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Hydrogeochemical Costal Hazard Assessment in North West Sinai, Egypt.

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List of Symbols and Abbreviations

amsl	above mean sea level
AI	Aggressiveness Index
DEM	Digital Elevation Model
Ec	Electrical conductivity
epm	Equivalent part per million
Ki	Kelley index
GIS	Geographic Information System
LI	Larson–Skold Index
mg/l	milligram per liter
MODFLOW	Software for simulating flow and contaminate transport behavior
MT3D	Engine in MODFLOW for simulating Contaminant transport behavior
HCA	hierarchical cluster analysis
PCA	Principal Component Analysis
PC	Principal Component
SAR	Sodium Adsorption Ratio
SI	Saturation Indices
TDS	Total Dissolved Solids
WQI	Water Quality Index
IDW	Inverse Distance Weighted
CVI	coastal vulnerability index
FFBI	flash flood potentiality index
SH	salinity hazard
GMWL	Global Meteoric Water Line



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Hydrochemical and multivariate analysis of groundwater quality in the northwest of Sinai, Egypt

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ABSTRACT

The northwestern coast of Sinai is home to many economic activities and development programs, thus evaluation of the potentiality and vulnerability of water resources is important. The present work has been conducted on the groundwater resources of this area for describing the major features of groundwater quality and the principal factors that control salinity evolution. The major ionic content of 39 groundwater samples collected from the Quaternary aquifer shows high coefficients of variation reflecting asymmetry of aquifer recharge. The groundwater samples have been classified into four clusters (using hierarchical cluster analysis), these match the variety of total dissolvable solids, water types and ionic orders. The principal component analysis combined the ionic parameters of the studied groundwater samples into two principal components. The first represents about 56% of the whole sample variance reflecting a salinization due to evaporation, leaching, dissolution of marine salts and/or seawater intrusion. The second represents about 15.8% reflecting dilution with rain water and the El-Salam Canal. Most groundwater samples were not suitable for human consumption and about 41% are suitable for irrigation. However, all groundwater samples are suitable for cattle, about 69% and 15% are suitable for horses and poultry, respectively.

Key words | Egypt, groundwater quality, multivariate analysis, northwestern Sinai

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INTRODUCTION

Coastal areas are highly sensitive to natural or anthropogenic effects. The northwestern coast of Sinai (site of the study area; [Figure 1](#)) is home to many economic activities: industry, agriculture, tourism, fisheries, trading and other development programs.

Securing water resources of appropriate quantity and quality is of prime importance for development programs in this important sector. This emphasises the importance of evaluation of the sustainability, potentiality and vulnerability of water resources from a development perspective.

The annual rainfall in the study area is limited; it varies between 26 and 54.8 mm and the total quantity of rainfall generally increases northward ([El-Sheikh 2008](#)). The national project of the El-Salam Canal has been started and River Nile water is being carried to Sinai. According to the [Ministry](#)

of Water Resources and Irrigation (1991, 2009) and [Hafez \(2005\)](#), it is expected that the Nile water supply to this area will not fulfill the requirements of all the planned projects. Therefore, the demand for freshwater supplies has accordingly increased and attention is focused on groundwater utilization as an alternative or additive to rainfall.

The quality of groundwater resources in coastal zones is affected by many constraints (natural and/or anthropogenic). These include seawater intrusion, rock/water interaction, evaporation, irrigation return and drainage water effects, etc. Identifying the principal factors that control the salinity evolution and water quality aspects helps to achieve sustainable use of coastal resources.

This paper describes the prevailing groundwater conditions in the northwestern coastal zone of Sinai and

CONTENT

CONTENTS

	Page
Contents	I
List of Figures	V I
List of Tables	X
Abstract	
Chapter 1: INTRODUCTION AND LITERATURE REVIEW	1
1.1 Introduction	1
1.2 Objective and conducted activities	1
1.3 Thesis Structure	3
1.4 Location and climate of study area	3
1.5 Literature review	4
Chapter 2: TECHNIQUES AND METHEDOLOGIES	8
2.1 Sampling of water samples	8
2.1.1 Sampling for hydrochemical analysis	8
2.1.2 Sampling for isotopes	9
2.2 Hydrochemical analyses	9
2.3 Environmental isotopes analyses	10
2.4 Geographic Information System (GIS) applications	11
2.5 Application of MODFLOW	12
Chapter 3: RESULTS AND DISCUSSION	15
3.1 Hydrogeological and hydrogeochemical characterization	15
3.1.1 Hydrogeological characterization	15
3.1.1.1 Geomorphological conditions	15
3.1.1.2 Lithostratigraphic conditions	18

