APPLICATION OF BIOCOAGULANT *Acanthocereus tetragonus* (TRIANGLE CACTUS) IN DYE WASTEWATER TREATMENT

M. Chethana, Sorokhaibam Laxmi Gayatri, Bhandari Vinay M.*, Ranade Vivek V.¹ and S. Raja ²

1. Chemical Engineering and Process Development Division, CSIR-National Chemical Laboratory, Pune (INDIA)
2. Department of Biotechnology Manipal Institute of Technology, Manipal, Karnataka (INDIA)

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ABSTRACT

A new biocoagulant and coagulation behaviour of *Acanthocereus tetragonus* (Triangle cactus) has been studied for removal of congo red dye. Effect of various parameters such as initial dye concentration (50-500 ppm), pH of the solution (3-8), coagulant dose etc. has been investigated in detail. The use of bio coagulant is highly effective in removal of dye and in reducing colour. The extent of dye removal is practically unaffected by dye concentration as against conventional inorganic coagulants and a maximum dye removal of 96.7% has been observed. The optimum dose for coagulant was in the range 600-1200 ppm. Up to 93% colour removal could be achieved using this new biocoagulant. Similar to chemical coagulants, coagulation is pH sensitive and pH 6 was found to be most suitable for maximum coagulation effect. Though the bio-coagulant dose is relatively higher than conventional chemical coagulants, volume of sludge generated was found to be less and a sludge volume index of ~50 mL/g for 1 hour was obtained. A comparison of the coagulation performance has been made by comparing the results with those obtained using conventional chemical coagulants such as alum, ferric and aluminium based coagulants and it can be concluded that use of biocoagulant in the form of new coagulant-*Acanthocereus tetragonus* can be promising alternative for effecting coagulation in dye wastewater treatment.

Key Words: *Acanthocereus tetragonus*, Biocoagulant, Coagulation, Dye wastewater, Effluent

INTRODUCTION

Dyes and textile industry is one of the most important and continually developing industrial sector especially in India. It has a high environmental impact as it consumes huge volumes of processed water and produces highly polluted /colored wastewater. Removal of these pollutants require strategies for selecting most appropriate method/methods from physico-chemical treatme-nt, bio oxidation, biological treatment, active sludge treatment, microfiltration, coagulation flocculation processes, fenton oxidation, adsorption, electrochemical oxidation and electro coagulation, cavitation etc. Among these, coagulation flocculation has historically attracted considerable attention for its high removal efficie

*Author for correspondence*
released into the aquatic systems may continue to cycle between the sediments. In view of the limitations of chemical coagulants and the possibility of serious threat to public health arising due to biological amplification, it is instructive to design and develop alternative coagulants that are environment friendly, inexpensive and practically implementable. Some plant based natural coagulants that have been studied include Moringa oleifera, Stryconus potatorum, Cactus species, Phaseolus vulgaris, surjana seed, maize seed, tannin, gum arabic, Prosopis juliflora and Ipomoea dasysperma seed gum, as coagulants. Among these, cactaceae family have an outstanding ability to adapt to adverse and contrasting environments, tolerate conditions ranging from drought to high and low temperatures and can also survive in soils poor in nutrients and organic matter. It has long been associated with its medicinal properties and dietary food sources and the pulp material is usually composed of several carbohydrates and proteins. Cactaceae can transform various toxic textile dyes including red HE7B into less phytotoxic, non-hazardous metabolites. Besides, these plant based coagulants need little processing and provide sustainable means for treatment.

Acanthocereus tetragonous (common names include night-blooming cactus, barbed-wire cactus, sword pear, dildo cactus, triangle cactus) is one of the 660 species of cactaceae family. It is a tall, columnar and dark green cactus which is also cultivated as an ornamental plant. Flowers and tender shoots are edible and have medicinal properties. Peel and pulp extracts of Acanthocereus tetragonous fruits have high antimicrobial activity. Although Opuntia sp. have been widely studied for its coagulating potential, Acanthocereus tetragonous has not been previously reported as coagulants for dye wastewater treatment. The water extract of Acanthocereus can offer practical and inexpensive solution to dye wastewater treatment.

AIMS AND OBJECTIVES

To assess the feasibility and efficiency of the Acanthocereus tetragonous, a novel biocoagulant for the reduction of colour and concentration of the dye with relatively less amount of sludge production. A systematic evaluation of coagulation performance of Acanthocereus sp. at different coagulant doses, pH and different dye concentrations was investigated to optimize the coagulation, measured by reduction in dye concentration and colour. The coagulating efficiency of Acanthocereus is also comparatively analysed with that of chemical coagulants like aluminium sulphate, PAC and ferric chloride. The mechanism behind coagulation-flocculation may be due to anyone or combination of the following : (1) double layer compression (2) sweep flocculation or enmeshment within colloidal floc (3) adsorption and charge neutralization by oppositely charged ions and (4) adsorption and interparticle bridging in case of polymeric coagulant. A plausible coagulation mechanism on the use of plant based Acanthocereus coagulant is also attempted in the present study.

