

**A STUDY OF ELECTROCHEMICAL TREATMENT OF
WASTEWATER FROM A SELECTED GOLD MINNING SITE**

AT

ITAGUNMODI, OSUN STATE

KEHINDE ADEDAYOBOLORUNDURO

B.Sc. Civil Engineering (Obafemi Awolowo University, Ile-Ife)

TP13/14/H/1332

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of
Degree of Master of Science (M.Sc.) In Civil Engineering, Obafemi Awolowo
University, Ile-Ife, Nigeria.

2016

AUTHORIZATION TO COPY

OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA

HEZEKIAH OLUWASANMI LIBRARY

POSTGRADUATE THESIS

AUTHOR: Adedayo Kehinde BOLORUNDURO

TITLE: A Study of Electrochemical Treatment of Wastewater from a Selected Gold
Mining Site at Itagunmodi, Osun State

DEGREE; M.Sc. Civil Engineering

YEAR: 2017

I, Adedayo Kehinde BOLORUNDURO hereby authorize the Hezekiah Oluwasanmi Library to copy my thesis in part in response to request from individual researchers or organization for the purpose of private study or research.

.....

Signature

.....

Date

DEDICATION

This research work is dedicated to the memory of my late sister, BolatitoBolorunduro, my parents, Chief and Mrs MorakinyoBolorunduro whose love and integrity prepared me for these challenges of life. To my wife, MrsAdebimpeBolorunduro and my children, Gbolahan and AkindunmadeBolorunduro whose tolerance and perseverance brought me thus far.

OBAFEMI AWOLOWO UNIVERSITY

ACKNOWLEDGEMENTS

Glory, honour and adoration to the Lord Jesus Christ for the opportunity bestowed upon me to be a student of this citadel of learning, for giving me the opportunity to learn under a thorough bred supervisor who spent a lot of time on me, leaving me miles better than he met me. My gratitude goes to my selfless, versatile, magnanimous and supportive supervisor, Dr I.AOke for his effort and concern throughout the years of this academic pursuit. I cannot forget his insistence that his students should take his place in academics.

I appreciate the fatherly and mentorship role played by Dr. H. Mohammed, the head of department, Civil Engineering Department, ObafemiAwolowo University, Ile-Ife. My sincere gratitude also goes to the following: Dr. (Mrs) A.L. Ayodele, Dr A.A. Akindahunsi, Dr. K.T. Oladepo, Dr. K.A. Olonade, Dr. A. B. Fajobi, Mr. J. O. Jeje, Mrs. O. F. Rotimi all of Civil Engineering department, ObafemiAwolowo University, Ile-Ife

I wish to recognise the effort of the following persons, without which the pursuit of these feet may have been impossible. Mr AyodejiBolorunduro, Mr AkintayoBolorunduro, Mr AyodimejiAgboola, Mrs AdejokeAgboola, Mr & Mrs AkinwumiBolorunduro, Dr & Mrs DemolaAluko, Mr BoyeAjayi, Mr SuaraRidwan, Mr MayowaOloso, Miss Jennifer Anyegbo, Mr & Mrs LanreOlomo, Ven. AkintundeFademi, Mr IsrealKayode, Mr Kayode Sunday, Hon Dr. Wale Bolorunduro, Pastor OlumideBolorunduro, Mama Okoro and all members of staff of FobolSolutions.

I want to acknowledge with utmost sense of gratitude, the various parts played by the following persons: Mr S.A. Owolade (Civil Engineering laboratory), Mr E. Akinola (Central Science laboratory), Mrs YemiFadipe, Engr. Abimbola Emmanuel, Mr Jesse Oluwsegun, Mr TayoAdedeji and Mr BayoElufowoju.

Finally, I am grateful to all others too numerous to mention here, thank you and God bless you richly.

OBAFEMI AWOLOWO UNIVERSITY

TABLE OF CONTENTS

	Page
TITLE PAGE	i
CERTIFICATION	ii
AUTHORIZATION TO COPY	iii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS	vii
LIST OF PLATES	xii
LIST OF FIGURES	xiii
LIST OF TABLES	xv
ABSTRACT	xvii
CHAPTER ONE: INTRODUCTION	1
1.1 Background of the Study	1
1.2 Statement of Research Problems	2
1.3 Justification of the Study	2
1.4 Objectives of the Study	3
1.5 Contribution to Knowledge	4
1.6 Scope of the Work	4

