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HYDROGEOCHEMICAL ASSESSMENT OF GROUNDWATER AT THE AREA BETWEEN WADI QENA AND WADI EL-MATHULA, UPPER EGYPT

SAYED ABDOU AHMED SELIM

Geology Department, Faculty of Science in Aswan, South Valley University

ABSTRACT

The Quaternary sediments in the area between Wadi Qena and Wadi Mathula represent an important aquifer both in the floodplain area and in the desert fringes. The Nubian Sandstone rocks represent another aquifer, in which has groundwater exists under high artesian condition. All wells tapping these rocks are flowing and have relatively high temperature water (47°C).

The potentiometric map reveals that the Quaternary aquifer, under the floodplain area, has water level in the range from 65 to 70m (above sea level), while it varies from 70 to 115m under the desert fringes and along the wadies. The flow direction of groundwater is from the desert fringes to the floodplain areas. The source of groundwater recharge is mainly from the irrigation system in the Nile Valley and secondary from the underflow from the catchments areas of wadi Qena and wadi El-Mathula which receive heavy rainfalls during winter months every few years. The aquifers are discharged by pumping from the drilled wells which used for irrigation purposes, as well as by seepage to the Nile River.

The groundwater salinity of the Quaternary aquifer varies from fresh to brackish which has an average TDS value from 728 to 3308 mg/l. In the Nubian Sandstone aquifer, the groundwater salinity ranges from 1531 to 2187 ppm.

The water chemistry of the study area indicates that sodium ions represent the main dominating cation, while chloride and sulphate are the main dominating anions. The high concentration of these ions in the groundwater of the desert fringes may be related to leaching processes of highly soluble minerals, which has high effect in the geochemistry of the groundwater in its flow path.

The hypothetical salt combination revealed the presence of different salts arranged in terms of their predominance as: $NaCl$, Na_2SO_4, $MgSO_4$, $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $CaSO_4$, KCL and $NaHCO_3$.

The suitable water for drinking includes all the groundwater of the floodplain area, while the majority of the groundwater under the desert fringes is unsuitable for drinking. The groundwater from the Nubian Sandstone aquifer is slightly suitable for drinking.

According to the Sodium Adsorption Ratio (SAR) values, all groundwater samples from the floodplain areas are suitable for irrigation and can be used for all soil types. Under the desert fringes, 10% of the groundwater is suitable, 59% is moderately suitable, 29% is fairly suitable and 2% is unsuitable for irrigation purposes. All the groundwater samples from the Nubian sandstone aquifer are moderately suitable for irrigation.

More effective monitoring programs are recommended to be installed, and environmental impact assessment (EIA) studies are required by law for all new major projects that can adversely affect the quality of groundwater. Projects prior to the EIA requirement should be reviewed and, if necessary, modified. The present study offers a valuable basis for land-use planning and sustainable groundwater management in the studied area.

Keywords: floodplain area, the desert fringes, wadi Qena, wadi El-Mathula, water suitability

INTRODUCTION

The study area located to the east of the Nile; it is located within the transitional zone between the Eastern desert and the Nile valley. It extends between latitudes 25° 50' - 26° 33' N and longitudes 32° 40' - 33° 10' E and bounded by two major wadies in the south valley region (Wadi Qena and Wadi El Mathula), Fig.1. It is characterized by simple topography follows the regional northwest slopes towards the Nile. The average ground elevation varies from about 72 m above sea level in the western part (cultivated area) to about 126 m above sea level in the eastern part with a gentle slope to the northwest.

It covers a region that includes both the floodplain and the desert fringes which extends to the downstream of the wadis. During the last decade, a strip of the desert fringes has been reclaimed and irrigated completely with groundwater (Fig 2). In the near future, this area considers an important desert area for building new settlements (new Qena city, new Qift city, new industrial areas, etc.) and for new reclamation. These activities required a groundwater quality suitable for drinking, domestic and agricultural purposes.

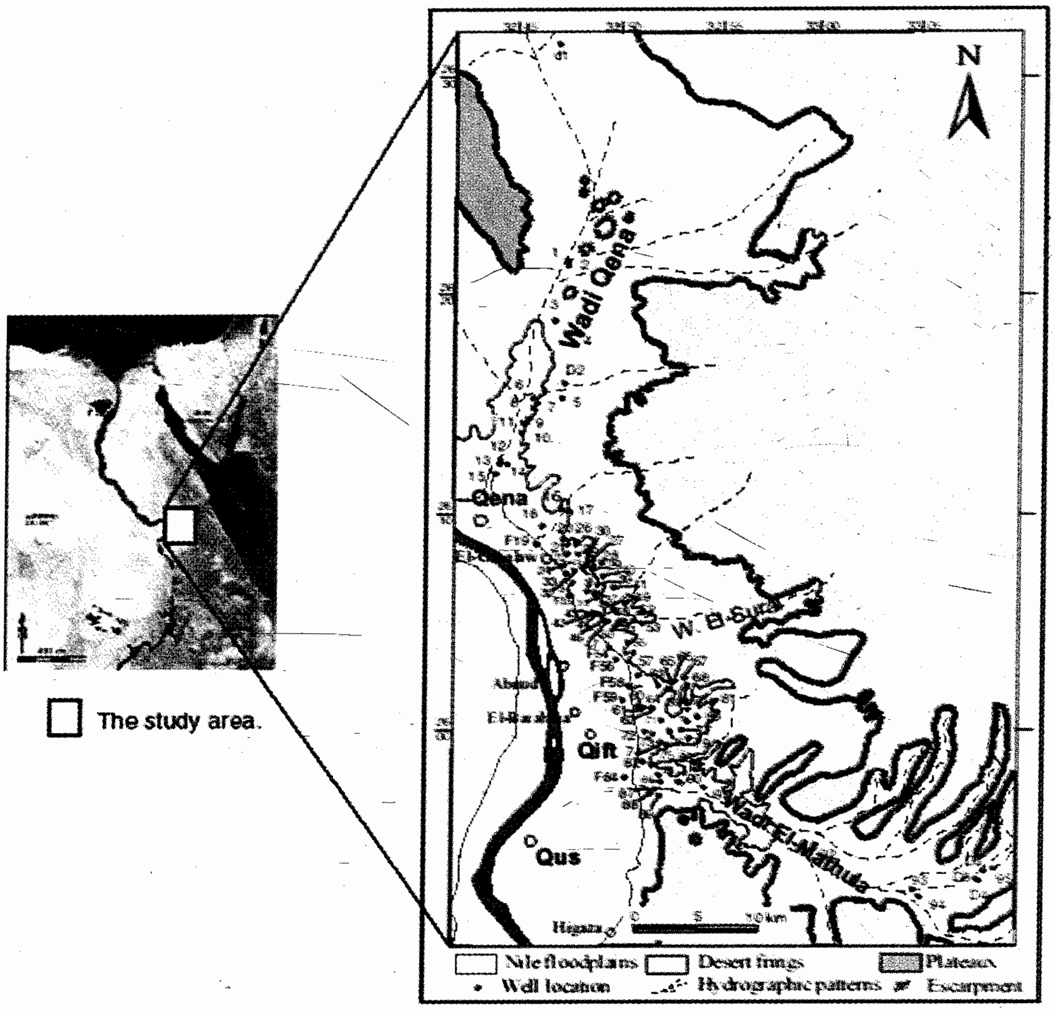

Fig. (1): The location and the main landforms of the studied area

The sustainable use of water requires a thorough understanding of the local geology, hydrogeology and hydrgeochemistry. Therefore the purpose of this paper is to study the geology, hydrogeology and to analyze the major constitutes of the groundwater from the different aquifers and to obtain a comprehensive picture of the quality of the groundwater in the studied area.

