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Replenishment and miniralization processes of Lower Miocene aquifer at Wadi El-Farigh area and its vicinities, using environmental isotopes and hydrochemistry.

K. Dahab[1], M. A. Sadek[2] and M. A. El-Fakharany[3]

[1]Geol. Deprt. Fac. of Sci. Menufiya Univ
[2]Siting and Environmental Deprt. National center for Nuclear safety and radiation control, Cairo, Egypt
[3]Geol. Deprt. Fac.of Sci. Benha Univ.

Abstract:

The purpose of the present work is to identify the origin of replenishment and mineralization processes of lower Miocene Moghra aquifer at Wadi El-Farigh area and its vicinities. Hydrogeological, isotopic and hydrochemical studies were carried out. This aquifer is mainly composed of sand and sandstone with shale and clay inter-beds (fluviatile facies) at wadi El- Farigh area and changes to marine limestone and sandstone facies toward northwest. Its thickness shows gradual increase in the northwest direction, where, it ranges between 150 and 550 m and reaches more than 900 m at the west.

Salinity content (TDS) of groundwater ranges from 222 to 667 ppm at W. El- Farigh area reflecting fresh water type. It increases to more than 3000 ppm at the west due to marine facies effect. The ionic concentrations of bicarbonates are the highest between the anions and followed by chloride and sulphate ions. Among the cationic concentrations the sodium ions prevail and followed by calcium and magnesium ions The dominant water type is Ca-Mg-Sodium, Cl-Bicarbonate, which indicates meteoric water genesis.

The obtained results of the stable and radioactive isotopes contents revealed depleted oxygen^{18} and deuterium, absence of tritium and high carbon^{14} age. This indicates less active recharge and significant contribution for non regenerating paleowater that alarm a wise exploitation schemes for the groundwater resources. The paleowater component could be in part represented by intensive local paleometeoric water and in the other part paleo-Nile water entraped in the buried old Nile channels. The groundwater is suitable for domestic purposes and reflects a hazard for irrigation purposes due to sodium

toxicity.

Introduction:

Wadi El-Farigh area is located to the southwest of the Nile Delta (Fig.1). It is bounded by Latitudes 29° 50′ & 30° 30′ N and Longitudes 30° 05′ & 30° 55′ E. It has the form of an elongated depression, extending along E-W direction. It is bounded from the north and east by El- Tahrir gravelly Plain and from the northwest by Maryut limestone tableland and from the southwest by W. El- Tarfaya (Fig.2). Wadi El- Farigh has a catchement area of 1112.5 km^2 enclosed between the contours of 150 m above sea level in the south and southwest and 50 m in the north. The low area of W. El-Farigh depression is dominated by sand accumulations and rock fragments which represent reclaimable good soil and a pilot area for a large land reclamation projects including more than 100,000 Feddan. However, reclamation projects require extraction of considerable amounts of water. The present work shed the light on the origin of groundwater and mineralization processes at wadi El-Farigh area to simulate the effect of future water-extraction on the groundwater storage and water quality of the utilized aquifer system.

Methodology:

Twenty-six groundwater samples were collected during April 1998 from Moghra aquifer at wadi El Farigh area and its vicinities (Fig.1). Ec, pH, and temperature were measured in the field. The chemical composition was determined according to the methods adopted by US. Geological Survey (Fishman and Friedman, 1985). The concentrations of major cations and major anions were expressed in ppm, epm and epm % (Table.1).

The stable isotopic composition $Oxygen^{18}$ and deuterium were determined for a selected fourteen samples. The radioactive isotopes (tritium and $carbon^{14}$) were measured in one sample of a significant value in the interpretation.

The Micromass Spectrometer was used for measuring O^{18} and D and the liquid scintillation counter was used for tritium and $Carbon^{-14}$. Pretreatment procedures were carried out before measuring, (Tanweer et al 1988), (Epstein et al 1953) and (Swailem, 1969)

Oxygen^{18} and Deuterium were expressed as (δ) values which denote to the relative deviation in isotopic content of a sample and that of a reference water (Standard Mean Ocean water,SMOW) as follow:

$$\partial = \frac{R_{sample} - R_{STD}}{R_{STD}}$$

$$\text{Where} \quad R = \frac{D}{H} \quad or \quad \frac{O^{18}}{O^{16}}$$

Tritium is expressed in tritium unit (T.U.) that is defined as one tritium atom per 10^{18} hydrogen atom. Carbon^{-14} is expressed as percentage modern carbon (pmc) which is the relative activity of the carbon^{-14} in the sample and that of recent carbon before 1954.

