REMOVAL OF REACTIVE DYE FROM EFFLUENT USING SUGARCANE BAGASSE AS A LOW-COST ADSORBENT

DAL SINGH KHARAT

DEPARTMENT OF CHEMICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY DELHI

NOVEMBER 2014

REMOVAL OF REACTIVE DYE FROM EFFLUENT USING SUGARCANE BAGASSE AS A LOW-COST ADSORBENT

by

DAL SINGH KHARAT

DEPARTMENT OF CHEMICAL ENGINEERING

Submitted
in fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the

Indian Institute of Technology Delhi
November 2014

CERTIFICATE

This is to certify that the thesis titled '**Removal of Reactive Dye from Effluent using Sugarcane Bagasse as a Low-cost Adsorbent**' being submitted by **Mr. Dal Singh Kharat** to the Indian Institute of Technology Delhi for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by him under my guidance and supervision in conformity with the rules and regulations of the Indian Institute of Technology Delhi.

The research report and results presented in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

Date :
New Delhi

(Dr. A.K. Saroha)
Professor
Department of Chemical Engineering
Indian Institute of Technology Delhi
New Delhi-110016

ACKNOWLEDGEMENTS

It is with a deep sense of gratitude and indebtedness that I would like to thank Prof. A.K. Saroha, Department of Chemical Engineering, Indian Institute of Technology Delhi for guiding me through this research programme and for encouragement, inspiration, motivation and timely advice that always helped in instilling within me a sense of optimism and confidence. I shall remember him forever for inculcating within me the qualities of perseverance and a sense of commitment towards work. I specially thank him for giving time with me and being very kind and considerate towards me in time of need. It has been my proud privilege to work under him.

I would like to record my deepest gratitude, sincere respect and graceful regards to Prof. A.K. Gupta, Professor Emeritus, Department of Chemical Engineering for inculcating my interest in wastewater treatment in general and adsorption separation in particular. His inspiring guidance and intense interest have been the factor responsible for accomplishing the research work. The affection, bestowed upon me, would be a cherished possession of my life.

I am extremely grateful to Prof. S.K. Gupta, former Head, Department of Chemical Engineering and Prof. T.R. Sreekrishnan, Head, Department of Biochemical Engineering and Biotechnology, who have guided me from time to time in the research work.

I would like to place on record my gratitude and thanks to Dr. V.V. Buwa, Associate Professor and Coordinator, Ph.D. Programme, Department of Chemical Engineering for valuable support.

I am extremely grateful to Prof. S. Basu, Professor and Head, Department of Chemical Engineering and Prof. A.N. Bhaskarwar, former Head, Department of Chemical Engineering for extending all the necessary help.

I would like to place on record my gratitude and thanks to Prof. Ratan Mohan and Dr. S. Upadhyayula, Associate Professor, Department of Chemical Engineering who have always been an object of reverence for teaching the Environmental Engineering.

I would like to place on record my gratitude and thanks to Dr. A.B. Akolkar, Member Secretary, Central Pollution Control Board who gave me opportunity to collect literatures relevant to the project from various libraries.

The co-operation extended by the textile industry during effluent sampling, is gratefully acknowledged.

I would like to thank my fellow students with whom I had useful discussions. I sincerely appreciate the help rendered by the staff of the Department of Chemical Engineering, Indian Institute of Technology Delhi.

Dal Singh Kharat

ABSTRACT

Textile dyeing effluent contains a large number of organic and inorganic chemicals such as surfactants, chlorine compounds, salts, alkali, dyes and finishing agents, The dyes can be classified as acid, basic, direct, azoic colours, vat, sulphur, reactive and metal complex dyes. Removal of the dyes from the effluent is a major problem due to the high tinctorial value and the complex structure of the dyes, toxicity and the presence of metals in some dye structures. The colouring matter has to be removed from the effluent before its discharge as it usually constitutes the major fraction of chemical oxygen demand of the effluent. Various techniques are used for the removal of colour which can be classified into physical (adsorption, ultrafiltration, nano-filtration and reverse osmosis) or physicochemical, chemical, biological, electrochemical and advanced oxidation processes (ozonation, peroxidation and photo catalysis).

Adsorption is commonly used for the effluent treatment due to its potential in removal of pollutants too stable for the conventional biological techniques. Although activated carbon is an ideal adsorbent, it is expensive for effluent treatment due to its high production and regeneration cost. High cost of activated carbon has led to the search for the low-cost adsorbents. Sugarcane bagasse is generated in the sugar industry and is used as a fuel in the boilers. Therefore, the use of sugarcane bagasse as a low-cost adsorbent for the removal of Reactive blue 19 dye from the effluent was explored in the present study.

In the present work, adsorption studies were performed by treating the solution containing Reactive blue 19 dye using sugarcane bagasse. Sugarcane bagasse was collected from a sugar mill and dried. The dried sugarcane bagasse was ground to obtain powder. The bagasse powder was treated with 0.1N NaOH solution to remove the soluble matter. Batch equilibrium studies were conducted to study the effect of the particle size of the adsorbent, dose of the adsorbent, salinity of the solution and the solution pH on adsorption and the results were evaluated in terms of dye removal efficiency. No significant effect of the adsorbent particle size on the adsorption efficiency was noticed. The dye removal efficiency was found to increase from 12.88 % to 57.81 % with an increase in the adsorbent dose from 1.5 g/L to 15 g/L for a solution with an initial dye concentration of 80 mg/L. The effect of the salinity of the dye solution on the dye removal efficiency was also investigated. The dye removal efficiency was found to increase from 60.82 % to 73.59 % with an increase in the salinity of the dye solution from 2 g/L to 10 g/L. A significant increase in the dye removal efficiency (from 8.33 % to 74.22 %) was observed with change in the solution pH from 9.5 to 11.5. The equilibrium study results were found to be in agreement with the linear isotherm.

Adsorption kinetic studies were carried out and it was observed that most of the dye adsorption is accomplished in a contact time of 120 min. Increase in the dose of the adsorbent resulted in an increase in the dye removal efficiency. Salinity in the solution exhibited positive impact on the adsorption of Reactive blue 19 dye.

A kinetic model has been proposed and the concentration of the dye in the solution at time t can be estimated using the proposed model by the following correlation:

$$C = \frac{1}{\frac{b^2 km}{V} t + \frac{1}{Co(1 - \frac{V}{mb})}} + \frac{V}{mb} Co$$

where, Co = initial dye concentration in the solution (mg/L), t = contact time (min), C = concentration of dye in the solution (mg/L) at time t, V = volume of the dye solution (L), m = dose of adsorbent (g), $b = \left(\frac{V}{m} + a\right)$, a = equilibrium constant (L/g) and k = kinetic rate constant (min^{-1}). The kinetic experimental data was found to be in good agreement with the proposed model. Experiments were also performed with the real textile industry effluent using sugarcane bagasse as an adsorbent and a dye removal efficiency of 81.52 % was obtained with an adsorbent dose of 11.25 g/L and initial dye concentration of 66.32 mg/L.

CONTENTS

Page No.