Fig. (2): Photographs showing new reclaimed areas (Desert fringes).

TOPOGRAPHIC FEATURES

In the study area, the landforms are mainly of sedimentary origin and can be summarized as follows (Fig. 1):

1- The floodplain of the Nile.

2- The desert fringes of the Nile valley.

3- The calcareous structural plateau.

4- The desert hydrographic pattern.

In the following a brief description of each feature is given.

1- The young alluvial plains (The Nile Floodplains)

The young alluvial plains form the cultivated lands bordering the stream of the Nile River on the east and west sides. The young alluvial plains are almost flat and gently slope from south to north with an average ground elevation of about 72 m above sea level. The surface of such plain is underlain by silt deposited possibly during Neolithic times (said, 1981)

2- The old alluvial plains (the desert fringes of the Nile valley)

These old plains fringe the Nile valley from both sides and exist as terraces found at vary heights above the young alluvial plains. The average ground elevation, above sea level, varies from about 72 m close to the floodplain area to about 126 m eastword with a gentle slope to the northwest. The terraces were formed as a result of the aggradations and degradation of the Nile valley relative to the eustatic changes of the ultimate base level of the Mediterranean (Ball: 1939). In some localities, these terraces were removed by water erosion.

3- The calcareous structure plateau.

The plateau in Qena area is composed of Limestone. The River cuts it Own stream through that plateau dividing it into two portions, one to east of the river and the other is to west, both of them are terminated with cliffs overlooking the flood plain. The Eastern plateau has an irregular surface, and rises to more than +450 m.

4- The desert hydrog aphic patterns

These are natural drainage lines that have the shape of elongated deeply incised depressions or gullies opened to the Nile valley. They cut the escarpment of the calcareous plateau as dry wadis and constitute a portion of the hydrographic pattern toward the Nile River e.g. Wadi Qena, wadi El Mathula and W. El Surai (Fig. 1). The origin of the. e wadis is believed to be due to faulting, modified later by erosion and deposition of young Quaternary sediments.

GEOLOGICAL SETTING

The study area is built up mainly of Quaternary sediments that bounded from the east by the Lower Eocene limestone plateau (Fig. 3). Information about the lithostratigraphic units of Upper Cretaceous - Lower Eocene exposures, along the central part of the Eastern Desert, is found in the work of Abd El Razik (1972) and Said (1962, 1981, and 1990) Sandford (1929 and 1934).

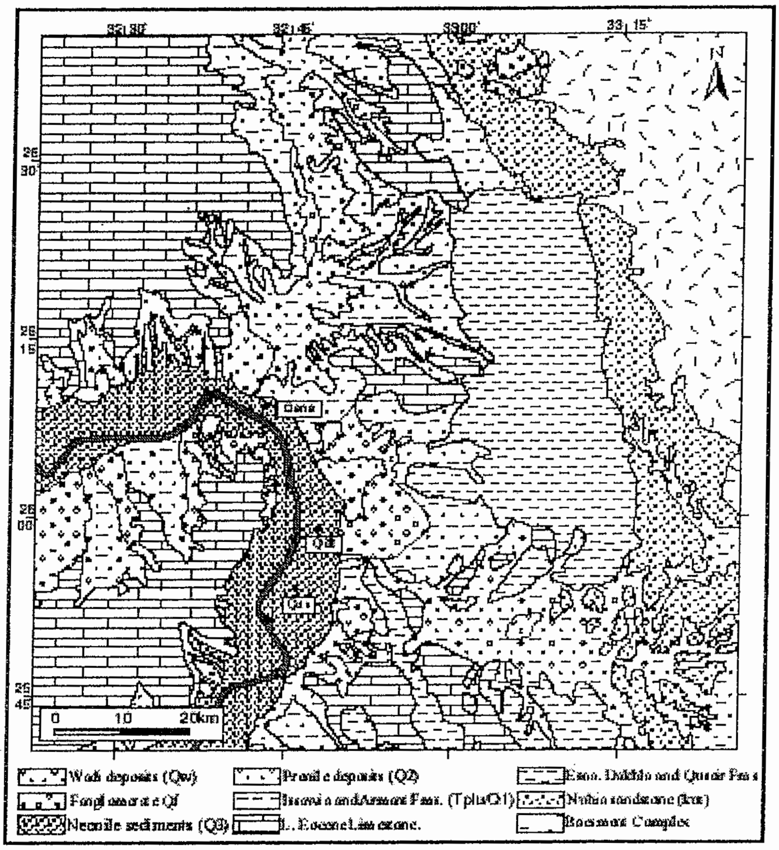

Fig. (3): Geological map of the studied area (after CONOCO, 1987)

The Quaternary deposits, which forming the main aquifer at the studied area, can be subdivided into the following units according to Said's classification (1981), figure 4:

i) Recent deposits (Qw): these deposits comprise unconsolidated sediments of terrestrial origin represented by wadi filling and sand deposits. The wadi filling is composed of gravels of different sizes with washed macrofossils and nummulitic in sandy, limy and clayey matrix which is derived from the adjacent limestone plateau. Sand deposits are represented as sand drifts along the foot of the scarps, and wind-blown sand sheets covering most of the slopes of the elevated plateaus.

ii) Neonile sediments (Q3): represent the last and extant river (the Neonile) occupying the valley of the Nile that rests over the eroded surface of the Prenile sediments with a marked unconformity. They are made up of the modern Nile silts and fluvatile sands which belong to the Late Pleistocene and the Holocene.

iii) The Prenile sediments (Q2): they outcropped in the southwestern part of the studied area and obscured beneath the recent sediments (Qw) along the wadi course (Fig. 4). They are represent by Qena Formation which is made up of cross bedded fluvial sands and gravel with minor clay beds. It overlies the Late Pliocene sediments (Madamoud Formation). The composite thickness of the formation including the subsurface graded sands and gravel unit exceeds 70m.

iv) Paleonile/Protonile interval sediments (Tplu/Q1): this interval was essentially one of great seismicity during which the climate was exceedingly arid. The resulting sediments from this pluvial phase which were deposited over the eroded surface of the Paleonile sediments were shared mainly into two formations (Armant and Issawia formations). The Armant Formation constitutes the early part of the hybrid Paleonile/Protonile interval and made up of conglomeritic deposit that crop out along the foot slopes of the bounding cliffs of the valley and in the delta of wadi Qena. Its thickness ranges from few meters to more than 40m. The Isawia Formation follows on top of Armant one and made up of massive rubble breccias, marl, clay and travertine.

v) The Paleonile (Tplu), Madamoud Formation: sediments belonging to the Paleonile river system consist of a long series of interbedded red-brown clays and thin fine-grained sand and silt laminae which crop out along the banks of the valley.

