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Hydrogeochemical and Hydrogeological Studies for Groundwater Resources in the Area between Abu Ghusun And Bernice, South Eastern Desert, Egypt.

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ABSTRACT: In the investigated area, groundwater represents one of the most valuable resources for the local inhabitants, military, tourism and generally for the sustainable development of the area. For that, special attention should be focused on the future for the water supplies. Serious plans for the development and assessment of groundwater resources are required. The current research has been conducted to evaluate groundwater aquifers qualitatively in the area between Abu Ghusun and Bernie, Southeastern Desert. Analysis of collected groundwater samples from the existing water wells was performed and the different geochemical parameters were calculated which clarify the origin of the groundwater. The groundwater exists under unconfined to semiconfined conditions at depths varying between 4 m and 80 m. The chemical analyses of 37 samples from the investigated groundwater indicate that, the groundwater salinity ranges from 1300 ppm to 20367 ppm. About (10.8%) of the total samples are fresh and 54.1% are brackish, while only 35.1% are saline. The total and permanent hardness increase as water salinity increases and vice-versa in case of temporary hardness in the groundwater samples. The chemical water types and the ion ratios indicate meteoric origin of groundwater as well as marine salts. The most recharge source is from the precipitation. Much of the solutes and physicochemical parameters in these waters are under the undesirable limits of World Health Organization (WHO) for drinking purpose and a plot of sodium adsorption ratio versus EC shows that about 23% of the groundwater samples are good water quality, about 45% of groundwater samples are moderate quality and 23% of the groundwater samples are intermediate water class, the rest of samples (9%) are out of range.

Keywords: Groundwater, hydrogeochemistry, hydrogeology, water quality, Eastern Desert, Abu Ghusun- Bernice area.

INTRUDUCTION:

Egypt has turned to the use groundwater to satisfy the growing demand of water. The water resources represent the greatest difficulty towards the development of desert regions. Special attention should be focused on the future development for groundwater exploration, evaluation. In the last decades, the Eastern Desert of Egypt attracts the attention of numerous investments, especially in the fields of tourism, marine sports, diving, fishing, medical treatment, agriculture, petroleum exploration, mining and quarrying as basis for local industries. The present water supplies in the Eastern Desert are insufficient to meet the expected increase of demands for civic, industrial, mining and touristic uses. The water supplies comprise the pipelines of Qena-Safaga (8000m^3/day) and El Kuraimate-Hurghada (55,000m^3/day), Desalinized water (4105m^3/day) as indicated in the different desalinized stations and groundwater exploitation (about 25000m^3/day). Therefore, exploration and detection of new groundwater resources with good quality considered as a national target.

The study area locates at the Southeastern Desert, about 78 km to the south of Mersa Alam and covers a surface area of about 4000 Km^2. The study area between Abu Ghusun and Barnes and is bounded by latitudes 23° 55' and 24° 35' North and longitudes 34°45` and 35°35` East (or the Red Sea coast). Six hydrographic basins were selected for this study; these are Um Al Abas, Abu Ghusun, Ranga, El Reidi, Lahami and Mukhit basins (Fig 1). The objectives of this study are determining the distribution of the main aquifers, analysis of collected water samples from the existing water wells and the geochemical parameters were calculated to clarify the origin of the groundwater and to evaluate the groundwater aquifers for different uses.

The present area previously studied by Samuel and Saleeb-Roufaiel (1977), Abd El Khalik (1978), Samir et al. (1982), Khaled (1995), Aggour (1997), Gheith and Sultan (2002), El Tamamy (2008), Kamal (2010) and Tahoon (2011). The study area is characterized by desert climate conditions dominated by extreme aridity terrain with low and erratic rainfall; sometimes with flash floods, high evaporation rates, generally vigorous winds and the maximum temperature recorded during the year are 41°C (Abdel Monem, 2005) and minimum temperatures recorded during the year are 22°C (Aggour and Sadek, 2001), and increase southward. The average daily relative humidity ranges from 54% in summer to 47% in winter. Generally, the mean annual evaporation increasing to the south, the rainfall is varied from one season to another. Although the paucity of the rainfall events, many flash floods were reported from the Eastern Desert (Naim, 1995).

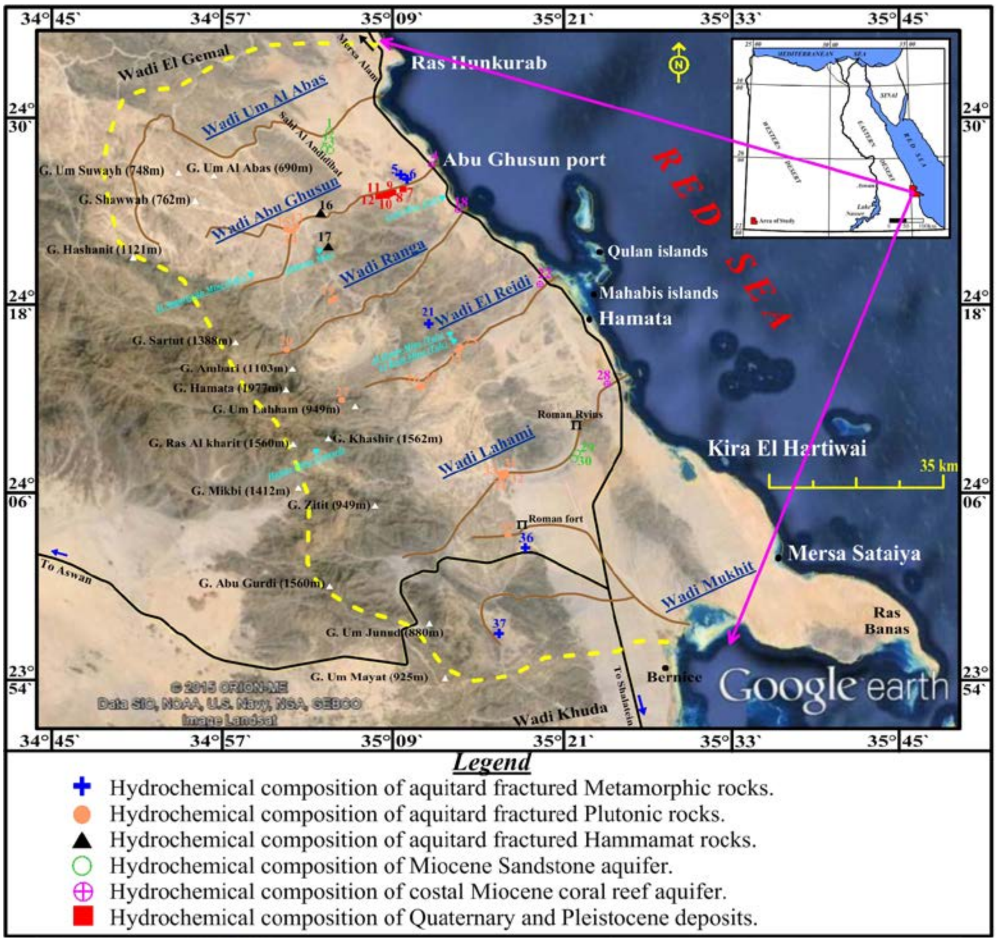

Fig (1): Location map and the distribution of the aquifers and wells in the study area.

1. GEOMORPHOLOGIC, GEOLOGIC AND HYDROGEOLOGIC SETTINGS:

1. 1. Geomorphologic features:

Geomorphologically, based on the topographic maps, scale 1:50,000 the investigated area is built mainly of three geomorphologic units as follows (Fig 2):

1- Red Sea coastal plain: The Red Sea Basement Mountains built up of igneous and metamorphic rocks; they represent the catchment's area of groundwater recharge for the aquifers in the area.

2- Watershed areas include hills and traces which scatter along both sides of the main streams.

3- Hydrographic drainage basins and the water collectors of wadis which represented by morph tectonic depressions and the drainage lines that receive heavy occasional storms. The depressions reflect the different types of structures or erosional processes. The studied basins have the following characteristics.

a. The main direction of these basins is from S-W to N-E with many tributaries taking different directions.
b. All the basins cross different rock types.
c. Their drainage patterns are dendritic or semi-dendritic in the mountainous region, and trillic pattern in the sedimentary region.
d. The groundwater potentiality in these basins is affected to a large extent by the direction, density and length of the fractures and joints as well as the dykes and meanders of the drainage channels.

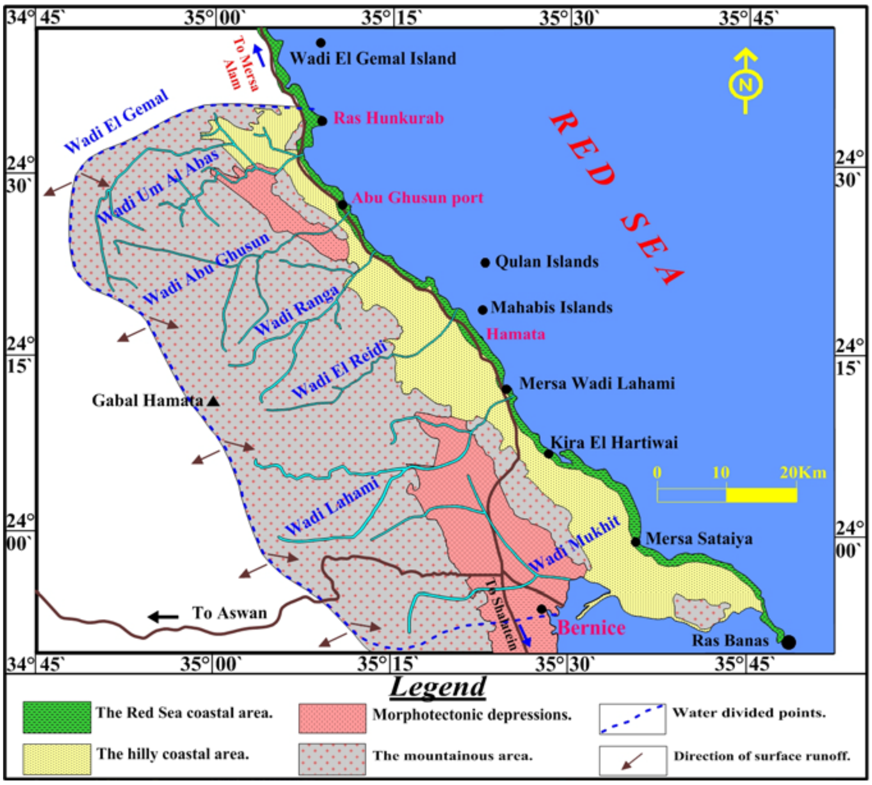

Fig (2): The main Geomorphologic units of the study area.

1. 2. Rock stratigraphy: The area under study, Late Proterozoic Pan-African rocks constitutes the main bulk of the mountainous terrain. These are composed of igneous and metamorphic rocks. On the other hand, Pre-Miocene strata are preserved in the downstream portions of the existing wadis, e.g. wadis Um Al Abas-Mukhit and also within the morpho-tectonic depressions, which are hollowed out in the basement of these wadis (Fig 3). These rocks constitute prominent plateaus. The younger sediments which include Miocene and younger deposits (Pliocene, Quaternary and Recent) exist in the coastal plain and wadi alluvial.

The lithostratigraphic succession in the area under investigation ranges in age from Precambrian to Recent. This succession is divided into the Late Proterozoic basement rocks and the Phanerozoic sedimentary succession. The sedimentary succession overlies unconformable the Precambrian rocks from the older to the youngest (Said, 1962), as:

1. The Pre-Cenonian clastics with minor carbonates: It is composed of Nubian sandstone, Quseir variegated shale formation, Duwi formation, Dakhla shale formation, Tarawan chalk, Esna shale formation, Thebes formation and Rewagan formation
2. The Oligocene- Miocene clastics and evaporates: The sedimentary sequence of Ras Banas was subdivided into two units. The lower unit comprises of Gabal El Rusas of upper Miocene age, Shagra formation of Pliocene age and Ras Ranga formation of Pleistocene age as well the upper unit comprises of alluvium deposits of Holocene age.
3. The Post-Miocene sediments (Quaternary deposits) include undifferentiated Pliocene, Pleistocene to Recent sediments. They are composed of conglomerates, limestone and silt (Issawi et al. 1971), and are differentiated into, raised beach sediments, the sediments resulting from moving (creeping)

of detritus and rock fall, sand sheets and their accumulations, wadi filling sediments, flood flush sediments, fan delta deposits and sediments of flood terraces.

