



Sources of Salinity and Suitability for Irrigation and Drinking Use of the Groundwater of Northwest of ElMinia, Upper Egypt.

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Abstract

The present work is devoted to determine sources of groundwater salinity and suitability of its use for irrigation and drinking in northwest ElMinia, Upper Egypt. This information is important for sustainable and reliable development of the groundwater resources. A hydrochemical study using results of major ions and trace elements analysis of 43 groundwater samples collected from the study area have been conducted in this work. The TDS and major ionic concentrations vary in considerably wide ranges, these increase westward and northward under effect of rock minerals dissolution and upward leakage of saline water. The water types, ionic orders, hypothetical salts combination, multivariate analysis and ions / ions relations reflect a high stage of salinity development with (SO_4^{2-} , Cl^-/Na^+ , Ca^{2+}) hydrochemical facies in 80% of the samples, the rest (20%) are less developed with higher HCO_3^- on expense of SO_4 . The groundwater salinity in the study area is developed under effects of rock minerals dissolution (halite, calcite, dolomite, and gypsum), cation exchange and mixing waters between aquifers. The hazards of increasing salinity and major ions / trace elements toxicity for groundwater use in irrigation and drinking have been evaluated using hydrochemical indexes and standard classifications.

Keywords : Groundwater ; Hydrochemistry ; Quality ; Salinity ; Dissolution ; Ionic Exchange ; Drinking, Irrigation.

1. Introduction

The steadily growing population with the shortage of water resource and deficit of agriculture in the Nile Valley, let Egyptian government plans to reclaim the desert hinterlands to the west of the valley, this implies an increasing demand for sustainable and reliable groundwater resources to cope with the excessive needs. The sustainability and reliability of groundwater resources, not only depend on quantitative aspects and reserves but equally depend on qualitative and salinity aspects to secure environmental protection and safe use. The hydrochemical investigations uses the chemical composition of groundwater with information about physical setting of the system to determine its sources of salinity (e.g. water-rock interactions, concentration by evaporation, dilution by recharge or

mixing as well as anthropogenic impacts) and to evaluate the quality hazards on environment and surroundings during groundwater uses. These information are important for decision makers to protect the resources or treat them, for sustainable development.

This work is conducted on the groundwater resources of one of the areas allocated by Egyptian government for desert reclamation and agricultural expansion, in north-western ElMinia, Upper Egypt., This area was the subject of several studies (eg. M.El kashouty et al 2013 (1), M.Abdulaziz et al 2017 (2), G.M.Redha et al 2017 (3)) that used hydrogeological, hydrochemical, hydrophysical and isotopic tools to investigate the water resources occurrence, potential, recharge and flow. The present work is a progression to the previous ones, it is concerned with the qualitative aspects of groundwater resources toward its sustainable

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development, it is devoted to determine the sources, degree and facies of salinity of the groundwater resources. The major ions (Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl^- , SO_4^{2-}) and trace elements composition (Al^{3+} , Si^{4+} , Cd^{2+} , Cr^{3+} , Co^{2+} , Cu^{2+} , Fe^{3+} , Mn^{2+} , Mo^{2+} , Ni^{2+} , Pb^{2+} , V^{5+} , Zn^{2+}) of 43 groundwater samples collected from the study area have been determined, statistically treated, processed and analyzed to determine the hydrochemical characteristics, sources of salinity and evolution trends and to evaluate quality hazards of drinking and irrigation.

The study area is located in mid upper Egypt, it lies between longitudes $30^\circ 05'$, $28^\circ 15'$ and latitudes $30^\circ 55'$, $28^\circ 45'$, Fig. (1) it is characterized by arid to semiarid climate with hot dry summer and rare precipitation winter. The average rainfall value for the last fifteen years ranged from 23.05 to 33.15 mm/y (Korany, 1980) (4), the minimum temperature varies from 4.5 (January) to 20.5°C (August), while the maximum temperature varies from 20.7 (January) to 39.7°C (August). The mean monthly relative humidity during daytime ranges from 36% in May to 62% in December (Korany, 1984) (5). The location map with its digital elevation (using Digital Elevation Model "DEM") is presented in Fig (1).

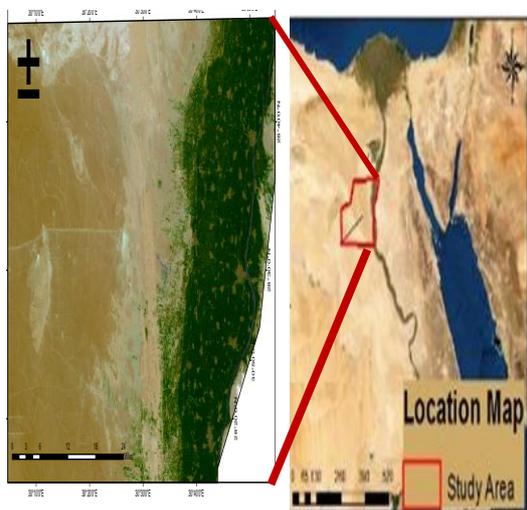


Fig. (1): Location Map of the Study area.

2. Physical Setting of the Study Area

Geo-morphologically, three units can be described in the study area from east to west: -The present alluvial plain occupied by Holocene silt and clay at

the extreme east, bordered by Nile. It represents the old agricultural areas irrigated with surface water diverted from the Nile and from main canals. -The old alluvial plain dominated by Pleistocene sands and gravel, following the young alluvial plain westward, it includes the new desert reclamation lands as well as scattered urbanized areas, it is irrigated by surface water and groundwater. The lower Eocene plateau at the extreme west, it is moderately elevated with respect to the River Nile, structurally formed and composed of limestone covered with alluvial deposits of sands and gravels. The digital elevation map of the study area have been extracted using DEM (Digital Elevation Model) and utilized in ARCGIS 10.3 tool and the geomorphologic units of the study area are delineated on it, Fig. (2A).

