[Downloaded free from http://www.ijehe.org on Friday, February 3, 2023, IP: 5.238.148.104]

original article

Application of coagulation process reactive blue 19 dye removal from textile industry wastewater

Ali Assadi, Roya Nateghi, Gholam Reza Bonyadinejad[1], Mohammad Mehdi Amin[1]

Department of Environmetal Health Engineering, Zanjan University of Medical Sciences, Zanjan, Iran and Pars JooyAb, Consulting Engineers, Isfahan, Iran, [1]Environment Research Center, Isfahan University of Medical Sciences (IUMS), Isfahan, Iran, and Department of Environmental Health Engineering, School of Health, IUMS, Isfahan, Iran

Address for correspondence:
Eng. Roya Nateghi,
Department of Environmetal Health Engineering, Zanjan University of Medical Sciences, Zanjan, and Pars JooyAb, Consulting Engineers, Isfahan, Iran.
E-mail: r59_nateghi@yahoo.com

ABSTRACT

Aim: This study aimed to evaluate effectiveness of the coagulation process for reactive blue 19 dye (RB19) removal from textile industry wastewater.
Materials and Methods: In this research, coagulation process using three coagulants poly aluminum chloride (PACl), alum, and ferric chloride in the presence of anionic polyelectrolyte and kaolin as coagulants aid were studied for the removal of RB19 dye from synthetic wastewater. The influence of effective parameters such as pH, coagulant dose, initial dye concentration, and addition of coagulants aid was investigated.
Results: The results showed that the best dye removal efficiency using three coagulants was archived in neutral pH. Under this condition, the optimum dose of PACl, alum, and ferric chloride was 200, 300, and 400 mg/L and corresponding to dye removal efficiency of 91%, 92%, and 81%, respectively. Addition of polyelectrolyte as a coagulant aid with ferric chloride slightly increased process efficiency, whereas adding polyelectrolyte with alum and PACl slightly decreased dye removal efficiency. By addition of kaolin as a coagulant aid with PACl increased dye removal efficiency about 5%, whereas adding kaolin with alum slightly decreased removal efficiency and can be ignored also, in the case of ferric chloride no significant effect on process efficiency observed in the presence of kaolin.
Conclusion: Regarding to obtained results, coagulation can be a robust treatment method for the management of wastewater containing reactive dye.

Key words: Alum; coagulation; ferric chloride; poly aluminum chloride; reactive dye.

INTRODUCTION

Textile industry wastewaters are considered as one of the main environmental pollutants that usually contain color, high temperature, dissolved solids, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and in some cases are highly alkaline.[1,2] Discharge of wastewaters containing dye materials into receiving waters such as lakes and rivers decreases light transmission, soluble oxygen and increases COD, and in this way disturbs the marine life. In addition, researchers have found that some dyes can produce carcinogenic aromatic amines during the process of reductive degradation.[3] Without adequate and appropriate treatment, these dyes can remain in the environment for a very long time

Access this article online	
Quick Response Code:	Website: www.ijehe.org
	DOI: 10.4103/2277-9183.107913

Copyright: © 2012 Assadi A. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

This article may be cited as:
Assadi A, Nateghi R, Bonyadinejad GR, Amin MM. Application of coagulation process reactive blue 19 dye removal from textile industry wastewater. Int J Env Health Eng 2013;2:5.

[Downloaded free from http://www.ijehe.org on Friday, February 3, 2023, IP: 5.238.148.104]

