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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.

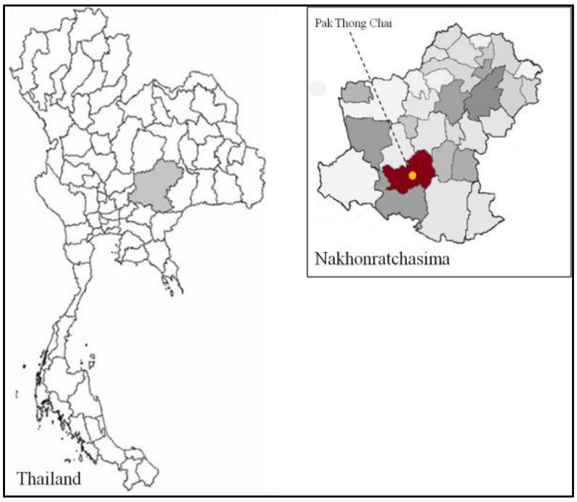

Fig. 1 The scope of this study namely Pak Thong Chai in the southern part of Nakhon Ratchasima Province

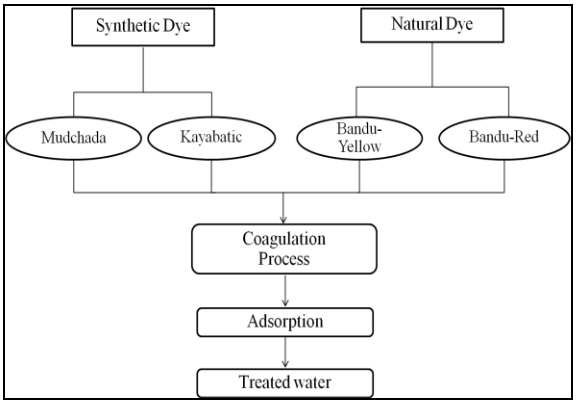

Fig. 2 The procedure of the study

2.1 The Characteristics of Wastewater and Analytical Methods

The study was carried out to collect raw wastewater from four sampling sites of textile household industries were MC, KY, BY and BR. Wastewater samples were analyzed for various parameters and analytical methods as shown in Table 1.

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
TS	mg/L	2540 B.Total Solid Dried at 103-105ºC
TDS	mg/L	2540 C.Total Dissolve Solid Dried at 180^{o}C
TSS	mg/L	2540 D.Total Suspended Solids Dried at 180^{o}C
TVS	mg/L	2540 E. Fixed and Volatile Solid Dried at 550ºC
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 ($Al_2(OH)_3Cl_3$) 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).

$$\%\,\text{Removal}\ \ Efficiency = \frac{(C_0 - C_e)}{C_0} \times 100 \quad (1)$$

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
Contac 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 543-51,867 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	
	MC	KY	BY	BR
COD (g/L)	2.87	2.73	84.61	10.71
pH	6.1	9.7	8.9	4.1
Color(Pt-Co)	543	9,671	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

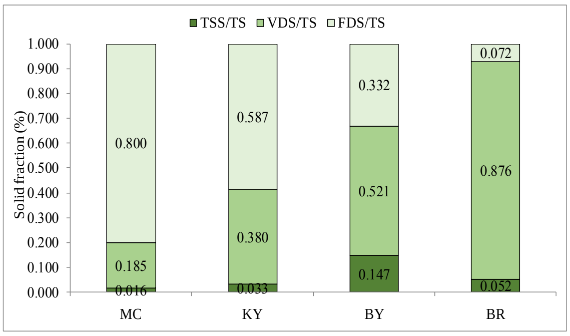

Fig. 3 The solid fraction of raw textile wastewater

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.

