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GEOLOGY

Hydrogeochemical Studies on The Groundwater East Gabel El Qalamoon Area, Western Desert, Egypt

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Abstract: The Quaternary deposits of Pleistocene and Holocene cover the major part of the area under study. The Pleistocene deposits are composed of sand and gravels, and covered by Holocene unconsolidated silt and clay. The Pleistocene deposits represent the main water bearing formation in the area. Water samples were collected from 34 wellsin the area. The samples were analyized chemically for studying the water quality for the drinking and irrigation purposes. The hydrochemical studies show that the salinity of the groundwater ranges from 645 to 273170 ppm according to the locality of the studied wells. It increases in the western part of the area which is close to the Eocene aquifer water . The salinity and major ions are higher in shallow wells than deep wells. In some localities the groundwater can be used for domestic and irrigation purposes.

Introduction: The area under study lies at East of Gabal Al Qalamoon (Fig. 1), with coordinates 28° 15', 28° 55' N and 30° 30', 30° 45' E, crossing the Assiut-Cairo western road. It is bounded to the east by the cultivated areas (west Maghaghah, Beni Mazar and Samalut areas) and the River Nile, to the west by limestone of the Middle Eocene, and surrounded from northern and southern borders by Beni Suef and El Minia Governorate respectively. The surface geological map (Fig. 2) which is drawn by the author, shows that most of the area is covered by different rocks from Tertiary to Quaternary with some exposures of Oligocene basalt.

The climatic conditions of the study area are of arid type being hot, dry and rainless in summer and rare rainfall in winter. The average temperature varies from 21°C in winter to 36°C in summer.

The present work is devoted for studying the groundwater quality for irrigation and drinking purposes. Samples of groundwater from 34 wells (Fig. 1) were collected and analyzed chemically for cations (K^+, Na^+, Ca^{++} and Mg^{++}), and anions (HCO_3^-, CO_3^-, Cl^- and SO_4^-).

