materials at multiple stages of production. In the processing of textiles, the industry utilizes a number of dyes, chemicals, auxiliary chemicals and sizing materials. As a result of which contaminated wastewater is generated which is the major challenging issue for the environment and living beings unless properly treated before its disposal. Other minor issues of concern of textile industries include solid waste, resource wastage and occupational, health and safety [1]. The textile dyeing industry exhausts large quantities of water and generates large volumes of wastewater from different stages in the dyeing and finishing processes. Wastewater from printing and dyeing units is mostly rich in colour, containing residues of reactive dyes and chemicals, which are complex components, many aerosols, high chroma, high Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) and Total Organic Carbon (TOC) concentration as well as non-biodegradable materials [17]. Physical and/or chemical treatment methods have been consequently used to remove colour, or to partially degrade the dyes in dye house effluent to make them more amenable to a secondary biological treatment [2]. There are various treatment technologies to remove colour from this wastewater out of which coagulation-flocculation method is the most primitive, yet effective method [9].

A. Effects of Textile Wastewater

The fundamental strength of the textile industry comes from its strong production base of a wide range of fibers/yarns from natural fibers like cotton, jute, silk, and wool to synthetic/man-made fibers like polyester, viscose, nylon, and acrylic. With an increasing demand for textile products, textile mills and their wastewater have been increasing proportionally, causing a major problem of pollution in the world. Many chemicals used in the textile industry cause environmental and health problems. Among the many chemicals in textile wastewater, dyes are considered important pollutants. Depending on exposure time and dye concentration, dyes can have acute and/or chronic effects on exposed organisms [6]. The presence of very small quantities of dyes in water (less than 1 ppm) is highly visible due to their brilliance, thus causing aesthetic problems. The greatest environmental concern with dyes is their absorption and

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reflection of sunlight entering the water. Light absorption diminishes photosynthetic activity of algae and seriously influence on the food chain. Use of synthetic dyes has an adverse effect on all forms of life. Presence of sulphur, naphthol, vat dyes, nitrates, acetic acid, soaps, enzymes chromium compounds and heavy metals like copper, arsenic, lead, cadmium, mercury, nickel, and cobalt and certain auxiliary chemicals all collectively make the textile effluent highly toxic.

Worldwide environmental problems associated with the textile industry are typically those associated with water pollution caused by the discharge of untreated effluent and those because of use of toxic chemicals especially during processing. The effluent is of critical environmental concern since it drastically decreases oxygen concentration due to the presence of hydrosulfides and blocks the passage of light through water bodies which is detrimental to the water ecosystem. Textile effluent is a cause of significant amount of environmental degradation and human illnesses. About 40 % of globally used colorants contain organically bound chlorine, a known carcinogen. The textile waste water can cause hemorrhage, ulceration of skin, nausea, skin irritation and dermatitis [3].

II. MATERIALS AND METHODS

A. Materials

Laboratory grade Ferric Chloride ($\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$), Ferrous Sulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) and Polyaluminium chloride (PACl) were used as coagulants. 1.0M H_2SO_4 and 1.0M NaOH were used to adjust the desired pH. The other chemical additives used in the preparation of the synthetic wastewater were of analytical-grade.

B. Textile Wastewaters

Three type of effluent samples were analysed in the study. Two Synthetic textile wastewater samples were prepared in accordance with the chemical constituents of actual textile wastewater [14], with a total dye concentration of 200 mg/L. The total dye concentration was prepared along with the various chemical additives such as starch, acetic acid, sodium hydroxide, sucrose, sodium carbonate, sulphuric acid, sodium hydroxide, and detergent, which are used in textile processes. Wastewaters were prepared using two commercial dyes namely, Reactive Orange (ME2R) and Disperse Red (F2BL) in the tap water. Dyes were procured from Alaska Fabtech, Zirakpur. Along with these dyes actual wastewater samples were also collected from the same industry for the analysis. The characteristic wavelength for each dye wastewater was determined by scanning in the visible range using UV-VIS spectrophotometer. The maximum absorbance wavelengths (λ_{max}) for the wastewaters were 538, 463 and 520 nm respectively for ME2R, F2BL and actual wastewater, and the same was used to measure the absorbance of respective treated wastewater. The characteristics of textile wastewaters were: COD = 1200 to 2000 mg/L, pH = 10.4 to 11.6, Abs (538) = 4 for the wastewater containing ME2R; Abs (463) = 2.73 for the wastewater containing F2BL; Abs (520) = 2.94 for the actual wastewater. Percentage colour removal was calculated by comparing the absorbance values of the wastewater before and after the treatment. Tap water served as a reference. [16]

