

LB/DON/30/09

COIR PITH ACTIVATED CARBON FOR THE REMOVAL OF DYES, ORGANICS AND HEAVY METALS FROM AQUEOUS SOLUTIONS

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

by
D.W.DHANUSEKERA



This thesis was submitted to the
Department of Chemical & Process Engineering
of the University of Moratuwa
in partial fulfillment of the requirements
for the degree of
Master of Science
www.lib.mrt.ac.lk

| | |
|--------|-------------|
| ADDA | YTBRSVBU |
| YRABLI | |
| | AM HGBSTQDA |
| | AM ZBAUC |

66 "08"

66(043)

TH

Department of Chemical & Process Engineering
University of Moratuwa
Sri Lanka

July 2008
University of Moratuwa



92926

92926

92926

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university and to the best of my knowledge and belief it does not contain any material previously published, written or orally communicated by another person except, where due reference is made in the text.

Dhanusekera

D.W.Dhanusekera
(07/8009)

 University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
Amarasinghe www.lib.mrt.ac.lk

Supervisor
Dr.B.M.W.P.K. Amarasinghe

ACKNOWLEDGEMENT

I would fall short in my duty, if I fail to thank several people without whose help my research wouldn't be a success. So I would like to express my heartfelt gratitude to;

- My supervisor, Dr (Mrs.) B.M.W.P.K. Amarasinghe, Senior Lecturer, Department of Chemical & Process Engineering, University of Moratuwa for being a guiding light right through the research.
- My progress review committee members, Prof. Ajith de Alwis and Dr. Shantha Walpolage Senior Lecturers, Department of Chemical & Process Engineering, University of Moratuwa for their encouragement and valuable suggestions.
- National Science Foundation and University Research Grant for providing me the research funding.
- Post graduate studies division, University of Moratuwa for approving my research project.
- Coir mill, Waskaduwa for providing me coir pith right throughout the research, without which I couldn't carry my research.
- Mrs. Dinusha Martino of Environmental Engineering laboratory and all the staff of Energy Engineering, Chemistry, Latex Technology laboratories, Server Room, Department of Chemical & Process Engineering, University of Moratuwa for offering me their sincere help without any hesitation.
- My beloved mother, father and husband for their encouragement right throughout the research.
- Post graduate students of the Department of Chemical & Process Engineering, University of Moratuwa; Ms. Gayanee Karunarathna, Ms. Gayani Jayatunga and Ms. Irosha Kularathna, for helping me in formatting the thesis and encouraging me by thought word or deed.

CONTENTS

| | |
|--|------|
| DECLARATION..... | i |
| ACKNOWLEDGEMENT..... | ii |
| CONTENTS..... | iii |
| LIST OF TABLES..... | v |
| LIST OF FIGURES..... | vi |
| LIST OF ANNEXURES..... | vii |
| ABSTRACT..... | viii |
| CHAPTER 1: INTRODUCTION..... | 1 |
| CHAPTER 2: LITERATURE REVIEW..... | 7 |
| 2.1 INTRODUCTION..... | 7 |
| 2.2 ADSORPTION..... | 7 |
| 2.3 ADSORBENTS..... | 9 |
| 2.4 ADSORPTION KINETICS..... | 9 |
| 2.5 ADSORPTION EQUILIBRIA..... | 11 |
| 2.5.1 Freundlich Adsorption Isotherm..... | 11 |
| 2.5.2 Langmuir Adsorption Isotherm..... | 12 |
| 2.5.3 Tempkin Adsorption Isotherm..... | 13 |
| 2.6 FIXED BED ADSORPTION..... | 14 |
| 2.6.1 Fixed bed adsorption process..... | 14 |
| 2.6.2 Determination of length of unused bed..... | 16 |
| 2.6.3 Bed depth service time (BDST) model..... | 16 |
| 2.7 SCALE UP THEORY..... | 17 |
| 2.8 PAST STUDIES ON REMOVAL OF DYES..... | 19 |
| 2.8.1 Preparation of adsorbent..... | 19 |
| 2.8.2 Effect of parameters..... | 19 |
| 2.8.2.1 Effect of agitation time..... | 19 |
| 2.8.2.2 Effect of adsorbent dosage..... | 19 |
| 2.8.2.3 Effect of adsorbate pH..... | 20 |
| 2.8.3 Adsorption kinetics..... | 20 |
| 2.8.4 Adsorption equilibria..... | 20 |
| 2.9 PAST STUDIES ON REMOVAL OF ORGANICS..... | 20 |
| 2.9.1 Preparation of adsorbent..... | 20 |

