International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **2(6),** 49-53, June **(2013)** *Int. Res. J. Environment Sci.*

Treatment of Textile Effluent of Fokir Knitwear in Bangladesh Using Coagulation-Flocculation and Adsorption Methods

Mukhlish M. Zobayer B.[1] , Huq M. Mahmudul[1], Ferdous Kaniz[1,2], Mazumder M. Salatul Islam[1,2]
Khan Md. Maksudur Rahman[1,2,3#] and Islam M. Akhtarul[1,2]
[1]Department of Chemical Engineering and Polymer Science, Shahjalal University of Science and Technology. Sylhet 3114, BANGLADESH
[2]Centre for Environmental Process Engineering, Shahjalal University of Science and Technology. Sylhet 3114, BANGLADESH
[3]Faculty of Chemical and Natural Resources, Universiti Malaysia Pahang, 26300 Gambang, Kuantan, Pahang, MALAYSIA

Available online at: www.isca.in
Received 26th April 2013, revised 13th May 2013, accepted 10th June 2013

Abstract

Attempt has been made to study the treatability of textile water using coagulation- flocculation process and adsorption method. Experiments were carried out to attain the optimum doses of coagulant ($FeSO_4$) and flocculant (CaO). The result showed that 2.5 kg/m^3 of CaO and 2 kg/m^3 of $FeSO_4$ were the optimum doses achieving 61.3% COD reduction from the effluent. Batch sorption experiments were also conducted to remove COD from the effluent by using commercial activated charcoal. The obtained adsorption equilibrium data were found to follow Langmuir adsorption isotherm. The maximum monolayer sorption capacity was 0.25113 kg/kg. Effects of adsorbent dose and contact time were also investigated and found that adsorption of COD increased with contact time and adsorbent dose. Kinetic data were fitted with unified approach model and the rate constants were evaluated.

Keywords: Coagulation, flocculation, adsorption, Langmuir model.

Introduction

Textile is one of the fastest growing industries in Bangladesh. Among various industrial organizations textile industry is water intensive and utilizes wide variety of chemicals and dyes. The polluted effluent discharged from this sector into sewage or neighboring water receiving bodies is a cause of major environmental and health concern. Chemical Oxygen Demand (COD) of water of the river Buriganga near Dhaka varies in the range of 16-289 mg/L over the year while the normal range of COD for good water quality is 6-10 mg/L[1-3]. The best way to keep our surface water healthy is to treat the textile effluents and make them less hazardous before discharging into water stream. Only few factories have effective or any effluent treatment plant at all. The government of Bangladesh has therefore decided not to allow any textile industry without proper effluent treatment plant (ETP), which is under implementation stage. Physicochemical methods used to treat dyes laden wastewater include membrane filtration, advanced oxidation, precipitation, chemical degradation, photochemical degradation, biodegradation, electro-kinetic coagulation [4-8]. All these process are costly and cannot be used by small industries to treat the broad range of dye bearing wastewater. Coagulation has been found to be economically viable method for color removal for many years [9].

Recovery and reuse of industrial effluent are effective means for sustainable industrial development. But there is no single process capable of sufficient treatment, mainly due to the complex nature of the effluent. To get treated water with reliable quality several treatment techniques such as adsorption coupled with electrocoagulation, coagulation-flocculation coupled with membrane process, chemical coagulation coupled with ion exchange are being used. Lin and Liu conducted a continuous process of combined ozonation and chemical coagulation for treatment of dye containing wastwwater[10-13]. This combined treatment was seen to be very effective. It was observed that complete decolarization of the wastewater was achieved by ozonation, whilst chemical coagulation was responsible for removing the dissolved organic compounds and solid suspensions producing in a high percentage of COD (chemical oxygen demand)removal. Riera-Torres and Gutiérrez-Bouzán used a coagulation–flocculation process in combination with nanofiltration technique for textile waste water treatment. It was found that over 98% of color removal could be achieved using this combined process[14]. Sheng *et al.* used a combined treatment process consisting of Fenton process, chemical coagulation and ion exchange which reveals that the combined chemical treatment methods were very effective and were capable of enhancing water quality of the treated wastewater effluent to the reuse standard of the textile industry[12]. Flocculation process followed by adsorption process may be used to achieve the desired water quality in the most feasible way. The effectiveness of adsorption on commercial activated charcoal for removal of a wide variety of carbonaceous materials from waste water has made it an ideal alternative to other costly treatment option. In the present study real textile water was treated with coagulant (CaO) and flocculant ($FeSO_4$) to investigate the degree of removal of carbonaceous materials from the effluent and to optimize the dose of coagulant and flocculant. Isotherm and batch kinetic experiments were also conducted to characterize the adsorption behavior of activated char coal for the removal of carbonaceous materials from the effluent. Equilibrium data were fitted to Langmuir model and constants of isotherm equation were evaluated. The adsorption and desorption rate constant were estimated using unified approach model.

