

**ENVIRONMENTAL EFFECTS OF DRILLING ONSHORE  
OIL AND GAS WELLS AND STUDYING THE SITE  
RESTORATION**

**By**

**Khaled Gamal Mohamed Abdel Razeq  
B.SC. Science (Chemistry), Ain Shams University, 1994  
Master in Environmental Sci., Ain Shams University, 2003**

**A Thesis Submitted in Partial Fulfillment  
of  
The Requirement for the Doctor of Philosophy  
In  
Environmental Science**

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

***2013***

**APPROVAL SHEET**

**ENVIRONMENTAL EFFECTS OF DRILLING ONSHORE  
OIL AND GAS WELLS AND STUDYING THE SITE  
RESTORATION**

**By**

**Khaled Gamal Mohamed Abdel Razek**  
**B.SC. Science (Chemistry), Ain Shams University, 1994**  
**Master in Environmental Sci., Ain Shams University, 2003**

**This Thesis Towards a Ph.D. Degree in Environmental  
Science Has Been Approved by:**

<b>Name</b>	<b>Signature</b>
<b>Prof. Dr. Mohamed Gharib El-Malky</b> <i>Emeritus Prof. of Basic Science. Institute of Environmental Studies and Research - Ain Shams University</i>	.....
<b>Prof. Dr. Mahmoud Ahmed Ibrahim Hewehy</b> <i>Prof. of Basic Science. Institute of Environmental Studies and Research - Ain Shams University</i>	.....
<b>Prof. Dr. Mahmoud Sami Yousef</b> <i>Prof. of geology – faculty of science – Ain Shams University</i>	.....
<b>Prof. Dr. Youssef Barakat Youssef</b> <i>Prof. of Petroleum chemistry. - Egyptian Petroleum Research Institute</i>	.....
<b>Prof. Dr. Yaser Mohamed Mahmoud Mostafa</b> <i>Prof. of Petroleum chemistry. - Egyptian Petroleum Research Institute</i>	.....

**2013**

**ENVIRONMENTAL EFFECTS OF DRILLING ONSHORE  
OIL AND GAS WELLS AND STUDYING THE SITE  
RESTORATION**

**By**

**Khaled Gamal Mohamed Abdel Razeq**

**B.SC. Science (Chemistry), Ain Shams University, 1994**

**Master in Environmental Sci., Ain Shams University, 2003**

**A Thesis Submitted in Partial Fulfillment of  
the Requirement for the Doctor of Philosophy  
In  
Environmental Science**

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

**Under The Supervision of:**

**Prof. Dr. Mohamed Gharib El-Malky**

*Emeritus Prof. of Basic Sciences Department Institute of Environmental  
Studies and Research - Ain Shams University*

**Prof. Dr. Mahmoud Ahmed Ibrahim Hewehy**

*Prof. of Basic Sciences Department Institute of Environmental Studies and  
Research - Ain Shams University*

**Prof. Dr. Youssef Barakat Youssef**

*Emeritus Prof. of Petroleum Chemistry - Egyptian Petroleum Research  
Institute.*

**2013**

# ACKNOWLEDGEMENTS

*Thanks forever for ALLAH who allowed and helped me to accomplish this work,*

*I would like to express my profound gratitude and appreciation to Professor Dr. Mohamed Gharib El-Malky for his meticulous supervision, suggestions, and valuable discussions. I appreciate his 'supporting student' attitude, and hope to carry it along.*

*My grateful Thanks to Professor Dr. Mahimoud El Hewehy, for his keen interest, guidance and patience.*

*I would like also to express my deepest indebted and grateful thanks to Professor Dr. Youssef Barakat for his kind, sincere and valuable co-supervision of this work,*

## ABSTRACT

The environmental effects of wastes (drilling muds & cuttings) generated from the drilling of onshore oil wells in southern western desert, were studied through analyses of different salts, total hydrocarbons and heavy metals. The aim was to determine their possible impacts on their environments due to disposal of these wastes.

These drilled wastes generated from the drilling of onshore wells indicated the presence of considerable amounts of salts and relatively low concentrations of leached petroleum hydrocarbons and heavy metals. The highest concentration of chlorides and sulphates were recorded in the cutting samples which reached 31.5 and 4.2 mg/g respectively..

