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Decolorization of reactive dyeing wastewater by Poly Aluminium Chloride

Nghiên cứu khử màu nước thải nhuộm hoạt tính bằng Poly Aluminium Chloride

Research article

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Color removal of some reactive dyes (Blue 19, Black 5 and Red 195) using a local Poly Aluminium Chloride (PAC) was investigated with Jar-test experiment. The dyes were removed (above 94%) at optimal pH 7 (Red 195) and pH 10 (Blue 19 and Black 5). The PAC dosage of 220 mg/L (Blue 19 and Black 5) and 160 mg/L (Red 195) were found to be best for decreasing dye up to 50 mg/L (Black 5, Red 195) and 100 mg/L (Blue 19). Reaction time and agitation speed also affected the decolorization process. That result indicates that Vietnamese PAC can be a robust and economical coagulant for discolorization of reactive dyeing process.

Chất keo tụ Poly Aluminium Chloride (PAC) sản xuất tại Việt nam được ứng dụng khử màu của một số màu nhuộm hoạt tính phổ biến (Blue 19, Black 5 and Red 195) trên thí nghiệm Jar-test. Kết quả cho thấy màu bị loại gần như hoàn toàn (trên 94 %) tại pH 7 (Red 195) hoặc 10 (Blue 19 và Black 5). Nồng độ PAC đạt hiệu quả tốt nhất tại 220 mg/L (Blue 19 và Black 5) và 160 mg/L (Red 195) ứng với nồng độ màu 50 mg/L (Black 5, Red 195) hay 100 mg/L (Blue 19). Thời gian phản ứng, tốc độ khuấy cũng có tác động đến hiệu suất khử màu. Kết quả nghiên cứu cho thấy PAC sản xuất tại Việt nam không những là một chất keo tụ tốt mà còn rất kinh tế cho việc khử màu hoàn toàn trong nước thải nhuộm hoạt tính.

Keywords: coagulation, reactive Blue 19, reactive Black 5, reactive Red 195

1. Introduction

In Viet Nam, the textile and dyeing industries can be considered as one of the most important areas. However, wastewater effluent from this industry represents a significant environmental problem due to containing synthetic dyes (especially reactive dyes) which are resistant to biodegradation process (Gottlieb et al., 2003, Sadhasivam et al., 2005).

In recent years, a lot of modern techniques have successfully been applied for removing color from textile effluents such as ozonnation, electrocoagulation, adsorption, membrance, sonolysis, etc. (Alinsafi et al., 2005; Kim et al., 2005; Lee et al., 2006). Nonetheless, most of these techniques are limited by methods, costs or difficulties in operation. Hence, they could not be employed to treat real dyeing wastewater.

Coagulation is one of traditional techniques. It normally uses inorganic coagulants such as aluminium, ferric chloride, etc. to destabilize pollutant particles. Thus, the particles are removed by sludge forming. However, traditional coagulants do not seem to be significantly effective on removing organic substances (Shouli et al., 1992).

In the last few years, a number of studies have focused on poly aluminium chloride (PAC), a new generation coagulant which completely removes color from dyeing wastewater (Assadi et al., 2013; Golob et al., 2005; Joo et al., 2007).

In Vietnam, PAC on market is mostly imported from Asia, particularly from China, India or Korea with unclear quality. Lately, some PACs from local companies were used for textile treatment but little information was reported. In addition, there are huge reactive dyes used on dyeing process with difference in "color chromosome". Therefore, the aim of this study is to evaluate the possibility of utilizing local PAC for the color removal of common used reactive dyes: reactive Blue 19 (RB19), Black 5 (RB5), and Red 195 (R195) by investigating the influence of the following factors: PAC dosage, initial pH, initial dye concentration, agitation speed, and reaction time in Jar-test experiments.

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2. Materials and methods

2.1. Materials

2.1.1. Coagulant stock

PAC was supplied by South Basic Chemicals Company Ltd-Vietnam with bulk density of 0.5 g/cm, specific gravity 1.31 kg/L, chemical composition 15% w/w Al_2O_3.

The coagulant stock solution (5,000 mg/L) was achieved by completely dissolving 0.5 g PAC powder into 100 mL distilled water, and the solution was diluted to appropriate concentrations (80 - 280 mg/L) before using.

2.1.2. Reactive dye stock

Reactive Blue 19 (RB19) and Black 5 were purchased from Sigma-Aldrich Company while the reactive Red 195 (R195) is the product of Oh-Young, a Korean company. All dyes were directly used without purification and their characteristics were described in Table 1.

One gram of dyes was directly diluted in 1,000 ml hot water at pH 11 for an hour to get a dye stock solution 1,000 mg/L in the "hydrolyzed" form. Other dye concentrations varying between 10 and 160 mg/L were obtained by dilution of this stock.

