



شبكة المعلومات الجامعية

بسم الله الرحمن الرحيم



شبكة المعلومات الجامعية
@ ASUNET



شبكة المعلومات الجامعية التوثيق الالكتروني والميكرو فيلم



شبكة المعلومات الجامعية

جامعة عين شمس

التوثيق الالكتروني والميكرو فيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأفلام قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأفلام بعيدا عن الغبار

في درجة حرارة من ١٥-٢٥ مئوية ورطوبة نسبية من ٢٠-٤٠%

To be Kept away from Dust in Dry Cool place of
15-25- c and relative humidity 20-40%

بعض الوثائق الأصلية تالفة

بالرسالة صفحات لم ترد بالاصل

Remediation Techniques of Heavy Metals in Sludge

عق

A Thesis Presented
To

Chemistry Department
Faculty of Science
Cairo University

By

Shimaa Mohamed Abdel Moniem Mohamed

Environmental Research Division
Water Pollution Research Department
National Research Centre

B.Sc. Chemistry – Physics, 2004 (Very Good)
Faculty of Science - Cairo University

For

The Degree of
Master in Science

2010

APPROVAL SHEET FOR SUBMISSION

Title of (M.Sc) thesis: Remediation Techniques of Heavy Metals in Sludge.

Name of the candidate: Shima Mohamed Abdel Moniem Mohamed.

This thesis has been approved for submission by the supervisors:

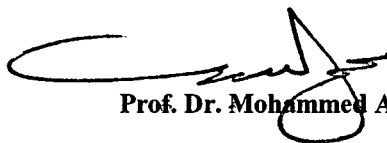
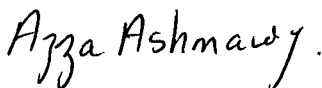
1. Prof. Dr. Motaza M. Khater

Signature:



2. Prof. Dr. Azza M. Abdel Moniem Ashmawy

Signature:



Prof. Dr. Mohammed A. Badawy

**Chairman of Chemistry Department
Faculty of Science – Cairo University**

ABSTRACT

Name: Shimaa Mohamed Abdel Moniem Mohamed
Title of thesis: Remediation Techniques of Heavy Metals in Sludge
Degree: (M.Sc) thesis, Faculty of Science, Cairo University, Egypt (2010)

Industry has become an essential part for progressive economic development in Egypt; solid waste production is an inevitable outcome of the developmental activities. Especially industrial solid wastes that are contaminated with heavy metals may pose a potential hazard to the human health or the environment when improperly treated, stored, transported, disposed off or managed. Heavy metals contaminated sewage sludge is the other kind of solid waste, which is produced through a sewerage system, the different metal forms are released and accumulated in the sludge, which limits its profitable use as a fertilizer and considered as hazardous waste. As the environment protection from hazardous pollutants associated with waste generation and its disposal are a major concern in today's heavily industrialized world. Therefore, the incentive objectives and results of this study are: (I) Monitoring the level and types of metals in sludge from different Wastewater Treatment Plants, where the metals concentration in all sludge samples were within the permissible values adopted by Egyptian Regulations in Decree 214/1997 for sludge permitted to be re-used in agriculture, except for lead in of El Gabal El Asfar (16, 19), El-Berka, Balaqus and Al-Sadat WWTP. (II) Assessment of the different remediation techniques for metals immobilization in sludge to reduce their negative impacts on human health and environment. Two different types of binding materials were used during immobilization technique of heavy metals contaminated sludge; from waste products such as (cement dust, cement clinker dust, fly ash, granite waste sludge and rice straw) and from low cost chemicals such as (low grade MgO and sodium silicate). Efficiency of using these different binders was evaluated with respect to the leachability of metals from the treated sludge for estimating the optimum binder to waste ratio in order to produce a waste form with high physical stability. The unconfined compressive strength test (UCS) after 28 days, were used for estimating the efficiency of metals solidified sludge matrix. Different leaching tests were selected, such as (the EN 12457-2 leaching test; TCLP test and MEP test). By comparing between different leaching tests used (European Union EN 12457-2 and US EPA TCLP test) to establish the interactions between countries with different regulatory requirements and to consider several relevant aspects of leaching behavior, statistical analysis of our results concluded that there was no significant variation between the two compared leaching standard methods to estimate the mobility of heavy metals under their specific condition. However, the MEP test represents the long term leaching effect which indicated that the heavy metals present in the sludge are highly stable and are not likely to dissolve in a natural environment for a long period of environmental exposure. The leachability results and application of optimum binder to waste ratio on three case studies from industrial and municipal contaminated sludge showed that, the concentration of all metals under investigation (Cd, Cr, Cu, Pb, Ni, Zn) were lower than the limit values set by Egyptian Regulations law 4/1994 for hazardous waste management. In addition, the unconfined compressive strength test concluded that all sludge samples that solidified with the optimum doses of the different binders have UCS higher than 0.35MPa which is the minimal compressive strength required for solid waste disposal at landfills, which indicated that the remediate sludge were well solidified and safe to be considered for use in a wide variety of applications such as a raw material to build concrete blocks or to be sold as pavement blocks or used in roadbeds and/or parking lots. Finally, heavy metals immobilization is considered as a cost-effective process for disposing solid hazardous wastes containing unacceptable levels of leachable metals in landfill and producing strong and durable stabilized products using waste materials or industrial by-products which themselves have negative impact on the environment.

Keywords: Hazardous sludge, Heavy metals; Remediation; Immobilization; Leachability; Compressive strength.