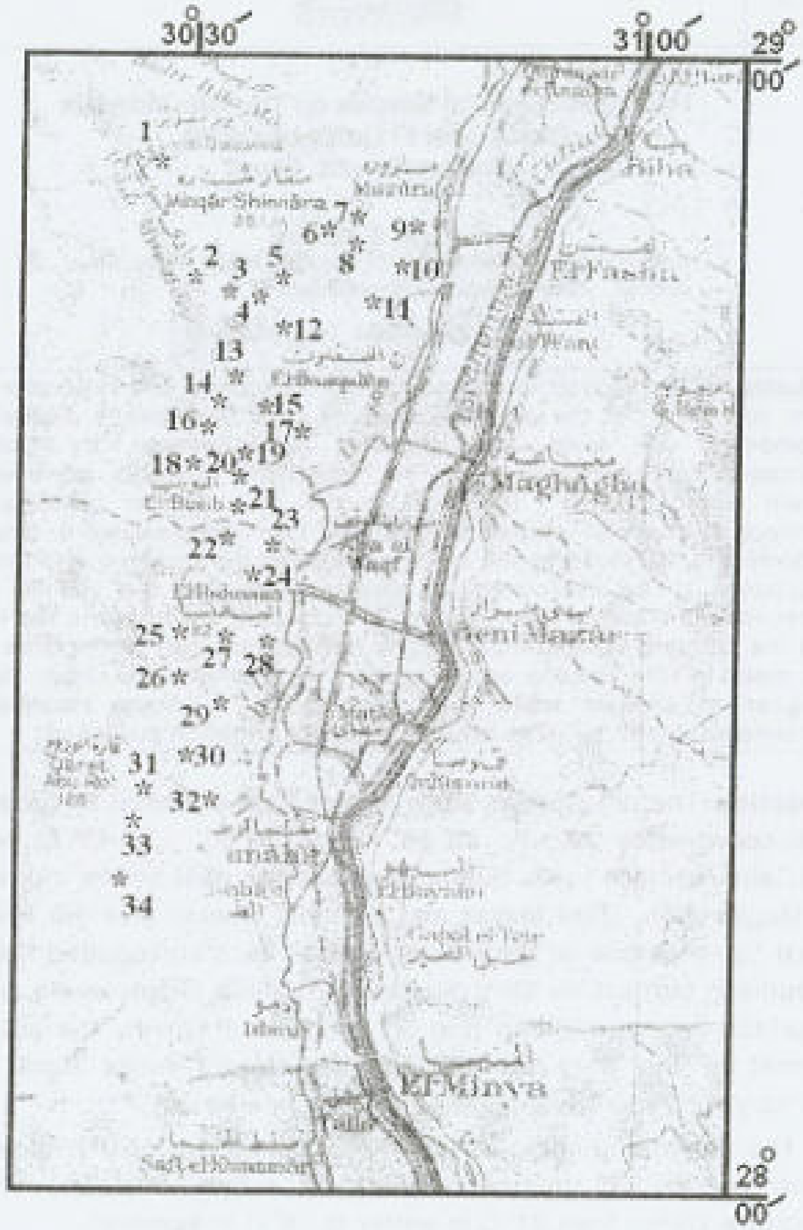

Fig. 1: Key map of the studied area and locations of water wells *

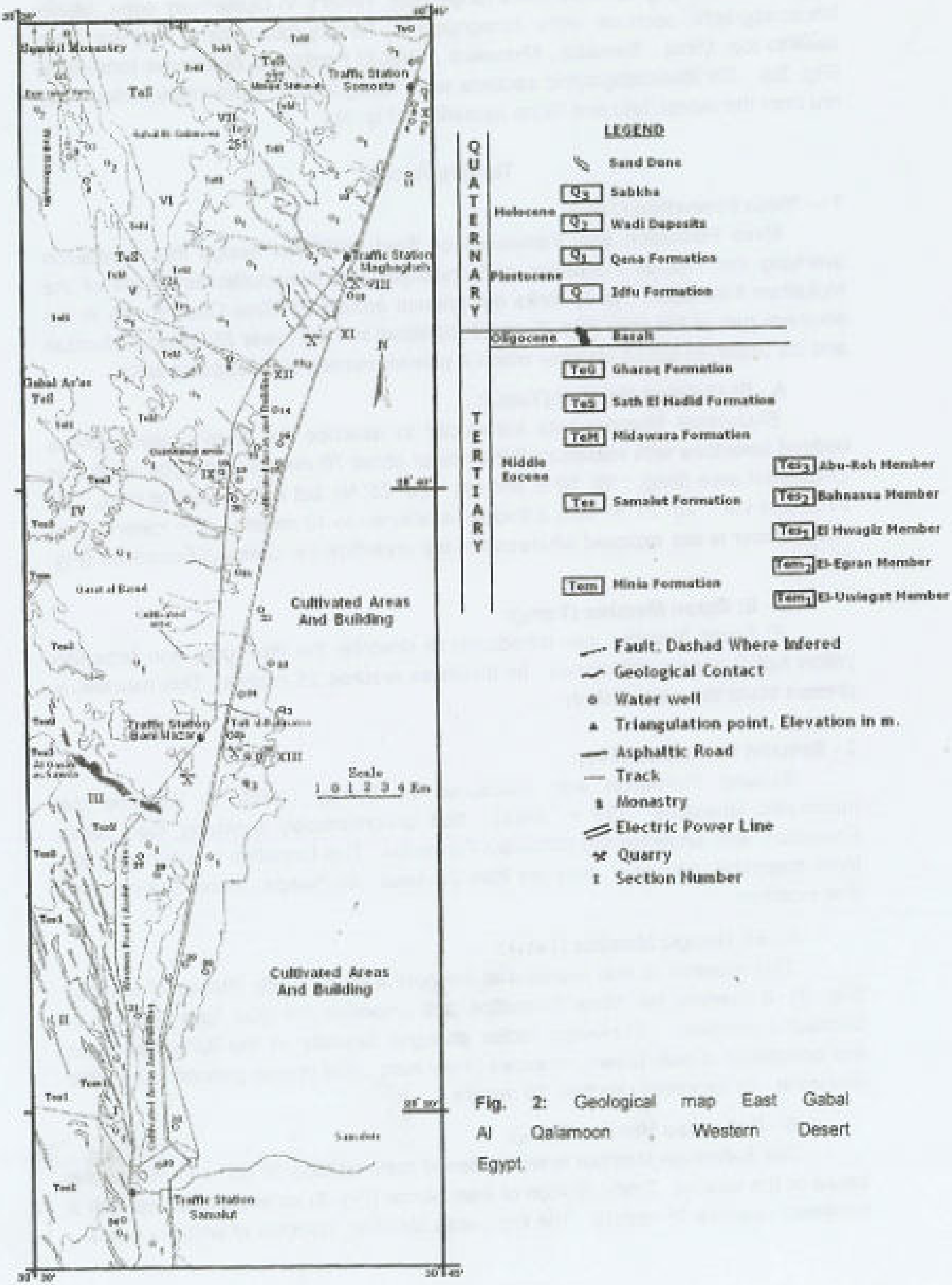

Fig. 2: Geological map East Gabal Al Qalamoon , Western Desert Egypt.

LITHOSTRATIGRAPHY

Thirteen stratigraphic sections are collected by the author from the area under study. These stratigraphic sections range from Tertiary to Quaternary ages. Seven lithostratigraphic sections were recognized in Tertiary rock units. They are from base to top: Minia , Samalut , Midawara , Sath El Hadid and El Gharaq formations (Fig. 3a) . Six lithostratigraphic sections were recognized in Quaternary rocks, They are from the oldest: Idfu and Qena formations (Fig. 3b).

Tertiary Rocks

1 — Minia Formation (Tem):

Minia Formation was introduced by Said (1960) to design the succession overlying the Thebes Formation and underlying the nummulitic limestone of the Mokattam Formation. These rocks are present around El Minia Governorate at the southern part of the map (Fig. 2) and subdivided into the lower El Uwiegat Member and the upper El Egran Member which is present outside the mappable area.

A - El-Uwiegat Member (Tem_1):

El-Uwiegat Member was introduced to describe the snow white siliceous bedded limestone with maximum thickness of about 70 meters in its type section in El-Uwiegat area (long. : 30' 10' E and Lat. : 28' 25' N), but it is present at long. : 30' 33' E and Lat. : 28' 21' N with a thickness reaches to 12 meters . The lower part of this member is not exposed whereas the top underlies the Samalut Formation (Fig. 2).

B - El Egran Member (Tem_2):

El Egran Member was introduced to describe the dark grey and brownish yellow highly porous dolostones . Its thickness reaches 25 meters . This member is present south the area of study.

2 - Samalut Formation (Tes):

Samalut Formation was introduced by Bishay (1966) to describe the nummulitic limestone (86 m. thick) that unconformably overlying the Minia Formation and underlies the Midawara Formation . This formation is subdivided into three mappable members , they are from the base : El-Hwagiz , Bahnassa and Abu Roh members.

A - El- Hwagiz Member (Tes_1) :

This member is well exposed at the northwest of Traffic Station of Samalut (Fig. 2). It overlies the Minia Formation and underlies the Abu Roh Member of Samalut Formation. El-Hwagiz facies changes laterally to the Bahnassa facies and composed of pale brown , massive , very hard , and coarse grained nummulitic limestone . Its thickness reaches 20 meters .

B - Bahnassa Member (Tes_2):

The Bahnassa Member is well exposed north latitude 28' 27' and around the basalt at the west of Traffic Station of Beni Mazar (Fig. 2) as small outcrops with a thickness reaches 15 meters . The Bahnassa Member consists of white to yellow , moderately hard , well bedded chalky limestone and marly limestone . The base of this member is unexposed and overlain by Abu Roh Member .