Total and leachable hydrocarbon concentrations (after 5 and 10 days) , were determined indicating that the highest value were 21.9  $\mu\text{g/g}$  and (5.88 and 31.19 $\mu\text{g/l}$ ), respectively. Contrarily, the lowest values were 8.6  $\mu\text{g/g}$  and (0.91 and 1.30 $\mu\text{g/l}$ ), respectively.

Seven heavy metal compounds: Ni, Ba, Cd, Cr, Pb, Ag and Zn were detected in five samples of drilling cutting wastes were collected from five active exploratory wells. Barium, Chromium, Zinc and Nickel were the abundant metals, while Cadmium was the least metal in the investigated cutting sediments of the different sites. Barium was detected in all leachable heavy metals with base water after 5 and 10 days with a concentration range from 2.6 to 7.8 $\mu\text{g/g}$ . Silver (Ag) values were below the detectable levels except at only one station. Values of the other metals varied significantly from one station to another.

The solid wastes (drilling muds & cuttings) if properly managed can serve as raw materials for cement producing plants, bricks and expanded clay producing plants and can also be used in land restoration projects. Disposal of cuttings and drilling wastes into the onshore environment should be totally discouraged and litigated.

<b>LIST OF TABLES .....</b>	<b>V</b>
<b>LIST OF FIGURES .....</b>	<b>VI</b>
<b>LIST OF ABBREVIATION.....</b>	<b>IX</b>
<b>CHAPTER 1 .....</b>	<b>1</b>
<b>INTRODUCTION.....</b>	<b>1</b>
AIM OF STUDY .....	1
HISTORY OF OIL DRILLING IN EGYPT .....	1
CURRENT AND FUTURE ACTIVITIES OF OIL DRILLING IN EGYPT .....	2
DRILLING WASTES AND ITS EFFECTS .....	4
SITE RESTORATION .....	6
<b>CHAPTER 2 .....</b>	<b>7</b>
<b>REVIEW OF LITERATURE .....</b>	<b>7</b>
2.1 OBJECTIVE OF DRILLING OIL WELLS .....	7
2.2 ROLE OF DRILLING MUD FLUIDS.....	8
2.3 CHEMICAL COMPOSITION OF MUD.....	10
2.3.1 Water – Base Mud.....	16
Classification of Water – Based Drilling Fluids: .....	17
Weighting Materials.....	19
2.3.2 Oil Base Mud .....	20
2.4 CHEMICAL COMPONENTS OF DRILL CUTTINGS .....	22
2.5 QUANTITIES OF MUD WASTES GENERATED FROM DRILLING OPERATIONS .....	23
2.6 MUD POLLUTANTS .....	26
2.6.1. HEAVY METALS .....	26
2.6.2. SALTS IN MUD.....	29

2.6.3. HYDROCARBONS IN MUD .....	30
2.7 ENVIRONMENTAL CONSIDERATIONS AND WASTE MANAGEMENT.....	30
2.8 OVERVIEW OF MUD/CUTTINGS WASTES TREATMENT.....	33
2.8.1 Dewatering.....	34
2.8.2 Thermal Desorption.....	35
2.8.3 Solidification/Stabilization.....	37
2.9 DRILL SITE RESTORATION.....	39
2.9.1 Land Application.....	43
2.9.2 Burial .....	48
2.10 REGULATIONS RELATED TO DRILLING OPERATIONS IN EGYPT AND WORLDWIDE .....	50
<b>CHAPTER 3 .....</b>	<b>59</b>
<b>MATERIALS AND METHODS .....</b>	<b>59</b>
3.1. STUDY AREAS .....	59
3.2. MATERIALS AND SAMPLING.....	61
3.3. WATER BASED ANALYSIS .....	64
3.4. DRILL CUTTING ANALYSIS .....	66
3.4.1 Concentrations Determination of Some Salts In Cutting Samples	67
3.4.1.1 Soluble Chloride and Sulfate Methodology .....	67
3.4.2. Heat Treatment of Cuttings.....	68
3.4.2.1- Moisture.....	68
3.4.2.2. Total Organic Carbon.....	68
3.4.3. Heavy Metals .....	69
3.4.3.1. Leachable Heavy Metals.....	69
3.4.3.2. Complete Digested Heavy Metals .....	69
3.4.4. Hydrocarbons .....	70

