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Performance of Anionic Polyelectrolytes for Treatment of Textile Wastewater

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Abstract: Flocculation methods are used in treatment of textile wastewater. The performance of anionic polyacrilamides (A-PAM) and other commercial polyelectrolytes for the treatment of textile wastewater based on molecular charges and weights were investigated. The effectiveness of the A-PAM for the removal of color, metal ions (Cu, Cd, Fe, Cr) and chemical oxygen demand (COD) was determined. Optimum concentrations of flocculants were determined by jar test experiments. For the removal metal ions, optimum dosage of A-PAM was 7mg.l^{-1}. Among commercial polyelectrolytes, Chemfloc 430A had maximum flocculation efficiency for the treatment of textile wastewater. Since the treatment process is considered as physical, therefore effect of temperature on A-PAM flocculation efficiency showed that as the wastewater temperature increased the efficiency of floc formation decreased. In addition, the polyelectrolytes floc partially removed bacteria from the textile wastewater.

Key word: Polyacrilamides · Textile wastewater · COD · Metal ions · Color removal · Chemfloc

INTRODUCTION

Textile industries are characterized as high water-intensive industries and consume excessive amount of water for the pre-treatment (desizing-scouring-bleaching) and dyeing processes [1]. Thus, resulted wastewater contained variety of polluting compounds. The sources of pollutions are naturally impurities extracted from the cotton fibers in chemicals and dye processing [2, 3]. The discharge of textile wastewater to the environment causes visual problems due to the remaining color and also damages the quality of the natural water resources. In fact, the color prevents light penetration and the dyes and their derivatives are carcinogenetic and highly toxic to aquatic life [4, 5].

Nowadays, azo-reactive dyes are the most common dyes used as coloring agents of cellulosic fibers [3, 6, 7]. In dyeing process, about 30% of the dye remains in aqueous phase, mainly in hydrolyzed form, leading to colorization of fibers [7]. The reminder of unused dyes resulted in effluent stream [1, 5]. In general, azo-reactive dyes are less harmful than other types of dyes. However most of them are highly toxic to fish, mammals, as well as to all living organisms [1, 8-10]. Furthermore, azo dyes are non-biodegradable via conventional activated-sludge treatment process and required intense physical/chemical treatments for the absolute removal of toxic compounds from industrial effluents specially textile wastewater [11-14]. So far an effective dye removal process, for the treatment of textile wastewater several techniques for decolorization of textile industrial effluents have been developed [6, 15]. Among all treatment processes, decolorization techniques with the use of coagulants were investigated [16-18]. Chemical coagulation/flocculation techniques, usually combined with activated-sludge treatment, have shown great interests, mainly due to process simplicity and applications [19-22]. Concerning treatment of textile wastewater via biological routes, several investigators have carried out conventional aerobic and anaerobic treatment methods [21, 23]. The performance of these methods such as aerated lagoons and activated sludge systems were unsatisfactory due to easily growth of filamentous bacteria, that may cause sludge flocs settle [8]. Other related textile wastewater problem is its high organic loading shock and effluent toxicity [13]. The conventional system has poor performance and the removal biodegradable toxic substances are limited. The biological treatment of diluted effluent with low toxicity from textile industry has been investigated by several researchers [15, 16]. Numerous physico-chemical processes have been developed such as ozonation, electron-beam and ultrafiltration often in

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combination with coagulation process [19, 24, 25]. Activated-carbon adsorption and nanofiltration techniques are used to remove dyes from the textile wastewater [5]. However, the above methods generate high solid wastes and sludge handling problems. The process elevation for the treatment textile wastewater using coagulants may also generate considerable amounts of sludge which is considered as the disadvantage of physical treatment [26, 27]. Advanced oxidation processes (ozonation, UV/H_2O_2) are based on the generation of hydroxyl radicals, which are highly reactive oxidants, are under investigation [15]. However, high process costs resulted in major process limitations [28]. The main disadvantage of these processes are the production secondary wastes generation that may requires further treatment and solid wastes disposal [4].

In recent years, the removal of toxic heavy metal ions from sewage, industrial and mining waste effluents has been widely investigated. Their presence in streams and lakes are responsible for some serious health problems in human, animals and plants [29]. The suitable techniques for the reduction of heavy metal concentrations in textile wastewater have been investigated [9, 30-32]. Application of modern membrane processes such as reverse osmosis, electro-coagulation, biosorptions via biomass and dried activated sludge for the removal of heavy metals from textile wastewater were seriously considered [3]. Use of dried living cells for the heavy metal removal from textile effluents was also considered [33].