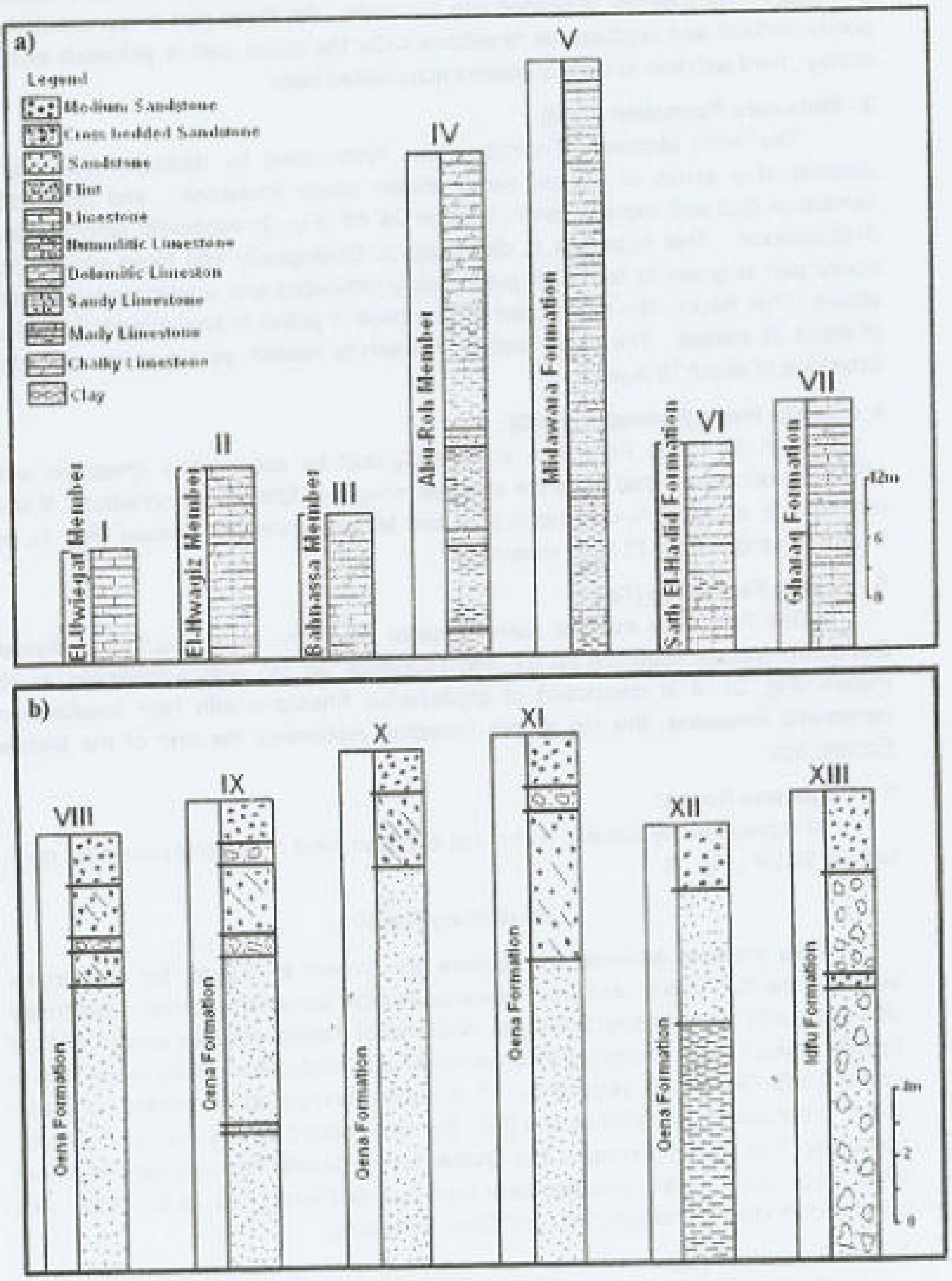

Fig. 3 : Lithostratigraphic Sections in Middle Eocene (a) and Pliestocene Rocks (b), East Gabal Al Qalamoon, Western Desert, Egypt.

C - Abu Roh Member (Tes_3):

Abu Roh Member underlies the Midawara Formation and well exposed north latitude 28° 34' and west the Bahnassa basalt (Fig. 2), with average thickness 51 meters. This member is divided into two parts , the lower part is represented by poorly bedded and argillaceous limestone while the upper part is yellowish white , chalky , hard with fine to coarse grained nummulites beds .

3 - Midawara Formation (TeM) :

The term Midawara Formation was firstly used by Iskander (1943) and consists of a series of shales, sandy shales sandy limestone , and glauconitic sandstone that well exposed north latittude 28' 40' (Fig. 2) especially around Gabal Al-Qalamoon . This formation is distinguished lithologically into three parts . The Lower part is green to brownish green finally laminated and arenaceous gluconitic shales (17m. thick) , The middle part is composed of yellow to brown marly limestone of about 29 meters . The upper part is brownish to reddish grey in colour , bedded limestone of about 16 meters.

4 - Sath El Hadid Formation (TeS):

Sath El Hadid Formation is characterized by snow white limestone with siliceous concretions that caps the elevated scarps of Midawara Formation . It well represented at Gabal Al-Qalamoon area and Minqar Shinnarah plateau (Fig. 2), by thickness ranges from 12 to 21 meters.

5 - Gharaq Formation (TeG):

This Formation overlies Sath El Hadid Formation and recorded at Minqar Shinnarah plateau (Latitude 28' 51' and Longitude 30' 38') with a thickness of 25 meters (Fig. 2). It is composed of argillaceous limestone with high fossiliferous nummulitic limestone, the top of this formation represents the end of the Middle Eocene age .

6 – Oligocene Rocks:

It represents by basaltic rocks that exposed west of El Bahnassa area north latitude 28'29' (Fig,. 2).

Quaternary Rocks

Two principal groundwater aquifers are present in Egypt, the Quaternary aquifer of the Nile Valley, and the Cretaceous Nubian Sandstone aquifer. Quaternary Nile sediments occupy about 5% of the land area of Egypt, yet they support 90% of Egypt's agricultural production (Brikowski and Faid, 2006). Most of the study area is covered with Quaternary sediments. It is mainly composed of graded sand and gravel intercalated with clay lenses (Fig. 3b), and capped by silty clay of Holocene, (generally, 5 to 15 m thickness). The Quaternary sediments have variable thickness which may reach 300m., and decrease from east and west (Atta, et al., 1992). And classified into two formations: Idfu and Qena formations.

7- Idfu Formation (Q):

The term of Idfu Formation was given by Said (1981) to a Quaternary gravel sequence cropping out at Idfu, in the Nile Valley, it consists of gravels derived from different rock types. In the area under study, a similar gravel sequence was found forming the basal part of the Quaternary, it is in the form of fluviatile deposits composed of complex gravel, coarse sand and loamy material (Fig. 4a and 4b). The gravels are mostly rounded to subrounded granules and pebbles of flint, limestone and basement rocks, cemented by yellow silt and fine sand (Fig. 3b). The age of Idfu Formation is Pleistocene. This formation could be considered the base of the Quaternary aquifer in the study area.

8- Qena Formation (Q_1):

The term Qena Formation was introduced by Said (1981) for the Quaternary sand sequence. The deposits of this unit are composed of loose sand (Fig. 3b), grey to yellow, fine to very coarse grained sand contains white pebbly qartizitic sand. Gravel intercalation are encountered, as lose to slightly cemented rocks (Fig.4c and 4d). Silt layers are observed either as continuous bed or lenses. Qena Formation is considered as the main unit containing groundwater in the area.

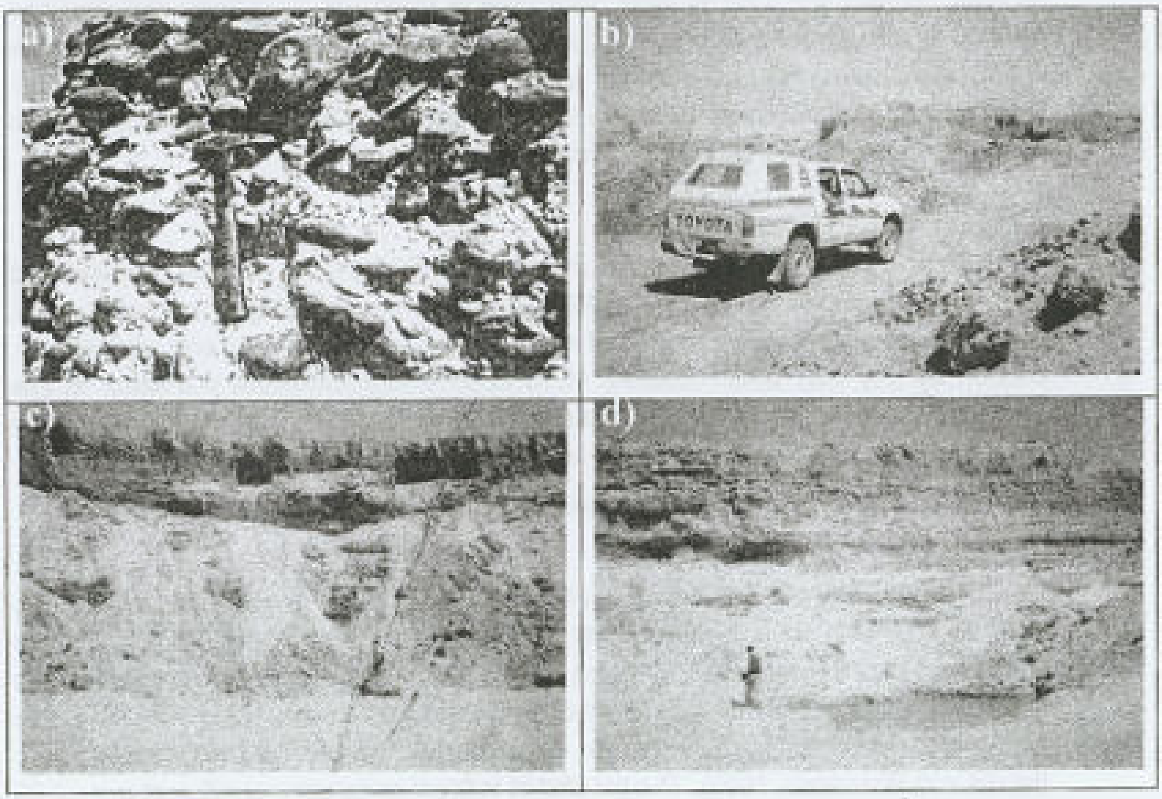

Fig. 4: a&b) Idfu Formation (Q) consists of flint and gravels, Al Bahnassa area, c&d) Qena Formation (Q_1) consists of sandstone of medium size, friable and covered by coarse sandstone at the top, east Gabal Al Qalamoon area.