CHAPTER TWO: LITERATURE REVIEW	5
2.1 Wastewater	5
2.2 Origin of Wastewater	5
2.3 Characteristics of Wastewater	12
2.3.1 Physical characteristics	12
2.3.2 Chemical characteristics	16
2.3.3 Biological characteristics	25
2.4 Mining and the Environment	27
2.4.1 Definitions	27
2.4.2 Importance of mining	29
2.4.3 History of mining	33
2.4.4 Social and economic impacts of mining	36
2.4.5 Environmental impacts of mining	37
2.5 Occurrence of Wastewater	38
2.6 Wastewater Treatment Processes	40
2.6.1 Physical treatment processes	41
2.6.2: Chemical treatment processes	47
2.6.3: Biological treatment processes	51
2.7 Advanced Wastewater Treatment	51
2.7.1 Electrochemical treatment process	52
2.8 Definition of Terms	53
2.9 Previous Works on Electrochemical Treatment of Wastewater	55

CHAPTER THREE: MATERIALS AND METHODS	70
3.1 Overview	70
3.2 Materials	70
3.3 Methods	71
3.3.1 Collection of wastewater from the gold mining site	71
3.3.2 Calibration of electrolysing equipment	71
3.3.3 Electrochemical treatment of Wastewater	71
3.4 Determination of water quality	79
3.4.1 Chloride determination	79
3.4.2 Zinc Determination	80
3.4.3 Lead determination	80
CHAPTER FOUR: RESULTS AND DISCUSSION	83
4.1 Calibration of Electrolyzing Equipment	83
4.2 Characteristics of the Selected Wastewater	85
4.2.1 Turbidity	85
4.2.2 Chloride	85
4.2.3 Suspended Solids	88
4.2.4 Total Solids	88
4.2.5 pH	89
4.2.6 Zinc	92

4.2.7	Lead	92
4.3	Electrochemical Treatment of the Wastewater	94
4.3.1	Removal of Turbidity from the wastewater	94
4.3.2	Removal of Suspended Solid from the wastewater	94
4.3.3	Removal of Total Solid from the Wastewater	99
4.3.4	Removal of Zinc from the Wastewater	99
4.3.5	Lead removal	99
4.4	Effects of the Selected Factors on the Performance of Electrochemical Treatment	106
4.4.1	Effect of Selected Factors on Turbidity Removal	106
4.4.2	Effect of Selected Factors on Suspended Solids Removal	108
4.4.3	Effect of Selected Factors on Total Solids Removal	108
4.4.3	Effect of Selected Factors on Zinc Removal	111
4.4.3	Effect of Selected Factors on Lead Removal	113
4.4	Optimization of effects of selected factors on wastewater	114
4.4.1	Turbidity removal	114
4.4.2	Suspended solid removal	118
4.3	Total Solid Removal	121
4.4	Zinc Removal	125
4.5	Lead Removal	129

CHAPTER FIVE: ONCLUSION AND RECOMMENDATIONS

5.1 Conclusions 132

5.2 Recommendations 132

REFERENCES 133

LIST OF PLATES

Plates

3.1: Wastewater Pond at the Old Mining Site.	66
3.2: Extraction of Gold from Sludge at the Mining Site	66

LIST OF FIGURES

Figures:

3.1:	Geographical Map of Nigeria showing Osun State.	65
3.2:	Geographical Map of Osun State showing the Study Area	65
3.3:	Schematic diagram showing the setup of the Electrolysing unit	68
3.4:	Laboratory setup of the equipment showing the Electrolysing unit.	68
4.1a:	Relationship between expected and obtained voltages in the calibration of equipment	75
4.1b	Calibration of Electrolysing Unit (current)	75
4.2a;	Effects of Time on percentage Turbidity Removed	100
4.2b;	Effects of Speed on percentage Turbidity Removed	100
4.2c;	Effects of pH on percentage Turbidity Removed	101
4.2d;	Effects of Contact area to volume ratio on percentage Turbidity Removed	101
4.3a;	Effects of time on percentage Suspended Solid Removed	103
4.3b;	Effects of Speed on percentage Suspended Solid Removed	103
4.3c;	Effects of pH on percentage Suspended Solid Removed	104
4.3d;	Effects of Contact area to volume ratio on percentage Suspended Solid Removed	104
4.4a;	Effects of Time on percentage Total Solid Removed	107

4.4b; Effects of Stirring Speed on percentage Total Solid Removed	107
4.4c; Effects of pH on percentage Total Solid Removed	108
4.4d; Effects of Contact area to volume ratio on percentage Total Solid Removed	108
4.5a; Effects of Time on percentage Zinc removed	111
4.5b; Effects of Stirring Speed on percentage Zinc removed	111
4.5c; Effects of pH on percentage Zinc removed	112
4.5d; Effects of Contact area to volume ratio on percentage Zinc removed	112
4.6a; Effects of Time on percentage Lead removed	114
4.6b; Effects of Stirring Speed on percentage Lead removed	114
4.6c; Effects of pH on percentage Lead removed	115
4.6d; Effects of contact area to volume ratio on percentage Lead removed	115

