Malaysian Journal of Chemistry, 2003, Vol. 5. No. 1, 034 - 043

Effectiveness of Peat Coagulant for the Removal of Textile Dyes from Aqueous Solution and Textile Wastewater

A.B.M. Helal Uddin, Amat Ngilmi Ahmad Sujari and Mohd. Asri Mohd. Nawi
School of Chemical Sciences, Universiti Sains Malaysia,
11800 Minden, Penang, Malaysia.

Email: masri@usm.my (M. Asri M. Nawi)

Abstract : Tropical peat soil after chemical modification was found to be an effective coagulant for clarification of some textile dyes from their aqueous solution. A thorough comparative study with conventional coagulant had also been done. Results show that it can remove reactive, vat and disperse dyes from their 50 mg/L aqueous solution. It was found that the removal for reactive blue 19 and cibacron brilliant red was 99% and 97%, vat blue 14 and disperse red 72, 98% and 97% respectively. Even though our study with 10% alum and PAC (Poly Aluminium Chloride) solution showed a 100% removal of disperse and vat dyes, both of them showed a poor removal of two reactive dyes. Peat coagulant had a wide pH working range, however its optimum pH range was from pH 3 to 5. On the other hand, alum and PAC showed specific working pH of 5 for two reactive dyes, but they showed wide pH working range for disperse and vat dyes. The mechanism for coagulation by peat coagulant was proven as charge adsorption neutralisation process. The study with textile wastewater shows a 94% removal of colour and 98% removal of suspended solids by using peat coagulant.

Key words: Peat coagulant, Coagulation, Dyes, Textile wastewater.

Received : 07.08.02; accepted : 21.06.03

Introduction

Peat soil is a naturally occurring polyelectrolyte, which is mainly the resultant product of the decayed vegetation over a period of time (Shotyk, 1988). It is organic in nature and the major components are humic acid, lignin and carbohydrates. Peat soil in Malaysia is known as tropical peat soil, which is chemically and structurally different from the fibrous peat soil of Europe and Canada. This tropical peat soil is not very useful for agriculture unless with proper conditioning. Use of this soil as a source of fuel for energy like the peat soil of European countries is also very limited. Due to high leaching, it contributes high colour and COD (Chemical Oxygen Demand) to the effluent, thus making it not useful as filter media. It also has a low mechanical strength that causes a poor hydraulic conductivity (Mutalib *et al.* 1991). Because of these characteristics, this peat soil is considered as a problematic soil in Malaysia.

Due to its ionic functional groups, peat soil is normally used as an ion exchange material to remove metal ions from industrial waste effluent. Compared to commercial ion exchanger, peat is comparatively inexpensive and easily available (Couillard, 1994). Another use of peat soil is as filter media. Its porous nature allows it to adsorb a wide variety of pollutants mainly organic compounds (Poots *et al.* 1976). Rock *et al.,* (1984) and Brooks *et al.,* (1984) used peat as a filter medium for removal of COD and BOD (Biological Oxygen Demand) from the domestic sewage. Another area of research is the chemical modification or treatment of peat soil in order to introduce or increase the functional groups for improved efficiency in wastewater treatment (Smith *et al.*, 1978; Dissanayake and Weerasooriya, 1981).

In this paper, we report the use of Malaysian peat in form of coagulant for removal of textile dyes. Tropical peat soil was chemically modified to introduce positively charged functional group to work as a coagulant. This chemically modified peat was found effective for removal of colloidal particles from aqueous solution (Mohd. Asri *et al.*, 2002). The aim of the present work is to study the effectiveness of this peat coagulant to remove reactive dyes (cibacron brilliant red and reactive blue 19), vat dye (vat blue 14) and disperse dye (disperse red 72) from their aqueous solution and the removal of colour from textile wastewater. This study focused on the effect of pH, dosage and comparison with conventional coagulants namely alum and PAC.

Materials and Methods

Peat soil for preparing peat coagulant was collected from Batu Pahat, Johor of West Malaysia. Alum [Al_2 $(SO_4)_3.16H_2O$] analytical grade was obtained from Fluka, PAC commercial grade was obtained from CCM Chemicals, cibacron brilliant red (CR) dye was from Aldrich. USA, reactive blue 19 (RB) was from BASF, India, vat blue 14 (VB) and disperse red 72 (DR) were from Bayer. NaOH and HCl analytical grade were used for this study. Textile wastewater was collected from one of the textile manufacturing companies situated in Penang, Malaysia. The wastewater sample was collected in a 25 L plastic container from the first waste-collecting pond, which was receiving effluents from all the processing units of the factory.

Peat coagulant (PC) was prepared according to the procedure described by Mohd. Asri *et al.* (2002). Peat coagulant solution used in this study was 3.95% (w/v) solution while for alum and PAC, solutions of 10% (w/v) were used.

Dye concentration used was 50 mg/L for all four dyes. Concentrations of the dye samples were measured at the wavelength of their maximum absorbance (λ_{max}), which was determined using a Hitachi UV-Vis spectrophotometer. The percentage removal of the dye was calculated from the absorbance value of the supernatant to the standard curve of each dye obtained from its known dye concentration. For textile wastewater, the λ_{max} was determined by similar method and the percentage removal of the colour was calculated considering the original wastewater absorbance value as 0% removal. HACH DR-2000 spectrophotometer was used for the measurement of absorbance of the supernatant.

Coagulation studies were based on jar test method. For this purpose, a six-paddle flocculator from Stuart Scientific was used for the jar test study. Sample volume for dye solution and textile wastewater used was 250 ml. After settlement of the sludge, the supernatant was collected for the absorbance measurement and the percentage colour removal calculated.

