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Natural auxiliary coagulants - perspectives for the treatment of textile wastewater

Chất trợ keo tụ tự nhiên - tiềm năng ứng dụng trong xử lý nước thải dệt nhuộm

Research paper

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Applying chemical coagulants and auxiliary coagulants in wastewater treatment has become more popular in Vietnam. Although the efficacy of chemical coagulants has been well recognized, there are disadvantages associated with the use of these products, such as the inefficiency at low temperatures, increasing the residual cation in solution, causing health problems and distribution water, relatively high cost, producing high volume of sludge. Thus, it is desirable to replace these chemical coagulants for products that do not generate such drawbacks, such as natural polymers. In this paper, the authors conducted experiments by using natural auxiliary coagulants extracted from seeds of *Cassia fistula* (gum MHY) and chemical polymer as auxiliary coagulation to treat textile wastewater with basic polluted parameters: pH = 9.0; COD = 800 mgO_2/L, color = 750 Pt-Co. The Jartest experiment results showed that the process efficiency of chemical polymer and gum MHY is not so different, with the COD removal efficiencies of 60.3% and 59.7%; the color removal efficiencies of 87.3% and 87.1%; the SS removal efficiencies of 93.2% and 92.6%. There-fore, coagulants obtained from gum MHY can be applied as the alternatives for chemical polymer in the process of treating textile wastewater.

Các ứng dụng chất keo tụ và chất trợ keo tụ hóa học trong xử lý nước thải ngày càng trở nên phổ biến tại Việt Nam. Mặc dù có nhiều ghi nhận về hiệu quả xử lý của chất keo tụ hóa học, phương pháp xử lý này vẫn tồn tại một số nhược điểm như hiệu suất xử lý thấp ở nhiệt độ thấp, nước thải sau khi xử lý còn chứa nhiều hóa chất tiếp tục làm ô nhiễm nguồn tiếp nhận, chi phí xử lý cao và tạo ra nhiều bùn thải. Do đó việc tìm kiếm một phương án xử lý thay thế, chẳng hạn sử dụng polymer tự nhiên, có thể khắc phục những nhược điểm này là rất cần thiết. Nghiên cứu này tiến hành đánh giá hiệu quả sử dụng chất trợ keo tụ sinh học ly trích từ hạt trái Muồng Hoàng yến (Cassia fistula) và chất trợ keo tụ hóa học để xử lý nước thải dệt nhuộm có các thông số ô nhiễm cơ bản: pH = 9,0; COD = 800 mgO_2/L, độ màu = 750 Pt-Co. Các thí nghiệm trên bộ Jartest cho thấy hiệu quả xử lý nước thải dệt nhuộm của chất trợ keo tụ gum Muồng Hoàng yến và chất trợ keo tụ hóa học không khác biệt có ý nghĩa với hiệu suất xử lý COD lần lượt là 60,3 và 59,7%; hiệu suất xử lý độ màu là 87,3 và 87,1%; xử lý SS là 93,2 và 92,6%. Kết quả nghiên cứu cho thấy gum hạt Muồng Hoàng yến có thể sử dụng làm chất trợ keo tụ thay thế chất trợ keo tụ hóa học trong xử lý ô nhiễm nước thải dệt nhuộm.

Keywords: biological coagulant, *cassia fistula* seed, chemical coagulant, textile wastewater

1. Introduction

Nowadays, the textile industry of Vietnam has been extensively developed, providing diversified and multi-colorful products with high quality for increasing needs of consumers. This industry also attracts huge amount employments and promotes an increment in export volume of the country. However, textile is one of the fields that need massive use of water as well as chemicals and result in a variety of complex wastewater. The composition of wastewater from textile varies with different factors including the production factory, the type of cloth and dyeing environment (acidic, basic or neutral). Usually, in the dyeing process, absorption efficiency of dye ranges from 60 to 70% and the

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excess dye is in the original state or other decomposed ones. In addition, several electrolytes, surfactants, environment-making substances, etc. are also present in the wastewater (Le Xuan Hong, 2006). As a result, the textile wastewater often appears in deep color. Therefore, it is necessary and essential to solve the pollution of textile wastewater (Pham Ngoc Ho, 2009).

