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Treatment of Industrial Textile Wastewater Using Polyarcrylamide (PAM) and Polyaluminium Chloride (PAC)

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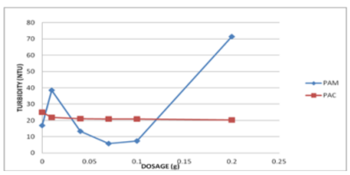
Graphical abstract



Abstract

In this study, polyacrylamide (PAM) and polyaluminum chloride (PAC) was used as a flocculant to treat industrial textile wastewater. The experiment was conducted using a Jar test experiment. The effect of dosage, mixing speed and settling time on the performance of the fflocculation process was investigated. The treated textile wastewater was analyzed by its color removal, turbidity and COD reductions. The results obtained showed that PAM performed better in treating the textile wastewater compared to PAC. PAM recorded the highest reduction of parameters, which are 6 NTU for turbidity, 744 mg/l for COD, and scale less than 0.5 for colour. The best performance of PAM was achieved at dosage 0.07 g and when the flocculation process was conducted at 200 rpm of mixing speed and 30 min of settling time. It was also found that the investigated operating parameters (i.e. dosage, mixing speed and settling time) did not influence much on removal of color and reduction of turbidity and COD when PAC was used as flocculant.

Keywords: Flocculation; polyacrylamide (PAM); polyaluminum chloride (PAC); textile wastewater

Abstrak

Dalam kajian ini, poliacrylamid (PAM) dan polialuminium klorida (PAC) telah digunakan sebagai bahan pengental untuk merawat air sisa industri tekstil. Eksperimen ini telah dijalankan dengan menggunakan ujian balang. Kesan dos, kelajuan percampuran dan masa pemendapan ke atas keberkesanan proses flokulasi telah dikaji. Air sisa yang terawat dianalisis untuk penyingkiran warna, pengurangan COD dan pengurangan kekeruhan. Keputusan yang diperolehi menunjukkan bahawa PAM adalah lebih baik daripada PAC dalam merawat air sisa tekstil. PAM mencatatkan penurunan parameter tertinggi, iaitu 6 NTU untuk kekeruhan, 744 mg / l untuk COD, dan scala kurang daripada 0.5 untuk warna. Prestasi tebaik PAM dicapai pada dos 0.07 g dan apabila proses flokulasi dijalankan pada 200 rpm kelajuan percampuran dan 30 min masa pemendapan. Kajian ini juga mendapati bahawa parameter operasi yang dikaji (iaitu dos, kelajuan percampuran dan masa pemendapan) tidak banyak mempengaruhi ke atas penyingkiran warna, dan penurunan kekeruhan dan COD apabila PAC digunakan sebagai bahan pengental.

Kata kunci: Pengelompokan; poliacrylamid (PAM); polialuminium klorida (PAC); air sisa tekstil

■1.0 INTRODUCTION

Textile wastewater is known as difficult-to-treat pollutants due to the contents contained in the wastewater that hard to be characterized. It is characterized by its high color, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solid (TSS). The textile industry produces large quantities of highly colored effluents that commonly toxic and resistant to destruction by biological treatment method. Besides that, textiles wastewater is a mostly non-biodegradable under both natural and sewage treatment plant conditions that is potentially nuisance to the environment (Ledakowicz *et al*., 2001).

There are various available technologies that can be applied for the treatment of textile wastewater such as ozonation, membrane filtration, activated carbon adsorption and fenton's oxidation [Abu Hassan *et al*., 2008]. However, most of the technologies are suffering from high cost and involved complicated steps [Khouni *et al*., 2011]. Thus, textile industry wastewater treatment by means of simple, cheaper and environmental friendly technologies is still a major challenge.

