

Removal of Chromium in aqueous solutions using Powdered Activated Carbon treated with Humic Acid.

By

B.H. Sooriyabandara

(06/8835)

**Dissertation submitted in partial fulfillment of the
requirements for the Master of Science degree in
Environmental Management**



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

Dr. Rohan Weerasooriya

Dr. J.M.A. Manatunge

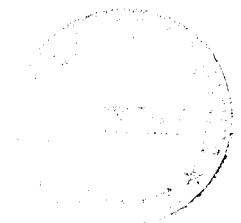
**Department of Civil Engineering
University of Moratuwa
Sri Lanka**

University of Moratuwa



96451

96451



Declaration

I do hereby declare that the work reported in this thesis was exclusively carried out by me under the supervision of Dr. J. M. A. Manatunge and Dr. R. Weerasooriya. It describes the results of my own independent research except where due reference has been made in text. No part of this thesis has been submitted earlier or concurrently for the same or any other degree.

.....

Date: 0...../...../.....

Signature of the Candidate

The above particulars are correct to the best of our knowledge



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

1. Supervisor (name): Dr. R. Weerasooriya

(Signature):.....

Date:...../...../.....

2. Supervisor (name): Dr. J. M. A. Manatunge

(Signature):.....

Date:...../...../.....

Acknowledgements

First and foremost, I would like thank my thesis adviser Dr. Rohan Weerasooriya, Senior Lecturer, Department of Chemistry, University of Peradeniya and Dr. J. M. A Manatunge, Senior Lecturer, Department of Civil Engineering, University of Moratuwa, for all their supervision, guidance, assistance and emotional support given to me during this research project.

I also thank to Dr. Mahesh Jayaweera, Senior Lecturer, Department of Civil Engineering, University of Moratuwa, who always encouraged me to do this research. I wish to mention with deep respect Prof. Nerangie Rathnayaka, Professor, and former Head of Department of Civil Engineering, University of Moratuwa.

I wish to extent my thank to Environmental Laboratory staff of Department of Civil Engineering, University of Moratuwa for giving facilities during my research.

In particular I would like to thanks Mr. I.G.C.K. Kumara and Mr. I. P.L. Jayarathna and Mrs. D. Aluthpatabendi, Research Assistants at Institute of Fundamental Studies, Kandy for their assistance and help to continue my experiments and their patience in explaining me the basics of adsorption research. I would like to thank Mrs. Manjula Ranasinghe, Chemist, Environmental Laboratory staff of Department of Civil Engineering, University of Moratuwa. Finally I would like to thanks Mr. Justin Silva who extended to their co-operation and assistance to me many ways throughout the period of study.

Abstract

Because of its toxicity, Chromium (VI) causes water pollution and threatens to the environment. Its solubility in nature is strongly influenced by adsorption process. Relatively few studies have focused on adsorption properties onto the Powdered Activated Carbon (PAC). In this work, the PAC and humic acid treated PAC adsorption properties were compared.

This study proposed humic acid treated Powdered Activated Carbon as a low cost adsorbent for removal of Chromium from aqueous solution. Adsorption of Cr (VI) by PAC was conducted using batch tests. The influence of pH, contact time, initial Chromium concentration on removal of Chromium (VI) was investigated. This test was also repeated with humic acid treated PAC. The optimum initial pH for maximum adsorption of Cr (VI) from aqueous solution was found to be 4.0. The removal efficiency was found to be correlated with the initial Cr (VI) concentration, ionic strength, as well as the contact time between the Chromium (VI) and the adsorbent. For humic acids treated PAC, the optimum adsorption also was found at 4.0. Therefore acidic medium is favorable to the Chromium removal.

According to the experimental data obtained from this study, the percentage metal removal increased with increasing PAC dosage at the same initial metal concentration. After using humic acid treated PAC increased the metal removal percentage with same adsorbent dosage.

When the effluent is in acidic medium, the PAC is more suitable as the adsorbent while the humic acid treated PAC is more suitable for basic effluent.

Table of Contents

Acknowledgements	i
Abstract	ii
Table of contents	iii
List of Tables	vi
List of Figures	vii
List of symbols and abbreviations	viii
Chapter 01: Introduction	
1.1 Background	01
1.2 Previous studies	03
1.3 Scope of the study	04
Chapter 02: Literature Review	
2.1 Heavy metals and Chromium	06
2.2 Chemical properties of Chromium	06
2.3 Physical properties of hexavalent Chromium	07
2.4 Chromium compounds	08
2.5 Chromium Application and uses of Chromium	08
2.6 Chromium in the Environment	09
2.7 Health effect of Chromium	10
2.8 Powdered Activated Carbon (PAC)	11
2.9 Humus/ Humic acid	12
2.10 Humic acid treated Powdered Activated Carbon	13
2.11 Textile industries and Chromium	13
2.12 Tanning industries and Chromium	13
2.13 Adsorption and adsorption isotherms	14
2.14 Regulations	15

