Degradation of Congo Red Dye in Aqueous Solution by Using Phytoremediation Potential of Chara Vulgaris

Pooja Mahajan and Jyotsna Kaushal
School of Applied Sciences, Chitkara University, Punjab (INDIA)
Email: pooja.mahajan@chitkara.edu.in
Email: jyotsna.kaushal@chitkara.edu.in

Abstract
Phytoremediation is an eco-friendly and non destructive method of dye removal from water and soil. In this research study, phytoremediation potential of a macroalgae Chara vulgaris was investigated as a viable biomaterial for biological treatment of congo red in aqueous solution. The effects of parameters such as reaction time, pH, initial dye concentration, temperature and amount of algae on biological decolourization efficiency were examined with help of UV-Vis and FT-IR spectroscopy. It has been found that Chara vulgaris is efficiently degrading congo red dye in aqueous solution through phytoextraction process.

Keywords: Phytoremediation, Congo red, Chara vulgaris, Degradation

1. INTRODUCTION

Today, more than 100,000 commercial dyes are available in market and nearly one million tonne per annum are produced, whereas 10% of dyes are released in environment and natural resources as dyestuff waste [1]. This production is increased day by day to meet the needs of growing population, also increases the release of dye effluent. The disposal of these coloured substances poses one of industry’s major problems in waste water treatment. This is because the discharge of coloured wastes is not only damaging to the aesthetic nature of the receiving streams but also toxic to aquatic life and even carcinogenic or mutagenic in nature [2]. In such cases, removing colour from wastes is imperative, because the presence of even small amounts of dyes (below 1 ppm) is clearly visible and influences water environment considerably. The treatment of dyes is fraught with numerous problems as most of dyes are non biodegradable, stable to light and oxidation and hence cannot be treated by conventional methods. Several other physical and chemical methods have been suggested for the treatment of dye-contaminated wastewater such as like flocculation with lime, charcoal, coagulation, ultra filtration, reverse osmosis, adsorption on activated carbon, bark, rice husk, coal, pea-nut shell, clay, cotton waste, biogas slurry waste banana pith and
coconut husks have been used with varying degrees of success[3-10]. But these methods are not widely used because of high cost, low efficiency, and inapplicability to avoid variety of dyes as well as formation of toxic by-product and secondary pollution that can be generated by excessive use of chemicals. However, these processes are considered as non destructive since they merely transfer the dye from liquid to solid wastes. Consequently, the regeneration of the adsorbent material and post-treatment of solid wastes, which are expensive operations, are needed. Alternatively, the approach is shifting towards the use of some other biological methods to treat such waste water containing dyes. These methods are gaining more importance nowadays because of their lesser cost, effectiveness and eco-friendly nature. Phytoremediation is one of such promising non-destructive and eco-friendly technology that uses green live plants for contaminants, degradation or extraction of xenobiotics from water or soil. There are several ways by which plants clean up or remediate contaminated sites like Phytoextraction, Rhizofiltration, Phytotransformation, Phytostabilization and Phytovolatilization[11-13].The application of various aquatic species like Phragmites australis, Typhonium flagelliform, Eichhornia crassipes, Azolla caroliniana, Typha, lemna etc. to remediate dye and other pollutants from waste water has gained increasing interest now-a-days[14-22]. Chara has also been reported for phytoextraction of heavy metal arsenic [23]. So the present study was undertaken to evaluate the phytoremediation potential of the Chara vulgaris (a macroalga, also called as Brittlewort or stonewort) for degradation of a diazo dye congo red which is carcinogenic as well as mutagenic in nature [10].

2. EXPERIMENTAL

2.1 Plant Material

The macroalgae Chara vulgaris is a genus of aquatic plant with a wild distribution, has the strong ability to extract nutrients through its fine rhizoids (very thin root like structure) and have whorls of leaf like branches bearing reproductive structure [24]. On the basis of this ability, Chara was investigated for Phytoremediation. The height of algae ranges from a few inches to several feet long. It is anchored to the substrate by fine rhizoids. Chara survives in all types of water. It is found in shallow water to depths over 20 ft depending upon clarity of water. It can also survive in ponds of rainy season which are completely dry in rest part of year. For present study, Chara vulgaris was collected from a lotus pond in the botanical garden of the punjab university. Then plant was washed and cleaned for experiment.
2.2 Chemicals and Dyes

All chemicals used were of the highest purity available and of analytical grade. Congo red, hydrochloric acid and sodium hydroxide were obtained from Merck. Solutions were prepared by dissolving appropriate amount of the dye in double distilled water before each experiment. Congo red of highest quality of Merck is the sodium salt of 3,3’-(1,1’-biphenyl)-4,4’-diylbis(4-aminonaphthalene-1-sulfonic acid)(formula: C$_{32}$H$_{22}$N$_6$Na$_2$O$_6$S$_2$; molecular weight: 696.66 g/mol). It is a secondary diazo dye. Congo red is water soluble, yielding a red colloidal solution [10]. The chemical structure of dye is shown in Figure 1.