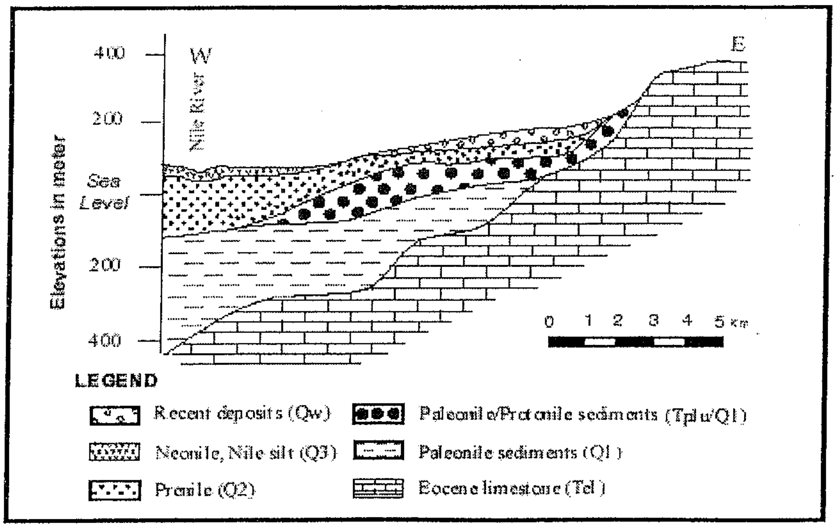

Fig. 4: Transverse geologic cross sections along Wadi Qena
(after Said, 1981 and Selim et al, 2007)

HYDROGEOLOGICAL SETTING

At the study area, the Quaternary sediments represent the main aquifer in both the floodplain and the desert fringe areas. Most of wells in the area are partially penetrating this aquifer, where the total depth of these wells varies from 15m in the Nile floodplains (the traditional cultivated land) to 200 m in the Desert fringes (reclaimed areas), (Mahmoud, 2005).

The Quaternary sediments are made up of successive layers of fluvial sands and gravels with minor clay intercalations (Prenile, Qena Formation). In the floodplain area, the Quaternary aquifer is capped with the Neonile silt and fine-grained sand that constitutes the base of the cultivated lands, which is replaced by the recent sediments (Qw) in the desert fringes. Therefore, the aquifer system is under semi-confined condition in the floodplain, but it is under unconfined condition in the desert fringes. In some locations of the desert fringe, the Nubian Sandstone aquifer was detected by deep drilling actions. In the study area, all wells tapping the Nubian sandstone are flowing artesian wells with water of high temperature, so the Nubian aquifer in this area has high artesian conditions (Fig. 5).

In the Quaternary aquifer, the depth to groundwater ranges from 5.0 m. to 40m. The hydrogeological data from the drilled wells (in Mar. 2008) is used for the construction of a potentiometric map of the Quaternary aquifer (Fig. 6). The map shows that the Quaternary aquifer has water level ranges between 65 and 70m (above sea level) in the floodplain area, while it varies between 70 and 115m at the desert fringes and along the wadies. Also the map indicates that the groundwater flow is from the desert fringes to the floodplain areas.

The recharge to the aquifer is mainly from the irrigation system in the Nile Valley, Secondary source of groundwater recharge is the underflow from the catchments areas of wadi Qena and wadi El-Mathula which receive heavy rainfalls during winter months each few years. The aquifers are discharging by pumping from the drilled wells which are being used for irrigation purposes, as well as by seepage to the Nile River. Generally, the relief of the studied area influences to wide extent the flow of the groundwater in the Quaternary aquifer, Rashed et al (2006).

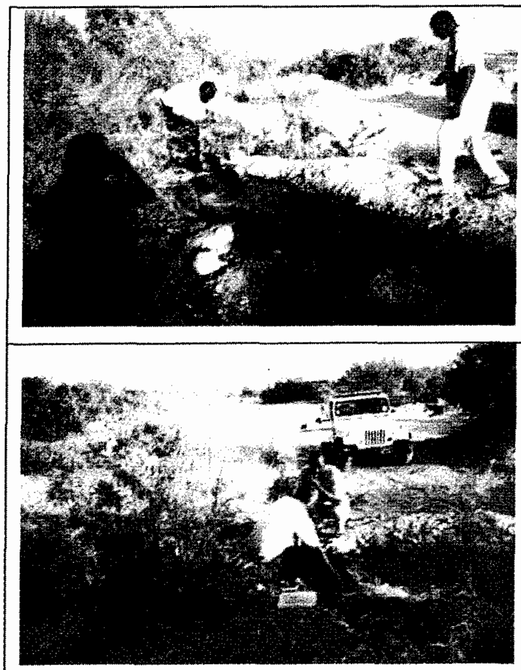

Fig. (5): Photos showing the artesian well tapping the Nubian sandstone aquifer

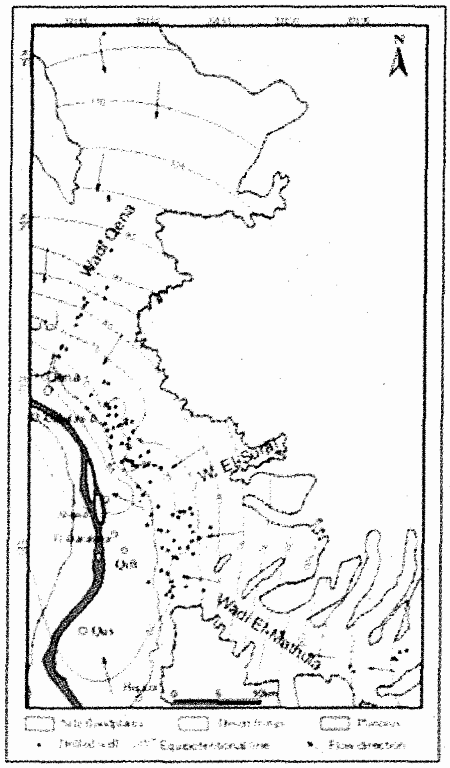

Fig (6): Potentiometric map of the studied area.

HYDROGEOCHEMICAL CHARACTERISTICS

In Mars 2008, a total of 101 groundwater samples were collected from the Quaternary aquifer (88 samples from the desert fringes and 7 from the Nile floodplain) and from Nubian aquifer (6 samples). These samples were analyzed to determine the concentration of major ions (Table 1). The results of the chemical analyses were used to understand the various possibilities for water recharge, movement and mixing in the study area.

Physical properties of the groundwater

According to the results of chemical analyses, the pH values range between 6.2 and 7. 5 which shows that groundwater is slightly acid to alkaline.