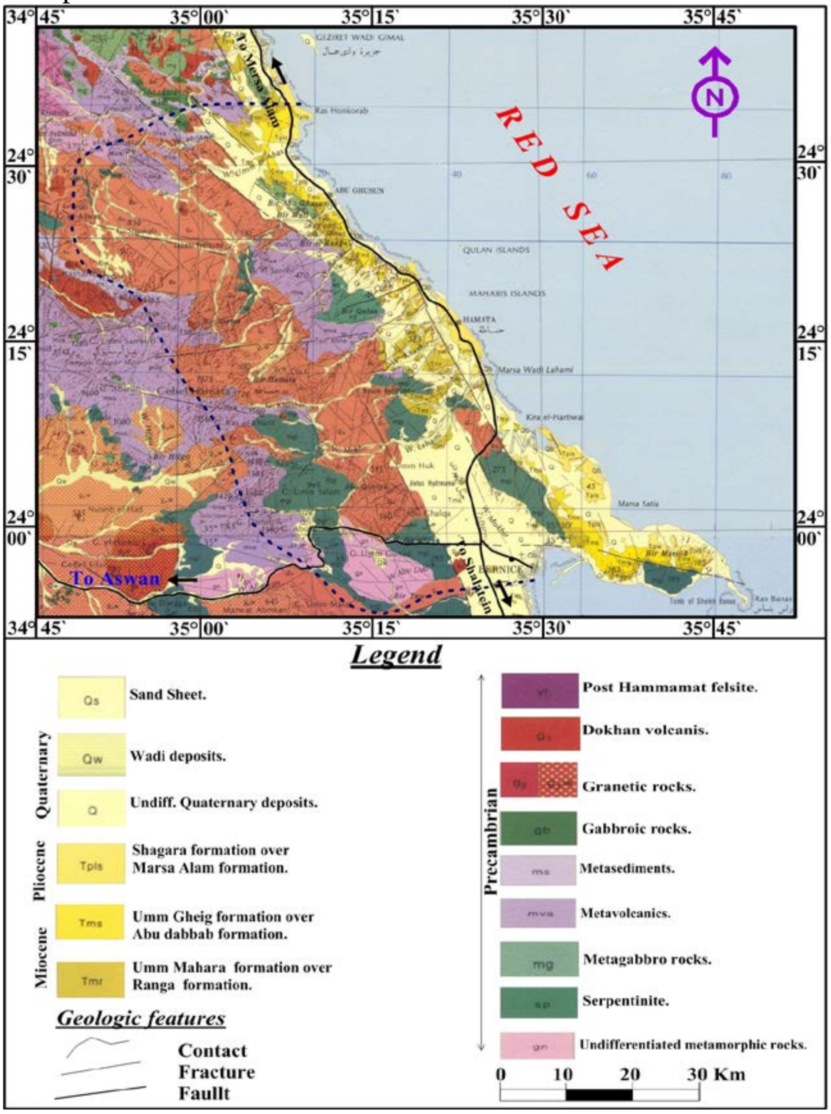

Fig (3): Geological map of the studied area (Geological Survey of Egypt, 1997).

1. 3. Geologic structures: Structurally, the concerned area dissected by NW-SE set of faults, Parallel to the Red Sea coast. Faults of NE trends are relatively limited. Different trends of dykes and fracture systems are predominant structures in the basement rocks which have a direct effect on groundwater accumulation. The general parallelism among the Cretaceous-Eocene folds, the individual basement hills in the hilly zone and the coastal line and the Red Sea itself seems to indicate that the present topography was determined to a very extent by Pre-Middle Miocene events (Said, 1962).

1. 4. Hydrogeologic setting:

The area of study represented itself as a part of the regional hydrogeological basins of first order, bounded from the east by the Red Sea coast, and from the west by the high mountainous range of basement rocks. Six hydrogeological basins inside the regional Red Sea basin are distinguished within the area of study namely, Um Al Abas, Abu Ghusun, Ranga, El Reidi, Lahami and Mukhit (Fig 1). In that area the water resources are found in the drainage basins dissecting the Red Sea mountainous region. Different types of water bearing formations containing water of variable salinities are recorded. On the other hand, saline water is mainly detected in the deltas of several wadis at the coastal plain and also in the mining waters. The local precipitation and temporary floods represent the main source of groundwater recharges. The physical properties of several rock types and the areal extension of the catchment areas lead to the development of several aquifers and aquifer complexes including both hard and unconsolidated rock types.

The regional catchment area of the first order basin (Red Sea) lies at the mountainous range of the basement rocks. A water divide, differentiates the water flows towards the Red Sea coast at the east and to the Nile Valley at the west. The runoff of the second order basins are generally directed to the north east, but some wadis slightly deviated into the NW-SE trend, as in wadi Mukhit. The area of study constitutes a part of an arid belt and recharges from the occasional, limited local precipitations and tolerant floods during autumn season which fall on the basement complex range at the west, as well as the sedimentary hills which act as additional water recharges to the aquifers.

Generally, in the investigated area, the groundwater is tapped from two main types of aquifers arranged vertically and passed upon age assignment, lithological and hydrogeological characters of the rock units. These are:

I. The aquitard fractured Precambrian basement water bearing rocks: Aquitard fractured Metamorphic Rocks, aquitard fractured plutonic rocks and aquitard fractured Hammamat rocks.

II. The sedimentary aquifers: the Miocene sandstone water-bearing aquifer, the costal Miocene coral reef aquifer and the Quaternary and Pleistocene deposits.

2. MATERIALS AND METHODS:

2. 1. Field works: The present studies deal with the analytical results of 37 water samples collected from 37 water points, besides rain, Nile and Red Sea water samples (Table 1). The water points are arranged according to lithology and age of the water bearing formation from north to south within the studied area (Fig 1). It was of interest to sample tributary water to look for common features reflected in their hydrochemistry. Most samples were colorless, but a few were yellow, gray or turbid in color due to dissolved Fe or suspended solid particles. The sample locations were determined using a handheld global positioning system (GPS) (GARMIN, Germany), water samples were collected in 1-L high-density polyethylene (HDPP) bottles (washed with distilled water and then with raw water three times before sampling). Each sample was immediately filtered on site through 0.45 ml Millipore membrane filters of cellulose acetate. Samples for trace elements analysis were acidified with ultra-pure HNO_3 to below PH 4.5. All the samples were brought to the Desert Research Center and stored in a refrigerator at a temperature of 4°C until further analyses were performed.

2. 2. Laboratory and office works:

The analyses of groundwater were carried out into the Hydrogeochemistry Department, Desert Research Center (DRC), and were checked for error to be less than 5% (Table 2). The used analytical procedures of water samples followed the methods adapted by Rainwater and Thatcher (1960), Fishman and Friedman, (1985) and American Society for Testing and Materials (ASTM, 2002). The analyses include the determination of electrical conductivity (EC) in micro-mhos/cm at 25°C., PH value, Total dissolved solids (TDS) in ppm and expressed in the hydrochemical formula in g/l, Major cations (K^+, Na^+, Mg^{++} and Ca^{++}) represented as milligrams/liter (mg/l); milligram equivalents/liter (meg/l) and as equivalent percentage value (e %), Major anions (Cl^-, SO_4^{--}, HCO_3^- and CO_3^{--}) reported as mg/L, meg/L and (e %) together with 12 Minor and trace elements which are Al, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sr, V, Zn and Phosphate represented as milligrams/liter (mg/l) (Table 4).

The chemical character of water samples are summarized as: Total salinity, Dominance of ions, Ionic ratios and Hypothetical salt combinations and their percentages. The hydrochemical compositions are expressed as hydrochemical formulae, in which the anionic and cationic concentrations are expressed in equivalent percentages and arranged in a decreased order. The groundwater types are determined, where each of the anionic and cationic concentrations which exceeds 15%, are taken into consideration, (Altovisiki, 1962).

2. 3. Interpretation techniques:

The concentration of major ionic constituents of groundwater samples were plotted in the Sulin and Ovitchinikov diagrams to determine the water type as well as any possible geochemical processes that affect the water genesis in the study area.

Sulin classification (1963) has proved to be a useful tool in the study of the chemical characteristics of natural water. It based on the percentage equivalent per million of the anions and the cations. Four equal triangle diagrams used to represent the composition of water with respect to both cations and anions. Generally, the water samples which appear in the upper two triangles have secondary salinity properties (sulphates and chloride exceed sodium and potassium). On the other hand, those which appear in the lower two triangles are considered to have primary alkalinity properties (carbonate and bicarbonate exceed calcium and magnesium).

Chemical data of groundwater samples from the study area presented by plotting them on a Sulin diagram for Quaternary, and Miocene sandstone, Costal Miocene coral reefs and Precambrian aquifers (Fig.4). These diagrams reveal the dissimilarities and different water types. The samples of the same aquifer were classified into different groups, each group determine a definite drainage basin.

Table (1) The groundwater type in every water point (serial Nos.1 - 37).

No.	Basin Name	Well name	Well type	depth to water(m)	Total depth(m)	TDS (mg/l)	Water bearing formation	Chem. Comp. (Water Type)
1	Um Al Abas	Um Al Abas 1	Rotary	19	108	8583	Miocene S.S.	Mg, Ca, Sodium – CO_3, SO_4,Chloride
2		Um Al Abas 2	Rotary	18	102	3822	Miocene S.S.	Mg, Ca Sodium-Cl, Sulphate
3		Um Al Abas 3	Rotary	18	104	7430	Miocene S.S.	Mg, Ca Sodium - SO_4 ,Chloride
4	Abu Ghusun	Abu Ghusun	Hand dug	4	4.4	12673	Costal Miocene Coral reef	Mg, Ca, Sodium – SO_4, Chloride
5		Al Arab 1	Hand dug	2	2.6	4721	Metamorphic	Mg, Sodium –SO_4 ,Chloride
6		Al Arab 2	Hand dug	1.5	2.3	11782	Metamorphic	Mg, Sodium – SO_4 ,Chloride
7		Al Ahaly	Hand dug	10.5	11.1	9875	Q & Pleistocene	Mg,Ca, Sodium –CO_3, SO_4 Chloride
8		Abu Ghusun	Hand dug	5.5	5.9	2989	Q & Pleistocene	Mg, Na, Calcium - SO_4 ,Chloride
9		Farm 1	Hand dug	8	8.7	4881	Q & Pleistocene	Mg,Sodium – SO_4 ,Chloride
10		Farm 2	Hand dug	11.5	12	4467	Q & Pleistocene	Mg, Sodium – SO_4 ,Chloride
11		Farm 3	Hand dug	12.5	12.9	7629	Q & Pleistocene	Mg, Ca, Sodium – SO_4 ,Chloride
12		Farm 4	Hand dug	13	13.8	4173	Q & Pleistocene	Mg Sodium– SO_4 Chloride
13		Rumayt1	Hand dug	22	22.3	1400	Plutonic	Mg Sodium – SO_4 Chloride
14		Rumayt2	Hand dug	19.5	20.2	1300	Plutonic	Mg, Sodium–SO_4, CO_3,Chloride
15		Rumayt3	Hand dug	21	21.8	1400	Plutonic	Mg, Sodium - SO_4, HCO_3, Chloride
16		Abu Ghusun	Hand dug	22	22.6	11438	Hammamat	Mg, Sodium – SO_4 Chloride
17		Abu Ghalagah	Shaft	31.3	31.9	13872	Hammamat	Mg, Sodium – SO_4 CO_3, Chloride
18	Ranga	Ranga coastal	Hand dug	2.5	3	9500	Costal M. Coral reef	Mg, Ca, Sodium - SO_4 Chloride

19		Daurt	Hand dug	4.2	4.7	3934	Plutonic	Mg, Sodium- CO_3' SO_4,Chloride
20		Hileifi	Hand dug	4.7	5.3	3890	Plutonic	Ca,Na,Magnesium-CO_3' SO_4,Chloride

Table (1) The groundwater type in every water point (serial Nos.1 - 37), cont.

21	Qulan	Qulan	Shaft	4.5	4.95	20367	Metamorphic	Mg, Ca, Sodium – SO_4, Chloride
22	El Reidi	El Reidi coast	Hand dug	3.5	3.9	6360	Costal Miocene coral reef	Ca, Na,Magnesium – SO_4, Chloride
23		El Reidi	Hand dug	4	4.4	5860	Plutonic	Na, Magnesium – SO_4, Chloride
24		El Reidi	Hand dug	4.2	4.9	3905	Plutonic	Ca, Mg, Sodium - CO_3' SO_4,Chloride
25		Haratreit1	Hand dug	7	7.6	4725	Plutonic	Mg. Ca, Sodium - CO_3' SO_4,Chloride
26		Haratreit2	Hand dug	10	10.6	4721	Plutonic	Mg, Sodium – CO_3' Cl, Sulphate
27		Hamata	Hand	11	11.5	3708	Plutonic	Na, Magnesium – CO_3' Cl, Sulphate
28	Lahami	Lahami coast	Hand dug	4.8	5.3	7098	Costal Miocene coral reef	Mg, Sodium – SO_4, Chloride
29		Eisa1	Rotary	48.5	106	3846	Miocene S.S.	Sodium - CO_3' Cl, Sulphate
30		Eisa2	Rotary	46	105	2904	Miocene S.S.	Mg, Sodium – SO_4 Chloride
31		Lahami1	Hand dug	20	20.7	3155	Plutonic	Sodium - CO_3' SO_4, Chloride
32		Lahami2	Hand dug	14.5	15	3599	Plutonic	Ca, Mg, Sodium - SO_4, Chloride
33		Lahami3	Hand dug	21	21.5	4082	Plutonic	Mg, Sodium - CO_3' Cl, Sulphate
34		Lahami4	Hand dug	19	19.7	1600	Plutonic	Mg, Sodium – SO_4, Chloride
35	Mukhit	Abu Qurayyah	Hand dug	3	3.8	4415	Plutonic	Mg, Sodium – SO_4, Chloride
36		Al Hafiri	Hand dug	4.5	5.2	2652	Metamorphic	Mg, Sodium – SO_4, Chloride
37		Taww	Hand dug	6.5	7	3890	Metamorphic	Mg, Sodium – SO_4, Chloride
38	Red Sea	------	------	------	------	43740	------	Mg Sodium- Chloride
39	Nile water	------	------	------	------	172	------	Ca, Na, Magnesium – HCO_3, Sulphate
40	Rain water	------	------	------	------	80	------	Mg Sodium-SO_4, Cl Carbonate

Ovitchinikov's diagrams (1963) were used to determine the water type, water origin, water genesis and any geochemical processes that affect the water genesis in the study area. It consists from a rectangle that divided into 8 triangles, 4 represent the marine water type and the other 4 triangles represent the continental water type (Fig.5).

3. RESULTS AND DISCUTIONS:

3. 1. Groundwater salinity distribution:

According to Chebotarev classification (1955), the salinity of the collected water samples shows a wide variation as shown in Table (3). This is generally attributed to lithology variation, rate of evaporation, weathering, fractures intensity and amount of recharge. In the study area, the groundwater salinity ranges from 1300 ppm (well No.14) in Abu Ghusun basin (Rumayt tributary) at the north to 20367 ppm (well No.21) in the central part. The water supplies in the area of study are found in the drainage basins dissecting the Red Sea mountainous region.

