

## Ain Shams University Faculty of Science

# Influence of feed groundwater characteristics on the mass transfer; its applications in the area between El-Negeila and Baqbaq - Northwestern coast - Egypt

#### A Thesis Submitted by

Aya Ahmed Saleh Gallab (B.Sc., Special Chemistry 2011)

For the Partial Fulfillment of the Requirements of the Master's Degree in Science (Analytical Chemistry)

to
Department of Chemistry
Faculty of Science
Ain Shams University

(2017)



### Ain Shams University Faculty of Science

# Influence of feed groundwater characteristics on the mass transfer; its applications in the area between El-Negeila and Baqbaq - Northwestern coast - Egypt

A Thesis Submitted

For the Partial Fulfillment of the Requirements of the Master's Degree in Science (Analytical Chemistry)

by
Aya Ahmed Saleh Gallab
B.Sc. (Special Chemistry, 2011)
Desert Research Center

Supervised By

Prof. Dr. Mohamed Sabry Abdel-Mottaleb

Prof. of Inorganic Chemistry
Faculty of science
Ain Shams University

Prof. Dr. Hosam Ahmed Shawky

Prof. of Water chemistry Desert Research Center

Late. Dr. Adel Abdel-Aleem Hasan

Researcher at the hydro geo-chemistry department Desert Research Center

2017



#### **Approval Sheet for Submission**

# Influence of feed groundwater characteristics on the mass transfer; its applications in the area between El-Negeila and Baqbaq - Northwestern coast – Egypt

A thesis submitted

For the Partial Fulfillment of the Requirements of the Master's Degree in Science (Analytical Chemistry)

by:

#### **Aya Ahmed Saleh Gallab**

(B.Sc., Special Chemistry, 2011)

This thesis has been approved by supervisor con	nmittee:
Prof. Dr. Mohamed Sabry Abdel-Mottaleb	•••••
Prof. of Inorganic & Photo-Chemistry	
Faculty of Science-Ain Shams University	
Prof. Dr. Hosam Ahmed Shawky	•••••
Prof. of Water Chemistry-Desert Research Center	
Late. Dr. Adel Abdel-Aleem Hasan	• • • • • • • • • • • • • • • • • • • •
Researcher at Hydrogeochemistry DepDesert Research C	Center
This thesis for M.Sc. degree has been approved	by:
Prof. Dr. Mohamed Sabry Abdel-Mottaleb	•••••
Prof. Dr. Hosam Ahmed Shawky	•••••
Prof. Dr. Mohamed Mohsen Badr El-Sabah	•••••
Prof. Dr. Alaa El-Sayed Amin	•••••
DATE OF EXAMINATION: / /2017	

Prof. Dr. Ibrahim Husseiny Badr

Head of Chemistry Department



جامعة عين شمس الكلية: العلوم

العنوان: تأثير خواص المياه الجوفية المستخدمة في عملية التحلية بتقنية التناضح العكسي على معدل حركة الأملاح وتطبيقاتها في المنطقة ما بين النجيلة وبقبق – الساحل الشمالي الغربي – مصر

اسم الطالب: آية أحمد صالح

الدرجة العلمية: ماجستير في العلوم

القسم التابع له: الكيمياء التحليلية

اسم الكلية: العلوم

الجامعة: عين شمس

سنة التخرج: ٢٠١١

سنة المنح: ٢٠١٧



كلية العلوم جامعة عين شمس

عنوان الرسالة:

تأثير خواص المياه الجوفية المستخدمة في عملية التحلية بتقنية التناضح العكسي على معدل حركة الأملاح وتطبيقاتها في المنطقة ما بين النجيلة وبقبق – الساحل الشمالي الغربي – مصر

رسالة مقدمة للحصول على درجة الماجستير في العلوم كجزء مكمل لمتطلبات رسالة الماجستير كلية العلوم- جامعة عين شمس في تخصص الكيمياء التحليلية

مقدمة من الطالبة: آية أحمد صالح جلاب (بكالوريوس علوم-كيمياء خاص-٢٠١١)

### تحت إشراف:

**ا.د.حسام أحمد شوقي** أستاذ كيمياء وتحلية المياه بمركز بحوث الصحراء ا.د. محمد صبري عبد المطلب أستاذ الكيمياء غير العضوية والضوئية المتفرغ بكلية العلوم جامعة عين شمس

المرحوم. د. عادل عبدالعليم حسن باحث بمركز بحوث الصحراء

2017



### كلية العلوم رسالة ماجستير في العلوم

اسم الطالبة : آية أحمد صالح جلاب عنوان الرسالة :