and permanently.[4] In the recent years, regulations on dye pollutants are becoming more and more stringent worldwide. Thus, dyes in wastewater have to be removed completely before discharged into receiving waters.[3] To decolorize the textile industry wastewater, there are different methods such as coagulation, biotechnology, chemical oxidation, electrochemical technique, ion exchange, surface absorption processes, and also combination processes including ozonation and a combination of electrochemical flocculation and ion exchange.[5,6] Exploitation and maintenance cost of most of these processes is high, so using them for dye wastewaters treatment in many countries is not suitable and economical. Coagulation is one of the most common and most effective processes for treatment of water containing degradation of dye.[2,3,7] One of the most important benefits of decolorization with coagulation and flocculation is lack of production of toxic and harmful by-products due to lack of dye compounds degradation in this method. Furthermore, this method is highly economical and executable.[7,8] Now alum is used as a coagulant worldwide due to its low cost and high applicability for treatment water and wastewater with different properties.[5] The combination of poly aluminum chloride hydrate or aluminum chloride (PACl) with the chemical formula $AL_2\ (OH)_nCL_{6-n}$ is also a pre-polymerized coagulant widely used in recent years so that today; it has become one of the most widely used coagulants for water treatment in countries such as America, Canada, China, Italy, France, and England. The wide application range of pH, less sensitivity to heat, less residue compared to other metal coagulants, lower produced sludge, and easy to sludge dewatering are the advantages of PACl caused an increase in its usage in the water and wastewater. [9] Reactive dyes are anionic and soluble in water that are provided with relatively simple dyeing methods. These dyes are usually used for dyeing cellulose fibers such as cotton and rayon and also for silk, wool, nylon, and leather fabrics. Reactive dyes are used extensively in textile industry, and mainly, due to the capacity of their reactive groups, are transplanted to textile fibers by forming covalent bonds. The main environmental problem of using reactive dyes is their wasting in the dying process. The reactive blue 19 dye has extremely become stable and very resistant to chemical oxidation due to anthraquinone cyclic structure by resonance.[10] Regarding the carcinogenic and mutagenic properties of some reactive dyes, the harmful effects of dye in receiver waters and specified resistance of wastewaters toward biological degradation, the necessity of investigating new options for suitable treatment of this pollution is clear.[11]

According to performed investigations of valid databases, similar results regarding decolorization of reactive blue 19 in the presence of anionic polyelectrolyte and kaolin as coagulant aid have not been achieved. This study that relates to the mentioned advantages and the extensive use of three coagulants alum, PACl, and ferric chloride aims to investigate the efficiency and conditions of applying the three coagulants for decolorizing RB19 dye.

MATERIALS AND METHODS

In thist study RB19 dye was purchased from Sigma-Aldrich company and the characteristics and chemical structure of RB19 was reflected in Table 1. Other chemicals were purchased from Germany Merck Company. pH meters (WTW), Jar apparatus (HACH) and DR5000 spectrophotometer devices (HACH-LANGE Company) were used.

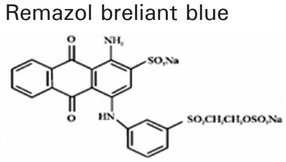
Three coagulants such as alum, PACl and ferric chloride and also anionic polyelectrolyte (NALCO 8172 PULU) and kaolin coagulant aids were investigated. At first the investigation of coagulation and flocculation was done at a fixed dye concentration (100 mg/L) and fixed coagulant concentration (300 mg/L) for different pH values in the range of 5 to 10 to determine the optimum pH for the above-mentioned coagulant. Then the optimum amount of coagulant was obtained at this optimum pH and fixed dye concentration with different amounts of coagulant (100, 200, 300, 400, 500 and 700 mg/L). Finally, regarding the optimum coagulation conditions such as optimum pH and coagulant concentration, the effects of applying polyelectrolyte and kaolin as coagulant aids were investigated.

At first, the stock solution of RB19 with the concentration of 1000 mg/L was prepared. The standard solutions with concentrations of 5, 10, 15, 20, 25, 30, 40, and 50 mg/L were prepared by diluting stock solution in deionized water. Then, calibration curve was prepared by spectrophotometer at 529 nm and the concentration of unknown sample dye was determined. The jar test were done according to the following protocol: rapid mixing with 120 rpm about 90 s and flocculation with 30 rpm about 20 min and sedimentation about 30 min.

RESULTS

Based on the obtained results the solution pH is a very effective factor in decolorizing of RB19 dye, which must be adjusted for optimum use of coagulants. The optimum solution pH for decolorizing RB19 for alum, PACl and ferric chloride is neutral. The optimum PACl dose for decolorizing of RB19 dye was equal to 200 mg/L, for alum equal to 300 mg/L, and for ferric chloride equal to 400 mg/L.