2.3. Method - Decolourization Experiments

First, a preliminary experiment was done with Chara vulgaris for Phytoremediation. In experiment, Chara (5 g) was suspended in 100 ml of congo red 50 ppm aqueous solution. After getting promising results, further experiments were carried out with different concentration of congo red dye in double distilled water. In these experiments, algae of same growth stage (algae at reproductive stage is taken as reproductive parts antheridium and oogonium are quite large and visibly seen at nodal portion of algae and almost of equivalent wet weight of 5 g (weight was taken after taking algae on filter paper) in the dye solutions of 5 ppm, 10 ppm, 20 ppm, 40 ppm, 100 ppm. Aliquots of 1 ml-solution were withdrawn at regular intervals and analysed for dye concentration using a Shimadzu UV-160 UV-visible spectrophotometer at $\lambda$max 498 nm. Decolourization percentage was calculated as follows:

\[
\text{Decolourization (\%)} = \frac{\text{Initial absorbance} - \text{Observed absorbance}}{\text{Initial absorbance}} \times 100
\]

Figure1: Structure of Congo red (C.I. Direct Red 28)
With the help of this method, the effects of parameters such as reaction time, pH, initial dye concentration, temperature and amount of algae on biological decolourization efficiency were examined. FT-IR of algae was examined to determine the effect of dye on algae.

3. RESULTS AND DISCUSSION

In this present work, excellent response of *Chara vulgaris* is observed for Phytoremediation of congo red dye from its aqueous solution after 1 day observations in preliminary experiment. Algae show very good visible result with accumulation of red colouration and gave 95% decolourization. Transverse section (T.S.) of various parts of algae under compound microscope confirms red colour pigmentation. It confirms absorption of congo red dye from its solution by Chara. These results indicates the strong phytoextraction ability of chara toward congo red dye.

3.1 Effect of Reaction Time

The effect of reaction time on the removal of the dye was determined by keeping amount of algae (5 g), temperature (33°C) and pH (7.0) constant. For varying initial dye concentrations 5 ppm, 10 ppm, 20 ppm, 40 ppm, the absorption spectrum was analyzed at regular time interval. On average 50% of the dye was found to be removed from each concentration within 1 hour of experimentation. After 6 hour, maximum % decolourization was found in 10 ppm dye solution and minimum in 40 ppm dye solution (Figure.2). However, after 24 hours of experimentation, % decolourization is approx. 100% in each case.

3.2 Effect of pH

The effect of pH was studied under equilibrium conditions. The pH of the solution was adjusted with either dilute HCl or NaOH before experimentation. The pH of the samples were maintained using a portable pH meter. The pH meter was calibrated with 4.0 and 9.2 buffers. The dye concentration was maintained at 10 ppm. Figure. 3 show the effect of pH on % decolourization of congo red by *Chara vulgaris*. It is observed that the removal of dye by *Chara vulgaris* was maximum at pH between 7-8 and when pH was lower than 6, the phytoremediation ability of *Chara vulgaris* was decreases. The decrease could be attributed to the presence of H+, making phytoremediation less favourable.

*Chitkara Chemistry Review* (CCR), Volume 1, March 2013
Degradation of Congo Red dye in aqueous solution by using Phytoremediation potential of Chara vulgaris

3.3 Effect of Initial Dye Concentration

The effect of initial concentration was studied by varying the concentrations of the dye solution from 5-100 ppm. Samples were taken in 100 ml of dye solution and % decolourization was calculated after 6 hour experimentation.

Figure 2: Plots of Reaction time Vs % Decolourization

Figure 3: Plots of pH Vs % Decolourization
3.4 Effect of Amount of Algae

In the study of the effect of amount of algae on dye absorption, the wet weight of *Chara* was varied from 5.0-25.0g. The dye concentration was maintained at 10ppm. It is observed that with increase in amount of algae, Phytoremediation becomes fast and more effective.

3.5 Effect of Temperature

The Phytoremediation experiments were performed in different seasons to observe efficiency of algae at different temperatures. Maximum Phytoremediation potential of algae was observed in summer season when temperature ranges from 33-40°C.

3.6 IR Study

Fourier transform infrared spectroscopy (FTIR) was used to determine the functional groups on the carbon surface. The spectra were measured within the range of 400 -4000 cm⁻¹ in a Bruker (Alpha-T) spectrophotometer. Some fundamental FTIR frequencies of the chara, before and after absorption of

*Chitkara Chemistry Review* (CCR), Volume 1, March 2013
Degradation of Congo Red dye in aqueous solution by using Phytoremediation potential of Chara vulgaris

Figure 5(a): FTIR Spectrum of Chara vulgaris

Figure 5(b): FTIR Spectrum of Chara vulgaris after congo red dye absorption

congo red dye can be inferred from Figure 5. The absorption frequencies are shifted to higher wave numbers with the absorption of congo red by algae chara. From these findings it is presumed that the dye was incorporated into the algae through interaction with the active functional groups [25].

Chitkara Chemistry Review (CCR), Volume 1, March 2013
4. CONCLUSION

In this research study it has been found that the algae *Chara vulgaris* is an easily available aquatic plant and has sufficient Phytoremediation potential for removing congo red dye from its aqueous solution under optimized conditions of temperature 33-40°C and pH 7-8. It has also been found that algae has more potential to phytoremediate and grow in low concentrations rather than higher concentrations. Keeping in view this research study concludes that *Chara vulgaris* can be used for removing congo red dye from its aqueous solution after dilution. Knowledge from present work can be employed on large scale at actual contamination sites. Our future study aims to find out the mechanism of this biodegradation of congo red dye by *Chara vulgaris*.

REFERENCES


Degradation of Congo Red dye in aqueous solution by using Phytoremediation potential of Chara vulgaris


**Pooja Mahajan,** Assistant Professor, School of Applied Sciences, Chitkara University, Punjab (INDIA)

**Prof. (Dr.) Jyotsna Kaushal,** Dy, Dean School of Applied Sciences, Chitkara University, Punjab (INDIA)