Turbidity, Color and Chemical Oxygen Demand Removals from Synthetic Textile Wastewater Using Chitosan as a Coagulant

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Abstract. The study investigates the performance of chitosan as a coagulant towards a treatment of synthetic wastewater by combined process of coagulation–flocculation followed by granular filtration. In this study, chitosan used due to some novel characteristics of coagulants such as non-toxic, ecosystem appropriate characteristic, biodegradability, etc. The optimum conditions for this study were at 40 mg/l of chitosan, 5 mg/l of dye, the reduction percentage is further than 98.5%, 92.5% and 94.2% for color, turbidity and chemical oxygen demand (COD) individually. In conclusion, chitosan is an effective coagulant, which can be used to remove certain pollutants with a high percentage from textile wastewater.

1. Introduction

Water is the most abundant material on earth, even though, 97% of water contains salt with percentage exceeds the threshold value and make it basically not suitable for drinking or for the various industrial purposes, 2/3 of the remaining 3% is the form of ice, then leaving only about 1% of the total water as fresh water. The environmental legislations exist to ensure the quality of the environment and these legislations involve the properties of the water drained by industrial areas [1]. Industrialized wastewater is generally handled to perform the principles for discharges to rivers or lake. Water re-use and recycling can be considered as a clear method to decrease the volume of water which must be withdrew from the surface water sources. Direct re-use and recycling require only a minimum of capital outlay and extremely low running cost [2]. In the preparations and accomplishment of water reclamation and reuse, the proposed water reuse implementations affect the level of wastewater treatment desired. The quality of resulted water, and the way of allocation and implementation, water reuse may involve a completely controlled "pipe-to-pipe" system with an intermittent storage step, or it may include blending with non-reclaimed water either directly in an engineered system or indirectly through surface water supplies or groundwater recharge [3]. The principal considerations in reuse of water are (1) dependable treatment of wastewater to satisfy hard water quality needs for the designed reuse, (2) preservation of public health and (3) achievement public approval. Water reuse as well needs accurate test of framework and facilities development [4]. Textile processing production is a water intensive consumptive industry in almost every stage for processing, from sizing, desizing, scouring and bleaching, of the dyeing, finishing and printing of fabrics. Every textile plant requires large volumes of water about one hundred m³/ton and produces large quantities of effluent wastewater, that is generally described through color, salts, and organic matter [5]. The standard methods of treating textile wastewater are physical, chemical or biological methods. These methods can be adopted to reduce color and other pollutants in the wastewater...
with variable efficiency according to the kinds of colors and their concentration. Physical-chemical methods are always used for color removal, and other organic and inorganic impurities. Advanced filtration like (UF, NF and RO) has proved that it is more efficient and effective in removing the color, COD and other pollutants from wastewater [6],[7]. But these methods are relatively expensive and sensitive for impurities and colors which cause damage [8]. To achieve acceptable quality for the treated wastewaters, sand filters are widely used and the technology for design and production are more adequate and of low cost. The maintenance of the sand filter is technically easier than advanced filters. The coagulation/ flocculation process is an important part of surface water and wastewater treatment. It has a direct impact on the reliability of plant operations and final water quality together with cost control [9]. The aim of this study is to:

- The investigation using chitosan as a coagulant material to reduce the rate of discharged wastewater pollutants to the surface water sources during minimizing the pollutants concentrations of the reclaimed water.
- Determine the best dose for chitosan throughout studying their effects on the treated water characteristics (Turbidity, Color and COD removals) by physical-chemical treatment using the coagulation flocculation and filtration processes.

2. Methodology

2.1. Synthetic Wastewater

Synthetic wastewater was used to study the bench scale parameters and pilot plant model performance, the synthetic wastewater prepared to meet the original textile wastewater. For preparation synthetic wastewater, several concentrations of dye (5;10;15;20;25 mg/l) and additive (as shown in the table 1) added to a liter of deionized water.

