



Faculty of Women for Arts, Science and Education
Chemistry Department
Cairo- Egypt

STUDIES ON THE USE OF MODIFIED SURFACE ACTIVATED CARBON IN TREATMENT OF RADIOACTIVE WASTE SOLUTIONS

**A Thesis
Submitted to
The Chemistry Department.
Faculty of Women for Arts, Science and Education,
Ain Shams University**

**In Partial Fulfillment of the Requirements for the
Degree of Master of Science
Inorganic and analytical Chemistry**

**Presented By
SARA SAYED MOHAMED MAHROUS
(B.Sc., 2009)**

SUPERVISED BY

Prof.Dr. Wafaa S. Hegazy
Prof.of Physical Chemistry
Chemistry Department
Faculty of Women for Arts,
Science and Education,
Ain Shams University
Cairo

Prof.Dr. Hanan M. Moloukhia
Prof. of Environmental Radioactive pollution
Environmental Radioactive Pollution Department
Hot Lab. Centre,
Atomic Energy Authority
Inshas

Prof.Dr. Nabil A. Belacy
Prof.of Physical Chemistry
Environmental Radioactive Pollution Department
Hot Lab. Centre,
Atomic Energy Authority
Inshas
**Cairo, Egypt
2015**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ

سورة هود آية {٨٨}

Approval Sheet for Submission

**Thesis title:" STUDIES ON THE USE OF MODIFIED
SURFACE ACTIVATED CARBON IN TREATMENT OF
RADIOACTIVE WASTE SOLUTIONS"**

Candidate Name: Sara Sayed Mohamed Mahrous

This thesis has been approved for submission by the supervisors:

Prof. Dr . Wafaa S. Hegazy

Prof. of physical Chemistry
Faculty of Women for Arts,
Science and Education
Ain Shams University

Prof. Dr. Hanan M. Moloukhia

Prof. of Environmental Radioactive Pollution
Environmental Radioactive Pollution Department,
Hot Laboratories Center,
Atomic Energy Authority

Prof. Dr. Nabil A. Belacy

Prof. of Physical Chemistry
Environmental Radioactive Pollution Department,
Hot Laboratories Center,
Atomic Energy Authority

Head of Chemistry Department

Approval Sheet

Thesis title: STUDIES ON THE USE OF MODIFIED SURFACE ACTIVATED CARBON IN TREATMENT OF RADIOACTIVE WASTE SOLUTIONS

Candidate Name: Sara Sayed Mohamed Mahrous

This thesis has been approved by:

Prof. Dr . Hisham F. Ali

Prof. of radiation chemistry
Hot Laboratories Center
Atomic Energy Authority

.....

Prof. Dr . Ahmed A. Taha

Prof. of physical Chemistry
Faculty of Women for Arts,
Science and Education
Ain Shams University

.....

Prof. Dr . Wafaa S. Hegazy

Prof. of physical Chemistry
Faculty of Women for Arts,
Science and Education
Ain Shams University

.....

Prof. Dr. Hanan M. Moloukhia

Prof. of Environmental Radioactive Pollution
Environmental Radioactive Pollution Department
Hot Laboratories Center
Atomic Energy Authority

.....

Prof. Dr. Nabil A. Belacy

Prof. of Physical Chemistry
Environmental Radioactive Pollution Department
Hot Laboratories Center
Atomic Energy Authority

.....

ACKNOWLEDGEMENT

I am deeply thankful to Allah, by the grace of whom the progress of this work was possible.

I would like to offer my deepest thanks and appreciation to **Prof. Dr. Wafaa S. Hegazy**, for her sponsorship of this thesis, valuable guidance, deep significant remarks and help during the progress of this thesis.

I would like to express my deep sincere thanks and appreciation to **Prof. Dr. Hanan M. Moloukhia**, for suggesting the point, direct supervision, valuable guidance, valuable comments and discussion, continuous encouragement and help during the whole work.

I would like to offer my deepest gratitude and appreciation to **Prof. Dr. Nabil A. Belacy**, for his supervision, his endless help and encouragement, valuable significant remarks and instructive guidance during the experimental work.

Many thanks are also due to **Dr. Ezzat Abdel Kader and Dr. Yasser Faried**, lecturers of Chemistry, Hot Lab. Centre, Atomic Energy Authority, for their keen interest, valuable guidance and continuous help throughout the completion of the thesis.

I am very grateful to all colleagues and staff members of Hot Lab. Centre, Atomic Energy Authority, for their sincere cooperative interactions.

Many thanks for all the staff members of the chemistry department, Faculty of Arts, Science and Education, for their kind help.

Finally, I cannot forget the complete assistance and faithful encouragement of my family during the preparation of this thesis.

CONTENTS

	Page
List of Tables.....	i
List of Figures	ii
List of Abbreviations	V
Aim of the Present Work	Vi
Abstract	Vii
CHAPTER I	
INTRODUCTION AND REVIEW OF LITERATURE	
1.1. Radioactive Waste and its Sources	1
1.1.2. Types of Radioactive Waste	2
1.2. Activated Carbon (AC)	3
1.3. Classification of Activated Carbon	4
1.3.1. Powdered Activated Carbon (PAC)	4
1.3.2. Granulated Activated Carbon (GAC)	4
1.3.3. Impregnated Activated Carbon (IAC)	4
1.4. Physical and Chemical Properties of Activated Carbon Surfaces	4
1.5. Applications of Activated Carbon	6
1.6. Different Surface Modification Techniques	7
1.6.1. Chemical Modification	8
1.6.2. Physical Modification	9
1.6.3. Plasma Oxidation	9
1.6.4. Biological Modification	9
1.7. Properties of the Studied Metal Ions	9
1.8. Literature Survey	12

