# Removal of Industrial Dye Effluent (Drimarene Yellow) by Renewable Natural Resources

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**Abstract.** Dyes and pigments represent one of the problematic groups emitted into wastewaters from various industrial branches, mainly from the dye manufacturing and textile finishing which have complex aromatic structures and provide them physico-chemical, thermal and optical stability. Present investigation deals with the utilization of natural biosorbents i.e., jute stick, chitin, chitosan for the removal of toxic reactive dye providing many beneficial aspects including low cost, biodegradability, nontoxicity, and biocompatibility. Diamerene yellow is a reactive dye which lowered the pH of the solution from 7 to 3.17. Among the jute stick, chitin and chitosan; chitosan showed better results for the removal of diamerene yellow and the removal potential was decreased with incubation time. The amount of dye removed by adsorbent was increased with the increase of adsorbent dose and initial dye concentration. Chitosan and chitin showed better results at 30 °C whereas jute sticks at 40 °C. For the irradiated chitin, dye uptake was reduced with the higher dose of gamma radiation. So, the utilization of this biosorbent can reduce the use of chemicals which is a potential burden for the aquatic biodiversity.

**Keywords:** Dye Adsorption, Jute stick, Chitin, Chitosan, Radiation.

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## 1 INTRODUCTION

Textile industrial sector is one of the most important and largest industrial sectors of Bangladesh with regard to production source of foreign exchange and labor force employment. 78% of the total export earning comes from textile and textile related goods. The textile industries are estimated to consume as much as two-third of the total annual production of dyes (Melgoza et al., 2004). Over 10% of the dye used in textile processing does not bind to the fibers and is therefore released to the environment (Reisch, 1996). Many industries, such as the textile, dyestuffs, plastics, leather, and paper industries, discharge colored wastewaters and dyes that remain in the effluents, undergo chemical changes, consume dissolved oxygen, and may cause carcinogenic and genotoxic effects (Crini, 2006).

Dyes with striking visibility in recipients may significantly affect photosynthetic activity in aquatic environment due to the reduced light penetration (Fu & Virarahavan, 2001). Therefore, it is necessary to remove dyes from wastewater before it is discharged into the environment.

It is difficult to treat dye containing wastewater by conventional methods as most of the dyes have complex aromatic structure of synthetic origin and thus hardly amenable to biodegradation (Banat et al., 1996, Chatterjee et al., 2005). In chemical methods coagulation produced high concentration of sludge production. A secondary pollution problem can also arise because of excessive chemicals used in treatment processes. Physical treatment methods require high energy and cause formation of hazardous by-products. Sometimes it requires regeneration or disposal (Saraswathi & Balakumar, 2009).

Adsorption is considered to be an effective method for the removal of dye due to the ease of operation and comparable low cost of application. At present, the most commonly used adsorbent in wastewater treatment is activated carbon, which has also been studied for the dye removal. But the extensive application of activated carbon is still in difficulty due to its high cost. Therefore, it is necessary to explore cheaper adsorbent for wastewater treatment. So, the aim of the present study was to find out the potentiality of the biosorbent for removal of toxic dyes.

## 2 MATERIALS AND METHODS

### 2.1 Sources of adsorbent and chemicals

Jute stick was collected from the local market; cut into small pieces; washed with water to remove any adhering substances and dried at 80 °C. Chitin and chitosan prepared from prawn shell in Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Savar, Dhaka, Bangladesh. NaOH and HCl were purchased from BDH and Merck, respectively.

### 2.2 Estimation of dye absorption

Drimerene yellow solution was prepared by dissolving of drimerene yellow in 100 mL distilled water at different concentrations. pH of the dye solutions were determined by digital pH meter (Philips, UK). The $\lambda_{max}$ of the dye solution was obtained from the light absorption spectrum (Taken by UV-Vis spectrophotometer, TG Instrument, UK). Different biosorbent of different doses was incubated for different time period in different concentrated dye solution. After incubation to different time the biosorbents was separated from the dye solution by sieving. Then the solution was diluted and absorbance was taken at $\lambda_{max}$ 461 nm. The amount of dye uptake, q ($mgg^{-1}$), was calculated using the following equation:

$$Q = (C_i - C_f)\, V \div 1000\, W , \qquad (1)$$

Where, $C_i$ ($mgL^{-1}$) =Initial dye concentration, $C_f$ ($mgL^{-1}$) = Dye concentration after adsorption W (g) =Amount of biosorbent and V (mL) =Volume of the solution

### 2.3 Effect of adsorbent dose

To examine the effect of adsorbent dose on the adsorption of dye, different amount of adsorbents were incubated in dye solution and absorbance was taken at 461 nm.

### 2.4 Effect of different temperature

Effect of solution temperature on dye adsorption by different adsorbents was examined by incubating the dye solution with adsorbents at different temperatures and absorbance was taken at 461 nm.