Different types of water bearing formations containing water of variable salinities are recorded, 10.8 % of the total samples are fresh water (T.D.S. < 1500 ppm) which is detected in 4 wells (13, 14, 15 & 34) and 54.1 % of the total samples are brackish water (T.D.S. ranges from 1500 to 5000 ppm) is detected in 10 wells (2, 5, 8, 9, 10, 12, 19, 20, 24, 25, 26, 27, 29, 30, 31, 32, 33, 35, 36 & 37). On the other hand, 35.1 % of the total samples are saline water (T.D.S. > 5000 ppm) (1, 3, 4, 6, 7, 11, 16, 17, 18, 21, 22, 23 & 28), is mainly detected in the deltas of several wadis at the coastal plain (Um Al Abas, Abu Ghusun, Ranga, El Reidi and Lahami wells), and also in the mining waters (the Shaft of wadi Abu Ghalagah mine).

3. 2. Major hydrogeochemical parameters:

The physicochemical parameters measured in the water samples and their statistical summaries are presented in table 2. The pH values of the selected water samples varies from 7.1 (wells No's.18, 22 & 25) in the center to 8.4 (well No.29) in the South with average value of 7.5 indicating that the waters are generally neutral to slightly alkaline. The variation of major cations (K^+, Na^+, Mg^{++} and Ca^{++}) and anions (Cl^-, SO_4^{--}, HCO_3^- and CO_3^{--}) concentrations measured in the studied water samples where SO_4^{--} and Na^+ are the dominant anion and cation, respectively.

The order of relative abundance of major cations in the studied waters is $Na^+ > Mg^{++} > Ca^{++}$ (on mg/l basis) while that of anions is $SO_4^{--} > HCO_3^- > Cl^-$. Large percentages of contribution to the TDS of water samples are from Cl^-, Ca^{++} and SO_4^{--}. Other ions, such as Al, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Ph, V and Zn are rare in the studied water samples.

The local precipitation and temporary floods represent the main source of groundwater recharges. The physical properties of several rock types and the areal extension of the catchment areas lead to the development of several aquifers and aquifer complexes, which include both hard and unconsolidated rock types.

3. 3. The hydrogeochemical formations:

The hydrogeological formations of the water points in the area are deduced. According to lithology, age and location, the hydrochemical compositions, hydrogeochemical formations and variations from the oldest till the youngest water bearing units are given as follows:

3. 3. 1. The Aquitard Fractured Basement Rocks:

a) The Aquitard Fractured Metamorphic Rocks:

These include the vast distribution areas of metasediments, metavolcanics and serpentinites and related rocks. This aquitard is represented by five water points namely; Abu Ghusun (2 wells), Qulan, and Mukhit (2 wells), No's.5, 6, 21, 36 and 37, respectively (Table 2). Their water salinities range from 2652 ppm (brackish) to 20367 ppm (saline), and their solutions are alkaline (PH values vary from 7.4 to 7.8). The E.C. values range from 3730 to 30859 micro mhos /cm. The ionic concentrations of chloride ions are higher followed by SO_4 and HCO_3.

The concentration of Na ions dominates among the cations followed by calcium ions in wells No's.5, 36 and 37, while in well No.6, the Na ions is followed by Mg ions and in well No.21 Mg ions exceeds Na ions. The origin of water is marine in water wells No.5, 21, 36 and 37 where, $r(K+Na)/ rCl < 1$, and meteoric in well No.6, where the above hydrochemical parameter is > 1.

The representation of these water samples on Sulin's graph (Fig.4), (Sulin, 1948), shows that samples No's.5, 21, 36 and 37 lie in the $CaCl_2$ triangle, where $rCl – r(K+Na)/ rMg > 1$, reflecting the old marine water origin, while well No.6 lie in the Na_2SO_4 triangle of meteoric origin, where $r(K+Na) - rCl/ rSO_4 < 1$.

While the interpretation of the hydrochemical compositions on Ovitichinikov's graph of oxidation environment (Fig.5), (Ovitchinikov, 1963), shows that samples No's.6 and 36 fall in triangle IV_O indicating the leaching of meteoric water to clays and carbonate rocks in wadi fillings. Samples No's.5 and 37 fall in triangle V_O reflecting deep meteoric water percolations. The sample No.21 falls in triangle VII_O (of marine water genesis), where $Mg^{++} + Ca^{++}$ ions are $> K^+ + Na^+$ ions.

The value of the hydrochemical parameters rK/rCl, rNa/rCl, rMg/rCl, rCa/rCl and rSO_4/rCl in equivalent concentrations are calculated and compared with the values of similar parameters in the normal sea water, which are 0.0181, 0.8537, 0.1981, 0.0385 and 0.103, respectively. A relative increase in the concentration of Na, Mg, Ca and SO_4 ions are noticed, indicating the leaching of meteoric water to the rock fragments.

From the salt combinations of samples No's.5 and 6 [KCl, NaCl, $CaSo_4$, Ca $(HCO_3)_2$] as well $MgCl_2$ & $CaCl_2$ in well No.5, Na_2So_4 & $MgSo_4$ in well No.6. Forming $CaCl_2$ indicates that these waters are mixed marine waters ascending along deep faults with meteoric ones. The hydrochemical composition of water sample No.21 still reflects the marine genesis of water, although it is diluted by meteoric water flows. The mixing of the old marine $CaCl_2$ type with meteoric waters transfers the hydrochemical composition from $CaCl_2$ to $MgCl_2$ water type. In water samples No's.36, and 37 the salt combinations are KCl, NaCl, $MgCl_2$, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$, as well $CaCl_2$ and $CaCO_3$ in well No.37. Salts of permanent hardness namely, $MgCl_2$, $CaCl_2$, $MgSO_4$ and $CaSO_4$ with a minimum one salt or a maximum three salts appear in the hydrochemical compositions of all water samples. The appearance of $NaHCO_3$ salt in the hydrochemical composition cancels the formation of permanent hardness salts.

Table (2): Hydrochemical analyses data of the investigated groundwater samples.

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Well No.	Well Name	PH	Ec	TDS		K	Na	Mg	Ca	Total Cations	Cl	SO_4	HCO_3	CO_3	Total Anions	Hydrochemical Formula
1	Umm Al Abas 1	7.55	13411	8583	ppm	52	908	285	894.4		2642.5	1700	101.2	13.06		$Cl_{67}\ SO^{4}_{35}\ CO^{3}_{2}$
					Epm	1.33	39.13	31.63	44.63	116.78	74.52	35.39	1.66	0.44	112	$M_{8.58}$ --------------------
					%	1.14	33.52	27.1	38.24		66.53	31.6	1.48	0.39		$Ca_{38}\ Na_{35}\ Mg_{27}$
2	Umm Al Abas 2	7.6	5880	3822	ppm	13	760	137.7	416.6		977.3	1506	65.9	8.67		$Cl_{57}\ SO^{4}_{40}\ CO^{3}_{3}$
					Epm	0.35	34.4	11.45	16.06	62.3	34.76	22.75	1.37	0.26	58.46	$M_{3.8}$ --------------------
					%	0.72	63.6	17.81	15.28		57.14	40.21	2.1	0.55		$Na_{64}\ Mg_{18}\ Ca_{18}$
3	Umm Al Abas 3	7.2	10205	7430	ppm	16	1600	266.2	823.1		1859.5	3000	132.7	16.52		$Ca_{53}\ SO^{4}_{42}\ CO^{3}_{3}$
					Epm	0.4	69.89	21.89	31.1	122.92	59.5	3000	132.7	0.52	117.62	$M_{7.43}$ --------------------
					%	0.33	65.58	17.81	15.28		53.44	42.46	2.18	0.54		$Na_{66}\ Mg_{18}\ Ca_{15}$
4	Abu Ghusun coastal	7.6	19370	12673	ppm	42	2100	425	1655		5854	2400	153.7	21.6		$Cl_{76}\ SO^{4}_{23}\ CO^{3}_{1}$
					Epm	1.07	91.66	34.95	82.58	214.1	165.08	49.97	2.52	0.72	218.93	$M_{12.67}$ --------------------
					%	0.5	44.65	16.32	38.55		75.63	22.89	1.15	0.33		$Na_{45}\ Ca_{39}\ Mg_{16}$
5	Al Arab 1	7.8	73770	4721	ppm	15	950	84.63	656.7		2252.5	800	58.9	17.47		$Cl_{78}\ SO^{4}_{20}\ CO^{3}_{2}$
					Epm	0.38	41.31	6.96	32.77	81.42	63.52	16.66	0.97	0.58	81.72	$M_{4.72}$ --------------------
					%	0.47	50.73	18.86	40.25		77.73	20.38	1.18	0.71		$Na_{51}\ Ca_{40}\ Mg_{9}$
6	Al Arab 2	7.4	18410	11782	ppm	28	3150	294.12	315.75		3673.5	2979	209.47	30.3		$Cl_{61}\ SO^{4}_{36}\ CO^{3}_{4}$
					Epm	0.72	137.03	24.19	15.76	177.69	103.59	62.02	3.43	1.01	170.06	$M_{11.78}$ --------------------
					%	0.4	77.12	13.61	8.87		60.92	36.47	2.02	0.59		$Na_{77}\ Mg_{14}\ Ca_{9}$
7	Al Ahaly	7.6	15430	9875	ppm	36	2450	314.3	1314		5461.7	1900	170.9	--		$Cl_{78}\ SO^{4}_{20}\ HCO^{3}_{1}$
					Epm	0.92	106.5	25.56	65.56	198.9	154.02	39.56	2.8	--	196.4	$M_{9.87}$ --------------------
					%	0.44	53.57	32.97	13.03		78.48	20.14	1.43	--		$Na_{54}\ Mg_{33}\ Ca_{13}$
8	Abu Ghusun Khazan	8.1	4670	2989	ppm	3.5	500	90.66	189.1		712.4	620	316	13.53		$Cl_{52}\ SO^{4}_{33}\ CO^{3}_{15}$
					Epm	0.09	21.74	7.46	9.43	38.72	20.09	12.91	5.18	0.45	38.63	$M_{2.99}$ --------------------
					%	0.23	56.15	19.26	25.37		52.12	33.41	13.4	1.17		$Na_{56}\ Ca_{25}\ Mg_{19}$
9	Farm 1	7.4	7520	4881	ppm	34	650	246.6	716.4		2556.5	600	84.46	--		$Cl_{84}\ SO^{4}_{15}\ CO^{3}_{1}$
					Epm	0.87	28.2	20.28	35.75	85.16	72.09	12.49	1.38	--	85.97	$M_{4.88}$ --------------------
					%	1.02	33.19	23.82	41.98		83.86	14.53	1.61	--		$Ca_{42}\ Na_{34}\ Mg_{24}$
10	Farm 2	7.2	6980	4467	ppm	10	669	260.87	505		1275.5	1639	144.78	12.12		$Cl_{49}\ SO^{4}_{47}\ CO^{3}_{4}$
					Epm	0.26	29.1	21.45	25.2	76	35.97	34.97	2.37	0.4	72.87	$M_{4.47}$ --------------------
					%	0.43	38.28	58.22	3.16		49.36	46.83	3.26	0.55		$Mg_{58}\ Na_{39}\ Ca_{3}$
11	Farm 3	7.6	91110	7629	ppm	62.1	1605	308.3	700.2		4042	606.5	244	31.7		$Cl_{87}\ SO^{4}_{18}\ HCO^{3}_{5}$
					Epm	1.59	69.79	25.35	34.94	131.7	113.98	12.67	4	1.06	131.67	$M_{7.63}$ --------------------
					%	1.21	53.19	19.26	26.54		86.57	18.45	3.04	0.8		$Na_{54}\ Ca_{27}\ Mg_{19}$
12	Farm 4	7.3	6520	4173	ppm	28.55	1235	62.86	77.66		644.6	1255	532.7	23.2		$SO^{4}_{52}\ Cl_{34}\ HCO^{3}_{9}$
					Epm	18.11	1125	5.07	3.77	61.75	18.1	30.21	8.65	0.81	59.68	$M_{4.17}$ --------------------
					%	1.24	48.95	28.68	21.13		31.43	52.44	14.83	1.29		$Na_{50}\ Mg_{29}\ Ca_{21}$
13	Rumayt 1	7.6	2154	1400	ppm	2.5	249	83	115		553	302	55	--		$Cl_{66}\ SO^{4}_{26}CO^{3}_{8}$
					Epm	0.064	10.78	6.8	5.74	23.38	15.6	6.29	1.92	--	23.81	$M_{1.4}$ --------------------
					%	0.27	46.11	29.08	24.55		65.52	26.42	8.06	--		$Na_{46}\ Mg_{29}\ Ca_{24}$
14	Rumayt 2	7.2	2000	1300	ppm	2.1	342	77	72		649	244	38	--		$Cl_{74}\ SO^{4}_{21}\ CO^{3}_{5}$
					Epm	0.054	14.8	6.33	3.59	24.784	18.3	5.08	1.33	--	24.71	$M_{1.3}$ --------------------
					%	0.22	59.71	25.54	14.48		74.06	20.56	5.38	--		$Na_{74}\ Mg_{21}\ Ca_{5}$
15	Rumayt 3	7.7	2154	1400	ppm	3.9	249	89	105		573	304	63	--		$Cl_{68}\ SO^{4}_{24}\ CO^{3}_{8}$
					Epm	0.1	10.78	7.3	5.24	18.42	16.16	6.33	2.2	--	26.83	$M_{1.4}$ --------------------
					%	0.54	58.52	22.49	18.45		68.21	23.59	8.2	--		$Na_{59}\ Mg_{22}\ Ca_{18}$
16	Abu Ghusun	8.0	17597	11438	ppm	20.99	2480	1007	280		5455	1883	189	17.2		$Cl_{79}\ SO^{4}_{19}\ CO^{3}_{2}$
					Epm	0.51	107.7	82.82	13.97	205.1	54.47	39.2	0.57	0.57	202.3	$M_{13.87}$ --------------------
					%	0.26	52.56	40.37	6.81		78.81	19.37	1.25	0.25		$Na_{53}\ Mg_{40}\ Ca_{7}$
17	Abu Ghalagah	7.9	21341	13872	ppm	61	5250	42.3	49.8		4011	1400	2987	83.2		$Cl_{78}\ CO^{3}_{22}SO^{4}_{10}$
					Epm	1.56	227.3	3.48	2.49	236.8	113.1	29.15	48.95	2.77	236.32	$M_{13.87}$ --------------------
					%	0.6	96.81	1.48	1.05		78.16	12.34	8.43	1.17		$Na_{96}\ Mg_{2}\ Ca_{2}$
18	Ranga coastal	7.1	19797	9500	ppm	31	1709	348	1300		3719.1	1250	66.4	--		$Cl_{76}\ SO^{4}_{23}\ CO^{3}_{1}$
					Epm	0.79	85.25	28.62	56.52	171.2	104.88	26.03	1.09	--	282.42	$M_{9.5}$ --------------------
					%	0.46	49.8	16.72	33.02		76.44	22.76	0.64	--		$Na_{50}\ Ca_{33}\ Mg_{17}$
19	Daurt	7.9	6250	3934	ppm	25	1150	62.86	71.64		708	1450	597	--		$SO^{4}_{51}Cl_{33}\ CO^{3}_{9.5}$
					Epm	0.64	50	5.17	3.57	59.39	19.79	30.19	9.5	--	59.65	$M_{3.93}$ --------------------
					%	1.1	84.2	8.71	6.02		33.47	50.61	15.9	--		$Na_{85}\ Mg_{9}\ Ca_{6}$
20	Hileifi	7.8	6290	3890	ppm	31.5	1100	60.46	79.6		627.3	1450	564	19.6		$SO^{4}_{52}Cl_{31}\ CO^{3}_{17}$
					Epm	0.81	47.83	4.97	3.97	57.58	17.69	30.19	9.24	0.65	57.77	$M_{3.89}$ --------------------
					%	1.4	83.07	10.78	5.75		30.62	52.25	16	1.13		$Na_{84}\ Mg_{11}\ Ca_{6}$

