COMBINATION COAGULATION AND ADSORPTION PROCESSES FOR TREATING TEXTILE WASTEWATER IN HOUSEHOLD INDUSTRY

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ABSTRACT: Textile wastewater is a considerable source of environmental contamination due to its strong color, high pH and chemical oxygen demand (COD), and low biodegradability. The discharge of textile wastewater not only has diverse aesthetic effects, but such discharge can be carcinogenic, mutagenic and generally detrimental to our environment. Thus, textile wastewater should be removed completely before they are discharged into received water. Many methods have been reported for treating textile wastewater, among which coagulation and adsorption are widely used processes due to their relatively simple operation and low cost and suitable for household industry. The aim of this study was using the combination coagulation and adsorption processes to treat textile wastewater in household-scale industry. Coagulation performance and removal efficiencies in COD and color from four varies sources of textile wastewaters were investigated. The effluent from coagulation was treated with adsorption. The adsorption isotherm and removal efficiencies were investigated. The results showed the combination processes had the overall COD were in the range of 72.9 - 93.8% and color removal efficiencies were in the range of 70.6 - 98.5%. The results of coagulation study were found that in some cases of wastewater were effective in color removal but failed in COD removal, in another case, had failed in color but were effective in COD removal efficiencies. The results showed varies of pH had much affected on color removal efficiencies more than COD removal efficiencies. The further experiments should be carried out to improve the combination removal efficiencies for application as suitable for textile household industry.

Keywords: Coagulation, Adsorption, Textile wastewater, Household industry

1. INTRODUCTION

Textile wastewater is a considerable source of environmental contamination due to its strong color, high pH and chemical oxygen demand (COD), and low biodegradability. Due to toxic and carcinogenic effects of textile wastewater on living creatures and negative effects to photosynthetic activities of aquatic plants, removal of the coloring agent, and chemical complex compounds in wastewater appears to be very important for human health and environment [1,2]. Thus, textile wastewater should be removed completely before they are discharged into received water. Elimination of both dyes and COD in the textile wastewater by conventional wastewater treatment methods is very difficult. Conventional treatment methods such as biological, anaerobic microbial degradation, coagulation, adsorption and chemical oxidation, membrane separation process, electro-chemical are generally unsuccessful for the removal of wastewater containing dyes [2]. However, all of the methods suffered from one or another limitation. There is no single economically and technically viable method to solve this problem and usually two or three methods have to be a combination in order to achieve an adequate level of color and COD removal [1]. Many methods have been reported for treating textile wastewater, among which coagulation and adsorption are widely used processes due to their relatively simple operation and low cost [3,4] thus they are suitable for household industry. In this study the coagulation and adsorption processes were selected as a combination to treat textile wastewater because of they were the most effective techniques for treatment textile wastewater and its simple design and low cost. The dyes of textile household industry can be classified as natural and synthetic which are complex organic molecules having groups such as azo, carbonyl, methane, nitro, quinoid, etc. [5]. The aim of this study was using the combination of coagulation and adsorption processes to treat textile wastewater in household industry. The performance of coagulation and adsorption processes were investigated in term of COD and color removal efficiencies. The outcome of this study could be applied to be used as the wastewater treatment process for textile household industry.

2. MATERIALS AND METHODS

The scope of this study was carried out to investigate wastewater treatment of textile household industry on the sub-district namely Pak
Thong Chai, Pak Thong Chai district, this district is in the southern part of Nakhon Ratchasima Province, northeastern Thailand as shown in Fig.1. And it is a famous place to produce textile products especially Thai silk. There are many groups of household industry. Thus, in this study divided the group of textile household industries in two groups according to dye type. The dyes can be classified as a natural and synthetic dye. The four sampling sites of textile household industries were selected; two sampling sites have used synthetic dyes in their process namely, Mudchada (MC) and Kayabatic (KY). Another two sampling sites have used natural dyes in their process namely, Bandu-Yellow (BY) and Bandu-Red (BR). The procedure of study is presented in Fig.2.

Table 1 Parameter and analytical methods for wastewater

| Parameter                  | Unit         | Analytical methods[6]                  |
|----------------------------|--------------|---------------------------------------|
| Physical and Chemical quality |             |                                       |
| pH                        | -            | pH Meter                              |
| Color                     | Pt-Co        | 2120 C.Spectrophotometric Method      |
| COD                       | mg/L         | 5220 C.Closed Reflux Method           |
| TS                        | mg/L         | 2540 B.Total Solid Dried at 103-105°C  |
| TDS                       | mg/L         | 2540 C.Total Dissolve Solids Dried at 180°C |
| TSS                       | mg/L         | 2540 D.Total Suspended Solids Dried at 180°C |
| TVS                       | mg/L         | 2540 E. Fixed and Volatile Solid Dried at 550°C |
| VSS                       | mg/L         |                                       |
| VDS                       | mg/L         |                                       |

2.2 The Coagulation Process

2.2.1 The chemicals of coagulation

The coagulation-flocculation studies were carried out using the jar test method to determine the optimum pH range, suitable volume of poly aluminum chloride (Al₂(OH)₃Cl₃) or PAC (dosages 50 g/L) and polymer (dosages 1 g/L) for each sampling wastewater.