Hydrogeologic setting of the study aquifer:

Moghra aquifer represents the main water bearing formation under wadi El-Farigh area. The whole thickness of this aquifer has been penetrated by Natrun Ghibli-1 and W. D. 343/1 wells (Fig. 3). The bottom of the Lower Miocene (Moghra) aquifer has been deposited on the Oligocene basaltic sheet. It is composed mainly of sand and sandstone with shale and clay interbeds and shows lateral variation in its lithological characteristics in the northwest direction, where fluviatile facies are replaced by marine limestone and sandstone facies in the north west (Shaltut-1 well) (Fig.3). The lithofacies change plays an important role in the increase of salinity and development of groundwater quality west wadi El- Farigh area. The thickness of Lower Miocene (Moghra) aquifer shows gradual increase in the northwest direction, where, it ranges between 150 and 550 m at Wadi El- Farigh area (Fig.4) and reaches about 600 -900 m in the west of wadi El-Natrun (Fig.3). The Average hydraulic conductivity of the Lower Miocene aquifer at wadi El-Farigh area is 12 m/day, its average transmissivity is 3100 m^2/day and its storage coefficient is 1.32×10^{-2} (Ahmad, 1993). Groundwater in the Lower Miocene aquifer occurs mainly under semiconfined condition, where shale and clay intercalated with sand and sandstone acts as semi-pervious layer. In the area between Beni Salama and Khatatba, clay changes into sands and the ground water exists under water table conditions (Fig. 3,a, b).

Potentiometric heads of this aquifer range from +2 m at the east and northeast of wadi El-Farigh to -20 m at the south west of wadi El-Farigh and south wadi Natrun depression. Groundwater movement is from northeast to southwest (Fig.5). Recharge-discharge conditions of Moghra aquifer at wadi El- Farigh area was discussed by many authors. Abdel Baki (1983) stated that the Lower Miocene aquifer is recharged from the southern portion of the Nile Delta basin while both wadi El-Natrun in northwest and Moghra depression in the far west acts as discharging areas for the groundwater from the Lower Miocene aquifer. Ahmad (1993) stated that the groundwater movement from east to west through wadi El- Farigh is controlled by an old buried Nile channel which diverts the groundwater flow towards wadi El- Natrun depression.

Hydrochemistry:

The total dissolved solids (TDS) of the studied groundwater samples varies from 222 ppm to 667 ppm at wadi El- Farigh area (Table.1). These values reflect the fresh water character and less developed stage due to the lithologic nature of the aquifer. Abrupt change in salinity content (more than 1000 ppm) is noticed at some localities due to extensive extraction rate, closeness of production wells and increasing thickness of shale and clay intercalation. On the other hand, high salinity content more than 3000 ppm exist west of Wadi El-Natrun (samples 26) is due to marine environmental effect on groundwater quality. The sequence of ion dominance in the studied groundwater follows a general order $Na \rangle Mg \geq Ca / HCO_3 \rangle Cl \rangle SO_4$; i.e. Ca- Mg-Sodium, Cl-bicarbonate water type in about 75 % of the samples (Table.2). Chloride increases on the expense of bicarbonates in the rest of samples and water type becomes Ca-Mg-Sodium, HCO3-Chloride. The last type is dominant in Rowad El-Arab farm that is dominated by lagoonal deposits rich in chloride. The increase in chloride content does not affect the noticed relation between Na and ($Cl + SO_4$), where Na is greater than ($Cl + SO_4$) in all samples and accordingly the meteoric $NaHCO_3$ water type is formed in the salt compositions (Table.2). The combination assemblage salts are NaCl, $Na_2 (SO_4)$, $NaHCO_3$, $Mg(HCO_3)_2$, $Ca(HCO_3)_2$. These salt assemblages reflect meteoric water origin developed under the effect of leaching and cationic exchange on the surface of fine sediments due to the long rock water-contact, where sodium and potassium increases in water on the expenses of calcium and magnesium that left behind on rock surface.

Environmental Isotopes:

The stable isotopic composition (δD & δO^{18}) of natural water encodes much information about mechanism of recharge and salinization. The radioactive isotopes (T and C^{14}) layout the highlights on the time dependant criteria and flow dynamics characteristics.

The stable isotopic composition of the studied groundwater show values in the range from –2.32 to 0.91 for oxygen^{18} and from –10.15 to 5.3 for deuterium (Table.2). These values are different (significantly depleted) compared to Nile water, either present day or the one flooded before construction of High Dam (Awad et al., 1997). This difference can be explained in term of the contribution of a recharge source of depleted isotopic content.

The data points concentrate within a narrow area in the δO^{18} - δD diagram (Fig.6) reflecting the homogeneity and similarity of recharge conditions of. the aquifer. The points fall mostly around the paleometeoric water line ($\delta D = 8\ \delta O^{18} + 5$) (Sonntage et Al, 1978). This line fits with the pluvial time fossil water of Western Sahara to which Western Desert Nubian sandstone water belongs. The very cool and humid climate that was prevailing during pluvial time leads to an extreme isotopic depletion in this paleowater (Sadek, 1996). The accumulation of Nile water behind Aswan High Dam causes evaporation and isotopic enrichment in the present day Nile water compared to the one which was present prior to completion of the Dam. Two mixing lines (AC) and (BC) were drawn (Fig.6) between Nile waters and paleowater. The studied groundwater are higher compatible with the mixing pattern indicated by line (BC) than (AC) reflecting a less active recharge and retarded flow where the recent change in isotopic content of Nile water (enrichment due to evaporation) are not directly reflected in the groundwater composition. The Nile water entraped in the fluviatile deposits of old buried Nile channel in combination with non regenerating pluvial time outflowing eastward from desertic aquifers play important role in the recharge of groundwater aquifer.