The objective of present research was removal of COD, color, bacteria and heavy metals from textile wastewater using anionic polyacrylamide (A-PAM) in a bench scale. The optimum dosage of coagulants and effect of physical process parameters were investigated.

MATERIALS AND METHODS

Textile Wastewater Characterization: The wastewater used in this research was obtained from a Textile factory. The characteristic and features of the wastewater summarized in Table 1.

Anionic Polyacrylamide: Various anionic commercial grades of polyacrylamides in a wide range of molecular weight and charges were used. The commercial coagulant, organopol 5540 was supplied by Ciba Specialty Chemicals (Basel, Switzerland). Chemfloc 1515C and AN-913SH manufactured by SNF Floerger were supplied by Kempro (Florence, Italy). The properties of the polyacrylamides used are reported in the literature [17].

Table 1: Textile wastewater characterization

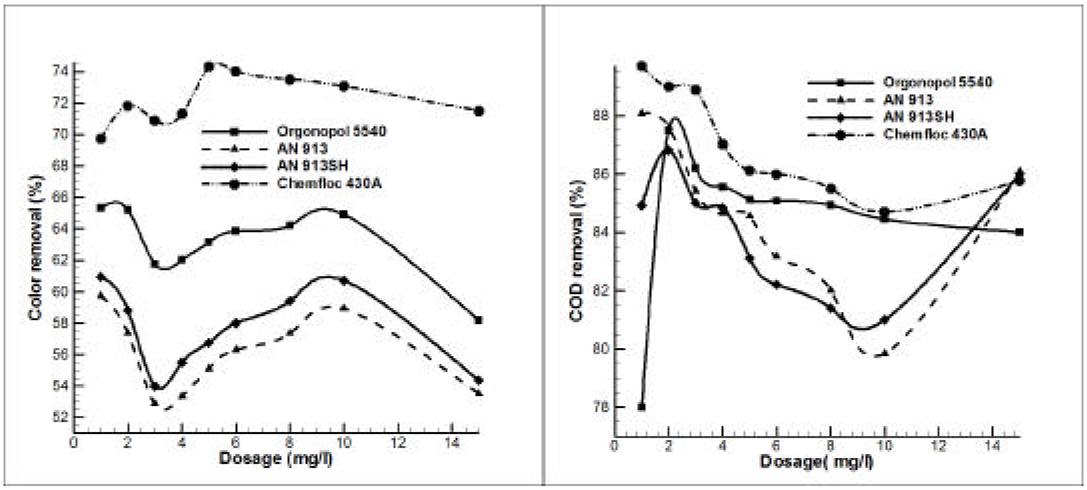
Parameter	Range	Average
pH	8.5-8.7	8.6
COD	950-1100	1025
Color (at 600 nm)	0.26-0.29	0.275
Cu	1.1-1.72	1.41
Cd	0.17-0.53	0.35
Fe	1.5-2.4	1.95
Cr	2.1-2.6	2.35
Temperature, °C	32-40	36
Bacteria	$> 8.5\times10^3$	-
Fecal Coliforms	>1100	-

Experimental Procedure: Jar test procedures were performed with the conventional jar apparatus using 250 ml wastewater samples. The experiments were carried out in jar tests with the A-PAM dosages range of 1-15 $mg.l^{-1}$ while keeping other variables constant. The selected polyelectrolyte dosage was added to 250 ml of wastewater and it was stirred for a period of 3 min at 300 rpm. It was followed by a further slow mixing of 20 min at 50 rpm. The flocs formed were allowed to settle for 30 min.

Analytical Techniques: The concentrations of heavy metals were determined by atomic adsorption (Unicam Model 929, UK). COD determination method was developed based on standard method using Spectrophotometer (UV-2100) at 600 nm [APHA, 2005]. A pH meter model (PH 730, WTW, Germany) was used to determine the pH of sample solution. The fecal Coliforms count in the wastewater and the treated wastewater were conduct based on standard methods [34].