2.2.2 The performance of coagulation process

The coagulation studies were carried out by using the optimum pH range, volume of PAC and polymer from chemical of coagulation study. Calculated COD and color removal efficiencies by using Eq. (1).

\[
\text{% Removal Efficiency} = \left( \frac{C_0 - C_e}{C_0} \right) \times 100
\]

2.3 The Adsorption Process

2.3.1 Adsorption isotherm

Adsorption isotherm studies were carried out at six different activated carbon (AC) mass (1, 2, 3, 4, 5 and 6 g.) which had Iodine was 1,015.30 mg/g. A series of 250 mL Erlenmeyer flask containing 200 mL of treated textile wastewater with coagulation process and required an amount of AC mass were mixed using the shaker at a constant agitation speed of 150 rpm. The sorbent was then separated by filtration. The filtration treated textile wastewater was measured color.
2.3.2 The performance of adsorption process

Batch adsorption experiments were performed as a function of varies pH (2, 4, 6, 8, 10, and 12). The conditions of the batch experiment are shown in Table 2. A series of 250 mL Erlenmeyer flask containing 100 mL of treated textile wastewater with coagulation process, 2 g of AC mass and required varies of pH were mixed using the shaker at a constant agitation speed of 150 rpm. The sorbent was then separated by filtration. The filtration treated textile wastewater was measured color. Influent and effluent of adsorption process were analyzed COD and color. Calculated COD and color removal efficiencies by using Eq. (1).

Table 2 The conditions of Batch adsorption experiments

| Factor                | MC | KY | BY | BR |
|-----------------------|----|----|----|----|
| Mass (g)              | 2  | 3  | 2.5| 3  |
| Temperature (°C)      | 25 | 25 | 25 | 25 |
| Volume of Sample (mL) | 100| 100| 100| 100|
| Contact time (hr)     | 4.24| 4.24| 4.24| 4.24|
| Agitation speed (rpm) | 150| 150| 150| 150|
| pH                    | 2.4 | 6.8 | 10 | 12 |

3. RESULTS AND DISCUSSION

3.1 Characteristics of Textile Wastewater

As shown in Table 3, The results of raw wastewater characteristics were in the wide range of COD from 2.73-84.61 g/L, pH from 4.1-9.7 and color from 543-18,677 Pt-Co. The ratio of TDS/TS of all wastewater samples were in the range of 0.85-0.98. These results indicated that raw wastewater contained dissolved solid more than 80%. And in Fig.3 showed the raw wastewater of synthetic dye group, MC and KY had the ratio FDS/TS higher than the natural dye group of BY and BR. On the other hand, the natural dye group had the VDS/TS volatile dissolved solid higher than synthetic dye group. These indicated that raw wastewater of natural dye contains mainly organic substances which were in form of dissolved solids. The natural dye extracted from many kinds of plants which are organic matter. Whereas the synthetic dye group contained mainly complex organic molecules having a group such as azo, carbonyl, methane, nitro, quinoid, etc. [5]. These results similar to many types of research [7] that reported wastewater from textile industries contains low biodegradability and had different types of dyes, which because of high molecular weight and complex structures.

Table 3 The characteristic of raw textile wastewater from household industry

| Parameter | Synthetic Dye | Natural Dye |
|-----------|---------------|-------------|
| COD (g/L) | MC            | KY          | BY | BR |
| pH        | 2.87          | 2.73        | 84.61| 10.71 |
| Color (Pt-Co) | 543    | 9,677      | 51,867| 5,650 |
| TS (g/L)  | 11.83         | 2.93        | 72.04| 6.73  |
| TSS (g/L) | 0.19          | 0.10        | 10.58| 0.35  |
| TDS (g/L) | 11.64         | 2.83        | 61.46| 6.38  |
| TVS (g/L) | 2.30          | 1.26        | 47.26| 6.67  |
| VSS (g/L) | 0.12          | 0.14        | 9.73 | 0.78  |
| VDS (g/L) | 2.18          | 1.11        | 37.52| 5.90  |
| VS/TS     | 0.19          | 0.43        | 0.66 | 0.99  |
| TDS/TS    | 0.98          | 0.97        | 0.85 | 0.95  |
| VDS/TS    | 0.18          | 0.38        | 0.52 | 0.86  |

