

**USING OF DRINKING AND INDUSTRIAL WATER SLUDGE  
IN THE TREATMENT OF INDUSTRIAL LIQUID WASTES  
PRODUCED FROM POWER PLANTS"**

**Submitted By**

**Ali Ahmed Maan El-Ghanam**

B.Sc. Science, Faculty of Science, Mansoura University, 1985

Diploma of Environmental Sciences, Institute of Environmental Studies & Research,

Ain Shams University, 2009

A thesis Submitted in Partial Fulfillment  
Of  
The Requirements for the Master Degree  
In  
Environmental Science

Department of Environmental Basic Science  
Institute of Environmental Studies and Research  
Ain Shams University

**2015**

## APPROVAL SHEET

# **USING OF DRINKING AND INDUSTRIAL WATER SLUDGE IN THE TREATMENT OF INDUSTRIAL LIQUID WASTES PRODUCED FROM POWER PLANTS"**

**Submitted By**

**Ali Ahmed Maan El-Ghanam**

B.Sc. Science, Faculty of Science, Mansoura University, 1985

Diploma of Environmental Sciences, Institute of Environmental Studies & Research,  
Ain Shams University, 2009

This thesis Towards a Master Degree in Environmental  
Sciences has been Approved by :

Name

Signature

**1. Prof. Dr. Mostafa Mohamed Hassan Khalil**

Prof. of Inorganic and Analytical Chemistry  
Faculty of Science  
Ain Shams University

**2. Dr. Gamal Ab El-Aziz Al-Melegy**

Associate Prof. of Organic Chemistry  
Faculty of Science  
Ain Shams University

**3. Dr. Taha Abd El Azim Mohamed Abd El-Razek**

Associate Prof. of Analytical Chemistry and Head of Department of  
Environmental Basic Sciences  
Institute of Environmental Studies and Research  
Ain Shams University

**2015**

# **USING OF DRINKING AND INDUSTRIAL WATER SLUDGE IN THE TREATMENT OF INDUSTRIAL LIQUID WASTES PRODUCED FROM POWER PLANTS"**

**Submitted By**

**Ali Ahmed Maan El-Ghanam**

B.Sc. Science, Faculty of Science, Mansoura University, 1985

Diploma of Environmental Sciences, Institute of Environmental Studies & Research,  
Ain Shams University, 2009

A thesis Submitted in Partial Fulfillment  
Of  
The Requirements for the Master Degree  
In  
Department of Environmental Basic Science

Under the supervision of :

**1.Dr. Taha Abd El Azim Mohamed Abd El-Razek**

Associate Prof. of Analytical Chemistry in Department of  
Environmental Basic Sciences  
Institute of Environmental Studies and Research  
Ain Shams University

**2.Dr. Ashraf Ibrahim Shehata Hafez**

Water treatment department  
Central Chemical laboratory  
Egyptian Electricity Transmission Company.

**2015**



## Acknowledgement

*At First, I thank **God** for being giving me the power to complete this work and all his gifts along my life.*

*My thanks due to **Dr. Taha A.Azim M.A.Razek**, Associate Professor of Environmental analytical Chemistry Dept. of Env. Basic Science-Institute of Environmental Studies and Research, Ain Shams University, for his valuable supervision, guidance, encouragement and all facilities given through the whole thesis and his continuous encouragement and scientific discussion for the obtained data.*

*I would like to express my sincere gratitude and appreciation to the supervisor of the present work, **Dr. Ashraf Ibrahim Shehata Hafez**, water Treatment Department., Center Chemical lab. E*

*gyptian Electricity Transmission Company, for his great effort in planning this research, his kind care during the progress of this work and his sincere encouragement and finishing of this work.*

*Thanks to all staff and members of water division department and all members of the central chemical labs for their help and co-operation.*

# Abstract

The aim of this thesis is to study the probability of using drinking and industrial water sludge in the treatment of industrial liquid wastes produced from power plants.