$$\text{Reduction efficiency (\%)} = [(A_b - A_t) / A_b] \times 100 \quad (1)$$

Where A_b and A_t are the absorbance of the solution before treatment and after treatment of effluents, respectively.

C. Coagulation and flocculation test procedures

The optimum pH and coagulant dosage required for decolourisation were measured by jar test procedure. 1 litre beakers containing 500mL of wastewater were used for the experiments. Chemical coagulant was added and mixed at 80 rpm for 3 minutes. The solution was then mixed slowly for 15 min at 30 rpm. After allowing to settle for 30 min, supernatants from the top of the beaker were taken for the analysis [14].

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D. Analyses

The pH of samples was adjusted to about neutral before the absorbance was measured. The COD was analysed according to the closed reflux colorimetric method as described in Standard Methods. After digestion of the samples in a COD reactor (model DRB 200, HACH Company), the COD measurements were determined on UV-VIS spectrophotometer at 600nm (model DR 6000, HACH Company). Sludge production in terms of settled sludge volume was also determined at optimised conditions for all the wastewaters. All the methods used for the analysis of wastewater characteristics were according to the Standard Methods and performed at room temperature ($25 \pm 5^\circ\text{C}$).

Table 1: Treatment Efficiency at Optimised pH for Different Combination of Synthetic Textile Wastewater

Coagulants	Parameters	Reactive Orange (ME2R)	Disperse Red (F2BL)	Actual Textile Waste Water
FeSO ₄ .7H ₂ O	Dosage (mg/L)	500	800	1000
	Optimum pH	11.5	10	11.5
	Colour Removal and COD Reduction (%)	63 (48)	74 (40)	69.5 (50)
FeCl ₃ .6H ₂ O	Dosage (mg/L)	500	800	800
	Optimum pH	8	8.3	8.5
	Colour Removal and COD Reduction (%)	64 (52)	91 (58)	74 (42)
PACl	Dosage (mg/L)	600	200	600
	Optimum pH	7.5	6	7
	Colour Removal and COD Reduction (%)	89 (55)	95 (68)	74 (42)

Note: % COD reduction is given within the parenthesis ()

III. RESULTS AND DISCUSSION

A. Determination of Optimum pH for Chemical Coagulation of Textile Effluent

pH plays a very vital role in determining the efficiency of coagulants used in treating wastewater. Therefore, experiments were conducted to determine the optimum pH for all the effluent samples that allowed for maximum decolourisation and COD reduction efficiency. The effect of pH on the treatment efficiency was examined using fixed amount of coagulant at various pH conditions (from 5 to 12) for all the coagulants. NaOH and H₂SO₄ were used to adjust the desired pH, as pH affects the molecular structure of the dyes, which in turn changes the absorbance of the solution. So, the pH of the untreated wastewater as well as treated effluent was adjusted to neutral before measuring the absorbencies for evaluating the percentage of colour removal. The optimum pH for selected coagulants against various dyes containing textile effluent is shown in Table 1. Percentage colour removal increases with the increase in pH from 5.0 to 11.5 when FeSO₄.7H₂O was used as coagulant for all the wastewaters. The optimum pH for FeCl₃.6H₂O was found to be in the range of 8 to 8.5, whereas PACl gave good results near neutral conditions for all the effluents. Decolourisation was found to be decreasing at pH greater or lower than the optimum pH. Variations in the optimum pH of same coagulants for different dyes prove that coagulation not only depends on the coagulant types but also on the nature of dyes.