Oxygen-18 zonation map is superimposed on TDS values map (Fig.7). The oxygen^{18} content shows a general decrease from east to west. This decrease could not necessarily be explained in term of an eastern recharge front only, where TDS does not change considerably from east to west and water types are dominated by high percentage of $NaHCO_3$ salt of advanced stage of evolution. Moreover, the northward groundwater samples show a significant isotopic depletion accompanied with low salinity content. The tritium and carbon^{14} radioactive isotopes were measured for the sample of least O^{18} and D contents (sample No. 1). The tritium was nil and the carbon^{14} age was 16737 YBP. The old age confirms the presence of ancient recharge component accompanying the recent one. The identification of this old component is a questionable issue, where the pluvial time fossil Nubian sandstone water that could outflow from desertic aquifer has an extremely negative oxygen-18 content (avg.-10 %o Sadek, 996), on mixing with Nile water (O-18=3.5%, Awad, et al 1997) the proportion of recent recharge in sample No (1) will be about 57% that nescissitates measurable tritium content. The absence of tritium in the studied water sample leads to a suggestion that the paleowater component may be effected at least in part by an old water component of oxygen-18 not as high as Nile water or as low as Nubian sandstone water. This may be remnant of paleonile water entraped for long time in the buried old Nile channels. This opinion agree with the studies that given by Husein et al, (1994), Awad et al, (1997) and Ahmad, (1993).

٦ Evaluation of water quality for drinking and irrigation purposes:

The chemical composition of the studied groundwater (pH, TDS, Cl, SO_4, Ca, Mg and Na) was compared with the acceptable and permissible limits recommended by WHO (1984) for drinking purposes. This water can be considered suitable for drinking usage. The suitability for irrigation purposes is evaluated based on sodium content that accumulate in the soil reducing its permeability and affecting plant growth. The sodium hazard is studied based on the percentage of sodium to the total cations (Na %) and the relation between sodium and other anions (Stybler factor). The Na % shows values generally higher

than the permissible limit (60 %) (Table.2) recommended by US. Irrigation Dept (1954). Four samples only are of values less than 60 %. Kamensky (1947) expresses the relation between sodium and other anions (staybler factor) for water, which have Na⟩ Cl ⟩ SO_4, as follow:
a=288/ 10Na – 5Cl – 9 SO_4
It shows values in the range from 6-18 reflecting a satisfactory class where a special treatment are to be taken against accumulation of alkalis except for shallow soil having free drainage

Conclusions:

The hydrogeological, hyderochemical and isotopes studies revealed the following:

1- The Lower Miocene aquifer at Wadi El- Farigh is composed of sand and sandstone with shale and clay interbeds changes to marine limestone at the west. Its thickness ranges between 150 and 550 m. This aquifer exist under semi confined condition. The direction of groundwater flow is from northwest to southwest.

2- Salinity content of groundwater ranges between 222 and 667ppm. High salinity detected west of Wadi El- Natrun indicates marine environmental effect on groundwater quality. Abrupt change in water salinity is noticed at some localities as a result of over pumping and increasing shale and clay thickness.

3-The hydrochemical composition of water samples show that the water is alkaline in reaction where the pH value ranges between 7.1 and 7.91. The ionic concentrations of bicarbonates are the highest between the anions and followed by chloride ions. Among the cationic concentrations the sodium ions prevail and followed by magnesium ions. The main water type is Ca-Mg-Sodium, Cl-Bicarbonate. The hydrochemical compositions indicate meteoric water genesis, where the equivalent concentrations of potassium and sodium are greater than that of chloride (r (K+Na) /rCl >1) and the combination assemblages salts are KCl, NaCl, Na_2 SO4, Na (HCO_3), Mg $(HCO_3)_2$ and Ca $(HCO_3)_2$.

4-The estimated C^{14} age is 16737 YBP. The old age confirms the presence of ancient recharge component accompanying the recent one. The absence of tritium in water samples leads to the suggestion that the paleowater may be affected by an old one of O^{18} not high as the Nile water or low as the Nubian sandstone water.

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عمليات التغذية و التمعدن لخزان الميوسين السفلى فى منطقة وادى الفارغ و متاخما ته باستخدام النظائر البيئية و الهيدروكيميائية.

كمال دهب - مصطفى صادق - محمد الفخرانى

يهدف هذا البحث إلى تحديد أصل عمليتى التغذية و التمعدن لخزان الميوسين السفلى فى منطقة وادى الفارغ و متاخما ته ، لهذه الأغراض قد أجريت دراسات هيدرولوجية و هيدروكيميائية كما استخدمت النظائر البيئية و قد تبين الآتي:

يتكون خزان الميوسين السفلى فى منطقة وادى الفارغ من رمال و زلط مع تداخلات من الطفلة و الطين و يتراوح سمكه ما بين ١٥٠ متر فى الشمال الشرقي إلى ٥٥٠ متر في الجنوب الغربى فى حين يصل سمك هذا الخزان إلى أكثر من ٩٠٠ متر غرب منطقة الدراسة.