Collection of four different types of sludge from different water treatment plants in power station. Complete analysis, TGA and X-ray investigation were performed for the different types of sludge.

The method of recovery of aluminium and iron from different types of sludge was carried out by acid digestion using sulphuric , nitric and hydrochloric acids.

The evaluation of the recovered aluminium and iron in the clarification of industrial waste water was carried out by Jar test method which the most way to simulate clarification and permits, the comparison of various chemical program in the clarification of water.

The obtained results showed that the optimum condition for maximum recovery was ( $\text{pH} = 1$  for 2 hours at  $80^{\circ}\text{C}$  ) for aluminium and iron recovery. At these conditions, the percentage of aluminium and iron recovery reached to 99 and 98 % respectively.

The experiments confirm the significant effect of coagulant dosage (recovered aluminium and iron) on coagulation process. Under optimal conditions of process parameters, a coagulant dose about 20 to 30 mg/l at  $\text{pH} = 8$  gives acceptable results better than that when using 35 to 45 mg/l of commercial alum and ferric chloride.

The specification of the produced water after treatment by recovered aluminium and iron is compatible with Egyptian standard to drain to surface water or to use as industrial water.

**Keywords:** Industrial water, sludge, recovered aluminium and iron, TGA , X-ray analysis.

# List of Contents

	Page
<b>Abstract</b> .....	--
<b>Acknowledgment</b> .....	--
<b>List of abbreviations</b> .....	i
<b>List of tables</b> .....	ii
<b>List of figures</b> .....	iv
<b>Chapter (1):</b> .....	1
<b>Introduction</b> .....	1
<b>Research objectives</b> .....	2
<b>Chapter (2):</b>	
<b>Literature review:</b> .....	3
2-1 Background .....	3
2-2 Sludge production in water treatment .....	3
2-2-1 Water treatment .....	3
2-2-2 Clarification of water by coagulation .....	4
2-2-3 Flocculation process .....	7
2-2-4 Sedimentation process .....	9
2-3 Sludge disposals and recycling .....	11
2-4 Sludge Re-use in water treatment .....	13
2-4-1 Coagulant recovery methods .....	14
2-4-1-1 Acid digestion of sludge .....	14
2-4-1-2 Heavy metal release by acidification .....	15
2-4-1-3 Alkalization .....	16
<b>Chapter (3):</b>	
<b>Materials and Methods:</b> .....	17
3-1- Source of aluminum and iron sludge .....	17
3-2- Selection of wastewater sludge for reuse test .....	17

3-3- Chemicals.....	22
3-4- Analysis .....	22
3-4-1 Sludge analysis .....	22
3-4-2 Industrial Waste water analysis .....	23
3-5-Aluminum and iron recovery and determination .....	24
3-6-Water sample preparation in clarification process.....	24

## **Chapter (IV):**

<b>Results and discussion.....</b>	<b>21</b>
4-1 Nature of water works sludges .....	21
4-2 Thermogravimetric analysis .....	30
4-3 X-ray analysis of sludge .....	32
4-4. Sludge conditioning by acidification technique.....	37
4-4-1. Effect of acid on sludge volume reduction .....	37
4-4-2. Percentage recovery of aluminium and iron.....	42
4-4-2-1. Effect of pH, temperature and soaking time on percentage recovery.....	42
4-5.Effect of acidic solutions on the dissolution of elements for different types of sludge (A, B ,C ,D).....	50
4-6 Evaluation of recovered iron as flocculant for treatment of waste water .....	62
4-7- Benefits of study .....	71
4-7-1 Amount of alum and ferric chloride saving.....	71
4-7-2 Environment Impact .....	73
<b>Conclusion.....</b>	<b>74</b>
<b>Summary.....</b>	<b>75</b>
<b>References.....</b>	<b>78</b>
<b>Arabic summary</b>	

# **List of Abbreviations**

AAS	: Atomic Absorption Spectroscopy.
ASTM	: American Society for Testing and Materials.
AWWA	: American Water Works Association.
BOD	: Biochemical Oxygen Demand.
COD	: Chemical Oxygen Demand.
OM	: Organic Matter.
TDS	: Total Dissolved Solid.
TGA	: Thermo Gravimetric Analysis.
TSS	: Total Suspended Solid.
TTWW	: Tertiary Treated Waste Water.
USEPA	: US Environmental Protection Agency.
WS	: Working Sludge.
WWTP	: Waste Water Treatment Plant.