Table 1: Characteristics and chemical structure of RB19

Reactive blue 19	Dye scientific name
Remazol breliant blue	Dye trade name
	Molecular structure
$C_{22}H_{16}O_{11}N_2S_3Na_2$	Chemical formula
626.5 g/mol	Molecular weight
592 nm	Maximum absorption wavelength

[Downloaded free from http://www.ijehe.org on Friday, February 3, 2023, IP: 5.238.148.104]

By addition of polyelectrolyte as a coagulant aid along with ferric chloride has slightly increased the dye removal efficiency, while adding polyelectrolyte along with alum and PACl not only has not increased the removal efficiency, but also has slightly decreased the efficiency. But the remarkable point is that polyelectrolyte addition in both cases has decreased the time of the process and also has formed bigger and more stable floc. Addition of kaolin as a coagulant aid along with PACl has increased the process efficiency about 5%, while kaolin addition along with alum led to decreasing removal efficiency around 3%. In the case of ferric chloride, addition of kaolin has no effective role on the process efficiency. Decolorization amount decreases with increasing dye concentration.

DISCUSSION

Determining the optimum pH

Figure 1 shows the performance of three coagulants at different solution pH. The results showed that alum and ferric chloride have the highest removal efficiency at pH value of 7, and in the optimum conditions, (solution pH: 7), application of alum and ferric chloride result in dye removal efficiency of 89 and 90%, respectively. PACl has the highest removal efficiency in pH range of 6–8 as the optimum conditions. In this study, in the pH value of 7, decolorization efficiency was 98%. Since reactive dyes are in anionic dyes category and functional groups in these dyes contain anionic groups such as sulfonic, hydroxyl and amin, so the presence of anionic groups on these dyes led to carried negative charged by dissolving in water. For coagulation, their negative charge must be neutralized. Therefore it is expected that with decreasing pH, neutralizing the negative charge occurs with greater severity.[3]

According to Figure 1, it can be seen that the highest removal efficiency for alum and ferric chloride was occurred at neutral pH, and the amount of decolorization was significantly reduced at low pH (<6). So, charge neutralization wasn't most effective mechanism in floc formation. Therefore, we can say that floc formation by alum at neutralized pH has mostly been done by sweep flocculation and trapping dye molecules in coagulant sediment. The highest removal for ferric chloride was obtained at neutral pH but in the case of PACl, dye has been removed significantly at acidic pH (<6). So, charge neutralization was one of the effective mechanisms for floc formation.[3] The comparison of obtained results with literature was presented in Table 2. This comparison showed that the dye chemical structure have a very important role in determining the optimum solution pH in coagulation process.[14]

The effect of the coagulants dose on decolorization

The influence of coagulant dose on decolorization amount at the optimum pH was presented graphically in Figure 2. Generally, the decolorization of RB19 was improved with increasing the coagulants dose. Addition 100 mg/L of alum led to dye removal of about 44%, whereas increasing its dose to 200 mg/L, the removal efficiency has reached 81%. After this point, with increasing alum dose, the decolorization has gradually was increased. According to Figure 2, the alum, PACl and ferric chloride dose of 300, 200 and 4000 mg/L corresponding to 98, 91 and 92% dye removal was chosen for farther experiments.

It is important that decolorization of RB19 was decreased with increasing PACl and ferric chloride over 500 mg/L due to restabilization. The obtained results are in line to Shi *et al.*[3]

The effect of anionic polyelectrolyte and kaolin as a coagulant aid on decolorization

As shown in Figure 3, adding polyelectrolyte as a coagulant aid along with ferric chloride has slightly increased the process efficiency. The polyelectrolyte addition along with alum and PACl not only has not increased the process efficiency, but also has slightly decreased the efficiency. This is consistent with results of other studies.[15] For all of the coagulants, with increasing polyelectrolyte coagulant aid, coagulation, and flocculation process has been done in short time and also bigger and more stable floc have been formed. Figure 4 shows that