CONTENT

3.1. 1.3 Groundwater and surface water characterization	20
3.1.2 Hydrogeochemical conditions	22
3.1.2.1 Spatial distribution of TDS and the major ions	25
3.1.2.2 Multivariate statistical analysis	30
3.1.2.3 Hydrochemical Facies and Salinization Processes	35
3.1.3 Isotopic integration (in-sight hydrogeological and hydrogeochemical characterization)	43
3.2 Coastal hazard analyses in the study area	48
3.2.1 Groundwater quality hazards	49
3.2.1.1 Hazards of groundwater usage	49
3.2.1.2 Hazard of soil salinity	55
3.2.1.3 Seawater intrusion vulnerability	57
3.2.1.4 Contaminant transport modeling in the groundwater of the study area	62
3.2.2 Hydrologic hazards	72
3.2.2.1 Coastal erosion due to seawater rise	72
3.2.2.2 Extreme rainfall value analysis (EVA)	78
3.2.2.3 Hazard of flash flood	80
Summary and Conclusion	88
References	97
Arabic Abstract	

LIST OF FIGURES

Figure	Page
Figure (1-1): Location map of the study area.	4
Figure (2-1): Location map of the collected groundwater samples, northwest Sinai.	8
Figure (2-2): Schematic of Isotopic Ratio Mass Spectrometer (IRMS).	11
Figure (2-3): Modeling protocol (Prommer et al., 2002)	13
Figure (3-1): Geomorphological map of northwestern Sinai (compiled after Yousef and El-Shenawy, 2000).	17
Figure (3-2): Generalized stratigraphic column of Northwestern Sinai (after Geological Survey of Egypt, 1992).	19
Figure (3-3): Geologic map of northwest Sinai, Egypt (after Geological Survey of Egypt, 1992).	20
Figure (3-4): Map of North Sinai showing the location of the North Sinai	21
Figure (3-5): Hydrogeological cross sections along the study area, (El Osta, 2000).	22
Figure (3-6): Spatial distribution of TDS for groundwater samples in the studied area using ARCGIS.	26
Figure (3-7): Spatial Distribution of Cl ⁻ in the study area using ARCGIS.	27
Figure (3-8): Spatial Distribution of SO ₄ ²⁻ in the study area using ARCGIS.	27
Figure (3-9): Spatial Distribution of HCO ₃ ⁻ in the study area using	28

ARCGIS.

Figure (3-10): Spatial Distribution of Ca^{2+} in the study area using ARCGIS.	28
Figure (3-11): Spatial Distribution of Mg^{2+} in the study area using ARCGIS.	29
Figure (3-12): Spatial Distribution of Na^+ in the study area using ARCGIS.	29
Figure (3-13): Spatial Distribution of K^+ in the study area using Super GIS.	30
Figure (3-14): Hierarchical clustering analysis of groundwater samples in the study area.	32
Figure (3-15): Plot of loadings for the first two components with varimax normalized rotation.	35
Figure (3-16): Piper Diagram for groundwater samples in the study area.	37
Figure (3-17): Relation between Na and Cl for the studied groundwater samples.	39
Figure (3-18): Ca and Mg ratio.	40
Figure (3-19): Relation between Na/Cl and EC.	40
Figure (3-20): Distribution of study groundwater samples on Gibbs diagram.	41
Figure (3-21): Relationship between $\text{Ca} + \text{Mg-HCO}_3\text{-SO}_4$ versus Na-Cl for the studied groundwater samples.	42
Figure (3-22): The relationship between $\delta^{18}\text{O}$ and δD	46
Figure (3-23): Spatial distribution of $\delta^{18}\text{O}$.	47
Figure (3-24): The relation between $\delta^{18}\text{O}$ and TDS	48
Figure (3-25): Salinity hazard risk map.	57

Figure (3-26): GALDIT result: (A) Impact status of existing seawater intrusion; (B) distance from shore; (C) aquifer hydraulic conductivity (m/day); (D) height of groundwater level (amsl)(m); (E) saturated aquifer thickness (m); (F) Groundwater occurrence/aquifer type; (G) GALDIT Index.	62
Figure (3-27): Conceptualization of the study area.	66
Figure (3-28): Calibration of the model.	67
Figure (3-29): Simulated head in the year 2017	68
Figure (3-30): Drawdown in the head in the year 2017	68
Figure (3-31): Pb concentration after 100 day	69
Figure (3-32): Pb concentration at the end of the simulation.	69
Figure (3-33): Cr concentration after 100 day.	69
Figure (3-34): Cr after at the end of the simulation.	70
Figure (3-35): Expected concentration of Pb during the simulated period in the continuous release scenario.	71
Figure (3-36): Expected concentration of Cr during the simulated period.	71
Figure (3-37): Retarded velocity change with time.	72
Figure (3-38): Geomorphologic rating along the shore in the study area.	75
Figure (3-39): Erosion and accretion areas along the shore in the study area	75
Figure (3-40): Slope percentage of the study area using ARC GIS.	77
Figure (3-41): Final CVI map of the study area.	78
Figure (3-42): Exceedence Probability Function (Probability vs Rainfall Intensity)	80

