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Hydrochemistry and evaluation of groundwater in Sidi Barrani, Egypt; determination of the best sites for desalination plants

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ABSTRACT

Qualitative and quantitative water scarcity represents a problem for sustainable development in the developed countries, especially in the semi-arid and arid zones. Sidi Barrani locality that lies on the North-Western Coast of Egypt was chosen as an example of an arid area that suffers from the water shortage and high salinity of groundwater. It lies between longitudes 25º 30′ & 26º 18′ E and latitudes 31º 21′ & 31º 39′ N. It covers about 660 Km^2. The groundwater in the investigated area presents in three main water bearing formations, Holocene (alluvial), Pleistocene (oolitic limestone) and Middle Miocene (limestone). During the study period, thirty three groundwater samples were collected from the three different aquifers, physically and chemically analyzed and then classified according the total dissolved solids (TDS), hardness, the concentration of major, minor and trace components. The results of the analysis of water samples show wide ranges of TDS (372-12926 mg/l), total hardness (120-804 mg/l as $CaCO_3$) and chloride concentration (101-7200 mg/l). Also, the presence of metals such as iron and manganese is observed. Moreover, according to chemical characteristics of the groundwater, best sites for possible desalination projects were selected.

Key words: Water Chemistry ; Groundwater Evaluation ; Desalination; North Western Coast.

Introduction

Water scarcity is the most dangerous problem facing human kind as water is the key of life for every living being. There are two types of water scarcity; qualitative or quantitative, where the qualitative water scarcity takes place when all the water resources are of poor water quality and not suitable for drinking and domestic uses. Whereas the quantitative water scarcity takes place when the amount of clean fresh water is not sufficient to be available for everyone within a region

The good groundwater potentialities and potential soils for agricultural expansion make the study area is mainly a bedouin community with some houses and a very few farms. The study area has a dry climate where the precipitation is around 105.07mm/year. The air temperature ranges from 23° to 26°C in summer while it ranges from 13 to 15 °C in winter (Atwa, 1979). The relative humidity in the area is high due to sea effect; it is about 63% in July and 46 % in February. The rainy Season starts at October till March and the dry season lasts from July till the end of September. The climatic conditions of the study area are typically arid, characterized by a long hot dry summer, mild winter with little rainfall, high evaporation with moderately to high relative humidity (Ali *et al*, 2007).

Bedouins at this area depend on preserved rainwater which is insufficient to provide them with fresh water until the next rain season. After their rain stock run out, they are forced to use the groundwater of high salinity. The dry weather and the fresh water shortage made it necessary to search for a new way to provide fresh water resources and make the best use of the existed groundwater aquifers and this solution is the desalination.

Determination of groundwater quality and evaluation of it for different various uses provide the basic information necessary to determine the problem and identify the possible solutions. They also essential for desert reclamation, establishing desalination plants, making industrial and tourism activity

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and achieving sustainable development. Reliable geologic, hydrogeological and hydro geochemical information are the proper bases to the development.

The aim of studying groundwater quality is to evaluate its suitability to be used in different purposes. As the natural groundwater chemistry directly affects the human health, therefore it is necessary to completely analyze the constituents of groundwater in details. Some important water quality standards will be examined on the bases of water quality to assess its suitability for various uses. The evaluation of water quality for these uses relies mainly on physical nature and chemical constituents. Moreover, the study will be to select the best sites for establishing desalination plants based on type of groundwater.

2. General features of the study area:

Sidi Barrani is the largest and main town at the study area which considered an arid area overlooking at the charming Northwestern Mediterranean coast of Egypt but without the exploitation of tourism activities. It lies between longitudes 25º 30′ & 26º 18′ E and latitudes 31º 21′ & 31º 39′ N. It covers about 660 Km^2, Fig. (1).