Table 2: Comparison of obtained results obtained with literature concerning decolorization of various dyes using PACl, alum, and ferric chloride

Dye type	Dye concentration	Coagulant	Optimum coagulant dose	Optimum pH	Dye Removal (%)	Reference
Sulfur Colorants	...	Alum	200 mg/L	8.2	100%	[2]
Sulfur Colorants	...	Ferric	200 mg/L	8.3	100%	[2]
Acid Blue 292	100 mg/L	PACl	40 mg/L	6-8	83%	[15]
Reactive Blue	1000 mg/L	Mixture of Alum and Magnesium Chloride	4000 mg/L	4.5 & 9.5	97%	[5]
Dianix BLue	12.5 mg/L	Alum	75 mg/L	9.13	88%	[16]
YeLLow P-6GS	125 mg/L	Alum	75 mg/L	8.87	55%	[16]
Reactive Blue 19	100 mg/L	PACl	200 mg/L	7	91%	Present study
Reactive Blue 19	100 mg/L	Alum	300 mg/L	7	92%	Present study
Reactive Blue 19	100 mg/L	Ferric Chloride	400 mg/L	7	88%	Present study

[Downloaded free from http://www.ijehe.org on Friday, February 3, 2023, IP: 5.238.148.104]

kaolin addition as coagulant aid along with PACl has increased the process efficiency about 5%, while kaolin addition with alum result in decreasing 3% in removal efficiency. In the case of ferric chloride, kaolin addition does not have an effective role in the process efficiency. The results of other studies show that using anionic polyelectrolyte in the presence of alum and magnesium chloride has not had a positive effect on decolorization.[2] In another study, in the presence of 40 mg/L aluminum chloride for decolorizing blue dye 292 (AB292), increasing kaolin by 30 mg/L has slightly increased the removal efficiency by the maximum value of 7%, and by increasing higher concentrations, the removal efficiency has decreased.[12]

The effect of the initial dye concentration on decolorization

At this stage, the effect of the initial dye concentration on decolorization amount at the optimum pH and constant concentration of three coagulants was studied. As seen in Figure 5, the removal efficiency decreases with increasing dye concentration. At dye concentrations equal to or less than 100 mg/L, PACl and ferric chloride have better performance compared to alum, but at higher concentrations of dye, alum is more effective. The results of this step show that the removal efficiency vigorous decreases at the initial concentration of dye over 100 mg/L . At dye concentrations of less than 100 mg/L, the removal efficiency for coagulants was above 90%, but with its increase to 150 mg/L, the removal efficiency reaches to 70%, especially in the case of PACl application. Similar results have been reported in the literature.[2,12] The effects of the initial dye concentration on the process efficiency provides important information for operation of industrial wastewater treatment plants. Therefore, optimum coagulant type or changing treatment process cloud be considered. The comparison of these results with the results offered by other studies about decolorization using PACl, alum, and ferric chloride is collected in Table 2. Among various coagulants, PACl with minimum required dose and the highest decolorization efficiency, is a suitable alternative for industrial wastewaters treatment.

REFERENCES

1. Lopes A, Martins S, Morao A, Magrinho M, Goncalves I. Degradation of a Textile Dye C. I. Direct Red 80 by Electrochemical Processes.

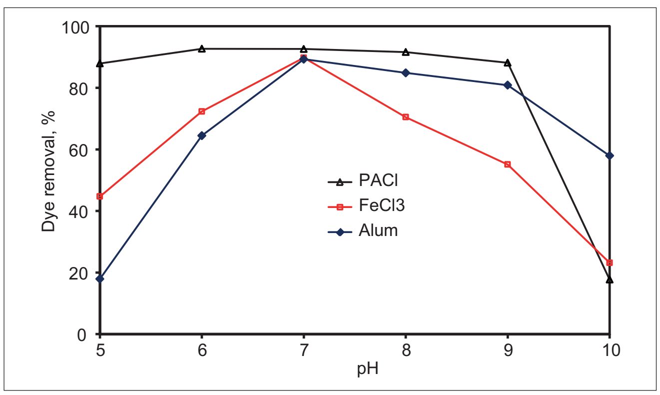


Figure 1: The effect of pH on the decolorization amount of RB19 dye by PACl, Alum and Ferric chloride (Initial dye concentration: 100 mg/L, Coagulant dose 100 mg/L)

