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Treatment of textile waste water using natural catalyst (chitosan and microorganism)

Abstract

The study investigates the performance of chitosan and microorganism towards treatment of textile wastewater by using aeration & flocculation process. Chitosan is found from chitin by deacetylation. Flocculation and the process are done using Jar test experiment. The effect of dosage, reduction of COD, reduction of BOD and color of textile wastewater is studied. The results obtained found that chitosan is very effective for reduction of COD, BOD and color. The best condition for COD and BOD removal is achieved at 0.1- 0.2g dosage, pH 4.17 and 30minutes of settling time. Under this condition, about 40% of COD and 43% of BOD is removed, respectively. However, the results obtained using microorganism also good. Microorganism is able to remove both COD and BOD of the wastewater but COD is slightly higher than the acceptable range.

Keywords: chitin, chitosan, textile wastewater, microorganism, flocculation

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Introduction

Textile industries are the largest consumers of water and chemicals for wet processes of textile like dyeing, hence must generate high doses of effluent rich in the chemicals, which are highly toxic to the environmental components. Effluents from the textile industries are highly colored containing dyes that vary from 2% for basic dyes to as high as 50% for reactive dyes, leading to severe contamination of surface and ground waters. In general, the wastewater from a typical cotton textile industry is characterized by high values of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), color, and pH. Because of high BOD and color, the untreated dye effluents reduce dissolved oxygen content and light penetration respectively, in receiving water bodies and without suitable treatment, such wastewater would destroy the natural water environment. Bisschops and Spanjers report BOD values between 380±2020mg L-1 and COD values ranging from 2600 to 11500mg L-1 for cotton processes. Much of the BOD and COD originate from fats, waxes and fibers used and washed off during the process. Moreover, salts are used to enhance the adherence of dyes to the textile fiber. pH can vary from 5.5 to 11.6 in different systems. Most of the physical and chemical methods like adsorption, chemical oxidation, precipitation, coagulation, filtration, electrolysis, photo degradation employed, which in spite of high cost, are low efficient and do not always ensure that the contaminants are completely removed. On the other hand, biological methods involving the use of microorganisms like fungi, bacteria, yeasts, and algae for the removal of synthetic dyes from industrial effluents either by degradation or by sorption are generally considered environmentally friendly, relatively inexpensive, the running costs are low, and the end products of complete mineralization are not toxic. Bioremediation is one such process and it is effective and environmental friendly technology for treating industrial dye wastewaters. It is a pollution control technology that involves the use of microorganisms to catalyze the degradation or transformation of various toxic chemicals to less harmful forms. Biosorption involves the entrapment of dyes in the matrix of the adsorbent (microbial biomass) without destruction of the pollutant. Several researchers have described the use of microorganisms as bio-sorption agents in the removal of pollutants from wastewater. A number of microorganisms display a remarkable ability to degrade a range of industrial contaminants (bioremediation) and to restore natural environmental conditions. Here anaerobic microorganism is used with the aim to reduce BOD, COD and to degrade color. The major process used worldwide is activated sludge process. It is an aerobic biological process that utilizes microorganisms such as bacteria, and protozoa for the decomposition of organic matter. This process has been named so since it involves the production of an activated mass of microorganisms which effectively stabilize the organic content of wastes in presence of oxygen and convert them to carbon dioxide and water which are safe to be disposed of in the environment. This is effectively achieved by a series of metabolic reactions carried out by the microorganisms.[1]

Coagulation or flocculation process was conducted for the treatment of industrial wastewater to achieve maximum removal of COD, BOD and color.[2] Therefore, Amudaa & Amoob[3] investigated the effect of coagulant dose, polyelectrolyte dose, pH of solution and addition of polyelectrolyte as coagulant aid and found to be important parameters for effective treatment of textile industrial wastewater. Two basic types of coagulants, i.e. inorganic and organic, are used in the processes of coagulation. The first ones contain primarily aluminum and iron salts.[4]

The use of inorganic coagulants is not particularly preferred because after purification metal ions from coagulants may occur in the wastewater treated. It is preferable to use organic compounds – polyelectrolytes, especially those of cationic nature. This is due to the prevalence of anionic compounds in textile wastewater, which increases the effectiveness of treatment. Organic coagulants based on synthetic polymers have many advantages over inorganic coagulants. These include smaller doses required in the process of coagulation and lower sensitivity to pH values. Natural polymer polyelectrolytes are called bioflocculants and contain biopolymers such as starch, chitosan and algae. They are organic coagulants and do not create secondary pollutants. An especially promising bioflocculant is chitosan. Chitin is cellulose like biopolymer widely distributed in nature, especially in marine invertebrates, insects, fungi, and yeasts. Its deacetylated product, chitosan, is readily soluble in acidic solutions, which makes it more available for applications. Chitosan is a biodegradable, non-toxic, linear cationic polymer of high molecular weight.