Supervisors:

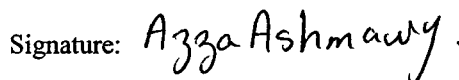
1. Prof. Dr. Motaza M. Khater

Signature:



2. Prof. Dr. Azza Ashmawy

Signature:



Prof. Dr. Mohammed A. Badawy

Chairman of Chemistry Department
Faculty of Science – Cairo University



ACKNOWLEDGEMENT

Acknowledgement is due to **CAIRO UNIVERSITY** and **NATIONAL RESEARCH CENTRE** for their support in carrying out this research.

First of all, I am deeply thankful to **Professor Dr. Motaza M. Khater**, Professor of Analytical and Inorganic chemistry, Chemistry Department, Faculty of Science, Cairo University, for supervising this work, valuable advice, guidance and invaluable criticism and discussions.

It is my pleasant duty to assure my sincere appreciation, my deepest thanks and gratitude to **Professor Dr. Azza Ashmawy**, Professor of wastewater treatment technology, Water Pollution Research Department, National Research Centre, for suggesting the topic of this study, her kind supervision, valuable assistance, valuable advice, guidance and suggestions through these studies.

My very sincere gratitude goes to **Assoc. Professor Dr. Hanan Sayed Abdel-Rahman**, Associate Professor of wastewater treatment technology, Water Pollution Research Department, National Research Centre, from whom I received the most important support during this study.

I would like to express my great thanks to the staff members of the Water Pollution Research Department of the National Research Centre (NRC), Egypt.

Last but not least, I would like to thank with all my heart my dear parents, my lovable sisters, their families, my truehearted husband Assoc. Researcher Mohamed Eid for their spiritual support and continuous encouragement. I owe deep gratitude to my parents for educating me and for their endless love and understanding.

SHIMAA MOHAMED ABDEL MONTEM

CONTENTS

Page

Chapter I

1. Introduction

1.1. Environmental Impact of Solid Waste in Egypt	1
1.2. Legislative Framework for Wastewater Management in Egypt.....	2
1.3. Sludge Management.....	3
1.3.1. Sludge Generation Management and Metals Impact.....	3
1.4. The Objectives.....	5
1.5. Literature Review.....	6
1.5.1. The Negative Impact and Hazards of Heavy Metals Pollution.....	6
1.5.2. Landfill.....	7
1.5.2.1. Landfill types and construction.....	7
1.5.2.2. Impacts of Landfills	8
1.5.3. Standard leaching methods.....	9
1.5.3.1. The standard European EN 12457-2 leaching test.....	9
1.5.3.2. The Toxicity Characteristic Leaching Procedure TCLP (USEPA method 1311).....	10
1.5.3.3. The multiple extraction procedure (USEPA method 1320).....	11
1.6. Remediation technologies of heavy metals in sludge.....	12
1.6.1. Common binder selection criteria.....	12
1.6.1.1. Interaction between binder and waste.....	15
1.6.2. Immobilization techniques.....	14
1.6.2.1. Solidification.....	14
1.6.2.2. Stabilization.....	14
1.6.2.3. Encapsulation.....	15
1.6.3. Heavy metals immobilization in hazardous sludge.....	16
1.6.3.1. Heavy metals immobilization in hazardous sludge using Fly ash.....	17
1.6.3.2. Heavy metals immobilization in hazardous sludge using Cement by-products.....	18
1.6.3.3. Heavy metals immobilization in hazardous sludge using Granite waste sludge.....	20
1.6.3.4. Heavy metals immobilization in hazardous sludge using Rice straw.....	21
1.6.3.5. Heavy metals immobilization in hazardous sludge using low-grade MgO.....	25
1.6.3.6. Heavy metals immobilization in hazardous sludge using Sodium silicate.....	23

Chapter II

2. Materials and Methods

2.1. Sludge Sampling.....	25
2.2. Analysis.....	26
2.2.1. Sources of binding materials.....	26
2.2.2. The X-ray fluorescence analysis.....	27

	Page
2.2.3. The remediation process.....	28
2.3. Evaluation of the performance of the remediation schemes.....	29
2.3.1. The standard European leaching test (EN 12457-2).....	29
2.3.2. Toxicity Characteristic Leaching Procedure (TCLP).....	29
2.3.3. Multiple extraction procedure.....	30
2.3.4. Unconfined compressive strength (UCS).....	30
2.4. Statistical Analysis.....	31
2.5. Calculations.....	31
Chapter III	
3. Results and Discussion	
3.1. Metals concentration in sludge from different Wastewater Treatment Plants (WWTP).....	32
3.2. Remediation of Heavy Metals in Hazardous Sludge.....	33
3.2.1. Heavy metals immobilization in hazardous sludge using Fly ash.....	34
3.2.2. Heavy metals immobilization in hazardous sludge using Cement by-products.....	53
3.2.3. Heavy metals immobilization in hazardous sludge using Granite waste sludge.....	84
3.2.4. Heavy metals immobilization in hazardous sludge using Rice straw.....	101
3.2.5. Heavy metals immobilization in hazardous sludge using low-grade MgO.....	118
3.2.6. Heavy metals immobilization in hazardous sludge using Sodium silicate.....	143
3.3. Case Studies: Remediation of different types of hazardous sludge.....	150
3.3.1. Sludge produced from Balaqus WWTP.....	150
3.3.2. Sludge produced from Metal Plating Plant.....	154
Conclusion and Remarks	169
Summary	173
References	181
Arabic Summary	