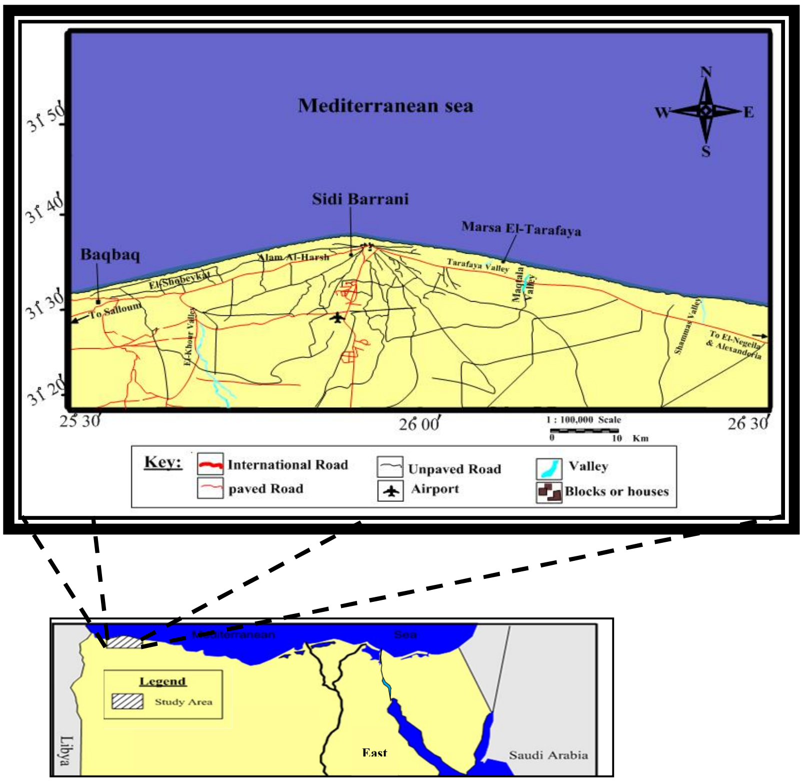

Fig. 1: Location map of the study area

2.1. Geomorphology:

Geomorphologically the area of study includes three units; a coastal plain, piedmont plain, and hydrographic basins, Fig. (2). (Mousa, 1976).

The coastal plain with oolitic limestone ridges. It occupies the northern narrow strip of land, which stretches for about 500km adjacent to the present Mediterranean shoreline at the middle and west of the study area.

Piedmont plane with dissected ridges represent the inland ward extension of the coastal plain varies in different localities and being controlled by the condition of the elevated plateau to the south. This plain slopes significantly in the northward direction and displays elevations ranging from 60m above sea level to approximately the sea level. The piedmont plain is developed at the foot slope of the structural plateau. It is occupied by thick calcareous soils of fine alluvial deposits of many wadis. The plain has relatively gradated surface and slopes at a rate of 5m /km.

The hydrographic basins are variable in the density and nature. They are few, shallow and short at the study area till Baqbaq (west of the study area) where the drainage lines are deep, mature, incised and extended with alluvial terraces.