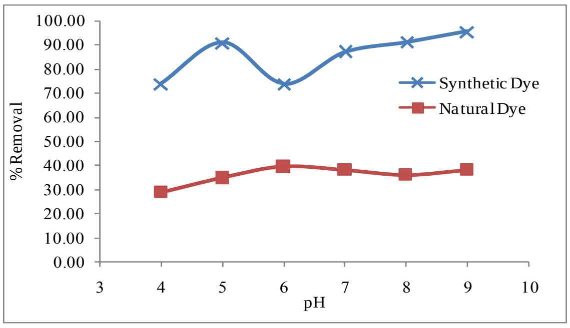

Fig. 4 The Results of coagulation studies to determine the optimum pH

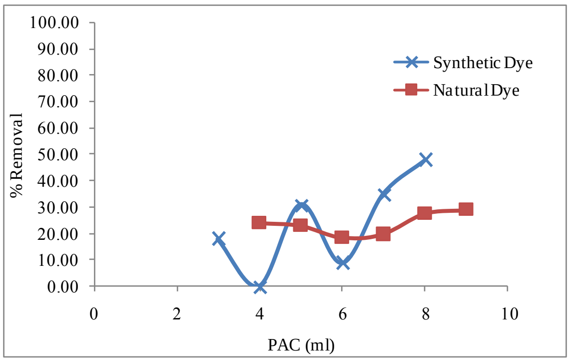

Fig. 5 The Results of coagulation studies to determine the optimum PAC

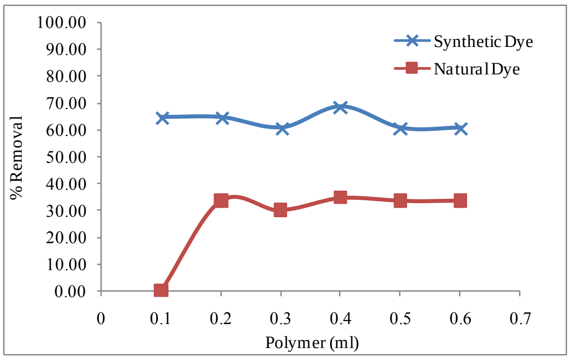

Fig. 6 The Results of coagulation studies to determine the optimum polymer

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)[a]	Polymer (mL)[b]	pH
Synthetic Dye	MC	5	0.4	9
	KY	5	0.4	9
Natural Dye	BY	9	0.4	6
	BR	9	0.4	6

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

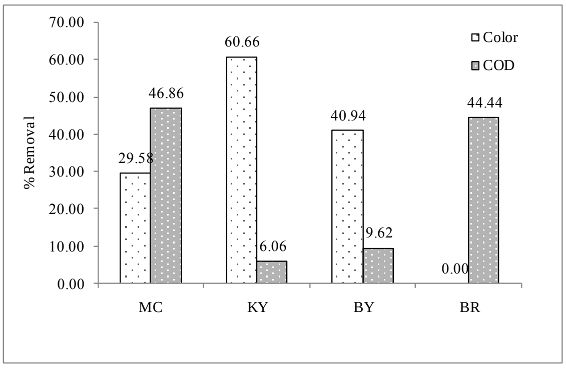

Fig. 7 The results of COD and color removal efficiency of the coagulation process

3.3 The Adsorption Process

3.3.1 Adsorption isotherm

Langmuir and Freundlich isotherms are widely recognized and have been successfully applied to defining many adsorption equilibriums and evaluate adsorption equilibrium of dyes from the effluent of coagulation. Therefore, dye adsorption data were analyzed by Langmuir and Freundlich Eq. (2) and (3), respectively;

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

$$\frac{C_e}{X} = \frac{C_e}{X_m} + \frac{1}{KX_m} \qquad (2)$$

$$\log X = \log K_f + \frac{1}{n} \log C_e \qquad (3)$$

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.