Table (2): Hydrochemical analyses data of the investigated groundwater samples (cont.).

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Well No.	Well Name	PH	Ec	TDS		K	Na	Mg	Ca	Total Cations	Cl	SO_4	HCO_3	CO_3	Total Anions	Hydrochemical Formula
21	Qulan Shaft	7.7	31823	20367	ppm	61	1100	2382	630.5	276.75	9000	288.42	60	7.2	279	$Cl_{66}\ SO^4_{33}\ CO^3_1$
					Epm	1.56	47.83	195.9	31.46		187.4	93.82	0.98	0.24		$M_{203.4}$ -------------------
					%	0.5	17.38	70.75	11.37		66.35	33.22	0.35	0.08		$Mg_{71}\ Na_{18}\ Ca_{11}$
22	El Reidi coast	7.1	9938	6360	ppm	42	800	110	37.9	96.1	2935	640	82.95	--	97.3	$Cl_{84}\ SO^4_{14}\ HCO^3_2$
					Epm	1.6	24.78	85.5	37.9		82	13.32	1.35	--		$M_{6.36}$ -------------------
					%	1.1	35.73	24.16	39.0		84.23	13.86	1.91	--		$Ca_{39}\ Na_{37}\ Mg_{24}$
23	El Reidi 2	7.24	9156	5860	ppm	16	900	146.5	683.4	85.6	2346	997	74.62	--	88.2	$Cl_{75}\ SO^4_{124}\ CO^3_2$
					Epm	0.4	39.1	12.03	34.1		66.2	20.8	1.22	--		$M_{5.86}$ -------------------
					%	0.48	45.68	14.03	39.61		75.04	23.58	1.38	--		$Na_{46}\ Ca_{40}\ Ca_{14}$
24	El Reidi 3	7.6	6102	3905	ppm	13	398	48.4	80	28.62	800	155.6	450.2	225	28.44	$Cl_{49}\ SO^4_{27}\ HCO^3_{24}$
					Epm	0.33	19.88	3.98	3.48		16.66	4.39	738	0.81		$M_{3.9}$ -------------------
					%	1.21	71.82	14.39	12.58		48.64	27.49	22.56	1.31		$Na_{73}\ Mg_{14}Ca_{13}$
25	Haratreit 1	7.1	4258	2725	ppm	14.5	443.4	107.7	230	41.35	1300	340	314.8	--	41.81	$Cl_{65}\ SO^4_{23}\ CO^3_{12}$
					Epm	0.37	22.13	8.86	10		27.07	9.59	5.16	--		$M_{2.72}$ -------------------
					%	0.9	53.5	21.42	24.18		64.73	22.93	12.34	--		$Na_{54}\ Ca_{24}\ Mg_{21}$
26	Haratreit 2	7.2	7263	4721	ppm	15	950	84.63	657	81.43	2253	803	59	17.5	81. 76	$Cl_{64}\ SO^4_{17}\ CO^3_2$
					Epm	0.38	41.31	6.96	32.8		63.53	16.67	0.98	0.58		$M_{4.72}$ -------------------
					%	0.47	50.73	8.56	40.24		77.71	20.39	1.19	0.71		$Na_{51}\ Ca_{40}\ Mg_9$
27	Hamata	7.6	5705	3708	ppm	14	1055	88.6	621	83.3	1103	2011	41	15	75.2	$SO^4_{56}\ Cl_{42}CO^3_2$
					Epm	0.36	45.67	7.28	30.99		31.11	41.87	1.43	0.62		$M_{3.7}$ -------------------
					%	0.48	54.8	8.72	35.1		42.38	55.61	1.92	0.09		$Na_{55}\ Ca_{35}\ Mg_9$
28	Lahami coast	7.3	11090	7098	ppm	26	1100	267	823.5	115.34	3544	82.67	600	--	111.9	$Cl_{88}\ SO^4_{11}\ HCO^3_1$
					Epm	0.86	47.8	22	46.1		100	1.36	12.49	--		$M_{7.1}$ -------------------
					%	0.65	40.98	18.9	39.47		87.8	11	1.2	--		$Na_{42}\ Ca_{39}\ Mg_{19}$
29	Lahami 4``	8.4	6210	3846	ppm	31.5	1100	60.46	79.6	57.58	627.3	1450	564	19.6	57.77	$SO^4_{52}Cl_{31}\ CO^3_{18}$
					Epm	0.81	47.83	4.5	3.97		17.69	30.19	9.24	0.65		$M_{3.85}$ -------------------
					%	1.4	83.06	8.64	6.9		30.62	52.25	16	1.13		$Na_{84}\ Mg_9\ Ca_7$
30	Lahami 8``	7.7	4538	2904	ppm	6.5	342.7	74.7	500	45.15	1700	261.4	41.3	--	45.59	$Cl_{81}\ SO^4_{17}\ CO^3_2$
					Epm	0.17	17.1	6.14	21.74		35.39	7.57	0.68	--		M_{29} -------------------
					%	0.37	47.88	13.61	28.14		81.47	16.97	1.56	--		$Na_{48}\ Ca_{28}\ Mg_{14}$
31	Lahami 1	7.98	4930	3155	ppm	29	1011	59.83	2.6	52.18	783	1100	376.7	42.5	52.6	$Cl_{42}\ SO^4_{34}\ CO^3_{13}$
					Epm	0.74	44	4.92	4.98		22.1	22.9	11.75	1.42		$M_{3.15}$ -------------------
					%	1.42	82.18	9.51	6.89		42.12	33.57	21.6	2.71		$Na_{83}\ Mg_{10}\ Ca_7$
32	Lahami 2	7.3	5545	3599	Ppm	13	550	134	411.8	57.69	1772	41.34	300	--	62.43	$Cl_{88}SO^4_{11}\ CO^3_1$
					Epm	0.43	23.9	11	23.1		50	1.36	6.25	--		$M_{3.6}$ -------------------
					%	0.55	40.98	18.97	39.5		87.5	11.3	1.2	--		$Na_{41}\ Ca_{40}\ Mg_{19}$
33	Lahami 3	7.6	6378	4082	Ppm	5.2	1000	318.4	38.6	62.68	1234	1100	288.7	--	62.43	$Cl_{56}\ SO^4_{37}\ CO^3_8$
					Epm	0.14	43.48	15.89	3.17		34.8	22.9	4.73	--		$M_{4.1}$ -------------------
					%	0.23	69.36	25.35	5.06		55.74	36.68	7.58	--		$Na_{70}\ Mg_{25}\ Ca_5$
34	Lahami 4	7.7	2500	1600	ppm	15	360	88.24	31.58	24.88	267.86	512.75	341.94	48.48	25.45	$SO^4_{42}\ Cl_{30}\ CO^3_6$
					Epm	0.38	15.66	7.26	1.58		7.55	10.08	5.6	1.62		$M_{1.6}$ -------------------
					%	1.53	62.67	29.27	6.53		29.68	41.95	22.02	6.35		$Na_{30}\ Mg_{64}\ Ca_7$
35	Abu Qurayyah	8.0	7921	4415	ppm	33	1109	3.48	33.1	73	1820	710	70.7	25.16	72.4	$Cl_{71}\ SO^4_{26}\ CO^3_3$
					Epm	0.84	48.1	0.28	19.78		52.4	18.83	18.75	0.84		$M_{4.41}$ -------------------
					%	1.17	66.45	4.53	27.85		71.3	26.1	1.62	1.16		$Na_{68}\ Ca_{28}\ Mg_5$
36	Al Hafiri	7.8	4080	2652	ppm	17.5	711	42.1	263.4	67.3	1168	620	91	--	47.1	$Cl_{70}\ SO^4_{28}\ CO^3_2$
					Epm	0.45	30.46	3.46	13.14		32.88	18.8	1.16	--		$M_{2.65}$ -------------------
					%	0.95	64.2	7.2	27.65		69.87	28.42	1.71	--		$Na_{65}\ Ca_{28}\ Mg_7$
37	Taww	7.7	5994	3890	ppm	33	950	84.63	656.7	81.88	2153	800	58.9	17.5	87.69	$Cl_{78}SO^4_{20}\ CO^3_2$
					Epm	0.84	41.31	6.96	32.77		65.75	20.8	0.97	0.59		$M_{3.89}$ -------------------
					%	0.49	50.72	8.55	40.54		77.72	20.39	1.18	0.71		$Na_{51}\ Ca_{41}\ Mg_9$
38	Red Sea water	7.7	68344	43740	ppm	250	14000	1644	277	775.31	24235	3200	110	25	753.02	$Cl_{90}\ SO^4_9\ HCO^3_2$
					Epm	6.4	608.7	135.2	13.83		583.43	66.62	1.8	0.17		$M_{43.75}$ -------------------
					%	0.84	79.66	17.69	1.81		90.36	8.86	0.26	0.52		$Na_{80}\ Mg_{18}\ Ca_2$
39	Nile water	8.0	261	172	ppm	25.26	18.16	14.00	6.00	3.52	9.09	129.38	37.3	6.38	3.38	$SO^4_{63}\ HCO^3_{28}\ Cl_9$
					Epm	1.26	1.49	0.61	0.15		0.30	2.12	0.783	0.18		$M_{0.17}$ -------------------
					%	35.85	42.47	17.32	4.36		8.96	62.74	22.98	5.32		$Mg_{43}\ Na_{36}\ Ca_4$
40	Rain water	6.9	136	80	ppm	16.8	8.00	6.00	4.00	1.86	0.00	43.13	38.80	15.3	1.95	$HCO^3_{64}\ SO^4_{36}$
					Epm	0.84	0.66	0.26	0.10		0.00	0.71	0.81	0.43		$M_{0.08}$ -------------------
					%	45.08	35.38	14.04	5.50		0.00	36.32	41.51	22.17		$Na_{80}\ Mg_{14}\ Ca_6$

Table (3) The frequency distribution of groundwater salinity in the study area.

Groundwater Salinity (mg/l)		% Frequency distribution (mg/l)			Total samples
Max.	Min.	Saline water T.D.S > 5000	Brackish water T.D.S 1500-5000	Fresh water T.D.S < 1500	
20367	1300	35.1 %	54.1 %	10.8 %	37

Table (4) Concentrations of minor and trace constituents (ppm) of the groundwater samples.