The measured temperature of the water of the Quaternary aquifer was natural of approximately 25°C, but the Nubian aquifer shows a slightly high temperature, where it reaches 47°C. The high temperature is related to the deep situation of this water, and its presence under high hydraulic pressure (artesian conditions).

The total hardness values range between 154 and 2152 ppm showing general increase toward the desert fringes and decrease toward the floodplain area. The groundwater classes according to the total hardness are 3% moderately hard water, 52% very hard water, and 45% lies in the range of excessively hard water (Fig. 7). The predominance class is the very hard water, mainly at the studied area.

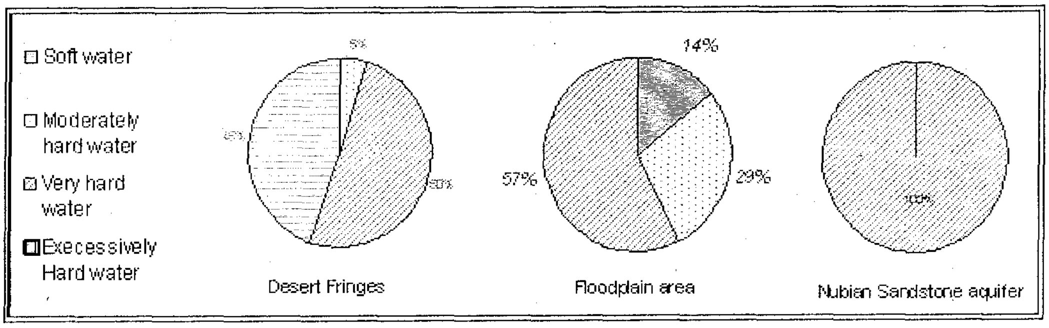

Fig. (7): Graphical presentation of the total hardness of the groundwater at the studied area.

Higher values of EC (average of 5168) are recorded in the groundwater of the desert fringes area indicating a longer residence time and less circulation of the groundwater.

The distribution of TDS in the groundwater of the study area is presented in Table 1. In the floodplain area, the TDS value is relatively low and ranges from 368 to 1026 mg/l with an average of 728 mg/l. The fresh character of the groundwater of this area may be related to its connection to water of the Nile River directly or through the irrigation system.

The majority of the groundwater sampled from the desert fringes area show high TDS values (Fig. 8), where there average values are 3308 mg/l in the Quaternary aquifer and 1831 mg/l in the Nubian sandstone aquifer (Table 1). The high salinity values of the Quaternary aquifer, under this area, may be related to dissolving of natural salts from the host sediments and from soil during rains and irrigations that percolate to the aquifer to increase its salinity. The moderate salinity of the

Nubian sandstone aquifer (relative to the Quaternary aquifer) may be due to its seasonal recharge by the rain water from fissures in the basement rocks of the Red Sea hills. A narrow strip to the western part of the desert fringes is subjected to mixing and dilution from the fresh water of the floodplain sector. This led to the lowering of the TDS of the Quaternary aquifer along this strip (TDS range between 1000 and 2000mg/l).

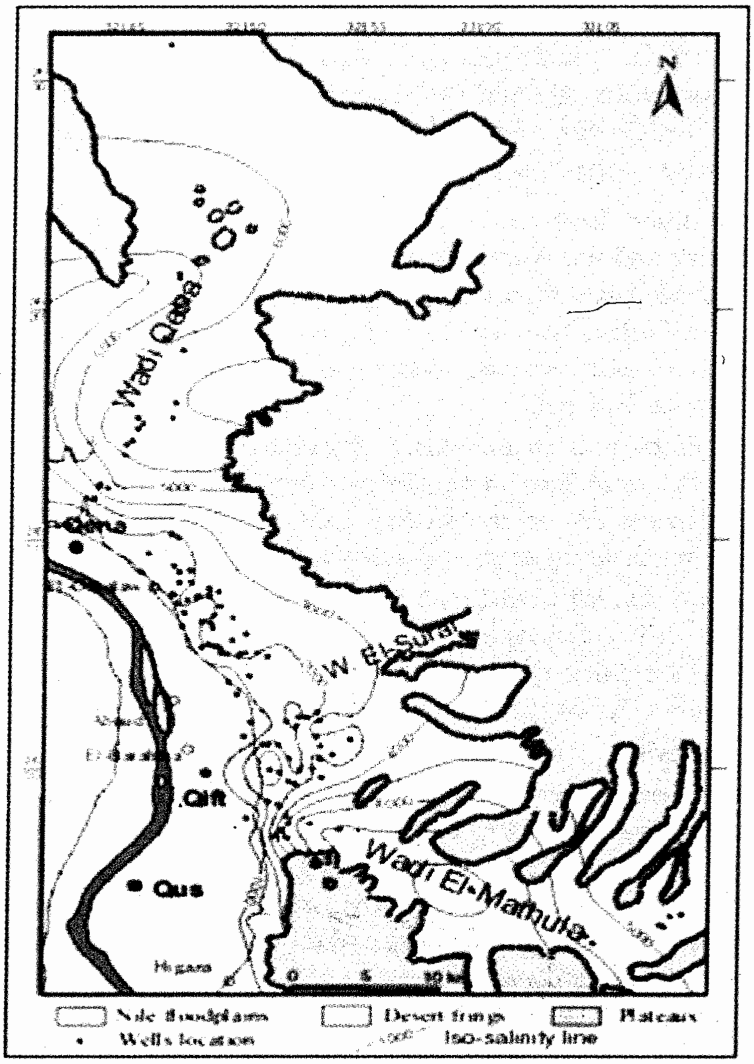

Fig. (8): Salinity map of the groundwater at the studied area.

Major ions concentration and distribution

The hydrochemical properties of groundwater samples collected from the studied area are shown in Table 1. Most samples were from boreholes tapping the Quaternary aquifer at the desert fringes area.

Under the floodplain area, the chemical composition of the groundwater is dominated by Sodium Na^+ and Bicarbonate HCO_3^- (Table 1). The high concentration of HCO_3^- indicates the intense chemical weathering processes taking place in this aquifer. Natural processes such as the dissolution of carbonate minerals and of soil CO_2 gas could be a mechanism which supplies HCO_3^- to the groundwater of the Quaternary aquifer.

Under the desert fringes, Na^+ and Cl^- are dominant in the groundwater of both the Quaternary and the Nubian sandstone aquifers (Table 1). In general, all chemical constituents have shown an increase in their concentrations under the desert fringes. The high concentration of these ions may be related to leaching processes of highly soluble minerals, which has high effect in the geochemistry of the groundwater in its flow path.

Sulphate (SO_4^{2-}) is the next in abundance and constitutes an average of 138, 932 and 429 mg/l to the total ions in floodplain, fringes and the Nubian sandstone water samples, respectively. In the studied area, the sources of sulphate include the dissolution of sulphide minerals, rainfall and fertilizers.

Thus, the order of cations abundance in both floodplain and desert fringes is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$. Among the anions, the order of their abundance in both the floodplain and the desert fringes are $HCO_3^- > SO_4^{2-} > Cl^-$ and $Cl^- > SO_4^{2-} > HCO_3^-$, respectively (Fig. 8).