The ground elevation, lithology, geomorphology, climate and structures, integratively determine the surface drainage pattern which affects groundwater recharge and salinity. The Satellite Image and ARCGIS 10.3 tools have been used in this work to construct the surface drainage pattern in the study area, Fig. (2B). The drainage network is not well developed, it initiates along the fractures of the elevated tableland westward and flows with few tributaries downstream to the flood plain with limited chance of groundwater recharge due to the aridity of the study area.

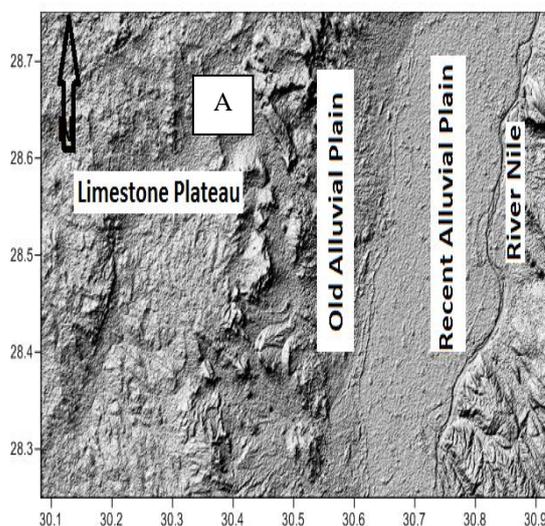


Fig.(2): (A)-Geomorphological map of the study Area, with DEM

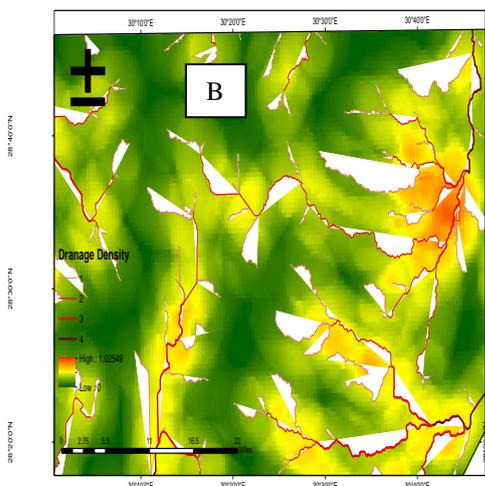


Fig.(2): (B)- Drainage density in the study area .

According to H. I. Abdel-Shafy et al 2016 (6), groundwater aquifers in Egypt are classified into renewable located in the Nile valley and delta system and non renewable in the Nubian sandstone at western desert.

Groundwater exists in two main aquifers in the study area ; one belongs to Quaternary , dominating eastward in the present and old flood plain , it is confined to semi confined and is made of (alluvium deposits; graded sand and gravel with intercalations of clay lenses overlain by Holocene silt and clay), the other aquifer is the Eocene limestone which is dominating westward from the desert fringes to limestone plateau , it is found under unconfined conditions. In addition to these two aquifers, the deep Nubian sandstone aquifer which underlain the whole western desert and contains paleowater of no recent recharge. The two aquifers are connected and get recharge mainly from Nile River system, with upward leakage of deep paleowater appears and increases in limestone aquifer westward. Fig (3A) shows a general hydrogeologic cross section extending from the flood plain eastward to the limestone plateau westward. The depths to groundwater at the sampling points were measured in the field , Table (1), the elevation thematic map subtracted from the depth to water map through raster calculation function to get the groundwater level map of the study area(m). (3B)

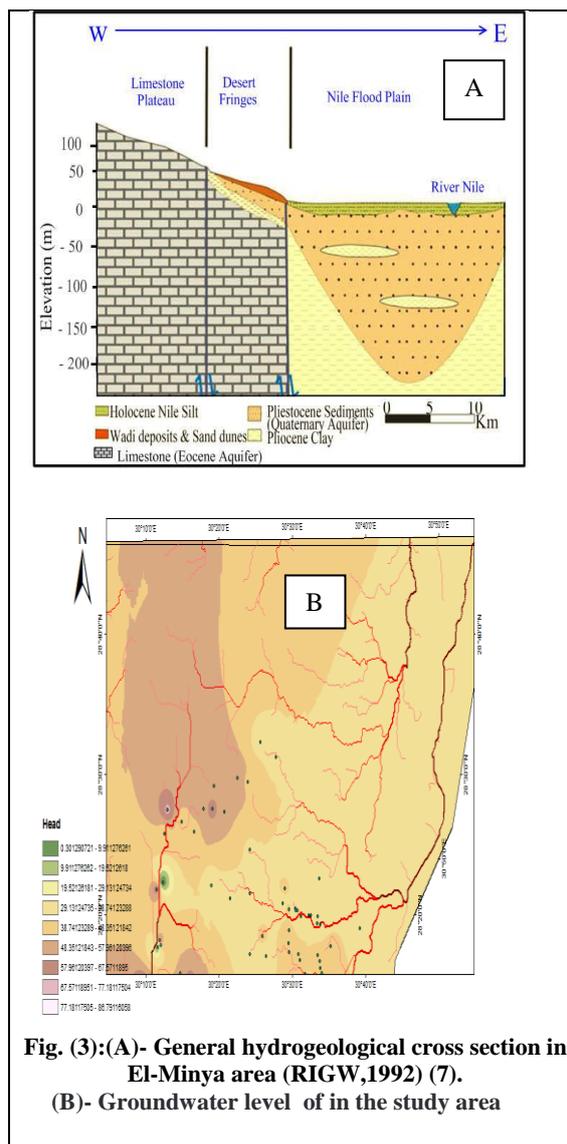


Fig. (3):(A)- General hydrogeological cross section in El-Minya area (RIGW,1992) (7). (B)- Groundwater level of in the study area