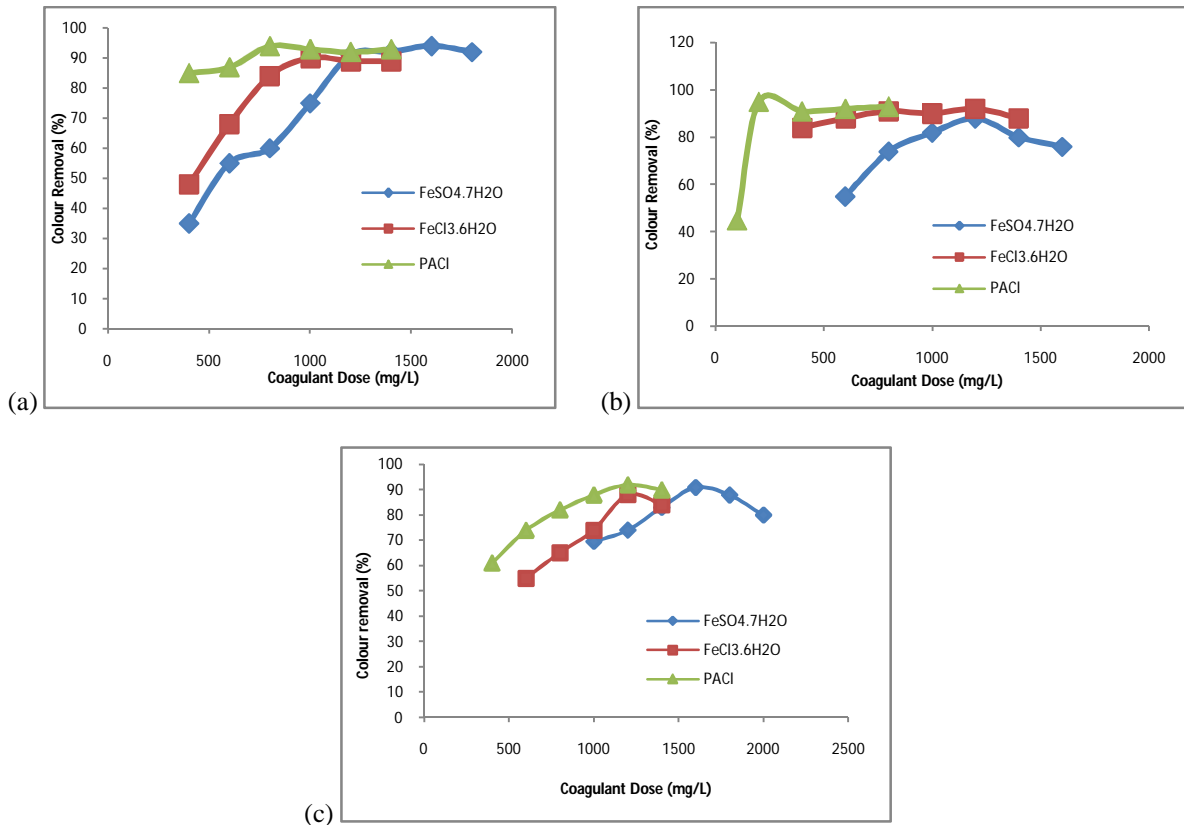


Fig. 1. Effect of coagulant dosage on the colour removal for textile wastewater containing (a) Orange ME2R (b) Red F2BL (c) Actual Textile Wastewater

B. Determination of Optimum Coagulant Dosage for Chemical Coagulation of Textile Effluent

The optimum dosage of coagulants for the selected textile effluents was determined by varying the coagulant dosage and maintaining the optimum pH. Colour removal as a function of coagulant dosage is shown in Fig. 1.

It was observed that in almost all the cases percentage colour removal increases with the increase in coagulant dosage.