Groundwater genesis

The hydrochemical parameters (rK/rCl, rNa/rCl, rMg/rCl, rCa/rCl, and rSO_4/rCl.) are useful in comparing water from different sources and to define its genesis. The standard values for sea water are 0.0181, 0.8537, 0.1986, 0.0385 and 0.103 respectively (Ovchinnikov, 1955). In the study area, the values of these parameters are greater than the standard values of normal sea water indicating meteoric origin of the groundwater.

The meteoric genesis of groundwater can be detected using the hydrochemical parameter ($\frac{(rK + rNa) - rCl}{rSO4}$), its value ranging between 0.098 and 2.86 that the majority of the groundwater (60%) belonging to the surface and shallow meteoric water type, while the other are deep meteoric genesis.

Table (1): The results of the chemical analyses for the groundwater samples collected from the Quaternary aquifer and from the Nubian sandstone aquifer (units in mg/l).

The Quaternary aquifer (Nile Valley desert fringes)											
Sample No	**pH**	**EC**	**TDS**	**Ca^{++}**	**Mg^{++}**	**Na^{+}**	**K^{+}**	**$HCO3^{-}$**	**$SO4^{--}$**	**Cl^{-}**	**SAR**
1	7.0	5705.6	3651.6	146.4	108.1	1031.7	25.5	213.5	998.9	1127.6	15.8
2	6.8	7071.0	4525.5	164.3	115.9	1310.8	27.9	217.8	1379.4	1309.4	19.1
3	6.2	8731.8	5588.3	310.8	215.4	1329.6	47.9	103.7	1603.8	1977.2	14.2
4	6.2	10262.6	6568.1	267.2	237.8	1799.4	56.9	128.1	1838.3	2240.4	19.3
5	6.6	13414.6	8585.3	342.0	301.6	2407.7	73.8	146.4	2346.1	2967.8	22.9
6	6.5	9544.2	6108.3	273.9	190.2	1660.8	43.8	140.3	1821.1	1978.2	18.9
7	6.8	8990.0	5753.6	267.2	212.4	1518.8	36.9	219.6	1661.8	1836.9	16.8
8	7.3	13065.4	8361.8	315.3	281.6	2319.0	63.9	103.7	2399.8	2878.5	22.9
9	6.9	12077.3	7729.5	393.9	254.0	2051.0	76.9	152.5	2282.1	2519.0	19.8
10	6.6	8409.0	5381.7	67.1	145.1	1720.7	56.9	109.8	1400.0	1882.2	27.1
11	6.6	11103.8	7106.4	332.1	204.3	1978.8	53.8	170.8	2071.7	2294.9	21.1
12	6.4	5703.7	3650.4	91.9	72.0	1132.0	20.9	296.9	1042.8	993.9	21.5
13	6.2	9777.0	6257.3	227.9	203.8	1768.3	45.3	322.8	1703.2	1985.9	20.5
14	6.3	9065.1	5801.7	245.8	190.8	1561.1	38.8	313.5	1765.2	1686.4	18.2
15	6.8	3924.8	2511.8	72.5	65.4	742.3	18.3	176.9	646.0	790.5	15.2
16	6.8	3780.1	2419.3	62.4	55.7	717.8	38.2	276.6	512.3	756.3	15.9
17	6.8	2893.1	1851.6	41.4	31.8	554.9	13.8	274.5	515.0	420.3	15.8
18	7.0	2349.4	1503.6	42.1	33.2	393.7	13.8	355.8	336.9	328.1	11.0
20	7.2	2708.9	1733.7	24.0	32.4	497.3	13.8	463.6	406.5	296.0	15.6
21	7.2	2586.8	1655.6	24.0	30.8	492.0	6.9	427.0	337.3	337.6	15.7
22	7.4	2201.6	1409.0	28.7	24.6	419.0	13.8	237.9	356.3	328.8	13.9
23	7.3	2088.9	1336.9	62.4	46.7	319.5	13.8	274.5	243.1	376.9	7.4
24	7.1	2849.6	1823.8	46.8	32.9	554.9	13.8	170.8	527.7	476.9	15.2
25	7.4	3109.5	1990.0	50.8	35.7	537.8	34.4	359.9	527.3	444.2	14.1
26	7.2	2670.4	1709.1	41.0	34.3	509.9	13.8	219.6	463.2	427.3	14.2
27	7.2	5533.3	3541.3	96.1	81.9	1029.6	55.0	396.3	941.3	941.1	18.6
28	6.9	3692.3	2363.1	42.8	51.9	751.0	16.9	164.2	624.9	711.4	18.3
29	7.5	3352.6	2145.7	62.2	43.2	640.8	13.8	219.6	653.1	513.1	15.3
30	6.9	2813.2	1800.4	62.8	38.7	528.9	12.0	225.2	416.7	516.1	12.9
31	7.4	3263.2	2088.5	52.8	49.7	627.8	13.8	231.8	529.6	582.9	14.9
32	7.4	4135.8	2646.9	66.4	52.5	810.8	38.2	247.2	570.2	861.7	18.0
33	7.4	3366.5	2154.5	70.8	43.8	584.9	55.0	347.7	542.1	510.3	13.5
34	6.7	2617.7	1675.3	65.6	41.0	462.8	13.5	255.7	432.7	404.0	11.0
36	6.8	2381.1	1523.9	41.4	31.5	465.9	9.2	166.4	367.6	441.9	13.3
37	6.4	3973.0	2542.7	62.2	48.5	788.3	13.9	203.5	774.1	652.1	18.2
38	6.5	5644.0	3612.2	84.3	66.9	1123.6	19.1	290.1	1076.6	951.7	22.2
39	6.8	2664.0	1704.9	48.0	32.8	518.4	11.5	184.7	441.7	467.8	14.1
40	6.8	3708.4	2373.4	52.5	51.6	744.7	14.6	194.7	601.7	713.6	17.5
41	7.2	3356.3	2148.0	50.8	45.3	667.5	12.6	184.7	562.4	624.7	16.4
42	7.2	2414.0	1544.9	65.4	51.5	387.2	9.8	335.5	353.0	342.4	8.7
43	6.7	4094.8	2620.7	109.6	68.5	713.8	19.1	253.5	694.4	761.9	13.2
44	6.5	5046.6	3229.8	96.3	65.9	973.3	19.1	324.5	890.1	860.5	18.7
45	6.8	5243.3	3355.7	113.7	108.9	891.6	22.1	195.2	1047.7	976.5	14.3
46	7.2	1930.1	1235.3	45.4	34.0	327.5	6.5	244.0	304.9	273.0	8.9
47	6.9	3456.9	2212.4	59.5	52.4	662.5	16.1	254.7	543.4	623.9	15.1
48	6.9	3840.4	2457.9	62.5	51.9	753.3	15.6	237.4	640.7	696.5	17.0
49	6.7	5111.5	3271.3	84.2	71.7	994.6	17.6	316.9	911.0	875.3	19.2
50	6.9	3503.2	2242.1	61.1	52.0	671.4	14.1	251.8	557.3	634.3	15.3
51	6.9	4174.7	2671.8	88.2	73.0	742.7	16.5	245.7	824.3	681.5	14.2
52	6.8	3220.5	2061.1	56.1	43.8	618.4	11.8	231.8	546.3	553.0	15.0
53	7.2	2527.8	1617.8	50.7	37.0	481.9	9.8	190.8	371.6	475.9	12.5
55	7.1	2803.9	1794.5	61.5	42.3	513.6	10.5	245.7	461.7	459.3	12.3
57	6.8	1855.5	1187.5	46.8	38.9	302.1	7.4	237.9	313.4	241.1	7.9
60	6.7	1944	1244	34.0	27.6	332.3	5.6	330.4	316.7	197.3	10.3