Holocene Rocks

1-Recent Nile silt:

This unit comprises the cultivated lands forming the floor of the Nile Valley. The deposits are formed of alternating silts and fine sands. The surface is rather flat except for few corrugations caused by abandoned channels.

2- Sand dunes:

The largest area covered by dunes lies south latitude 28' 30'. The dunes are small seifes forming parallel crowded sandy ridges running in a north east-southwest direction. Generally the length of the dunes reach to 4Km and rise to 15m above the surface.

HYDROGEOLOGY

The hydrogeology of the north west El Minia area, was discussed by Atta et al., 1985 and 1992, RIGW-IWACO, 1986 and Armanious et al., 1988. The hydrogeological conditions of the study area can be discussed under the following topics :

1- Surface water system. 2- Groundwater system.

1-Surface water system :

The surface water system comprises the River Nile and the irregation system as Bahr Youssef and Tirat al-Jabal, Tirat kafer al Maghrabi, Tirat Kafer al-Salhin and Al Muhit al Gharbi drain and Dayr al Sanguriyyah drain. These canals and drains are essentially passing through Nile silt and clay deposits belonging to the Holocene. Because of small thickness of the Holocene, water from these canals infiltrates the Nile silt and clay contaminating the Pleistocene aquifer.

2- Groundwater system :

The Quaternary sediments dominating the study area can be distinguished into a Holocene silt and clay and a Plistocene aquifer. The Plistocene aquifer (Fig. 3a&b) is mainly composed of graded sand and gravel intercalated with clay lenses, capped by silty clay which reaches 10 m in thickness. Generally the water in this aquifer is found under confined conditions. In some localities it is present under free conditions where the Nile silt and clay is absent.

HYDROGEOCHEMISTRY

Hydrogen Ion Activity (pH):

The pH values of the groundwater aquifer range from 6.32 to 9.02 with an average of 7.95 (Table 1). It indicates slightly alkaline to alkaline types depending to local conditions and not completely match with water salinity. The pH values of the groundwater are slightly higher than those of the surface water within the River Nile and contected canals in Egypt, which show an average pH 7.5 from Aswan- Cairo (Ismail and Ramadan, 1995). The pH shows indirect correlation coefficient ($r = -0.22$) with Ca^{++} ions (Fig. 5a) due to releasing of HCO_3^- ions from the Pleistocene carbonate rocks referring to the reaction:

$$CaCO_3 + H^+ = Ca^{++} + HCO_3^-$$

Salinity Content (TDS) :

The TDS was calculated from sum of the concentrations of the major ions in the groundwater. Salinity content in the River Nile is below 290ppm and the surface water ranges from 645ppm in Bahr Youssef to 632ppm in Al Muhit drain. Salinity content of the groundwater samples ranges from 645 to 273170ppm according to the geographical localities of the studied wells, the minimum values was found beside the cultivated lands in well No. 9 and the maximum values was found in wadi Al-Muwaylih beside Samwil Monastry in well No. 2 (273170ppm). This high salinity content is due to intensive leaching processes at wadi Al Muwaylih in the northern western salt affected lands. The salinity content varies allover the study area. This variation of TDS is mainly affected by the recharge from canals, exploitation rate and aquifer bearing strata. Thirty four samples of groundwater wells are gathered and chemically analyzed in Nuclear Materials Authority (Table 1) and Fig. 5c, 5e and 5h appears the distribution of some salinity in the area under study with cations and anions. The salinity classification proposed by the U.S. Salinity Laboratory Staff (Richard, 1954), was used in the present work with slight modification in the high salinity levels (El Ghandour et al., 1983); according to the following classes:

From the data in table 1 and Fig. 2, low saline water is not shown in the studied wells. The medium salinity water class is only found in the eastern part of the area, due to seepage of fresh water from the River Nile. High salinity water class is represented by wells Nos. 9, 10, 11, 13, 19, 20, 21, 29, 30, 32, 33 and 34. Very high salinity water class is the most predominant and locates in the western area due to the effect of Eocene aquifer, represented by 15 wells Nos. 6, 7, 8, 14, 15, 16, 17, 18, 22, 23, 24, 26, 27, 28 and 31. The last water class is the predominant water type due to many factors as soil leaching, high water level and high temperature climatic conditions which lead to evaporation process and effect of Eocene aquifer to the west of the study area. Too high salinity water class is represented by 7 wells Nos. , 1, 2, 3, 4, 5, 12 and 25. Generally, the salinity content in shallow wells is higher than that in the deeper ones. Removal of all the total dissolved salts (TDS) from water is possible by distillation and deionization but on economical grounds, this is not practical or desirable for most uses.

Table 1 : Chemical analysis of groundwater samples , east Gabal Al Qalamoon area, in ppm and epm.