Besides, chitosan was an effective agent for coagulation of suspended solids from various food processing wastes. Moreover, chitin extraction also does not cause any disturbance to the ecosystem. . Chitosan coagulation produced flocs of better quality, namely larger flocs and faster settling velocity. The effectiveness of chitosan for coagulating mineral suspensions was improved due to the presence of inorganic solutes or due to addition of materials extracted from soils at high pH. Therefore, this study was carried out to analyze the effect of chitosan and microorganism in clarifying textile wastewater by aeration and flocculation process in different experimental conditions. The optimum pH, dosage and mixing time needed to achieve the best performance of chitosan in flocculation process were determined.[2]

Materials

The textiles wastewater was obtained from the Epyllion group which is situated in Dhaka. The wastewater that was used for microorganism treatment was from same batch of textiles and the wastewater that was used for chitosan treatment was from another batch (Tables 1−3).

Table 1 List of materials that has been used for chitosan and microorganism treatment and their source

Name of the materials	Source
Acetic acid	Wet processing lab
Anhydrous alcohol	Chemistry Lab
1M HCL	Wet processing lab
Lemon	Local Market
Shrimp	Local Market
Aerobic microorganism	Chemical Engineering Construction Co.

Table 2 Initial characteristic of textile wastewater (Chitosan Treatment)

Parameter	Value
pH	11.89
COD	240mg/l
BOD	56mg/l
Color	Yellowish

Table 3 Initial characteristic of textile wastewater (Microorganism Treatment)

Parameter	Value
pH	11.5
COD	400mg/l
BOD	61mg/l
Color	Dark Blue

Collection and modification of chitosan

The wastewater for chitosan and microorganism treatment was collected from Epyllion Group. Chitosan or poly [β(1-4)-2-acetamido-2-deoxy-D-glucopyranos]-poly [β(1-4)-2-amino-2deoxy-D-glucopyranos, is a linear biopolymer originally from shells of crustaceans and cell walls of insects and fungi. It is polysaccharide and a derivative of chitin. There are two types of monomers randomly distributed on chitosan's chain, namely N-acetyl glucosamine (GlcNAc) and glucosamine (GlcN), as shown in Figure 1. For this experiment chitin is collected from shrimp shell and then it is modified to create chitosan.

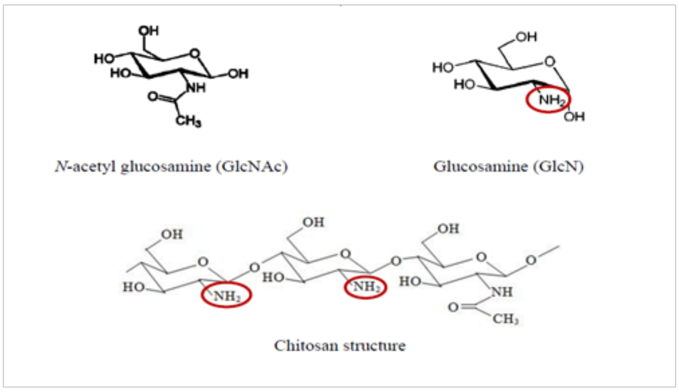

Figure 1 Molecular structure of N-acetyl glucosamine (GlcNAc), glucosamine (GlcN) and chitosan.

Chitosan is obtained from partial deacetylation of chitin which is removal of acetyl groups (-CH3CO) on N-acetyl glucosamine (GlcNAc) units of chitin polymer to reveal amino groups (-NH_2), as shown in Figure 2.

