

# **Upgrading of Ceramic Wastewater Treatment for Reuse**

**Submitted By  
Ahmed Ahmed Ahmed Elserwy**

B. Sc., of Science (Chemistry), Faculty of Science Ain Shams University, 1993

A Thesis Submitted in Partial Fulfillment  
Of  
The Requirement for the Master Degree  
In  
Environmental Science

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

2014

## **APPROVAL SHEET**

### **UPGRADING of CERAMIC WASTEWATE TREATMENT for REUSE Wastewater**

#### **Submitted By**

**Ahmed Ahmed Ahmed Elserwy**

B. Sc., of Science (Chemistry), Faculty of Science Ain Shams University, 1993

This Thesis Towards a Master Degree In Environmental Science  
Has Been Approved by:

**1-Prof. Dr. Mohamed Yousef Elkady**

Prof. of General Chemistry, Faculty of Science  
Ain Shams University

**2-Prof. Dr. Mostafa Mohamed Hassen Khalil**

Prof. of Analytical Chemistry, Faculty of Science  
Ain Shams University

**3-Dr. Enas Mohamed Abou Talab**

Assistant. Prof of Wastewater Treatment Technology  
National Research Center

# **Upgrading of Ceramic Wastewater Treatment for Reuse**

**Submitted By**

**Ahmed Ahmed Ahmed Elserwy**

B. Sc., of Science (Chemistry), Faculty of Science Ain Shams University, 1993

**A Thesis Submitted in Partial Fulfillment**

**Of**

**The Requirement for Master Degree**

**In**

**Environmental Sciences**

**Departement of Environmental BasicSciences**

**Under The Supervision of:**

**Prof. Mostafa Mohamed Hassan Khalil (Ph.D.)**

Professor of Inorganic Chemistry, Chemistry Dept., Faculty of Science  
AinShams University

**Prof. Dr. / Mohamed Hamdy Mohamed El Awady**

Prof. of Water Pollution Control & Environmental Protection  
National Research Center

**Dr. / Mohamed Aly Ahmed Fergala**

Assistant. Prof of Sanitary &Environmental Engineering, Faculty of Engineering  
Ain Shams University

## Acknowledgment

In the first and lastly, the words cannot express my deepest and greatest thanks to **Allah**, Al-Aziz for helping me in my life and in producing this work. I wish that this work becomes helpful for all students in the environmental science.

I would like to express my great thank to my supervisors Dr. **Mostafa M H ., Khalil** Prof. of Analytical Chemistry, Faculty of Science, Ain Shams University ; Dr. **M 'd Hamdy,M, El Awady** Prof. of Water Pollution Control & Environmental Protection, National Research Center ; and Dr. **Mohamed A A .,Fergala** Ass. Prof of sanitary &Environmental Engineering, Faculty of Engineering, Ain Shams University for suggestion the topic of the present thesis, keen interest, encouragement and continuous help at all stages of this work.

Grateful Acknowledgment is due to the staff members of Environmental Basic Science Department, Institute of Environmental Studies and Research Ain Shams University for useful guidance during the study period.

Last but not the least; I would like to thank my family: my parents for supporting me spiritually throughout my life.

**Ahmed Ahmed Elserwy**

## **Abstract**

In this study, upgrading of ceramic wastewater treatment for reuse was performed using different physical and physico-chemical processes. Additional pre-settling as a physical process was used to partially-treated ceramic wastewater. Coagulation-flocculation as physico-chemical processes by using different coagulants was carried out to treat ceramic wastewater. This wastewater was also treated using polyaluminum chloride as dual coagulant/ flocculent and coagulant aid. Also, ferric chloride was used as coagulant and anionic polyelectrolytes as coagulant aids. The overall enhancement of the treatment process was studied by adding pre-settling stage; then coagulation/-flocculation process was applied using ferric chloride solution; followed by anionic polyelectrolyte. A sand filter unit was added as a tertiary treatment step.

Technical assessment of the performance of the running wastewater treatment process of existing plant was carried out by analyzing TSS, COD and BOD for the raw industrial wastewater to detect the compliance/non of discharging limits onto the city sewerage network. Analyses of the raw wastewater showed that the concentration of suspended solids was as high as 18173 mg/l, indicated that it was exceeding the trigger levels of discharging wastewater on the city sewerage network.

Coagulation/ flocculation and precipitation studies were performed using different coagulants in a conventional Jar-test apparatus. Alum, ferric chloride and polyaluminum chloride were used as coagulants, respectively. A sand filter unit was added as tertiary stage at the end of treatment processes.

Sand filtration after coagulation– flocculation using alum coagulant enhances TSS, COD and BOD<sub>5</sub> % removal to 97.8, 89.7 and 86.6, respectively.

