Chitosan as a Widely Used Coagulant to Reduce Turbidity and Color of Model Textile Wastewater Containing an Anionic Dye (Acid Blue)

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Abstract. The study focuses on using chitosan as a widely used coagulant (a biopolymer) to treat model textile wastewater containing an anionic dye (acid blue). Jar test experiments had been used in the coagulation-flocculation process. Acid Blue was selected as a model dye for testing chitosan’s ability to treat model textile wastewater. Chitosan is found from chitin by deacetylation. The biopolymers, because of biodegradable properties, availability and low cost have been used as coagulants. The dosage impact, pH, settling time, decolorization and turbidity reduction of simulated textile wastewater were studied. Chitosan showed great performance to remove turbidity and color. The usage of chitosan as a primary coagulant would decrease the cost of wastewater treatment. Besides, it is eco-friendly coagulant without harmful impacts.

Keywords: Coagulant; chitosan; model textile wastewater; coagulation-flocculation; biopolymer; turbidity; color

1. Introduction

Textile industries have a highly positive effect on the economic development countries. However, the unacceptable heterogeneous aspects in composition effluent are one of the basic problems associated with textile factories [1]. Textile finishing’s wastewater, especially dyeing process effluent, contains a wide range of chemicals, organic dyes, and auxiliaries. Color, inorganic salts, chemical oxygen demand (COD), total dissolved solids (TDS) and heavy metals are sorted as the main contents in the effluent of the textile industry. So, dye effluent must be treated before being discharged [2]. Some techniques such as coagulation, adsorption, or advanced oxidation can be used for the decolorization and reduction the level of pollutants from textile wastewater. Electrocoagulation is another process to remove pollutants from water and wastewater [3]. K.S. Hisham et al. investigated the impact of the electrocoagulation method on the analysis of the surface of aluminum electrodes for phosphate reduction process, findings of the study demonstrated that 99% of phosphate was eliminated within 1 hour of electrolysis at an initial pH of 6, primary dose of phosphate of 100 mg/L [4]. While Omwenea et al. investigated the impact of initial pH, current density initial phosphorus dosage and electrocoagulation period on phosphorus reduction from domestic wastewater. Phosphorus removal from domestic wastewater was 99.99% [5]. Among the available treatment techniques, Coagulation- flocculation can be considered as one of the most important solid-liquid separation processes due to simplicity, cost-effective, easy technique for treating the textile effluent [6] and it can be used as a pre-treatment, a post-treatment or even a main
Chemical coagulants are commercially available with wide usage. Negative impacts on human health and the possible contribution to Alzheimer’s disease and percentile dementia have been recorded. Therefore, special importance has been focused on a new generation of coagulants classified as environmental friendly coagulant such as chitosan. Chitosan is an amino polysaccharide obtained in the process of deacetylation of chitin, which, besides cellulose, are the most common natural polymers in the world. The main sources of chitosan are organisms living in seawater – shrimps, crabs, and lobster shells. Chitosan has a structure similar to those of chitin and cellulose and has unique properties as compared to other biopolymers. However, chitosan has greater solubility in an aqueous acid medium than its precursor polymer (chitin) and cellulose, result from the presence of amine groups and primary and secondary hydroxyl groups, which are responsible for its application in multiple functions. The main advantages of chitosan are non-toxicity, no harmful effect on human health, linear cationic polymer of high molecular weight and biodegradability.

This study examines chitosan capability as a widely used coagulant to remove color and the turbidity of simulated textile wastewater in coagulation-flocculation process. Initial pH, chitosan dosage and settling time were considered to know the optimum conditions to achieve the best performance of chitosan.

2. Materials and methods

2.1. Wastewater

For the preparation of model textile wastewater, a varying concentration of acid blue dye in range of (5 -10 and 15) mg which was supplied from Al-Kut Textile Factory /Iraq as a source of color and other additive shown in table 1, were added into a liter deionized water. The dye solution was suspended at a fast speed (120 rpm) for 2 minutes followed by slow speed (20 rpm) for 20 minutes. Then, the mixture was left for 30 minutes to deposit. When the settling period has been ended, samples were taken to measure the initial parameters.

| Substance                  | Concentration (mg/l) | Chemical formula | Using                  | Supplied from/ Purchased from       |
|----------------------------|----------------------|------------------|------------------------|-------------------------------------|
| Starch                     | 1000                 | C₆H₁₀O₅          | Source of TSS          | Macclesfield, Cheshire, UK          |
| Hydrochloric acid          | 300                  | HCL              | pH adjustment          | BDH Chemicals Ltd Pool, England     |
| Sodium lauryl sulfate      | 100                  | CH₃(CH₂)₁₁OSO₃Na | Spread the dye         | CDH Ltd. India                      |
| Sodium chloride            | 3000                 | NaCl             | pH adjustment          | Macclesfield, Cheshire, UK          |
| Sodium carbonate           | 500                  | Na₂CO₃           | pH Fixation            | HiMedia Lab. Pvt. Ltd. India        |

2.2. Chitosan

Chitosan was supplied by CDH Ltd. (India) as shown in figure 1(a). The chitosan (1 g) was added after being ground and sieved to (1L) of demineralized water, after which 1 g of acetic acid was added under agitation for 1 hour to dissolve the chitosan powder. The acetic acid was being used in chitosan preparation due to chitosan solubility in the aqueous acid medium. The solution (figure 1 (b)) with pH 4 was used as a coagulant after leaving it for 48 hours.
2.3. Coagulation–flocculation experiments