No.	TDS	SAR	Units	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$SO_4^{=}$	$CO_3^{=}$	HCO_3^{-}	pH
1	6560	57.4	ppm	700	158	1188	1100	1674	1372	89	253	7.15
			epm	17.2	6.5	51.7	28.1	47.2	14.2	1.5	4.1	
2	273170	423.7	ppm	6232	3366	29352	33083	186145	4727	60	175	6.32
			epm	152.7	138.5	1276.7	846.1	5250.9	48.9	1	2.9	
3	101650	387.1	ppm	7991	840	25704	5519	42205	18986	149	234	8.55
			epm	195.9	34.6	1118.1	141.2	1190.6	196.5	2.5	3.8	
4	31810	164.9	ppm	1822	1137	6333	10030	10519	1840	30	88	7.64
			epm	44.7	46.8	275.5	256.5	296.7	19	0.5	1.4	
5	5672	145	ppm	266.5	21.9	1739.9	30.5	496.3	2992.1	0	97.6	8.76
			epm	6.5	0.9	75.7	0.8	14	31	0	1.6	
6	2030	15.2	ppm	314.6	37.7	201.5	19.4	354.5	933.8	0	151.3	7.91
			epm	7.7	1.6	8.8	0.5	10	9.6	0	2.5	
7	2120	82	ppm	120.3	56.2	766.7	39.8	518	412	33	131.2	7.51
			epm	2.9	2.3	33.3	1	14.6	4.3	0.6	2.2	
8	1830	14.7	ppm	248.5	55.9	181.3	12.9	177.3	946.6	0	165.9	8.21
			epm	6.1	2.3	7.9	0.3	5	9.8	0	2.7	
9	645	13.3	ppm	64.1	9.7	80.6	5.5	106.4	218.7	12.4	146.4	9.02
			epm	1.6	0.4	3.5	0.1	3	2.3	0.2	2.4	
10	1088	89.3	ppm	24.1	14.1	390.1	19.9	96	240	49.9	196.7	7.16
			epm	0.6	0.6	17	0.5	2.7	2.6	0.8	3.2	
11	1040	58.8	ppm	68.1	19.6	389.2	7.4	141.8	316.5	0	83	8.68
			epm	1.7	0.8	16.9	0.2	4	3.3	0	1.4	
12	3372	17.7	ppm	541	114.3	320.5	13.9	531.8	1656.8	0	173.2	7.57
			epm	13.3	4.7	13.9	0.4	15	17.2	0	2.8	
13	1162	12.9	ppm	146.3	26.7	120.9	7.4	177.3	437.3	0	207.4	8.36
			epm	3.6	1.1	5.3	0.2	5	4.5	0	3.4	
14	3006	21	ppm	364.7	75.4	311.4	16.6	744.5	1336.6	0	131.8	8.29
			epm	8.9	3.1	13.6	0.4	21	13.8	0	2.2	
15	2456	11.1	ppm	260.5	133.7	156	12.9	212.7	146.7	0	175.7	8.18
			epm	6.4	5.5	6.8	0.3	6	1.5	0	2.9	
16	2400	14.3	ppm	268.7	63.2	183.2	14.8	283.6	1333	2.4	134.2	8.41
			epm	6.5	2.6	8	0.4	8	13.8	0.04	2.2	
17	2568	30	ppm	240.8	51.1	332.4	7.4	496.3	1223.9	0	192.8	7.39
			epm	5.9	2.1	14.5	0.2	14	12.7	0	3.2	
18	2582	68.2	ppm	200	46.8	757.4	28.1	149	1096	33	98.4	8.08
			epm	4.9	1.9	32.9	0.7	4.2	11.3	0.6	1.6	
19	823	13.9	ppm	80.2	24.3	100.7	7.9	106.4	332.9	0	158.6	8.54
			epm	2	1	4.4	0.2	3	3.4	0	2.6	
20	969	14.8	ppm	88.2	21.9	109.9	6.5	177.3	384.7	2.5	173.2	8.48
			epm	2.2	0.9	4.8	0.2	5	4	0.04	2.8	
21	834	18.8	ppm	100.2	12.2	141	8.5	106.4	196.5	0	244.5	8.31
			epm	2.5	0.5	6.1	0.2	3	2	0	4	
22	1940	30.5	ppm	140.3	24.3	277	12.2	602.7	661.5	0	202.5	7.79
			epm	3.4	1	12	0.3	17	6.8	0	3.3	
23	1594	30.3	ppm	132.3	29.2	272	8.3	248.2	643.6	0	241.6	7.83
			epm	3.2	1.2	11.8	0.2	7	6.7	0	4	

Table 1, cont.

24	2454	5.1	ppm	383	127	82	43	727	538	0	164	7.61
			epm	9.4	5.2	3.6	1.1	20.5	5.6	0	2.7	
25	3200	70.8	ppm	160.3	111.8	826	24	1063.6	803.9	9.9	161	8.03
			epm	3.9	4.6	35.9	0.6	30	8.3	0.2	2.6	
26	2300	42.1	ppm	156.3	65.6	534.9	10.2	957.2	284.4	0	268.4	7.78
			epm	3.8	2.7	23.3	0.3	27	2.9	0	4.4	
27	1940	30.5	ppm	296.6	14.6	100.7	6.5	177.3	1136.8	0	170.8	7.56
			epm	7.3	0.6	4.4	0.2	5	11.8	0	2.8	
28	2408	30.3	ppm	276.6	19.5	366.3	11.1	602.7	928	0	171	7.76
			epm	6.8	0.8	15.9	0.3	17	9.6	0	2.8	
29	1082	69.2	ppm	61.4	42.2	352	84	102	223.6	7.4	168.4	7.71
			epm	1.5	1.7	15.3	2.1	2.9	2.3	0.1	2.8	
30	1196	41.7	ppm	73.7	46.8	324	25	86.2	401.1	6	195.2	8.11
			epm	1.8	1.9	14.1	0.6	2.4	4.2	0.1	3.2	
31	1750	7.6	ppm	310.6	24.3	137.4	6.9	106.4	927.2	0	212.3	7.65
			epm	7.6	1	6	0.2	3	9.6	0	3.5	
32	733	21.6	ppm	64.1	9.7	131	6.5	106.4	177.6	2.5	212.3	7.89
			epm	1.6	0.4	5.7	0.2	3	1.8	0	3.2	
33	830	9.9	ppm	120.2	12.2	80.6	8.3	106.4	273	0	195.2	8.44
			epm	2.9	0.5	3.5	0.2	6	2.6	0	3	
34	939	21.6	ppm	60.1	43.8	155.7	6.5	212.7	249.9	0	183	7.89
			epm	1.5	1.8	6.8	0.2	6	2.6	0	3	
River Nile	290	2.8	ppm	35.5	20.4	15	4	19.7	18.5	6	177	7.4
			epm	0.9	0.8	0.7	0.1	0.6	0.2	0.1	2.9	
Bahr Yousef	645	9.8	ppm	36	42	61	5	63	44	7	214	7.6
			epm	0.9	1.7	2.7	0.1	1.8	0.5	0.1	3.5	
Al Muhit	632	13.4	ppm	51.3	26.8	84	32.2	108	91.8	9	238	8.5
			epm	1.3	1.1	3.7	0.8	3	1	0.1	3.9	

High salinity samples Nos. 2, 3 and 4 are present in Wadi Maweilh (Rock salt).

1- Low saline water contains less than 160ppm.

2- Medium saline water varies from 160 to 480ppm.

3- High saline water varies from 480 to 1440ppm.

4- Very high saline water varies from 1440 to 3200ppm

5- Too high saline water contains more than 3200ppm.

Major Ions

1- Potassium :

The potassium content in surface water ranges from 4ppm in the River Nile to 5 in Bahr Yossef and reaches 32.2ppm in Al Muhit drains. In the groundwater it reaches 8.3ppm in 13 wells, from 10.2 to 19.9ppm in 10 wells, and from 24 to 28.1ppm in 3 wells, from 30.5 to 84ppm in 4 wells and with some very high exceptions in wells Nos. 1, 2, 3 and 4. Generally potassium is increased laterally to the west. High potassium content is due to decaying of organic matter associated with water and may be attributed to the applied potassium fertilizers. Its correlation coefficient with Cl^- (Fig. 5b) is very high ($r = 0.97$).