3. MATERIALS AND METHODS

Forty three samples were collected from the groundwater aquifers in the study area. Samples locations coordinates, Table (1) and ground surface elevation were recorded using a global positioning system (GPS) manufactured by Garmin. Temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS) were measured in situ utilizing portable meters ((Jenway, model 3150). Analyses of the water samples(Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl^- , HCO_3^- , SO_4^{2-}) were carried out in the laboratory of the Central Laboratory of Stable Isotope Hydrology at Egyptian Nuclear and Radiological Regulatory Authority

(ENRRA) following the methods described in ASTM E(2002-15) (8). All parameters are expressed in milligrams per liter. Data quality was assessed using the charge balance between the difference between cations and anions (expressed in mEq/L) divided by their summation, which was always $<\pm 5\%$. Trace elements (Al^{3+} , Si^{4+} , Cd^{2+} , Cr^{3+} , Co^{2+} , Cu^{2+} , Fe^{3+} , Mn^{2+} , Mo^{2+} , Ni^{2+} , Pb^{2+} , V^{5+} , Zn^{2+}) were measured by inductively coupled plasma (ICP) at the Desert Research Center (DRC), TJA model (POEMS3) using 1000 ppm (Merck) stock solution for standard preparation, and the results were reported in ppm.

The data have been treated, processed and analyzed using graphical, statistical and standard classifications. In addition to that, mapping the drainage pattern and ground surface / groundwater elevation, spatial distribution of thematic maps have been done using inverse distance weight (IDW) method in ARCGIS10.3 tool.

Multivariate statistical Analysis (MSA) have been conducted to insight the distribution pattern, its variation and mutual relations, the SPSS.22 software was used for MSA

The quality hazards of using the groundwater under study for irrigation and drinking were evaluated by using hydrochemical indexes and standard classifications.

4-RESULTS AND DISCUSSION

4-1 Sources of Salinity

The ionic orders, water types, salinity distribution, Multivariate Analysis, Hypothetical Salts Combination and ion/ion relations have been used for characterizing the salinity of collected samples and for evaluating the salinity sources and processes developing it.

The results of major ions analysis of the collected groundwater samples and the ranges of concentrations are given in Table (1). The orders of ionic concentrations show the domination of three water types $\text{Cl}^- \text{-Na}^+$ 60.46%, $\text{SO}_4^{2-} \text{-Na}^+$ 16.27% and $\text{SO}_4^{2-} \text{-Ca}^{2+}$ 16.27% reflecting the prevalence of (Cl^- & SO_4^{2-}) and (Na^+ & Ca^{2+}) in the anionic and cationic sides respectively.

The TDS is highly correctable to (Cl^- , Na^+ , Mg^{2+} , Ca^{2+} , SO_4^{2-}) with R2 equal 0.95, 0.89, 0.92, 0.89 and 0.89 respectively, The salinity generally increases, Fig. (3) from east to west where carbonates matrix dominates the aquifer materials and upward leakage of saline deep water increases, salinity also increases northward with increasing the shale and clay content in Wadi ElRayan Formation of the Eocene limestone and locally in the Quaternary deposits.