| Substance                  | Concentration (mg/l) | Chemical formula  | Using                  |
|----------------------------|----------------------|-------------------|------------------------|
| Starch                     | 1000                 | C6H10O5           | Source of TSS          |
| Acetic                     | 200                  | CH3COOH           | Carbon source (COD)    |
| Sucrose                    | 600                  | C12H22O11         | Food of bacteria       |
| Hydrochloric acid          | 300                  | HCL               | PH adjustment          |
| Sodium lauryl sulfate      | 100                  | CH3(CH2)11OSO3Na  | Spread the dye         |
| Sodium hydroxide           | 500                  | NaOH              | PH adjustment          |
| Sodium chloride            | 3000                 | NaCl              | PH adjustment          |
| Sodium carbonate           | 500                  | Na2CO3            | pH Fixation            |
| Dyes                       | 5, 10, 15, 20, 25    |                   | Color source           |

2.2 Apparatus

2.2.1. Pilot Plant

The pilot Plant model includes feeding tank, mixing tank provided with mixing motor with blades turbine agitator, settling tank, sand filter, collection tank and storage tank, besides the accessories included, dosing pump, coagulant mixing tank with mixing motor and agitator, U-tube manometer, valves flow meters and drain tank, as can be seen in figure 1.
2.2.1.1. Feeding and Mixing Tanks
A steel rectangular tank of 128-liter capacity used for pumping synthetic wastewater to coagulation/ flocculation tank which consists of mixing tank with dimensions of 45cm diameter and 60cm height has been used as a coagulation/ flocculation tank. Rectangular baffle of width 4.5 cm and length 60 cm was built inside of this mixing tank. Turbine agitator with 6, blades connected with electrical motor power 80 W, use for provided a flash mixing and gentle mixing during the coagulation and flocculation processes. The stirring speed (N) was controlled by a speed regulator of the electrical mixer. The coagulation process with rapid mixing and high velocity gradient (300-350), continued for 3 min, the velocity gradient reduced to 100 then to 30 1/sec, for 20 min for the flocculation process.

![Figure 1. Schematic diagram of the treatment system (mechanical mixing tank)](image)

2.2.1.2 Settling Tank
A rectangular steel tank of depth (D=45 cm), Length (L=90cm) and width (w=35cm) was used for settling process in a period of 30 min to remove the settling particles and flocs generated during the coagulation/ flocculation process, two steel plates of (35,40cm) height and width respectively was inserted into the sedimentation tank at the front of the inlet pipe about 10% of the projected area of the settling tank.

2.2.1.3. Sand Filter Column
Steel column of 20 cm diameter and 100 cm depth, filled with sand and gravel to use as a rapid sand filter instilled after the settling tank to remove or separate the fine particles and flocs that are not settled in settling tank from the treated wastewater. Commercial silica sand of 2.45 specific gravity and gravel was used as a filter media. A size analysis was done to the raw sand by a different mesh size sieve, the effective size d10 (Es) of the sand is (0.63) mm and d60 is (0.96) mm, the uniformity coefficient (UC) is (1.4).

2.2.1.4. Chitosan (coagulant) Tank
A steel tank of capacity 20 liter was used to prepare and supply the chitosan slurry. This tank was provided with electrical motor connected to a steel shaft with an impeller as a mixer inserted into the lime tank in order to keep continuous mixing and prevent the coagulant particles from settling at the bottom.

2.2.1.5. Drain (or sludge) and Storage Tanks
A steel tank of 300-liter capacity was used to collect the drains and the overflow from the mixer tank and hydraulic baffle channel as well as the drain exit from the settling tank and the backwash water
used to clean up the sand filter media. A steel tank of 300-liter capacity was set as a storage tank connected with a pump to supply the wastewater to be treating to the mixing tank or to the baffled mixing channel, controlled by a valve and flow meter.

2.3. Experiments and Tests
Turbidity, Color and COD tests which tested by using single beam UV spectrophotometer (SpectroDirect) further experiments were repeated 3 times for identical test results and conditions then the average values were used for calculations. The experiment procedures and tests were used according to [10] to determine the characteristics of raw and treated wastewater.

2.3.1. Chemicals and Coagulants
The coagulants and chemicals used to enhancement the removal efficiency, included chitosan. Stock solution of chitosan was prepared by adding 10 gm of chitosan to 1000 ml of tap water at 80˚c to make a homogenous solution of chitosan solution strength of 1%. Thus, each 1 ml/L of stock solution contained 10 mg/L of chitosan.