## List of Tables

Table	Title	Page
4-1	Typical composition of the four types of sludge sample (average values).	29
4-2	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 80°C for 120 minute at pH = 1.	50
4-3	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A, B,C,D) at 80°C for 120 minute at pH = 3	51
4-4	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 80°C for 120 minute at pH =5.	52
4-5	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C, D) at 80°C for 120 minute at pH =6.	53
4-6	Effect of Acidic solution on the Dissolving of elements for the different types of sludge (A,B,C,D) at 60°C for 120 minute at pH = 1.	54
4-7	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 60°C for 120 minute at pH = 3	55
4-8	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 60°C for 120 minute at pH = 5	56

## List of Tables

Table	Title	Page
4-9	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B, C, D) at 60°C for 120 minute at pH =6	57
4-10	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 30 °C for 120 minute at pH = 1	58
4-11	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 30 °C for 120 minute at pH = 3	59
4-12	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 60 °C for 120 minute at pH = 5	60
4-13	Effect of Acidic solution on the Dissolution of elements for the different types of sludge (A,B,C,D) at 30 °C for 120 minute at pH = 6	61
4-14	Effect of recovered aluminium and iron and commercial alum and ferric chloride in the treatment of waste water	69
4-15	The amount of alum and ferric chloride saved during day , month and years	73

# List of Figures

Figure	Title	Page
2-1	Stable and unstable colloids.	6
2-2	The coagulation processes.	6
2-3	The flocculation processes.	8
2-4	The shape of coagulated and flocculated particles.	9
3-1	Sludge (A) in solid and powder form.	18
3-2	Sludge (B) in solid and powder form.	19
3-3	Sludge (C) in solid and powder form.	20
3-4	Sludge (D) in solid and powder form.	21
3-5	illustrate an image for the typical Jar test apparatus in case of using recovered alum (A) and recovered iron (B) for the clarification of industrial waste water.	26
4-1	Schematic diagram of water treatment plant in power station.	28
4-2	TGA of dry working sludge (A, B, C, D).	31
4-3	X-Ray of sludge (A).	33
4-4	X-Ray of sludge (B).	34
4-5	X-Ray of sludge (C).	35
4-6	X-Ray of sludge (D).	38
4-7	Effect of pH on sludge volume reduction at 80 °C for different time intervals (sludge C).	38
4-8	Effect of pH on sludge volume reduction at 80 °C for different time intervals (sludge B).	39
4-9	Effect of pH on sludge volume reduction at 80 °C for different time intervals (sludge D).	40
4-10	Effect of pH on sludge volume reduction at 80 °C for different time intervals (sludge A).	41

## List of Figures (Cont.)

Figure	Title	Page
4-11	Effect of pH on Al recovery for different time intervals at 30 °C.	43
4-12	Effect of pH on Al recovery for different time intervals at 60 °C.	44
4-13	Effect of pH on Al recovery for different time intervals at 80 °C.	45
4-14	Effect of pH on Iron recovery for different time intervals at 30 °C.	46
4-15	Effect of pH on Iron recovery for different time intervals at 60 °C.	47
4-16	Effect of pH on Iron recovery for different time intervals at 80 °C.	48
4-17	Effect of recovered Iron Dose on the % Reduction of Turbidity, BOD, COD, TSS and Organic matter of treated water.	64
4-18	Effect of commercial ferric chloride Dose on the % Reduction of Turbidity, BOD, COD, TSS and Organic matter of treated water.	65
4-19	Effect of Recovered Aluminum Dose on the % Reduction of Turbidity, BOD, COD, TSS and Organic matter of treated water.	66
4-20	Effect of Commercial Alum Dose on the % Reduction of Turbidity, BOD, COD, TSS and Organic matter of treated water.	67

