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Research Article

DECOLORIZATION OF INDUSTRIAL DYEING WASTEWATER BY COAGULATION WITH ALUM, POLY ALUMINUM CHLORIDE (PAC), POLYELECTROLYTE AND OXIDATION USING CHLORINE

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ABSTRACT

Coagulation and flocculation is a widely practiced method for removing color from textile and tannery wastewaters. The aim of this research was to test the feasibility of using various coagulants and oxidants for treating textile wastewater. The effect of various operating variables like coagulant dose, pH, and reaction time were measured. Poly aluminum chloride (PAC), Alum and Chlorine were used for color removal. The collected wastewater had an average color of 12355 Pt-Co. PAC showed better color removal compared to Alum at similar doses. Also PAC was efficient over a wider pH range (3-11) compared to Alum. PAC also creates stronger flocs which settle faster than Alum. Up to 99% color removal could be achieved using a 2000 mg/l dose of PAC. Poly electrolyte enhances the color removal efficiency but also increases the Electrical Conductivity (EC) a lot. Oxidization by chlorine removes color, and combination of PAC with chlorine reveals great opportunities. Chlorine removes color but enhances the EC less compared to other chemicals. Mixing sequence of chlorine and PAC affects the color removal efficiency, and better color removal is possible with increased contact time with chlorine by successive mixing of chlorine and PAC with an interval of 15 minutes. Optimum dose was selected by selecting dose within the range of high efficiency. 99% color removal was achieved using a 200 mg/l dose of PAC and a 150 mg/l dose of chlorine.

INTRODUCTION

Textile industries are one of the major users of various chemicals on earth and the largest polluter of potable water (Verma, *et al*., 2011). The wastewater discharged from various textile processes is high in color, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, temperature, turbidity and toxic materials. These effluents produce high concentrations of inorganic salts, acids, and bases in biological reactors leading to increased treatment costs (Gholami, *et al*., 2001). Textile industries generate approximately 200-350 m^3 of wastewater per ton of finished product (Ranganathan, *et al*., 2007) which results in an average pollution of 100 kg COD per ton of finished fabric (Jekel, 1997).

Dye bath and dyed fabric washing water are the primary source of wastewater in a textile dye house (Gao, *et al*., 2007). Wastewater from textile industry contains a number of hazardous pollutants (Zafar, *et al*., 2015). Textile effluents contain different types of dyes, which possess high molecular weight and complex structures, and hence show very low biodegradability (Hsu and Chiang, 1997; Pala and Tokat, 2002; Kim, *et al*., 2004; Gao, *et al*., 2007). Some of the chemicals such as heavy metals either in free form in effluents or adsorbed in the suspended solids are carcinogenic (Tamburlini, *et al*., 2002; Bayramoglu and Arica, 2007) or mutagenic, and generally detrimental to our environment (Arslan, *et al*., 2000; Papic, *et al*., 2004). Also, the accumulation of color is detrimental to sunlight penetration which disrupts the ecosystem of receiving water (Georgiou, *et al*., 2002; Merzouk, *et al*., 2010). Also, several dyes and their decomposition

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derivatives have been proved to be toxic to aquatic life such as aquatic plants, microorganisms, fish, and mammals (Georgiou, *et al*., 2002; Kim, *et al*., 2004; Ustun, *et al*., 2007).

Coagulation processes are widely used for color removal because of their low cost, high speed, and lack of toxic intermediate products. (Kim, *et al*., 2004; Joo, *et al*., 2007). Despite the generation of a considerable amount of sludge, it is still used in developed and in developing countries (Verma, *et al*., 2011) as coagulation is regarded as the most successful pre-treatment (Huang, et al., 2009; Leiknes, 2009). Addition of some chemicals (polyelectrolyte) enhances coagulation by promoting the growth of large, rapid settling flocs and these massive flocs speed up the floc settling velocity, reduce the expense of decolorization and the volume of the settled sludge (Bidhendi, *et al*., 2007). The prime parameters to be considered in coagulation-flocculation are pH and concentration of coagulants such as alum (El-Gohary and Tawfik, 2009) and poly aluminum chloride (PAC) (Sanghi and Bhattacharya, 2005). Mixing speed and time (Gurses, *et al*., 2003), temperature, and retention time (Ong, *et al*., 2005) also influences the color removal efficiency.