LIST OF TABLES

Tables:

2.1:	Effluent from various sources from which wastewater emanated	7
2.2:	Constituents present in domestic wastewater	8
2.3:	Composition of Industrial wastewaters	12
3.1:	The factors and the levels of the experimental design method for the Electrochemical treatment process of the selected wastewater.	67
4.1a:	Calibration of Electrolysing Unit (Voltage)	75
4.1b:	Calibration of Electrolysing Unit (Current)	75
4.1c:	Analysis of variance (ANOVA) of the calibration of equipment (Voltage)	77
4.1d:	Analysis of variance (ANOVA) of the calibration of equipment (Current)	77
4.2:	Characteristics of the selected wastewater	79
4.3a	Results of Percentage Removal of Turbidity from the Wastewater	83
4.3b	Results of Percentage Removal of Suspended Solids from the Wastewater	86
4.3c	Results of Percentage Removal of Total Solids from the Wastewater	89
4.3d	Results of Percentage Removal of Zinc from the Wastewater	87
4.3e	Results of Percentage Removal of Lead from the Wastewater	89
4.3a:	Analysis of variance of Initial turbidity of the wastewater	73

4.3b:	Analysis of variance (ANOVA) of initial Chloride in the wastewater	73
4.3d:	Analysis of variance of Suspended Solids contained	75
4.3e:	Analysis of variance of Total Solids contained	75
4.3f:	Analysis of variance of pH	77
4.4a:	Orthogonal arrangement of the various factors	79
4.4b:	Performance Evaluation of the Process in Removing Turbidity	80
4.4c:	Effects of the Analysis of Factors on the Treatment Process (Turbidity)	81
4.4d:	Analysis of Variance of Turbidity Removed by the Process	81
4.4e:	Orthogonal arrangement of the various factors	83
4.4f:	Performance Evaluation of the Process in Removing Suspended Solids	84
4.4g:	Effects of the analysis of factors on the treatment process	85
4.3h:	Analysis of Variance of suspended solids removed by the process	85
4.4i:	Orthogonal arrangement of the various factors	87
4.4j:	Performance Evaluation of the Process in Removing Total Solids	88
4.4k:	Effects of the Analysis of Factors on the Treatment Process	89
4.4l:	Analysis of Variance of Total Solids Removed by the Process	89
4.4m:	Performance Evaluation of the Process in Removing Zinc	92
4.4n:	Orthogonal arrangement of the various factors	93
4.4o:	Effects of Analysis of Factors on the Removal of Zinc	94

4.4q: Analysis of Variance of Zinc Removed by the Process	94
4.4q: The Performance Evaluation of the Process in Removing Lead	96
4.4r: Orthogonal arrangement of the various factors	97
4.4s: Effects of Analysis of Factors on the Removal of Lead	98
4.4t: Analysis of Variance of Lead Removed by the Process	98

ABSTRACT

The study investigated the treatment of wastewaters from selected gold mining sites at Itagunmodi in Osun State electrochemically, with a view to developing a system that would remove selected contaminants from wastewaters effectively without losing much of the electrodes.

Wastewater samples were collected twice in a month from four main ponds in October, 2015 (rainy season) and February, 2016 (dry season). The samples were collected twice during the rainy season and twice during the dry seasons making a total of sixteen (16) wastewater samples. The wastewaters collected were characterized (turbidity, solids, chloride, pH, zinc and lead) using standard procedures; the electrolysing equipment was calibrated and the electrodes used were selected based on previous studies; electrochemical treatment of the wastewater at laboratory scales and effects of selected factors (operating time, stirring speed, contact area to volume ratio and pH value) on the performance of the electrochemical treatment were evaluated using orthogonal array factorial experiment (4^4). Performance of the electrochemical treatment of the wastewater was based on the ability to reduce selected parameters. The results of 4^4 orthogonal array factorial experiments were analysed using analysis of variance (ANOVA) to ascertain the effects and identify significant factors. The factors were optimized statistically using methods stated in literature.