| | | |
|--|--|----|
| 2.9.2 | <i>Effect of parameters</i> | 21 |
| 2.9.2.1 | <i>Effect of agitation time</i> | 21 |
| 2.9.2.2 | <i>Effect of adsorbent dosage</i> | 22 |
| 2.9.2.3 | <i>Effect of adsorbate pH</i> | 22 |
| 2.9.2.4 | <i>Effect of adsorbate temperature</i> | 22 |
| 2.9.3 | <i>Adsorption kinetics</i> | 22 |
| 2.9.4 | <i>Adsorption equilibria</i> | 22 |
| 2.10 | PAST STUDIES ON REMOVAL OF HEAVY METALS..... | 23 |
| 2.10.1 | <i>Preparation of adsorbent</i> | 23 |
| 2.10.2 | <i>Effect of parameters</i> | 23 |
| 2.10.2.1 | <i>Effect of agitation time</i> | 23 |
| 2.10.2.2 | <i>Effect of adsorbent dosage</i> | 24 |
| 2.10.2.3 | <i>Effect of adsorbate pH</i> | 24 |
| 2.10.2.4 | <i>Effect of adsorbate temperature</i> | 24 |
| 2.10.3 | <i>Adsorption kinetics</i> | 25 |
| 2.10.4 | <i>Adsorption equilibria</i> | 25 |
| CHAPTER 3: METHODOLOGY..... | | 26 |
| 3.1 | PREPARATION OF THE ADSORBENT..... | 26 |
| 3.2 | PREPARATION OF THE ADSORBATE..... | 27 |
| 3.3 | BATCH EXPERIMENTS..... | 28 |
| 3.3.1 | <i>Removal of dyes</i> | 28 |
| 3.3.2 | <i>Removal of organics</i> | 30 |
| 3.3.3 | <i>Removal of heavy metals</i> | 31 |
| 3.4 | FIXED BED EXPERIMENTS..... | 31 |
| CHAPTER 4: RESULTS AND DISCUSSION..... | | 33 |
| 4.1 | ADSORBENT CHARACTERIZATION..... | 33 |
| 4.2 | BATCH EXPERIMENTS..... | 33 |
| 4.2.1 | <i>Removal of dyes</i> | 33 |
| 4.2.1.1 | <i>Effect of adsorbent dosage</i> | 33 |
| 4.2.1.2 | <i>Effect of agitation time</i> | 37 |
| 4.2.1.3 | <i>Effect of adsorbate pH</i> | 40 |
| 4.2.1.4 | <i>Effect of initial dye concentration</i> | 41 |
| 4.2.1.5 | <i>Adsorption kinetics</i> | 42 |

| | | |
|------------------------------------|---------------------------------------|----|
| 4.2.1.6 | <i>Adsorption equilibria</i> | 44 |
| 4.2.2 | <i>Removal of organics</i> | 47 |
| 4.2.3 | <i>Removal of heavy metals</i> | 48 |
| 4.3 | FIXED BED EXPERIMENTS | 50 |
| 4.3.1 | <i>Breakthrough curves</i> | 50 |
| 4.3.1.1 | <i>Effect of bed depth</i> | 51 |
| 4.3.1.2 | <i>Effect of adsorbent type</i> | 53 |
| 4.3.2 | <i>BDST analysis</i> | 56 |
| 4.4 | SCALE UP | 57 |
| CHAPTER 5: CONCLUSION | | 58 |
| REFERENCES | | 59 |
| ANNEXURE | | 62 |

LIST OF TABLES

| | | |
|-----------|--|----|
| Table 1.1 | <i>Sources of heavy metals</i> | 2 |
| Table 4.1 | <i>Characteristics of raw and activated coir pith</i> | 33 |
| Table 4.2 | <i>First and second order kinetic parameters</i> | 42 |
| Table 4.3 | <i>Freundlich, Langmuir and Tempkin isotherm parameters</i> | 45 |
| Table 4.4 | <i>Bed capacity & LUB with varying bed depth</i> | 53 |
| Table 4.5 | <i>Bed capacity & LUB with varying adsorbent</i> | 55 |
| Table 4.6 | <i>Comparison of adsorption capacities in batch & fixed bed operations</i> | 55 |
| Table 4.7 | <i>BDST parameters for MB, MG and NB</i> | 57 |
| Table 4.8 | <i>Pilot scale parameters for batch operation</i> | 57 |
| Table 4.9 | <i>Pilot scale parameters for fixed bed operation</i> | 57 |