RESEARCH METHODOLOGY

The sample was collected over a period of six months June,2015-November,2015 from the Bangladesh Small and Cottage Industries Corporation (BSCIC) industrial city at Tarabo, Narayanganj, Dhaka. The dye is used to color threads that are used to make Jamdani sarees which are very famous in Bangladesh (Fig. 1). The coagulants used are Aluminum sulfate (Alum, $Al_2(SO_4).18H_2O$) and Poly aluminum chloride (PAC, $Al_{13}(OH)_{20}(SO_4)2Cl_{15}$). Poly electrolyte was used as the coagulant aid. Sulfuric acid was used to adjust pH and distilled water was used to prepare all solutions. Bleaching powder containing 20% chlorine was used to add chlorine for chlorination and to prepare the bleaching powder solution (Fig. 2a-2c).

The experimental work was carried out in the Environmental Engineering Laboratory, Department of Civil Engineering, BUET. Jar tests (Fig. 2c) were conducted to determine the effects of solution pH, types of coagulant, coagulant dosage, and chlorine dosage on color removal. A six-paddle stirrer was used and each of the six beakers contained 500 ml of sample. The paddle was rotated at 45 rpm for 1 minute, 25 rpm for 14 minutes, and 10 minutes settling time was allowed. All samples and treated water were filtered (Fig. 2b) before measuring color. pH and EC were measured using pH meter and "EC meter". Color was measured using "HACH DR/2010".

RESULTS AND DISCUSSION

Constituents of raw wastewater

The overall constituents of raw wastewater with their average values are shown in Table 1.

Biological treatment

The wastewater showed very low biodegradability. 16 litres of wastewater was added to 2.7 litres of sludge containing *E. coli* bacteria (Fig. 2a). 800 Pt-Co color was removed after aeration for 6 hours which is 6.5% of raw wastewater color. It occurred due to the dye's high molecular weight (Verma, *et al*., 2011).

Table 1. Constituents of raw waste water.

Sample	pH	EC (mS/cm)	Color (Pt-Co)	Turbidity (NTU)
1	8.5	19.1	12750	80
2	9.7	4.5	13120	75
3	8.8	3.7	10580	85
4	10.1	4.1	11940	64
5	8.2	4.7	12630	72
6	9.4	3.8	13110	87
Avg.	9.1	6.6	12355	77