3.4.4.1. Leachable Hydrocarbon .....	70
3.4.4.2. Total Hydrocarbon.....	72
3.4.5. Mechanical Analysis .....	72
3.5. STATISTICAL ANALYSIS .....	73
<b>CHAPTER 4 .....</b>	<b>74</b>
<b>RESULTS .....</b>	<b>74</b>
4.1 ANALYSIS OF WATER BASE MUD: .....	75
4.1.1. Physical and Chemical Properties of Water Base Mud Used for Leachable Heavy Metals And Hydrocarbon.....	75
4.2. DRILL CUTTINGS .....	76
4.2.1. Concentrations of Some Salts in Studied Cuttings: .....	76
4.2.2. Heat Treatment of Cuttings.....	79
4.2.2.1. Recorded Level of Moisture .....	79
4.2.2.2. Recorded Level of Organic Matter .....	79
4.2.3. Mechanical Analysis .....	82
4.2.3.1. Distribution of Gravel, Sand and Mud: .....	82
4.2.3.2. Structure of Grain in Cuttings .....	86
4.2.4. Heavy Metals .....	90
4.2.4.1. Recorded Level of Complete Digested Heavy Metals:.....	90
4.2.4.2. Leachable Heavy Metals.....	91
4.2.5 Hydrocarbons .....	110
4.3. Statistical Analysis .....	114
<b>CHAPTER 5 .....</b>	<b>117</b>
<b>DISCUSSION .....</b>	<b>117</b>
5.1 HEAVY METALS .....	117



## *List of Contents*

---

5.2 HYDROCARBONS .....	121
5.3 SALTS.....	121
5.4 QUANTITIES OF DRILLING WASTES .....	122
5.5 REGULATIONS .....	123
5.6 DRILL SITE RESTORATION.....	124
5.6.1 WASTE PITS .....	124
5.6.2 WASTE MANAGEMENT.....	127
<i>Pitless or Closed Loop Drilling</i> .....	130
SOLIDIFICATION OF DRILLING WASTES.....	131
BURIAL .....	132
5.6.3 SITE RESTORATION CASE STUDIES.....	134
CASE STUDY NO.1: RESTORATION OF WELL SITE DRILLED IN RECLAIMED LAND .....	135
CASE STUDY NO.2: RESTORATION OF WELL SITE DRILLED IN DESERT AREA .....	140
<b>CHAPTER 6.....</b>	<b>145</b>
<b>SUMMARY AND CONCLUSION .....</b>	<b>145</b>
SUMMARY .....	145
CONCLUSION.....	148
<b>REFERENCES.....</b>	<b>150</b>
<b>الملخص العربي.....</b>	<b>1</b>
<b>المستخلص.....</b>	<b>1</b>

## **List of Tables**

TABLE 3-1: SAMPLES LOCATION.....	61
TABLE 4-1: PHYSICAL AND CHEMICAL PROPERTIES OF THE WATER BASED USED FOR LEACHABLE HEAVY METALS AND HYDROCARBON .....	76
TABLE 4-2: CHLORIDE AND SULFATE CONCENTRATION AT THE CUTTING SEDIMENT OF THE STUDIED SITES .....	77
TABLE 4-3: THE PERCENTAGE OF GRAVEL, SAND AND MUD IN THE SAMPLES	83
TABLE 4-4: TOTAL AND LEACHABLE NICKEL (Ni) .....	92
TABLE 4-5: TOTAL AND LEACHABLE SILVER (Ag).....	94
TABLE 4-6: TOTAL AND LEACHABLE ZINC (Zn).....	97
TABLE 4-7: TOTAL AND LEACHABLE LEAD (Pb) .....	99
TABLE 4-8: TOTAL AND LEACHABLE CHROMIUM (Cr) .....	103
TABLE 4-9: TOTAL AND LEACHABLE BARIUM (Ba) .....	106
TABLE 4-10: TOTAL AND LEACHABLE CADMIUM (Cd) .....	110
TABLE 4-11: TOTAL HYDROCARBON LEVEL ( $\mu\text{g/g}$ ) AT THE CUTTINGS OF THE SELECTED CUTTINGS .....	112
TABLE 4-12: LEACHABLE HYDROCARBON LEVEL ( $\mu\text{g/L}$ ) AT THE CUTTINGS OF THE SELECTED CUTTINGS AFTER 5 AND 10 DAYS .....	113
TABLE 4-13: CORRELATION COEFFICIENT BETWEEN SOME PHYSICO-CHEMICAL VARIABLES AND HEAVY METALS, HYDROCARBON OF THE STUDIED CUTTING SEDIMENTS .....	115