2.15	Standard of Chromium	15
2.16	Wastewater treatment technology	15
2.17	Treatment of Chromium (VI)	15
	2.17.1 Sedimentation	16
	2.17.2 Chemical precipitation	16
	2.17.3 Ion exchange	16
	2.17.4 Reverse Osmosis	16
	2.17.5 Electrodialysis	17
	2.17.6 Adsorption	17
2.18	Parameters	19

Chapter 03: Materials and Methods

3.1	Materials	20
3.2	Selection of Methods	20
	3.2.1 Quantitative analysis of atomic Absorbance Spectrometer	21
	3.2.2 pH meter	21
	3.2.3 Surface titrations	21
3.3	Chromium (VI) adsorption of PAC	22
	3.3.1 Influence of the contact time into bare PAC	22
	3.3.2 Influence of solution initial pH onto bare PAC	23
	3.3.3 Influence of initial chromium concentration onto bare PAC	23
	3.3.4 Influence of initial bare PAC concentration on metal adsorption	23
3.4	Preparation of humic acid treated PAC	24
3.5	Chromium (VI) adsorption of humic acid treated PAC	24
	3.5.1 Influence of the contact time of Cr (VI) adsorption onto humic acid treated PAC	24



3.5.2	Influence of solution initial pH onto humic acid treated PAC	24
3.5.3	Influence of initial Cr (VI) concentration onto humic acid treated PAC	25
3.5.4	Influence of humic acid treated PAC concentration on metal adsorption	25
Chapter 04: Results and Discussion		
4.1	Surface titration	26
4.2	Chromium (VI) adsorption onto bare PAC and HA treated PAC	27
4.2.1	Influence of contact time	27
4.2.2	Influence of solution initial pH	29
4.2.3	Influence of initial Chromium concentration	32
4.3	Adsorption Isotherm	33
4.4	Effect of ionic strengths	36
4.5	Effect of the adsorbent dosage	36
Chapter 05: Conclusion		37
Chapter 06: Recommendations		38
Reference List		39
Appendices		
Appendices - A	Experimental data	41
Appendices - B	PAC sample analysis report	53
Appendices - C	Tolerance limits for effluent discharge	54



List of Tables

Table 2.1	Common hexavalent Chromium ions	07
Table 2.2	Hexavalent Chromium properties	07
Table 4.1	The estimated parameters a and b for Cr (VI) adsorption onto PAC using a nonlinear least square fit of the experimental data	34
Table 4.2	The estimated parameters a and b for Cr (VI) adsorption onto humic acid treated PAC using a nonlinear least square fit of the experimental data	35



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

List of Figures

Figure 2.1	A photograph of the Activated Carbon	11
Figure 4.1.	The surface titration curves of bare PAC as a function of pH	26
Figure 4.2.	Effect of contact time for chromium (VI) adsorption in the presence of humic acid treated PAC suspension	28
Figure 4.3	Effect of contact time for chromium (VI) adsorption in the presence of bare PAC suspension	28
Figure 4.4	Chromium (VI) percentage removals onto bare PAC in the presence of two ionic strengths are 0.01 and 0.001 mol dm ⁻³ NaNO ₃	31
Figure 4.5	Chromium (VI) percentage removals onto treated PAC in the presence of two ionic strengths are 0.01 and 0.001 mol dm ⁻³ NaNO ₃	31
Figure 4.6	Comparison between Freundlich equilibrium isotherms onto bare PAC using a nonlinear least square fit of the experimental data	34
Figure 4.7	Comparison between Freundlich equilibrium isotherms onto treated PAC using a nonlinear least square fit of the experimental data	35
Figure 4.8	Effect of adsorbent dosage variation on the percentage removal of Cr(VI)	36

List of symbols, abbreviations and units

Nomenclature

Concentration (C)	mole/L, ppm, mg/L
Volume (V)	mL
Weight (W)	g, mg
Acidic constant (Ka)	
Temperature	K, °C
Mass	g/mol
Density	g.cm ⁻³
Radius	nm
Energy	kJ.mol ⁻¹
Potential (volt)	V
Faraday constant (F)	C.mol ⁻¹
Surface charge density (σ_H)	C.m ⁻²
Specific Surface area(S)	m ² .g ⁻¹
Molarity (M)	mol/dm ⁻³
Freundlich coefficient	k _f
Ionic strength	I

Abbreviation

AAS	Atomic Absorption Spectrophotometer
PAC	Powdered Activated Carbon
GAC	Granular Activated Carbon

FTIR	Furious Transformation Infrared Spectroscopy.
XRD	X-Ray Diffraction Analysis
XRF	X- Ray Fluorescence
CEA	Central Environmental Authority
SEM	Scanning Electron Microcopy
HA	Humic Acid
PZC	Point of Zero Charge
CDA	Coconut Development Authority
WHO	World Health Organization
USA	United State of America
EPA	Environmental Protection Agency
MCL	Maximum Contaminant Level



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