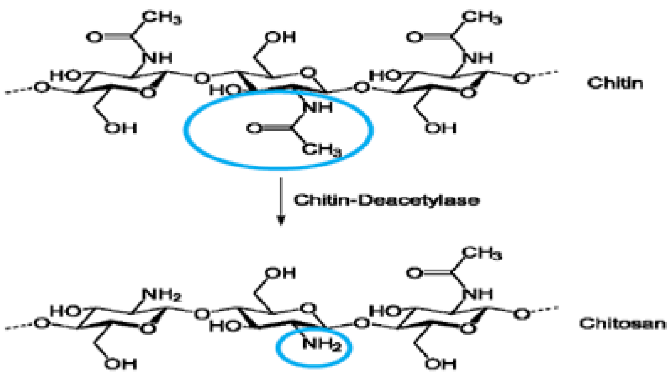

Figure 2 Deacetylation of chitin to obtain chitosan, acetyl group (-CH3CO) on acetyl glucosamine monomer on chitin chain is removed to reveal amino group (-NH2) becoming glucosamine monomer making chitosan.

For making chitosan shrimp shells are washed and dried. After Drying the shrimp shell is made powder form by blending. Then they are treated by acetic acid to dissolve calcium carbonate and then washed in anhydrous alcohol to solubilize protein; the result of these 2 steps is chitin. These two steps can be employed in reverse order. After those chemical treatments, chitin will go through the drying process at 65˚C temp.to obtain chitosan. A diagram of the commercial chitosan production process is shown in Figure 3.

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Shrimp Bio-waste (Wash and Dry)
↓
Purified by dissolving in acetic acid solution
↓
Washed by anhydrous alcohol for 3 times
↓
Dry at 65°C in vacuum for 48 hours
↓
Chitosan

Figure 3 Chitosan productions from shrimp shell.

Methodology

Method of chitosan treatment

In flocculation process, flocculant dosage plays an important role in determining the flocculation efficiency. Insufficient or overdosing dosage would give poor result in the performance of flocculation. Thus, it is crucial to determine the optimum dosage in order to minimize the cost and maximize the performance in the treatment. The experiment was conducted in order to determine the optimum dosage that affect to the performance of flocculation process. The experiments were done by varying the dosage of chitosan from 0.1 to 0.3g. The sample of the wastewater used was 150mL for every beaker at 3 minutes of mixing time with 150rpm of mixing speed, then 15 minutes of mixing time with 40 rpm and 30 minutes of settling time. The pH of solution was fixed at pH 4-4.2. The sample of wastewater was adjusted from 11.95 to pH 4-4.2 due to the chitosan that only applicable and soluble in the acidic aqueous phases.[5] The pH was controlled either by adding strong acid (0.1M) which is hydrochloric acid (HCl) or strong base (0.1M) which sodium hydroxide (NaOH) (Figure 4).

Microorganism treatment

The experiment was carried out using microorganism in waste water through aeration process. The pH of the wastewater is adjusted from 11.5 to 7.2 by adding Lemon-squash. Then 1lt waste water is oxidized for 48 hours. Then 3 times 9.55g microorganism was added in 250ml distilled water and was oxidized every time for 35 hours. The microorganism treated water was added in waste water and oxidized for 48 hours to reduce BOD and COD. The total quantity of microorganism needed per liter was 16.37g. The quantity was reduced than before waste water. Because in the aeration process, bacteria can break down organic compounds in water and reduce BOD &COD. These bacteria are called heterotrophic bacteria break down organic compounds due to the use of oxygen and CO_2 was produced as a by-product (Figure 5).[6] The reactions are given below,

Organic Waste+ Bacteria + $O_2 \longrightarrow CO_2 + CH_4$ + Radicals (Free) +Sludge +New Cell + Energy

C H N S P Microorganism
↓↓↓↓↓
Organic Radicals + $O_2 \longrightarrow CO_2$, H_2O, NO_3, Sulphate, Phosphate and CH_4

Before Chitosan Treatment

After Chitosan Treatment

Figure 4 Before and final chitosan treated sample water.

Before Microorganism Treatment

After Microorganism Treatment

Figure 5 Before and final microorganism treated sample water.

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Results

Result for chitosan treatment

The results indicated that percentage of COD and BOD removal was not increased with the flocculant dosage. Among three samples the highest COD & BOD removal at 0.1g chitosan dosage at 150ml. At this condition, the COD reduction is 40% and BOD reduction is 43%. At 0.2g the COD reduction is 25 % and BOD reduction is 29%. When the flocculant dose was above 0.1g, the efficiency began to decrease. Clearly the COD and BOD reduction percentage decreased above 0.1g. But the BOD & COD reduction efficiency lies within the range for chitosan dosage of 0.1 to 0.2g. And at 0.3g dosage it is out of range. So the optimum dosage was between 0.1 to 0.2g (Figure 6).