### 2.5 Effect of irradiated chitin

Chitin was irradiated by $^{60}Co$ gamma irradiation source at different doses e.g. 25 kGy, 50 kGy, 100 kGy and 200 kGy. Effect of gamma radiation on dye absorption capability of chitin was investigated by soaking irradiated chitin in dye solution for 16 hours. Absorbance (at 461 nm) of the solution was then measured to evaluate the effect of gamma radiation on dye absorption capability.

## 3 RESULTS AND DISCUSSION

**Table 1** indicates the effect of dye and the absorbents on the pH of the solution. In the present study the drimarene yellow lowered the pH of the solution from 7 to 3.17 which might have strong influences on the adsorption process. In case of chitin and chitosan, the media pH was higher, this might be because of the NaOH treatment on prawn shell to convert it chitin and chitosan. The amino groups of cross-linked chitosan are protonated under acidic conditions. As a result, the sorption process proceeds through electrostatic interaction between the two counter ions of reactive dye molecules and protonated chitosan. Increasing the pH of the solution, electrostatic interactions decrease due to the deprotonation of amino groups.

| **Solution** | pH |
|---|---|
| Distilled water | 7.05 |
| 0.5% dye solution | 3.17 |
| 0.5% dye solution with 1g jute stick | 3.80 |
| 0.5% dye solution with 1g chitin | 7.67 |
| 0.5% dye solution with 1g chitosan | 8.11 |

However, chitosan still sorbs dye molecules at pH 6–8, but in lower percentages. This fact occurs through a combination of other interactions, as Van der Waals forces and hydrogen bonding (Blackburn, 2004). Solution pH influences chemical nature of the surface of the adsorbent. A small increase in the adsorption of the dyes by jute stick powder was noted with increase in pH up to 7.0 (Panda et al., 2009).

Table 1. pH change of the sample.

### 3.1 Effect of different contact time and adsorbent dosages on uptake of dye

The uptake ($mgg^{-1}$) of drimarene yellow was appeared to increase with time up to 4 h of incubation period then decreased with time. Here, chitosan showed better results than chitin and jute stick in respect of uptake of dye (**Figure 1A**). The removal of the dye from aqueous solutions increased with time, till the equilibrium was attained and removal rate of adsorbate species from aqueous solution was controlled especially by the rate of transport of the adsorbate species form the outer sites to interior sites of the adsorbent particulars (Kannan & Sundaram, 2001).

In the recent study it was found that the removal of dye was increased with the adsorbent dosages. But uptake ($mgg^{-1}$) of dye with the adsorbent amount was reduced (**Figure 1B**). The percentage of dye removal increased with the increasing dose of adsorbent. This may be due to the increase in availability of surface active sites resulting from the increased dose and conglomeration of the adsorbent (Garg et al., 2003).

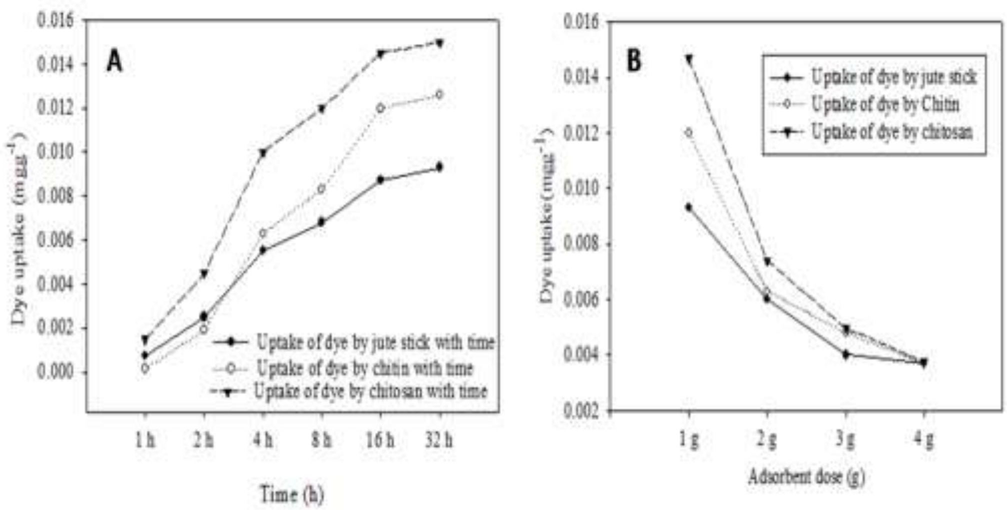


Fig. 1. (A) Uptake of dye by different adsorbent with time. (B) Uptake of dye for different adsorbent doses.

### 3.2 Effect of Initial Concentration of Adsorbate and Different Temperature

Initial concentration of adsorbate has some influences for the removal of dye from aqueous solution. In the present study it was found that dye uptake ($mgg^{-1}$) was higher for higher concentrations of each adsorbent (**Figure 2A**).