No	Fe	Cu	Zn	Pb	Co	Mn	Al	Ba	Mo	Ni	Sr	Ph
1	14.02	3.62	2.416	9.36	3.58	0.16	5.7	0.173	0.159	Nil	Nil	2.416
2	11.68	0.00	2.893	0.14	Nil	0.167	0.11	0.242	0.66	0.4	Nil	2.893
3	13.92	3.62	0.3481	4.51	Nil	0.12	1.82	0.68	0.149	0.39	0.63	0.348
4	49.38	0.65	1.059	0.15	0.644	0.14	0.39	0.4	0.132	0.4	Nil	1.059
5	23.93	1.16	0.54	0.492	Nil	6.99	4.25	0.27	0.13	Nil	0.28	0.505
6	49.51	0.56	4.01	0.14	0.116	0.128	0.45	19.2	0.192	0.106	0.15	4.01
7	18.53	1.17	1.326	6.99	Nil	0.42	0.612	0.58	0.12	0.62	0.79	1.326
8	47.39	0.22	22.6	4.51	Nil	5.22	0.558	0.59	0.111	0.42	Nil	22.6
9	25.13	6.70	4.029	12.41	0.33	0.96	0.882	0.57	0.16	0.32	0.85	4.029
10	0.101	0.00	0.494	0.00	Nil	0.404	0.438	0.94	0.023	Nil	Nil	0.494
11	0.174	0.62	1.174	5.80	Nil	1.42	1.606	1.69	0.2497	Nil	0.76	1.174
12	25.13	0.61	Nil	22.59	0.14	Nil	0.736	1.69	0.551	Nil	Nil	Nil
13	11.35	3.62	2.046	9.36	6.99	0.156	2.12	0.98	0.149	0.453	Nil	2.046
14	27.01	0.00	3.08	0.14	Nil	Nil	2.58	2.59	0.67	Nil	0.752	3.08
15	12.89	0.65	3.18	0.218	Nil	Nil	0.764	7.3	0.68	Nil	Nil	3.18
16	14.02	1.16	2.134	nil	0.342	0.243	0.625	15.5	0.62	0.31	Nil	2.134
17	25.22	0.56	Nil	Nil	Nil	Nil	0.911	12.5	0.22	0.54	0.401	00
18	1.063	0.277	0.185	1.54	Nil	0.259	1.89	16.65	0.276	0.135	0.152	0.185
19	0.449	Nil	6.282	Nil	1.22	0.123	15.7	0.173	0.79	0.43	0.16	6.282
20	Nil	Nil	0.48	Nil	Nil	Nil	0.173	15.72	00	Nil	0.143	Nil
21	Nil	0.39	0.106	0.66	0.86	33.93	0.242	0.11	0.96	Nil	0.165	4.53
22	65.33	0.25	0.21	26.88	Nil	1.39	0.677	1.815	0.537	0.126	1.954	10.35
23	27.20	0.95	0.106	Nil	0.82	0.468	0.396	0.388	1.365	Nil	2.068	Nil
24	Nil	Nil	0.131	Nil	Nil	0.736	0.269	4.254	1.447	Nil	7.1	1.99
25	0.378	0.495	0.105	2.13	Nil	30.67	19.32	0.452	0.22	0.557	0.791	8.44
26	Nil	Nil	0.51	Nil	0.924	0.67	0.578	0.612	0.308	Nil	1.439	11.69
27	Nil	0.133	0.66	Nil	Nil	0.68	0.579	0.558	0.363	Nil	1.439	6.80
28	23.59	Nil	0.4	2.91	Nil	0.787	0.57	0.882	0.688	0.674	1.37	0.00
29	12.50	1.33	0.52	0.62	0.35	1.381	0.936	0.438	0.064	Nil	2.072	3.43
30	10.16	Nil	0.63	2.45	Nil	1.067	1.689	1.606	0.566	Nil	6.074	1.99
31	16.37	0.61	0.82	6.92	Nil	2.107	1.693	0.736	0.453	0.645	1.467	8.44
32	11.06	0.83	0.84	3.19	0.975	1.09	0.898	2.102	0.426	Nil	9.45	11.69
33	19.45	0.45	0.88	0.36	Nil	2.442	2.589	2.577	0.517	Nil	5.81	6.80
34	Nil	Nil	0.121	Nil	Nil	8.028	7.252	0.762	0.508	0.657	0.293	23.28
35	0.57	0.14	0.157	1.23	0.439	27.9	15.54	0.625	0.708	Nil	3.975	1.51
36	0.604	0.327	0.208	Nil	Nil	27.9	12.49	0.901	2.191	Nil	0.293	0.88
37	Nil	Nil	0.41	0.964	0.652	17.93	6.65	1.889	0.563	0.976	9.89	0.64

b) The Aquitard Fractured Plutonic Rocks:

The fractured plutonic rocks include the vast distribution areas of granite, granodiorite and related rocks. This aquitard is represented by 15 water points [wadi Abu Ghusun (3 wells), wadi Ranga (2 wells), wadi El Reidi (5 wells), wadi Lahami (4 wells) and wadi Mukhit (one well)] with No's.13, 14, 15, 19, 20, 23, 24, 25, 26, 27, 31, 32, 33, 34 and 35 (Table 2). Their salinities range from 1300 to 5860 ppm and their solutions are alkaline in reaction (PH ranges from 7.1 to 8.0). The E.C. values vary from 1970 to 8879 micro mohs/cm. The ionic concentration of Cl always dominates and followed by SO_4, while in wells No's.19, 20, 27 and 34 the SO_4 exceed the Cl.

Among the cationic concentrations, the Na > that of the Mg, followed by Ca, except in wells No's.23, 25, 26, 27, 32 and 35, where Ca > Mg. The hydrochemical compositions in wells No's.19, 20, 24, 27, 31, 33 and 34 reflect its meteoric genesis where the hydrochemical parameter r(K+Na)/ rCl > 1, while wells No's.13, 14, 15, 23, 25, 26, 32 and 35 reflect the marine water genesis, where the hydrochemical parameter r(K+Na)/ rCl < 1.

The Sulin's graph (Fig.4), reveals that the Na_2SO_4 of meteoric water type represented by the parameter r(K+Na)- rCl/ rSO_4 < 1, appears in the water wells No's.19, 20, 24, 27, 31, 33 and 34. The $MgCl_2$ of marine type represented by the parameter rCl - r(K+Na)/ rMg < 1, is still reflected in the water wells No's.13, 14, 15, 25 and 32. The ionic concentration of chlorides is higher than the total concentration of potassium, sodium and magnesium ions, where the $CaCl_2$ water type of the old marine water genesis is still reflected in the hydrochemical composition of the water wells No's.23, 26 and 35 represented by the parameter rCl - r(K+Na)/ rMg >1.

The representation of these water samples on Ovitchinikov's graph (Fig 5) shows that they fall in the triangles either in the triangle No. II_O for water wells No's.24, 27, 31 and 34 or the triangle No. III_O for water wells No's.19 and 20 which belongs to meteoric water genesis leaching fine grained rock fragments, or in the triangle IV_O for water wells No.33 which refer to the water composition of the original marine water diluted by flushing with meteoric water percolations. The water samples No's14, 15, 25, 26 and 35 fall in triangle V_O (of marine water genesis), where Mg^{++} + Ca^{++} ions are greater than K^+ + Na^+ ions and the water samples No's13, 23 and 32 fall in the triangle No.VI_O of marine origin.

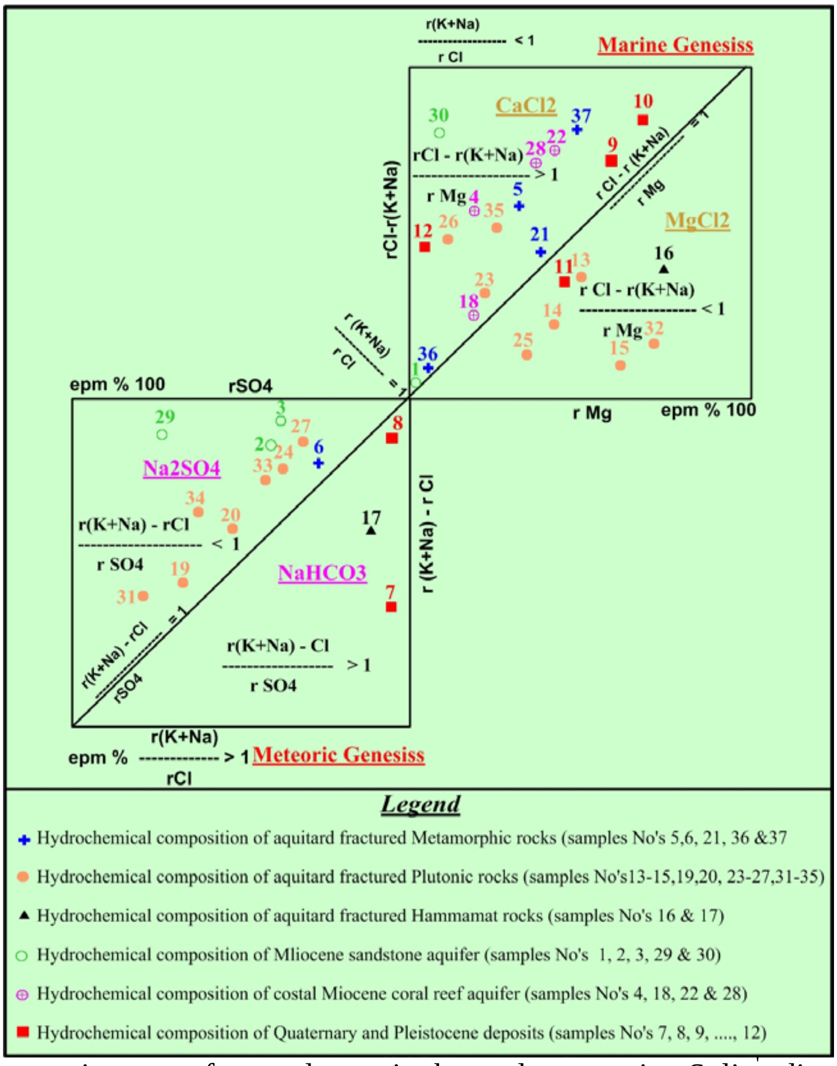

Fig (4): The genetic types of groundwater in the study area using Sulin's diagram (1948).

By comparing the hydrochemical parameters (rK/rCl, rNa/rCl, rCa/rCl, rMg/rCl and rSO_4/rCl) for water of these wells with values of the normal sea water with the marine ones. Although dilution of the different water genesis exists, the hydrochemical compositions still indicate the marine water genesis in the water wells No's.13, 14, 15, 25, 26 and 32. Water, a relative increase in the concentrations of sodium, magnesium and sulphate ions exists, which refers to leaching, dilution and mixing of the marine water with marine water.

From the hypothetical salt combinations, it clears that in the water well No's.19, 20, 24, 27, 31, 33 and 34 the Na_2SO_4 salt is formed which indicates the deep percolation of meteoric water with high flow rates, giving complete flushing to the original marine waters from open fractures in aquitard basement rocks. The $NaHCO_3$ salt exists in the hydrochemical composition of the water wells Nos.20, 29 and 31, and indicates the shallowness of water near to the catchment area. The water wells No's.13, 14, 15, 23, 25, 26, 32 and 35 the $MgCl_2$ salts are still present in spite of their dilution with meteoric water at high flushing rate. Salts of permanent hardness exist in the hydrochemical compositions of the all water wells drilled in fractured plutonic rocks either in waters still reflected by sea water origin or by meteoric waters of deep percolations.

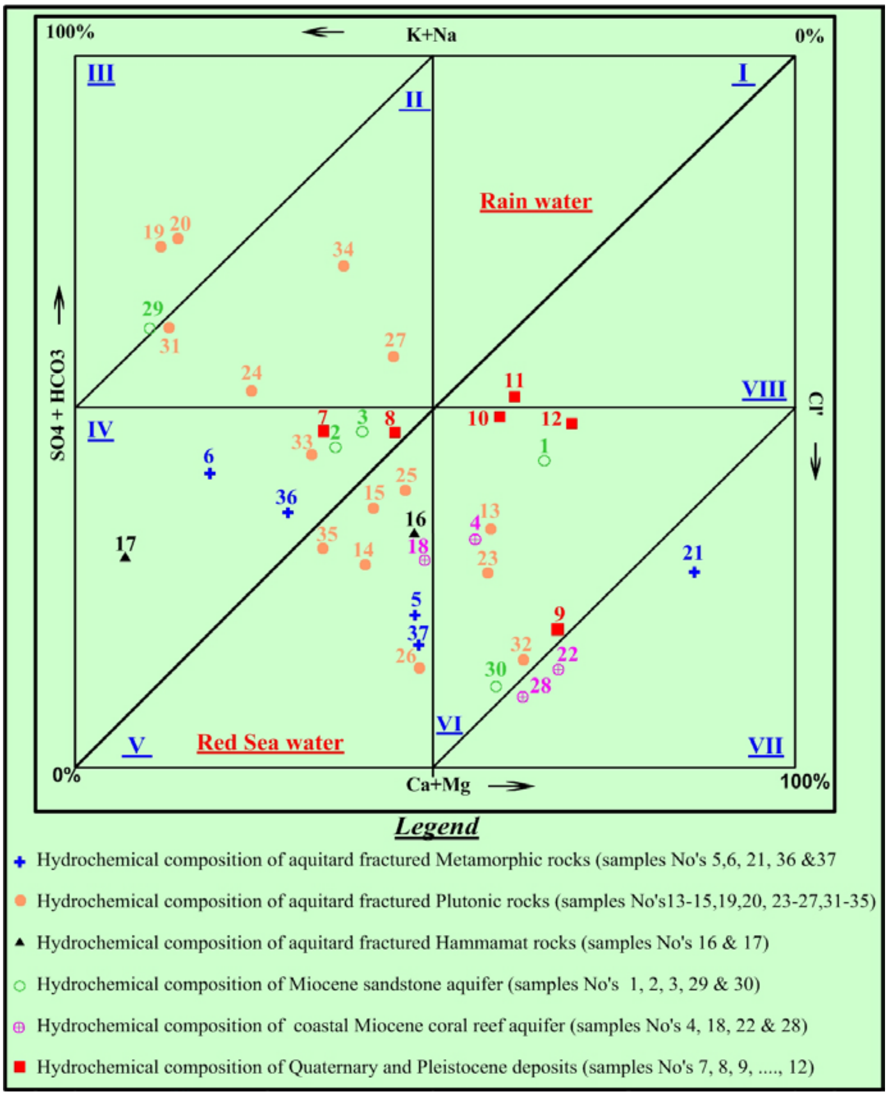

Fig (5): Ovitchinikov's graph (1963) for presentation of groundwater types.

c) The Aquitard Fractured Hammamat Rocks:

These rock types are represented by two water wells; i.e. in wadi Abu Ghusun wells No's.16 and 17 (Table 2). The solutions of these water samples are alkaline in reaction, where the PH values range from 8.0 to 7.9 respectively. The E.C. values attain 17330 to 21018 micro mohs/ cm respectively. The water salinities are saline (T.D.S. are 11438 and 13872 ppm respectively).