Different methods have been used to pre-treat the wastewater of textile industry. Among them, phytochemical method, using the chemically originated substances to treat the pollution is considered as one of the most popular methods. However, the excess of these substances after the treatment may, in its turn, contaminate again the treated water. Consequently, the study to find the alternative compounds is also crucial.

There is such of potential coagulants in Vietnam, in which *Cassia fistula* seed has been proved on high ability in industrial wastewater treatment. Moreover, these seeds would be safer for the environment in comparison to the chemical sources.

The study "Natural auxiliary coagulants - perspectives for the treatment of textile wastewater" is topical and relevant in this circumstance. Results from the study showed that it is able to utilize biological auxiliary coagulants to sub-stitute the chemical ones in the treatment of textile waste-water to improve the quality of water environment.

2. Methodology

2.1 Materials

Collect wastewater for study:

- Wastewater from factory 1 was taken at the discharge point of Phong Phu Textile Factory, Tang Nhon Phu ward, District 9, Ho Chi Minh city.

- Wastewater from factory 2 was taken at TK VINA Ltd Company, Bac Tan Uyen ward, Binh Duong province.

Chemicals: using the chemical coagulants and auxiliary coagulants including:

- PAC: $Al_n(OH)_mCl_{n-m}$ and polymer $(-CH_2CHCONH_2-)_n$ which are industrial grade.

- Gum extracted from *Cassia fistula* seeds collected in Binh Duong province. The gum is in solid state with the extraction efficiency is 150 g gum/1.4 kg seed. The extraction was done following reported pro-cedure in previous studies by Pal & Singh (2014) and Bhatnagar *et al*. (2013).

Instruments: the experiments were carried out on the lab-scale Jartest apparatus. The Jartest consist of 6 paddles simultaneously rotating at the same speed. The speed was adjustable through the gear. The time was controlled to find the best operating parameters.

2.2 Experimental setup

2.2.1 Selecting the parameters for coagulation

Nguyen Thi Lan Phuong (2008) recorded that, in a standard Jartest experiment, the stirring time of 2 - 3 mins is considered as quick (stirring speed is in the range of 100 - 200 rpm) while 20 - 30 mins is considered as slow stirring time (stirring speed ranges from 20 - 50 rpm). In addition, sedimentation time usually varies from 30 - 60 mins.

All following experiments were performed on Jartest in which samples were put in 6 beakers with the volume of 1 L. Each beaker contained around 500 mL of wastewater. The quick stirring speed was fixed at 120 rpm in 2 mins meanwhile the slow one was 40 rpm keeping for 25 mins. The sedimentation time was 30 mins.

According to Huynh Long Toan (2014), the used amount of coagulants may vary from 200 - 1000 mg/L for wastewater and 20 - 100 mg/L for drinking water. In this study, 150 - 300 mg/L was chosen for the experiments to find the best amount of PAC which plays the role of the coagulant (the step between samples is r = 50 mg/L). In addition, the necessary concentration of the auxiliary coagulant usually falls in the range of 1.0 - 5.0 mg/L (Tran Hieu Nhue, 2001). Then, the auxiliary coagulant concentration of 5.0 mg/L was used for the study.

2.2.2 Methods

Sample collection and data analysis

Sample collection: the wastewater for all experiments were collected 10 times (5 times for each factory). The uniform timepoint of collection is at 10 am.

Sample analysis: all samples were analysis according to the procedure regulated by current Vietnamese standards.

Data analysis: raw data were analyzed using MS Excel and statistics were done with SPSS.

Experiments

Experiment 1: determining the optimum amount of PAC

- Purpose: to find the optimum PAC quantity for the coagulation of the samples. The obtained result of this experiment would be used for the succeeding ones.

- Experimental procedure is as follows:

  - Step 1: 6 beakers were put on the Jartest apparatus, each beaker contained 500 mL of wastewater.

  - Step 2: quickly stirred the wastewater in 2 mins with the stirring speed of 120 rpm. Depending on the experiment, various chemicals with suitable amount were added into the beakers. Then, slowly stirred with a speed of 40 rpm for 25 mins. The solutions then were settled naturally in 30 mins.