Results and Discussion

Even though many dyes are commercially available, due to the unavailability of the chemical structure for most of them, our study was restricted to a few types of dyes. Hence, four dyes of three different classes were selected for this study namely cibacron brilliant red, reactive blue 19, disperse red 72 and vat blue 14. Figure 1 shows the chemical structure of these dyes.

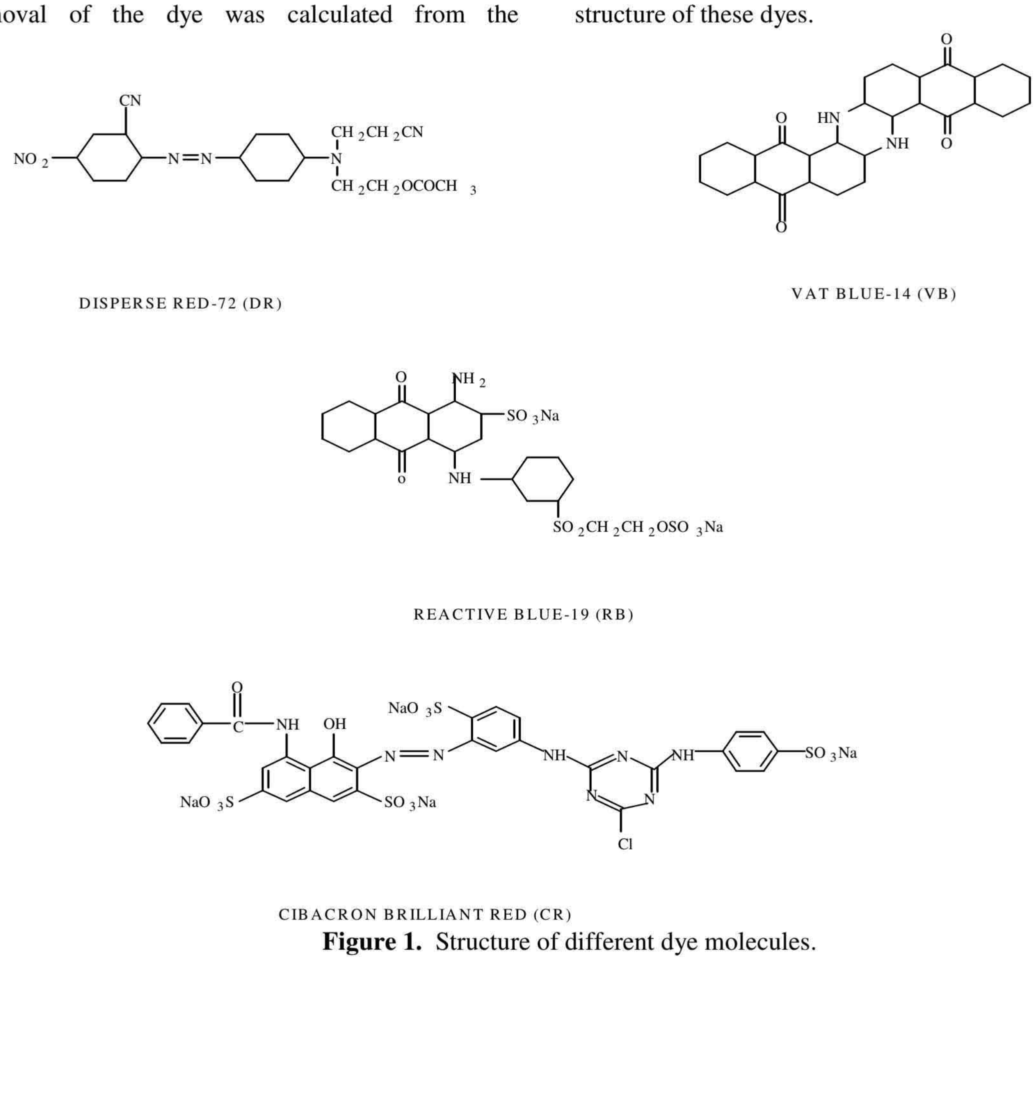


Figure 1. Structure of different dye molecules.

In coagulation studies, there are a few physical parameters, which play an important role. They are rapid mixing, slow mixing and settling time. Rapid mixing ensures the total mixing of the coagulant in the solution whereas slow mixing causes the agglomeration of the flocs produced during the rapid mixing. Optimum conditions for the coagulation of each dye are listed in Table 1.

Figure 2 shows the effect of pH on the coagulation of different dyes with a dosage of 650 μL (CR), 200 μL (VB), 450 μL (RB) and 350 μL (DR) of peat coagulant. A very good removal of all dyes can be achieved in the pH range of 3 to 5. As the pH increases towards alkaline value the removal becomes poorer. Removal of DR and VB are essentially zero at pH above 8, while a very insignificant removal of CR at pH above 9 was observed. Among these dyes only RB shows significant removal within alkaline pH.

Sample	**First Stirring**		**Slow Stirring**		**Settling Time (min)**
	Speed (rpm)	**Time (min)**	**Speed (rpm)**	**Time (min)**	
CR	120	2-3	15-20	35-40	45
RB	120	2-3	15-20	35-40	45
VB	100	1	15-20	25-30	30
DR	100	1	15-20	25-30	30
Textile waste water	120	2-3	15-20	35-40	45

Table 1. List of the physical parameters for coagulation.