The dominant cations arrange in the order of $Na^+ > Mg^{++} > Ca^{++}$, in the two wells· The dominant anions are in the order of $Cl^- > SO_4^{--} > HCO_3^-$ in these water wells. The water of meteoric genesis in water well No.17 where the parameter r(K+Na)/ rCl >1, while the water well. No.16 is marine water genesis, where the parameter r(K+Na)/ rCl < 1. The representation of the hydrochemical compositions of these water samples on Sulin's graph (Fig 4) shows that the water belongs to the $NaHCO_3$ type of meteoric origin in well No.17 with the parameter r(K+Na)- rCl/ rSO_4 >1, composed of fragments of shales, clays and carbonates, but in well No.16 the water belongs to the marine origin of $MgCl_2$ with the parameter rCl - r(K+Na)/ rMg < 1.

On Ovitichinikov's graph of oxidation environment (Fig.5), the hydrochemical compositions of water well No.16 falls in triangle No.V_O of marine water origin leaching mainly to clays of wadi fill. The water well No.17 falls in triangle No.IV_O, where the water is meteoric in origin due to leaching processes to the wadi fill, inspire of the high increase in the chloride content, probably due to leaching of some rock salts.

The values of the hydrochemical parameters (rK/rCl, rNa/rCl, rMg/rCl, rCa/rCl and rSO_4/rCl) are calculated and compared with the values of similar parameters in the normal sea water, which are 0.0181, 0.8537, 0.1981, 0.0385 and 0.103, respectively (Ovitchinikov, 1963). A relative increase in the concentrations of Na^+, Ca^{++} and SO_4^{--} is noticed, which indicates that they are formed by leaching of meteoric water to the rock fragments constituents.

3. 3. 2. The Sedimentary Aquifers:

a) The Miocene Sandstone Aquifer:

This aquifer is represented by five water wells in wadi Um Al Abas (three productive wells, one is drilled by the DRC), wadi Lahami (two wells), No's.1, 2, 3, 29 and 30 (Table 2). The water salinities of these wells are range from brackish to saline (T.D.S. range between 2904 and 8583 ppm). The water of these wells are alkaline in reaction (PH values ranges between 7.2 and 8.4), and the E.C. values are 4400 and 13004 micro mhos/ cm, respectively. The dominant cations are arranged in the order of $Na^+ > Mg^{++} > Ca^{++}$ in wells No's.2, 3 and 29, while they are arranged in the order $Na^+ > Ca^{++} > Mg^{++}$ in wells No's.1 and 30. The dominant anions are and arranged in the order $Cl^- > SO_4^{--} > HCO_3^-$ in all wells except in well No.29 where the arrangement is $SO_4^{--} > Cl^- > HCO_3^-$. The water types in these wells are (Mg, Na, Calcium – SO_4^{--}, Chloride in well No.1 , Ca^{++}, Mg^{++}, Sodium – SO_4^{--}, Chloride in wells Nos. 2 and 3, Sodium – HCO_3^-, Cl^- Sulphate in well No.29 and Mg^{++}, Ca^{++} Sodium – SO_4^{--} - Chloride in well No.30). The water of the wells No's.1, 2, 3 and 29 reflect the meteoric water genesis, where the hydrochemical parameter r(K+Na)/ rCl >1, while the water of wells No.30 reflect the marine water genesis, where the same parameter < 1.

The interpretation of the hydrochemical composition on Sulin's graph (Fig.4) reveals the meteoric Na_2SO_4 type of deep water percolation in wells No's.2, 3 and 29, where the parameter r(K+Na)- rCl/ rSO_4 < 1, while the hydrochemical composition reveals the meteoric $CaCl_2$ type of marine water in well No's.1 & 30 where the parameter rCl - r(K+Na)/ rMg >1.

On Ovitchinikov's graph of oxidation environment (Fig.5), the water well sample No.29 lies in the triangle No.III_O of meteoric water genesis. Besides, the dominance of chloride ions among the anions indicates the leaching of meteoric water to different rock constituents mainly shales, clays, gypsum and probably rock salts. The water samples No's.2 and 3 lie in the triangle No.IV_O of deep percolated meteoric water. The water samples No's.1 and 30 lie in the triangle No.VI_O of marine water origin.

The study of the hydrochemical parameters, and comparing their values with those of the normal sea water, shows that a relative increase in the concentrations of K^+, Na^+, Mg^{++}, Ca^{++} and SO_4^{--} ions exist. Such relative increase is due to leaching processes by the deeply percolating meteoric water affected by the gypsum deposits of Miocene sediment at that locality.

The hypothetical salt assemblages are KCl, NaCl, $CaCl_2$, Na_2SO_4, $MgCl_2$, $MgSO_4$, $CaSO_4$ and $NaHCO_3$ due to the high ionic concentration of the sulphates. The presence of Na_2SO_4 salt indicates the deep percolation of meteoric water in semi-closed fractures. Salts of permanent hardness are represented by $MgSO_4$ and $CaSO_4$, while the salt of temporary hardness [Ca $(HCO_3)_2$] is 15% and 13% in these water points.

b) The costal Miocene Coral Reef Aquifer:

This aquifer is represented by four water points (Abu Ghusun well No. 4, Ranga well No. 18, El Reidi well No. 22 and Lahami coastal well No. 28) (Table 2). The water is saline, where the salinities range from 6360 to 12673 ppm. It is alkaline in chemical reactions, where the PH values range from 7.1 to 7.6, while the E.C. values differ from 9636 to 19202 micro mhos/ cm. The relative abundance of the anions is $Cl^- > SO_4^{--} > HCO_3^-$ in all water points and the cations is $Na^+ > Ca^{++} > Mg^{++}$, in water wells No's.4, 18 and 28, while in water well No.22 the relative abundance of the cations is $Ca^{++} > Na^+ > Mg^{++}$. The hydrochemical parameter r(K+Na)/ rCl < 1, reflects the marine water origin in all water wells.

Interpretation of the hydrochemical compositions on Sulin's graph shows that the all water points No's.4, 18, 22 and 28 lie in the $CaCl_2$ triangle of old marine water origin where the parameter is rCl - r(K+Na)/ rMg >1. On Ovitchinikov's graph of oxidation environment, the water point No.18 belongs to triangle No.V_O, but well No.4 belongs to triangle No.VI_O and the water points No's.22 and 28 belongs to triangle No.VII_O, both of them reveal the marine water origin.

The values of the hydrochemical parameters are calculated and compared with the same parameters of the normal sea water. The obtained values are near to those of the sea water composition, while the decrease in K^+ and Na^+ ions reflects the cationic exchange before their dilution by the meteoric water. The salt combinations are KCl, NaCl, $MgCl_2$, $CaCl_2$, $CaSO_4$ and $Ca(HCO_3)_2$ in four wells No's. Three salts of permanent hardness exist, namely $MgCl_2$, $CaCl_2$ and $CaSO_4$.

c) The Quaternary and Pleistocene Deposits:

This is represented by six water wells in wadi Abu Ghusun (water wells No's.7 - 12). The water salinities range from 2989 to 9875 ppm, and their solutions are alkaline in reaction where the PH values range from 7.2 to 8.1. The values of E.C. vary from 4529 to 14962 micro mhos/ cm (Table 2). Mostly the Cl ions dominate among the anions, except in water well No.12, where the SO_4 exceed the ionic concentration of the Cl. Among the cations, Na ions prevail in water wells No's.7, 8, 11 and 12, followed by Mg, while in water well No's.8 & 11 the Na ions are followed by Ca ions. In water well No.10 the ionic concentration of Mg exceeds those of the Na followed by Ca ions.

Interpretation on Sulin's graph reveals that, water well No's.7 & 8 lies in $NaHCO_4$ triangle of meteoric water type of parameter r(K+Na)- rCl/ rSO_4 >1, referring to their deep percolation. The water wells No's.9, 10 and 12 lie in $CaCl_2$ triangle of old marine water type with the parameter rCl - r(K+Na)/ rMg >1, while the water wells No.11 lie in $MgCl_2$ triangle of old marine water type with the parameter rCl - r(K+Na)/ rMg < 1.

On Ovitchinikov's graph of oxidation environment, water well No's.7 & 8 falls in triangle No.IV_O of meteoric genesis also, referring to the process of leaching to the rock salts, The water wells No's.9, 10 and 12 fall in triangle No.VI_O of marine water genesis, while the water well No.11 falls in triangle No.$VIII_O$, of marine water origin.

The hypothetical salt combinations are KCl, NaCl, $MgCl_2$, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$ in water wells No's.7 and 10, where these salt assemblages show a prolonged reduction of the old marine water. The assemblage KCl, NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$, $Ca(HCO_3)_2$ and $CaCO_3$ in water wells No's.8 and 12 belongs to the Na_2SO_4 water type of deep meteoric water percolations, while the presence of $MgCl_2$ indicates the presence of faulting. The salt combinations of water wells No's.9 & 11 are KCl, NaCl, $MgCl_2$, $CaCl_2$, $CaSO_4$ and $Ca(HCO_3)_2$, (more close to those of rain water), due to the shallowness of the aquifer and the leaching of the soil constituents under normal air temperature.

The hydrochemical parameters of these water wells are calculated and compared with those of normal sea water. An increase in the concentration of calcium, magnesium and Sulphate ions is noticed, referring to the mixing and dilution of the original old marine water with meteoric ones, besides a decrease in K^+ and Na^+ ions in water wells No's.7, 8 and 10 represents the preserved relics of the old marine water during its diagenesis and adsorption of ions to clay to give cationic equilibrium between water and rocks.

By comparing the hydrochemical coefficients rK/rCl, rNa/rCl, rCa/rCl, rMg/rCl and rSO_4/rCl of these water wells to those of normal sea water, the hydrochemical composition of well No.11 indicates a relative increase exists in the values of these parameters, which refers to the leaching processes of the alluvial sediments by meteoric water. The obtained values of the same parameters for the hydrochemical compositions of water wells No's.7, 8, 9 and 10, show a relative decrease in the concentration of K and Na ions, but Mg, Ca and SO_4 ions increase. The decrease in the concentration of K and Na ions is due to their adsorption to clayey sediments to maintain cationic equilibrium between water and rock, while the increase in the concentrations of Mg, Ca and SO_4 is due to mixing by meteoric waters. Fig (6) is a diagram shows the metasomatic changes in the groundwater (Burdon, 1958).

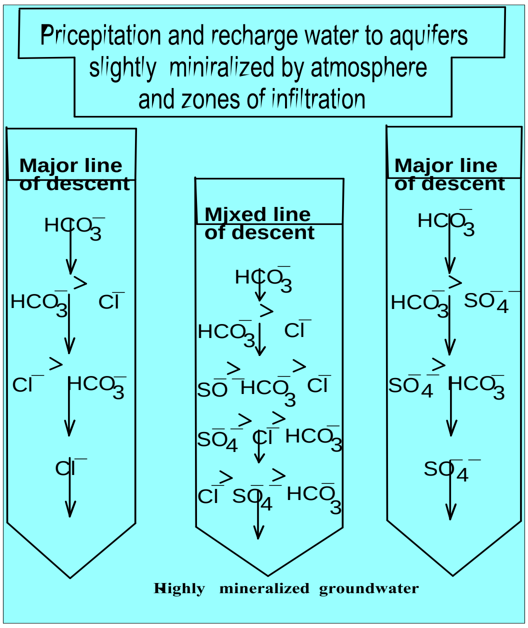

Fig (6): A diagram for the metasomatic changes in the groundwater (After Burdon, 1958).

3. 4. Total Hardness (TH):

Total Hardness (TH) of water is defined as its content of metallic ions that react with sodium soaps to produce solid soaps, or the content of negative ions, which produce scummy residue and solid scale in boilers. According to American Society for Testing and Materials (ASTM 1976), waters are classified into several categories according to the total hardness (Table 5).

Table (5) Classification of natural waters in terms of total hardness, (ASTM 1976)

Hardness	Water type
00- 55	Soft
56- 100	Slightly hard
101- 200	Moderately hard
201- 500	Very hard
> 500	Excessively hard

4. GROUNDWATER QUALITY EVALUATION:

The natural water quality is discussed for deferent using purposes (for drinking, domestics, irrigation, livestock and poultry and industrial) in the study area, based on the recommended standards of the World Health Organization (WHO, 2008).

4. 1. Evaluation of groundwater for drinking and domestic purposes:

The water to be suitable for drinking and domestic uses should be colorless, odorless, tasteless, clear and free from excessive solids. Chemically, the water should preferably be low in dissolved solids, soft and free from poisonous constituents. In the study area the evaluation of groundwater quality for drinking and domestic uses is attempted depending on the standards recommended by the Egyptian Higher Committee for Water (EHCW 2007) and World Health Organization (WHO 1996) as listed in Table (6).

a) Salinity:

Based the table below, the groundwater of the hydrogeological units named basement rocks (Metasediments, Plutonics and Hammamat), and the sediments (Miocene sandstones, coral reef and the Quaternary alluvial) show that the groundwater of the Metasediments are brackish to saline, and those of the Plutonic is also generally brackish. But the Hammamat rocks, all the wells give highly saline water (> 10000 ppm). The ground waters of the Middle Miocene sandstones aquifers are classified as brackish water, while that of the Pliocene coral reef is highly saline and that of the Quaternary aquifers is fresh, brackish or saline waters. Chebortrev (1955) give the following classification of groundwater (Table 6).

b) Domestics:

For the domestic uses hardness of water (ppm of Ca $(HCO_3)_2$, should be blow 100 ppm. Where, the values greater than excessive (ppm) markedly impair the potability of water. Samples less than 100 ppm of calcium are Nos.12, 14, 17, 19, 20, 22, 24, 29, 34 and 35. The other water well exceed 100 ppm of calcium. According to the above standards no groundwater of the aquitards are suitable for drinking (tables 7&8).