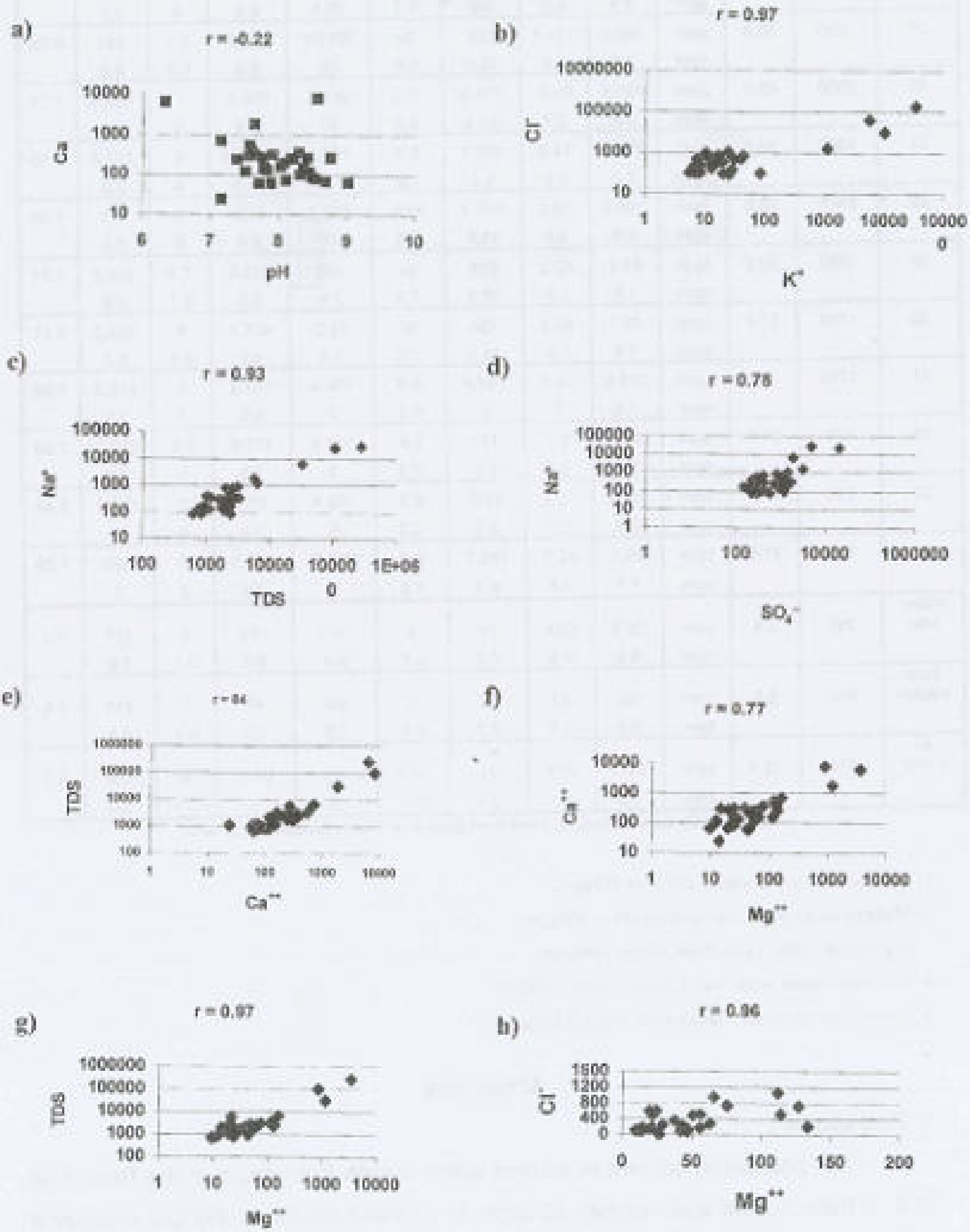

Fig. 5: Empercal relationship between TDS, Cl^-, So_4^{--}, K^+, Ca^{++}, Mg^{++}, Na^+ and pH.

2- Sodium:

The sodium content in the surface water is 15ppm in the River Nile, 61ppm in Bahr Youssef and 84ppm in Al- Muhit drains. In the groundwater, it is below 82ppm in wells Nos. 9, 24 and 33 and from 100.7 to 183.2ppm in wells Nos. 8, 13, 15, 16, 19, 20, 21, 27, 31, 32 and 34. It is also ranges from 201.5 to 390.1ppm in 11 wells Nos. 6, 10, 11, 12, 14, 17, 22, 23, 28, 29 and 30. Four wells Nos. 7, 18, 25 and 26 may reach 826ppm, with another 5 wells Nos. 1, 2, 3, 4 and 5 have higher sodium content. Sodium increased laterally to the west and become medium to the south. Fig. 5c shows the correlation coefficient of sodium (r = 0.93) with TDS in all wells. The observed excess of Na^+ indicates that the salinity in the groundwater is mainly attributed to NaCl. Principally, the amount of sodium rises as the chloride content increases in the investigated samples, supporting the view that geochemical processes play a role in the chemistry of groundwater (Xiaoping Yang, 2006). Also there are high correlation coefficient (r = 0.78) between Na^+ and $So_4^{=}$ (Fig. 5d).

3- Calcium :

The Calcium content in surface water is 35.5ppm in River Nile, 36ppm in Bahr Youssef and 51.3ppm in Al-Muhit drains . In the groundwater it ranges from 24.1ppm in well No. 10 to 383ppm in well No. 24, in some exception cases, it reachs 700ppm in well No. 1 and 6232ppm as in well No. 2. The increasing of Ca^{++} concentrations in these samples is regarding to the lack of ferromagnesian and abundance of carbonate minerals that present within the rocks of the area, by ion exchange processes and by the precipitation of calcite. The surface water and ground water are suitable for drinking as the calcium content is still below the WHO (1984a) excessive limit (200 ppm) . Fig. 5d show, the distribution of Calcium in different wells in the area under study and appear that more than 17 wells Nos. are 7, 9, 10, 11, 13, 19, 20, 21, 22, 23, 25, 26, 29, 30, 32, 33 and 34 are below WHO' limit. Calcium content appears normally near the River Nile and increased laterally to the west beside Maghaghah and also normal to the south beside Beni Mazar and Bahnassa area. There are high correlation coefficient between calcium with TDS (r = 0.84) and calcium with magnesium (r = 0.77) in figs 5e and 5f respectively.

4- Magnesium :

The Magnesium content in surface water ranges from 20.4ppm in the River Nile , 42ppm in Bahr Youssef and 26.8ppm in Al-Muhit drains. But in the groundwater it ranges from 9.7ppm in wells No. 9 and 32, and 133.7ppm in well No. 15, with some exceptions as 158ppm in well No. 1 and 3366ppm in well no. 2. The magnesium in 20 wells below 50ppm. These wells Nos. are 5, 6, 9, 10, 11, 13, 18, 19, 20, 21, 22, 23, 27, 28, 29, 30, 31, 32, 33 and 34. The majority of wells show less Mg^{++} concentration due to seepage water from River Nile and Bahr Youssef. Magnesium is increased laterally to the North, and to the west at wadi Muwelih. Fig. 5g appear the distribution of magnesium with TDS in different wells in the area under study (r = 0.97), and also Fig. 5h shows high correlation coefficient (r = 0.96) with chloride.