The results revealed that there was no significant difference between the outputs (expected and obtained currents; expected voltages and obtained voltages) at 95 % confidence level ($f_{1,10}=4.96$; $p=0.99$, $p > 0.05$ for current and $f_{1,8}=0.00$; $p=0.98$, $p > 0.05$ for voltages). Turbidity of the wastewater samples at the different locations were between 92.51 and 95.42 NTU, pH values ranging between 7.6 and 7.8 and concentration of zinc in the wastewater was between 0.01 and

0.04 mg/l. The treatment showed that the process was capable of removing 20.42 % of the zinc, removed 99.69% of suspended solid and removed 62.02% of lead concentration. The study revealed that pH, operating time, volume to surface area ratio and stirring speed had effects on turbidity removal from the wastewater. The effect of stirring speed was significant ($F = 23.22$) at 95 % confidence level.

The study concluded that the treatment method was able to remove the contaminants in the wastewater (turbidity, solids, pH, zinc and lead) and stirring speed, operating time, pH and surface area to volume ratio are significant factors in removing these pollutants.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

A prerequisite for sustainable development must be to ensure uncontaminated water bodies (streams, rivers, lakes and oceans). There are growing environmental and public concerns about the condition of freshwater in Nigeria especially areas where mining activities take place. It is well known that mining affects fresh water through the heavy use of water in processing ore. It also affects it through water pollution from discharged mine effluent and seepage from tailings and waste rock impoundments. Water bodies are among the most vulnerable water bodies to contamination. It is necessary to prevent and control contamination of these water resources and to have reliable information on the quality of the water (Singh *et al.*, 2005). It has been documented that human activities such as mining operations threaten to the potable water sources on which man, plants and animals depend. Water has been called “mining’s most common casualty because the most pressing environmental problems associated with abandoned hard rock mine sites relate to water pollution.

Adequate drinking water (quality and quantity) is essential for the well-being of man and animal. In many developing countries around the world, drinking water supplies have become contaminated, which has impacted on the health and economic status of most people (Akoto and Adiyah, 2007). There is a growing awareness of the environmental legacy of mining activities with little concern for the environment. Mining activity by its nature consumes, diverts and can seriously pollute water resources. Although there are improvements in mining practices and activities in the recent years, but the issues on environmental risks and pollutions remain. The issues of negative impacts of mining activities can vary from the sedimentation of sludge caused

by poorly built roads during exploration to the sediment of clay in water, and disturbance of water quality during mine construction. Polluted water from mine waste rock and tailings need to be controlled for a longer period after the closure of the site. These impacts of mining activities depend on a variety of factors (nature of the local terrain, mineral composition of the soil at the site, the type of technology in use, the skill acquired and applied, knowledge and environmental commitment of the company, and ability to enforce and compliance with environmental regulations). The major problem is that mining activities have become more mechanized (able to handle more rock and ore material than ever before) and mining waste has multiplied enormously. It has been highlighted that new mining technologies have been developed to make the action more profitable, but these technologies produce newer and more wastes (solid and liquid wastes), which are complex and treatment resistance.

1.2 Statement of Research Problem

Recent reports of lead poisoning from gold mining sites in Nigeria call for urgent solutions, such as its removal from wastewater. The effect of lead on living things have been documented, but its removal from wastewater generated from wet process gold from mining sites are rare, hence this study.

1.3 Justification for the Study

Frequent report of lead poisoning from gold mining sites in Nigeria calls for the urgent removal of lead and other pollutants from wastewater. Lead in water affects man, plant and animals. Effects of lead on man have been documented, but its removals from wastewater generated from gold mining sites (using artisan methods of mining) are rare. In Itagunmodi (Atakunmosa West), surface gold mining operations generate substantial revenue for the Osun

State Government. The surface gold mining activity involves extraction and exploitation of gold as minerals from the ore in the earth's crust by the surface (strip) mining operation. Surface gold mining operations basically involve the clearing of vegetation cover from the area to be mined, stripping off topsoil, creating pit with ramps, waste rock dumps and stockpiles and haul roads. Gold extraction process depends on the ore mineralogy of the area being mined. However, if its activities are not well monitored and proper measures put in place, it will be a major cause of environmental degradation (e.g. loss of farmland, air pollution, water resource contamination, etc.). It is therefore essential to identify the water sources within the gold mining area and determine the actual sources of impact on the water quality in relation to the geochemistry and mining activity. The study seeks to assess and compare the physicochemical qualities of water sources in Itagunmodi and its environs in order to attempt removing the contaminants. Previous researchers attempted to remove these toxic contaminants from wastewater using chemical methods, but the current cost of chemicals and availability of the required chemicals makes the method cumbersome, hence the need to remove these toxic contaminants through electrochemical method.

1.4 Objectives of the Study

The objectives of the research are to

- (a.) determine the quality of wastewater from a selected gold mining site in Itagunmodi in Osun State,
- (b.) subject the collected wastewater to electrochemical treatment using orthogonal array factorial experiment, and