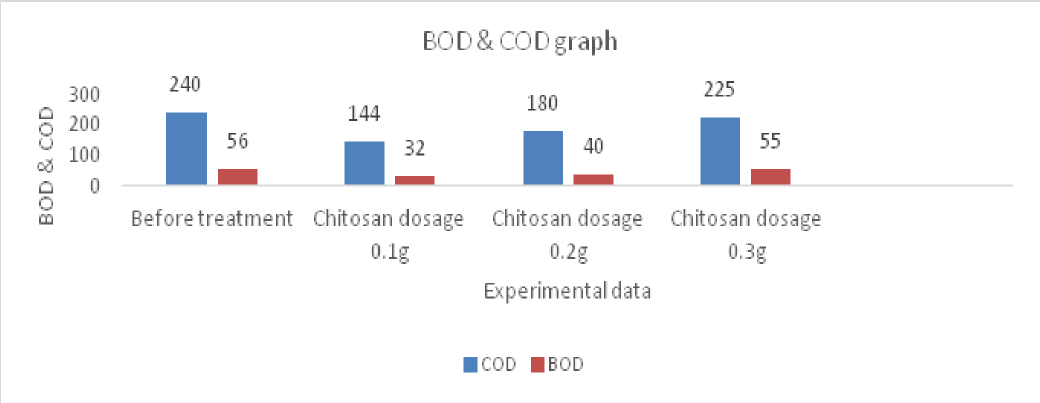

Figure 6 Chitosan treatments in waste water.

This could be explained due to the charge density. If compared to the other flocculants such as polyaluminium chloride and polyacrylamide, chitosan has a high charge density. Therefore, chitosan can be categorized as a flocculant that has a high charge density which means only require less amount of dosage to destabilize the particles. The extent addition of the chitosan dosage from 0.2 to 0.3g resulted to decrement in percentage removal of COD and BOD. This performance is due to the overdosing of chitosan that gave the phenomenon of excess polymer is adsorbed on the colloidal surfaces and producing re-stabilized colloids. Thus there were no sites available on the particle surfaces for the formation of inter-particle bridges. The chitosan dosage VS COD reduction % shown in Figure 7.[7–10]

The chitosan dosage VS BOD reduction % shown in Figure 8.

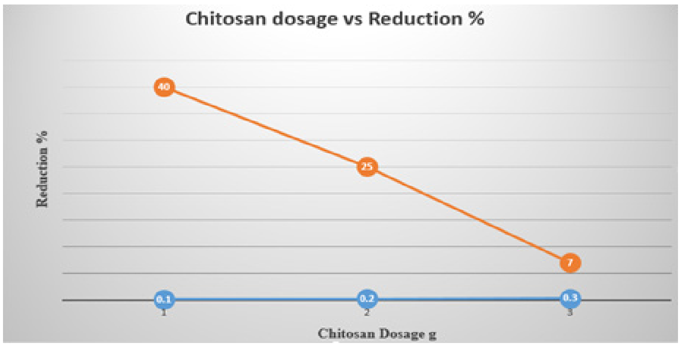

Figure 7 Effects of chitosan dosage on percentage reduction of COD.

Result for microorganism treatment

This process is usually used in waste water with a COD of less than 3000mg/L. The COD level reduced than before COD but is not perfect because COD value is not within the limit. But BOD range is satisfactory. The COD value is not perfect so reduction percentage was not measured. But the BOD reduction percentage for microorganism process is 27% (Figure 9).

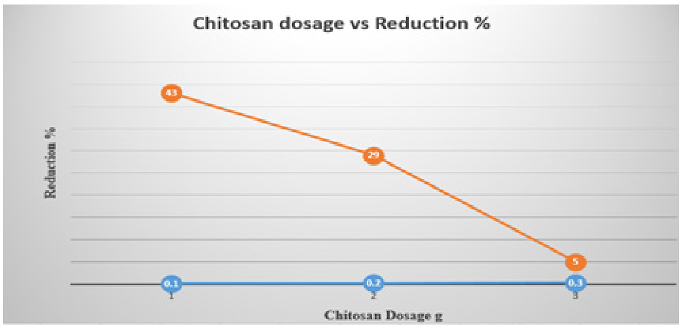

Figure 8 Effects of chitosan dosage on percentage reduction of BOD.