- Step 3: observed the sedimentation of the sludge, the clear water was decanted for pH and color intensity measurements as well as the analysis of the SS and COD measures.

Each experiment was repeated for 5 times. After data analysis, suitable amount of PAC was obtained as X (mg/L PAC). The arrangement of samples on the Jartest was described in Table 1.

Table 1. Sources of PAC applied to the study

Beaker	Dosage (mg)	Notes
M_{00}	0	Initial sample
M_{10}	0	Control sample
M_{11}	150	
M_{12}	200	
M_{13}	250	
M_{14}	300	

Experiment 2: determining the proper amount of *Cassia fistula* gum as the auxiliary coagulant (to treat the textile wastewater collected from two factories).

- Purpose: to compare the efficiency on improving the quality of wastewater of the auxiliary coagulants including the natural *Cassia fistula* gum and chemical-ly synthesized polymer.

- Procedure: the experimental setup was similar to the one in the experiment 1. Herein, the used amount of PAC was the best one obtained from the previous experiment while the amount of polymer and biological *Cassia fistula* gum were fixed at 5.0 mg/L. The recorded results would be the difference in treatment efficiency when combining PAC with polymer or *Cassia fistula* gum.

3. Results and discussions

3.1 Analysis of input textile wastewater

The results showed that the wastewater from both factories possessed an extremely high COD content and color intensity in comparison to both standard QCVN 13-MT:2015/ BTNMT - National technical regulation on the effluent of textile industry and standard QCVN 40:2011/ BTNMT - National technical regulation on industrial wastewater. Therefore, it is essential to improve the quality of the wastewater before discharging to the receiving sources.

Table 2. Analytical results of input wastewater

Parameter	1st factory	2nd factory	QCVN 13:2015/ BTNMT (col. A)
pH	9.0	6.5	6 - 9
COD (mg/L)	800	910	75*
Color (Pt-Co)	750	1035	50*
SS (mg/L)	162	512	50**

*: applied for new factory
**: QCVN 40:2011/BTNMT (column A) - National technical regulation on industrial wastewater

3.2 Determining the optimum amount of PAC

As showed from Figures 1, 2 and 3, the treatment of M_{12} contained 200 mg/L PAC at pH = 7 gave the best SS, color intensity and COD values. Particularly, color intensity reduced to 110 Pt-Co with an efficiency of 85.3%, COD content decreased to 337.3 mg/L with a removal efficiency of 57.8%. Meanwhile, with a high treatment efficiency of 91.4%, a low SS value of 14 mg/L was obtained. Then, PAC amount of 200 mg/L and pH 7 were chosen for the other experiments to decide the best amount of needed substances for chemical polymer and biological gum.