تأثير خواص المياه الجوفية المستخدمة في عملية التحلية بتقنية التناضح العكسى على معدل حركة الأملاح وتطبيقاتها في المنطقة مّا بين النجيلة وبقبق - الساحلّ الشماليّ الغربي - مصر

الدرجة العلمية: ماجستير في العلوم- تخصص الكيمياء التحليلية

لجنة الاشراف: أد/محمد صبرى عبد المطلب: أستاذ الكيمياء غير العضوية والضوئية المتفرغ - كلية العلوم-جامعة عين شمس

أ.د./ حسام أحمد شوقى: أستاذ كيمياء المياه ـ مركز بحوث الصحراء

المرحوم د./ عادل عبد العليم حسن: باحث بقسم الهيدروجيوكيمياء- مركز بحوث الصحراء

لجنة الحكم اد./محمد صبرى عبد المطلب أستاذ الكيمياء غير العضوية والضوئية المتفرغ بكلية العلوم جامعة عين شمس

ا.د./ حسام احمد شوقى

أستاذ كيمياء المياه بمركز بحوث الصحراء

ا.د./ محمد محسن بدر الصباح أستاذ الكيمياء الفيزيائية بكلية العلوم ( بنين) جامعة الازهر

ا.د./ علاء السيد أمين

أستاذ الكيمياء التحليلية بكلية العلوم جامعة بنها

#### الدر اسات العلبا

أجيزت الرسالة بتاريخ

تساريخ السبحث Y.14/ ختم الإجازة

موافقة مجلس الجامعة Y. 1 /

موافقة مجلس الكلية Y.1V / /

### Acknowledgment

The author wishes to express her deepest thanks to the Chemistry Department, Faculty of Science, Ain Shams University for giving a chance to do graduate research.

Many thanks are due to *Prof. Dr. Mohamed Sabry Abdel-Mottaleb*, Prof. of Inorganic Chemistry, Faculty of Science, Ain Shams University, for his kind help, patience and facilitating carrying out this work and for letting me finish this work under his wise supervision.

My special thanks are due to the *Prof. Dr. Hosam Ahmed Shawky*, Prof. of Water Chemistry, Hydrogeochemistry department, Desert Research Center, for planning, suggestions and supervising this work, for effective guidance and fruitful discussions his helps to initiate and achieve this work. I could not have imagined having a better advisor and mentor for my MSc. Study.

I'm grateful to Late. Dr. Adel Abdel-Aleem Hasan, my supervisor who passed away before I finish the experimental part, for his guidance and superior help in collecting the important relevant research papers.

And *Dr. Mohamed El-sayed Abdelfattah*, Researcher at the Hydrogeochemistry department for helping in revising my research papers and this thesis, guidance, massive help, cooperation and wise directions.

I also wish to thank all staff members and friends at the hydrogeochemistry department and in the Desert Research Center central labs for their support and help.

Finally, I wish to express my deep thanks, gratitude and appreciation to my father, mother, sisters and husband whose dedicated help, patience and continuous encouragement are greatly acknowledged.

It is a pleasure to acknowledge the financial support provided by the Science and Technological Development Fund (STDF) in Egypt through Grant 5240 (Egyptian Desalination Research Center of Excellence, EDRC).

Subject	page
Contents	i
List of Figures	viii
List of Tables	XI
Appendix	XIV
English Abstract	a
Chapter 1. Introduction	
1.General outlines	1
1.1.Problem definition	1
1.1.1. Location of the study area	3
I.1.2. Climatic conditions	5
1.1.3. Main problem in the area	5
I.2. Water desalination	5
I.2.1. Reverse osmosis	6
1.2.2. Theory of Mass Transfer	11
1. Introduction	11
2. Estimation of mass transfer	13
1.3. Scope of the present work	15
Laboratory work	16
Office work	17
Thesis frame-work	17
Chapter 2. Review of literature	
2.1. The main objective of the thesis	18
2.2. Previous studies on the area of investigation	19
2.3.Previous work investigated the source of mineralization in the ground water	21
2.4. Review of desalination, reverse osmosis (RO) technique and the problems facing the membrane	21
2.4.1.Review on the desalination technique	21
2.4.2.Review of RO membranes	23