Comparison of performance between chitosan & microorganism

The experiment was carried out in two methods coagulation (chitosan) and aerobic process (microorganism) but from the methods it was clearly noticed that chitosan method is the most efficient and cost effective method. The quantity of chitosan needed for removal of COD and BOD was less than the quantity of microorganism. From Figure 7 and Figure 8 it has been found that the COD & BOD reduction % for chitosan treatment was more than the COD & BOD reduction % for microorganism treatment. The COD value is not within range for microorganism treated water but BOD lies. But its value is more than chitosan treated BOD reduction value. Besides, the cost of microorganism is more than the chitosan as well as the chitosan is easily available. So, between the two methods of waste water treatment the chitosan treatment method is the most efficient and cost effective method.[11–14]

The waste water treatment conducted by microorganism got better result but not perfect as chitosan treatment. For the microorganism treatment the report showed that more quantity microorganism was needed to reduce BOD & COD. And the minimum time required for this experiment is 83 hours. So it requires more time than chitosan treatment which needs only 48 minutes.

Both of these methods are environment friendly. But Comparing between chitosan and microorganism treatment chitosan treatment shows most efficient, cost effective and time effective result.[15–17]

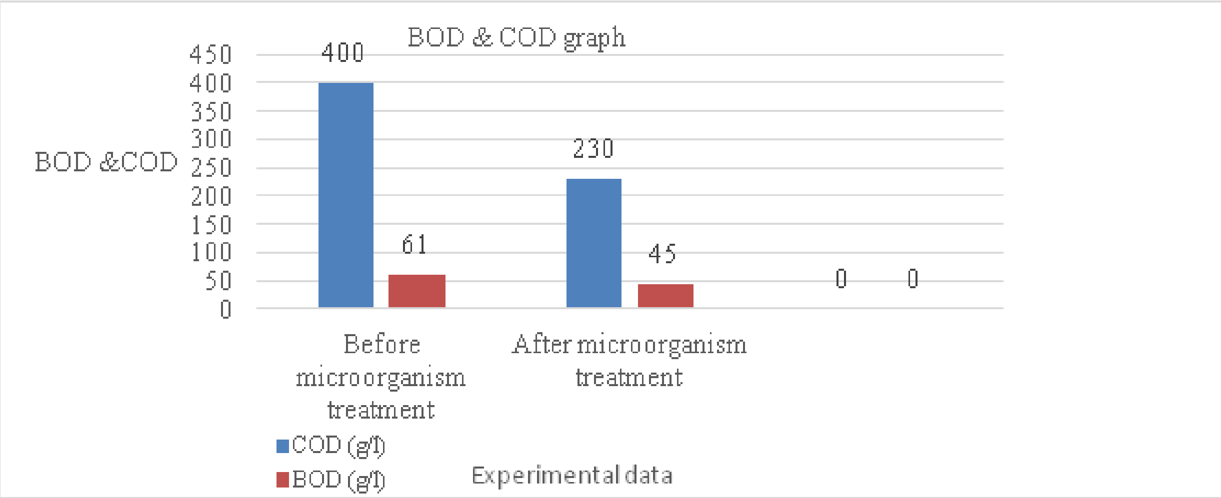

Figure 9 Microorganism treatments in waste water.

Conclusion

Based on their proved properties, chitosan can be a very promising adsorption additive for wastewater pollutants. Aiming to improve their adsorption performances, chitosan can be modified by grafting, cross linking, functionalization. Based on its origin product (chitin which can be found largely in marine media, i.e. in the exoskeleton of crustaceans, cartilages of mollusks or from the shrimp shell), the potential of chitosan to be used as (bio) adsorbent for wastewater pollutants is strong. The cationic nature of chitosan influences the adsorption mechanism of chitosan. In acid pH conditions, the amino groups of chitosan form protonated amines which can retain the dirt, metal ion and dyes group.

This research has demonstrated coagulation flocculation process using chitosan as a coagulant in treatment of textile wastewater. Chitosan as a biological cationic polymer and as a natural coagulant. The results show that chitosan is an effective coagulant for pollutants removal compared with microorganism. The data obtains from the experiment shows that only small amounts of chitosan are required for optimum removal of COD and BOD.

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Conflict of interest

Author declares there is no conflict of interest in publishing the article.

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