Table (1): Continued

Sample No	pH	EC	TDS	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$HCO3^{-}$	$SO4^{--}$	Cl^{-}	SAR
61	6.8	5285	3382	133.6	84.3	927.0	19.5	196.4	1093.0	928.5	15.5
62	7.0	2196.0	1405.5	51.8	41.8	373.2	12.1	241.8	377.2	307.7	9.4
63	7.1	3082.8	1973.0	85.5	76.5	465.4	12.7	225.7	563.7	543.6	8.8
64	7.2	3448.0	2206.7	61.5	50.3	664.6	14.5	247.4	527.7	640.9	15.2
65	6.8	5168.1	3307.6	155.0	97.4	887.6	21.2	244.0	977.8	924.5	13.8
66	7.5	1877.9	1201.9	43.4	34.2	329.7	7.9	201.3	268.3	317.0	9.1
67	7.5	2085.5	1334.7	38.1	43.0	360.8	9.8	223.4	362.1	297.5	9.5
68	6.8	6667.5	4267.2	92.9	82.4	1347.4	25.8	297.9	1222.3	1198.4	24.5
69	6.9	4890.4	3129.9	78.8	58.6	972.4	19.9	247.4	904.7	847.9	20.2
70	7.1	3367.1	2154.9	61.8	45.4	658.0	13.5	213.5	521.2	641.5	15.5
71	6.8	2419.5	1548.5	59.8	41.9	427.0	12.7	254.7	323.4	428.9	10.4
72	6.3	6794.9	4348.8	183.0	145.4	1179.7	26.5	201.3	1343.8	1269.1	15.8
73	6.7	6268.4	4011.8	168.6	127.3	1083.2	28.5	226.8	1194.9	1182.5	15.3
74	6.9	3336.0	2135.0	94.2	68.1	554.3	12.7	225.2	598.0	582.5	10.6
75	6.7	4266.1	2730.3	82.6	52.2	823.8	15.6	259.1	814.0	683.0	17.5
76	7.1	1945.2	1244.9	45.4	33.9	341.6	12.4	198.2	298.0	315.5	9.3
77	6.9	5576.9	3569.2	130.9	110.7	987.8	23.2	128.1	1105.8	1082.7	15.4
78	7.1	5737.8	3672.2	136.3	101.3	983.5	23.6	170.8	1172.1	1084.5	15.5
79	6.6	4656.8	2980.3	61.8	62.3	941.5	18.7	224.7	779.4	891.9	20.2
80	6.4	2601.6	1665.0	40.8	34.3	514.4	12.9	145.9	429.9	486.8	14.4
81	6.4	4236.3	2711.3	64.5	50.5	849.5	15.6	196.9	805.4	728.8	19.2
82	7.0	3543.2	2267.7	73.3	47.9	658.9	15.6	266.2	672.4	533.4	14.7
83	6.3	3881.7	2484.3	82.9	54.1	724.3	12.7	296.9	711.1	602.3	15.2
85	7.4	6626.0	4240.7	149.6	123.8	1140.9	31.8	115.9	1281.9	1396.7	16.7
86	7.5	9991.4	6394.5	259.3	159.7	1784.5	47.3	97.6	1909.0	2137.1	21.5
87	7.2	9273.3	5934.9	259.3	161.6	1642.3	45.5	225.7	1836.4	1764.2	19.7
88	6.4	5908.0	3781.1	120.2	97.8	1049.0	21.8	274.5	1189.2	1028.5	17.2
89	7.5	7511.6	4807.4	93.2	97.0	1536.4	29.2	311.3	1327.6	1412.8	26.6
90	7.2	10769.2	6892.3	214.6	194.0	2028.1	52.5	109.8	1949.8	2343.4	24.1
91	7.3	11257.1	7204.6	340.9	223.2	1945.8	47.2	315.9	2110.9	2220.7	20.1
92	6.4	13330.4	8531.5	397.3	281.9	2317.7	57.1	183.0	2784.4	2510.2	21.7
93	7.5	8179.6	5234.9	168.3	123.2	1493.3	37.2	174.2	1508.0	1730.7	21.3
94	7.5	10663.4	6824.6	290.6	218.1	1893.7	41.4	183.7	2207.4	1989.8	20.4
Average	*6.9*	*5168*	*3308*	*116*	*90*	***940***	*25*	*232*	*932*	*972*	*16*
Minimum	*6.2*	*1856*	*1188*	*24*	*25*	*302*	*6*	*98*	*243*	*197*	*5*
Maximum	*7.5*	*13415*	*8585*	*397*	*302*	*2408*	*77*	*464*	*2784*	*2968*	*27*

The Quaternary aquifer (Nile floodplain area)

Sample No	pH	EC	TDS	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$HCO3^{-}$	$SO4^{--}$	Cl^{-}	SAR
F1	7.4	1566.0	1002.2	24.0	25.9	245.8	13.8	439.2	155.5	98.0	8.3
F2	6.8	1603.1	1026.0	48.4	31.3	253.2	9.1	225.7	227.8	230.4	7.0
F3	7.3	1444.1	924.2	54.7	35.9	194.1	4.7	292.8	164.4	177.5	5.0
F4	7.4	1091.4	698.5	41.7	32.7	125.7	7.4	244.0	183.2	63.8	3.5
F5	7.4	995.2	636.9	41.4	27.7	124.0	5.6	213.5	117.2	107.5	3.7
F6	7.1	574.9	368.0	26.7	21.3	44.5	2.9	229.4	25.4	17.7	1.6
F7	7.1	688.0	440.3	32.0	20.6	76.3	2.1	166.0	92.0	51.3	2.6
Average	*7.2*	*1137.5*	*728.0*	*38.4*	*27.9*	***151.9***	*6.5*	***258.7***	*137.9*	*106.6*	*4.5*
Minimum	*6.8*	*574.9*	*368.0*	*24.0*	*20.6*	*44.5*	*2.1*	*166.0*	*25.4*	*17.7*	*1.6*
Maximum	*7.4*	*1603.1*	*1026.0*	*54.7*	*35.9*	*253.2*	*13.8*	*439.2*	*227.8*	*230.4*	*8.3*