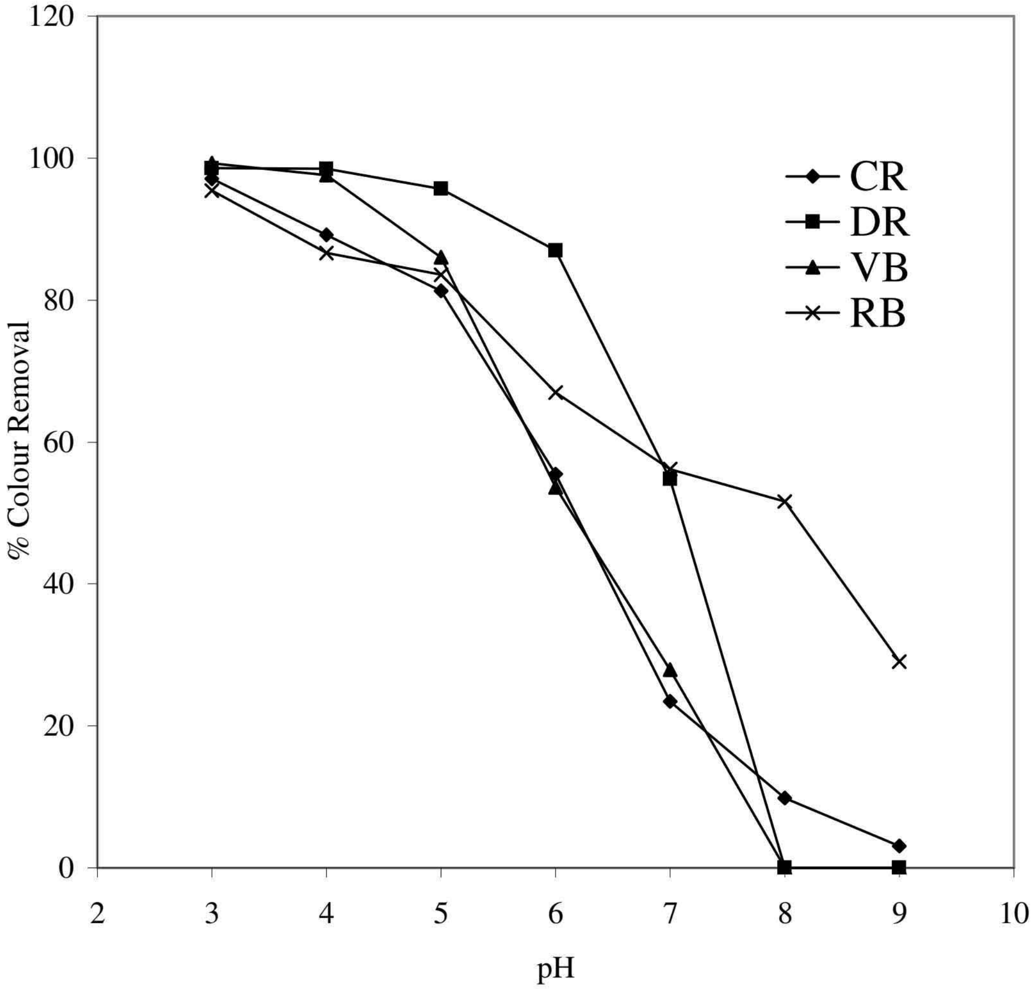
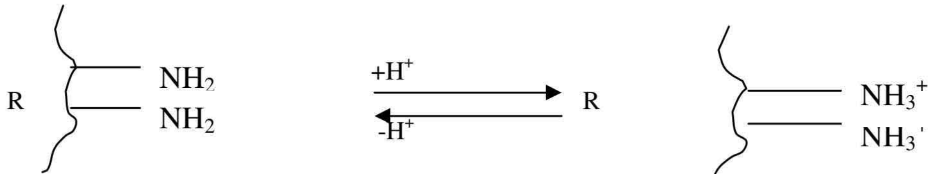


Figure 2. pH study of peat coagulant on 250 ml of CR, VB, RB and DR having 50 mg/L concentration with of 650 μL (CR), 200 μL (VB), 450 μL (RB) and 350 μL (DR) of peat coagulant dosage at their optimum coagulation condition.

The poor performance of peat coagulant within the alkaline pH range may be due to the nature of the peat coagulant itself. Mohd. Asri *et al*. (2002) has proven that peat coagulant had been inserted with amine functional group. These amine groups in peat coagulant are protonated in acidic pH, which means its positive charges increased at low pH values. This protonation is expected to be as illustrated in Equation 1.

With increased positive charges in the matrix, coagulation becomes more effective. As the pH increased, the charge concentration in the peat coagulant decreased, thus, resulting in low or almost no removal of dyes. It is thus apparent that peat coagulant is best to be used at pH below 5 even though 60% of dye removal can still be achieved at pH 6.

The effect of pH on dye removal with alum and PAC shows almost a similar trend. Both alum and PAC respectively showed an optimum removal of RB and CR at pH 5, with a sharp drop of removal occurring on either side. . In the case of VB and DR, alum and PAC showed a very good removal from pH 3 to 6. Between pH 6 and 8, decrease of percentage removal of all dyes was observed for both coagulants. Both coagulants could not achieve significant dye removal above pH 8. A typical result of the effect of pH on different coagulants for CR is shown in Figure 3.