LIST OF FIGURES

| | |
|---|----|
| Fig 2.1: Breakthrough curve of a fixed bed adsorption column..... | 14 |
| Fig 2.2: Breakthrough curve | 16 |
| Fig 3.1: Muffle furnace..... | 27 |
| Fig 3.2: Orbital shaker | 28 |
| Fig 3.3: Spectrophotometer | 29 |
| Fig 3.4: pH meter..... | 29 |
| Fig 3.5: Fixed bed adsorption column..... | 32 |
| Fig 4.1: Effect of activated coir pith dosage on MB adsorption..... | 34 |
| Fig 4.2: Effect of activated coir pith dosage on MG adsorption | 34 |
| Fig 4.3: Effect of activated coir pith dosage on NB adsorption | 35 |
| Fig 4.4: Comparison of raw and activated coir pith dosage on MB adsorption | 35 |
| Fig 4.5: Comparison of raw and activated coir pith dosage on MG adsorption | 36 |
| Fig 4.6: Comparison of raw and activated coir pith dosage on NB adsorption | 36 |
| Fig 4.7: Comparison of adsorption capacity with various dosages | 37 |
| Fig 4.8: Effect of agitation time on MB adsorption on to activated coir pith | 37 |
| Fig 4.9: Effect of agitation time on MG adsorption on to activated coir pith. | 38 |
| Fig 4.10: Effect of agitation time on NB adsorption on to activated coir pith... .. | 38 |
| Fig 4.11: Comparison of % removal with adsorbent type | 39 |
| Fig 4.12: Effect of pH on dye adsorption | 40 |
| Fig 4.13: Effect of initial concentration on adsorption capacity of MB..... | 41 |
| Fig 4.14: Effect of initial concentration on adsorption capacity of MG | 41 |
| Fig 4.15: Effect of initial concentration on adsorption capacity of NB | 42 |
| Fig 4.16: Second order kinetics for MB adsorption on to activated coir pith ... | 43 |
| Fig 4.17: Second order kinetics for MG adsorption on to activated coir pith... .. | 44 |
| Fig 4.18: Second order kinetics for NB adsorption on to activated coir pith.... .. | 44 |
| Fig 4.19: Fit of Freundlich isotherm for MB adsorption | 45 |
| Fig 4.20: Fit of Freundlich isotherm for MG adsorption..... | 46 |
| Fig 4.21: Fit of Freundlich isotherm for NB adsorption | 46 |
| Fig 4.22: Adsorption capacity of phenol with activated & raw coir pith | 47 |
| Fig 4.23: Second order kinetics for phenol adsorption onto activated coir pith | 48 |
| Fig 4.24: Adsorption of zinc on to activated and raw coir pith..... | 48 |

| | |
|--|----|
| Fig 4.25: Adsorption of lead on to activated and raw coir pith | 49 |
| Fig 4.26: Second order kinetics for zinc adsorption on to activated coir pith .. | 49 |
| Fig 4.27: Second order kinetics for lead adsorption on to activated coir pith.. | 50 |
| Fig 4.28: Break through curve for MB with activated coir pith..... | 51 |
| Fig 4.29: Break through curve for MG with activated coir pith | 52 |
| Fig 4.30: Break through curve for NB with activated coir pith | 52 |
| Fig 4.31: Effect of adsorbent on breakthrough curve of MB | 53 |
| Fig 4.32: Effect of adsorbent on breakthrough curve of MG | 54 |
| Fig 4.33: Effect of adsorbent on breakthrough curve of NB..... | 54 |
| Fig 4.34: Fit of BDST model for MB, MG and NB | 56 |

LIST OF ANNEXURES

| | |
|---------------------------------|----|
| 1. Kinetic data of MB | 62 |
| 2. Kinetic data of NB..... | 62 |
| 3. Kinetic data of MG | 63 |
| 4. Kinetic data of zinc | 63 |
| 5. Kinetic data of lead | 63 |
| 6. Kinetic data of phenol | 63 |
| 7. Equilibrium data of MB..... | 64 |
| 8. Equilibrium data of MG | 64 |
| 9. Equilibrium data of NB..... | 64 |

ABSTRACT

Adsorption of textile dyes, organics and heavy metals onto coir pith based adsorbents from aqueous solutions were studied. Raw coir pith and thermally activated coir pith at 700°C were used as adsorbents. Batch experiments showed that both adsorbents are capable of binding appreciable amounts of impurities from aqueous solutions. Thermally activated coir pith was superior to raw coir pith for dyes and phenol removal. Heavy metal adsorption capacities for both adsorbents were similar. Batch adsorption experiments were conducted in detail for dye removal to determine the factors affecting adsorption and kinetics of the process. Fixed bed column experiments were performed to study practical applicability and breakthrough curves were obtained. The maximum adsorption was observed at solution pH values between 5-9 for Methylene blue and Malachite green. Solution pH value of 2 showed maximum adsorption for Nylosan blue. The adsorbent to solution ratio and the dye concentration in the solution affect the degree of dye removal. The equilibrium data were satisfactorily fitted to Freundlich isotherm. The kinetic data fits to pseudo second order model and kinetic parameters were calculated. Column experiments showed 'S' shaped breakthrough curves and the results followed Bed Depth Service Time (BDST) model. Fixed bed adsorption capacities were lower compared to batch experiments.