2.4.3.Review of the evolution of TFC RO membranes	24
2.4.4.Review on the applications of the RO membranes	26
2.5. Review on the problems facing the RO membranes. (fouling)	29
2.6. Review on the Mass Transfer and transport properties of RO membranes	29
Chapter 3. Materials and Methods	
3.1. General outline	32
3.2. Field Work	32
3.3. Laboratory work	32
3.3.1 Chemical analyses of collected water samples.	34
3.3.2. Reverse osmosis measurements	34
1. Determination of the pure water permeability (A)	34
2. Determination of Salt rejection and water flux	35
3. RO experiments on artificial feed water	35
4. RO experiments on ground feed water	35
3.3.3. Detecting the degree of membrane deterioration	37
3.4. Office work	37
3.4.1. Groundwater data processing	37
3.4.2. Applying the Graphical method.	38
Chapter 4. Aquifer system and groundwater chemistry	
4.1. Aquifer system	39
4.1.1.General Outlines.	39
٤.1.2. Climatic conditions.	39
٤.1.3. Geomorphology	40
1. Coastal plain.	40
1.1. Foreshore sand dunes.	41
1.2. Coastal ridges.	42
1.3. Coastal depressions.	42
2. Piedmont Plain.	43
3. Hydrographic Basins.	43
4.1.4. Geology	43
1. Lithostratigraphy	44
1.1. Tertiary deposits.	45
1.2. Quaternary deposits	45
1.2.1. Pleistocene sediments	45

1.2.2. Holocene deposits.	45
2. Geological Structure.	47
3. Geological History.	47
3.1. Middle Miocene.	47
3.2. Pleistocene – Holocene (Recent).	47
4.1.5. Hydrogeological conditions.	48
1. Pleistocene limestone aquifer (Pleistocene age).	48
2. Alluvium aquifer (Holocene age).	48
3. M. Miocene limestone aquifer (Middle Miocene age).	52
4.2. Groundwater chemistry	53
4.2.1. Chemical Parameters	54
1. Groundwater salinity	55
2. Groundwater chemical type	59
3. Ions distribution	60
3.1.Distribution of calcium and magnesium	61
3.2.Distribution of sodium plus potassium	63
3.3.Distribution of carbonate and bicarbonate	63
3.4. Distribution of sulphate	64
3.5. Distribution of chloride	65
4. The hydrochemical coefficients (Ion ratios)	66
4.1. r Na <sup>+</sup> /r Cl <sup>-</sup>	67
4.2. r SO <sub>4</sub> <sup>2-</sup> /r Cl	68
4.3. $rCa^{2+}/rMg^{2+}$	68
5. Hypothetical salts assemblages	69
6. Geochemical classification of groundwater	72
6.1. Piper's tri-linear diagrams	72
6.2. Semi-logarithmic diagram	74
4.2.2.The hydro geochemical processes	75
1. Carbonate weathering	75
2. Silicate weathering	77
3. Leaching and dissolution processes	80
3.1.Multible ionic ratios	81
4. Ion exchange:	84
5. Oxidation/reduction processes	85
Chapter 5. Evaluation of Groundwater	

5.1.General outlines	86
5.2. Evaluation of groundwater quality for human drinking, laundry and	86
domestic purposes	
5.2.1. Evaluation of groundwater quality for human drinking	87
1.Salinity	87
2.Iron	88
3.Manganese	89
4.Strontium	89
5.Phosphorous	90
6. Cadmium, Copper and Lead	90
7. Silica	90
5.2.2. Evaluation of groundwater quality for drinking of livestock and poultry	91
5.2.3. Evaluation of groundwater for domestic and laundry uses	92
5.2.4. Evaluation of groundwater for Irrigation of different crops	94
1. U.S. Laboratory classification of irrigation water (Richards, 1954)	94
2. Evaluation for irrigation according to the Boron contents (B <sup>3+</sup> )	98
5.2.3. Evaluation of groundwater quality for the best sites of desalination plants	100
Chapter 6. Mass Transfer in RO desalination	
6.1. Background	104
6.2. Mass transfer and fouling detection using artificial feed water.	105
6.2.1. Determination of pure water permeability (PWP)	105
6.2.2. Membrane performance.	106
6.2.3. Estimation of mass transfer coefficient	109
6.2.4. Effect of applied pressure( $\Delta P$ ) and feed concentration on the mass transfer coefficient and the fouling indication	110
6.2.5. Estimation of membrane deterioration.	114
6.3. Mass transfer and fouling detection using ground feed water	119
6.3.1. Membrane selectivity	119
6.3.2. Mass transfer coefficient in case of groundwater desalination	123

6.3.3. Effect of $\Delta P$ & Feed concentration in case of desalination of ground feed water	124
6.3.4.Estimation of the degree of membrane deterioration	127
Chapter 7 Application of thin film composite membranes in ground & seawater desalination in the study area	
7.1. General Outline	132
7.2. TDS and Ions rejection	133
7.3. Evaluation of the desalted water for drinking	138
SUMMARY AND RECOMMENDATIONS	140
References	150
Arabic summery	j