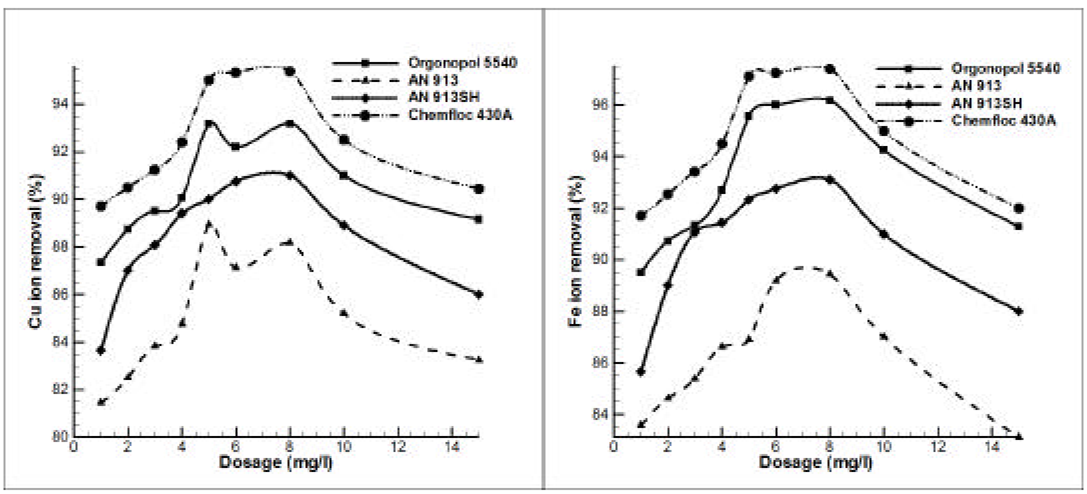
RESULTS AND DISCUSSION

Figure 1a depicts the color reduction was obtained with A-PAM, for all of the four types of A-PAM. It was observed that there was a drop in the percentage of color removal with respect to dosage of 3 $mg.l^{-1}$. This result suggested that the A-PAM may have optimum dosages in the concentration range of 1-15 $mg.l^{-1}$, one obtained at the lower dosage range and the other at the higher dosage range. After the fall, the reduction efficiency of color increases until the optimum value and then decreases towards the following dosage. The highest color removal was 74%, with anionic chemfloc 430A, had high molecular weight and high molecular charge density at dosage of 5 mg. l^{-1}. It was noted that, the optimum dosage obtained for the A-PAM is 5 $mg.l^{-1}$ with Chemfloc 430A.