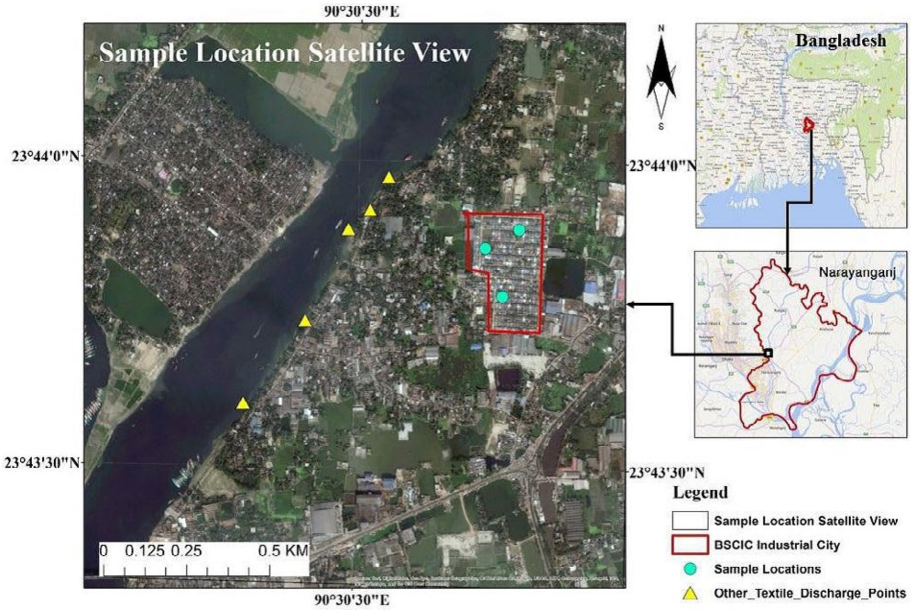

Fig. 1 Sample location and other similar waste generating points

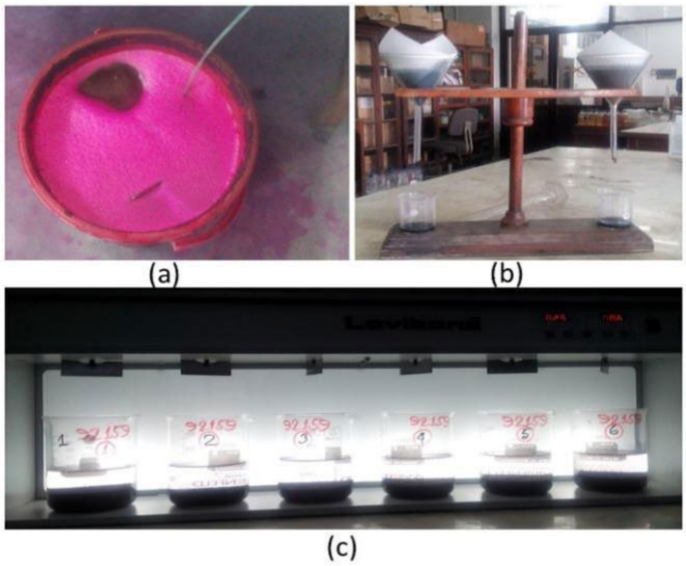

Fig. 2 (a) Biological treatment (b) Filtration before measuring color (c) Chemical coagulation jar test.

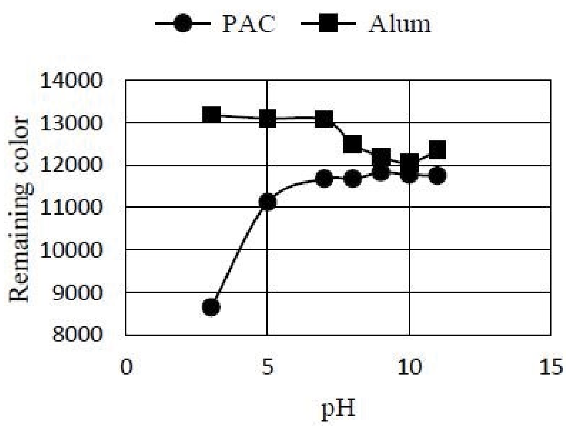

Fig. 3 pH ranges for Alum and PAC.

Effect of pH on color removal

Optimum pH for Alum and PAC were found by adding a fixed dose of coagulants to samples having various pH ranging from 3 to 11. pH was adjusted using sulfuric acid.

It can be seen from (Fig. 3) that PAC gives the same color removal over a wide pH range of 3-11 and also shows very good color removal at pH 3. Optimum pH for Alum is seen to be 10. PAC is more user friendly as it has a wider pH range. This can be attributed to the fact that PAC is pre-neutralized, because of which it has a smaller effect on pH and also reduces the need for pH correction (Verma, *et al.*, 2011).

Comparison of Alum and PAC

PAC gives more rapid flocculation and strong flocs than that of alum at equivalent dosage. This can be attributed to the fact that these coagulants are pre-neutralized, have smaller effects on the pH of water and hencereduce the need for pH correction (Gregory and Rossi, 2001). Flocs created by PAC are stronger and settle more quickly compared to alum. From the test results we have found that PAC shows better color removal than Alum for similar doses (Fig. 4) but also enhances the EC more. pH decreases for both the coagulants. PAC is better suited because Alum requires a higher dose which increases cost.

Optimum dose selection of PAC

From (Fig. 5), It can be seen that a 99% color removal can be achieved at PAC dose 2000 mg/l. But the curve becomes flat after 1000 mg/l of PAC dose indicating that after adding an additional 1000 mg/l of PAC it

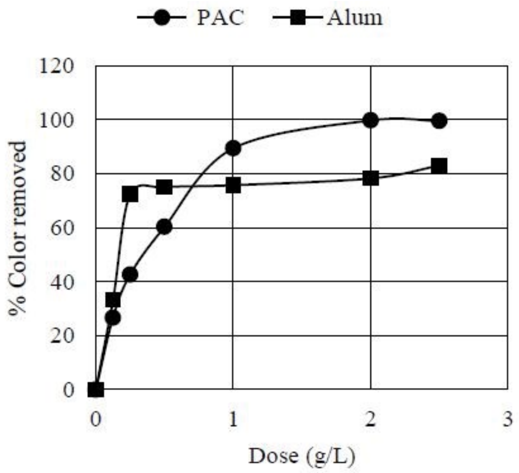

Fig. 4 Comparison of Alum and PAC.