Title	Page
Chapter I. Introduction	
Fig. (1.1): Water scarcity in the world, according to (UN-DESA, 2007).	2
Fig. (1.2): Population distribution in Egypt.	2
Fig.(1.3) Location map of the study area.	4
Fig.(1.4): Comparison between membrane filtration technologies.	6
Fig.(1.5) Normal and Reverse Osmosis.	7
Fig.(1.6): Interfacial polymerization reaction of meta phenylene di amine and 1,3,5-trimesoyl chloride.	8
Fig.(1.7):Schematic diagram illustrating the Concentration polarization layer.	10
Chapter 3. Materials & Methods	
Fig. (3.1): Photographs showing groundwater sampling from the study area by the author.	33
Fig.(3.2): Schematic diagram of the three cross-flow units system.	36
Fig.(3.3): photograph of the EDRC RO cross-flow lab unit.	36
Chapter 4. Aquifer system and groundwater chemistry	
Fig.(4.1): Geomorphological map of the study area after Mousa (1976).	41
Fig.( 4.2): Geologic map of the study area showing the wells location (after Atwa,1979).	44
Fig.(4.3): Lithostratigraphic column of different aquifers in the study area.	46
Fig.(4.4): the outcrop of the alluvial deposit represented by sample no. 13.	49
Fig. (4.5): Sampling wells in the study area.	54
Fig. (4.6):Salinity zonation map of the study area.	60
Fig. (4.7): Major cations distributions for the groundwater samples.	62
Fig. (4.8): Major anions distributions for the groundwater samples.	65
Fig.(4.9): Ratio of Sodium vs. Chloride in different aquifers.	68
Fig. (4.10): Bar graphs representing groundwater samples in (A) Alluvial aquifer, (B) Pleistocene aquifer and (C) M. Miocene aquifer in the study area.	71
Fig.(4.11): groundwater samples represented in Piper's tri-linear diagram.	73
Fig.(4.12): Semi-Logarithmic representation for groundwater samples.	75
Fig.(4.13): Cross plot of $Ca^{2+}+Mg^{2+}$ vs. $SO_4^{2-}+HCO_3^{-}$ of the groundwater	76

samples.	
Fig.(4.14): Cross plot of $SO_4$ <sup>2-</sup> vs. $Ca^{2+}$ for the groundwater samples.	77
Fig.(4.15): Cross plot of total cations vs. $Na^+ + K^+$ for the groundwater samples.	78
Fig.(4.16): Cross plot of Total cations vs. Ca <sup>2+</sup> +Mg <sup>2+</sup> for the groundwater	
samples.	79
Fig.(4.17): Cross plot of SiO <sub>2</sub> vs. HCO <sub>3</sub> for the groundwater samples.	80
Fig.(4.18): Cross plot of HCO <sub>3</sub> vs. Na <sup>+</sup> for the groundwater samples.	80
Fig. (4.19): Mechanism controlling groundwater chemistry (Gibbs, 1970).	82
Fig. (4.20): Cross plots of Cl <sup>-</sup> vs. Na <sup>+</sup> for the groundwater samples.	83
Fig. (4.21): Cross plot of Mg <sup>2+</sup> vs. Ca <sup>2+</sup> for the groundwater samples.	83
Fig.(4.22): Bar diagram showing Chloro-Alkaline Indices for water samples.	84
Fig.(4.23): Cross plots of $SO_4^{2-}$ vs. $Cl^-$ for the groundwater samples.	85
Chapter 5.Evaluation of groundwater	
Fig.(5.1): U. S. Lab. Classification of irrigation water for the ground water	96
samples in the study area.	
Fig.(5.2): salinity zonation map of the groundwater samples.	101
Chapter 6. Mass Transfer during RO desalination of	
artificial and groundwater	
Fig.(6.1): Effect of feed presure on the pure water flux.	105
Fig.(6.2) :Salt rejection of different salts at constant 2000 mg/l concentration at 3 folds of the osmotic pressure using cross-flow RO Desalinator.	107
Fig.(6.3): Effect of feed concentration on the salt rejection at: (a). Applied pressure $=2\pi$ and (b). Applied pressure $=3\pi$ .	109
Fig.( 6.4 ): The effect of increasing the feed salt concentration and $\Delta P$ on the 'k' values for the artificial feed solution	113
Fig.(6.5): SEM images of a)surface of the clean control membrane, b) cross-section of the control membrane.	115
Fig.(6.6): SEM images of: a,b,c) surface of the membrane used with NaCl salt, d) cross-section of this membrane.	115
Fig.(6.7): SEM images of: a,b,c) surface of the membrane used with Na <sub>2</sub> SO <sub>4</sub> salt, d) cross-section of this membrane.	116
Fig.(6.8): SEM images of: a,b,c) surface of the membrane used with CaCl2 salt,	116