5-Chloride:

The chloride content in surface water ranges from 19.7ppm in the River Nile , 63ppm in Bahr Youssef and 108 ppm in Al-Muhit drains. But in the groundwater it ranges from 86.2ppm in well No. 30 and 1o63.6ppm in well No. 25 and with some high exceptions in wells No. 1, 2, 3 and 4. The high relations of chloride samples against magnesium appear in Fig. 5h, and in Fig. 5b with potassium. The surface water and ground water are suitable for drinking as the chloride content still below the WHO (1984a) excessive limit (250ppm) . Eighteen well samples are agreeable for drinking as WHO' level, Nos. are 8, 9, 10, 11, 13, 15, 18, 19, 20, 21, 23, 27, 29, 30, 31, 32, 33 and 34. Chloride is laterally increased to the north of the study area and to the west (wadi Muweilh).

6- Sulphate :

The sulphate content in surface water is 18.5ppm in River Nile, 44ppm in Bahr Youssef and 91.8ppm in Al-Muhit drains. In the groundwater, the sulphate content reaches 146.7ppm in well no. 15, and 643.6ppm in well no. 23 and 18 wells with high percentages. The surface water and ground water are suitable for drinking as the sulphate content still below the WHO (1984a) excessive limit (250ppm). Seven wells are below the WHO' content (Fig. 5g). These wells are 9, 10, 15, 21, 29, 32 and 34. Sulphate is increased laterally to the west of the studied area. Fig. 5d appears the high relation between sodium and Sulphate (r = 0.87).

7- Carbonate :

The carbonate content are absent in some samples, but it have value ranging from 2.4ppm in well No. 16 to 49.9 in well No. 10 and may reach 149ppm in well No. 3. The recorded values were generally low, may be to local contaminations, mainly through fertilization processes.

8- Bicarbonate :

The bicarbonate content in the surface water ranges from 177 ppm in the River Nile, 214 ppm in Bahr Youssef and 238 ppm in Al- Muhit drains. In the groundwater it varies from 83ppm (less than in the Nile River) in well No. 11 and

268.4ppm in well No. 26. It shows irregular distribution, mainly due to contaminations as in case of carbonate content.

ORIGIN OF THE GROUNDWATER

The most abundant sources of irrigation water in Egypt are surface water of the River Nile, followed by groundwater supplied by leakage from the River Nile into its Quaternary valley-fill sediments. Outside of the valley, the most important groundwater source is the Nubian Sandstone, supplying many of the oases and reclaimed areas in Egypt's Western Desert (Ebraheem et al., 2003). With reference to the chemical information, the groundwater of east Gabal Al Qalamoon area is located in the following categories of ion dominance: $Na^{+}>Ca^{++}>Mg^{++}$ and $Cl^{-}>SO_4^{--}>HCO_3^{-}$ (Table 1). Concerning the salt assemblages resulted from the combination between cations and anions, the following salt groups are formed in the groundwater of the area under study: Na_2SO_4, NaCl, Mg_2SO_4, $Na(HCO_3)$ and $Ca(HCO_3)_2$. The studied groundwater has originated from the seepage of surface water as River Nile, Bahr Yossef and Al -Muhit drains. Applying Sullin diagram (1948) on the collected water samples (Fig. 6), the water samples are of meteoric origin since they belong to

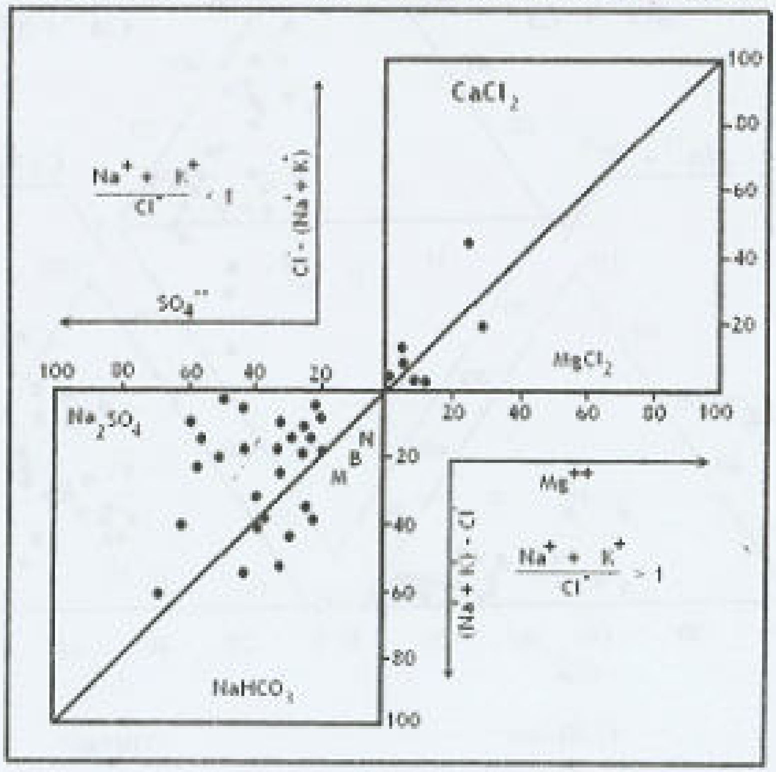

Fig. 6 : Sullin diagram for representation of the hydrochemical composition of the collected water samples in epm%.
Ground water well ● N: River Nile B: Bahr Yousef M: Al Mahit

$Na(HCO_3)$ triangle (in 7 wells represent 20.5% from the total wells, Nos. 10, 11, 19, 21, 29, 30 and 32) denoting alkaline meteoric origin and have temporary hardness character (Iliase, 1997). The water samples of the wells Nos. 1, 5, 6, 7, 8, 9, 12, 13, 16, 17, 18, 20, 22, 23, 25, 27, 28, 31, 33 and 34, represent 59% of the total studied wells belongs to triangle Na_2SO_4 of alkaline meteoric origin, and has permanent hardness character. Wells 2, 3, 4 and 242, 3, 4 and 24 belong to $CaCl_2$, however wells Nos. 14, 15 and 26 belong to $MgCl_2$.

The trilinear diagram (piper, 1944) shows a certain hydrochemical pattern was revealed, (Fig. 7). The following were deduced:

1- The water sample which appears in the upper triangle has secondary salinity properties, where $SO_4^{--} + Cl^- > Na^+ + K^+$, the hypothetical salts are Ca and Mg chloride and sulphate. They have salty water quality, that suffered from leaching process for long periods.