MATERIAL AND METHODS

Coagulant

The plant pads of natural coagulant Acanthocereus tetragonous were collected from National Chemical Laboratory (NCL) Pune campus, Pune India. Chemical coagulants, aluminium sulphate hexadecahydrate, iron (III) chloride hexahydrate, PAC (medium) obtained from sigma aldrich and congo red indicator dye used in this study were procured from Loba Chemie. All the chemicals/reagents were of analytical grade.

Preparation of biocoagulant

Acanthocereus tetragonous pads were collected and washed thoroughly with tap water and manually chopped into small pieces after removing the spines. The external skin as well as the inner off-white portion of the cactus pieces were grinded with a food processor and extracted with water in equal weight by volume ratio. It was then filtered to remove the fibrous part of the pads and the active ingredient of the coagulant was in the form of residual water extract. Fresh extracts were prepared for each batch run. The collected pads can be stored under refrigeration for at least 1 month. (Fig. 1).
**Experimental methodology**

The dye stock solution was prepared by dissolving dyes in concentration of 500 mg/L and the experimental solutions of 50 and 100 mg/L were prepared by further dilution of the stock solution. The coagulation experiments were carried out by using a conventional jar test apparatus (Stuart SW6, UK) which consisted of series of six paddles with six beakers. Dye solutions of predetermined concentrations were taken in these beakers and predetermined coagulant dose was added followed by rapid mixing at 200 rpm for 5 min and then by slow mixing at 50 rpm for 15 min. A settling time of 1h was provided. Colour removal corresponding to various doses of biocoagulant from 300-1800 mg/L was measured to determine the optimum biocoagulant dose with minimum sludge. Typically 914 mg/L of *Acanthocereus tetragonus* extract can be considered as the optimum dose and pH study was conducted using this optimum dosage. After settling 50 ml of the supernatant liquid was collected using pipette and was used for analysis. Colour/dye concentration in the present work was analysed using spectrophotometer -ter spectroquant pharo 100 at λ<sub>max</sub> value of 498 nm while spectralab multipara-5 pH meter was used for pH measurements. The readings were taken in duplicate for each individual solution to check the repeatability. The percentage reduction in dye concentration was calculated by using the difference in initial and final concentrations. The sludge characteristic is given by Sludge Volume Index (SVI) which is measured as:

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\text{Sludge Volume Index} (\text{SVI}) = \frac{\text{Settled sludge volume (mL/L)}}{\text{Suspended solids (mg/L)}} \times 1000
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The settled sludge was dried at (103-105) ±2°C for 1 hour and placed in dessicator before weighing for determination of MLSS required for determination of SVI.

**RESULTS AND DISCUSSION**

**Effect of coagulant dose**

An important parameter in coagulation is the coagulant dose. The optimum dosage determines the performance of the coagulants in terms of techno-economic viability. Dosage lower than optimum may result in insufficient coagulation while too high dosage may lead to again lowering the effect due to stabilization of charges and will not improve further efficiency. The effect of coagulant dose (300-1800 mg/L) on the removal of different concentrations of congo red-50, 100 and 500 ppm and with respect to time using *Acanthocereus tetragonus* at natural pH of the dye is shown in Fig. 2 to Fig. 4. The maximum dye reduction was found at the coagulant dose range of 600-1200 mg/L and optimum coagulant concentration can be obtained from this study. The reduction was found to be 83.77 % at coagulant dose of 1218 mg/L for a contact time of 20 hour for congo red-50 ppm; 89.85% and 96.70% for the dye concentrations 100 and 500 ppm respectively for the same coagulant dosage and contact time. This study also showed that a contact time of the
coagulant with the dye for 6 hour also gives significant reduction in dye concentration for congo red with initial concentration of 50 ppm. However, for the higher initial dye concentrations of 100 and 500 ppm, a contact time/settling time of 20 hour could produce enhanced reduction in dye concentration as compared to 6 hour.

Fig. 2 : Effect of Acanthocereus tetragonus doses on removal of 50 ppm congo red

Fig. 3 : Effect of Acanthocereus tetragonus doses on removal of 100 ppm congo red

Fig. 4 : Effect of Acanthocereus tetragonus doses on removal of 500 ppm congo red
There is a continuous removal of congo red with the increase in coagulant dose up to ~1200 mg/L for the dyes with varying initial concentration and here after there was either no significant reduction in dye concentration or decrease in reduction as in the case of 50 ppm congo red dye. A further increase in coagulant dose is causing the re-dispersion of the charged particles in the dye or re-stabilisation of the dye suspension. The increase dosage beyond optimum may also result in change in pH of the medium and may result in re-dissolving of the flocs or sludge. From the % removal values at different concentrations it is observed that *Acanthocereus tetragonus* is a more effective coagulant at higher dye concentration i.e. 500 ppm in the present study in terms of maximum reduction. However lower coagulant dose ~ 600 mg/L could remove almost total colour for lower initial dye concentration of 50 ppm. The fading of dye colour with increase in coagulant dose from left to right for the different dye concentrations is shown in Fig. 5.