The Nubian sandstone aquifer											
Sample No	**pH**	**EC**	**TDS**	**Ca^{++}**	**Mg^{++}**	**Na^{+}**	**K^{+}**	**$HCO3^{-}$**	**$SO4^{--}$**	**Cl^{-}**	**SAR**
D1	7.1	2392.9	1531.5	59.5	36.7	432.8	12.4	229.1	322.5	438.5	10.9
D2	6.7	2755.1	1763.2	40.1	34.0	519.0	16.9	280.6	446.4	426.2	14.6
D3	7.1	2976.6	1905.0	58.5	41.2	578.0	12.9	219.6	382.0	612.9	14.2
D4	7.1	2531.8	1620.3	62.2	43.4	449.4	10.2	258.7	363.3	433.2	10.7
D5	7.4	3417.7	2187.3	57.8	49.0	673.8	14.1	219.1	467.8	705.6	15.8
D6	7.2	3091.7	1978.7	62.2	46.3	570.9	10.9	243.5	592.4	452.5	13.4
Average	*7.1*	*2861.0*	*1831.0*	*56.7*	*41.8*	*537.3*	*12.9*	*241.8*	*429.1*	*511.5*	*13.2*
Minimum	*6.7*	*2392.9*	*1531.5*	*40.1*	*34.0*	*432.8*	*10.2*	*219.1*	*322.5*	*426.2*	*10.7*
Maximum	*7.4*	*3417.7*	*2187.3*	*62.2*	*49.0*	*673.8*	*16.9*	*280.6*	*592.4*	*705.6*	*15.8*

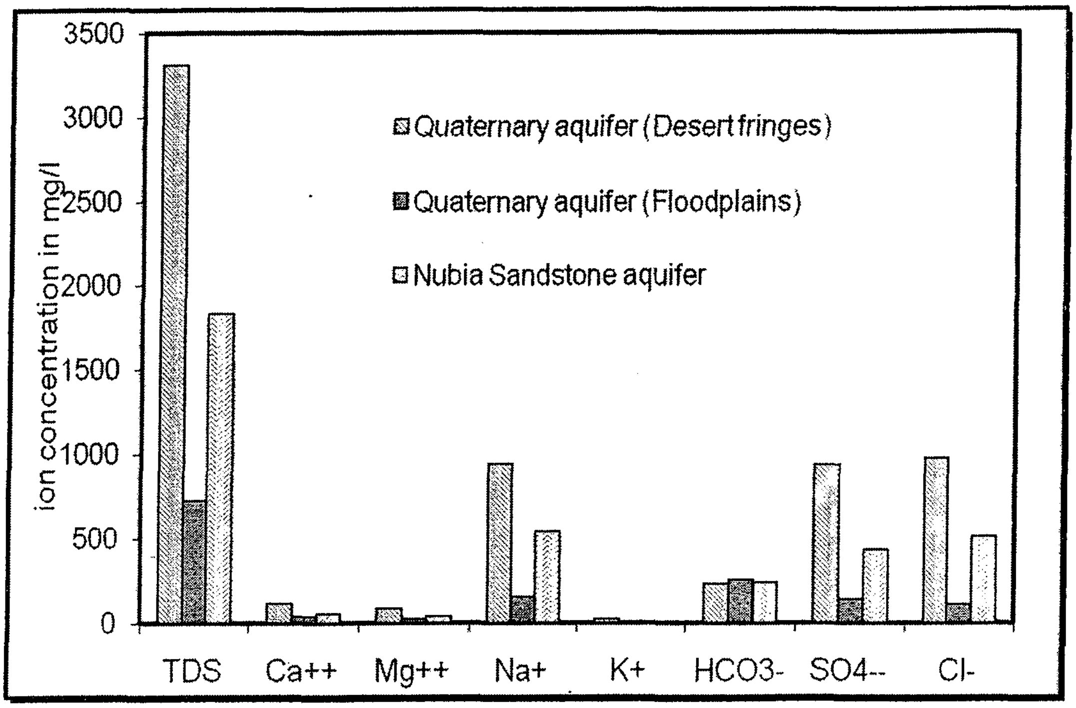

Fig. 9 Graphical representation of variations in mean concentration of in the different aquifersthe chemical constituents

rNa+rK/rCl also give an indication about the genesis and origin of the groundwater. In marine or sea water it ranges between 0.85 and 0.87, while in the meteoric water it is more than unity. The calculations of rNa+rK/rCl ratio reveal that it ranges between 1.06 and 4.02. According to these calculations, it is clear that all the collected groundwater samples from the study area are of meteoric origin.

Hypothetical salt combination

The hypothetical salt combination of the groundwater samples revealed the presence of the following groups of most salt assemblages:

- $NaCl > Na_2SO_4 > Mg(HCO_3)_2 > Ca(HCO_3)_2$
- $NaCl > Na_2SO_4 > MgSO_4 > Ca(HCO_3)_2$
- $NaCl > Na_2SO_4 > MgSO_4 > CaSO_4$
- $NaCl > Na_2SO_4 > Ca(HCO_3)_2 > MgSO_4$
- $NaCl > MgSO_4 > Na2SO_4 > CaSO_4$
- $Na_2SO_4 > NaCl > Ca(HCO_3)_2$
- $Na_2SO_4 > Mg(HCO_3)_2 > Ca(HCO3)_2$
- $Mg(HCO_3)_2 > Ca(HCO_3)_2 > NaHCO_3$

The hypothetical salt combination revealed the presence of different salts arranged in terms of their predominant as NaCl, Na_2SO_4, $MgSO_4$, $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $CaSO_4$, KCL and $NaHCO_3$ where the average of equivalent percentage is 50.13%, 23.77%, 10.11%, 7.9%, 3.78%, 2.89%, 1.1% and 0.32% respectively.

Hydrochemical genetic classification

The groundwater samples in the investigated area interpreted and classified by using Trilinear diagram of Piper (1944) and Schoeller's diagram (1962), using UN. GWW software program (1994).

The trilinear diagram (Fig. 10) shows two hydrochemical facies: Na-HCO_3-SO_4 in the floodplain area and Na-Cl-SO_4 in the desert fringes Quaternary and Nubian sandstone aquifers.

Schoeller diagram (Fig. 11), reveals a high of sodium, chloride and sulphate ions which indicates that the dominant salts, in the studied area, are sodium chloride and sodium sulphate.

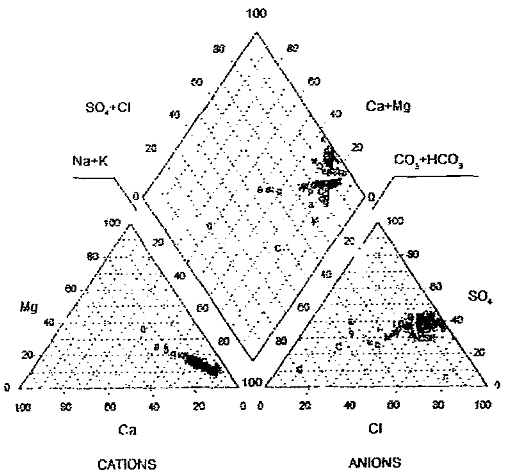

Fig. (10): Piper trilinear diagram for the groundwater samples in the study area.