Flocculation is one of the preferable technologies that have been used widely in wastewater treatment process. It is an economical and effective technique which plays a dominant role in removing suspended particles, dyes and heavy metals [Pal *et al*., 2011; Jiang *et al*., 2010; Crini *et al*., 20064]. In flocculation process, flocculant agent is an important chemical used to make finely divided or dispersed particles aggregate and forming a large flocs which then settled down and separated from the wastewater [Pal *et al*., 2011; Chang *et al*., 2008].

Polyacrylamide (PAM) and polyaluminium chloride (PAC) have been extensively used in wastewater treatment as flocculant agent. In this study, it is aimed to investigate the ability of both flocculants in treating textile industry wastewater. The effect of operating conditions (i.e. dosage, mixing speed and sedimentation time) on the performance of flocculation process was also studied.

■2.0 MATERIALS AND METHOD.

2.1 Materials

The sample of textile wastewater was collected from American and Efird (Malaysia) Sdn. Bhd., Kulai, Johor. The sample was stored in the refrigerator in order to minimize the changes in the characteristics of wastewater. Polyacrylamide (PAM) and polyaluminum chloride (PAC) were purchased from Sigma Aldrich and were used without further purification.

2.2 Jar Test Experiment

The flocculation performance of each flocculants sample (PAM and PAC) was studied by standard jar test experiments. Before fractionated into the beaker, the sample of textile wastewater was mixed homogeneously. An initial reading of turbidity, COD and colour intensity of the sample was taken. Then, 500 mL of the sample was taken to fill in of each 1 L beaker. After that, desired amount of flocculant ranged from 0.01 to 0.2 g was added to the beakers. The mixture was then stirred initially for 3 min at a various mixing speed which ranged from 100 to 250 rpm. Then the stirring speed was lowered to 40 rpm for next 15 min. The flocs then finally were allowed to settle at various settling time (from 15 to 90 min).

Lastly, the supernatant liquid was withdrawn using a pipette from the top inch of supernatant for final reading of turbidity, COD and colour intensity.

2.3 Analytical Analysis

The turbidity was measured by using HACH Ratio/XR turbiditimeter. Meanwhile, the COD test was conducted using spectrophotometer HACH Model DR/2000 by colorimetric method. To measure the colour intensity of the samples, ASTM colorimeter was used.

■3.0 RESULTS AND DISCUSSION

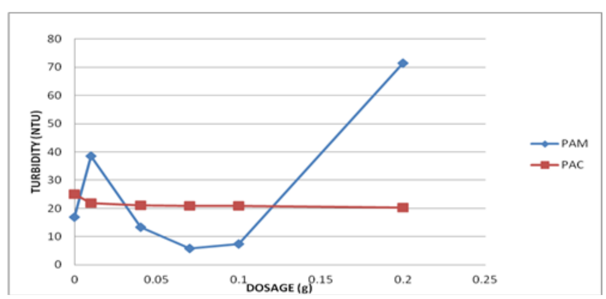
3.1 Effect of Flocculant Dosage on Turbidity, COD and Color Removal

The textile industry wastewater treatment with and without flocculant was analyzed at different dosage of flocculant. Dosage is one of the most important parameters that affect to the performance of the flocculation process. Basically, insufficient or over dosage would result in poor performance in flocculation process. Therefore, it was crucial to determine the best flocculant dosage to ensure effective performance.

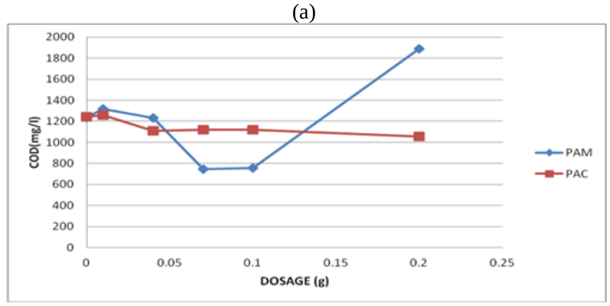
Figures 3.1 (a) and 3.1 (b) show the effect of PAM and PAC dosage on turbidity and COD removal, respectively. As can be seen, the turbidity of the waste just slightly reduced from about 25 to 20 NTU after being treated with PAC. It seems that dosage of PAC range from 0.01 to 0.2 g did not significantly affect to turbidity reduction. By contrast, the turbidity level of the wastewater decreased drastically from about 18 to 5 NTU when the dosage of PAM increased from 0.01 to 0.1 g. Yet, further adding of PAM dosage resulted in increment of the turbidity level.