Nearly 94% colour removal was observed at 800 mg/L of PACI for the wastewater containing Reactive Orange ME2R dye. FeSO₄·7H₂O was also found to be effective which gave more than 90% colour removal efficiency at a higher coagulant dosage of 1600 mg/L. FeCl₃·6H₂O was also found to be giving a decent colour removal of nearly 90% at a coagulant dose of 1000 mg/l (Fig. 1a). PACI in case of textile wastewater containing Red F2BL dye had been observed to produce a very high colour removal of more than 95% at a very low coagulant dosage of 200 mg/L. FeCl₃·6H₂O also gave a colour removal efficiency of more than 90% but a significantly higher dose of 800 mg/L. However, FeSO₄·7H₂O was found giving quite low colour removal efficiency for this particular dye (Fig. 1b). Colour removal efficiency of almost 92% had been achieved at 1200 and 1600 mg/L of PACI and FeSO₄·7H₂O respectively, for the actual textile effluent. Approximately, 88% colour removal had also been observed at the FeCl₃·6H₂O dosage of 1200 mg/L. So, ferrous sulphate and PACI was found to be quite effective for the actual textile effluent. The experimental result also shows that comparatively reduced coagulant dosage is required for the decolourisation of the effluent containing disperse dye as compared to the reactive dyes.