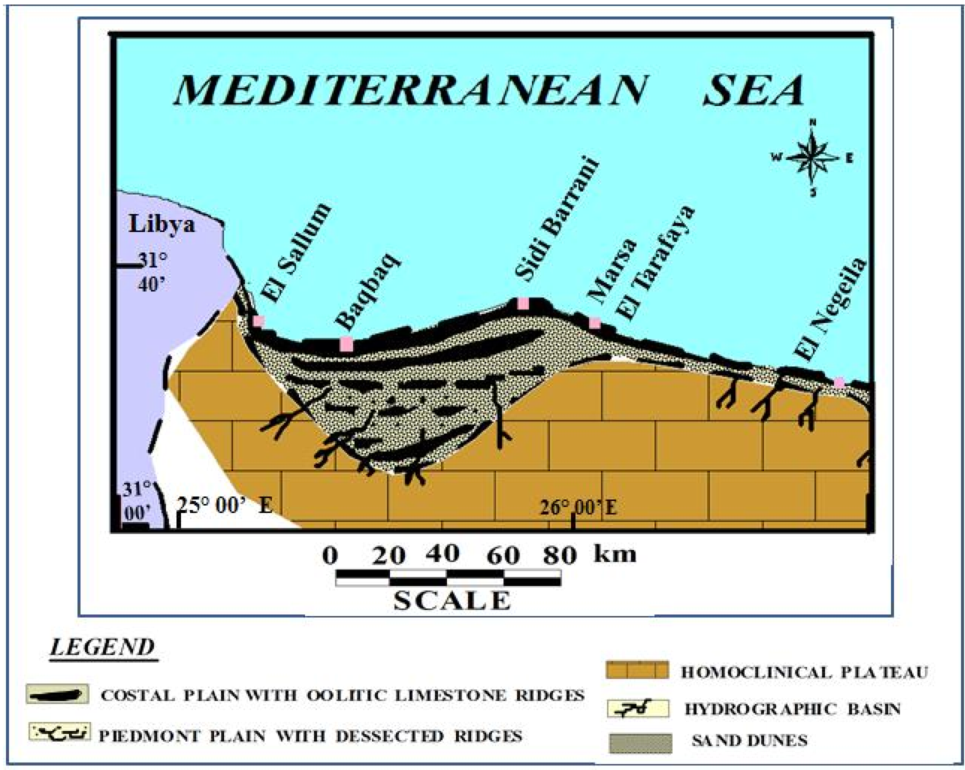

Fig. 2: Geomorphologic map of the study area after Mousa (1976)

2.2. Geology:

In the North- Western Mediterranean coastal zone of Egypt, the exposed rocks are completely of sedimentary origin, ranging in age from Tertiary Middle Miocene (limestone) to Pleistocene (oolitic limestone) and Holocene (alluvial) with maximum thickness of about 150 m, (Atwa, 1979), Fig.(3).

1-The Tertiary deposits are represented in the area of study by middle Miocene M.Miocene limestone rocks.

2-The Quaternary deposits of the investigated area are Pleistocene oolitic limestone and Holocene alluvial sediments. In the coastal area, Holocene deposits are wide spread in the study area and represented by the alluvial deposits, which are composed of quartz sand, silt and clay and rock fragments, enriched with carbonates in the northern parts of the area. These deposits are sometimes converted into Sabkhas and salt marshes which are rich in evaporates. The Pleistocene oolitic limestone have wide distribution especially at the north western part of the study area. These deposits composed of carbonate grains with dispersed quartz grains and fossil allochems, all cemented in various degrees by carbonate cement. Also these deposits exhibiting considerable ground-water potentialities. Such formation has been tapped by several shallow water wells

2.3. Hydrogeological conditions

Throughout the area under consideration the main groundwater aquifers are classified into Alluviul aquifer (Holocene age), Oolitic limestone aquifer (Pleistocene age) and Miocene limestone aquifer (Middle Miocene age).

(a) The alluvial deposits aquifer of Holocene age which exist at the middle and west of the study area and extend along the narrow strip of the eastern coast of the study area. This aquifer is considered of very high importance (the main aquifer) and it contains variety of salinity from fresh to highly saline groundwater.

(b) The oolitic Pleistocene limestone, having a narrow extension at the north western coast of the study area along the coastal plain. This aquifer is considered the least important among others in the study area. The groundwater exists in the form of main free water table dominating whole investigation area. The general groundwater movement is on regional basis from South to North. The local precipitation over the elongated ridges forms extended fresh water lenses which locally cause, reverse direction of water movement, i.e., from North to South, (Atwa, 1979).

(c) The M.Miocene limestone aquifer of Middle Miocene age is located in the middle and east of the study area. This aquifer is characterized by high salinity with no fresh water to be found. It is of primary importance in this area, especially the area to the south west of Sidi Barrani village.