Additional presettling of raw wastewater to coagulation with alum and polymer followed by sand filtration achieved the good removal efficiency for all measured parameters so that the effluent wastewater was comply to be discharged to marine environment additional treatment is required to be reused for unrestricted irrigation, and to be recycled in the factory.

The optimal condition was obtained at the dosage 285 mg/l ferric chloride and polymer followed by sand filtration provide the TSS, COD & BOD removal efficiency of 98.9%,93.7& 90.6, respectively..

The optimal removal efficiency of pollutants from ceramic wastewater was obtained when using presettling then coagulation with ferric chloride and polyacrylamide followed by sand filtration achieved the highest removal efficiency for all parameters, so that the treated wastewater can reused in unrestricted irrigation after chorine addition as disinfectant, and / or to be recycled in the factory.

## **Table of contents**

<b>Acknowledgment:</b>	i
<b>Abstract:</b>	ii
<b>Table of contents:</b>	iv
<b>Abbreviation List:</b>	x
<b>List of Tables:</b>	xi
<b>List of Figures:</b>	xiv

<b><u>Chapter (1) INTRODUCTION</u></b>	1
1.1 BACKGROUND	1
1.2 STUDY OBJECTIVE	4
1.3 SCOPE of WORK	4
1.4 THESIS ORGANIZATION	5
1.4.1 CHAPTER I: INTRODUCTION	5
1.4.2 CHAPTER II: LITERATURE REVIEW	5
1.4.3 CHAPTER III: MATERIAL & METHODS	5
1.4.4 CHAPTER IV: RESULTS	5
1.4.5 CHAPTER IV: DISCUSSION	5
1.4.6 CHAPTER VI: CONCLUSION	6
<b><u>Chapter (2) LITERATURE REVIEW</u></b>	7
2.1 GENERAL DESCRIPTION OF CERAMIC INDUSTRY	7
2.1.1. RAW MATERIAL STORAGE AND HANDLING	8
2.1.2. EFFLUENTS OF CERAMIC INDUSTRY	11
2.1.3. CERAMIC INDUSTRY WASTEWATER	12
2.2. METHOD OF TREATMENT OF INDUSTRIAL WASTEWATER of CERAMIC INDUSTRY	14
2.2.1. PHYSICAL TREATMENT PROCESSES	14
2.2.2. CHEMICAL TREATMENT PROCESSES	16

2.3. ELSHARQ CERAMIC MANUFACTURING FACTORY (CASE STUDY)	19
2.3.1 ELSHARQ CERAMIC WASTEWATER TREATMENT PLANT	22
2.4 INDUSTRIAL WASTEWATER TREATMENT	22
2.5 SELECTIONS OF INDUSTRIAL WASTEWATER TREATMENT PROCESSES	27
2.6 INDUSTRIAL WASTEWATER TREATMENTS	28
2.6.1 COAGULATION and FLOCCULATION	28
2.6.1.1 Coagulation	28
2.6.1.2 Flocculation	34
2.6.1.3 Coagulants and coagulants aids	35
2.6.1.3.1 Aluminum sulphate (Alum)	37
2.6.1.3.2 Ferric chloride ( $\text{FeCl}_3$ )	38
2.6.1.3.3 Polymers	39
2.6.1.3.3.1 Polyacrylamides	40
2.6.1.3.3.2 Polyaluminum Chloride (PAC)	41
2.6.1.3.4 Effect of pH on coagulation	42
2.6.1.3.5 Optimum coagulant dosage	43
2.7 APPLICATION AROUND THE WORLD	44
2.8 APPLICATION in EGYPT	45
<b><u>Chapter (3) MATERIALS &amp; METHODS</u></b>	47
3.1 STUDY PLACE	47
3.2 THE EXISTING PLANT	47
3.3 SUBJECT	48
3.4 SAMPLING STATIONS	49
3.5 COLLECTION AND PREPARATION OF WASTEWATER SAMPLES	50