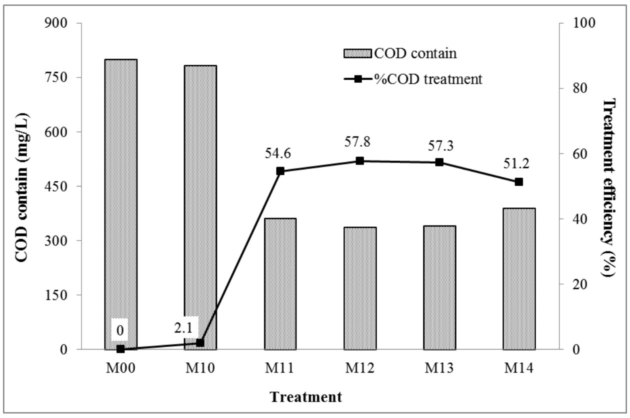


Figure 1. COD treatment efficiency vs PAC quantity

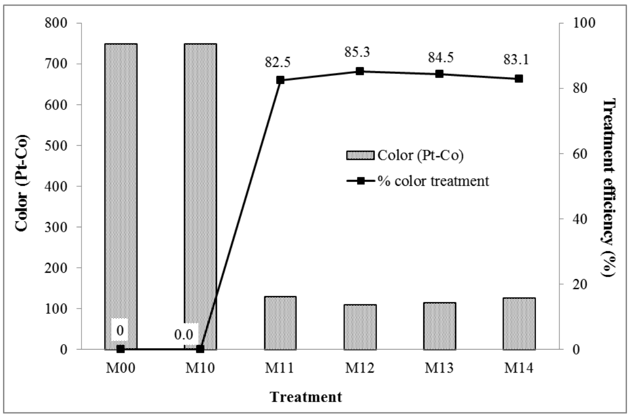


Figure 2. Color treatment efficiency vs PAC quantity

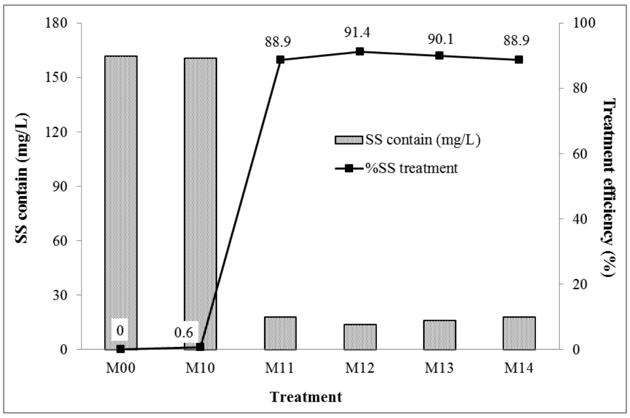


Figure 3. SS treatment efficiency vs PAC quantity

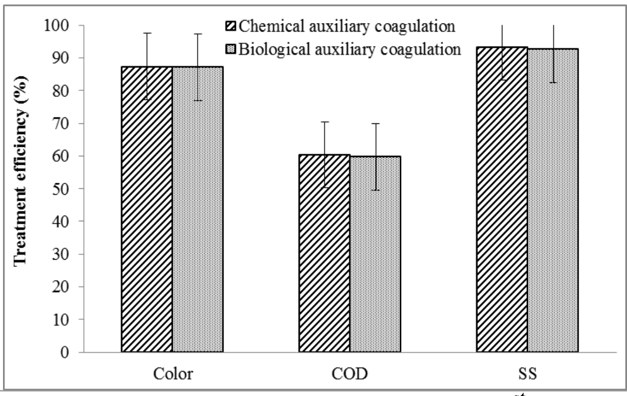
3.3 Evaluating the treatment efficiency

3.3.1 Treatment of wastewater from factory 1

Figure 4 (left) showed that the coagulant PAC when combining with polymer as the auxiliary coagulant gave the highest efficiency in improving the quality of water. Indeed, this combination resulted in a color intensity of 95 Pt-Co with an efficiency of 87.3%; COD content reached 317.3 mg/L with an efficiency of 60.3% and SS decreased to 11 mg/L with a removal efficiency of 93.2%. In addition, when using the biological auxiliary coagulant, the obtained results of treatment were comparable with the chemical one as can be seen clearly from Figure 4. Particularly, a color intensity of 97 Pt-Co with an efficiency of 87.1%; COD content of 322.4 mgO_2/L with a removal efficiency of 59.7% and an SS of 12 mg/L with an efficiency of 92.6% were achieved. In another word, textile wastewater can be treated by either chemical or biological substances.

3.3.2 Treatment of wastewater from factory 2

The analysis results clearly showed that the wastewater which was treated with PAC combined with polymer gave higher treatment efficiency in comparison to PAC combined with biological gum (Figure 4 - right). Particularly, the treatment efficiency based on COD, SS and color intensity were 57.52%, 76.56%, 57.87% respectively for the case of PAC polymer while the corresponding values in the case of biological gum were 52.33%, 75.00% and 52.27%.



