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Coagulation performance and floc characteristics of aluminum sulfate using sodium alginate as coagulant aid for synthetic dying wastewater treatment

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The effect of coagulant aid sodium alginate (SA) on coagulation behavior and floc characteristics of aluminum sulfate (AS) was investigated for synthetic dye wastewater treatment. Coagulation performance and floc characteristics of AS were investigated for comparison. The results showed that AS plus SA exhibited synergic effect on color removal depending on the dose of AS and SA. Color removal was more enhanced by SA at low AS doses than at higher ones. Floc properties including floc growth rate, size, strength and reversibility were investigated by Photometric Dispersion Analyzer (PDA). AS plus polymer SA exhibited an obvious improvement on floc size and floc growth rate. Besides, the AS–SA dual-coagulants significantly improved the floc recoverability as reflected by higher recovery factors compared to AS.

1. Introduction

Dye wastewater discharged from textile dye printing industries is a considerable source of environmental contamination due to its strong color, high pH and chemical oxygen demand (COD), large amount of suspended solids (SSs) and low biodegradability [1,2]. The presence of color not only affects scenery, but also disturbs photosynthetic activity of hydrophytes. In terms of public health, it has been found that some azo dyes are able to produce carcinogenic aromatic amines in the process of reductive degradation [1,3]. With regard to aquatic biosphere, dye polluted natural waters can seriously disturb aquatic biosphere due to the reduced sunlight penetration and depletion of dissolved oxygen [4]. Thus, dyes in wastewater should be removed completely before they are discharged into receiving waters.

Many methods have been reported for removing color from dye wastewater, among which coagulation is a widely used process due to its relatively simple operation and low cost [5]. The most commonly used coagulants in dye wastewater treatment are Al(III) salts and Fe(III) salts [6–8]. However, there are some disadvantages with those in-coagulants. Recent epidemiological, neuropathological and biochemical studies suggest a possible link between the neurotoxicity of aluminum and the pathogenesis of Alzheimer's disease [9,10]. Ferrite flocculants can be costly and the resultant excessive iron may cause unpleasant metallic taste, odor, color, corrosion, foaming or staining [11].

In view of the above, many factors have been taken into consideration to improve the conditions and reduce the dosage of the harmful inorganic coagulants. In recent years, Sanghi et al. found that coagulation aids could enhance the coagulation efficiency on reactive dye wastewater [12] and many synthetic polymers have been used as the main coagulant aids and some good results have been reported [13,14]. The most common practice is to add polymer some time after the metal coagulants [15]. However, polymers, used as coagulant aids, have also been reported to contain contaminants from the manufacturing process which have potentially negative impact on human health [16]. Therefore, there is an increasing demand for environment-friendly and effective coagulant aids. Sodium alginate (SA), the sodium salt of alginic acid, with an average molecular weight of 500,000, is a linear water-soluble anionic polymer (Fig. 1). It is widely used to produce microsphere, beads, microcapsule and tablets for drug delivery system [17]. However, there has been no report on the use of SA combined with aluminum sulfate (AS) in water treatment. In principle, the coagulation efficiency could be improved when SA is used in combination with AS, and the dosage of AS could also be reduced.

Generally, the effectiveness of flocculation is measured by the parameters such as residual turbidity or chromaticity removal because they are directly related to the solid–liquid separation and water quality. However, they only provide limited information of flocculation process. The information of floc size distribution and structure would be much needed [18]. The flocculation dynamic monitoring technology, Photometric Dispersion Analyzer (PDA), was adopted to observe the floc aggregation processes in this

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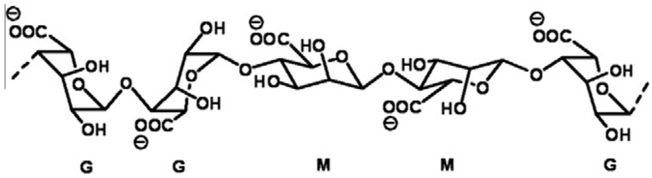


Fig. 1. Chemical structure of sodium alginate.

study. Gregory is the first researcher to introduce PDA in monitoring the state of aggregation of floc [19], and more researchers adopted the optical technique to describe the dynamics of flocculation in recent years [20].

The aim of the present work was to test the effect of SA used as coagulation aids in disperse yellow (D.Y. RGFL) wastewater treatment with AS. The coagulant performance was investigated in terms of color removal efficiencies and zeta potentials. In this study, the evolution of floc ratio as a function of coagulation time was measured by PDA. Floc aggregates were characterized in terms of size, floc growth rate, breakage and subsequent regrowth potential. The relationship between floc properties and coagulation mechanism was also discussed.