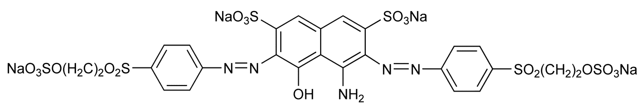
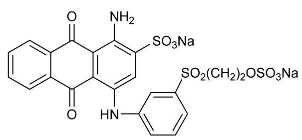
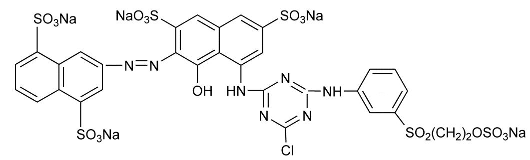
2.1.3. Procedures

Coagulation studies were conducted using Jar-Test apparatus (Stuart flocculator sw6) with six beakers (one liter capacity each) which is based on the ASTM D2035-13 standard (ASTM, 2013). The effect of pH, initial dye concentration, PAC dosage, reaction time and agitation speed on dye removal were performed by mixing 10 mL solution containing different PAC doses with 500 mL of different dye concentration.

After 2 hours of coagulation process, spectroscope analysis of samples was carried out using spectrophotometer UV-VIS GENESYS 10, Thermo Fisher Scientific Inc., at suitable wavelengths of maximum absorption (λ_{max}) given in Table 1.

Other water analysis followed standard methods and the results presented here are the mean values ± standard deviations (SD).

Table 1. Characteristics of used dyes

Dye (C.I. name)	Mw (g mole^{-1})	λ_{max} (nm)	Molecular structure
Reactive Black 5	991.82	599	
Reactive Blue 19	626.54	590	
Reactive Red 195	1136.30	542	

3. Results and discussion

3.1. pH influence

It has been established that pH plays an important role in the performance of dye coagulation process because it could affect the specialization of coagulant and the hydrolysis behavior of dye (Golob et al., 2005, Joo et al., 2007). A series of experiments were carried out by varying the pH between 3 and 12 using 0.5 N NaOH (or HCl) solution, with other constant factors: PAC dosage 100 mg/L, initial dye concentration (IDC) 100 mg/L, time contact of 30 min, and agitation speed 60 rpm. As can be observed in Figure 1, pH strongly influenced removal of the reactive dyes.

The best removal results for RB19 and RB5 were 40 and 32% at pH 7, respectively. This might be caused by the effect of hydrolysis rate of the dye on decolorization process. At alkaline pH, the hydrolysis of the dye is faster than the coagulation process. The hydrolysed dye can not bind on PAC. At acidic and neutral pH, the hydrolysis is slow and the coagulation process is more effective.

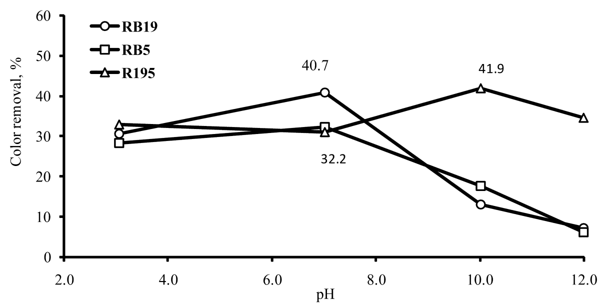


Figure 1. Effect of pH on color removal of RB 19, RB5 and R195 using PAC

Whereas, the optimal yield achieved was 41.81% at pH 10 in the case of R195. A possible explanation might come from the fact that R195 has additionally a reactive chlorine atom at the triazine ring which may react better with PAC at pH 10 than the vinyl sulfone group of RB5 and RB19. The poor yield even at optimum pH for all studied dyes may be because of inadequate PAC dosage for color removal (Assadi et al., 2013). And, the positive charge caused by PAC could not be enough to destabilize the dye particles.

3.2. Effect of agitation speed

The effect of agitation speed on the decolorization process study was performed by changing the speed (30–90 rpm) of stirrers in slow mixing phase while maintaining constannt the optimal pH value (10 for RB19, RB5 and 7 for R195), the initial dye concentration (100 mg/L), PAC dosage (100 mg/L), and contact time (30 min). The result is shown in Figure 2.

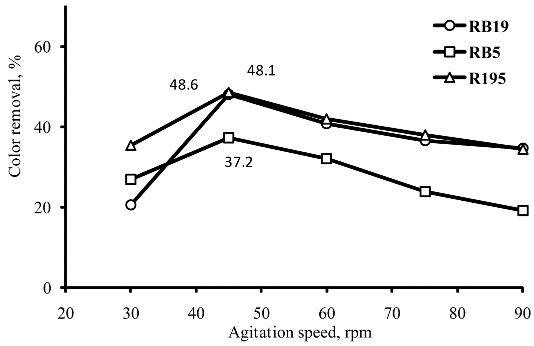


Figure 2. Influence of agitation speed on dye color removal of RB19, RB5 and R195 using PAC

As can be seen in Figure 2, the highest color removal percentage of PAC can be obtained in all dyes solutions with 45 rpm as compared to the other speed. This result corresponds to the agitation speed in the previous report (Tatsi et al., 2003). Hence, the agitation speed of 45 rpm (PAC) was chosen for the next study.