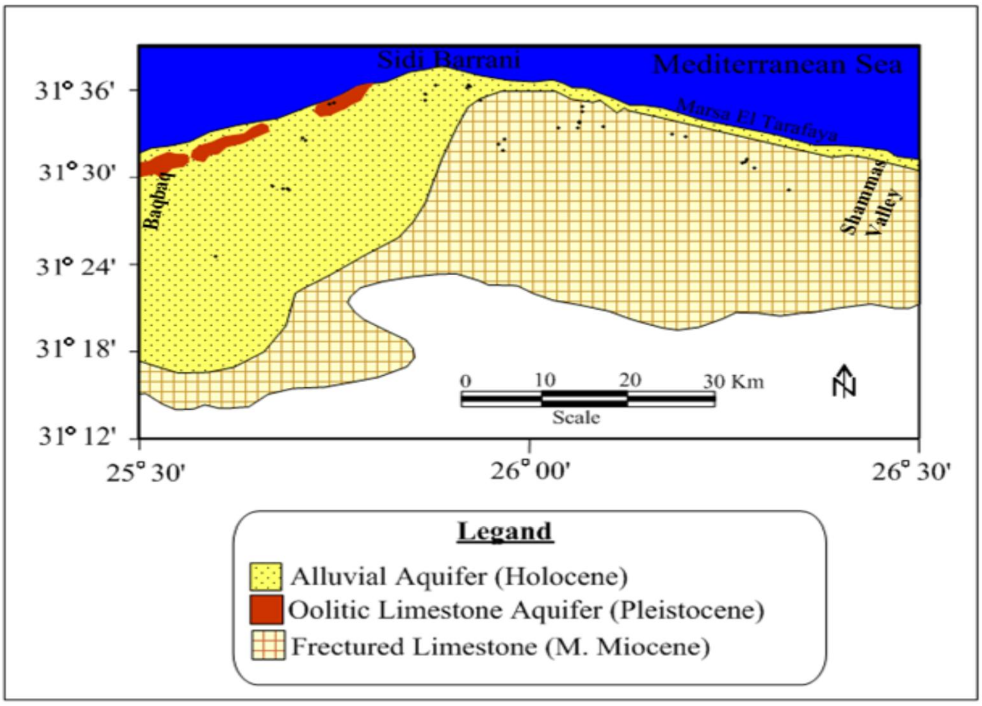

Fig. 3: Aquifers distribution map of the study area showing the sampling wells (after Atwa,1979).

3. Samples collection

Thirty three groundwater samples were collected, in the mid of September (2015), from different wells distributed along the study area in addition to one rain and one sea water sample, Fig. (4) and Table (1).

Detailed physical and chemical analyses of samples were carried out in the Desert Research Center labs following the methods adopted by ASTM, 2002. The physical properties of the groundwater samples were detected by measuring the specific Electrical Conductance (EC) using EC meter Model LF 538, WTW, USA and expressed in micromhos per centimeter (µS/cm) at 25 °C, and pH value was measured by 3320 pH meter (Jenway, UK). The Chemical properties were determined by measuring the total dissolved salts (TDS), major cations and anions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-} and Cl^{-}) and minor & heavy metals concentrations. Heavy and trace elements were analyzed using inductively coupled plasma method. The results of all chemical analyses are listed in Table (3).