Material and Methods

Collection of the sample effluent: The sample effluent was collected from Fokir Knitwear, Narayanganj, Bangladesh on 5th April 2009 and stored in a refrigerator at 5ºC.

Reagents and adsorbent: All reagents used in the study were of analytical grade and used without further purification. Sulfuric acid, potassium dichromate, ferrous ammonium sulphate, silver sulphate, mercurous sulphate, 1, 10-phenonthroline, paraffin oil, $FeSO_4$, CaO were purchased from MERCK, Germany. Activated char coal (100-400 mesh) was collected from Sigma chemical co. USA.

Sample analysis and treatment methods: The physiochemical parameters such as total suspended solid (TSS), total dissolved solid (TDS) and chemical oxygen demand (COD) of the sample effluent were measured using various standard methods [15]. To optimize the dose of iron salt and lime a trial-and-error method was followed and the sample effluent was treated with different concentrations of iron salt ($FeSO_4$) and lime (CaO) varying from 10000 ppm to 100000 ppm. In each event 5 ml of $FeSO_4$ and 5 ml of CaO were added to 100 ml sample. The solution was stirred in a conical flask using magnetic stirrer for 30 minutes to allow complete mixing and was taken in a cylinder to settle down the sludge. When the sludge settled down completely, 10 ml of clear water from the top of the cylinder was taken for COD measurement. The sample effluent was also set for batch adsorption experiments on activated char coal to determine various equilibrium and kinetic parameters. To work with real textile water it is practically very difficult to find out the concentration of each of its components. COD of the effluent was considered as equivalent of concentration and following terms were defined as:

$C_o \equiv COD_0$ = initial COD of the waste water, $C \equiv$ COD at any time t, $C_e \equiv COD_e$ =COD at equilibrium. Batch sorption tests were conducted in 250 ml conical flasks on a flash shaker at 500 rpm. In the adsorption isotherm tests, 1g adsorbent was thoroughly mixed into 100ml effluent sample having initial COD in the range of 1078-3180 mgL^{-1}. After the flasks has been shaken for 24h, the solution was centrifuged for the separation of solid particles and final equilibrium COD of each sample was analyzed. The amount of adsorption at equilibrium, q_e(kg adsorbed/kg adsorbent), was calculated by:

$$q_e = \frac{(COD_0 - COD_e)V}{W} = \frac{COD_0 - CODe}{w_a} \quad (1)$$

where COD_o and COD_e (kg/m^3) are the initial and equilibrium COD of the sample respectively and V is the volume of the solution (m^3) and W is the mass of dry adsorbent used(kg), w_a is the adsorbent dose (kg adsorbent/m^3). Adsorption kinetic tests of different samples having same initial COD (2560mg/L) with various adsorbent doses such as 1.5g, 2.0g and 2.5g were also performed. The amount of adsorption at any time t, q (kg adsorbed/kg adsorbent) was calculated by:

$$q = \frac{(COD_0 - COD)}{w_a} \quad (2)$$

Results and Discussion

Physiochemical properties: Physiochemical properties of the effluent sample are shown in table 1. The levels of pollution of the effluent were compared with composite textile-plant effluent parameters standard value as recommended by DoE, Bangladesh[16].

Table-1
Physiochemical properties of the effluent sample

Parameters	Sample effluent	DoE standard
TDS(mg/L)	45280	2100
TSS(mg/L)	nil	100
EC(μs/cm)	13109	2000
pH	10.9	9.0
COD(mg/L)	6613	200

The pH of the effluent was 10.9, which is higher than the DoE standard. The higher pH is primarily caused by different kinds of dye stuff or detergent used in the dyeing process. The electric conductivity (EC) indicates the total concentration of the ionized constituents of water. The electrical conductivity of the effluent is 13109.45 μs/cm which implies that a large amount of ionic substances is discharged from textile industries like sodium, chloride etc. The EC is 6 fold higher than the DoE standard. Such a high value of EC is not suitable for aquatic life and irrigation purposes. Total suspended solids (TSS) denote the suspended pollutants present in the water. However, no suspended solid was found in the effluent. TDS in water mainly consist of ammonia, nitrite, nitrate, phosphate, alkalis, some acids, sulphates, metallic ions etc. The TDS value of the effluent of the study area is 45280 mg/L which is 20 times higher than the DoE standard. The COD value of the effluent is 6613.33 mg/L which is around 33 times higher than the DoE standard. Excess COD is severely harmful for aquatic life. Therefore the effluent strength is much higher than the tolerable limit.