3. Results and Discussion

3.1. Impact of Chitosan Concentration on Reduction of Dyes
For calculation the optimum concentration of chitosan coagulant, many chitosan concentrations (10, 20, 30, 40, and 50 mg/l) for several selections of synthetic textile wastewater were investigated and examined for calculation the sound concentration. Dye dosages of synthetic wastewater were (5, 10, 15, 20, and 25 mg/l). Figure 2 displays the impact of chitosan as a coagulant on dye reduction percentage. The concentration of 40 mg/l has great impact on color removal for a fixed dye concentration 5 mg/l of dye wastewater; the dye removal percentage was 98.5%. This optimum dosage (40 mg/l) was applied for different range of dyes concentrations as shown in figure 3 the impact of optimum chitosan on dye removal adequacy for different range of dye concentrations. It is knowable that concentration of 40 mg/l has great impact on the color reduction for dye concentration 5, 10, 15, 20 and 25 mg/l the color removal efficiency were 98.5%, 96.2%, 95%, 87.4% and 82.3%, respectively.

Figure 2. Optimum chitosan dosage for color removal (constant dye 5 mg/l).

Figure 3. Color removal for different colors at optimum chitosan 40 mg/l.
3.2. Impact of Chitosan Concentration on Turbidity Reduction

Many different concentration (10, 20, 30, 40, and 50 mg/l) for several specimens of dye wastewater were experienced for selection the proper concentration of chitosan to achieve higher turbidity removal percentage. The dye dosages of synthetic textile wastewater are (5, 10, 15, 20, and 25 mg/l). Figure 4 demonstrates impact of chitosan dye removal percentage. It is knowable that concentration of 40 mg/l has valuable impact on turbidity reduction for a fixed dye concentration 5 mg/l of synthetic wastewater; the turbidity removal percentage was 92.5%. This optimum dosage (40 mg/l) was applied for different range of dyes concentrations as shown in figure 5 the impact of optimum chitosan as a coagulant on turbidity removal percentage for different range of dye concentrations. It is knowable that concentration of 40 mg/l has valuable impact on the removal of color for dye concentration 5, 10, 15, 20 and 25 mg/l the turbidity removal efficiencies were 92.5%, 90%, 87%, 79% and 73.5%, respectively.

![Figure 4](image1.png)

**Figure 4.** Optimum chitosan dosage for turbidity removal (constant dye 5 mg/l).

![Figure 5](image2.png)

**Figure 5.** Turbidity removal for different colors at optimum chitosan 40 mg/l.

3.3 Impact of Chitosan Concentration on COD Reduction

To investigate the proper concentration of chitosan coagulant, various portions (10, 20, 30, 40, and 50 mg/l) for varied samples of dyes wastewater were examined to determine the best amount of coagulant. The dye dosages of synthetic dye wastewater are (5, 10, 15, 20, and 25 mg/l). Figure 6 displays impact of chitosan on COD removal percentage. It is obvious that concentration of 40 mg/l has meaningful impact on COD reduction for a fixed dye concentration 5 mg/l of dye wastewater; the COD removal efficiency was 94.2%. This optimum dosage (40 mg/l) was applied for different range of dyes concentrations as shown in figure 7 the impact of optimum chitosan on COD removal efficiency for different range of dye concentrations. It is detectable that concentration of 40 mg/l has considerable impact on COD reduction for dye concentration 5, 10, 15, 20 and 25 mg/l the COD removal efficiencies were 94.2%, 92.8%, 90.06%, 82.8% and 77.4%, respectively.
3.4. Discussion
The main causes of the high percentage of color, turbidity and COD removals were due to:
1- High charge density of chitosan [11]. So, this property helped to occur rapid destabilization of the particles in less amount of chitosan.
2- The settling particles and flocs generated during the coagulation/ flocculation process were removed through the settling process in settling tank.
3- Granular filtration efficiency including removing or separate the fine particles and flocs that are not settled in settling tank.

4. Conclusions and Recommendations
The treatment of colored material in textile wastewater before discharging into rivers is important for water sources preservation using natural and chemical coagulants. Therefore, adopting chitosan powder a coagulant can be applicable at a great efficiency in dyeing and other pollutants removal from textile wastewater. The reduction percentage is further than 98.5%, 92.5% and 94.2% for color, turbidity and COD, respectively.

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