## I-Introduction

Sludge produced from drinking and industrial water treatment results in some problems. Many studies have been tried to provide new and suitable solutions to solve part of sludge problem. One of them is to reuse water treatment sludge in several fields. It is still an issue to choose a disposal method for water treatment sludge that would be reasonable in terms of technology and economy. According to environment protection regulations it is required to minimize the quantity of wastes produced. If possible, the wastes should be re-used or processed as secondary raw materials as much as possible.

The composition and properties of the water treatment sludge depends typically on the quality of raw water as well as on types and doses of chemicals used during the water treatment. Typically hydrated aluminium oxides and iron oxides are present in the water treatment sludge (this depends on coagulants used for the treatment) (**Boaventura et al., 2000**).

The sludge that produced from the treatment of water and production of drinking water when alumina and iron coagulants are used for coagulation and clarification of surface water is mainly rich in some elements such as aluminium and iron.

Efforts are carried out to recover aluminium and iron from water treatment sludge during water treatment or to use the sludge for industrial wastewater treatment or as a secondary raw material. Recently, however, more work has been done to improve means of disposal of the solid residues from the municipal treatment processes (**Farrow and Warren, 1993; Fitzpatrick et al., 2003 and Amuda et al., 2006**).

## **Research Objectives:**

Some of the water treatment plants discharge their sludge to the environment without consideration of possible side effects. Since this kind of sludge is generally considered pollutant, the sludge treatment of water industry seems to be an essential task. Obviously the weight and volume of solids produced during coagulation process are much more than other wastes of water treatment operations, and their treatment is much more difficult as well. Besides, this sludge contains metal hydroxide.

### **The overall objective of this study is:**

- 1- To find an alternative solution to reduce the large volume of sludge produced in the water treatment plants in the Egyptian power station.
- 2- To reduce the consumption of chemicals used in the Treatment of water such as (alum and ferric chloride).
- 3- To prevent pollution resulted from sludge disposal by landfilling.

To face the aforementioned problems, recovery of coagulant metals from waste sludges for reuse has been investigated in this work.

Aluminum and iron metals were recovered by acidification of these sludges.

Therefore the thesis was designed to investigate the following:

- 1- Separation of aluminium and iron from water treatment sludge.
- 2- Choosing the optimum condition for maximum recovery of the above mentioned element.
- 3- Evaluation of obtained aluminium and iron doses in the clarification of industrial waste water by Jar test method which the most way to simulate clarification and permits, the comparison of various chemical program in the clarification of water.

## 2- Literature Review

### 2-1. Background:

Sludge is a by-product. It is one of final products of wastewater treatment at treatment plants. The wastewater treatment plants (WWTPs) equipment concentrate impurities in wastewater into solid form and then separate these solid from liquid. The solid remain is known by sludge (**Howard *et al.*, 1985**).

The recovery of coagulant metals from water works sludge have been studied for several years, because of the toxic nature of free and complex aluminum and other species to aquatic life, cost benefit issues of metal recovery and the stringent environmental regulations on disposal of these sludge on land or into water bodies gain much concern (**Al-Malack *et al.*, 2002 and Accepta, 2010**).

The pollution resulted from discharge of sludge on land cause several problems, among them are:

- Difficulty in locating new landfill site due to the disposal cost.
- Pollution of ground water reservoir, which have adverse effect on human health and environment.

### 2.2- Sludge production in water treatment plants:

#### 2.2.1- Water treatment:

Raw water that includes waste from industrial processes required treatment before it can be safely discharge and released back into local water systems. The water passed through a series of screens, chambers,