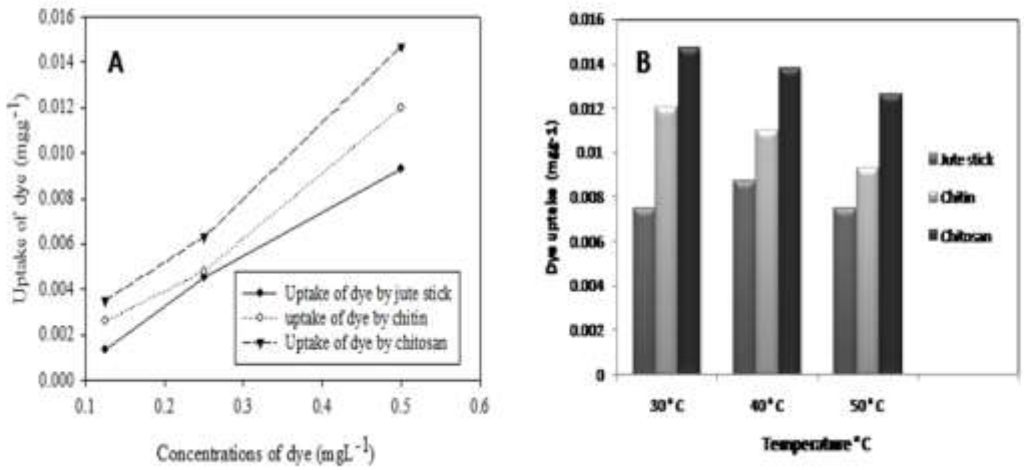


Fig. 2. (A) Uptake of different concentrations of dye by different adsorbent.
(B) Dye uptake by different adsorbent at different temperature.

Temperature is an important design parameter affecting the biosorption process as various textile dye effluents are discharged at relatively high temperature (50-60°C). Only a little change in the adsorption of dye by each biosorbents were found for changing temperature from (30-50°C) in present investigation (**Figure 2B**). Particle size does not have any great influence on saturation adsorption capacity and an increase in temperature decreases the saturation adsorption capacity of chitosan which leads to decrease of absorption (Mckay et al., 1989). As the temperature increase, rate of diffusion of adsorbate molecules across the external boundary layer and interval pores of the adsorbent particle increase (Waranusantigul et al., 2003). This may be the cause of increased dye absorption of jute stick at 40°C. But the absorption was decreased at higher temperature due to increase of interval pores which induce diffusion and reduce dye retention.

### 3.3 Effect of Radiated Chitin on the Removal of Dye

Chitin has binding sites i.e., amine /amide, carboxyl and hydroxyl groups. These radicals of chitin are responsible for binding ionic pigments and dye constituents. Gamma radiation modifies these groups by cross-linking these radicals, which influences the adsorption performance of this natural polymer. The level of cross-linking increases with the increasing radiation dosages which reduces the uptake capability of the radiated chitin (**Figure 3**).

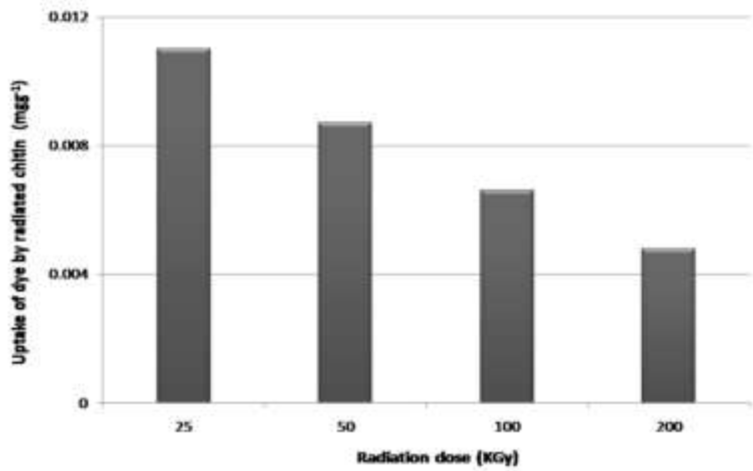


Fig. 3. Dye uptake by irradiated chitin.

## 4 CONCLUSIONS

Drimarene yellow is a reactive dye and in the present experiment it lowered the pH of the solution from 7 to 3.17. Lower pH causes greater effect on environmental pollution by reducing water and soil pH and thus causing alteration of aquatic life and soil biodiversity. Incorporation of biosorbent leads to reduction of the pH and thus can minimize the pollution effect. In this study, concentration of dye reduced significantly by soaking biosorbents. These biosorbents are biodegradable, environmental friendly and nontoxic. So, soaking of biosorbent can be a low cost and effective way to reduce water pollution by industrial effluents.

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## Biography

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