## **List of Figures**

FIGURE 3-1: PHOTO (1)"DRILLING WASTES" .....	62
FIGURE 3-2: PHOTO (2) )"DRILLING WASTES" .....	63
FIGURE 3-3: PHOTO (3)"DRILLING WASTES" .....	63
FIGURE 3-4: PHOTO (4)" DRILLING WASTES" .....	64
FIGURE 4-1: COCENTRATION OF CHLORIDE IN CUTTINGS SAMPLES .....	78
FIGURE 4-2: COCENTRATION OF SULFATE IN CUTTINGS SAMPLES .....	78
FIGURE 4-3: VARIATION OF MOISTURE, ORGANIC MATTER AND ASH CONTENT OF S1 .....	80
FIGURE 4-4: VARIATION OF MOISTURE, ORGANIC MATTER AND ASH CONTENT OF S2 .....	80
FIGURE 4-5: VARIATION OF MOISTURE, ORGANIC MATTER AND ASH CONTENT OF S3 .....	81
FIGURE 4-6: VARIATION OF MOISTURE, ORGANIC MATTER AND ASH CONTENT OF S4 .....	81
FIGURE 4-7: VARIATION OF MOISTURE, ORGANIC MATTER AND ASH CONTENT OF S5 .....	82
FIGURE 4-8: DISTRIBUTION OF GRAVEL, SAND AND MUD IN S1 .....	83
FIGURE 4-9: DISTRIBUTION OF GRAVEL, SAND AND MUD IN S2 .....	84
FIGURE 4-10: DISTRIBUTION OF GRAVEL, SAND AND MUD IN S3 .....	84
FIGURE 4-11: DISTRIBUTION OF GRAVEL, SAND AND MUD IN S4 .....	85
FIGURE 4-12: DISTRIBUTION OF GRAVEL, SAND AND MUD IN S5 .....	85
FIGURE 4-13: GRAIN SIZE DISTRIBUTION OF CUTTINGS AT STUDIED SITES .....	86
FIGURE 4-14: GRAIN SIZE DISTRIBUTION OF CUTTINGS AT STATION-2 .....	87
FIGURE 4-15: GRAIN SIZE DISTRIBUTION OF CUTTINGS AT STATION-3 .....	88
FIGURE 4-16: GRAIN SIZE DISTRIBUTION OF CUTTINGS AT STATION-4 .....	89
FIGURE 4-17: GRAIN SIZE DISTRIBUTION OF CUTTINGS AT STATION-5 .....	90

## *List of Figures*

---

FIGURE 4-18: TOTAL CONCENTRATION OF NICKEL IN CUTTINGS SAMPLES .....	93
FIGURE 4-19: CONCENTRATION OF LEACHABLE NICKEL (Ni) WITH DISTILLED WATER / 0.1N HCL AFTER 10 DAYS.....	93
FIGURE 4-20: LEACHABLE NICKEL (Ni) LEVEL IN THE CUTTINGS SAMPLES AFTER 5 AND 10 DAYS, USING WATER BASE .....	94
FIGURE 4-21: TOTAL CONCENTRATION OF SILVER IN CUTTINGS SAMPLES .....	95
FIGURE 4-22: CONCENTRATION OF LEACHABLE SILVER (Ag) WITH DISTILLED WATER / 0.1N HCL AFTER 10 DAYS.....	96
FIGURE 4-23: LEACHABLE SILVER (Ag) LEVEL IN THE CUTTINGS SAMPLES AFTER 5 AND 10 DAYS, USING WATER BASE.....	96
FIGURE 4-24: TOTAL CONCENTRATION OF ZINC IN CUTTINGS SAMPLES .....	98
FIGURE 4-25: CONCENTRATION OF LEACHABLE ZINC (Zn) WITH DISTILLED WATER / 0.1N HCL AFTER 10 DAYS.....	98
FIGURE 4-26: LEACHABLE ZINC (Zn) LEVEL IN THE CUTTINGS SAMPLES AFTER 5 AND 10 DAYS, USING WATER BASE .....	99
FIGURE 4-27: TOTAL CONCENTRATION OF LEAD (Pb) IN CUTTINGS SAMPLES ...	100
FIGURE 4-28: CONCENTRATION OF LEACHABLE LEAD (Pb) WITH DISTILLED WATER / 0.1N HCL AFTER 10 DAYS .....	101
FIGURE 4-29: LEACHABLE LEAD (Pb) LEVEL IN THE CUTTINGS SAMPLES AFTER 5 AND 10 DAYS, USING WATER BASE .....	102
FIGURE 4-30: TOTAL CONCENTRATION OF CHROMIUM (Cr) IN CUTTINGS SAMPLES .....	104
FIGURE 4-31: CONCENTRATION OF LEACHABLE CHROMIUM (Cr) WITH DISTILLED WATER / 0.1N HCL AFTER 10 DAYS.....	104
FIGURE 4-32: LEACHABLE CHROMIUM (Cr) LEVEL IN THE CUTTINGS SAMPLES AFTER 5 AND 10 DAYS, USING WATER BASE .....	105
FIGURE 4-33: TOTAL CONCENTRATION OF BARIUM (Ba) IN CUTTINGS SAMPLES .....	107