تتراوح محتوى الملوحة للمياه ما بين ٢٢٢ مليجرام في اللتر إلى ٦٦٧ ملجم في اللتر فى منطقة وادى الفارغ و تصل إلى أكثر من ٣٠٠٠ مليجرام في اللتر ناحية الغرب و أن نوع المياه الجوفية هو صوديوم-كالسيوم - ماغنسيوم، بيكربونات - كلوريدات و هى فى الاصل مياه أمطار و قد بينت نتائج النظائر الثابته و المشعة للعينات التى تم تحليلها أن محتوى الاكسجين^{١٨} و الديوتيريوم شحيح و الترتيوم غير موجود و مدى زمنى كبير للكربون^{١٤} و هذا يعنى أن المياه الموجودة أصلها مياه قديمة و أن التغذية الحالية غير فعالة و لذا يرجع أصل المياه الموجودة إلى مياه قديمة جزء منها تابع للمياه الإقليمية القديمة أما الجزء الآخر يمثل مياه فرع نيل قديم.

Table.1 Shows results of chemical analysis of the collected grounwater samples

No.	Name	Aquifer	Date	Depth	TC°	pH	EC	TDS	Unit	Ca	Mg	Na	K	HCO_3	SO_4	Cl
1	El-Rowad El Arab (2)	Miocene	5/4/98	170	28.1	7.7	882	542	ppm	17	7.2	136	5	204.9	13	141
									epm	0.76	0.59	6.05	7.52	3.35	0.27	4.03
									epm%	10.10	7.84	80.45	0.12	43.79	3.52	52.67
2	El-Rowad (5)	Miocene	5/4/98	170	27	7.6	1108	667	ppm	37	21	163	6	253	42	197
									epm	1.84	1.7	7.41	0.15	4.14	0.87	5.638
									epm%	16.57	15.31	66.75	1.3	38.87	8.16	52.86
3	El-Rowad El Arab (72)	Miocene	5/4/98	145	26.7	7.8	827	545	ppm	25	15	106	4	186	28	151
									epm	1.24	1.23	4.82	0.10	3.04	0.58	4.32
									epm%	16.73	16.59	65.04	1.3	38.28	7.10	54.40
4	El-Rowad El Arab (38)	Miocene	5/4/98	150	27	7.6	746	456	ppm	25	15.1	106	4	159	30	117
									epm	1.24	1.23	4.82	0.06	2.60	0.62	3.30
									epm%	16.82	16.73	65.57	7.35	3.98	9.50	5.061
5	El-Rowad El Arab (60)	Miocene	5/4/98	160	28	7.1	764	503	ppm	26	16	107	4	215	32	126
									epm	1.29	1.32	4.87	0.06	3.52	0.66	3.56
									epm%	17.10	17.50	64.58	0.2	45.5	8.5	47.21
6	Lino (75) K	Miocene	5/4/98	200	26.6	7.3	346	222	ppm	15.6	11.5	57	5.2	160	14	21.6
									epm	0..275	0.953	2.478	0.13	2.622	0.291	0.693
									epm%	17.96	21.96	57.2	2.92	72.7	8.059	19.21
7	El Marwa (11)	Miocene	5/4/98	200	26.7	7.2	330	232	ppm	15	8	59	6.5	146	2080	411
									epm	0.718	0.657	2.565	0.16	2.392	0.416	1.24
									epm%	13.4	15.4	3.31	3.31	59.11	10.316	30.63
8	El Marwa (1)	Miocene	5/4/98	180	26.4	7.4	2360	1369	ppm	128	30.72	389	12.8	458	65	565
									epm	6.387	2.53	17.60	0.32	7.50	1.35	15.933
									epm%	23.77	9.42	65.59	1.19	30.26	5.44	64.28
9	Farm-7	Miocene	5/4/98	160	25.3	7.91	601	370	ppm	24.2	18.1	89	6.5	215	49	58
									epm	1.20	1.49	4.0.5	0.16	3.52	1.02	1.63
									epm%	17.39	21.59	58.06	2.31	57.06	16.53	26.41
10	Regwa (75)	Miocene	5/4/98	170	28	7.8	864	518	ppm	28	15	153	5.7	250	70	155
									epm	1.39	0.68	6.51	0.145	4.09	1.45	4.38
									epm%	15.94	7.79	74.65	1.66	41.29	14.61	44.15
11	Regwa (2)	Miocene	5/4/98	170	26	7.6	577	304	ppm	19	13	59	5	209	13	54
									epm	0.94	1.07	2..68	0.12	3.42	0.27	1.52
									epm%	19.54	23.24	55.49	2.49	65.64	518	29.17
12	Regwa (217)	Miocene	5/4/98	150	26.4	7.25	577	369	ppm	59	13	59	5	209	13	54
									epm	2.9	1.6	2.6	0.13	3.42	0.27	1.52
									epm%	40.11	22.13	35.96	1.798	65.64	5.18	29.17
13	Regwa (35)	Miocene	5/4/98	160	26.23	7.5	689	441	ppm	22	13	137	6.1	231	68	105
									epm	1.098	1.6	5.9	0.15	3.78	1.42	2.96
									epm%	12.55	18.289	67.44	1.71	46.323	17.4	36.27