Table (6) Classification of groundwater according to Chebortrev, (1955)

Water quality	T.D.S (PPM)	Water type
(good potable)	>500	Fresh water
(F.) fresh	500 - 700	
(F.F.) fairly fresh	700 - 1500	
(P.F.) possible fresh	1500 – 2000	
(S.B.) slightly brackish	2000 – 3200	Brackish water
(B.) brackish	3200 – 4000	
(D.B) Definitely brackish	4000 – 5000	
(S.S.) Slightly salty	5000 – 6000	Saline water
(S.) Salty	6000 – 7000	
(V.S.) Very salty	7000 – 10000	

Table (7) The maximum permissible limits of the main parameters for domestics according to WHO (1996), and the Egyptian Higher Committee for Water (2007).

Parameter	EHCW (2007)	WHO (1996)	Parameter	EHCW (2007)	WHO (1996)
Ph	------	6.5- 8.5	SO_4	250	400
TDS	1000	1000	HCO_3	------	350
Na	200	200	Total hardness	500	------
K	------	12	Ammonia, NH_4	0.5	No Guideline
Cl	250	250	Nitrate, NO_3	45	50
Ca	------	200	Phosphate, PO_4	------	------
Mg	------	500			

From the chemical analysis of the collected water samples (table 2) and the above mentioned standards, the following can be deduced:

a) Total dissolved solids (TDS) and total hardness (TH) in the collected water samples exceed the maximum of the permissible limits.

b) In most of samples (90%), the concentration of chloride and sodium exceed the critical safe limits, however most of samples (99%) have an acceptable limit of (pH) and HCO_3 ion concentrations.

c) In the study area, there is no source for sewage and also there is no agriculture activity except around Abu Ghusun wells No's. (7, 8, 9, 10, 11 and 12). Accordingly there is a very limited probability for presence of anthropological effect on the water quality, or pollution by NO_3 except around these wells (Tahoon, 2011).

Table (8) The permissible limits for domestic purposes water uses as presented by EAESCO and UNESCO, 1963.

Substances	Permissible (ppm)	Excessive (ppm)	Sample No.
T.D.S.	500	1500	- 13, 14, 15
Ca	75	200	- 8,12-15,17, 19, 20, 22, 24, 29, 31, 33-35
Mg	50	150	- 2,5,8,12-15,17, 20-27, 29-32,34-37
SO_4	200	400	- 13-15, 21, 24, 28, 30.
Cl	200	600+	- 12-15, 20, 29, 34
PH range	7.0 – 8.5	8.5-9.2	- All samples.

4. 2. Evaluation of groundwater for irrigation purposes:

The most important factors affecting water quality for irrigation are; silt, the total concentration of salts, the proportion of sodium to other cations and special toxic ions as boron or iodine for some crops, Na^+, Cl^- and HCO_3^- (Thorne and Peterson, 1945). Effects of excessive salts on soils causing changes in soil structure, permeability and aeration which indirectly affect plant growth. The concentration of certain heavy metals as copper, zinc, cobalt and manganese have a direct bearing on iron chlorosis. One plant species may tolerate more of a certain minor element than another. Considering the quality of groundwater and their suitability for irrigation purposes, the following two factors are taken into consideration: 1- The total salinity.

2- The relative proportion of sodium to other cations, Sodium Absorption Ratio (SAR).

4. 2. 1. Silt:

It's content in water play an important beneficial role in reclaiming sandy areas for cultivations.

4. 2. 2. The total dissolved solids (T.D.S.):

The total dissolved solids (T.D.S.) should not generally exceed 1000 ppm, but it have been found that this limit does not hold good when salts are present in the form of carbonates and bicarbonates (Singh and Shawla, 1946).

4. 2. 3. Sodium:

The main problem with high sodium concentration is its effect on soil permeability and water infiltration. Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops. When the proportion of sodium to other cations in irrigation water increases, sodium replaces the soil calcium and magnesium as follows:

$$2\,Na^+ + Ca\,(clay) \text{-----------} Na(clay)\,Na^+ + Ca^{++}$$

$$2\,Na^+ + Mg\,(clay) \text{------------} Na(clay)\,Na^+ + Mg^{++}$$

This reaction is called Base Exchange which alkalises the soil. The granular and permeable soils are converted into sticky clay of low permeability due to this reaction, which dries up into lump sand are difficult to plough. Hence, various ratios of sodium to calcium and magnesium have been used to evaluate the water to irrigation.

a) Wilcox's (1948) classification:

Wilcox defined a sodium percentage in items of epm of the common cations: $Na^+ \% = (Na^+ + K^+) / (Ca^{++} + Mg^{++} + Na^+ + K^+) \times 100$ ppm . He represented a diagram with total cations in epm as abscissa and (Na%) as ordinate and subdivided it into divisions (0 -100) to delineate good and bad water. As shown from Figure (7) samples No's.7, 10, 13, 14, 19, 24, 25, 29, 30, 31 and 32 fall in the doubtful to unsuitable class and the samples No's. 9, 15 falls in the permissible to doubtful class while the rest samples fall in the unsuitable class (i.e. out of the classification).

b) The U.S. salinity laboratory staff's classification:

The sodium hazard of irrigation water is estimated by the sodium absorption ratio (SAR), which is calculated by the following formula that proposed, by the U.S.S.L. staff (1954): $SAR = 2\,Na^+ / (Ca^{++} + Mg^{++})$ where the cations are expressed in meq/l.

They proposed a diagram (Fig 8) consists of a plot of specific conductivity (in micro mhos/cm at 25°C) which is a function of total dissolved solids concentration, against SAR, the water is divided into classes C1, C2 , C3, ... etc in which C denote to conductance (EC) and S1, S2, S4, ... denote the SAR, (Table 9). Continued use of water having a high SAR leads to a breakdown in the physical structure of the soil. Sodium replaces calcium and magnesium in clay minerals and causes dispersion of soil particles. This dispersion results in breakdown of soil aggregates and causes a cementation of the soil under drying conditions as well as preventing infiltration of rain water. Classification of irrigation water based on SAR values is shown in Table (10), (College of Agriculture Sciences 2002).

1) Conductivity classification (C) and description.

Table (9) Conductivity (EC) and Sodium ion classifications (S) and descriptions.

C	Degree	Description
C1	Low salinity water	Good.
C2	Moderate to saline water	Good for soils of medium permeability for most plants.
C3	Medium to high saline water	Satisfactory for plants having moderate salt tolerance on soils of moderate permeability with leaching.
C4	High saline water	Satisfactory for salt tolerant crops on soils of good permeability with special leaching.
C5	Excessive saline water	Not fit for irrigation.

2) Sodium classification ions (S) based on SAR values and descriptions.

Table (10) Sodium classification ions (S) based on SAR values and descriptions, (College of Agriculture Sciences, 2002)

S	SAR	Degree	Description and hazard
S1	< 10	Low sodium water	Good, No harmful effect from sodium.
S2	10 – 18	Medium sodium water	Good for coarse-grained permeability soils, unsatisfactory for high (fine-textured) clayey soils with low leaching.
S3	18 – 26	High sodium water	Suitable only with good drainage, high leaching and organic matter addition, some chemical additives such as gypsum would be necessary to exchange sodium ions.
S4	> 26	V. high sodium water	Generally unsatisfactory for irrigation.

As shown from Figure (8) the samples No's.13, 14,15, 17, 18, 19, 20, and 36 fall in moderate water class, and the samples No's.7, 9, 11, 12, 22, 24, 29, 30, and 31 fall in the intermediate water class, while the rest water samples fall in the unsuitable category, which requires artificial drainage almost all the time. Most of samples collected during the study belonged to S1 group. Three samples related to S2 (No's. 33, 34 and 35) and only one samples (No. 4) related to S4 group (Fig8).

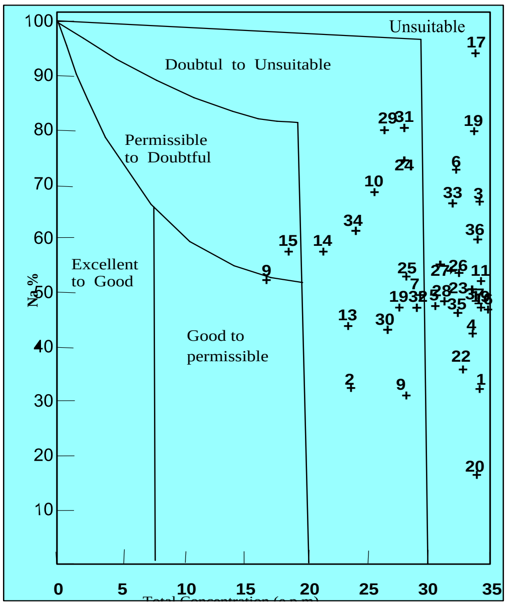

Fig (7): Classification of groundwater according to Wilcox method.

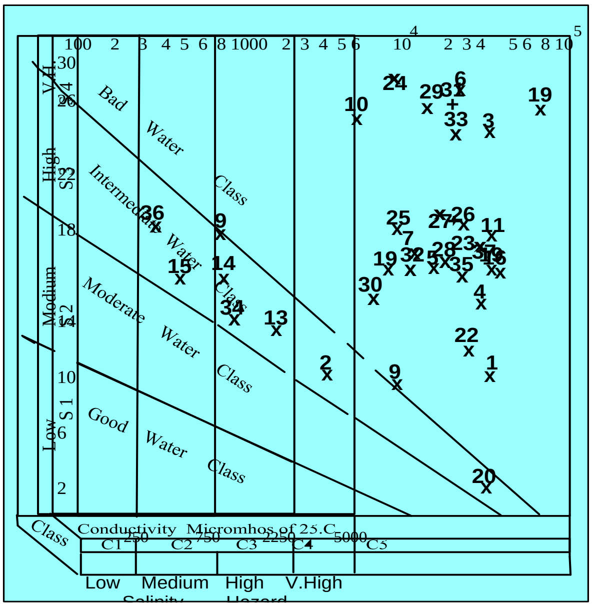

Fig (8): U.S. Salinity diagram for classification of irrigation water.

c) Irrigation Factor (a): It was proposed by Kamenesky (1947). The water can be evaluated according to a (the irrigation factor) which can be calculated as the following table:

Formula (epm)	Ionic aspect of groundwater (ppm)
A = 288 / 5 Cl	Na < Cl
A = 288 / Na + Cl	Cl + SO_4 > Na > Cl
a = 288 / 10 Na + Cl - 9504	Na > Cl + SO_4

According to the limits listed in the above table (11), the samples Nos.13, 14 15 and 34 fall in the satisfactory category, while the samples No's. 2, 7, 20, 34 and 36 fall in the unsuitable category which requires artificial drainage almost all the time. The rest samples are fallen in the bad category.

Table (11) Quality and condition of irrigation water according to the irrigation factor, (after Kamenesky, 1947)

(a) Factor	Quality	Condition of irrigation water
> 19	Good	Water can be satisfactory for irrigation many times, no special arrangements should be taken against accumulation of harmful alkaline salts.
19 – 6	Satisfactory	Special arrangement to be taken against accumulation of alkaline except for shallow soils having free drainage.
1.2 – 6	Unsuitable	It requires artificial drainage almost all the time (Nos. 2, 7, 9 - 12, 13, 14, 15, 23, 24, 29, 30 and 35.
< 1.2	Bad	Shouldn't be utilized for irrigation (all the rest wells).

d) Residual Sodium Carbonates (RSC):

According to Eaton (1950) irrigation water will be suitable if the R.S.C. is negative and is unsuitable if it is positive. This term is defined as:

RSC = (CO_3^{--} + HC_3^{-}) - (Ca^{++} + Mg^{++}). The analyzed water samples in the study area give a negative value except the samples Nos.13, 14, 15 and 34 which give a positive value of RSC. These means that all water samples are suitable for irrigation purposes.

e) Electric conductance (EC):

Excess salt increases the osmotic pressure of the soil water and produces conditions that keep the roots from absorbing water. This results in a physiological drought conditions. Even though the soil appears to have a plenty of moisture, the plants may wilt because the roots don't absorb enough water to replace water lost from transpiration. Based on the EC, irrigation water can be classified into five categories (College of Agricultural Sciences 2002) as shown in Table (12). This means that the groundwater samples No's.13, 14 and 15 only are suitable for irrigation and may be also samples No's.29, 30 and 34 of doubtful water class, while the rest water samples are unsuitable for irrigation.

Table (12) Classification of irrigation water based on salinity (EC) values, (College of Agricultural Sciences 2002)

Level	EC (µS/cm)	Hazard and limitations	Water points
C1	< 250	Low hazard; no detrimental effects on plants and no soil build-up expected, (Excellent).	Non.
C2	250 – 750	Sensitive plants may show stress; moderate leaching prevents salt accumulation in soil (good).	Non.
C3	750 – 2000	Salinity will adversely affect most plants; require selection of salt tolerant plants, careful irrigation, good drainage and leaching, (Permissible).	- Quaternary water point No. 14
C4	2000 > 3000	Generally un acceptable for irrigation, except for very salt tolerant plants, excellent drainage, frequent leaching and intensive management (Doubtful).	- Quaternary water points (15 and 16). - Plutonic rock water point (34)
C5	> 3000	Unsuitable	The rest of water samples

4. 3. Evaluation of groundwater for livestock and poultry purposes:

A classification presented by the National Academy of Science (NAS, 1972) for using the saline water for livestock and poultry is given in table (13). According to these guides, the groundwater in the study area can be classified as follow;

- It can be noticed that the no water samples are fallen in the first division.
- The water samples Nos.13, 14, 15, 25, 30, 34 and 36 fall in the second division and are very satisfactory for all classes of livestock and poultry.
- The water samples (17) No's. 2, 5, 8, 9, 10, 12, 19, 20, 24, 26, 27, 29, 31, 32, 33, 35, and 37 fall in the third division which is satisfactory for livestock, but may causes some diseases.
- The water samples No's.22 and 23 fall in the fourth division which uses in some livestock and not acceptable for poultry.
- Water samples No's.1, 3, 7, 11, 18 and 28 lie in the fifth division which is unfit for poultry and probably for swine.
- The rest water samples (Nos.4, 6, 16, 17 and 21); lie in the sixth division which can not be recommended for use under any conditions.

