TREATABILITY STUDY OF THE INDUSTRIAL EFFLUENT BY ELECTROCOAGULATION

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APRIL 2015

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by

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Submitted

in fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI
NEW DELHI 110016
INDIA

APRIL 2015

DEDICATED

TO

MY PARENTS & HUSBAND

CERTIFICATE

This is to certify that the thesis entitled, **"Treatability study of the industrial effluent by electrocoagulation"** being submitted by **Ms. Vinita Khandegar** to the Indian Institute of Technology Delhi for the award of **Doctor of Philosophy** is a record of bonafide research work carried out by her under my guidance and supervision in conformity with the rules and regulations of Indian Institute of Technology Delhi.

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

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Acknowledgements

First and foremost, many thanks to my research supervisor, Prof. Anil K. Saroha, Department of Chemical Engineering, for his consistent supervision, crucial remarks, and endless positivity that have made this dissertation a joy to compose. His support and encouragement throughout this study is highly appreciated. It was a great honor to have a chance of working with him and have been part of the pollution control lab, Chemical Department of the Indian Institute of Technology.

I would like to acknowledge the Department of Chemical Engineering, Indian Institute of Technology, Delhi for giving me the chance to undertake this study. Also many thanks to all the Heads of Chemical Engineering Department especially Prof. A. N. Bhaskarwar and Prof. S. Basu for providing me all the necessary laboratory facilities during my research.

I would also like to express my gratitude to my SRC committee members, Prof. A. N. Bhaskarwar, Prof.T.R. Sreekrishnan and Dr. A. Shukla for their constructive suggestions and helpful discussions.

I would like to thank all the faculty members, laboratory and office staff of the Chemical Engineering Department. I extend my hearty thanks to my lab mates cum motivators Mr. D. S. Kharat, Mr. Bhardwaj Adiraju, Ms. Parmila Sangwan, Ms. Shushma Yadav and Ms. Manjri Yadav for their friendship.

I wish to express my thanks to all my colleagues Mr. Sachchit Majhi, Mr. K.V.K. Kishore, Mr. Prabhakar Mohanty, Mr. Jogendra Singh, Mr. Pankaj Tiwari, Ms. Gurpreet Kaur, Ms. Rajalakshmi Chockalingam, Ms. Sangeeta Nagar, Mr. Murali Mohan Seepana,

Mr. Jay Pandey and all the research scholars in the Chemical Engineering Department for their concern, support and help during my Ph.D.

My gratitude to Ms. Meenakshi Majumdar, Ms. Indu Sharma, Ms. Parul Tyagi, Ms. Sudhesna Moka, Ms. Manisha Pande, Ms. Amita Chaudhary, Ms. Garima Dwivedi, Ms. Garima Chauhan and Ms. Guncha Munjal for being a great sources of learning and inspiration for me.

I would also like to thank my employers, Guru Govind Singh Indraprastha University, New Delhi, Dean of Chemical Technology Department for giving me opportunity to work at IIT Delhi.

I wish to express my special thanks to my in-laws for their patience and love during the study. I would also like to thank my beloved husband Vijay Kumar for his encouragement and support. My deepest appreciation goes to my daughter Ishnavi for her patience during my absence at home.

Finally, I want to express my heartfelt thanks to my dearest parents Mr. B. Khandegar and Mrs. S. Khandegar for their love, countless sacrifices and steady guidance.

Most importantly, a note of heartfelt devotion to God, who has made me capable of accomplishing this task.

(Vinita Khandegar)

Abstract

Various techniques such as physical, chemical, biological, advanced oxidation and electrochemical are used for the treatment of industrial effluent. The commonly used conventional biological treatment processes are time consuming, need large operational area and are not effective for effluent containing toxic elements. Advanced oxidation techniques result in high treatment cost and are generally used to obtain high purity grade water. The chemical coagulation technique is slow and generates large amount of sludge. Electrocoagulation (EC) has recently attracted attention as a potential technique for treating the industrial effluent due to its versatility and environmental compatibility. This technique uses direct current source between metal electrodes immersed in the effluent, which causes the dissolution of electrode plates into the effluent. The metal ions, at an appropriate solution pH, can form wide range of coagulated species and metal hydroxides that destabilize and aggregate particles or precipitate and adsorb the dissolved contaminants. The aim of this research is to assess the treatability of electrocoagulation process for the industrial effluent. Therefore, in the present study, the use of electrocoagulation has been explored for the treatment of different industrial effluent.