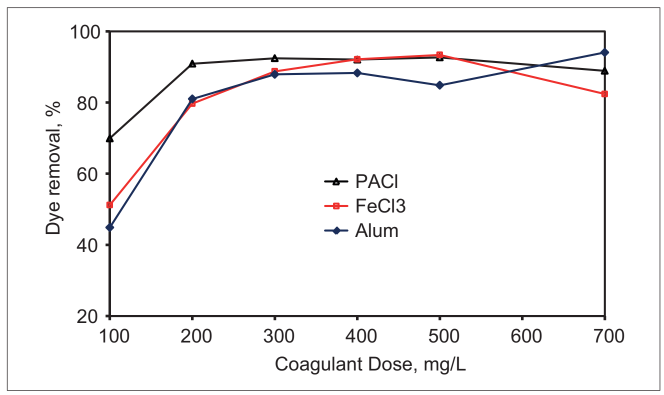


Figure 2: The effect of coagulants dose on the decolorization amount of RB19 at the optimum pH (Initial dye concentration: 100 mg/L)

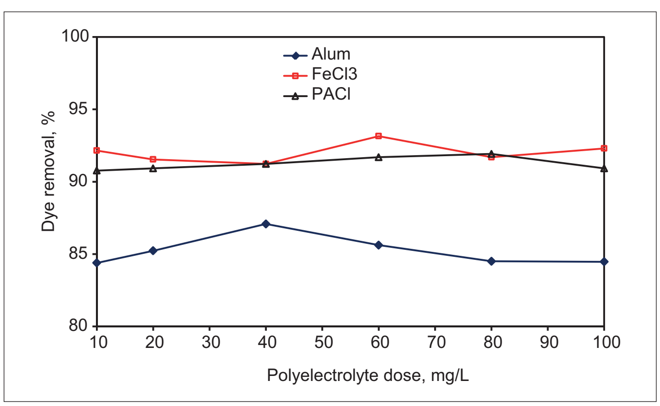


Figure 3: The effect of polyelectrolyte as coagulant aid on decolorization at the optimum pH (Initial dye concentration: 100 mg/L, PACl: 200 mg/L, Alum: 300 mg/L, $FeCl_3$: 400 mg/L)

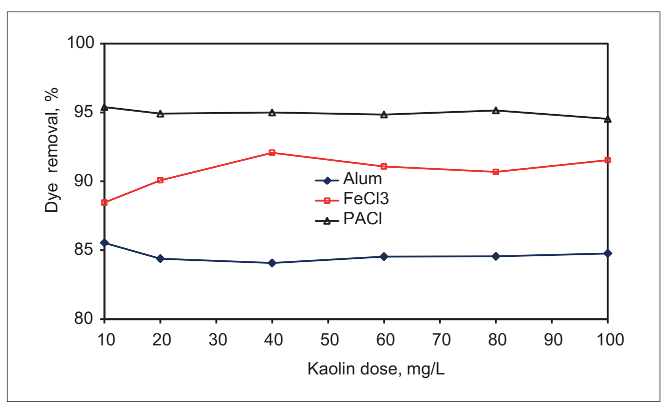


Figure 4: The effect of kaolin as coagulant aid on decolorization at the optimum pH (Initial dye concentration: 100 mg/L, PACl: 200 mg/L, Alum: 300 mg/L, $FeCl_3$: 400 mg/L)

[Downloaded free from http://www.ijehe.org on Friday, February 3, 2023, IP: 5.238.148.104]