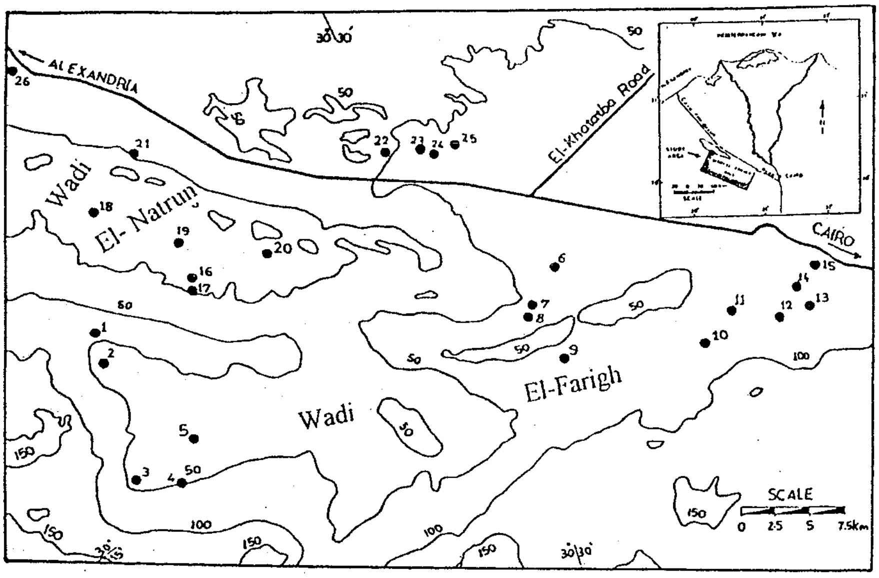
Table.1 Continue

No.	Name	Aquifer	Date	Depth	TC°	pH	EC	TDS	Unit	Ca	Mg	Na	K	HCO_3	SO_4	Cl
14	Regwa (11)	Miocene	5/5/98	160	26.7	7.6	931.	601	ppm	24	14	141	7.1	237	71	108
									epm	1.12	1.9	6.12	0.16	3.97	1.51	3.14
									epm%	13.7	20.1	66.12	1.52	44.56	12.78	38.76
15	Regwa (60 k)	Miocene	5/5/98	150	25.9	7.89	777	500	ppm	16.8	11.1	146	4.5	226	53	127
									epm	0.538	0.95	6.3	0.11	3.7	1.1	3.58
									epm%	6.811	12.028	79.76	1.392	44.155	13.12	42.72
16	Aba-Beshoy	Pliocene	5/5/98	55	22.5	7.9	881	576	ppm	-11.8	9	141	5	207	37	146
									epm	0.58	0.7	6.42	0.12	3.39	0.7	4.12
									epm%	7.14	8.95	82.09	1.53	41.29	8.52	50.18
17	Aba Beshay	Pliocene	6/5/98	5	23.5	7.4	4034	3298	ppm	134	89	695	15	889	123	1056
									epm	6.68	7.35	31.62	0.38	14.57	2.57	30.22
									epm%	14.51	15.96	68.69	0.8	30.21	5.45	64.28
18	El-Hamra / spring	Miocene	6/5/98	flowing	26	7.9	535	334	ppm	24	11.2	87	5.6	217	50	57
									epm	1.19	0.92	3.96	0.14	3.55	1.04	1..63
									epm%	19.16	14.81	63.76	2.24	57.07	15.72	26.20
19	Wadi El-Natm factory	Miocene	6/5/98	140	26.4	7.9	916	561	ppm	18.47	11.2	146	3.6	250	50	136
									epm	0.92	0.92	6.65	0.09	4.09	1.04	3.84
									epm%	10.72	10.72	77.50	1.04	45.59	11.59	42.8
20	Desert Road	Miocene	6/5/98	200	27.1	7.3	391	250	ppm	13.1	7.8	53	4.78	145	15	34
									epm	0.653	0.642	2.304	.15	2.376	0.312	0.958
									epm%	18.14	17.838	64.017	2.6	65.16	8.557	26.27
21	Bany Salama	Miocene	6/5/98	200	26.8	7.4	555	376	ppm	23.2	16.1	57	6.7	165	25	47
									epm	1.157	1.324	2.913	0.42	2.7	0.52	1.325
									epm%	21.449	24.54	54	5.7	59.41	11.44	29.15
22	El-Desert Road	Miocene	6/5/98	200	26.7	7.5	395	264	ppm	17.6	9.56	58.9	7.5	156	31	38.1
									epm	0.87	0.789	2.67	0.19	2.55	0.6	1.1196
									epm%	19.29	17.49	59.64	4.2	59.02	13.88	27.54
23	El-Desert Road	Miocene	6/5/98	200	25.9	7.6	402	254	ppm	13.1	8.1	54	5.7	146	17	35.5
									epm	0.553	0.666	2.35	0.34	2.392	0.353	1.0
									epm%	17.8	18.15	64.1	6.3	63.95	9.438	26.737
24	El-Desert Road	Miocene	6/5/98	200	26.1	7.6	388	244	ppm	15.1	9.1	53	6.7	148	14	33.614
									epm	0.73	0.748	2.3	0.23	2.42	0.291	.976
									epm%	19.81	19.76	60.5	5.78	68.03	8.16	27.23
25	El-Desert Road	Miocene	6/5/98	200	26.89	7.2	431	270	ppm	16.4	8	60	4.8	153	16	424
									epm	0.818	0.551	2.6	0.13	2.51	0.333	1.139
									epm%	20.122	16.122	63.3	5.43	63.03	8.3	28.6
26	West Wadi El- Natrun	Miocene	6/5/98	200	26.7	7.5	5310	3260	ppm	123	76	654	7.9	765	145	988
									epm	6.13	6.27	28.8	0.13	12.535	3.031	28.27
									epm%	19.81	19.76	60.5	4.56	68.03	8.169	23.75