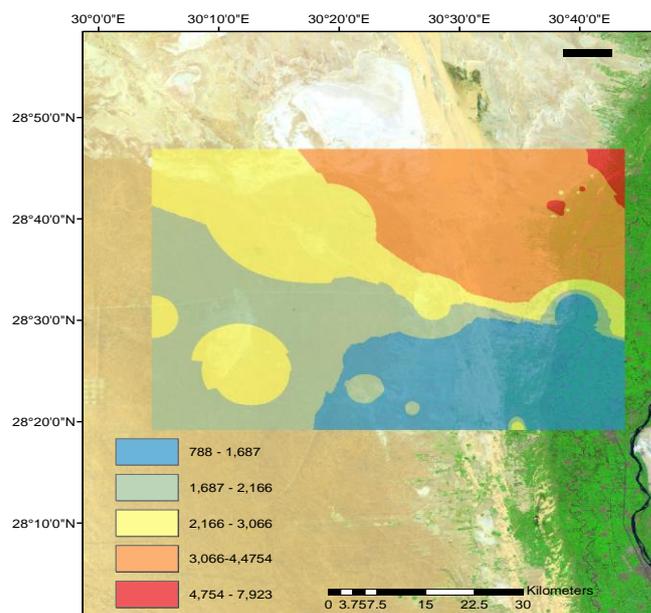


Fig. (3): Areal Distribution of TDS for samples of the studied area

Table (1), Results of Chemical Analysis of the Study Samples, in ppm

No	North	East	pH	EC	Major Cations				Major Anions			Hardness	SAR	RSC	MAR
				$\mu\text{S}/\text{cm}$	Na^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	HCO_3^-	SO_4^{2-}				
1	28.32	30.55	8.1	2350.0	205.0	13.9	76.8	96.0	354.6	219.6	246.7	554.9	3.8	-7.6	57.1
2	28.32	30.58	7.5	4460.0	652.0	20.6	70.0	212.0	788.1	183.0	1033.0	817.0	9.9	-13.4	35.5
3	28.33	30.54	8.0	1846.0	210.0	6.0	64.8	68.0	394.1	237.9	83.2	435.7	4.4	-4.9	61.4
4	28.33	30.53	7.8	2010.0	250.4	7.1	48.0	88.0	400.6	237.9	157.9	416.8	5.3	-4.5	47.6
5	28.33	30.52	7.8	1743.0	155.0	7.1	67.2	80.0	315.2	237.9	106.5	475.5	3.1	-5.7	58.3
6	28.34	30.51	8.1	1480.0	161.0	6.0	43.2	80.0	295.5	237.9	66.9	377.1	3.6	-3.7	47.4
7	28.34	30.5	8.3	1413.0	228.8	4.9	52.8	64.0	295.5	274.5	24.6	376.5	5.1	-3.1	57.9
8	28.34	30.49	8.6	1588.0	155.0	6.0	48.0	64.0	321.8	237.9	98.5	356.8	3.6	-3.3	55.6
9	28.35	30.48	8.2	1728.0	220.0	7.1	57.6	64.0	380.9	219.6	113.2	396.2	4.8	-4.4	60.0
10	28.35	30.46	8.1	2680.0	336.7	10.5	72.0	76.0	637.0	219.6	145.7	485.2	6.6	-6.2	61.2
11	28.35	30.46	8.1	2830.0	320.0	9.4	74.4	92.0	722.4	201.3	105.6	535.0	6.0	-7.5	57.4
12	28.35	30.44	8.2	3120.0	315.0	13.9	86.4	120.0	755.3	311.1	157.2	654.2	5.3	-8.1	54.5
13	28.36	30.44	8.0	3340.0	400.0	16.1	115.2	108.0	820.9	247.1	121.5	742.3	6.4	-11.0	64.0
14	28.35	30.4	8.2	2120.0	289.0	10.5	60.0	80.0	479.4	247.1	100.6	446.0	5.9	-5.0	55.6
15	28.37	30.39	8.2	2880.0	355.0	11.6	76.8	60.0	630.5	256.2	146.0	464.9	7.1	-5.2	68.1
16	28.38	30.38	8.2	3640.0	435.0	15.0	96.0	104.0	899.7	311.1	124.4	653.6	7.4	-8.1	60.6
17	28.32	30.55	8.5	1375.0	130.0	6.0	48.0	60.0	243.0	192.2	86.3	346.8	3.0	-3.9	57.1
18	28.33	30.6	7.6	1308.0	83.0	12.0	72.0	68.0	116.0	144.0	348.0	465.2	1.7	-7.0	63.8
19	28.72	30.67	7.6	8830.0	1300.0	20.0	126.4	457.6	1725.5	170.8	2000.0	1662.1	13.8	-30.6	31.5
20	28.78	30.71	7.6	10880.0	1300.0	21.0	454.9	416.0	3155.2	231.8	1250.0	2905.1	10.4	-53.1	64.6
21	28.78	30.72	7.7	12310.0	1100.0	17.0	480.0	945.0	3620.0	158.6	1740.0	4330.5	7.2	-84.7	45.8
22	28.76	30.7	7.6	12620.0	950.0	18.0	559.0	900.0	3549.6	158.6	1640.0	4541.9	6.1	-86.8	50.9
23	28.77	30.73	7.7	9850.0	600.0	11.0	485.0	765.0	1972.0	207.4	2244.6	3901.0	4.2	-75.3	51.4
24	28.77	30.73	7.8	7160.0	440.0	18.0	227.4	660.0	1479.0	164.7	1400.0	2582.5	3.8	-49.3	36.5
25	28.74	30.68	7.9	4950.0	580.0	12.0	164.3	208.0	831.9	201.3	1095.1	1193.5	7.3	-20.8	56.8
26	28.77	30.66	7.8	6210.0	340.0	24.0	270.0	487.0	856.4	262.3	1618.9	2324.5	3.1	-42.6	48.0
27	28.71	30.66	7.8	4110.0	360.0	16.0	126.4	312.0	493.0	201.3	1204.5	1298.1	4.3	-22.8	40.3
28	28.7	30.66	7.7	5240.0	240.0	31.0	260.3	407.6	929.8	109.8	1196.4	2086.1	2.3	-40.3	51.6

No	North	East	pH	EC μS/cm	Major Cations				Major Anions			Hardness	SAR	RSC	MAR
					Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺	Cl ⁻	HCO ₃ ⁻	SO ₄ ²⁻				
29	28.7	30.66	7.7	6230.0	480.0	23.0	201.0	490.0	1150.0	73.2	1391.4	2049.1	4.6	-40.1	40.6
30	28.68	30.65	7.7	3970.0	180.0	15.0	164.3	360.8	345.1	189.1	1200.0	1575.5	2.0	-28.6	43.1
31	28.69	30.64	7.7	12150.0	950.0	34.0	500.0	800.0	2760.8	128.1	2300.0	4050.0	6.5	-79.6	51.0
32	28.69	30.64	7.8	10840.0	850.0	29.0	460.0	720.0	2055.3	146.4	2472.4	3686.0	6.1	-71.9	51.6
33	28.69	30.64	7.8	8520.0	800.0	26.0	177.9	700.0	1626.9	128.1	1900.0	2479.4	7.0	-47.7	29.8
34	28.68	30.64	7.9	10520.0	1300.0	30.0	454.9	332.8	2267.8	152.5	2300.0	2697.1	10.8	-52.0	69.5
35	28.67	30.63	7.7	6120.0	760.0	19.0	250.0	480.5	1900.0	189.1	1100.0	2226.1	7.0	-41.8	46.4
36	28.67	30.63	8.2	1934.0	180.0	7.0	74.0	145.6	369.8	170.8	400.0	667.4	3.0	-10.6	45.9
37	28.66	30.63	7.7	3190.0	200.0	11.0	88.5	330.0	468.4	115.9	800.0	1187.7	2.5	-22.0	30.9
38	28.66	30.63	7.9	10330.0	1000.0	19.0	353.8	665.6	2366.4	128.1	2000.0	3114.6	7.8	-60.7	47.0
39	28.71	30.64	7.6	4320.0	280.0	15.0	75.8	499.2	468.4	146.4	1383.4	1558.8	3.1	-28.9	20.2
40	28.66	30.58	8.0	5410.0	800.0	16.0	151.6	166.4	1331.1	134.2	860.0	1037.7	10.7	-18.8	60.3
41	28.41	30.22	8.0	3800.0	530.0	26.0	135.0	105.0	1134.0	384.0	100.0	816.0	8.0	-10.2	68.2
42	28.52	30.66	7.6	1308.0	83.0	12.0	72.0	68.0	116.0	144.0	348.0	465.2	1.7	-7.0	63.8
43	28.66	30.33	7.4	4000.0	530.0	24.0	135.0	98.0	1134.0	250.0	174.0	798.5	8.1	-12.1	69.7
Max			8.6	12620.0	1300.0	34.0	559.0	945.0	3620.0	384.0	2472.4	4541.9	13.8	-3.1	69.7
Min			7.4	1308.0	83.0	4.9	43.2	60.0	116.0	73.2	24.6	346.8	1.7	-86.8	20.2
Avg			7.9	5125.4	498.2	15.9	184.0	313.5	1126.5	200.4	886.3	1536.1	5.8	-27.6	51.7