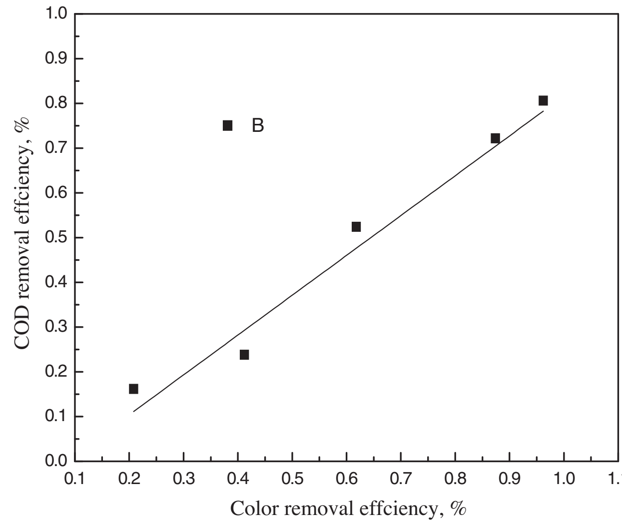


Fig. 2. Relationship between the removal efficiency of color and COD of the tested D.Y. RGFL solution.

2. Materials and methods

2.1. Coagulants

In this study, the following stock solutions of coagulants were prepared; (1) aluminum sulfate (Alum 1000 mg/L as Al, analytic reagent, Sinopharm Chemical Reagent Co. Ltd., Beijing, China), (2) Sodium alginate (cSA, 1000 mg/L, Medicine Group Chemical Reagent Co. Ltd., Tianjin, China). All the solutions were prepared using deionized water and stored at 4 °C.

2.2. Test water

The raw water in the coagulation experiment was prepared by adding designated amounts of D.Y. RGFL in tap water. The dye was obtained from Jinan No. 2 Textile Dyeing Mill, China. The synthetic dye wastewater was prepared by adding 0.1 g of D.Y. RGFL powder in 1.0 L tap water and the concentration of D.Y. RGFL reached 100 mg/L which was close to that in actual printing and dyeing wastewater [21]. The characteristic wavelength for the dispersed dye water was determined by a spectrophotometer (TU-1810, Pgeneral Instrument Co. Ltd., Shanghai, China). The maximum absorbance wavelength (λ_{max} = 445) was used for all absorbance readings. The relationship between absorbance value at λ_{max} and dye concentration was linear, constituting a basis of conversion of absorbance value at λ_{max} data into an "equivalent" dye concentration. Color removal efficiency was calculated by comparing the absorbance values of the treated wastewater and the absorbance value of the original dye wastewater, with distilled water serving as a Ref. [21]. The characteristics of D.Y. RGFL were shown in Table 1.

2.3. Wastewater characteristics and analytical methods

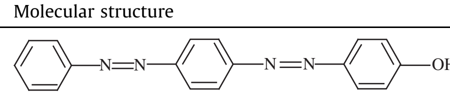
Wastewater to be tested was obtained from the Binzhou Textile Company, Shandong Province, China. The wastewater was dark yellow in color, which was caused by two main dyes – disperse yellow and reactive yellow, and it also contained high concentrations of organic matter including dyes, additive, surfactant and others. Dyes can contribute about 20% COD. The characteristics of the wastewater were: COD = 2860 mg L^{-1}, Abs (sum) = Abs($_{330}$) + Abs($_{400}$) + Abs($_{445}$) = 2.756, pH = 10.26.

The color and COD of influent were measured throughout the experiment. Color measurements were conducted with TU-1810. As the wastewater contained different kinds of dyes, the traditional method of applying the maximum absorbance was not utilized. Color content was determined by measuring the absorbance at three wavelengths (330 nm, 400 nm, 445 nm) and taking the sum of these absorbencies. The COD of the test water sample was measured on the TL-1A COD reactor.

2.4. Jar test

Coagulation experiments were preformed in 1.5 L plexiglass beakers using a conventional Jar-test apparatus (ZR4-6, Zhongrun Water Industry Technology Development Co. Ltd., China). Standard jar tests were conducted at room temperature (20 ± 1 °C). During the rapid stirring at 200 rpm (G = 51.6 s^{-1}), predetermined amount of coagulant was dosed to obtain a certain AS and SA concentration. The doses of AS ranged from 4.0 to 6.5 mg/L as Al, while SA dose (calculated as mg/L of SA) was 0.5, 1.0, and 2.0 mg/L, respectively. When organic polymer was used as coagulant aids, the best results were obtained when the polymer was added after the addition of the primary coagulant [22]. In this comparative experiment, AS was added firstly at the start of rapid mixing phase (200 rpm), followed by SA after 30 s. This dual-coagulant was denoted as AS–SA. The wastewater samples were mixed rapidly for 2.5 min after dosing, followed by slow stirring at 40 rpm (G = 11.8 s^{-1}) for 20 min and sedimentation for 30 min. After flocculation, supernatant samples were withdrawn from about 20 mm below the wastewater surface for measuring absorbance and analyzing color removal efficiency. In order to investigate the relation of color

Table 1
Dye characteristics.

Name	Type	Molecular structure	λ_{max} (nm)
D.Y. RGFL	Disperse yellow (RGFL)		445