Effluent treatment by chemical method: Chemical treatment process is one of the most popular methods for liquid waste treatment due to its low cost and simplicity. For better treatment of the effluent, dose optimization of coagulant ($FeSO_4$) and flocculant (CaO) is crucial.

Effect of $FeSO_4$ and CaO doses on the removal of COD from the effluent: Figure 1 and figure 2 illustrate the effects of variation of $FeSO_4$ and CaO doses on the reduction of COD of the effluent respectively. $FeSO_4$ and CaO having concentrations of 40000 ppm and 50000 ppm respectively give the highest COD reduction individually, their combination reduces the COD of the effluent to the lowest value 2560 mg/L which means 61.3% COD was removed by this dose. Therefore Coagulation-flocculation process is not sufficient to reduce COD of the effluent to the level suggested by DoE standard.

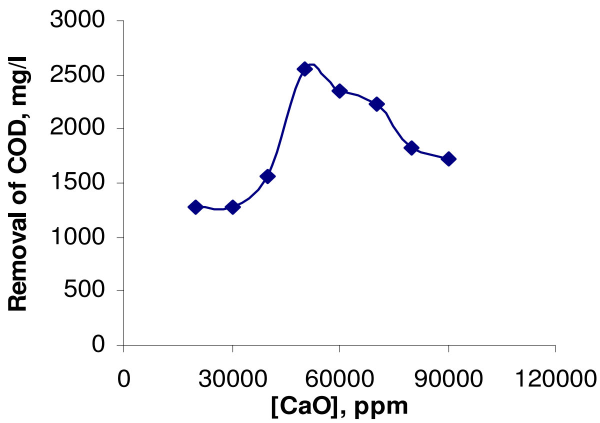

Figure-1
Effect of variation of CaO concentration on COD removal of the effluent at constant FeSO4 concentration (10000 ppm)

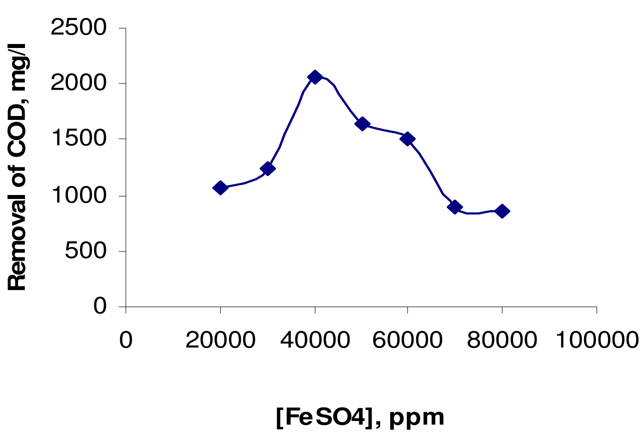

Figure-2
Effect of variation of FeSO4 concentration on COD removal of the effluent at constant CaO concentration (10000 ppm)

Effluent treatment by adsorption method: Adsorption can be an effective and versatile method for waste water treatment, particularly when combined with chemical treatment method. To find out economically viable adsorbent, characterization of adsorbate-adsorbent system is important.

Effect of adsorbent dose and contact time: Effluent samples with same initial COD (2560 mg/l) were treated with different adsorbent doses.

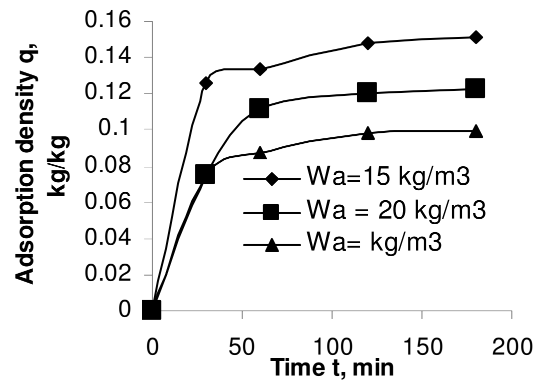

Figure-3
Effect of adsorbent dose and contact time.
(Temperature=26±2°C, shaking speed=500 Osc/min)

Figure 3 shows the effect of varying adsorbent dose against the amount of COD adsorbed. The amount of adsorption increases with increasing adsorbent dose and finally reaches a saturation point. This may be due to the fact that by increasing adsorbent dose, number of active site for the sorption also increases, thus increasing the amount of adsorption. When the surface active sites are covered completely, the extent of adsorption reaches a limit resulting in saturated adsorption. Figure 3 also shows the adsorption of COD by activated charcoal as a function of contact time for different adsorbent doses. It is observed that adsorption is rapid during initial stages and then approaches equilibrium after about 120 minutes. This indicates the independent nature of equilibrium period for the adsorbent dose.