4. 4. Evaluation of groundwater for industrial purposes:

Some industries may require water to be purer than domestic water, while others may require some specific minerals to be absent. The quality requirements of water at point of use for some industries (National Academy of Science 1972), are listed in table (14). By applying these standards listed the result reveals that, some of the groundwater samples are suitable for some industries. All water samples are unsuitable for paper and textile industrial purposes because the T.D.S. is high. For petroleum industries the water samples No's. 2, 5, 8, 13, 14, 15, 25, 30, 31, 34 and 36 are suitable, while the rest water samples are unsuitable, where the ions of potassium, sodium sulphate and chloride are higher than the permissible limits. For feed water all the samples are unsuitable.

Table (13) Guide to use of saline waters for livestock and poultry.

Div.	Concentration	Characters	Well No.
I	Less than 999 mg/l	Relatively low level of salinity, excellent for all classes of livestock and poultry.	------
II	1000-2999 mg/l	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to than on watery dropping in poultry.	13, 14, 15, 25, 30, 34, 36
III	3000-4999 mg/l	Satisfactory for livestock, but may cause temporary diarrhea or may refused at first by animals not accustomed to them, often causing water faces, increased growth, especially in true keys.	2, 5, 8, 9, 10, 12, 19, 20, 24, 26, 27, 29, 31, 32, 33, 35, 37.
IV	5000-6999 mg/l	Can be used with responsible safty for doing and beef cattle, for sheep, swine and hourses. Avoid use for pregnant or lactating animals. No acceptable for poultry.	22, 23.
V	7000-10000 mg/l	Unfit for poultry and probably for swine, considerable risk in using for pregnant or lactating cows, horses, sheep, on for the young of these species. In general, use should be avoided although older ruminants, horses, poultry and swine may subsist on them under certain conditions.	1, 3, 7, 11, 18, 28.
VI	Over 10000 mg/l	Risks with the highly saline water are so great that they can not be recommended for use under any conditions.	4, 6, 16, 17, 21.

On the other hand, some treatments are required for the other types of groundwater in the area. The groundwater could be used in some industrial activities such as ore dressing in the mining areas as well as small projects (Textile industry). It can be shown that the Langelier Saturation Index (LSI) approximates the base 10 logarithm of the calcite saturation level.

Table (14) The quality requirements of water at point of use for some industries.

Character	**Paper industry**	**Water textile**	**Petroleum**	**Feed low pressure**	**Intermediate water pressure**
PH	------	------	6 – 9	7 – 10	8.2 – 10
T.D.S.	200- 500	100 - 200	3500	700	500
Alkalinity	75 – 150	50 – 200	500	350	100
Hardness	------	0 - 50	900	350	1
$Na^{+} + K^{+}$	------	------	230	170	------
Ca^{++}	------	------	------	------	0.4
Mg^{++}	------	------	85	------	0.25
$HCO_3^{--} + CO_3^{--}$	------	------	480	170	1.26
SO_4^{----}	------	100	900	------	------
Cl^-	0 – 200	100	1600	------	------
Iron	0 – 1.1	0.0 - 0.3	15	1	0.3
Silica	20 – 100	25	82	130	10

The Langelier Saturation level approaches the concept of saturation using pH as a main variable. The LSI can be interpreted as the pH change required for bringing water to equilibrium. According to LSI, Most of samples (64%) recorded probably no treatment needed and the other recorded treatment may be needed. General recommendations can be shown for each water sample as in Table (15).

Table (15) Results of evaluation of the groundwater wells for domestic, irrigation, livestock and industries purposes.

Well No.	Hydrogeologic Unit	For Drinking	For Irrigation	For Livestock	For Industries
5	F. Basement Metamorphic	Unsuitable	Unsuitable	Suitable	Suitable
6		Unsuitable	Unsuitable	Unsuitable	Unsuitable
21		Unsuitable	Unsuitable	Unsuitable	Unsuitable
36		Unsuitable	Unsuitable	Suitable	Suitable
37		Unsuitable	Unsuitable	Unsuitable	Unsuitable
13	. Basement Plutonic	Suitable	Suitable	Suitable	Suitable
14		Suitable	Suitable	Suitable	Suitable
15		Suitable	Suitable	Suitable	Suitable
19		Unsuitable	Suitable	Suitable	Unsuitable
20		Unsuitable	Unsuitable	Suitable	Unsuitable
23		Unsuitable	Unsuitable	Suitable	Unsuitable
24		Unsuitable	Suitable	Suitable	Unsuitable
25		Unsuitable	Suitable	Unsuitable	Suitable
26		Unsuitable	Unsuitable	Suitable	Unsuitable
27		Unsuitable	Unsuitable	Suitable	Unsuitable
31		Unsuitable	Suitable	Suitable	Suitable
32		Unsuitable	Suitable	Suitable	Unsuitable
33		Unsuitable	Unsuitable	Suitable	Unsuitable
34		Unsuitable	Unsuitable	Unsuitable	Suitable
35		Unsuitable	Suitable	Suitable	Unsuitable
16	F. Basement Hammamat	Unsuitable	Unsuitable	Unsuitable	Unsuitable
17		Unsuitable	Unsuitable	Unsuitable	Unsuitable
1	Miocene sandstone aquifer	Unsuitable	Unsuitable	Unsuitable	Unsuitable
2		Unsuitable	Unsuitable	Suitable	Suitable
3		Unsuitable	Unsuitable	Unsuitable	Unsuitable
29		Unsuitable	Suitable	Suitable	Unsuitable
30		Unsuitable	Suitable	Suitable	Suitable
4	Coastal Miocene coral reef aquifer	Unsuitable	Unsuitable	Unsuitable	Unsuitable
18		Unsuitable	Unsuitable	Unsuitable	Unsuitable
22		Unsuitable	Unsuitable	Suitable	Unsuitable
28		Unsuitable	Unsuitable	Unsuitable	Unsuitable
7	Quaternary & Pleistocene deposits	Unsuitable	Suitable	Unsuitable	Unsuitable
8		Unsuitable	Unsuitable	Suitable	Suitable
9		Unsuitable	Suitable	Suitable	Unsuitable
10		Unsuitable	Suitable	Suitable	Unsuitable
11		Unsuitable	Unsuitable	Unsuitable	Unsuitable
12		Unsuitable	Unsuitable	Suitable	Unsuitable

SUMMARY AND CONCLUSION

The groundwater exists under free, unconfined to confined conditions at depths varying between 4m at and about 80m. This study depends on the results of chemical analyses of 37 groundwater samples collected from the studied aquifers. These analyses include the determination of salinity and major cations and anions besides the minor and micro lements and hardness of groundwater. In this study the following parameters are discussed in detail: Salinity, water chemical types, ion ratios, hardness, alkalinity, statistical analysis and water quality are also discussed. The study indicated the role of the different chemical processes in the evolution of the present chemical characteristics of the groundwater. The chemical water types and the ion ratios indicate meteoric origin for groundwater and dissolution of terrestrial and marine salts.

The hydrochemical compositions of the groundwater at the area of study reflect both the meteoric and the marine water geneses. The meteoric water genesis is represented by 15 water points, while the water points of the marine water genesis are exist in 22 localities. The characters of each water genesis are given as follows:-

1) The meteoric water genesis:

a) The $NaHCO_3$ water origin: It is detected in 3 water wells (two in the sedimentary aquifers, No's.7 & 8) and one in the aquitard fractured basement rocks No.17), in Wadi Abu Ghusun. Salinities of these waters vary from 2980 to 13872 ppm and the E. C. values range from 4529 to 21018 micro mhos/ cm. The solutions are alkaline in reactions, where the PH values range between 7.6 and 8.1. The ionic concentration of Na dominates among the cations, followed by Mg (except in water point No.8). The anionic concentrations of Cl > SO_4 in these water wells. This water genesis indicates the leaching of meteoric water to wadi fill due to the shallowness of the aquifer. The hydrochemical parameters show a relative increase in the ionic concentration of Na, Mg, Ca and SO_4 than in the same parameters of the normal sea water. The salt combinations are KCl, NaCl, $MgSO_4$, $CaSO_4$ and $CaHCO_3$ in wells No's.7 & 8 and KCl, NaCl, Na_2SO_4, $NaHCO_3$ and $CaCO_3$ at well No.17.

b) The Na_2SO_4 water origin: This water origin is detected in 12 water points (eight wells in the aquitards fractured basement rocks and 4 water wells in the sedimentary aquifers). These water wells are Um Al Abas wells (No's.1, 2 & 3), one well at Abu Ghusun basin (No.6), two wells at Ranga basin (No's.19 & 20) and two well in El Reidi basin (No's.24 & 27). Besides, there are four wells at Lahmi basin (No's.29, 31, 33 & 34). Salinities of these wells vary from 1600 to 8583 ppm and their E.C. values range from 2400 to 13004 micro mhos/cm. The water types of these water wells are 5 types. These are Ca, Mg & Sodium (wells Nos. 2, 3) Mg, Ca & Na (No.1)-SO_4, Chloride, in three Um Al Abas wells. Mg & Sodium- SO_4 & Chloride in well No. 6. Mg, Sodium–Cl, Sulphate in wells No's.19 & 20. The water type in well No.24 is Ca, Mg, Sodium–HCO_3, sulphate, Cl while in No.27 Ca, Sodium–Cl, sulphate, wells No's. 29, 31, 33 and 34 are Na- Cl, SO_4 in well No.29, Na- HCO_3, SO_4, Cl in well No.31, Mg, Na- SO_4, Cl in well No.33, Mg, Na- HCO_3, Cl, SO_4 in well No.34

The hypothetical salt combinations of this water genesis are; KCl, NaCl, $MgCl_2$, $CaCl_2$, $CaSO_4$, $Ca(HCO_3)_2$, in wells No's.1&2, KCl, NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$ $CaCO_3$ in wells No's.3, 6, 19 & 27, KCl, NaCl, Na_2SO_4, $NaHCO_3$, $MgHCO_3$, and $CaCO_3$ in wells No's.20, 29 & 31, KCl, NaCl, Na_2SO_4, $MgSO_4$, $MgHCO_3$, $Ca(HCO_3)_2$, and $CaCO_3$ in wells No's.24, 33 &34. The salt assemblages refer to deep meteoric water percolation in fissures leaching to the fine grained rock fragments. The hydrochemical parameters of water show an increase in the conc. of Na, Mg, Ca and SO_4 by comparison with the same parameters of normal sea water.

2) The marine water genesis:

a) The $MgCl_2$ water origin: There are 7 water wells represent this water origin No's.11, 13, 14, 15, 16, 25 & 32. These water wells lie in the aquitard fractured basement rocks (six wells), besides well No.11 lies in the sedimentary aquifer. The E.C. values vary from 1970 to 17330 micro mhos/ cm. The water salinities of these water wells range from 1300 to 11438 ppm. The dominant cations are in the order of $Na^+ > Ca^{++} > Mg^{++}$ in three wells No's.11, 25 & 32, $Na^+ > Mg^{++} > Ca^{++}$ in 4 water wells No's13-16. Among the anionic concentrations, it is found that the Cl ions dominated.

The water types of these water wells are Ca, Mg, Sodium-SO_4, Chloride in three wells. Mg, Ca, Sodium-SO_4 Chloride in four wells No's. 13-16. The hypothetical salt combinations characteristic to this water origin are KCl, NaCl, $MgCl_2$, $CaSO_4$, $MgSO_4$, and $Ca(HCO_3)_2$, as well $CaCl_2$ in wells No's.11 & 32, similar to that of the normal sea water. The presence of the $MgCl_2$ among the assemblage still reflects the original sea water solution between rock pores of these marine sediments in spite of their dilution by meteoric waters under low flushing rates.

b) The $CaCl_2$ water origin: This type of old marine water origin is represented by 15 water points No's.4, 5, 9, 10, 12, 18, 21-23, 26, 28, 30, 35-37. These are; 7 water wells in the aquitard fractured basement rocks and 8 water wells in the sedimentary aquifers. The water wells in the aquitard fractured basements (due to the marine transgression of the first paleo-hydrogeological cycle) are; Abu Ghusun well No.5, Qulan well No.21, wells No's.23 & 26 (El Reidi basin) and wells No's.35, 36 & 37 (Mukhit basin). The water wells tapped the sedimentary aquifers are; well No's4, 9, 10 & 12 (at Abu Ghusun basin), There are also three water wells in the coastal Miocene coral reefs (water wells No's.18, 22 & 28) beside one water well in the Miocene sandstone aquifer (Lahami water wells No.30). The water salinities of these water wells vary from 2652 to 20367 ppm and the E.C. values range from 4400 to 30859 micro mhos/ cm. The water solutions are alkaline in reaction, where the PH values range from 7.1 to 8.0 The types of these waters are Mg, Na Calcium - SO_4, Chloride in water wells No's.9 &22, Mg, Ca, Sodium- SO_4, chloride in 11 water wells (except No.12 chloride, SO_4), Ca, Sodium, Mg - SO_4, chloride in two wells No's.10 & 21. The salts of permanent hardness in these water wells are $MgCl_2$, $CaCl_2$, $MgSO_4$, $MgHCO_3$, $Ca(HCO_3)_2$ and $CaCO_3$ in all wells. The presence of the $MgCl_2$ and $CaCl_2$ salts are still represented as relics in spite of their dilution with meteoric water at low flushing rate in closed fractures.

The groundwater in the area of study is evaluated for the purposes of domestic, irrigation, industrial, livestock and poultry. The water of the Quaternary aquifer is suitable for drinking as waters in the basement fractures, while the water of the other aquifers is unsuitable for human drinking (T.D.S.>1500 ppm). The water of the Quaternary and Middle Miocene aquifers are suitable for livestock and poultry uses as well as irrigation purposes. All the analyzed water points are unsuitable to be used for the industrial purposes.

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