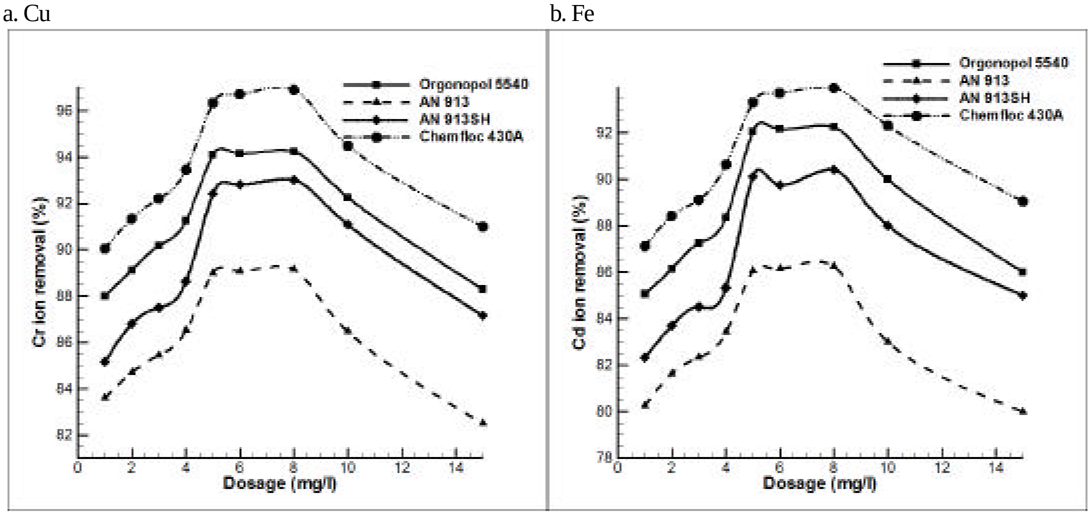


a. Color b. COD

Fig. 1: Color and COD removal efficiency with respect to A-PAM dosage

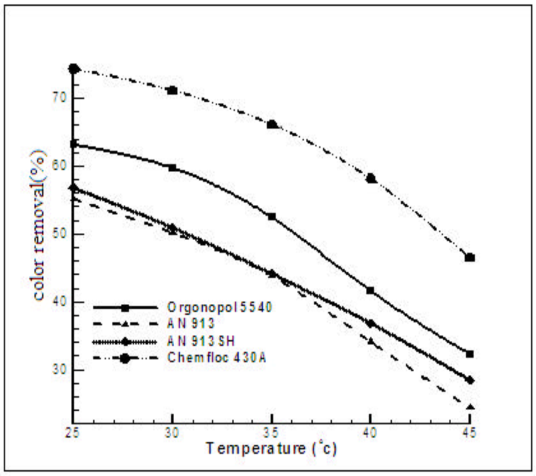


a. Cu b. Fe

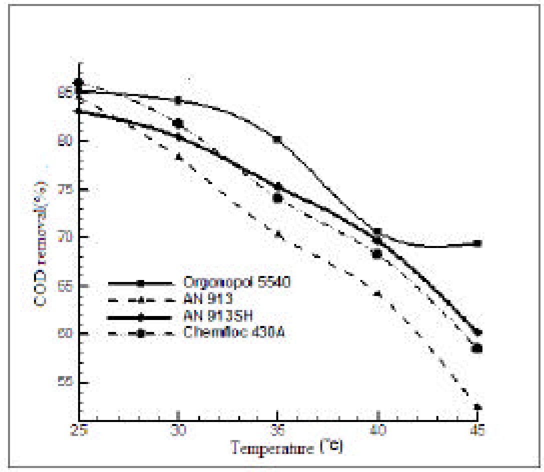


c. Cr d. Cd

Fig. 2: Removal efficiency of metal ions with respect to A -PAM dosage

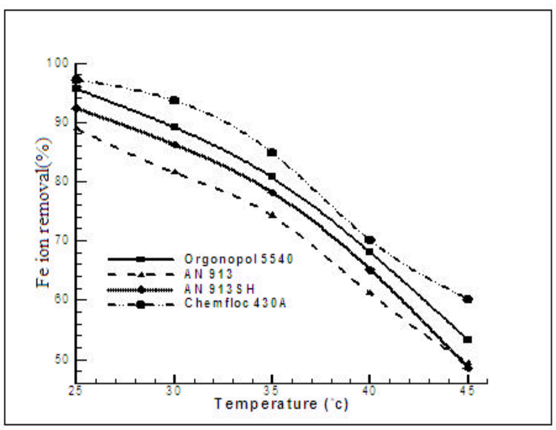


a. Color

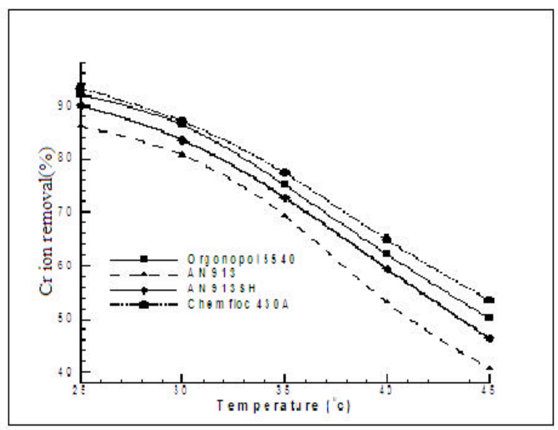


b. COD

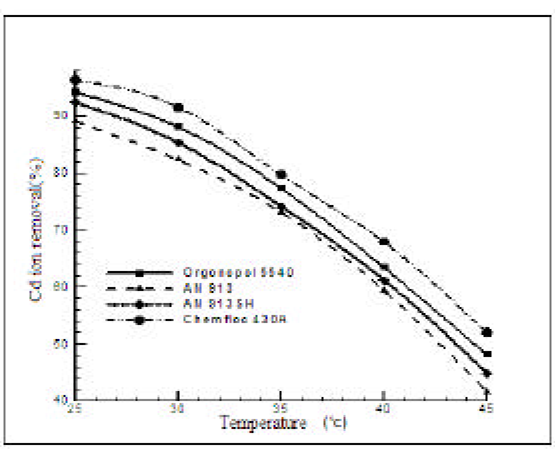
Fig. 3: Effect of temperature on color and COD removal efficiency