Experiments on model textile wastewater coagulation and flocculation were performed using a jar test apparatus (VELP Scientific, Italy) which consists of four beakers, four stainless steel paddles as shown in figure 2. This test considered the best way to assess the coagulation process by finding the best dosage of coagulant. Each 1000ml beaker was filled with synthetic textile wastewater with notable masses of dyes. In every beaker, a divergent coagulant concentration is adapted with dissimilar concentrations fluctuating from (10, 20, 30, 40, 50, 60 and 70) mg/l. In the jar test device, the beakers faced to fast mixing speed 120 rpm for 120 seconds to disperse chitosan solution in all solution, and after that to quit mixing speed 20 rpm for 1200 seconds to form the flocs. The mixers are switched for 1800 seconds for settling the flocs. At the end of the settling period, the samples were picked from a distance 3-4 cm under the surface of each beaker by syringe. These samples tested by using single beam UV spectrophotometer (SpectroDirect) turbidity and color. All the experiments were conducted at room temperature of 20 ±2. The experiments were performed in duplicates and the average values were considered.

![Figure 1](image1.png)

**Figure 1.** (a) Chitosan before ground (b) Chitosan solution.

![Figure 2](image2.png)

**Figure 2.** Jar test apparatus used in the experimentation.
3. Result and discussion

3.1 Chitosan dosage effect

The impact of chitosan concentration was studied at pH 6, 2 min with 120 rpm then 20 min with 20 rpm and 30 min of settling time for dosage (10-20-30-40-50-60 and 70 mg/l) of chitosan. Figure 3 shows the impact of chitosan dosage on color and turbidity removals when dye concentration 5 mg/l. It is clear from the results that when chitosan dosage equal to 40 mg/l, 99% and 76.5 % for turbidity and color respectively were recorded. From the dosage 10mg/l to 40 mg/l the removal of turbidity and color was increased. Charge density phenomenon could be explained in this case. Chitosan has a high charge density [19]. Therefore, this helped to occur rapid destabilization of the particles in less amount of chitosan. When increased chitosan dosage from (40-70) mg/l, the removals of turbidity and color decreased, explained by colloidal surfaces have been filled with adsorbent and no more places founded on it to format bridges between them. Figure 4 displays the reduction of turbidity and color when using optimum dosage of chitosan (40 mg/l) to treat dye with concentration (10 and 15 mg/l) with (90.6% turbidity, 70.1 % color) for dye 10 mg/l and (85.4% turbidity, 66.3 % color) for dye 15mg/l.

![Figure 3. Chitosan dosage effect on turbidity and color removals (constant dye 5 mg/l).](image1)

![Figure 4. Effect of optimum chitosan dosage 40 mg/l on turbidity and color removals for 10 and 15 dye concentration.](image2)

3.2 pH effect

pH value is an important parameter influence on the solubility of chitosan in aqueous solution. pH impact was studied for pH which started from pH 2 till pH 12 using dilute HCl or NaOH to adjust pH value, optimum dosage of chitosan 40 mg/l, 5 mg/l of dye, 2 min with 120 rpm, 20 min with 20 rpm and 30 min of settling time. Figure 5 demonstrates the pH impact on turbidity and color removal, pH 5-6 recorded the highest reduction with 99% and 76% of turbidity and color reduction respectively. This can be supported due to chitosan activity in the acid range of pH and indicating that the pH can be considered as a critical parameter affecting on chitosan ability to reduce the level of pollutants. Figure 6 represents the pH effect on reducing the level of certain pollutants when dye with concentration (10 and 15) mg/l and pH value 5.5 (average value). The highest removals were (91.2 % turbidity, 72 % color) for dye 10 mg/l and (89.4% turbidity, 69.1 % color) for dye 15mg/l.
3.3 Settling time effect

The impact of settling time on turbidity and color reduction was investigated by testing several experiments using optimum chitosan dosage (40 mg/l), dye (5 mg/l), pH value (5.5), 2 min with 120 rpm, 20 min with 20 rpm, and settling periods of (10-20-30-40-50 and 60 min). Figure 7 displays the effect of settling time on pollutants reduction. It can be stated; a direct correlation between settling period and percentage removals where the turbidity and color removal efficiency reaches to 99.7% and 78% respectively in time 50 min and after time 50 there no change observed in the removal percentage of certain pollutants. When dye concentration (10 and 15) mg/l at the same condition and settling time 50 min, the percentage reduction were (96 % turbidity, 74.1% color) for dye 10 mg/l and (92.8% turbidity, 70.3% color) for dye 15 mg/l as shown in figure 8.

Figure 5. PH effect on turbidity and color removals. Dye 5 mg/l.

Figure 6. Turbidity and color removals when PH = 5.5 for dye (10 and 15) mg/l.
Conclusions

Among different technologies available to treat textile wastewater such as physical, chemical, biological, and advanced methods, chemical coagulation-flocculation is still a suitable technology due to its cost-effectiveness and simplicity. In this study, chitosan used as a widely used coagulant to treat model textile wastewater containing an anionic dye (acid blue). Chitosan recorded 99.7% and 78% of turbidity and color removal for dye concentration 5 mg/l under an optimum condition.

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