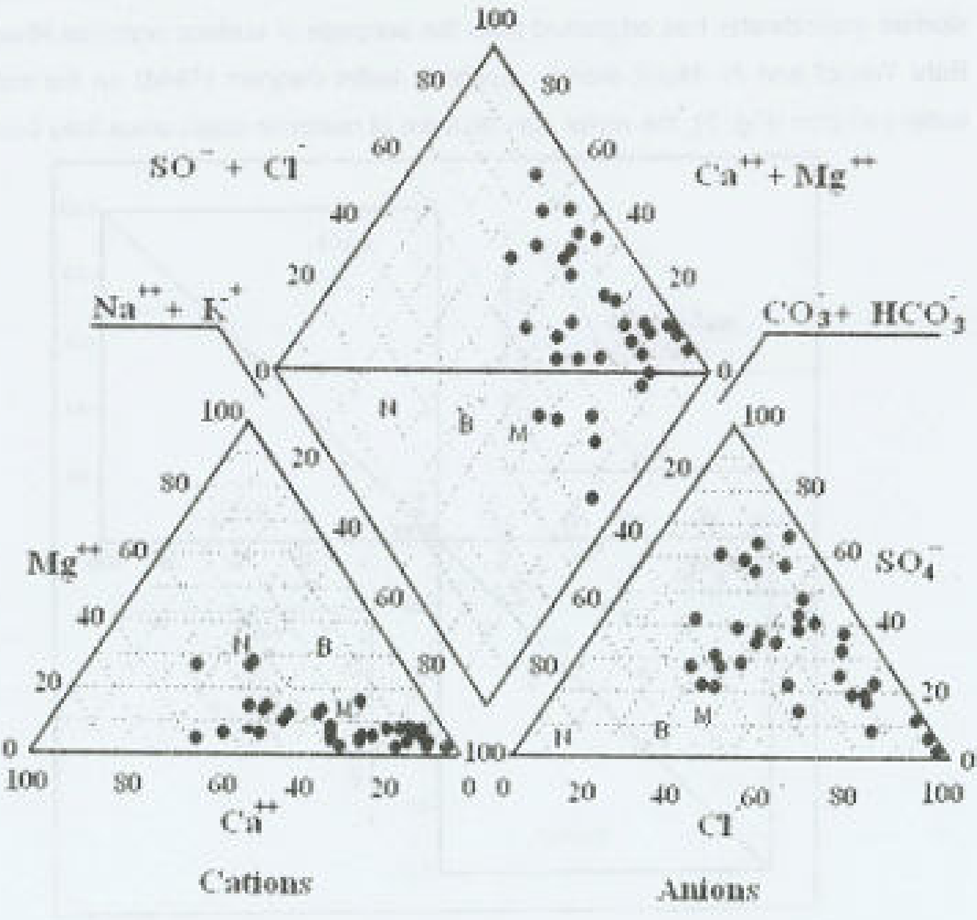

Fig. 7 : Trilinear diagram for representation of the hydrochemical composition.
Groundwater well ● N: River Nile B: Bahr Yousef M: Al Mahit

2- The water samples that in the lower triangle is considered to have primary alkalinity properties, where $CO_3^{-} + HCO_3^{-} > Ca^{++} + Mg^{++}$ and the characteristic salts are Na and K carbonate and bicarbonate. They have fresh water quality.

The sodium adsorption ratio (SAR) values for each water sample (Table 1) were calculated using Richard's equation (1954) as follow:

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

The observed irregularities may be attributed to the presence of clay sodium adsorption ratio (SAR) is the relative percentage of sodium to other cations according to U.S. Salinity Laboratory Staff, Richard (1954) as shown in table 2. Layers that, may under certain conditions release large quantities of exchangeable sodium, in addition to intensive leaching and evaporation processes.

Table 2 : Water Classification according to sodium adsorption ratio (SAR) .

Class	Sodium Content	SAR	Usage
1	Low	0-230	used for all soils
2	Medium	230-414	Preferably used for coarse textured soil of good permeability
3	High	414-598	Produce harmful effects and good soil management is essential
4	Very high	598 - 2300	Not satisfactory for irrigation

The replacement of Ca^{+} and Mg^{+} ions by Na^{+} ions on the soil clays, leads to reduction in permeability and hardening of the soil. Application of these standards on the collected water samples (Table 1) revealed that 32 wells follow class 1 of low Sodium content, only well No. 3 follows class 2 of medium sodium content and well No. 2 follows class 3 of high sodium content, No wells follow class 4 of very high sodium content. The wells Nos. 2 and 3 are not satisfactory for irrigation.

Groundwater for domestic uses (drinking and household uses) must be colourless, odourless, free from turbidity. Also harmfull micro-organisms and radioactivity must be absent. Chebotarev (1955), gave a classification for groundwater as shown in table, 3. Also, the permissible limits of cations and anions in drinking waters are given in table 4 (ECAFE and UNESCO, 1963).

Table 3: Chebotarev classification for groundwater salinity.

TDS (ppm)	Quality	Type
Less than 500 500-700 700-1500 1500-2000	Good potable Fresh Fairly fresh Possible fresh	Fresh water
2000-3200 3200-4000 4000-5000	Slightly brackish Brackish Definitly brackish	Brackish water
5000-6000 6000-7000 7000-10,000	Slightly salty Salty Very salty	Saline water

Based on the classifications of table 3&4, wells nos. 9, 10, 11, 19, 20, 21, 29, 32, 33 and 34 are of permissible fresh water and can be used in domestic purposes, while wells Nos. 6, 7, 8, 12, 13, 14, 15, 16, 17, 18, 22, 23, 24, 25, 26, 27 and 28 are of brackish water. Wells Nos. 1 and 5 are of saline water, while wells Nos. 2, 3 and 4 of very high saline water.

Table 4: ECAFE and UNESCO permissible limits of cations and anions in drinking water.

Substances	Permissible (ppm)	Excessive (ppm)
TDS	500	1500
Ca	75	200
Mg	50	150
So4	200	400
Cl	200	600
pH range	7 - 8.5	8.5 – 9.2

Atta, et. Al., (2005) concluded that brackish water is unsuitable for drinking purposes, but it may be used safely for irrigation of some crops under certain conditions.

CONCLUSIONS

This study revealed that, the main aquifer in the area belongs to the Pleistocene age, and consists of medium to coarse sand and gravel with lenticular clay layers. The aquifer is bounded from the west by Eocene limestone, and from the east by the River Nile. The salinity of the groundwater is mainly classified into medium to high near the River Nile but reaches very high near the Eocene limestone in the west. The studied groundwater has originated from the surface water as River Nile, Bahr Yossef and Al-Muhit drains.

The chemical analysis of the collected water samples revealed that the groundwater of Gabal Al Qalamoon area is suitable for cultivation of many crops according to local environment conditions. The Hydrochemical composition of the area under study belongs to the sodium sulphate and sodium bicarbonate. The surface water and some of the groundwater are suitable for drinking where they still below the WHO (1984 a) excessive limits. Some wells may comprise to some treatment before using. In some localities the groundwater can be used for domestic and irrigation purposes.

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دراسات هيدروكيميائية على المياه الجوفية , شرق جبل القلمون
الصحراء الغربية , مصر

رأفت منير صليب شحاتة
هيئة المواد النووية   ص.ب : 530 بريد المعادى , القاهرة ، مصر

تغطى رواسب العصر الرباعى معظم منطقة الدراسة والتى يمكن تقسيمها إلى رواسب البلاستوسين والهولوسين. وتعبر رواسب البلستوسين (تكوين أدفو وتكوين قنا) بأنها عبارة عن رمل وحصى ومغطاه بالغرين والطين من عصر الهولوسين. وتمثل رواسب البلستوسين التكوين الرئيسى الحامل للمياه فى منطقة الدراسة.

وقد أوضحت الدراسات الهيدروكيميائية أن درجة ملوحة المياه الجوفية فى منطقة الدراسة تتراوح مابين 645 إلى 273170 جزء من المليون حسب موقعها فى الآبار المدروسة. وإنها تزداد فى إتجاه الغرب وهذا لقربها من خزان مياه الأيوسين. وقد لوحظ أن توزيع درجة الملوحة والأيونات الرئيسية أعلى في الآبار الضحلة عن الآبار العميقة. كما وجد أن المياه الجوفية فى بعض الآبار يمكن أن تستخدم فى الأغراض المنزلية وفى الرى.