RSC: Residual Sodium carbonates

***MAR : Mg Hazards**

The Multivariate analysis of the data set under study was performed through two items: hierarchical cluster analysis (HCA) and Principal Components Analysis (PCA) using SPSS.22 software. Eight hydrochemical variables (TDS, Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻, HCO₃⁻ and SO₄²⁻) for a set of 43 samples were used in the multivariate analyses in this study. This helps to classify the groundwater samples into groups according to the similarity of hydrochemical properties. Also combines the variables into components according to how much they represent the overall characteristics of the data set.

The studied groundwater samples have been classified according to the proximity and similarity of the water quality and hydrochemical parameters into six groups (A, B, C, D, E and F), these include about 30.23 % , 20.93 % , 9.30 % , 16.28 % , 6.97% , 16.28 % of the samples respectively, Fig. (5). The grouping of the samples complies with variation of TDS and ionic composition, which are controlled by hydrogeochemical and physicochemical conditions.

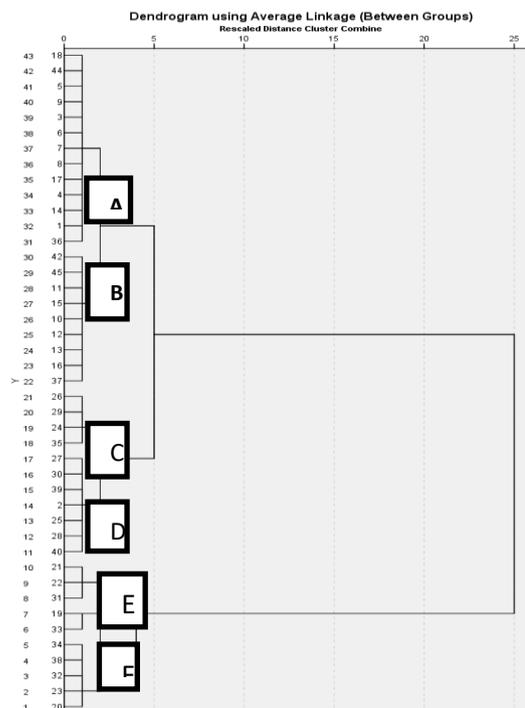


Fig. (5): Hierarchical clustering analysis of groundwater samples

The Principal Components Analysis (PCA) helps to reduce a large data set with underlying linear structures into a set of variables, called Principal Components, without sacrificing much of the original information of the data set. Ten principle components were calculated for hydrochemical data of this work, Table (2), their eigen values are calculated and compared. The Eigen values, percentage of variance of each principal component, cumulative percentage of variance of the ten PC's and the rotated component matrix are given in Table (2). The first two principle components with eigen values >1 account for 82.96% of the total variance and assumed to provide an adequate representation of the overall characteristics of the data set

Table (2): Total variance for the collected groundwater samples

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
	1	7.203	72.02	72.028	7.203	72.028
2	1.096	10.96	82.992	1.096	10.964	82.992
3	.673	6.728	89.719			
4	.415	4.148	93.867			
5	.328	3.284	97.151			
6	.178	1.782	98.933			
7	.101	1.008	99.941			
8	.005	.048	99.989			
9	.001	.009	99.997			
10	.000	.003	100.000			

Extraction Method: Principal Component Analysis.

Component		Component Matrix ^a	
		Component	
		1	2
1	PH	-.590	.522
2	EC	.985	.144
3	TDS	.988	.132
4	Na	.858	.296
5	K	.742	-.066
6	Mg	.921	.180
7	Ca	.911	-.097
8	Cl	.917	.306
9	HCO ₃ ⁻	-.501	.726
10	SO ₄	.922	-.177

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Based on Table (2), the first principle component (PC -1), accounts for 72.028% of the variance in the data set, it directly combines TDS, Cl⁻, Na⁺, Mg²⁺, Ca²⁺ and inversely combines pH and HCO₃⁻; the second component (PC -2) represents about 10.964 of the variance and combines HCO₃ and

pH as a major factors. The inverse association of pH and HCO₃⁻ with the other ions in the 1.st component could reflect the salts development due to dissolution of rock minerals activated by low pH acidic conditions. The direct association of pH with HCO₃⁻ with low ionic values in 2.nd component may reflect salts precipitation under high pH alkaline conditions.

The hypothetical salts combinations have been determined for the study samples based on the relative affinity of anions and cations to combine (in 1:1 epm%), to form the corresponding salts. The salt combinations determined for the study samples and the percentage of their occurrence are indicated in Table (3). The NaCl and Ca(HCO₃)₂ salts appear in salt combination of all the samples. The MgCl₂ and CaCl₂ of marine origin appear in 82% % and 7 % of the samples respectively, on the other hand, the Na₂SO₄ and NaHCO₃ of meteoric and terrestrial origin appears in 16% and 2.5% of samples respectively. The MgSO₄, CaSO₄, or Mg(HCO₃)₂ appear in the salts combination based on the relative domination of SO₄²⁻, Ca²⁺ and Mg²⁺. The hypothetical salts combinations of the samples reflect a high stage of salinity evolution of the groundwater under study and point out to effects of rock/water interaction processes during flow and storage contact.