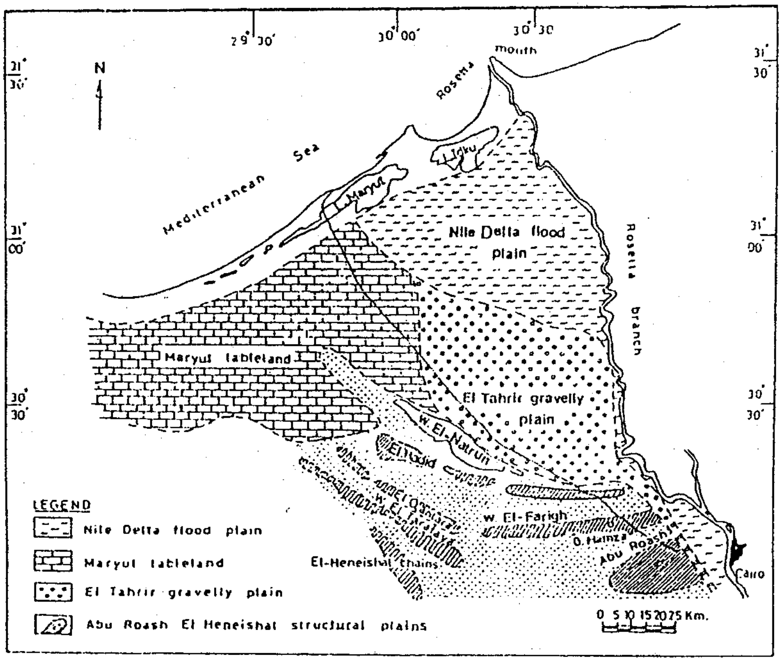
Table.2 Shows hypothetical salts, water type and isotopic contents of some groundwater samples.

No.	Name	Hypothetical salts	Water type	O^{18}	D	Na%	Stabyler Factor(a)
1***	El-Rowad El Arab (2)**	NaCl. Na_2SO. NaHCO3 , Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	HCO_3, Chloride-Ca,Mg-Sodium	- 2.32	- 10 65	66	7 6
3	El-Rowad El Arab (72)	NaCl. Na_2SO. NaHCO3 , Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	HCO_3, Chloride-Ca.Mg-Sodium	- 1 64	- 5 03	65	11
6	Lino (75) K	NaCl. Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	- 0.84	- 1 9	57	28.8
[illegible]	El Manya (1)	NaCl, Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	- 0.56	- 1.4	63	281
10	Regwa (75)	NaCl, Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	0.61	4.52	55	17
13	Regwa (35)	NaCl. Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	- 0.65	- 2.3	80	7.6
15	Regwa (60 k)	NaCl, Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	0.92	5.3	82	7.7
16	Aba-Beshoy	NaCl, Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	HCO_3, Chloride-Ca,Mg-Sodium	- 1.64	- 5 22	82	7 8
19	Wadi El-Natrn factory	NaCl. Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	- 1.80	- 8.25	62	8.5
21	Bany Salama	NaCl. Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	- 1.76	- 7.98	64	17
23	El Sadad (M)	NaCl. Na_2SO_4. $NaHCO_3$, Mg $(HCO_3)_2$. $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	- 1.23	- 3.05	64	19
24	El Sadad (l)	NaCl, Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	-1.2	- 5.02	63	16
25	El Sadad-N	NaCl. Na_2SO_4. $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	Cl,Bicarbonate-Ca,Mg,Sodium	- 1.05	- 1.8	64	18
26	West Wadi El-Natrun	NaCl, Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	HCO_3, Chloride-Ca,Mg-Sodium	-1.06	-1.9	63	17
27	Nile Before High Dam	NaCl, Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	HCO_3, Chloride-Mg, Na, Calcium	-0.6	4.3	41	7
28	Present day Nile water	NaCl. Na_2SO_4, $NaHCO_3$, Mg $(HCO_3)_2$, $Ca(HCO_3)_2$	HCO_3, Chloride-Mg, Na Calcium	3.8	31.6	41.2	7.2

