Journal of Environmental Management 211 (2018) 347–355

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Using Chitosan/CHPATC as coagulant to remove color and turbidity of industrial wastewater: Optimization through RSM design

Meysam Mohammad Momeni [a], Davood Kahforoushan [a, b, *], Farhang Abbasi [c], Saeid Ghanbarian [a]

[a] Faculty of Chemical Engineering, Sahand University of Technology, Tabriz, Iran
[b] Environmental Engineering Research Center, Faculty of Chemical Engineering, Sahand University of Technology, Tabriz, Iran
[c] Institute of Polymeric Materials, Sahand University of Technology, Tabriz, Iran

ARTICLE INFO

Article history:
Received 19 November 2016
Received in revised form
6 January 2018
Accepted 8 January 2018
Available online 8 February 2018

Keywords:
Color
Turbidity
Wastewater
Melanoidin
Coagulation
Experimental design
Natural coagulant
Modified chitosan

ABSTRACT

One of the most important solid-liquid separation processes is coagulation and flocculation that is extensively used in the primary treatment of industrial wastewater. The biopolymers, because of biodegradable properties and low cost have been used as coagulants. In this study, chitosan as a natural coagulant of choice, was modified by (3-chloro 2-hydroxypropyl)trimethylammonium chloride and was used to remove the color and turbidity of industrial wastewater. To evaluate the effect of pH, settling time, the initial turbidity of wastewater, the amount of coagulant, and the concentration of dye (Melanoidin) were chosen to study their effects on removal of wastewater color and turbidity. The experiments were done in a batch system by using a jar test. To achieve the optimum conditions for the removal of color and turbidity, the response surface methodology (RSM) experimental design method was used. The results obtained from experiments showed that the optimum conditions for the removal of color were as: pH = 3, concentration of dye = 1000 mg/L, settling time = 78.93 min, and dose of coagulant = 3 g/L. The maximum color removal in these conditions was predicted 82.78% by the RSM model. The optimal conditions for the removal of turbidity of the waste water were as: pH = 5.66, initial turbidity = 60 NTU, settling time = 105 min, and amount of coagulant = 3 g/L. The maximum turbidity removal in these circumstances was predicted 94.19% by the model. The experimental results obtained in optimum conditions for removal of color and turbidity were 76.20% and 90.14%, respectively, indicating the high accuracy of the prediction model.

1. Introduction

Color and turbidity are two major pollutants in industrial wastewaters. Color and turbidity are two major pollutants in an industrial wastewater (Verma et al., 2012). The industries such as pulp, paper, rubber, textile and polymer are the mainly sources of surface and underground water polluters (Ong et al., 2010). Discharged wastewater into surface waters such as rivers and lakes reduces the transmission of light in the water which reduces photosynthesis and the amount of dissolved oxygen in the water (Ali and Singh, 2009). Researchers have found that some kind of dyes can also decompose and produce carcinogenic aromatic amines. These poisoning compounds without the proper treatment, could stand quite stable in the environment for a very long time (Hao et al., 2000). The turbidity is created due to the presence of suspended solids such as clay, mud, minerals, organic and water-soluble particles. In addition to creating an unpleasant appearance for water, it is a safe haven for resistance of microorganisms against disinfection (Steel and McGhee, 1979; Wef, 1998).

Because of the complexity and variety of dyes used in various industries, finding an unique method which is able to remove dyes completely, is difficult (Mounir et al., 2007). Several methods are used for the treatment of the wastewater which include processes of coagulation and flocculation, membrane and biological methods (Mamba et al., 2014; Singh et al., 2014). A main problem for a membrane technology is fouling. High concentrations of dye cause severe fouling on the membrane (Zaroual et al., 2009). Biological treatment processes are not effective for complex dyes removal. Coagulation and flocculation is a simple and efficient method for

* Corresponding author. Faculty of Chemical Engineering, Sahand University of Technology, Tabriz, Iran.
E-mail address: kahforoushan@sut.ac.ir (D. Kahforoushan).

https://doi.org/10.1016/j.jenvman.2018.01.031
0301-4797/

removal of colloidal particles and dyes from water and wastewater due to its low capital cost (Golob et al., 2005; Zahrim et al., 2011). For wastewater treatment, this method includes the addition of chemicals to change the physical state of dissolved and suspended solids and to facilitate their removal by sedimentation. In general, coagulants are divided into three categories: mineral, synthetic polymers and natural coagulants. The use of mineral coagulants such as aluminum sulfate in wastewater treatment processes can produce non-organic sludge which is a secondary pollution (Anjaneyulu et al., 2005). The remaining metals of coagulants such as aluminum in the human body would cause some of the inefficiencies such as Alzheimer's disease (Ali et al., 2010). Because most synthetic polymers do not have the ability to biodegrade, they are considered as secondary pollution, too. Residual oligomers and monomers of some synthetic polymers such as polyacrylamide are toxic and some of them lead to cancer in humans (Yang et al., 2011). For this reasons, in some countries, strict laws have been considered for using these types of coagulants (Krentz et al., 2006). So, in order to resolve problems arising from the use of mineral and synthetic polymers coagulants, natural coagulants are suitable replacements. Chitosan is a kind of polysaccharide obtained by deacetylation of chitin, the second most abundant polysaccharide in nature after cellulose (Prado and Matulewicz, 2014). Although natural polymers such as chitosan or modified natural polymers have wide applications, how to improve their flocculation effectiveness is the main focus, because they are cost-effective and environmental friendly (Wang et al., 2007). Cationized chitosan has better properties than untreated chitosan. Cationic chitosan has several applications such as a dermal permeation enhancer of drugs, protein release controller, reduction of carbonyls to alcohols, removal of Mo(IV) and Cr(VI) and coagulant agent in papermaking because of its unique properties (Faizuloev et al., 2012; Spinelli et al., 2004; Xu et al., 2003).