Fig. 3 The solid fraction of raw textile wastewater

3.2 The Coagulation Process

3.2.1 The chemicals of coagulation

The results of coagulation studies were carried out to determine the chemicals and optimum pH for coagulation process. They were found the optimum pH were in range of 9 and 6 for synthetic dye group and for natural dye group respectively as shown in Fig 4 and the volume of PAC and polymer were 5 mL (Dosages PAC is 50,000 mg/L) and 0.4 mL (Dosages Polymer is 1,000 mg/L) for synthetic dye group and were 9 mL and 0.4 mL for natural dye group respectively as shown in Fig.5 and 6.

Fig. 4 The Results of coagulation studies to determine the optimum pH
% Removal PAC (ml)
Synthetic Dye Natural Dye

Fig. 5 The Results of coagulation studies to determine the optimum PAC

% Removal Polymer (ml)
Synthetic Dye Natural Dye

Fig. 6 The Results of coagulation studies to determine the optimum polymer

3.2.2 The performance of coagulation process

The results of optimum conditions for coagulation process as summarized in Table 4 were carried out to treated raw wastewater from four sampling sites for measuring the performance of coagulation process. The wastewater samples before and after treated by coagulation process were analyzed COD and color and calculated the removal efficiencies. The results of COD and color removal efficiencies of coagulation process were presented in Fig.7 and Table 5. They showed MC and BR had the same range of COD removal efficiencies were 44.44 and 46.86% respectively in the similar range of COD removal efficiencies only 6.06 and 9.62 %. In previous research of [8], it was reported that coagulation process could reduce COD in range of 10.3-54 %. The other hand, KY and BY had whereas, the color removal efficiencies KY and BY higher than MC and BR. And coagulation process showed none of color removal efficiencies from wastewater of BR. The mechanism of coagulation applied to decolorize wastewater is still not clear, color removal by coagulation is found in some cases very effective, in another case however, has failed at all [9]. The efficiency of the coagulation-flocculation method depends on the raw wastewater characteristics, pH and temperature of the solution, the type and dosage of coagulants, and the intensity and duration of mixing [10].

Table 4 The conclusion of optimum conditions for coagulation process

| Sample     | Optimum Condition | PAC (ml) | Polymer (ml) | pH  |
|------------|-------------------|----------|--------------|-----|
| Synthetic Dye | MC                | 5        | 0.4          | 9   |
| Dye        | KY                | 5        | 0.4          | 9   |
| Natural Dye | BY                | 9        | 0.4          | 6   |
| Dye        | BR                | 9        | 0.4          | 6   |

a: dosages PAC is 50 g/L
b: dosages Polymer is 1 g/L

Table 5 The results of COD and color removal efficiencies of the coagulation process

| Sample | Before Coagulation-Flocculation | After Coagulation-Flocculation | % Removal |
|--------|---------------------------------|--------------------------------|-----------|
|        | pH | Color(Pt-Co) | COD(mg/L) | pH | Color(Pt-Co) | COD(mg/L) | Color | COD |
| MC     | 9.0| 437         | 7,067     | 6.9| 333         | 3,755     | 29.58  | 46.86|
| KY     | 9.0| 9,778       | 7,533     | 5.1| 3,847       | 7,076     | 60.66  | 6.06 |
| BY     | 6.0| 19,000      | 34,667    | 6.9| 11,222      | 31,333    | 40.94  | 9.62 |
| BR     | 6.1| 4,507       | 1,200     | 4.2| 5,248       | 667       | 0.00   | 44.44|
\[
\frac{C_e}{X} = \frac{C_e}{X_m} + \frac{1}{KX_m} (2)
\]
\[
\log X = \log K_f + \frac{1}{n} \log C_e (3)
\]

Where \( K \) and \( X_m \) are Langmuir constants (L mg\(^{-1}\)) and maximum monolayer adsorption capacity (mg g\(^{-1}\)), respectively and Freundlich coefficients \( n \) and \( K_f \) is related to adsorption intensity and adsorption capacity, respectively. Isotherm coefficients of both models are given in Table 6. They were shown Freundlich isotherm are much closer to experimental points than Langmuir isotherm. The coefficients of determination, \( R^2 \) of Freundlich isotherm were in the range of 0.8583-0.9973 and \( R^2 \) of Langmuir isotherms were in the range of 0.6791-0.9940, MC had the highest adsorption capacity 1.39 Pt-Co/g.