*** Carbon-14 Age=16737 Y.B.P
Tritium = Nile

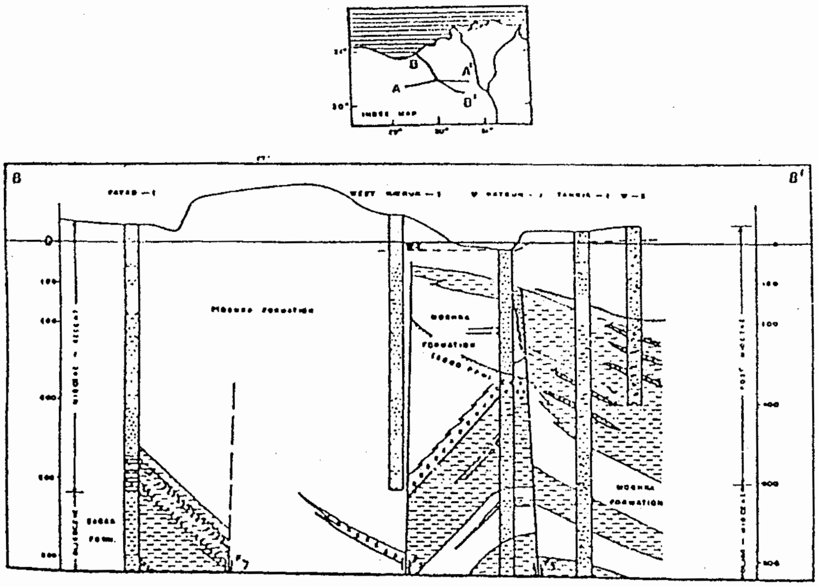


(Fig.1) Location and sampling sites map of the study area

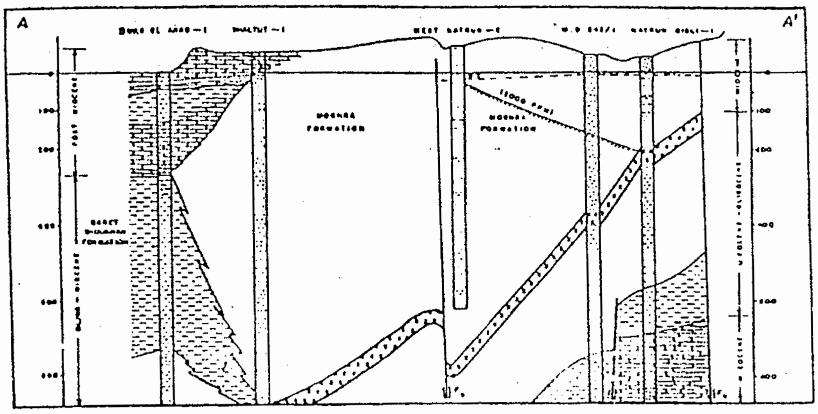


(Fig.2) Geomorphological map of the west Nile Delta area

(After El-Fayoumy, 1967)



(Fig.3a) Hydrgeological cross section(B-B) of Moghra aquifer(GPC,1977)



(Fig.3b) Hydrgeological cross section(A-A) of Moghra aquifer(GPC,1977)