CHAPTER II	
EXPERIMENTAL MATERIALS AND METHODS	17
2.1. Materials	17
2.2. Techniques	17
2.2.1. Preparation of Modified Surface Activated Carbon	17
2.2.1.1. Preparation of Activated Carbon (AC)	17
2.2.1.2. Surface Modification Process	17
2.2.2. Characterization of MSAC	18
2.2.2.1. Particle Size	18
2.2.2.2. Apparent Density	18
2.2.2.3. Bulk Density (Packed Density)	18
2.2.2.4. Ash Content	19
2.2.2.5. Carbon Yield	19
2.2.2.6. Moisture Content	19
2.2.3. Chemical Characteristics	20
2.2.3.1. Determination of the Adsorbent pH	20
2.2.3.2. Chemical Stability	20
2.2.4. Batch Adsorption Studies	20
2.2.4.1. Effect of pH	21
2.2.4.2. Effect of Contact Time	21
2.2.4.3. Effect of Initial Ion Concentration	21
2.2.4.4. Effect of Temperature	21
2.2.4.5. Effect of Competing Ions	21
2.2.4.6. Effect of Adsorbent Dose	22
2.2.5. Distribution Studies	22
2.2.6. Capacity Measurements	23
2.2.6.1. Saturation Capacity	23
2.2.7. Sorption Isotherms	23

2.2.8. Sorption kinetics	25
2.2.8.1. Pseudo-First Order Model	25
2.2.8.2. Pseudo-Second Order Model	26
2.2.8.3. Diffusion –Based Model	27
2.2.9. Column Operations	27
2.2.10. Equipments	28
2.2.10.1. Water Thermostat Shaker	28
2.2.10.2. pH-Meter	28
2.2.10.3. Atomic Absorption Spectrophotometer	28
2.2.10.4. Inductively Coupled Plasma	28
2.2.10.5. UV-Visible Spectrophotometer.....	28
2.2.10.6. Surface Area.....	28
2.2.10.7. Scan Electron Microscope	29
2.2.10.8. X-Ray Fluorescence (XRF)	29
2.2.10.9. Differential Thermal (DT) and Thermogravimetric (TG) Analyses.....	29
2.2.10.10. Infrared Spectral Analysis	29
2.2.10.11. X-Ray Diffraction Patterns.....	29
CHAPTER III	
RESULTS AND DISCUSSION	
3.1. Characterization of the Studied Sorbent Material (MSAC)...	30
3.1.1. The Physico-Chemical Characterization and Chemical Composition.....	30
3.1.2. Chemical Stability.....	32
3.1.3. FTIR Spectrum	32
3.1.4. Thermogravimetric Analysis	35
3.1.5. XRD	35
3.1.6. N₂ Adsorption Isotherms	37

3.1.7. Ultrastructural Morphological Analysis (SEM)	40
3.2. Adsorption Dynamics	42
3.2.1. Effect of Contact Time.....	42
3.2.2. Effect of Solution pH	42
3.2.3. Effect of Adsorbent Dosage	43
3.2.4. Effect of Initial Metal Concentration	46
3.2.5. Effect of Temperature	46
3.2.6. Effect of Competing Ions and Complexing Agent.....	48
3.4. Distribution Studies	52
3.4.1. Determination of the Distribution Coefficient (K_d)	52
3.4.2. Determination of the Thermodynamic Parameters (ΔH^0 , ΔG^0 , ΔS^0) of the Adsorption Reaction.....	55
3.5. Capacity Measurements	60
3.5.1. Saturation Capacity	60
3.6. Adsorption Isotherms	67
3.6.1. The Best Fitted Model	79
3.6.2. Thermodynamic Parameters	79
3.7. Kinetic Studies	83
3.7.1. Sorption Kinetic Models	83
3.7.1.1. Reaction-Based Models	83
3.7.1.1.1. Pseudo-First Order Model	82
3.7.1.1.2. Pseudo-Second Order Model	87
3.7.1.1.3. Diffusion-Based Model	94
3.8. Column Operation	100
SUMMARY	102
CONCLUSION	105
REFERENCES	106
ARABIC SUMMARY	

List of Tables

	Page
Table 1. Physico-chemical characteristic of MSAC.	30
Table 2. Elemental analysis of MSAC.	31
Table 3. Percentages of the ash components in the sorbent material.	31
Table 4. Solubility of the prepared sorbent MSAC in different media	32
Table 5. Surface area and porosity estimated by different methods of modification.	38
Table 6. Effect of NaCl and EDTA concentrations on the % removal of Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions by MACCS.....	49
Table 7. K_d values of various adsorbed ions on MSAC.	59
Table 8. Thermodynamic parameters for adsorption of Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions on MSAC.	59
Table 9. The MSAC capacity of the studied metal ions at different pH's and constant concentration (800mg/L).....	62
Table 10. The MSAC capacity of the studied metal ions at different concentration.	62
Table 11. Langmuir isotherm parameters for adsorption of Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions on MSAC at different reaction temperatures.	71
Table 12. Freundlich isotherm parameters for adsorption of Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions on MSAC at different reaction temperatures.	74
Table 13. Dibinin isotherm parameters for adsorption of Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions on MSAC at different reaction temperatures.	78
Table 14. Thermodynamic parameters for adsorption of Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions on MSAC.	82
Table 15. Adsorption rate constants, estimated q_e and coefficients of correlation associated for Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions according to the Lagergren-first order kinetic model.	86
Table 16. Adsorption rate constants, estimated q_e and coefficients of correlation associated for Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions according to the pseudo-second order kinetic model.	90
Table 17. Changes in the values of the intra-particle diffusion coefficients for Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+}	95
Table 18. Thermodynamic parameters for adsorption of Eu^{3+} , Ce^{3+} , Sr^{2+} and Cs^{+} ions on MSAC..	99