3.3.2 The performance of adsorption process

Batch adsorption experiments were performed as a function of varies pH (2, 4, 6, 8, 10, and 12) in effluents after coagulation processes. Influent and effluent of adsorption process were analyzed COD and color. The Calculations of COD and color removal efficiencies were summarized in Fig.8 and 9 respectively.

![Fig. 8 The performance of adsorption process in COD removal](image)

**Table 6 The constants of Langmuir and Freundlich isotherms for the adsorption process**

| Sample | \( q_{\text{max}} \) (Pt-Co/g) | \( K_L \) (L/g) | \( R^2 \) | \( K_f \) (Pt-Co/g) | \( n \) | \( R^2 \) |
|--------|-------------------------------|----------------|-----------|-------------------|------|-----------|
| MC     | 78.125                        | 6.57 x 10\(^{-3}\) | 0.9994    | 1.39              | 1.49 | 0.9973    |
| KY     | -31.95                        | -3.77 x 10\(^{-4}\) | 0.9980    | 2.92 x 10\(^{-14}\) | 0.21 | 0.9354    |
| BY     | -212.77                       | -8.10 x 10\(^{-5}\) | 0.6791    | 3.39 x 10\(^{-22}\) | 0.16 | 0.8583    |
| BR     | 294.11                        | 6.78 x 10\(^{-4}\) | 0.9356    | 0.038             | 0.47 | 0.8770    |

**Table 7 The selected performance of COD and color removal efficiencies of the adsorption process**

| Sample | Before Adsorption | After Adsorption | %Removal |
|--------|------------------|------------------|----------|
|        | pH   | Color(Pt-Co) | COD(mg/L) | pH   | Color(Pt-Co) | COD(mg/L) | Color | COD |
| MC     | 8.0  | 67         | 4,337     | 8.4  | 10          | 333       | 85.00 | 92.32|
| KY     | 8.0  | 2,730     | 9,131     | 8.9  | 1,529       | 280       | 44.00 | 96.93|
| BY     | 2.1  | 3,218     | 24,533    | 3.2  | 803         | 22,933    | 75.04 | 6.52 |
| BR     | 2.0  | 2,621     | 933       | 4.1  | 1,663       | 667       | 36.54 | 28.57|

The results showed varies of pH had much affected on color removal efficiencies more than COD removal efficiencies. It was similar as reported in research of [11] that pH had affected on color adsorption capacity. In table 7, the optimum condition and removal efficiencies for adsorption processes were selected and concluded the performance of adsorption processes by consideration of effluent characteristics and standard.

3.4 The Performance of Combination Coagulation and Adsorption Processes

The conclusions of COD and color removal efficiencies for combination coagulation and adsorption processes are presented in Table 8. The overall removal efficiencies were calculated by selection optimum condition for coagulation and adsorption process under the characteristics of effluent and standard for textile effluent. The results showed the combination processes had the overall COD were in the range of 72.9-93.8% and color removal efficiencies were in the range of 70.6-98.5%. Although the performance of the combination processes obtained high removal efficiencies but the COD concentrations did not meet the standard for...
Table 8 The conclusion of overall COD and color removal efficiencies for combination coagulation and adsorption processes

| Sample | Influent | Effluent | % Of all removal efficiency |
|--------|----------|----------|-----------------------------|
|        | pH       | Color(Pt-Co) | COD(mg/L) | pH     | Color(Pt-Co) | COD(mg/L) | Color | COD  |
| MC     | 6.1      | 543       | 2,872     | 8.4    | 10         | 333       | 98.2  | 88.4 |
| KY     | 9.7      | 9,671     | 2,733     | 8.9    | 1,529      | 280       | 84.2  | 89.8 |
| BY     | 8.9      | 51,867    | 84,614    | 3.2    | 803        | 22,933    | 98.5  | 72.9 |
| BR     | 4.1      | 5,650     | 10,708    | 4.1    | 1,663      | 667       | 70.6  | 93.8 |

industry effluent. Our studies are going on to improve the removal efficiencies of this combination system such as using the other type of coagulants and optimum conditions for adsorption process.

4. CONCLUSION

In conclusion, the results showed the combination processes had the overall COD were in the range of 72.9-93.8% and color removal efficiencies were in the range of 70.6-98.5%. The results of coagulation study were found that in some cases of wastewater from MC and BY were effective in color removal but failed in COD removal, in another case, wastewater from KY and BR, had failed in color but were effective in COD removal efficiencies. The results showed varied of pH had much affected on color removal efficiencies more than COD removal efficiencies. The further experiments should be carried out to improve the combination removal efficiencies for application as suitable for textile household industry.

5. ACKNOWLEDGMENTS

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