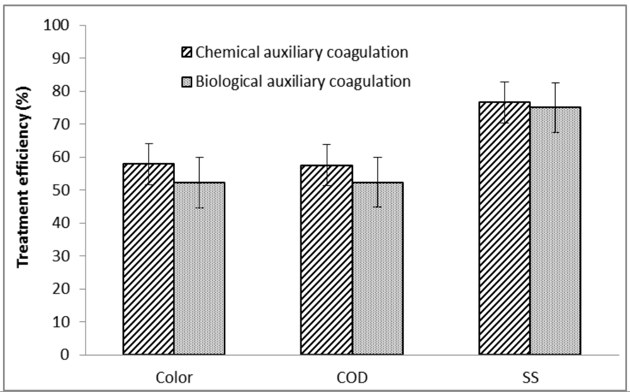


Figure 4. Wastewater treatment efficiency of 1st factory (left) and 2nd factory (right)

Table 2. Determining the best auxiliary coagulant

Parameters \ Sample	0	1	2
Wastewater (mL)	500	500	500
PAC (mg/L)	-	200	200
Auxiliary coagulant (mg/L)	-	Polymer (5 mg/L)	*Cassia fistula* Gum (5 mg/L)
COD (mg/L)	910 ± 0.07	386.61 ± 0.01	433.84 ± 0.05
SS (mg/L)	512 ± 0.1	120 ± 0.04	128 ± 0.2
Color (Pt-Co)	1035 ± 0.03	436 ± 0.1	494 ± 0.2

Bui Thi Vu (2012) reported that when using the coagulant with the PAC concentration of 500 mg/L at pH = 7.5, the COD treatment efficiency was 62.5%. In another study, combination of the mixed Fe : Al (ratio of 1 : 2) showed the best treatment efficiency with a COD removal efficiency reached 89% when using 18 mL mixed alum for each litter of the examined wastewater (Ngo Kim Dinh *et al*., 2013). According to Dinh Tuan (2011), treating the textile wastewater by coagulation combined with electrolytic flotation with a corrosive anode (Al, Fe) resulted in a COD removal efficiency of 66.7%.

Additionally, Smith *et al*. (1975) used $Al_2(SO_4)_3$ as coagulant in treating the wastewater from the stage before bleaching in textile dying and a high efficiency up to 95% based on SS was obtained when using the coagulant at concentration range of 70 - 100 mg/L (cited from Bui Thi Vu, 2012). Moreover, the study of Knocke *et al*. (1986; cited from Bui Thi Vu, 2012) showed that color treatment of textile wastewater can be done using ferrous com-pounds such as $FeCl_3$ and $FeSO_4$. It was reported that using 300 mg/L $FeCl_3$ gave a treatment efficiency of 95 - 99% while 100% efficiency was achieved when using 500 mg/L $FeSO_4$. According to another study on treating textile wastewater using potash alum and ferrous sulfate, when using the alum with concentration of 1.0 g/L, the efficiency in treating color was lower than 20%. However, when combining the alum with flocculating agent, the color of the wastewater was almost completely removed (Duk Jong Joo *et al*., 2005).

In comparison with mentioned researches, in this study, the combination of PAC with either chemical polymer or biological *Cassia fistula* gum gave satisfactory results in handling textile wastewater by using physicochemical method. With these results, biological gum can be potentially used for wastewater treatment in the near future and gradually be able to substitute the chemical compounds.

4. Conclusions

In this study, we experimentally determined the optimum amounts of coagulant for improving the quality of textile wastewater using the Jartest apparatus. In particular, the concentration of coagulant PAC was 200 mg/L while the amount of auxiliary coagulants including polymer and *Cassia fistula* biological gum was 5.0 mg/L.

In addition, when comparing the ability to apply chemical and biological polymers in treating the textile wastewater from two factories, it was found that these two types of auxiliary coagulants showed no remarkable differences in the treatment efficiency. Indeed, the efficiency based on COD measure was 59.70 - 52.33% for the biological gum and 60.30 - 57.52% for the chemical polymer while the efficiency evaluated by SS removal was quite high which was 92.6 - 75.0% in the case of the gum and was 93.2 - 76.56% in the case of the polymer. Finally, the efficiency based on color intensity for the gum and the polymer reached 87.1 - 52.27% and 87.3 - 57.87%, respectively. Consequently, it can be seen that the combination of biological compound in the improvement of wastewater quality is bringing new prospects to the wastewater treatment industry.

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