3.6 DETREMINATION of PHYSICO-CHEMICAL VARIABLES	50
3.7. MATERIAL	50
3.7.1. CHEMICALS	50
3. 7.1.1. Chemicals for COD	50
3. 7.1.2. Chemicals for Jar test	51
3. 7 .2 Instruments and Supplies	51
3.8 METHODS	52
3.8.1 PHYSICO-CHEMICAL CHARACTERISTICS OF CERAMIC RAW WASTEWATER of ELSHARQ CERAMIC PLANT.	52
3.8.2. PHYSICO-CHEMICAL CHARACTERISTICS OF CERAMIC TREATED EFFLUENT OF ELSHARQ WASTEWATER PLANT.	52
3.8.3 EFFECT of SETTLING TIME on THE REMOVAL of TSS	52
3.8.4 EVALUATION OF THE PERFORMANCE of EXISTING INDUSTRIAL WASTEWATER TREATMENT PLANT	53
3.8.4.1 Post Treatment Using Sand Filtration as an Additional Upgrading Step	54
3.8.4.2 Design parameters of proposed rapid sand filter	54
3.8.4.3 Additional Treatment Using Presettling and Sand Filtration as Additional Upgrading Steps	55
3.8.4.4 Design parameters of proposed settling tank	56
3.8.5 TREARTMENT OF CERAMIC INDUSTRIAL WASTEWATER BY COAGULATION /FLOCCULATION USING DIFFERENT COAGULANTS	56
3.8.5.1 Coagulation/Flocculation Using Ferric Chloride and Polymer	56
3.8.5.1.1 Post Treatment Using Sand Filtration as an Additional Upgrading Step	57
3.8.5.1.2 Additional Treatment Using Presettling and Sand Filtration as Additional Upgrading Steps	58
3.8.5.2 Coagulation/Flocculation using Polyaluminum chloride only	59
3.8.5.2.1 Post Treatment Using Sand Filtration as an Additional Upgrading Step	59

3.8.5.2.2 Additional Treatment Using Presettling and Sand Filtration as Additional Upgrading Steps	60
3.8.6 QUALITY ASSESMENT OF THE FINAL TREATED EFFLUENT THAT PRODUCED AFTER PROPOSED ADDITIONAL TREATMENT STEPS	61
3.9 LABORATORY TESTS	61
3.9.1 TOTAL SUSPENDED SOLIDS	61
3.9.2 CHEMICAL OXYGEN DEMAND (COD)	62
3.9.3 BIOCHEMICAL OXYGEN DEMAND (BOD)	63
3.10 STATISTICAL ANALYSIS	63
<b><u>Chapter (4) RESULTS</u></b>	64
4.1CHEMICAL POLLUTANTS	64
4.1.1 EFFLUENTS	64
4.2 RAW WASTEWATER RESULTS	64
4.3 WASTEWATER TREATMENT RESULTS	70
4.4 EFFECT of SETTLING TIME ON THE REMOVAL of TSS	75
4.5 EVALUATION OF THE PERFORMANCE OF THE CERAMAIC INDUSTRIAL WASTEWATER TREATMENT PLANT	78
4.5.1 Post Treatment Stage Using Sand Filtration as an Additional Treatment	82
4.5.2 Additional Treatment Using Presettling and Sand Filtration	85
4.6 TREATMENT of CERAMIC INDUSTRIAL WASTEWATER BY COAGULATION / FLOCCULATION USING DIFFERENT COAGULANTS.	86
4.6.1 TREATMENT of RAW WASTEWATER USING FERRIC CHLORIDE	86
4.6.1.1 Optimum pH	86
4.6.1.2 Effect of ferric chloride	87
4.6.1.3 Treatment of raw wastewater using ferric chloride and polymer	87
4.6.1.4 Post Treatment Stage Using Sand Filtration as an	90

Additional Treatment	
4.6.1.5 Additional Treatment Using Presettling and Sand Filtration	93
4.6.2 TREATMENT USING POLY ALUMINUM CHLORIDE POLYMER.	94
4.6.2.1 Post Treatment Stage Using Sand Filtration as an Additional Treatment	98
4.6.2.2 Additional Treatment Using Presettling and Sand Filtration	101
4.7. COMPARISON OF TREATMENT BETWEEN DIFFERENT COAGULANTS	102
<b><u>Chapter (5) DISCUSSION</u></b>	103
5.1 GENERAL	103
5.2 ANALYSIS OF CERAMIC RAW WASTEWATER	103
5.3 ANALYSIS OF TREATED WASTEWATER RESULTS	103
5.4 ANALYSIS OF SETTEABILITY RESULTS	103
5.5 ANALYSIS OF EVALUATION of PARAMETERS for EXISTING INDUSTRIAL WASTEWATER TREATMENT PLANT	104
5.5.1 ANALYSIS OF TREATMENT WITH ALUM AND POLYACRYLAMIDE POLYMER	104
5.5.2 ANALYSIS OF ADDITIONAL TREATMENT (ALUM COAGULATION + SAND FILTRATION) FOR EXISTING PLANT	105
5.5.3 ANALYSIS OF ADDITIONAL TREATMENT (PRESETTLING +ALUM COAGULATION + SAND FILTRATION)	105
5.6 ANALYSIS OF TREATMENT BY COAGULATION / FLOCCULATION USING DIFFERENT COAGULANTS	106
5.6.1 EFFECT OF USING FERRIC CHLORIDE AND POLYACRYLAMIDE POLYMER	106
5.6.2 EFFECT OF SAND FILTRATION AS ADDITIONAL TREATMENT	106