Table (3) : Hypothetical Salts Combinations for the Study Samples

1- Na Cl, Mg Cl ₂ , Mg SO ₄ , Ca SO ₄ , Ca (HCO ₃) ₂	55.81%
2- Na Cl, Mg Cl ₂ , Mg SO ₄ , Mg (HCO ₃) ₂ , Ca (HCO ₃) ₂	20.93%
3- Na Cl, Mg Cl ₂ , Ca Cl ₂ , Ca SO ₄ , Ca (HCO ₃) ₂	6.98%
4- Na Cl, Na ₂ SO ₄ , K ₂ SO ₄ , Mg SO ₄ , Ca SO ₄ , Ca (HCO ₃) ₂	13.95%
5- Na Cl, Na ₂ SO ₄ , K HCO ₃ , Na HCO ₃ , Mg (HCO ₃) ₂ , Ca (HCO ₃) ₂	2.33%

The ion/ion relations of Na⁺ vs Cl⁻ and (Ca²⁺+Mg²⁺) vs (HCO₃⁻+SO₄²⁻), Figs (5 A and 5 B) show strong direct patterns with high R² equal 0.75 and 0.8 respectively. These reflect that dissolution of halite salt (NaCl) as well as calcite (CaCO₃), dolomite (Ca, Mg CO₃) and gypsum (CaSO₄) salts could be major processes of salinity evolution in the study area. Some samples points shift above and below the direct linear patterns of

Fig. 5A and 5B reflecting that cation exchange of Na vs Ca and Mg could accompany the dissolution of mineral salts. To check the impact of ion exchange on the groundwater salinity of the study groundwater, the relation between $(Ca^{2+} + Mg^{2+} - SO_4^{2-} - HCO_3^{-})$ against $(Na^+ - Cl^-)$, (Jankowski et al., 1998) (9); has been constructed, Fig.(6). The plotted water samples are distributed on a linear pattern of a slope equal -1 in the upper left square of the figure. This indicates that the groundwater samples are affected by ion exchange reactions between Na and Ca & Mg in water and rock matrix.

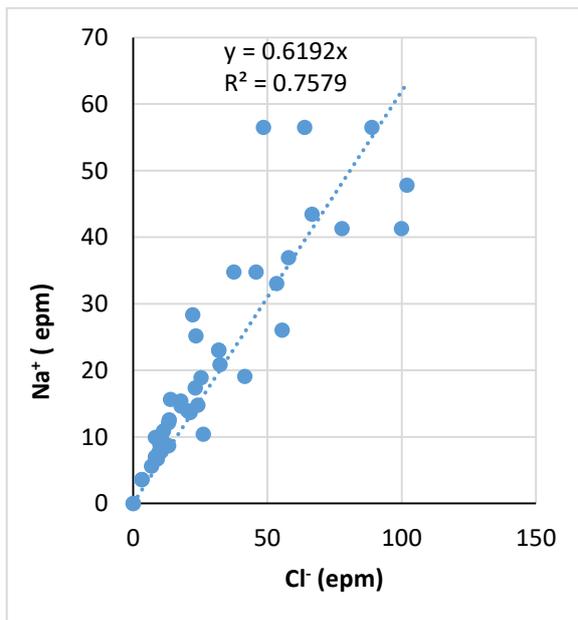


Fig. (5): A- Na^+ against Cl^- relationship.

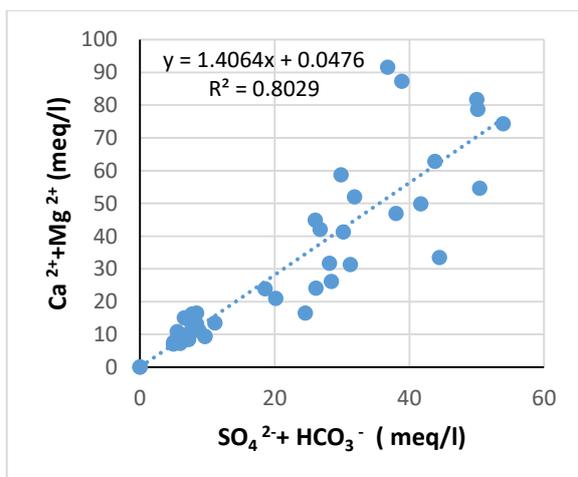


Fig. (5): B- $Ca^{2+}+Mg^{2+}$ against $SO_4^{2-}+HCO_3^-$ relationship

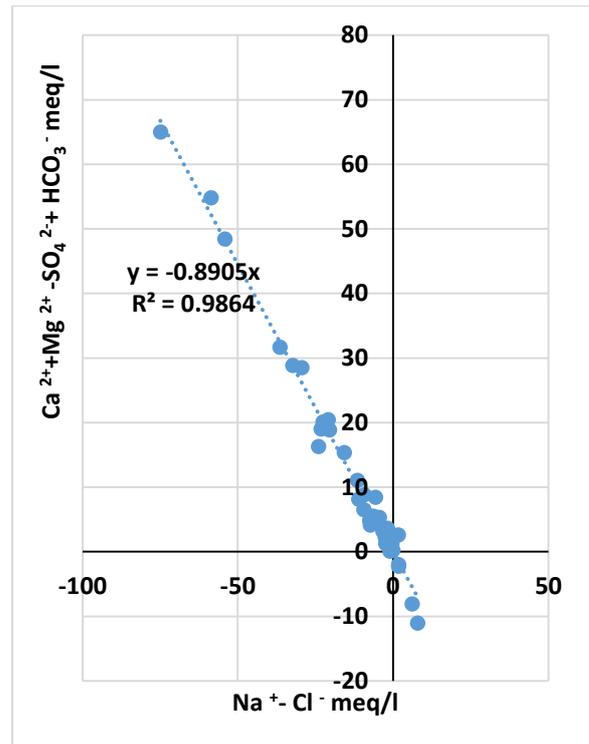


Fig. (6): Relation of $(Ca^{2+} + Mg^{2+} - SO_4^{2-} - HCO_3^{-})$ vs $(Na^+ - Cl^-)$ for the Study Samples.