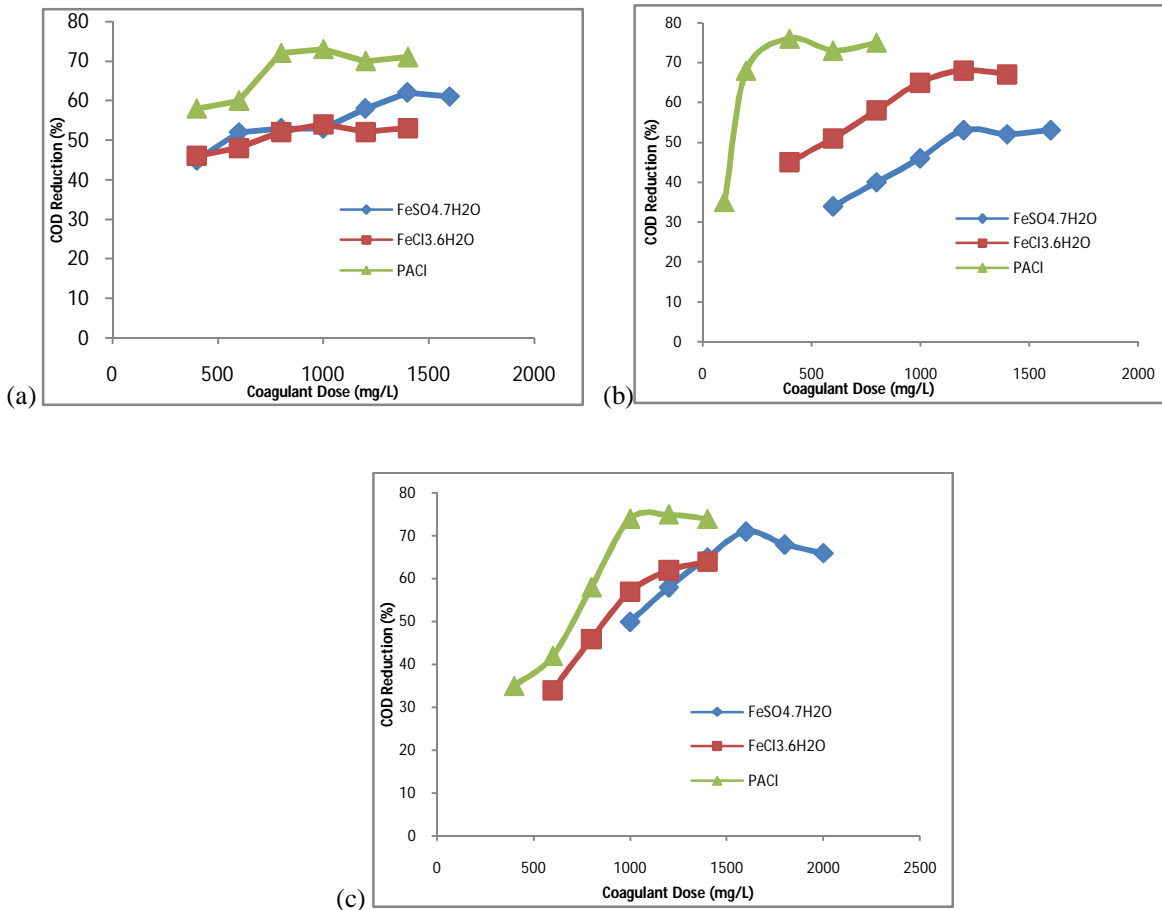


Fig. 2. Effect of coagulant dosage on the COD reduction for textile wastewater containing (a) Orange ME2R (b) Red F2BL (c) Actual Textile Wastewater

Some similar trends of COD reduction were observed with increasing coagulant dosage as obtained in case of colour removal for all the textile effluents using FeSO₄·7H₂O, FeCl₃·6H₂O and PACI (Fig. 2). A maximum of 75% COD reduction was observed at the optimum coagulant dosage of 1200 mg/L PACI for the actual industrial wastewater containing mixture of dyes (Fig. 2c). PACI was found to be giving better results for COD reductions in all the three cases (Fig. 2).

C. Sludge Production

The characteristics and amount of the sludge produced during coagulation/ flocculation mainly depends upon the type of coagulant used and the operating conditions. Therefore, sludge production was measured at optimised pH and at optimum coagulant dosage for all the Effluents. It was measured based upon the volume occupied by the flocs in 500 mL of sample volume after settling for 1h in the Imhoff cone. A maximum of 62, 36 and 30 mL settled sludge/500 mL of sample was observed in case of FeCl₃·6H₂O, PACI and FeSO₄·7H₂O respectively, for the wastewater containing Orange ME2R. PACI and FeSO₄·7H₂O was observed to be producing similar amount of sludge for almost all the cases, which is less than FeCl₃·6H₂O (Fig. 3). Both of these giving lesser sludge could be explained by the fact they have high adsorption as compared to FeCl₃·6H₂O.

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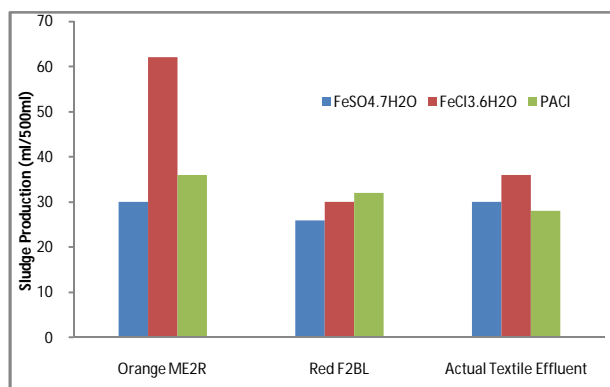


Fig. 3. Sludge production at optimised conditions for various textile effluents.

IV. CONCLUSIONS

Decolourisation and COD reduction efficiency of coagulants for synthetic as well as real textile wastewater has been successfully carried out in this study using FeCl₃.6H₂O, FeSO₄.7H₂O and PACI as coagulants. Both decolourisation and COD reduction efficiency of coagulants significantly depends upon the pH of wastewater. In view of the results obtained in this study, it can be concluded that PACI was highly capable to decolourise both the synthetic and real dye wastewater at a very low dosage. The highest decolourisation and COD reduction efficiency of more than 95 and 75%, respectively, were observed in case of disperse dye, when PACI was used as a coagulant. FeSO₄.7H₂O was found to be giving minimum sludge production in almost all the cases. However, PACI was also found to be giving quite reduced sludge production. Excellent treatment efficiency and reduced volume of sludge production at a very lesser dosage makes PACI a novel coagulant and may be recommended for industrial use. However, secondary treatment is required to remove the rest of the dissolved organic matter to meet the safe discharge standards set by the environmental pollution authorities of various countries.

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