Similar trend was observed for COD level with the effect of PAM and PAC dosages. The COD level decreased slightly from about 1200 to 1000 mg/ml as the PAC dosage increased from 0.01 to 0.2 g. Meanwhile, the COD level decreased significantly from 1200 to about 780 mg/ml with addition of 0.07 g PAM before level off with addition of more PAM (i.e. 0.1 g). Further adding the PAM dosage up to 0.2 g resulted to increment in COD level to about 1900 mg/ml.

With the increasing dose of the flocculants, the COD and turbidity reduction will be expected to be increased. This is because the flocculants allow neutralization of the anionic charges of the dyes that could bind together and settle with the aid of polymer bridging. However, as more flocculants were further added into the solution, the excess quaternary induced re-stabilization of the suspension and thus decreases the efficiency of the process. Wang *et al*. (2009) claimed that as the flocculant dosage increased, the zeta potential of the particle gradually increased and the compression of electrical double layer was enhanced. When the zeta potential was increased up to zero, the optimal flocculation was achieved. After the flocculant dosage was further increased, the presence of the excessive flocculant will make the suspended particles positively charged, and thus cause mutual repulsion [Ali *et al*., 2009]. In this case, a further increase in flocculant dosage would result in the re-dispersal of flocs and the reduction in COD and turbidity removal. It shows that 0.0.1 to 0.1 g was sufficiently enough in this study. Generally, PAM performed better than PAC in removal of turbidity and COD of the textile wastewater. It is believed due to longer polymer chain length owned by PAM as polymers with longer chains would be more efficient than the shorter chains [Ghosh *et al*., 2010]. Its long chain adsorbed on the surface of one colloid particle may be adsorbed onto the surfaces of the other ones, and thus two or more particles aggregated together, resulting in flocculation through ‘‘bridging’’. Thus, resulting to more particles attachment to the PAM compared to PAC



(a)



(b)

Figure 3.1 Effects of flocculants dosage on (a) COD level (b) turbidity level

Table 3.1 shows an ASTM colour scale of textile industry wastewater after being treated with PAM and PAC at different dosages. The scale of the colour is between 0.5 to 8.0 ASTM. The scale of 0.5 refers to the lightest while 8.0 refers to the darkest. As can been seen, increasing the PAM dosage from 0.01 to 0.1 g reduced the scale of colour from 3.5 to 0.5. Further adding the dosage to 0.2 g resulted to increment in colour scale to 4 which is higher than the initial colour of the textile wastewater. Meanwhile, treating the textile wastewater using PAC resulted to decrement in colour which is from 3.5 to less than 1.5 regardless of the dosage used. It shows that, for PAC, low dosage (i.e 0.01 g) was sufficiently enough to remove the colour of the wastewater.

Table 3.1 Effect of flocculant dosage on ASTM colour scale of textile industry wastewater

Colour Intensity (ASTM)	Dosage (g)					
	0.00	0.01	0.04	0.07	0.10	0.20
PAM	3.5	3.5	0.5	<0.5	0.5	4.0
PAC	3.5	<1.5	<1.5	<1.5	<1.5	<1.5