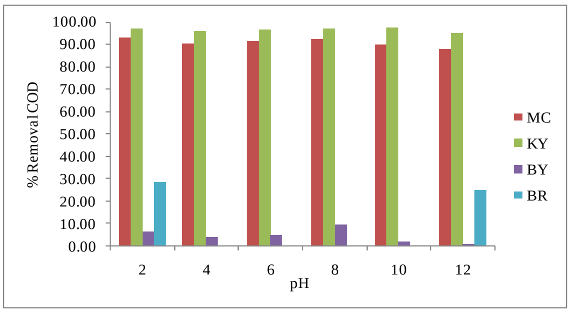

Fig.8 The performance of adsorption process in COD removal

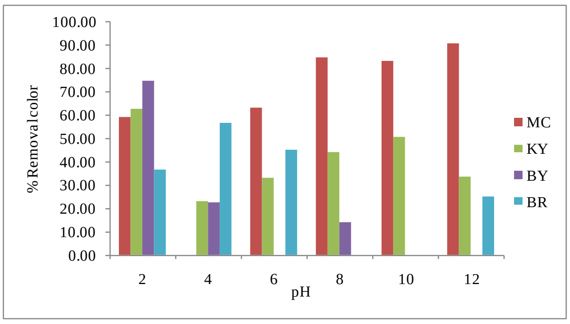

Fig. 9 The performance of adsorption process in color removal

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

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

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 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.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Deepa C., A review of the textile industries wastewater treatment methodologies, J. of Scientific & Engineering Research, Vol. 7, Jan. 2016, pp. 392-403.

[2] Santos S.C.R., Vilar V.J.P., and Boaventura R.A.R., Waste metal hydroxide sludge as an adsorbent for a reactive dye, J. of Hazard. Master, Vol. 153, 2008, pp. 999-1008.

[3] Gercel O., Ozcan A., Ozan A.S. and Gercel H.F., Preparation of activated carbon from a renewable bio-plant of Euphorbia rigida by H_2SO_4 activation and its adsorption behavior in aqueous solutions, J. of Applied Surface Science, Vol. 253, Mar. 2007, pp. 4843-4852.

[4] Chen T., Gao B.Y. and Yue Q.Y., Effect of dosing method and pH on color removal performance and floc aggregation of polyferric chloride-polyamine dual coagulation in synthetic dyeing wastewater treatment, J. of Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol. 355, Feb. 2010, pp. 121-129.

[5] Aci F., Nebioglu M., Arslan M., Imamoglu M., Zengin M. and Kucukislamoglu M., Preparation of activated carbon from sugar beet molasses and adsorption of methylene blue, J. of Fresenius Environmental Bulletin, Vol. 17, 2008, pp. 997-1001.

[6] APHA, AWWA, and WEF, Standard Methods for the Examination of Water and Wastewater, 22st ed. American Public Health Association, 2012.

[7] Verma A.K., Dash R.R. and Bhunia P., A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters, J. of Environmental Management , Vol. 93, Jan. 2012, pp. 154-168.

[8] Saraswati R. and Suresh S., Comparison of different Coagulants for Reduction of COD from Textile industry wastewater, in Proc. 5th Int. Conf. on , Materials Today, 2017, pp. 567-574.

[9] Janeczko M. and Gaydarazhiev S., Removal of dyes from textile effluents by chemical coagulation, in Proc 23rd Int. Conf. on International Mineral Processing Congress,2006, pp. 2163-2167.

[10] Wong P.W., Teng T.T. and Nik Norulaini N.A.R., Efficiency of the Coagulation-Flocculation Method for the Treatment of Dye Mixtures Containing Disperse and Reactive Dye, J. of Water Quality Research Journal of Canada, Vol. 42, 2007, pp. 54-62.

[11] Elmoubarki R., Mahjoubi F.Z., Tounsadi H., Moustadraf J., Abdennouri M., Zouhri A., El Albani A. and Barka N., Adsorption of textile dyes on raw and decanted Moroccan clays: Kinetics, equilibrium and thermodynamics, J. of Water Resources and Industry, Vol. 9, 2015, pp. 16-29.