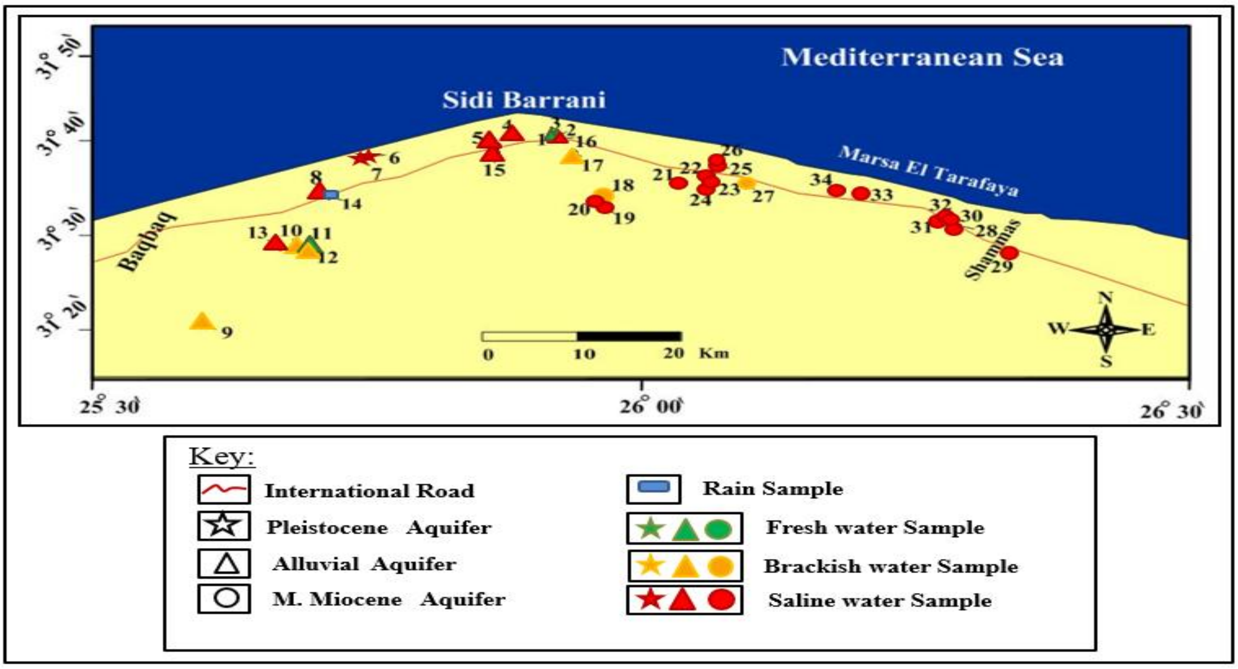

Fig. 4: Well location map of the study area

Table 1: The water points data.

Water point	Well Name	Wadi name or locality	TDS (mg/l)	Depth to water (m)	Total depth (m)	Epoch
1	Mahdy Hammad	Ezbet El Tawheed (Sidi Barrani)	6191	37	40	Holocene
2	Mohamed Farag	Harf Qoweya (Sidi Barrani)	960	36	40.5	Holocene
3	Mohamed Farag	Harf Qoweya (Sidi Barrani)	1131	36	44.5	Holocene
4	Taher Mohamed	Elwet El-Daba’	11746	10	40	Holocene
5	-	Alam El-Harsh	12926	40	-	Holocene
6	Mohamed Moftah	Al Aziziyya	7091	30	36	Pleistocene
7	Fayez Essa	Al Aziziyya	11178	36	46	Pleistocene
8	AbdEl-Hay Gomaa	Al Aziziyya	9370	40	43	Holocene
9	Shandrah Sanya	Baqbaq	2692	52	54	Holocene
10	Abdel Salam Masoud	Al-Kour	2582	33	50	Holocene
11	Al-Kour Sanya	Al-Kour	372	34	38	Holocene
12	-	Al-Kour	4299	31	47	Holocene
13	Garary Maazef	Al-Kour	6164	31	49	Holocene
15	Essa Taher Masoud	Alam El-Harsh	10144	41.2	-	Holocene
16	Saleh Obeida	Harf Qoweya (Sidi Barrani)	5394	36	42	Holocene
17	Hasan Rahoma	Abo-Milad	4728	43	45	Holocene
18	Farag Sliman Abo-Seif	Abo-Milad	1560	48	70	M. Miocene
19	Farag Soliman Abo-Seif	Abo-Milad	5436	48	70	M. Miocene
20	Farag Sliman Abo-Seif	Abo-Milad	6087	46	54	M. Miocene
21	Soliman Esrafeel	Abo-Steal	6778	45	65	M. Miocene
22	Saad Saleem Breda’	Al-Zafer	7092	45	57	M. Miocene
23	Saad Saleem Breda’	Al-Zafer	6389	31.26	-	M. Miocene
24	Saad Saleem Breda’	Al-Zafer	5915	32	62	M. Miocene
25	-	Al-Zafer	8506	26	40	M. Miocene
26	El-Saeedy Mohamed	Al-Zafer	8534	30	40	M. Miocene
27	Saeed El-Omda	Al-Zafer	4026	30	50	M. Miocene
28	-	Al-Zoayyeda	5995	45	55	M. Miocene
29	-	Shammas	6268	65	90	M. Miocene
30	-	Al-Zoayyeda	6144	45	55	M. Miocene
31	-	Al-Zoayyeda	5809	47	58	M. Miocene
32	Meme Maraea	Al-Zoayyeda	5701	45	65	M. Miocene
33	Nasef Hessein	Al-Zoayyeda	7956	30	44	M. Miocene
34	Farag Moftah	Al-Maqtala	6177	18	40	M. Miocene

4. Results and Discussion:

4.1. Water salinity

Comparing the chemical analysis of groundwater samples, Table (2) with Chebotarev (1955) classification, Table (3), it is clear that the majority of groundwater samples (73 %) are related to saline and extremely saline type, 18 % are brackish and only 9 % are fresh.