(1)

Where R represents the bulk of peat soil matrix

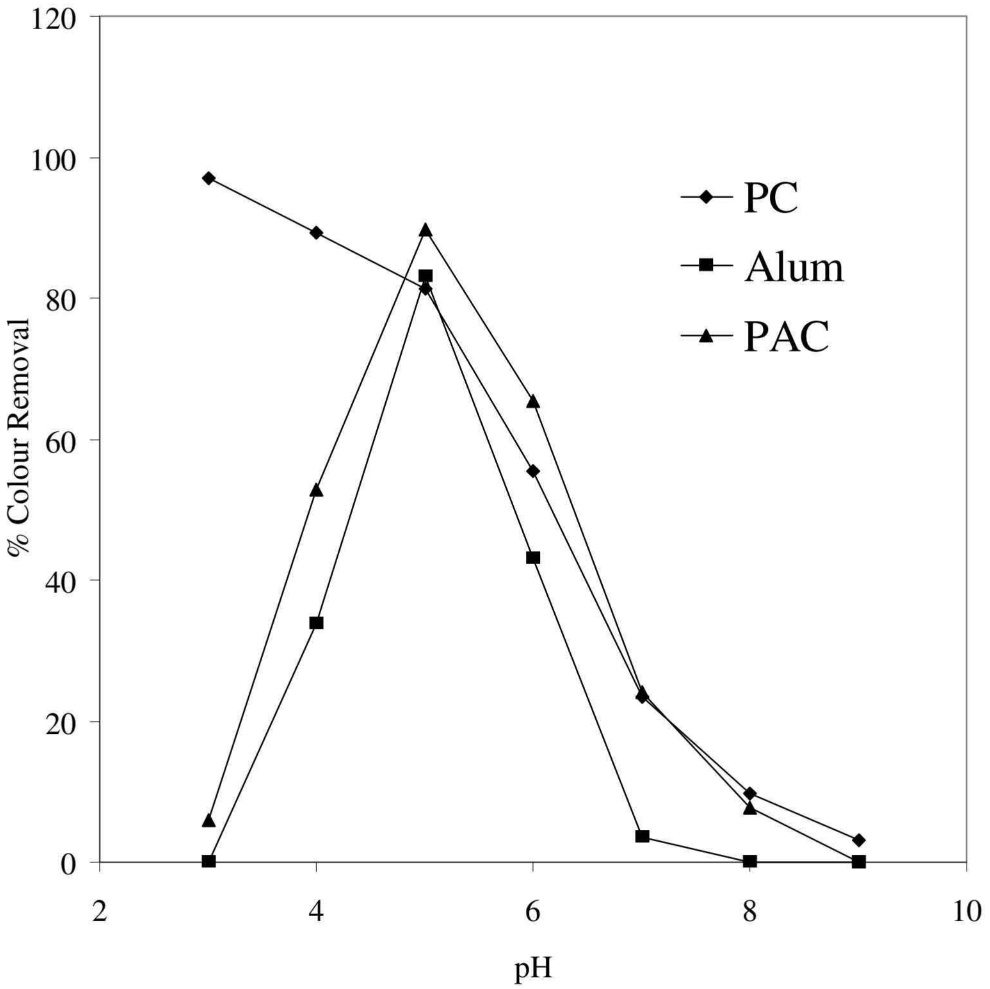


Figure 3. pH study of different coagulant on 250 ml volume of CR dye solution having concentration of 50 mg/L at their optimum coagulation condition.