3.3. Effect of initial dye concentration

Several experiments with different initial dye concentrations (IDC) in the range of 10–140 mg/L were conducted by keeping other parameters constant such as optimal pH (7 and 10), agitation speed (60 rpm), PAC dosage (100 mg/L), and contact time (30 min). Figure 3 shows the plot of removal percentage of the dyes versus the IDC. According to the data, with increasing of IDC, the removal efficiency decreased. However, at IDC of RB5 and R195 ranging from 10 mg/L to 50 mg/L, the decolorization efficient trends are more stable than other ranges. Hence, IDC 50 mg/L was selected for sequence study of RB5 and R195.

A similar situation was also found in RB19, the suitable IDC is 100 mg/L.

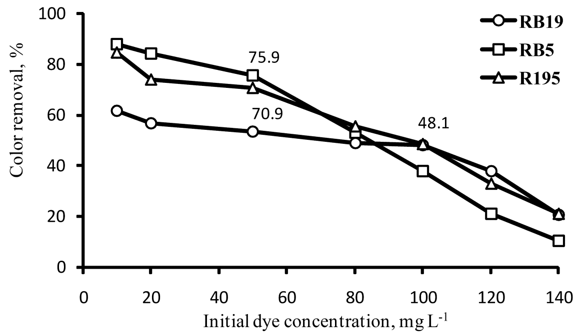


Figure 3. Effect of dye concentration on PAC coagulants for RB19, RB5 and R195

3.4. Effect of coagulant dosage

The following experiments were carried out at constant conditions: optimal pH (7 and 10), agitation speed 60 rpm, initial dye concentration 50 mg/L (RB5 and R195) and 100 mg/L (RB19), and contact time 30 min with different PAC dosage: 80-280 mg/L.

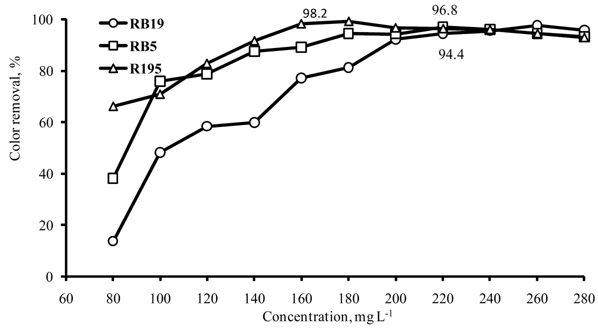


Figure 4. Effect of PAC concentration on dye removal efficiencies

Figure 4 notes that PAC achieved effectiveness for all the dyes. As expected, the increasing in PAC dose had a significant positive impact on the accomplished decolorization. There was approximately linear relationship between PAC dose and dye removal by electrostatic attraction of PAC and dyes. Therefore, 220 mg/L (RB19 and RB5) and 160 mg/L (R195) were chosen for further experiments.

The results confirm that PAC is the high positive-charged and very effective polymeric for dye removal (Assadi et al., 2013; Klimiuk et al., 1999).

3.5. Effect of contact time

At this stage, the effect of contact time between PAC and dye solutions in slow mixing phase of decolorization process was performed by increasing times (15–60 min) under constant parameters at equilibrium condition.

It is apparent from Figure 5 that with an increase in the contact time, the dye removal efficiency rises up for all dyes (94.4%, 98.2%, and 97.2% for RB19, R195 and RB5, respectively). Nevertheless, beyond the optimum contact times of 30 min (RB19, R195) and 45 min (RB5), the removal efficiency becomes constant or slightly decreases. This may be due to restabilization phenomenon (Klimiuk et al., 1999).

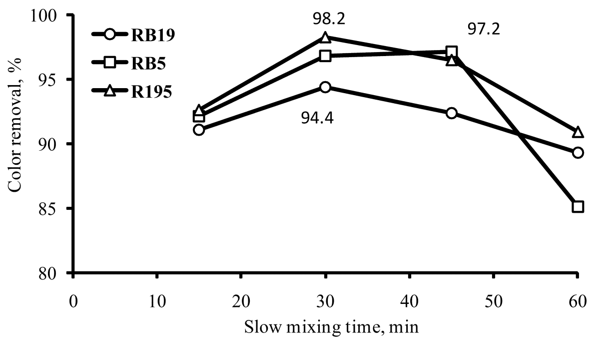


Figure 5. Color removal of studied dyes by PAC at various contact time

4. Conclusions

Three azonic reactive dyes (RB19, RB5 and R195) were efficiently removed (above 94%) using the Vietnamese PAC. The high color removal may be explained by the electrostatic attraction of the anion dye and positive PAC. pH critically influences the treatment capacities and the optimal pH is 7 (RB5 and RB19) and 10 (R195), respectively. Based on these results, PAC from Vietnam can be used as an efficient and low cost coagulant for color remove from reactive dye solution.

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