The salinity in all aquifers range from 372& 12926 mg/l with an average of 6097 mg/l. While the mean values of the salinity are 5612, 9134 and 6140 mg/l in the Alluvial, Pleistocene and Middle Miocene samples respectively. However, the high salinity in the Middle Miocene aquifer is attributed to the high evaporation rate in this aquifer. While the origin of salinity in the Pleistocene aquifer is the dissolution of rocks of marine deposits beside salt water intrusion. Finally the Alluvial aquifer salinity comes from the leaching and dissolution of rocks of marine origin.

Table 2: Chemical analyses of the groundwater samples in (mg/l)

Sample No.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	TDS	pH	TH	Fe^{2+}	Mn^{2+}	B^{3+}	Sr^{2+}
Pleistocene Aquifer															
6	151	316	2000	54	36	268	500	3900	7091	7.6	378	0.05	-	2.1	33
7	235	438	3200	70	24	61	900	6280	11178	7.3	589	1.23	0.018	3.1	24
Alluvial Aquifer															
1	165	253.7	1740	40	33	214	452	3400	6190	7.3	414	-	-	2.4	17
2	65	70.41	200	13	15	241	70	406	960	7.5	163	1.7	0.15	0.4	12
3	62	64.64	240	38	27	238	81	500	1131	7.8	155	-	-	0.5	11
4	217	476	3400	70	27	98	1007	6500	11746	7.4	545	0.03	-	3.8	17
5	274	500	3700	80	30	85	1100	7200	12926	7.3	686	0.04	-	4	22
8	253	398	2600	61	18	153	564	5400	9369	6.8	633	2.33	0.18	3.57	21
9	110	109	720	19	36	131	162	1470	2692	7.8	275	0.16	0.027	0.96	8
10	64	82	780	26	33	113	200	1340	2582	7.8	160	0.11	-	1.38	7
11	48	28	44	13	24	113	58	101	372	8	120	0.96	0.038	0.10	1.6
12	110	165	1200	34	27	125.	500	2200	4298	7.6	276	-	-	1.83	12
13	198	184	1800	44	12	91.5	400	3480	6163	7.4	496	1.02	0.016	1.98	13
15	215	249	3000	45	204	0	726	5704	10015	8	538	2.03	0.18	2.64	10
16	115	184	1600	35	36	146	500	2850	5393	6.8	289	-	-	1.88	11
17	124	232	1300	46	33	222	93	2789	4728	7.8	311	0.15	0.008	3.4	8
Middle Miocene Aquifer															
18	75	68	400	11	18	161.6	69.4	837	1559	8	189	-	-	0.41	4
19	156	179	1600	27	33	82.3	550	2850	5436	7.7	391	-	-	1.08	11.7
20	180	194	1780	31	12	134	400	3423	6087	7.6	451	-	-	1.15	13
21	164	231	2000	36	15	125	350	3920	6777	7.7	410	-	-	1.37	17.7
22	186	250	2050	39	15	113	439	4057	7092	7.8	466	0.14	0.003	1.37	16.6
23	314	218	1650	38	6	128	1300	2800	6389	7.7	785	3.85	0.09	1.37	15.7
24	252	209	1600	35	9	119	650	3100	5914	7.8	630	3.01	0.083	1.39	15.8
25	321	306	2350	57	24	128	534	4850	8506	7.7	804	1.80	0.023	2.00	18.5
26	174	325	2500	50	24	122	500	4900	8534	7.8	437	0.21	0.005	1.94	18.4
27	119	146	1150	21	18	122	280	2231	4026	8.1	298	0.02	0.002	0.99	11.4
28	136	250	1700	24	15	140	700	3100	5995	7.6	342	-	-	1.31	13.5
29	181	265	1700	29	21	122	710	3300	6268	7.6	454	0.11	0.004	1.57	21.6
30	154	260	1700	27	9	189	700	3200	6144	7.7	386	-	-	1.59	17
31	155	250	1600	28	6	140	800	2900	5809	8	388	0.06	0.005	1.59	15.8
32	160	250	1550	25	24	183	800	2800	5701	7.9	402	-	-	1.48	15.1
33	164	307	2300	42	6	153	1081	3980	7956	7.6	412	-	-	1.75	15.4
34	170	230	1780	29	21	125	584	3300	6177	7.8	427	-	-	1.53	15.6
sea	255	1352	11750	380	30	91.5	3000	21580	38393	8	643	-	-	5.44	6.44
Rain	69	9	36	8	27	174	19	71	325.7	8	173	0.27	0.0427	0.09	0.8