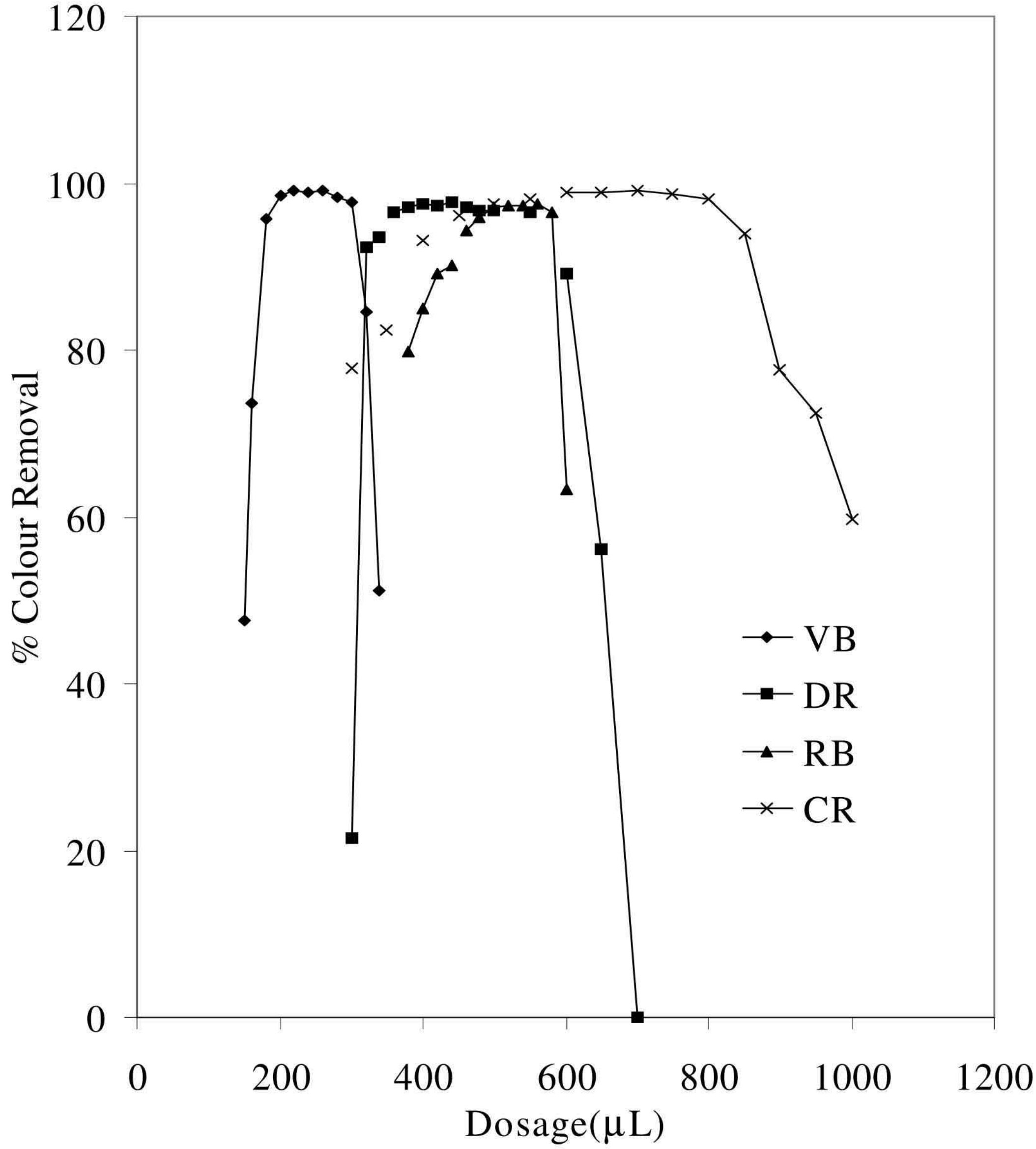


Figure 4. Dosage study of peat coagulant on 250 ml volume of 50 mg/L dye solution of CR, VB, RB and DR at their optimum pH and coagulation conditions.

Figure 4 shows the effect of dosage of peat coagulant in the removal of dyes. Peat coagulant could remove 99%, 97%, 97% and 99% of CR, RB, DR and VB respectively from their aqueous solution. To obtain this percentage removal, optimum dosages needed were 700 μL, 500 μL, 380 μL and 220 μL respectively. Higher dosage was needed for the reactive dyes. Such a need could be due to the dyes' high solubility with their reactive functional groups. Whereas vat and disperse dyes are less soluble and present mostly in colloidal form in the solution. In all cases, peat coagulant shows a reversal effect at too high a dosage. This is due to the charge reversal phenomenon of coagulation, where colloidal stability will restabilise if the coagulant charge concentration is higher than the total charge of colloids.

Table 2 summarises the results of optimum coagulant dosage for the removal of dyes. It appears that alum was able to remove 100% of VB and DR, 90% of CR and only 54% of RB. Optimum dosages needed for the removal of these dyes were 70 μL, 90 μL, 550 μL and 160 μL respectively. PAC showed a removal of 100% for VB 100% DR, 85% for RB and 91% for CR. Optimum PAC dosages needed were 70 μL, 80 μL, 220 μL and 500 μL respectively. Both coagulants showed a requirement of higher dosage in the case of reactive dyes, but a 100% removal could not be achieved in either case. The effect of dosage of different coagulants on CR is shown is Figure 5.

Dyes	Peat Coagulant		Alum		PAC	
	Optimum Dosage (μL)	% Colour Removal	Optimum Dosage (μL)	% Colour Removal	Optimum Dosage (μL)	% Colour Removal
CR	700 (11.06)	99	550 (22.0)	90	500 (20.0)	91
RB	500 (7.9)	97	160 (6.4)	54	220 (8.8)	85
DR	380 (6.0)	97	90 (3.6)	100	80 (3.2)	100
VB	220 (3.47)	99	70 (2.8)	100	70 (2.8)	100

Table 2. Summary of the results of optimum dosages and percentage colour removal of dyes by different coagulants. (Figures inside the brackets are the corresponding concentration of the dosage in mg/L)