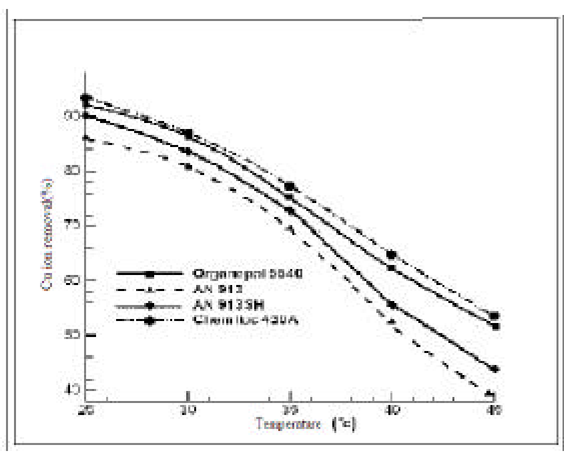
a. Fe



b. Cr



c. Cd



d. Cu

Fig. 4: Effect of temperature on metal ions removal efficiency

Table 2: Bacteria removal by Chemfloc 430A

Dosage (mg/l)	Fecal Coliforms(Number / 100 ml)	Bacteria(Number / 100 ml)
	>1100	$> 8.5 \times 10^3$
5	<650	<5800
15	<342	<3400

Table 3: Bacteria removal by AN 913SH

Dosage (mg/l)	Fecal Coliforms(Number / 100 ml)	Bacteria(Number / 100 ml)
	>1100	$> 8.5 \times 10^3$
5	<750	<7100
15	<460	<4450

Table 4: Bacteria removal by AN 913

Dosage(mg/l)	Fecal Coliforms(Number / 100 ml)	Bacteria(Number / 100 ml)
	>1100	$> 8.5 \times 10^3$
5	<690	<6650
15	<440	<3900

Table 5: Bacteria removal by Organopol 5540

Dosage(mg/l)	Fecal Coliforms(Number / 100 ml)	Bacteria(Number / 100 ml)
	>1100	$> 8.5 \times 10^3$
5	<740	<6750
15	<510	<4100

The COD removal with respect to dosages of four types of A-PAM (Orgonopol 5540, AN 913, AN 913 SH and Chem floc 430A) are shown in Figure 1b.The resulted data indicated that the COD removal efficiency was not influenced by the flocculants' molecular weight or charge density. This behavior suggests that floc break up occurred due to charge reversal and dispersion when there was an excessive or over dosage of the flocculants [35]. The optimum dosages obtained by the A-PAM in terms of COD removal were 2 $mg.l^{-1}$ of orgonapol 5540 and AN913SH, 1 $mg.l^{-1}$ with AN913 and Chemfloc 430A.

Figure 2 shows metal ions (Cu, Fe, Cr and Cd) Removal efficiency with respect to A-PAM dosages. The high performance of metal ions removal was obtained with A-PAM (Chemfloc 430A). The results indicate that the removal efficiency increase by increasing A-PAM dosage to an optimum value between 6-8 $mg.l^{-1}$ but beyond the desired PAM concentration of 10 $mg.l^{-1}$, the removal efficiency reduced as the A-PAM dosage increased. The Chemfloc 430A showed the highest metal ions removal (96-98%). The optimum dosage obtained for the A-PAM was about 5 $mg.l^{-1}$ of Chemfloc 430A. In all experiments and among all metal ions, the highest removal efficiency was related to Fe ions.

The effect of temperature on color and COD removal efficiency is demonstrated in Figure 3. The temperature had negative impact on performance of A-PAM. Maximum COD removal efficiency of 85% was obtained at 25°C. As the temperature increased to 45 °C the color and COD removal efficiency dropped to about 50%.

Figure 4 presents metal ions (Fe, Cr, Cd and Cu) removal efficiency with respect to temperature. The metal ions removal efficiency was inversely proportional to effluent temperature. Maximum metal ions removal efficiency at 25°C was 96%. The metal ions removal efficiency dropped to 45% as the temperature increased to 45°C.

The effect of A-PAM on total bacteria and fecal Coliforms are summarized in Tables 2-5. It was found that A-PAM reduced the fecal Coliforms and total bacteria, but it did not remove the entire population of bacteria in the wastewater. It was recommended that the use of A-PAM quite effective in primary treatment and reduction of bacterial populations in the textile industrial effluents. Among all of the four types of commercial flocculants, Chemfloc 430A was the most effective A-PAM for the removal of bacteria and fecal Coliforms from the textile wastewater.

CONCLUSION

In treatment of textile wastewater using commercial flocculants, it was found that Chemfloc 430A with optimal dosage of 6-8mg.l^{-1} had the highest performance in color, COD and metal ions removal efficiencies. As the effluent temperature increased the removal efficiencies drastically deceased. Temperature had negative impact on COD and metal ions removal efficiency. In addition, application of the A-PAM can reduce the bacteria population in the wastewater steam but absolutely the A-PAM was unable to remove the entire mass of bacteria.

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