5.6.3 EFFECT OF PRESETTLING AND SAND FILTRATION AS ADDITIONAL TREATMENT	107
5.6.4 EFFECT OF USING POLYALUMINUM CHLORIDE POLYMER.	107
5.6.5 ANALYSIS OF ADDITIONAL TREATMENT (POLYALUMINUM CHLORIDE COAGULATION + SAND FILTRATION)	107
5.6.6 ANALYSIS OF ADDITIONAL TREATMENT (PRESETTLING + POLYALUMINUM CHLORIDE COAGULATION + SAND FILTRATION)	109
5.7 COMPARISON of TREATMENT BETWEEN DIFFERENT COAGULANTS	110
5.7.1 RESULTS of EACH PARAMETER	110
5.7.1.1 TSS RESULTS	110
5.7.1.2 COD RESULTS	110
5.7.1.3 BOD RESULTS	110
5.8 COST OF TREATMENT	111
5.8.1 CHEMICAL COST OF TREATMENT	111
5.8.2 Cost of Chemicals for Existing Plant	111
5.8.3 Cost of Chemicals Using Ferric Chloride	111
5.8.4 Cost of Chemicals Using Polyaluminium Chloride	111
<b><u>Chapter (6) CONCLUSION &amp; RECOMMENDATIONS</u></b>	115
6.1 CONCLUSION	115
6.2 RECOMMENDATIONS	117
6.3 FURTHER WORK	118
SUMMARY	119
REFERENCES	122
APPENDIX	129

**Arabic Abstract**  
**Arabic Summary**

## Abbreviation List

Abbreviation	Illustration
BC	Before Christ
BOD	Biochemical oxygen demand
°C	Centigrade
COD	Chemical oxygen demand
EC	Electrical conductivity
m <sup>3</sup> /d	Cubic meter per day
m <sup>3</sup> /m <sup>2</sup> /d	Cubic meter per square meter per day
mg/l	Milligram per liter
ml /l	Milliliter per liter
min	Minute
PAC	Polyaluminum chloride
ppm	Part per million
% R	Percentage removal
rpm	Recycle per minute
RWW	Raw wastewater
SS	Suspended solids
TDS	Total dissolved solids
TS	Total solids
TSS	Total suspended solids
uS/cm	Micro siemens Per Centimeter
Z <sub>p</sub>	Zeta potential

## LIST OF TABLES

<b>Table No</b>	<b>Table title</b>	<b>Page</b>
2-1	Ceramic forming raw materials	9
2-2	Typical effluent characteristics of the Egyptian ceramic industry	12
2-3	Effluent level for ceramic tile	14
2-4	Unit processes in industrial wastewater treatment	24
2-5	Unit operations, unit processes and systems used for removal/ reduction important parameters in wastewater	25
2-6	Inorganic chemicals for coagulation in wastewater treatment	36
2-7	Optimum pH values for metallic coagulants	42
4-1	Physico-chemical characteristics of ceramic raw wastewater (Jan 2013)	65
4-2	Physico-chemical characteristics of ceramic raw wastewater (Feb 2013)	66
4-3	Physico-chemical characteristics of ceramic raw wastewater (March 2013)	67
4-4	Physico-chemical characteristics of ceramic raw wastewater and its relations	68
4-5	Physico-chemical characteristics of ceramic treated wastewater (Jan 2013)	71
4-6	Physico-chemical characteristics of ceramic treated wastewater (Feb 2013)	71
4-7	Physico-chemical characteristics of ceramic treated wastewater (March2013)	72
4-8	Chemical characteristics of ceramic treated wastewater	72
4-9	T-test for TSS values	74
4-10	T-test for COD values	74
4-11	T-test for BOD values	75

4-12	Effect of settling time on the removal of TSS	76
4-13	Results of TSS removal % after alum addition	78
4-14	Chemical treatment of raw wastewater using alum and polyacrylamide at the optimum operating condition	80
4-15	Chemical treatment of raw wastewater using alum and polyacrylamide at the	83
4-16	Pollutants removal % after settling then alum and polyacrylamide addition followed by additional treatment using sand filtration	85
4-17	Effect of pH variation on the removal of TSS.	86
4-18	Results of optimum ferric chloride dose for TSS removal	87
4-19	Chemical treatment of raw wastewater using ferric chloride and polyacrylamide at	88
4-20	Chemical treatment of raw wastewater using ferric chloride and polyacrylamide at the optimum operating condition followed by additional treatment using sand filtration.	90
4-21	Pollutants removal % after settling then ferric chloride and Polyacrylamide addition followed by additional treatment using sand filtration	93
4-22	Effect of polyaluminum chloride on TSS.	94
4-23	COD Results after polyaluminum chloride addition	96
4-24	BOD Results after polyaluminum chloride addition.	97
4-25	Chemical treatment of raw wastewater using polyaluminum chloride at the	98