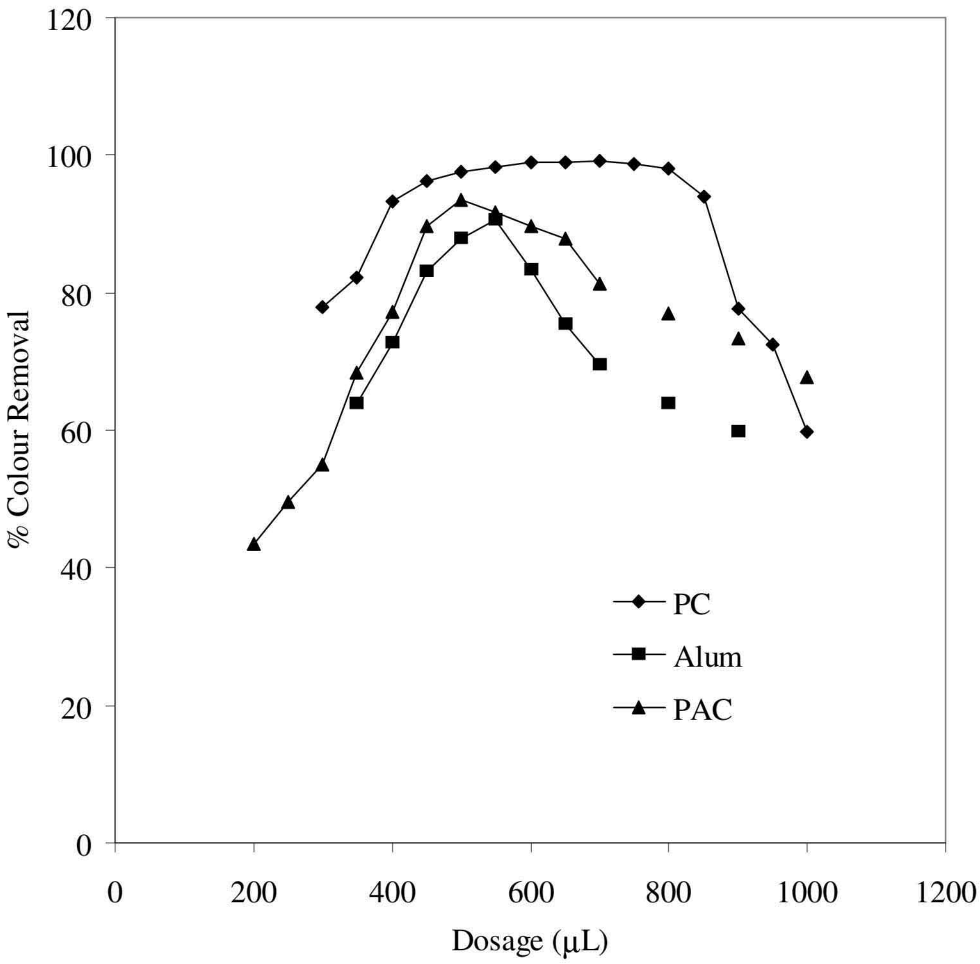


Figure 5. Dosage study of different coagulant on 250 ml volume of CR dye solution at their optimum pH and coagulation conditions.

Coagulation mechanism for peat coagulant was determined by coagulating different concentrations of the dyes with peat coagulant. The result shows an excellent linear relationship between optimum coagulant dosage and corresponding dye concentration. In Figure 6, their relationship is shown graphically for each dye with $R^2 > 0.9774$. As a result, the mechanism of coagulation followed by peat coagulant is proved to be charge adsorption neutralization. Theoretically, this type of coagulation mechanism will have a stoichiometric relationship between the colloid and the coagulant dosage. Moreover, with an overdose application colloids show a charge restabilisation, which was observed in the case of all dyes (Benefield *et al*. 1982). In this case it is assumed that the positively charged peat coagulant particles adsorbed the dye molecules, thereby neutralizing the surface charge to destablise the colloidal stability.

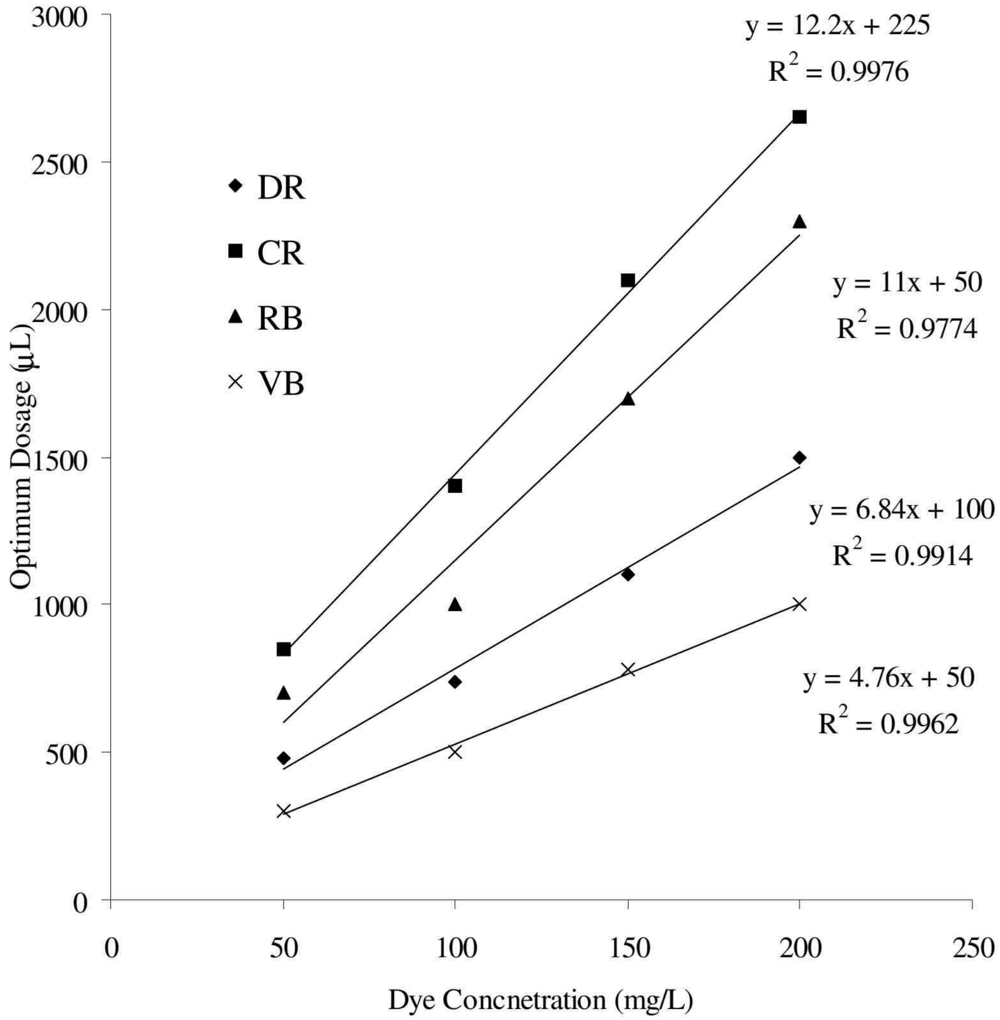


Figure 6. Relationship between optimum dosage of peat coagulant and different concentration of 250 ml volume of CR, VB, RB and DR dye solutions at their optimum pH and coagulation conditions.