Adsorption isotherm: The experimental equilibrium data of COD adsorption on activated charcoal were treated by Langmuir isotherm. The Langmuir isotherm can be represented by the following equation[17].

$$\frac{1}{q_e} = \frac{1}{(Kq_\alpha Ce)} + \frac{1}{q_e} \qquad (3)$$

In terms of COD Langmuir equation can be written as:

$$\frac{1}{q_e} = \frac{1}{(Kq_\alpha COD_e)} + \frac{1}{q_\alpha} \qquad (4)$$

where q_e is the amount adsorbed, kg COD/kg adsorbent at equilibrium; q_α is the maximum adsorption capacity (kg adsorbed/kg adsorbent), COD_e is the equilibrium COD of the solution, K is the adsorption equilibrium constant.

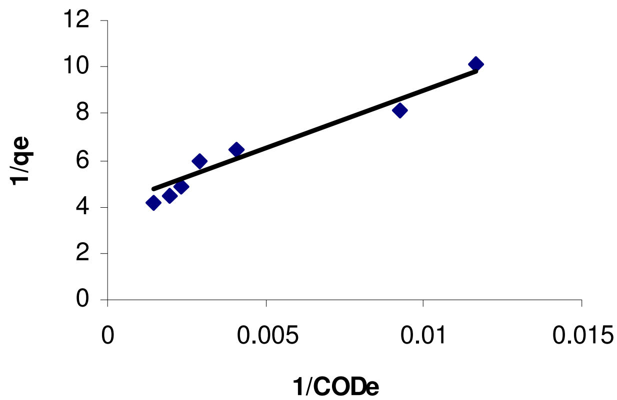

Figure-4
Langmuir isotherm "Eq. (2)" plot for COD adsorption onto activated charcoal (Adsorbent dose = 10 kg/m^3; contact time 24 h; Temperature=26±2°Cshaking speed=500 Osc/min)

The plot of $1/q_e$ vs $1/COD_e$ is linier (correlation coefficient, R^2 =0.9581) as shown in Fig. 4. Maximum adsorption capacity and equilibrium constant K are calculated from the slop and intercept of the plot and are found to be q_α = 0.25113 kg/kg adsorbent and K =8.0 m^3/kg.

Adsorption kinetics: Unified approach model represented by Eq. 5 was applied to analyze the adsorption kinetics and to determine the specific rate constant of adsorption process of COD on activated charcoal[18]. The model is valid for the systems where equilibrium data fitted well with Langmuir isotherm model. The unified approach model can be written as follow:

$$\frac{1}{a(\alpha-\beta)}\ln\frac{(q-\alpha)\beta}{(q-\beta)\alpha} = k_1 t$$

Where, $\alpha = \frac{b+\sqrt{b^2-4ac}}{2a}$, $\beta = \frac{b-\sqrt{b^2-4ac}}{2a}$,(5)

$a = w_a$, $b = COD_0 + w_a q_\infty + 1/K$, $c = q_\infty COD_0$

The calculated value of β directly gives the value of q_e for a given initial concentration and adsorbent dose. Rate constant for adsorption k_1 is determined from the slop of Eq.5 and rate constant for desorption k_2 is determined from the relation $k_2 = k_1/K$, where K is the adsorption equilibrium constant.

Table 2 summarizes the kinetic parameters found from unified approach model. The values of k_1 are very close to each other. The values of k_1 and k_2 are found to be independent of adsorbent doses which reveals the validation of unified approach model.

Conclusion

The optimum doses for the treatment of one cubic meter of effluent were 2 kg $FeSO_4$ and 2.5 kg CaO which can remove 61.3% of COD from the effluent. The coagulation-flocculation process is not sufficient to reduce the COD of the effluent to the desired level as prescribed by DoE standard. Activated charcoal was used as adsorbent and sorption data were treated with Langmuir model and found that the equilibrium data fitted very well in Langmuir isotherm equation, confirming the monolayer sorption capacity of COD onto activated charcoal with a maximum capacity of 0.25113 kg/kg. In the kinetic study the adsorption rate constant k_1 was evaluated using "Unified Approach Model" and it was found that, k_1 is independent of adsorbent doses which implies that COD can be used instead of concentration in precise modeling of an adsorption process. Finally, from this study it is seen that, for adequate treatment of the effluent an adsorption unit should be coupled with the coagulation-flocculation unit.