The objective of this study is to use chitosan biopolymer as a coagulant for the removal of color and turbidity of discharged wastewater from Iran Mayeh plant, Tabriz, I.R.I and to determine the optimal conditions for the process to reuse it in the production process. The reason behind using this wastewater was that it consisted a very complex dye named Melanoidin which is resistant against many treatment processes and causes color and turbidity in wastewater (Crini, 2006; Wang et al., 2005). Melanoidin is the result of the reaction between amino acids and carbohydrates, which is called the Millard reaction (Naik et al., 2010). Melanoidin is a structurally complex macromolecule, muddy brown color, with odor like phenol. The brown color of Melanoidin is because of the presence of C = C and C = N bonds in the molecular structure of the material (Stavropoulos, 2012). The chemical structure of Melanoidin is shown in Fig. 1 (Jiranuntipon et al., 2009).

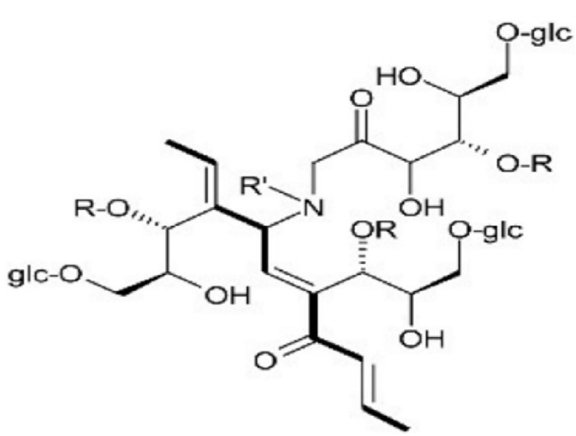

Fig. 1. Chemical structure of Melanoidin.

Releasing of this highly colored compound in surface waters reduces the influence of sunlight which prevents photosynthesis. Also, it reduces alkalinity level of soil and oxygen level of water and puts aquatic plant and animal life in danger (Naik et al., 2010).

The efficiency of the coagulation depended on appropriate selection of coagulant, optimization of process parameters such as pH, dosage of coagulant agent, mixing time, settling time and etc. An appropriate optimization of these factors could significantly increase the treatment efficiency. Response surface methodology (RSM) is an efficient way to achieve such an optimization by analyzing and modeling the effects of multiple variables and their responses and finally optimizing the process. The main objective of using RSM is to determine the optimum operational conditions for the system or to determine a domain that satisfies the operating specifications (Box and Wilson, 1951; Zaroual et al., 2009). The RSM reduces the number of experiments significantly and has an ability to study a large number of parameters and interaction between them. Response surface methods can describe the behaviors of complex systems in various experimental conditions. Optimization based on response surface methodology can be used in different processes to achieve the highest efficiency (Khataee et al., 2011).

In this study, the potential and effectiveness of a cationic chitosan was studied as an alternative and a low cost coagulant for the removal of Melanoidin. So, a modified natural polymer, prepared through the grafting of (3-chloro 2-hydroxypropyl)trimethylammonium chloride (CHPTAC) onto chitosan was used as flocculent. The grafting of this compound onto chitosan can increase the cationic content of the flocculent, and thus improve its flocculation efficiency. A yeast factory wastewater was selected as the target to be treated by the coagulation and flocculation process which was optimized by RSM. The turbidity and color of the treated water were chosen as the response variables. The optimal conditions for the two responses were also obtained and compared with experimental results.

2. Methods and materials

2.1. Wastewater

In this study, wastewater was provided from a yeast factory, which had high levels of turbidity and color at the same time. Melanoidin was the main source of its pollution. Some characteristics of the wastewater and their standard levels are shown in Table 1. It is clear that wastewater pollution is very high and it needs to be treated for reusing.

2.2. Coagulant

Dried chitosan (24 g) was mixed with 250 mL of distilled water. 10 mL of 10 mol/l NaOH was added to the mixture and then it was heated at 50 °C under controlled stirring for half of hour. 50 mL of the cationic monomer (CHPTAC) was added to the mixture as dripping. The reaction was then allowed to continue for next 24 h and was heated constantly at 50 °C under controlled stirring. Diluted hydrochloric acid was added to the mixture to decrease the reaction pH around 7 for stopping the reaction (Larsson and Wall, 1998). The precipitated modified chitosan was washed with ethanol and distilled water to remove the impurities. Then, it was dried under vacuum condition at 65 °C for 48 h. Chitosan can react with CHPTAC to form a crosslinked species at amine group and results in a cationic chitosan as shown in Fig. 2.

The physical and chemical properties of modified coagulant were studied. X-ray diffraction (XRD), elemental analysis (CHNOS)