	<i>List of Figures</i>
-------	------------------------

Figure (3-43): Land use/ land cover map of the study area.	83
Figure (3-44): NVDI map of the study area.	85
Figure (3-45): Final FFBI map of the study area.	87

LIST OF TABLES

Table	Page
Table (3-1): Results of major ions of groundwater samples in the study area.	24
Table (3-2): Statistical analysis of major cations for groundwater samples in both aquifers.	25
Table (3-3): Total variance for the collected groundwater samples.	34
Table (3-4): Saturation indices of collected groundwater samples using SPSS 22.	38
Table (3-5): Isotopic results of the collected groundwater samples.	44
Table (3-6): Statistical analysis of the chemical and isotopic data.	44
Table (3-7): Isotopic composition of the different possible recharge sources.	45
Table (3-8): Egyptian standards for drinking and domestic uses.	50
Table (3-9): TDS limits for water that can be used for drinking by livestock and poultry (McKee & Wolf, 1963).	50
Table (3-10): Selected variables used in the WQI calculation and their recommended values (Rown et al., 1972).	52
Table (3-11): WQI categories of collected groundwater samples according the classification of Rown et al., (1972)	52
Table (3-12): Water quality requirements for some selected industries and processes, (National Academy of Science, 1972).	53
Table (3-13): The indicators used in the model of hazard of soil salinization.	56
Table (3-14): Categorization of the salinity hazard scores	57
Table (3-15): Rating and weighting values of different parameters	56

according to their relative importance (Chachadi and Lopo-Ferreira, 2001)

Table(3-16): Rating and weighting values of different hydrogeological parameters according to their relative importance (Chachadi & Lopo-Ferreira 2001)	59
Table (3-17): Rates of CVI and its categories (Gornitz et al 1994).	74
Table (3-18): The fitness of the recorded metrological data set	79
Table (3-19): Slope index rating	82
Table (3-20): Landuse/land cover rating	83
Table (3-21): Soil classification rating	84
Table (3-22): Rating value of NVADI	86

ABSTRACT

ABSTRACT

Coastal hazards are of high concern because of their adverse effects or even catastrophic impacts. These hazards, either natural or human induced, constrain development prospective and endanger lives, properties and resources in the coastal zones, such as the area under study in the northwest of Sinai. Analysis and evaluation of coastal hazards is a mandatory task for proper and secured development where necessary protective and controlling actions are proposed.

The basic objective of this thesis is to investigate, analyze, and evaluate some hydrogeochemical, hydrogeological and meteorological hazards at northwestern coast of Sinai. An approach has been applied that integrates system characterization into hazard evaluation which functions weighting / rating indices techniques, numerical modeling and empirical formulation.

The study is based on results of literature review, field and laboratory work (39 groundwater samples have been sampled and analyzed for major cations, major anions, ^{18}O and ^2H isotopic values), statistical treatment, numerical modeling, indices evaluation and categorization, GIS overlay and mapping.

The hydrogeological characteristics of the system (including geomorphological, lithostratigraphic and groundwater conditions) and its hydrogeochemical ones (including ions distribution, ion dominance, water types , principle components, origin of salinity, its evolution and modification processes,...etc..) have been determined and isotopically insighted.

The results of characterization are fed into the hazard analysis processes conducted in this work, which include: hazard of groundwater

ABSTRACT

consumption (drinking, irrigation, construction), soil salinization, sea water intrusion , contaminant transport in groundwater, sea water rise and coastal erosion, extreme rainfall and flash flood. The attributes of the different hazards are rated, weighed and mathematically interrelated in an overall hazard values which are mapped to locate the areas of high hazard potential, this is important for proposing protective and early preparedness measures to secure development processes in the study area.

The total salinity of the study groundwater varies in a wide range (from 692 ppm to 9384ppm). Two major hydrochemical facies exist , (a) the Cl-Na and SO₄- Na brackish water that dominates more than 90% of the samples reflecting a developed stage of salinity evolution under the effects of marine salts dissolution, surface evaporation before infiltration, cation exchange and Sabkha soil water contribution , (b) the HCO₃-Ca fresh water that dominates less than 10% of the samples reflecting an early stages of mineralization and are located close to El-Salam Canal where surface water from the canal seeps to dilute the saline water in the aquifer.

The ¹⁸O and ²H isotpic content revealed that the predominant recharging source of the groundwater under study is meteoric water. Rain water falls on the coastal and inland sand dunes and seeps to cover and bond Sabkha deposits in the depression between sand dunes. The bonding water leaks to the aquifer with salts concentrated through dissolution of marine salts from Sabkhas.

The high salinity and major ions concentration render about 90% of the collected groundwater samples posing health hazard for human drinking, about 31% and 85% posing hazard for horses and poultry,