---

## *List of Figures*

---

FIGURE 4-34: CONCENTRATION OF LEACHABLE BARIUM (BA) WITH DISTILLED WATER / 0.1N HCL AFTER 10 DAYS.....	108
FIGURE 4-35: LEACHABLE BARIUM (BA) LEVEL IN THE CUTTINGS SAMPLES AFTER 5 AND 10 DAYS, USING WATER BASE .....	109
FIGURE 4-36: TOTAL HYDROCARBON LEVEL ( $\mu\text{G/G}$ ) IN THE CUTTINGS SAMPLES .....	112
FIGURE 4-37: LEACHABLE HYDROCARBON CONCENTRATION IN THE CUTTINGS OF SELECTED SITES AFTER 5 AND 10 DAYS .....	113
FIGURE 5-1: PHOTO SHOWS "OVERVIEW OF RESTORED WELL SITE LOCATION" .....	137
FIGURE 5-2: PHOTO SHOWS "RESTORED WELL SITE LOCATION AND THE LAND TENANT" .....	138
FIGURE 5-3: PHOTO SHOWS "REINFORCED ACCESS ROAD BY USING DRIED CUTTINGS" .....	139
FIGURE 5-4: PHOTO SHOWS "FROM LEFT, THE LAND TENANT, ENVIRONMENTAL SPECIALIST, REPRESENTATIVE OF LAND RECLAMATION AUTHORITY AND REPRESENTATIVE OF OIL COMPANY" .....	140
FIGURE 5-5: PHOTO SHOWS "ENVIRONMENTAL SPECIALIST AND REPRESENTATIVE OF OIL COMPANY" .....	142
FIGURE 5-6: PHOTO SHOWS "DRIED CUTTINGS CAN BE USED FOR ROADS IMPROVED OR BACKFILLED AGAIN INTO PIT " .....	143
FIGURE 5-7: PHOTO SHOWS "REINFORCED ACCESS ROAD BY USING DRIED CUTTINGS" .....	144

## **List of Abbreviation**

APHA	American Public Health Association
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
E&P	Exploration and Production
EC	Electrical Conductivity
EGPC	Egyptian General Petroleum Corporation
EIA	Energy Information Administration
EPI	Environmental Performance Indicators
EPA	Environmental Protection Agency
EPI	Environmental Performance Indicators
GOS	Gulf of Suez
IWMP	Integrated Waste Management Plan
OBM	Oil Base Mud
Offshore	Marine Activities
OGP	Oil & Gas Producers
Onshore	Activities on Land
PAHs	Polycyclic Aromatic Hydrocarbons
PCA	Principal Correspondence Analysis
RCRA	Resource Conservation and Recovery Act

*List of Abbreviation*

---

S/S	Solidification/Stabilization
SAR	Sodium Adsorption Ratio
SPIGEC	Saskatchewan Petroleum Industry Government Environment Committee
TDU	Thermal Desorption Units
TFM	Total Fluid Management
TPH	Total Petroleum Hydrocarbon
USEPA	United States Environmental Protection Agency
USCOTA	U.S. Congress Office of Technology Assessment
W.D.	Western Desert
WBM	Water Base Mud
CPCB	Central Pollution Control Board