Effectiveness of peat coagulant was tested with textile wastewater collected from a textile dyeing industry in Penang. The effect of pH on colour removal from textile wastewater using various coagulants is shown in Figure 7. As expected peat coagulant showed a very good colour removal at acidic pH range i.e. pH 3 to 6. In the case of alum and PAC, both of them showed optimum pH range between pH 4 to 6. A similarity of the colour removal behaviour of the coagulants is observed between aqueous dye solution and textile wastewater. This is in line with our observed results for the coagulants with synthetic dye solutions.

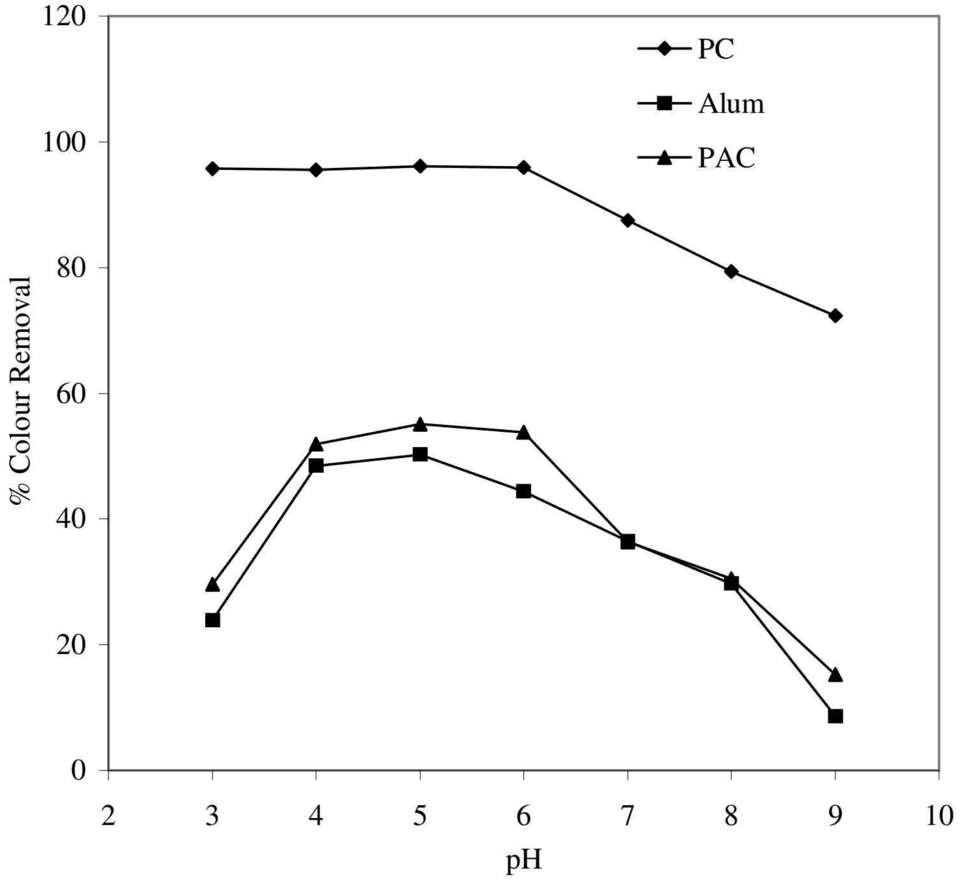


Figure 7. pH study of different coagulant with 250 ml of textile waste water at optimum coagulation conditions.

Figure 8 shows the results of the comparative study of dye removal from textile wastewater. Peat coagulant showed a better colour removal compared to alum and PAC. It shows an 87% of colour removal with 3 ml of peat coagulant without prior pH adjustment. 94% removal of colour was obtained with pH adjusted to 5. On the other hand, alum and PAC showed only 51.2% and 54.8% of colour removal respectively. Water quality parameters of the textile wastewater treated with different coagulants are summarised in Table 3.

Parameters	**Peat Coagulant**	**Alum**	**PAC**
Colour (% Removal)	94	51.2	54.8
Turbidity (% Removal)	70	62.5	59.3
Suspended Solids (% Removal)	98	85	87
COD (% Removal)	15.5	34.1	30.5
Dosage (mg/L)	63.2	100	100

Table 3. Percentage removal of several parameters of textile waste water after treatment with different coagulants.