4.2 Water Quality Hazards (WQH)

The concentration of major ions and trace elements determined for the study samples (Tables 1, 4) are compared with the limits of standards quality hazards classifications to determine the quality hazards of using the groundwater for irrigation and drinking purposes.

4.2.1 WQH of Irrigation

The high salinity of water beyond certain limits causes salts accumulation on soil, reducing the osmotic potential and increasing the force of water absorption. It also affects the yield potential of the crops and classifies them into groups according to tolerance. According to **FAO (1985) (10)** classification of salinity hazards in irrigation water, about 11.63%, 25.58% and 62.79% of the study samples are categorized as medium, high and very high salinity hazards respectively.

Although several ions can exert phytotoxic effects on crops with different dangerous level, Na and Cl

are the most common related to the salinity dangers. The degree of restriction of irrigation water due to chlorides concentration is as follow: (suitable Cl < 142ppm) & (marginal Cl 142-355) & (unsuitable Cl >355) , About 90% of the study samples have chloride values > 355ppm which are not suitable

Magnesium is essential nutrient for plant growth, but excess concentration can cause severe toxicity effects on plants, it may reduce the availability of potassium and reduces growth and yield. Magnesium Hazard (MH) index is used for calculating the hazards of magnesium toxicity according to the following equation:

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad (4)$$

If MH index is less than 50 , groundwater is considered suitable for irrigation whereas greater than 50 values are unsuitable. About 44% of the samples have MH> 50% reflecting a magnesium hazards in irrigation.

The infiltration rate of irrigation water and its availability to penetrated roots is highly affected by several parameters (e.g. Na⁺, Ca²⁺, Mg²⁺, HCO₃⁻, pH). These parameters are integrated together in several indexes that reflect suitability , the following two indexes are used in this work :

- Sodium Adsorption Ratio (SAR)
- Residual Sodium Bicarbonates (RSBC)

Sodium Adsorption Ratio (SAR)

The SAR describes the relative proportional ratio of Na to (Ca + Mg) which influences the adsorption and desorption processes on the cationic exchange sites of soils. The high sodium concentration tends to be absorbed by clay particles, dispersing magnesium and calcium ions, This dispersion causes a breakdown of soil aggregates and causes the soil to become hard and compact when dry and increasingly impervious to water penetration. Equation (1) is used for calculating SAR index as a tool to evaluate soil hazards due to sodicity ([Na⁺], [Ca²⁺], and [Mg²⁺] are expressed in meq/L).

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad (1)$$

According to **FAO (1985)** classification of SAR hazards in irrigation water, about 90.69% of the study samples are of low SAR hazards and 9.3% are medium.

Residual Sodium carbonates (RSC)

High carbonates and bicarbonates concentrations in irrigation water cause calcium and magnesium ions to form insoluble CaCO₃ and Ca(HCO₃)₂ salts leaving sodium as a dominant ion in an alkaline solution. This alkaline water could increase infiltration hazards of irrigation water by increasing SAR values due to the relative increase of Na⁺: (Ca²⁺ + Mg²⁺) ratio and by combining the excess CO₃ with the Na ions forming Na₂CO₃ salt which may be deposited causing reduction of permeability. The term RSC was suggested by Endaton to express suitability , it is calculated by the following equation (concentrations are in meq/l):

$$RSC = HCO_3^- + CO_3^{2-} - Ca^{2+} + Mg^{2+} \quad (2)$$

According to **USDA,1954(11)** classification of RSC hazards in irrigation water , all the study samples have RSC <1.25 (i.e safe with respect to RSC)>

The chemical composition of the study groundwater samples in comparison with the limits of safe irrigation water use , indicated that the hazards are mainly related to the total salinity in one side and to specific Cl or Mg toxicity in other side. This information is important for management the groundwater use in the study area.

4.2.1 WQH for Drinking

To evaluate the quality hazards of using the groundwater under study for drinking purposes , the concentrations of major ions, Table (1) and trace elements , Table (4) are compared with the maximum permissible limits indicated in standard classification,

Table (4), Results of Trace Elements Analysis

WHO limits	0.22	0.001	1	0.001	2	0.3	0.1		0.02	0.05			3
sample	Al	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Si	V	Zn
1	<0.01	<0.0006	<0.001	<0.01	<0.006	<0.02	<0.002	<0.001	<0.002	<0.008	5.516	0.0233	<0.0006
2	0.2937*	<0.0006	0.014	<0.01	<0.006	<0.02	<0.002	<0.001	<0.002	0.0876*	2.163	<0.01	<0.0006
3	<0.01	<0.0006	<0.001	0.031*	0.0139	<0.02	<0.002	<0.001	<0.002	<0.008	6.673	0.0372	0.0021
4	<0.01	0.002*	<0.001	0.0316*	<0.006	<0.02	<0.002	<0.001	<0.002	<0.008	6.939	0.0494	0.0338
5	<0.01	0.001*	0.0465	<0.01	<0.006	<0.02	0.0058	0.0108	<0.002	0.0538*	6.73	0.0361	<0.0006
6	<0.01	<0.0006	<0.001	<0.01	0.0199	<0.02	0.0039	<0.001	<0.002	0.0688*	6.404	<0.01	0.0654
7	<0.01	<0.0006	<0.001	0.0201*	<0.006	<0.02	<0.002	<0.001	<0.002	<0.008	6.246	0.02	<0.0006
8	<0.01	0.030*	<0.001	0.0266*	<0.006	<0.02	<0.002	<0.001	<0.002	<0.008	5.804	0.0248	<0.0006
9	<0.01	<0.0006	0.0192	<0.01	0.03	<0.02	<0.002	<0.001	<0.002	0.0632*	5.528	0.0306	0.0309
10	0.0428	<0.0006	<0.001	<0.01	<0.006	<0.02	<0.002	<0.001	<0.002	0.127*	5.238	0.0317	0.0261
11	0.092	0.012*	<0.001	<0.01	<0.006	<0.02	<0.002	<0.001	<0.002	0.0707*	4.554	0.0406	0.0062
12	0.1648	0.010*	<0.001	<0.01	<0.006	<0.02	<0.002	<0.001	<0.002	<0.008	4.511	0.0618	0.0139
13	0.3826*	<0.0006	<0.001	0.0231*	<0.006	<0.02	<0.002	0.0153	<0.002	<0.008	2.211	0.0452	<0.0006
14	0.3943*	<0.0006	<0.001	<0.01	<0.006	<0.02	0.0088	<0.001	<0.002	0.1139*	2.693	<0.01	0.0201
15	0.3515*	<0.0006	0.0203	<0.01	<0.006	<0.02	0.0036	0.019	<0.002	0.0425	3.215	<0.01	<0.0006
16	0.3027*	0.013*	<0.001	0.0401*	<0.006	<0.02	0.0064	<0.001	<0.002	<0.008	2.462	0.0321	0.0045
17	0.2655*	0.008*	0.0127	<0.01	<0.006	<0.02	0.0069	<0.001	<0.002	<0.008	2.84	<0.01	0.0122
max	0.3943	0.0298	0.0465	0.0401	0.03		0.0088	0.019		0.127	6.939	0.0618	0.0654
min	0.0428	0.0008	0.0127	0.0201	0.0139		0.0036	0.0108		0.0425	2.163	0.02	0.0021
avg	0.247909	0.011689	0.024557	0.029088	0.02154		0.005975	0.01498		0.0797	4.675211	0.036757	0.023558