**Fig. 5**: Coagulation of congo red dye of different concentrations at different coagulant dose.
Apart from dye concentration reduction, color reduction was also investigated in the present study. It is seen from (Fig. 6) that for all the dye concentrations ~1200 mg/L of dosage produce the maximum color reduction of 65 %, ~80 % and 90 % respectively for the initial concentration of dye 50, 100 and 500 ppm. The initial dye had 5600, 9750 and 41450 Hazen units as initial color for 50, 100 and 500 ppm dye concentration. It is also observed that the removal efficiency was higher for the higher initial dye concentration. This study also showed that a longer settling time resulted in higher reduction in the dye concentration. This can be attributed to slow settling of flocs, probably due to the size effect and consequently affecting dye removal according to sweep-flocculation mechanism. Fu and Yu\textsuperscript{14} have also observed similar findings that an increase in settling time could increase the removal of dissolved organic matters using coagulation.

![Fig. 6: Effect of coagulant dose on color reduction of congo red dye](image)

**Effect of pH**

pH affects the performance of the coagulants by controlling the charge carried by the coagulants and stability of the dye suspension. Fig. 7 indicates the effect of pH on the removal of congo red using 914 mg/L of dosage of natural coagulant, *Acanthocereus tetragonus* at different initial dye. The settling time for the pH study was 1 hour and it is observed that the preference of acidic or alkaline medium for maximum coagulation is different at lower initial dye concentration and at higher dye concentration. The coagulation at lower dye concentrations, viz. 50ppm and 100ppm showed favourability in the pH range 6 to 8, the maximum being at pH 6 for dye concentration of 50 ppm and 7 for dye having 100 ppm initial concentration. On the contrary, the pH study for the higher dye concentration of 500ppm indicated favourability in acidic medium with highest colour removal of 88.6 % and reduction in dye concentration of 91.37 % at pH 3. Fig. 8 shows the effect of pH on the color removal of congo red dye showing the same trend. The maximum color reduction for 50 ppm and 100 ppm dye concentration were 83.03 % and 50.76 % at pH 6 and 7 respectively. There was a drastic change in coagulation performance in terms of color removal and reduction in dye concentration in shifting the pH from acidic to near neutral or alkaline pH for higher dye concentration of 500 ppm. The reason for such anomalous behaviour needs further detailed investigation.

**Sludge volume index analysis**

The SVI can be used for obtaining insight into settling and stability of the coagulation system. The study of sludge volume index is useful in process optimization of coagulation. A lower sludge index indicates better settling ability. Typical SVI values in the range of 50 to 100 mL/g are considered being good.\textsuperscript{15} Fig. 9 shows the calculated sludge volume index as function of coagulant dose for the different dye concentrations.

818
concentrations. The SVI at the coagulant dose for 50, 100 and 500 ppm initial dye concentration are respectively 41.47, 38.28 and 47.58 mL/g which is on an average lower than 50 mL/g. This lower SVI also indicates good settling ability of the particulate flocs and better sludge. The amount of sludge produced by using this bio-coagulant is very low when compared with inorganic coagulants.

**Fig. 7**: Variation in dye reduction (%) for different dye concentrations at different pH at coagulant dose 914 ppm

**Fig. 8**: Variation in colour reduction (Congo red 50 ppm, 100ppm, 500 ppm) with *Acanthocereus tetragonus* (Triangle cactus) 914 ppm coagulant dose at different pH conditions

**Fig. 9**: Sludge volume index as a function of coagulant (*Acanthocereus tetragonus*) dose for initial dye concentrations
Comparison of coagulation efficiency with chemical coagulants

There have been numerous reports on the removal of congo red dye using different coagulants, specially at low concentrations. The data on coagulation of 500 ppm congo red dye, reported with conventional aluminum sulphate, ferric chloride and PAC medium at different coagulant doses was used to demonstrate a comparative overview with the plant based Acanthocereus tetragonus coagulant. It was observed that higher dosages were required to produce coagulation with Acanthocereus tetragonus as compared to the chemical coagulants. For the comparative study, the mixing time, coagulation time and pH of the medium were maintained. As seen from Fig. 10, the optimum coagulant dose for the selected chemical coagulants is 150-200 mg/L whereas the plant based coagulant could produce a color reduction of 80.45 % with 300 mg/L and 93.24 % color reduction at fairly high dose of ~1200 mg/L. However, considering the amount of sludge produced by chemical coagulants and other factors, Acanthocereus tetragonus coagulant appears to be a better option. A more detailed analysis in terms of viability is required to clearly establish the use of biocoagulants in wastewater treatment processes.

![Fig. 10: Colour reduction efficiency of chemical coagulant and biocoagulant](image)

CONCLUSION

The present study clearly highlights use of a new biomaterial, Acanthocereus tetragonus as biocoagulant for application in dye wastewater treatment. It was observed that the biocoagulant could bring up to 90 % reduction in color and exhibit wide operating pH near neutral to alkaline range at low initial concentrations and high efficiency under acidic pH for higher initial dye concentration. Though coagulant dose of the biocoagulant is higher as compared to the chemical coagulant, the sludge volume is comparatively less. The present research provides insight into the application of biocoagulant and Acanthocereus tetragonus (Triangle cactus) could form a useful biocoagulant alternative in treatment of textile dye wastewater effluent.

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