3.2 Effect of Mixing Speed on Turbidity, COD and Color Removal

Figures 3.2 (a) and 3.2 (b) illustrates the effect of mixing speed on turbidity and COD level of textile wastewater, respectively, after being treated with PAM and PAC. The dosages of PAM and PAC were kept constant at 0.07 g. The dosage of 0.07 g was chosen as it appeared to be the best dosage in reducing color, COD and turbidity of the sample as discussed early in section 3.1. The other parameters of the flocculation process were the same as in section 2.2 except the mixing speed. By using PAM as the flocculant, the turbidity level increased drastically from 18 to 58 NTU when the wastewater solution was mixed at 100 rpm. Increasing the mixing speed to 150 rpm resulted to dramatic decrease in turbidity to about 6 NTU. Increasing more mixing speed to 250 seems did not influence much on the turbidity level. However, when PAC was used as the flocculant, the turbidity of the wastewater increased slightly from 18 to 28 NTU when the mixing speed increased from 100 to 250 rpm. Mixing speed (i.e. rapid mixing) is considered one of the important stages in flocculation process. In this stage, the destabilization reactions occurred whereby the primary floc particles are formed. This explained the decrement in turbidity level when the mixing speed is increased. Nevertheless, extremely or excessive mixing in flocculation would destroy the previously formed polymer bridges and result in the restabilization of particles (Hao *et al*., 2006).

Based on Figure 3.3 (b), the value of COD decreased dramatically from 1230 to about 730 mg/ml for PAM from 100 to 150 rpm. Ali and Singh (2009) reported that lower rate of mechanical mixing rate would have better flocculating properties. From 200 to 250 rpm, the value of COD was constant due to the homogeneous dispersion of flocculant.

In other hand, when PAC was used as the flocculant, the turbidity and COD of the wastewater were almost constant with the increasing of mixing speed. This observation probably because the dosage used for PAC was not at the best dosage for treating textile wastewater.

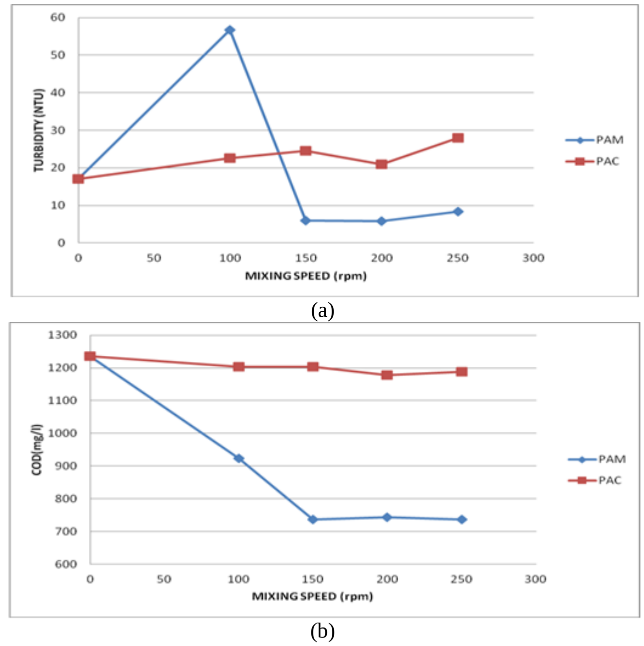


Figure 3.2 Effects of mixing speed on (a) COD level (b) turbidity level

Table 3.2 shows the effect of mixing speed on colour removal of textile wastewater. As can be seen, in general, PAM performed better in colour removal as compared to PAC. The colour of the treated wastewater showed scale less than 0.5 when treated with PAM especially when high speed of mixing was applied (i.e. 150 to 250 rpm). However, colour removal of the wastewater did not influence by the mixing speed when PAC was applied. The reduction of colour maintained at 2.5 regardless of the mixing speed.