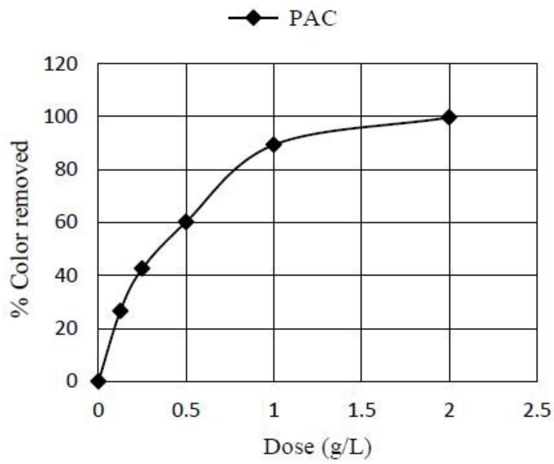

Fig. 5 Color removal with increasing doses of PAC.

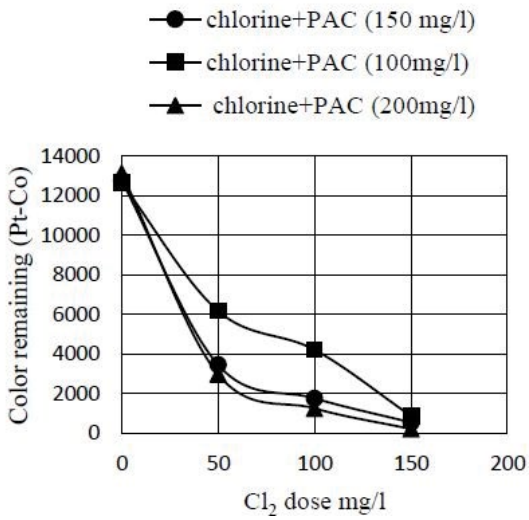

Fig. 6 Dose combination for PAC and chlorine.

only removes 15% more color. The curve is steepest up to dosage 500 mg/l. But it also increases the EC which is a major drawback of using any chemical coagulant.

Effect of poly electrolyte

Poly electrolytes increase the color removal efficiency of PAC when used as the coagulant aid. But it also increases the EC more. A 100% color removal was achieved using 1000 mg/l of PAC and 100 mg/l of poly electrolyte when the pH of the wastewater sample was 7. However, at pH 9 poly electrolyte did not show much impact.

Effect of Cl_2

Chlorine is normally used in wastewater treatment as a disinfectant. Bleaching powder dose is better than BP solution. BP solution may be less effective due to chlorine loss from the solution.

Also increasing contact time with chlorine affects the color removal. Successive mixing of Cl_2 and PAC with an interval of 15 minutes is better at color removal than consecutive mixing of chlorine and PAC.

Dose combination for PAC and chlorine

The graph in (Fig. 6) shows the variation of color with variation of PAC doses from 100 mg/l to 200 mg/l and variation of Cl_2 doses from 50 mg/l to 150 mg/l.

The samples had color 12630 and 12750 Pt-Co. Removal of color increases with increasing Cl_2 doses for a fixed PAC dose. 200 mg/l of PAC and 150 mg/l of Cl_2 reduced the color to 210 from 12630 Pt-Co which is aesthetically acceptable. The samples had EC 3.7 and 4.5 mS/cm. Although performance improves with increasing doses of Cl_2, EC remains largely unaffected.

CONCLUSION

Poly aluminum chloride shows better color removal compared to Alum but also increases the EC more. For this reason, PAC is a better alternative to Alum in treating wastewater containing high color. Poly electrolytes enhance the efficiency of PAC but also enhance EC a lot. Efficiency of polyelectrolyte is pH dependent. Oxidization by chlorine oxidizes organic as well as inorganic matter and removes color. Use of Cl_2 in combination with PAC can be beneficial. But pH of the wastewater will rise a little due to the addition of Cl_2 in combination with PAC dose. Mixing sequence of chlorine and PAC affects the color removal efficiency and better color removal is possible with increased contact with chlorine by successive mixing of chlorine and PAC.

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