*in table refer to the exceed max limit.

The maximum permissible limits for drinking water hazards based on TDS and major ions are indicated by (Rown et al , 1972) (12). Comparing the results of chemical analysis of the samples with the indicated limits , about 79.07 % , 48.83 % , 39.53 % , 60.46% , 79.07 % , 55.81 % , 52.94 % , 69.77 % of the samples are hazardous for drinking based on TDS , Ca^{2+} , Mg^{2+} , Cl^- , Na^+ , SO_4^{2-} , NO_3^- , Hardness and Ca, CO_3 , respectively.

According to the maximum permissible limits indicated by (WHO 1996) (13) for drinking water,

based on trace elements : (Fe^{3+} 0.3 mg/l & Cd^{2+} 0.001 mg/l & Co^{2+} 1 mg/l & Cr^{3+} 0.001mg/l & Cu^{2+} 2 mg/l & Mn^{2+} 0.1 mg/l & Ni^{2+} 0.02 mg/l & Pb^{2+} 0.05 mg/l & Al^{3+} 0.22 mg/l & Zn^{2+} 3 mg/l), nearly all the samples are safe except few ones indicated by (*) in table (4) which shows results of trace elements analysis and limits of drinking water hazards.

5. CONCLUSION

The present work presents a water quality study for the groundwater of northwest ElMinia governorate, mid upper Egypt. The results of

hydrochemical analysis of collected 43 groundwater samples have been treated, processed and analyzed using graphical, statistical and standard classifications.

The total salinity and major ions concentrations are highly variant and spatially increase westward and northward under the effects of rock minerals dissolution as well as upward leakage of saline water. The majority of samples (about 80%) shows a high stage of salinity development of (SO_4^{2-} , Cl^-) / (Na^+ , Ca^{2+}) hydrochemical facies, the rest are less developed with higher HCO_3^- proportions.

The hydrochemical composition of the study groundwater could be principally developed under rock / water interaction and mixing waters from different aquifers.

The water quality hazards of using the study groundwater for irrigation was evaluated based on TDS, Sodicity expressed as SAR, Alkalinity expressed as RSC and Specific Ions toxicity expressed by Na^+ , Cl^- , Mg^{2+} concentrations. The quality hazards for drinking are evaluated based on major ions and trace elements concentration in comparison with standards non exceeding limits.

6. Conflicts of interest

There are no conflicts to declare

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مصادر تملح المياه الجوفية ومناسبة استخدامها للرى والشرب , بنطاق شمال غرب المنيا , صعيد مصر

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يهدف هذا البحث الى تحديد مصادر تملح المياه الجوفية ومناسبة استخدامها لاغراض الرى والشرب بمنطقة شمال غرب المنيا وسط صعيد مصر , وهذا له اهميته فى برامج التنمية المستدامه والاستخدام الامثل للموارد المائية . اجريت دراسه هيدروكيميائية اعتمادا على نتائج تحليل الأيونات السائده والعناصر الشحيحة لعدد 43 عينه جمعت من منطقة الدراسه. تتفاوت قيم الملوحه الكليه وتركيزات الايونات السائده فى مدى واسع نسبيا , وتتزايد غربا وشمالا تحت تأثير ذوبان ماده الصخرية للخران الجوفى الى جانب تسرب المياه المالحة العميقه لأعلى. تعكس نوعيات المياه والتسلسلات الايونيه والتجمعات الملحيه والتحليل الاحصائى وعلاقة الايونات بالايونات , مرحلة متقدمه من التطور الملحى ونسبه عاليه من تدهور الجودة فى حوالى 80% من العينات تسود فيها السحنه الهيدروكيميائيه (SO₄²⁻, Cl⁻, Na⁺, Ca²⁺), بينما بقية العينات ذات تطور ملحى أقل وسياده للـ HCO₃⁻ على حساب الـ SO₄²⁻. كما تعكس تطور الملوحه الكليه للعينات من خلال عمليات ذوبان الصخور والتبادل الايوتى والخلط بين الخزانات الجوفيه. استخدمت المؤشرات الهيدروكيميائية والتصنيفات القياسية فى تقييم مخاطر الملوحه الزائده وسمية الأيونات الرئيسيه والعناصر الشحيحة كنتيجه لاستخدام المياه الجوفية فى الرى والشرب.