Table 3.2 Effect of mixing speed on ASTM colour scale of textile industry wastewater

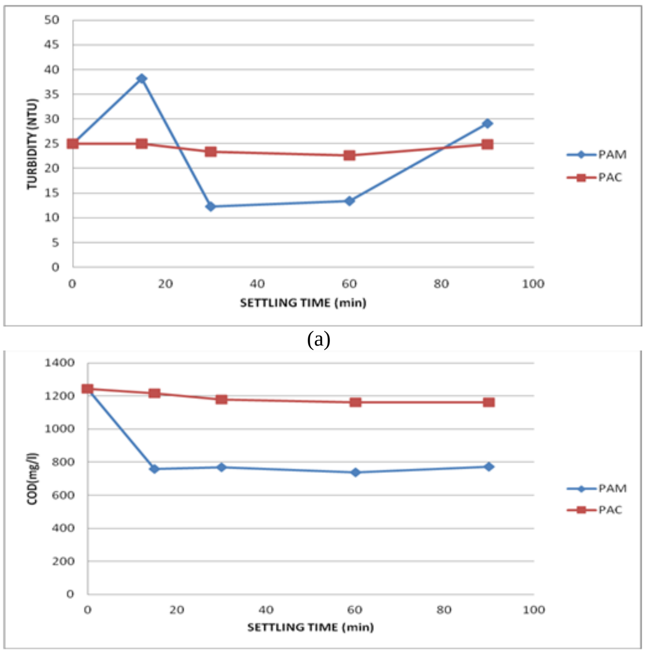
Colour Intensity (ASTM)	Mixing Speed (rpm)				
	0	100	150	200	250
PAM	3.5	0.5	<0.5	<0.5	<0.5
PAC	3.5	2.5	2.5	2.5	2.5

3.3 Effect of Settling Time on Turbidity, COD and Color Removal

In the flocculation process, the settling time of the formed flocs is also important since this parameter influenced the design of the settling tank and flow (and consequently the overall investment and operating costs). The effect of settling time (i.e. 15 to 90 min) on colour removal and turbidity and COD reductions was analyzed at constant dosage and speed mixing of 0.07g and 200rpm, respectively.

Figure 3.3 (a) shows the effect of settling time for turbidity of textile industry wastewater after being treated with PAM and PAC. The turbidity level seems fluctuated with settling time when PAM was applied as flocculant. At low settling time (i.e. 15 min), the turbidity increased from 25 to 38 NTU. Then, the turbidity was down to 12 NTU when the solution left to settle for 30 min. As the settling time increased to 90 min, the turbidity increased to 30 NTU. It seems that setting time from 30 to 60 min was sufficiently enough to settle the flocs. If the settling time was too long, the flocs formed might be break apart, thus, re-stabilizes the suspension of the particles. For PAC, the turbidity level seems did not significantly influence by the settling time.

Figure 3.3 (b) illustrates the effect of settling time on COD level of textile wastewater after being treated with PAM and PAC. Overall, both flocculants showed similar trend towards settling time. At settling time of 15 min, the COD level decreased from about 1210 to 780 mg/ml and from 1210 to 1200 when PAM and PAC were applied, respectively. Then the COD value level off with further increment in settling time. The results indicated that, settling time of 15 min was sufficiently enough to reduce the COD level.



(a)

(b)

Figure 3.3 Effects of settling time on (a) COD level (b) turbidity level

Table 3.3 shows the effect of settling time on colour removal of textile wastewater after being treated with PAM and PAC. As can be seen, PAM performed better in colour removal as compared to PAC. The colour of the treated wastewater showed scale less than 0.5 and 1.5 when PAM and PAC were applied, respectively. The results showed that the range of settling time used in this study (15 to 90 minutes) for the flocculation process seems did not give impact on the color removal. Most probably, 15 minutes were sufficiently enough to settle all the flocs formed.

■4.0 CONCLUSIONS

The performance of flocculation process was affected by dosage, mixing speed and settling time. PAM has showed better performance in treating textile industry wastewater compared to PAC under the ranged of parameters conducted in this study. From the results obtained, the best performance for PAM was at 0.07g, 200 rpm of mixing speed and 30 minutes of settling time. Under this condition, PAM recorded the highest reduction of parameters, which are 6 NTU, 744 mg/l and <0.5 ASTM for turbidity, COD and colour intensity, respectively. The results also revealed that under the range of the study, the flocculation process did not significantly affected by dosage, mixing speed and settling time when PAC was applied as flocculant.

Acknowledgement

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