References

1. Saha M.L., Khan M.R. and Ali M., Bacterial load and chemical pollution level of the river Buriganga, Dhaka, Bangladesh, *Bangladesh J. Bot.,* **38(1),** 87-91**(2009)**
2. Ahmad M.T., Sushil M. and Krishna M., Influence of dye industrial effluent on physico chemical characteristics properties of soil at Bhairavgarh, Ujjain, MP, India, *I Res. J. Environment Sci.,* **1(1),** 50-53 **(2012)**
3. Dorthy C.A.M., Sivaraj R. and Venckatesh R., Decolorization of Reactive Violet – 2RL Dye by Aspergillus Flavus and Aspergillus Fumigatus from Textile Sludge, *I. Res. J. Environment Sci.,* **1(2),** 8-12 **(2012)**
4. Akbari A., Remigy J.C. and Aptel P., Treatment of textile dye effluent using a polyamide-based nanofiltration membrane, *Chem Eng and Process* **(2002)**

Table-2
Adsorption kinetic parameters for COD-activated charcoal system

Langmuir parameters		Parameters from unified approach				
q_∞ kg/kg	K, m^3/kg	$k_1.10^3$, (m^{3}kg^{-1}min^{-1})			$k_1.10^3$ avg, (m^{3}kg^{-1}min^{-1})	$k_2.10^3$, min^{-1}
		w_a =15 kg/m^3	w_a =20 kg/m^3	w_a =25 kg/m^3		
0.25113	8	10.02	10.63	8.49	9.863 ±1.4	1.233 ±0.11

5. Singh A.K., Prakash D. and Shahi S.K., Decolorization of the textile dye (Brown GR) by isolated *Aspergillus* strain from Meerut region, *Int. Res. J. Environment Sci.* **2(2),** 25-29, **(2013)**

6. Al-Kdasi A., Idris A., Saed K. and Guan C. Teong, Treatment of textile wastewaters by advanced oxidation processes-a review, *Global Nest*, **6** **(3)** 222-230 **(2004)**

7. Paschoal F. M. M. and Tremiliosi-Filho G., Aplicação da tecnologia de eletrofloculação na recuperação do corante índigo blue a partir de efluentes industriais, *Química Nova,* **28(5)** 766 **(2005)**

8. Chithra K., Thilakavathi R., Arul Murugan A., Marimuthu C. and Balasubramanian N., Treatment of textile effluent using sacrificial electrode, *Modern Applied Science,* **2(4),** 38 **(2008)**

9. Olthof M.G. and Eckenfelder W.W., Color removal from pulp and paper wastewaters by coagulation, *Water Research*, **9(10)** 853-856 **(1975)**

10. Bhise R.M., Patil A.A., Raskar A.R., Patil P.J. and Deshpande D.P., Removal of Colour of Spent Wash by Activated Charcoal Adsorption and Electrocoagulation, *Res. J. of Recent Sci.,* **1(6)** 66-69 **(2012)**

11. Harrelkas F., Azizi A., Yaacoubi A., Benhammou A. and Pons N., Treatment of textile dye effluents using coagulation-flocculation coupled with membrane processes or adsorption on powdered activated carbon, *Desalinationle* **(2009)**

12. Lin S. H. and Chen M. L., Purification of textile wastewater effluents by a combined Fenton process and ion exchange, *Desalination* **(1997**)

13. Lin S. H. and Liu W. Y., Continuous treatment of textile water by ozonization and coagulation, *J. Environ. Eng*. **(1994)**

14. Riera-Torres M., Gutiérrez-Bouzán C. and M. Crespi, Combination of coagulation–flocculation and nanofiltration techniques for dye removal and water reuse in textile effluents, *Desalination* **(2010)**

15. APHA-AWWA-WPCF (1989). Standard methods for the examination of water and waste water: American Public Health Association, 17th ed., (New York, **(1989)**

16. The Environmental Conversation Rules, Bangladesh, E.C.R 97217, Schedule-12/B **(1997)**

17. McKay G., Design models for adsorption systems in wastewater treatment*, J Chem Technol Biotechnol.,* **31(1),** 717-731 **(1981)**

18. Islam M.A.., Khan M.R. and Mozumder M.S.I., Adsorption Equilibrium and Adsorption Kinetics: A Unified Approach, *J. Chem. Eng. Tech,.* **27**, 1095-1098 **(2004)**