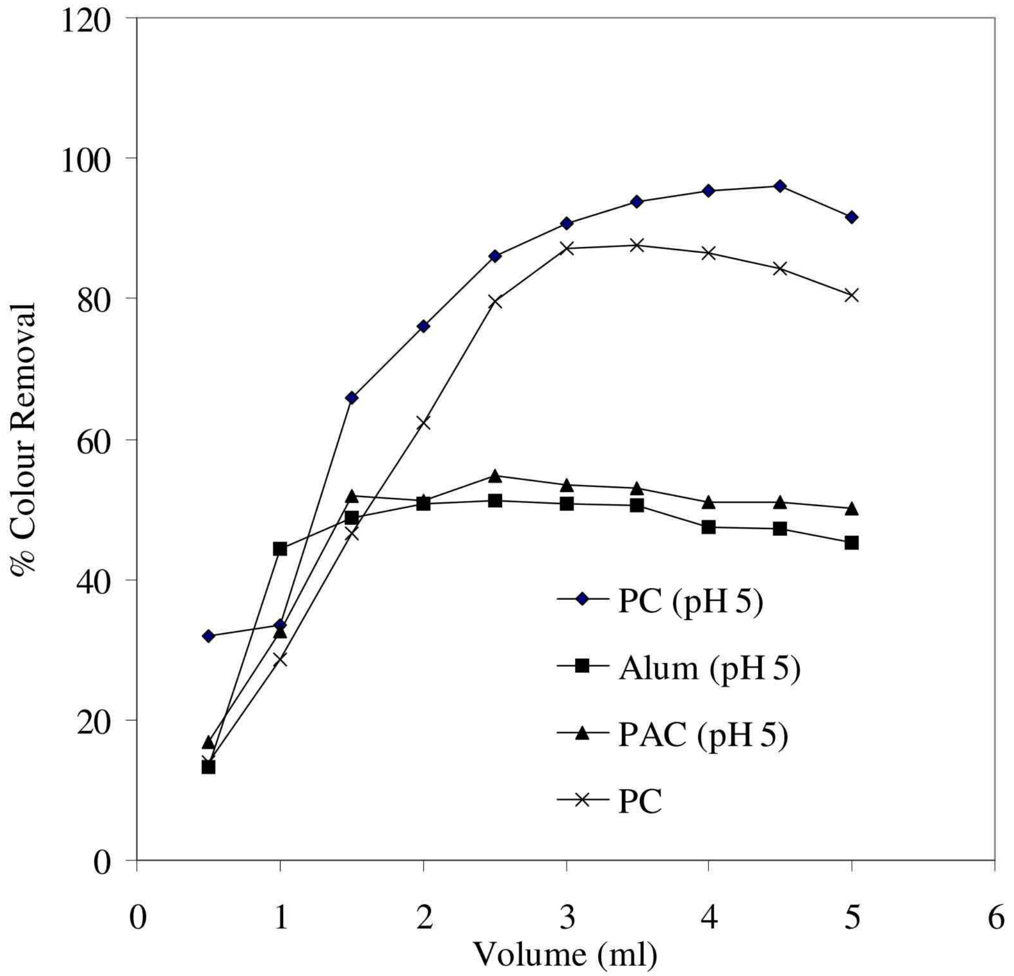


Figure 8. Dosage study of different coagulant with 250 ml of textile waste water at optimum pH and coagulation conditions.

Conclusions

Peat coagulant is able to remove efficiently 97% RB, 99% CR, 98% VB and 97% DR from their 50 ppm aqueous solution. pH plays a very important role in coagulation of all four dyes. In the pH range from pH 3 to 5, peat coagulant showed a higher colour removal percentage. The mechanism for coagulation with peat coagulant is found to be charge adsorption neutralization. For reactive dyes the colour removal efficiency using peat coagulant is better than using alum and PAC. Peat coagulant is also able to remove 87% colour from textile wastewater without any adjustment of pH. 100% removal of colour could be achieved when pH is adjusted to 5. However the removal with alum and PAC at their optimum pH is only 51% and 54%, which is even poorer than the result obtained with peat coagulant with unadjusted pH. None of the coagulants shows any significant reduction of COD values from textile wastewater. Therefore we can conclude that peat coagulant is effective to improve the quality of textile wastewater only by reducing colour, turbidity and suspended solids. Considering that peat coagulant is organic in nature and biodegradable, sludge resulting from this coagulation should be more environmentally friendly as compared to using alum and PAC.

Acknowledgement

The authors are grateful to the Government of Malaysia for the research grant under the Intensive Research for Priority Areas (IRPA) scheme to carry out this study. Also they express their gratitude to all the academic and technical staff of School of Chemical Sciences, USM, Penang, Malaysia for their help and support.

References

1. Benefield L. D., Judkins Jr. J. F. and Weand B. L. (1982) *Process Chemistry for Water and Wastewater Treatment*, Prentice-Hall, Inc. New Jersey.
2. Brooks J. L., Rock, C. A., Bradeen, S. A. and. Struchtemeyer, R. A (1984) *J. Environ. Qual.* **13**, 524-530.
3. Couillard D. (1994) *Wat. Res.,* **28**, 1261-1274.
4. Dissanayake C. B., Weerasooriya, S. V. R. (1981) *Intern. J. Environmental Studies,* **17**, 233-238.
5. Mohd. Asri Mohd. Nawi, A. B. M. Helal Uddin and M. Zaidi Ibrahim (2002) *Synthesis of coagulant material from peat soil. PI 20023170*, August, 2002, Malaysian Patent Pending.
6. Mutalib A. A., Lim, J. S., Wong, M. H. and Koonvai, L. (1991) *Characterization, distribution and utilization of peat in Malaysia*. Proceeding of the International Symposium on Tropical Peatland. Kuching, Sarwak, Malaysia. **7-16**.
7. Poots V. J. P., McKay, G. and Healy, J. J. (1976) *Wat. Res.,* **10**, 1061-1066.
8. Rock C. A., Brooks, J. L., Bradeen, S. A. and Struchtemeyer, R. A. (1984) *J. Environ. Qual.,* **13**, 518-523.
9. Shotyk W. (1988) *Earth- Science Reviews,* **25**, 95-176.
10. Smith E. F., Mark, Jr. H. B. and McCarthy, P. (1978) *Toxicological and Environmental Chemistry Reviews,* **2**, 237-256.