Electrochemical treatment of the synthetic solution containing acid red 131 dye was studied by performing experiments in batch mode of operation using aluminum electrodes. The effect of various parameters, such as pH of the solution, current density, inter-electrode distance, agitation speed, solution conductivity, electrolysis time and retention time was investigated. The results were analyzed in terms of color removal efficiency (CRE) and the optimum values of the parameters were determined. The maximum CRE of 98 % was obtained at the optimum conditions of current density 62.5 mA/cm^2 and solution pH of 11 for an electrolysis time of 120 min for the synthetic dye solution containing 10 mg/L acid red 131 dye.

Electrochemical treatment of the industrial effluent containing Reactive Black B, Orange 3R and Yellow GR dyes was carried out at the optimum values of the parameters and a CRE of 93.5 %, 92 % and 91.1 % was obtained for the three dyes respectively. Further electrocoagulation of small scale dyeing unit effluent containing Reactive Yellow 86, Indanthrene Blue RS, Basic GR 4 and Reactive Yellow 145 dyes was carried out at the optimum values of the parameters. The experiments were performed for 120 min keeping the inter-electrode distance at 3 cm with a current density of 62.5 mA/cm^2 and the CRE was determined for each of the four dyes. A CRE of more than 97 % was obtained for each of the dyes for an electrolysis time of 120 min. Experiments were also performed using aluminum sulphate as a coagulant to compare the CRE obtained by EC and chemical coagulation for the treatment of the dyes.

All the EC experiments reported in the literature have been performed with plane electrodes. Therefore efforts have been made to study the effect of shape of the electrodes on the performance of EC. The shape of the electrode was changed from plane to punched hole electrodes. The effect of the number of holes and the geometry (square, triangular and random pitch) of the punched holes on the performance of the electrocoagulation has been investigated. From the observation, it was found that, the discharge current was higher for the punched hole electrode than for the plane electrode. No effect of the pitch of the holes was observed on the performance of the EC process.

Electrocoagulation using direct current power supply source leads to passivation and increases the power consumption as well as the operating cost. Therefore, efforts were made to reduce the passivation problem by performing experiments using alternating current (AC) in place of direct current (DC) in the electrocoagulation process.

No significant effect of the type of power source was observed on the performance of the electrocoagulation. The maximum CRE of 99 % and 98 % for a dye solution was obtained at a current density 62.5 mA/cm^2 and solution pH of 11 for an electrolysis time of 120 min by AC and DC respectively.

Electrochemical treatment of the distillery spent wash was carried out using different combinations of aluminum and iron electrodes. The treatment results were analyzed in terms of chemical oxygen demand (COD) removal efficiency of the spent wash. The experiments were performed to study the effect of the operating parameters on the COD removal efficiency of the spent wash. It was observed that the aluminum electrodes were more suitable for the treatment of distillery spent wash as compared to iron electrodes. The maximum COD removal efficiency of 81.3 % was obtained with Al-Al electrodes at the current density of 187 mA/cm^2 and solution pH 3 for an electrolysis time of 120 min.

It can be concluded from the above batch scale studies, that the electrocoagulation technique has the potential for the treatment of various types of the industrial effluent.

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Abbreviations

AC	Alternating current (amp)
BOD	Biochemical oxygen demand (mg/L)
COD	Chemical oxygen demand (mg/L)
DC	Direct current (amp)
F	Faraday's constant (96, 485 C/mole)
FAS	Ferrous ammonium sulfate
ppm	Parts per million
SS	Suspended solids (mg/L)
TDS	Total dissolved solids (mg/L)
TFS	Total fixed solids (mg/L)
TOC	Total organic carbon (mg/L)
TSS	Total suspended solids (mg/L)
TVS	Total volatile solids (mg/L)
ϕ	Diameter (mm)

Nomenclature

a	Cost of electricity/kWh
AOPs	Advanced oxidation processes
b	Cost of electrode/kg electrode
Basic GR 4	Basic Green 4
BP-S	Bipolar electrodes in serial connections
c	Cost of chemical/kg of chemical
CC	Chemical coagulation

CHC	Chemical consumption (kg of chemical/m^3 of effluent)
CWAO	Catalytic wet air oxidation
EC	Electrocoagulation
ELC	Electrode consumption (kg of electrode/$m^3$of effluent)
ENC	Energy consumption (kWh/$m^3$of effluent)
I Blue RS	Indanthrene Blue RS
I	Applied current (A)
j	Current density (A/cm^2 or mA/cm^2 or A/m^2)
M	Relative molar mass of the electrode (g/mole)
MP-P	Monopolar electrodes in parallel connections
MP-S	Monopolar electrodes in serial connections
MS	Mild steel
n	Number of electrons in oxidation/reduction reaction
RY 145	Reactive Yellow 145
RY 86	Reactive Yellow 86
SS	Stainless steel
St	Steel
t	Electrolysis time (h)
U	Applied voltage (volt)
V	Volume of treated effluent (m^3)
WAO	Wet air oxidation