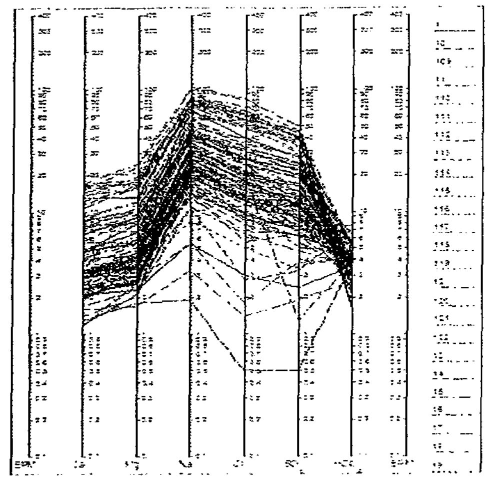

Fig. (11): Schoeller diagram presentation for the groun dwater samples in the study area

GROUNDWATER QUALITY

1- Groundwater suitability for drinking and domestic uses:

Fig. 12 shows a comparison between the chemical analysis of the collected water samples and the maximum acceptable concentration for drinking water according to the World Health Organization (1996). According to this figure, the groundwater quality of the study area can be classified as follow:

1- Suitable water for drinking includes all the groundwater at the floodplain areas, while the groundwater from the Nubian Sandstone aquifer is slightly suitable.

2- The majority of the groundwater under the desert fringes is unsuitable for drinking.

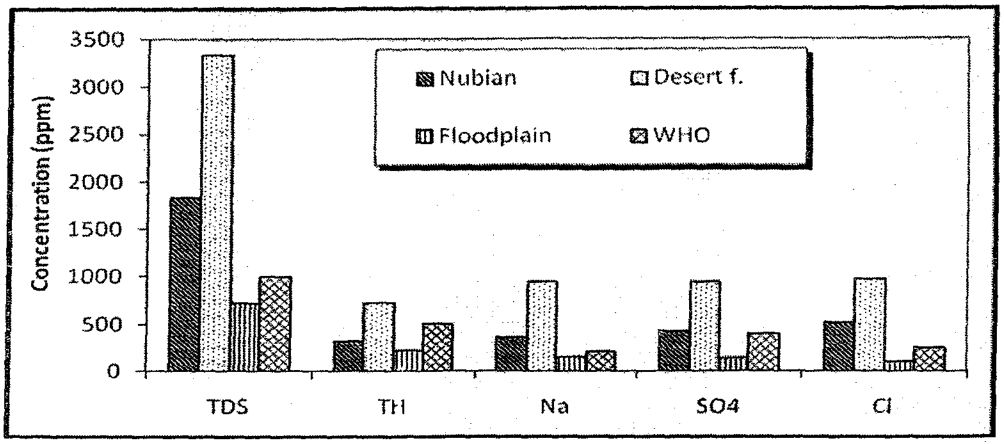

Fig. (12): Groundwater suitability for drinking according to WHO, (1996).

According to the degree of hardness, classified in terms of calcium carbonate concentration (Ayers et al, 1994), two water categories can be distinguished. Water can be used for laundry purposes (TH <180ppm), as some of the water sampled from the floodplain area. The second category is water of TH > 180ppm that can't be used for domestic use. They include all the wells of the desert fringes area and of the Nubian aquifer.

2- Groundwater suitability for irrigation purposes

a- According to the Sodium Adsorption Ratio

The SAR values of the Quaternary aquifer show that all of the groundwater sampled from the floodplain areas is suitable for irrigation and can be used for all soil types. Under the desert fringes 10% of the groundwater is suitable, 59% is moderately suitable, 29% is fairly suitable and 2% is unsuitable for irrigation purposes (the US salinity laboratory staff, 1954). All The groundwater sampled from the Nubian sandstone aquifer is moderately suitable for irrigation.

These results indicate that the majority of the groundwater in the studied area is moderately suitable and can be used for irrigation of sandy soils with good permeability. The unsuitable water can be used for soils with adequate drainage, special management and using plants with good salt tolerance.

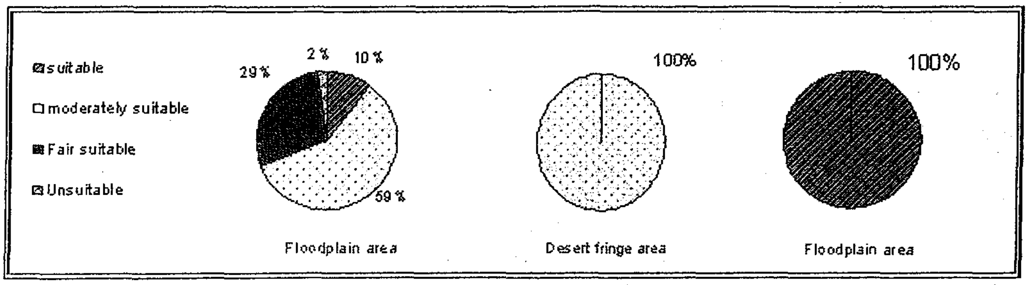

Fig. (13): Graphical illustrations for the groundwater suitability for irrigation, Qena area.

CONCLUSIONS

Hydrogeological and hydrochemical investigation was conducted on the Quaternary and the Nubian sandstone aquifers in the area between W.Qena and W. El Mathula, Upper Egypt.

High values of EC and TDS, associated with wells at the desert fringes area, are documented which may indicate a longer residence time and less circulation of the groundwater. This, in turn, led to dissolving natural salts from the host sediments and soil during rains and irrigations, then percolating to the aquifer and increasing its salinity.

The water chemistry of the study area indicates that sodium ions represent the main dominating cation, while chloride and sulphate are the main dominating anions. High chloride (and sodium) concentration can also result from dissolution of soil and rock minerals and/or evapotranspiration of the irrigation water resulting in the concentration of salts.

The geochemical composition of groundwater in the studied area indicates a direct relation between the lithology and relative abundance of ions. For instance, groundwater from the desert fringes has high dissolved solids, whereas sandstone rocks yield water with moderately low dissolved solids. Groundwater from the floodplain area has low dissolved solids due to the continuous recharge of fresh water from the Nile River through the irrigation conveying system.

Groundwater from the floodplain area has low salinity and SAR values; therefore water is suitable not only for drinking and domestic purposes, but also for agricultural uses. Most of groundwater samples related to the desert fringes exceed the limits of drinking water for major constituents according to the international standards. The majority of these waters are moderately suitable for irrigation purposes.

More effective monitoring programs are recommended to be installed, and environmental impact assessment (EIA) studies are required by law for all new major projects that can adversely affect the quality of groundwater. Projects prior to the EIA requirement should be reviewed and, if necessary, modified. The present study can provides a valuable basis for land-use planning and sustainable groundwater management in the studied area.

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