LEGEND

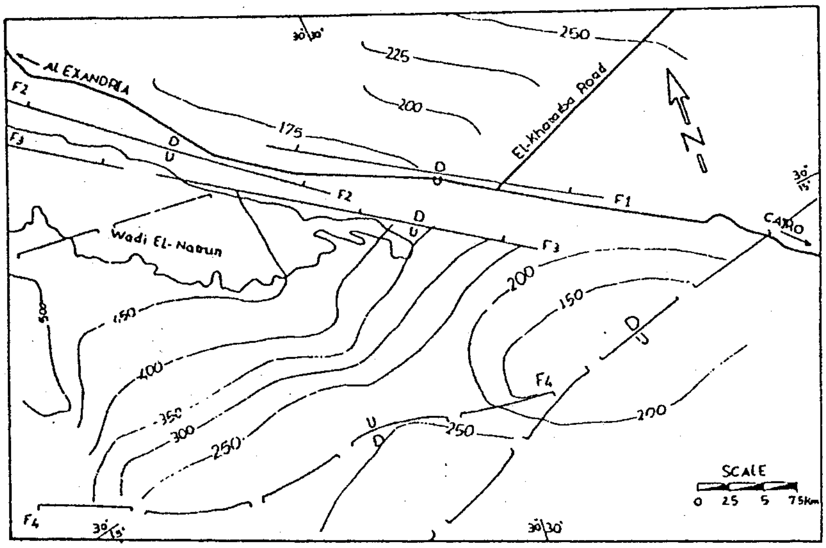
▨ Sand & SandStone

▤ LimeStone

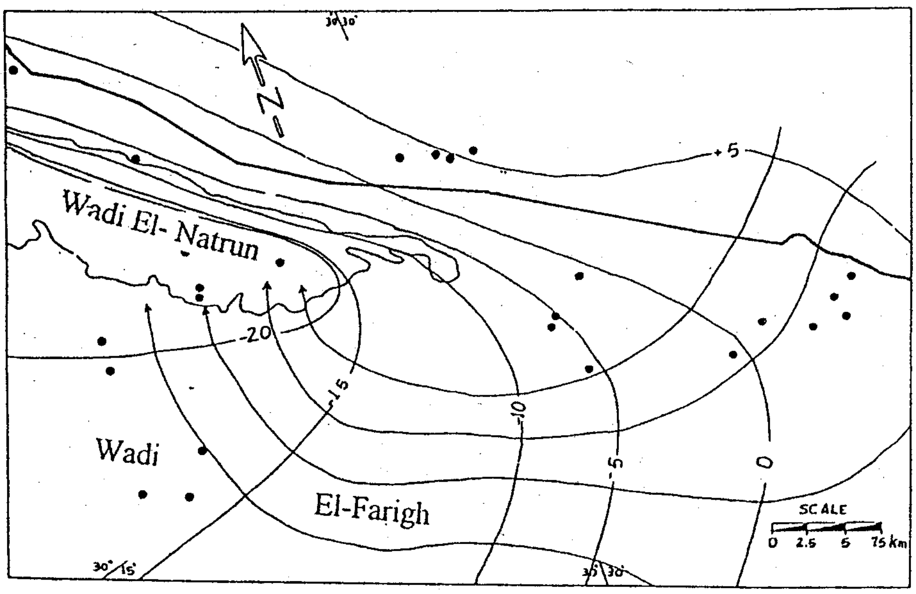
Base Fresh water Zone 2000ppm

▤ CLay & Shale

▨ Basalt



(Fig.4) Isopach map of Moghra aquifer at Wadi El- Farigh (GPC,1977)



(Fig.5) Potentiometric map of Moghra aquifer (Ahmad, 1993)

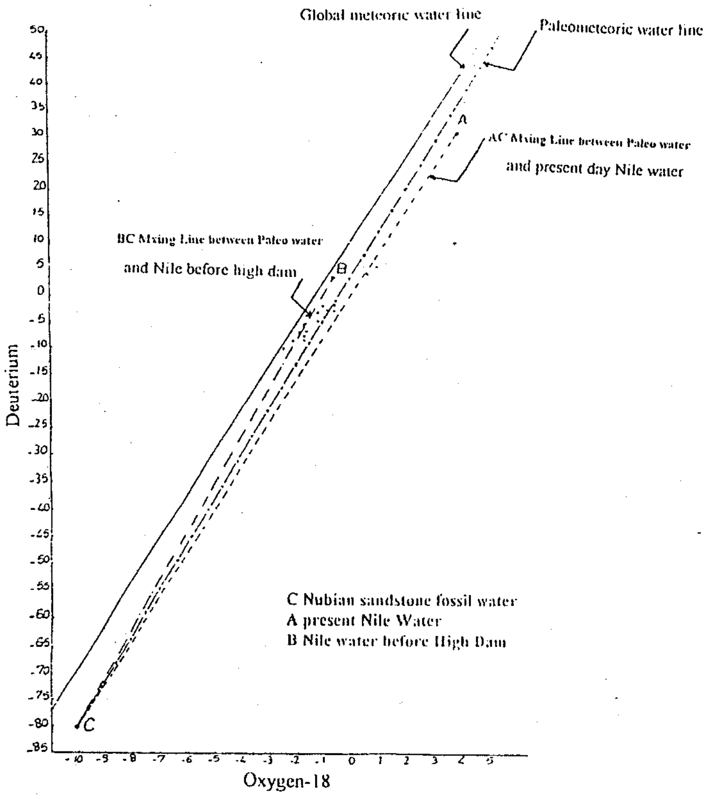
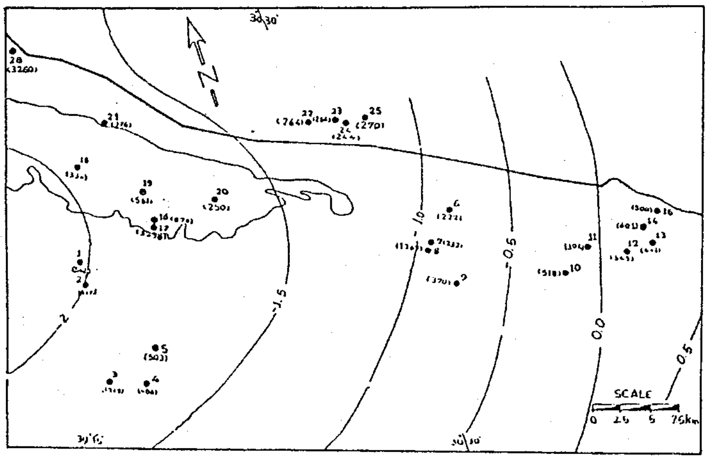


Fig. (6) Oxygen ^{18} Deuterium relationships of the collected water samples.



(Fig.7) Oxygen-18 contents and salinity contents of the water samples