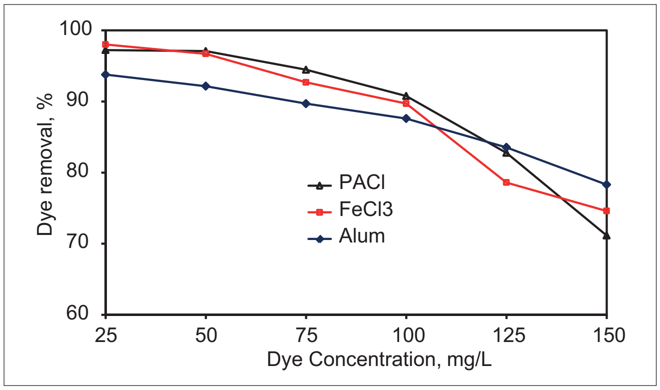


Figure 5: The effect of the initial dye concentration on decolorization amount at the optimum pH (Initial dye concentration: 100 mg/L, PACl: 200 mg/L, Alum: 300 mg/L, $FeCl_3$: 400 mg/L)

Portugaliae Electrochimica Acta 2004;22:279-94.

2. Nabi Bihendi Gh R, Torabian A, Ehsani H, Razmkhah N. Evaluation of industrial dyeing wastewater treatment with coagulants and polyelectrolyte as a coagulant aid. Iranian J Env Health Sci Eng 2007;4:29-36.
3. Shi B, Li G, Wang D, Feng C, Tang H. Removal of direct dyes by coagulation: The performance of performed polymeric aluminum species. J Hazard Mater 2007;143:567-74.
4. Santos BD, Cervantes FJ, Vanlier JB. Review paper on current technologies for decolourization of textile wastewaters: Perspectives for anaerobic biotechnology. Bioresour Technol 2007;98:2369-85.
5. Bina B, Asgari G. Survey of dye removal by mixed magnesium chloride and alum in textile industry wastewater. J Water Wastewater 2009;20:39-41.
6. Parvinzadeh M. Improving colorant absorption from pistachio hulls on wool fiber using protease enzyme. Prog Color Colorants Coat 2009;2:1-6.
7. Golob V, Vinder A, Simonic M. Efficiency of the coagulation/flocculation method for the treatment of dyebath effluents. Dyes Pigm 2005;67:93-7.
8. Wang D, Sun W, Xu Y, Tang H, Gregory J. Speciation stability of inorganic polymer flocculant-PACl. Colloids Surf A Physicochem Eng Asp 2004;243:1-10.
9. Mostafapoor FK, Bazrafshan E, Kamani H. Effectiveness of three coagulants of polyaluminum chloride, aluminum sulfat and ferric chloride in turbidity removal from drinking water. Tabib-E- Shargh 2008;10:17-24. [In Persian]
10. Rezaee A, Ghaneian MT, Khavanin A, Hashemian SJ, Moussavi G, Ghanizadeh G, *et al.* Photochemical oxidation of reactive blue 19 dye (RB19) in textile wastewater by UV/$K_2S_2O_8$ process. Iran J Environ Health Sci Eng 2008;5:95-100.
11. Gouvea CA, Wypycha F, Moraes SG, Durn N, Peralta-zamora P. Semiconductor-assisted photocatalytic degradation of reactivedyes in aqueous solution. Chemosphere 2000;40:433-40.
12. Hasani Zonoozi M, Alavimoghaddam MR, Arami M. Removal of C.I. Acid Blue 292 using Polyaluminum Chloride. J Color Sci Technol 2008;2:87-94.
13. Chu W. Dye removal from textile dye wastewater using recycled alum sludge. Water Res 2001;35:3147-52.
14. Sanghi R, Bhattacharya B, Dixit A, Singh V. Ipomoea dasysperma seed gum: An effective natural coagulant for the decolorization of textile dye solutions. J Environ Manage 2006;81:36-41.
15. AWWA. Principles and Practices of Water Supply Operations: Water Treatment. Third Ed. 3rd ed. New York: American Water Works Association; 2003.

Source of Support: Zanjan University of Medical Sciences, **Conflict of Interest:** None declared.