4.2. Total hardness

From table (2), the total hardness in all aquifers range from 120-804 mg/l with an average of 415 mg/l. While the mean values of total hardness are 361, 483 and 406 mg/l as $CaCO_3$ in the Alluvial, Pleistocene and Middle Miocene samples respectively. This reflects the obvious effect of carbonate weathering that lead to hardness increase with particular importance of effect of ionic strength on increasing Ca^{2+} and Mg^{2+}solubility;(Hem, 1989). About eight samples from the total groundwater samples (27%) had total hardness above the permissible limit (>500 mg/l).

Table 3: Statistical and frequency distribution of water salinity in mg/l

Aquifer	Total samples	Fresh Water TDS<1500		Brackish Water 1500-5000		Saline to Extremely saline water TDS>5000		TDS	
		No. of Samples	%	No. of Samples	%	No. of Samples	%	Range	Average
Alluvial	14	3	21	4	29	7	50	372-12926	5612
Middle Miocene	17	-	-	2	12	15	88	1559-8533	6139
Pleistocene	2	-	-	-	-	2	100	7090-11178	9134
Total samples	33	3	9	6	18	24	73	-	-

4.3. Groundwater chemical type

According to chemical analysis of groundwater samples, the water chemical types are classified according to the dominant anions and cations into:

Chloride – Sodium; type characterizing 97 % of samples. This reflects the role of leaching and dissolution processes of marine deposits and high evaporation process in addition to the old recharge of groundwater with a long water-rock interaction.

Chloride – Calcium that characterizing one sample, wells (No. 11), showing the intermediate stage of groundwater metasomatism.

4.4. Hypothetical salts assemblages

To clarify such combinations, the relations between cations and anions in the investigated waters, are illustrated in the form of bar graphs as outlined by Collin's (1923), Fig (5).

The combination between major anions and cations reveals the formation of three main groups of hypothetical salts in the groundwater samples from different aquifers. As a matter of fact, chemical evolution gradation starts from dominant HCO_3 salts which changed to dominant SO_4 salts and ended by dominant chlorides salts.

I- II-NaCl, $MgCl_2$, $MgSO_4$, Mg $(HCO_3)_2$ and Ca $(HCO_3)_2$

II- NaCl, $MgCl_2$, $MgSO_4$, $CaSO_4$ and Ca $(HCO_3)_2$

III- NaCl, $MgCl_2$, $CaCl_2$, $CaSO_4$ and Ca $(HCO_3)_2$

Assemblage I represents the intermediate stage of chemical development (two bicarbonate salts and two chloride salts) is resulted from leaching of terrestrial salts. It represents three samples in the alluvial aquifer, about (9%) from the whole samples.

Assemblage II, contains two chloride salts and two sulfate salts (intermediate stage of chemical development) reflects the effect of leaching and dissolution of marine salts and rocks rich in halite (NaCl) beside the leaching of local evaporites rich in sulphate & leaching and dissolution processes occurring in the gypsums sediments. It represents about 71.4%, 94% and 100% of the alluvial, middle Miocene and the Pleistocene aquifers, respectively.

The assemblage III is the most chemically developed among the hypothetical salts combination (contain three Cl^- salts), pointing to the leaching of marine some deposits. This is observed in one sample in the alluvial and one in the middle Miocene aquifer, about 6% from the total samples.

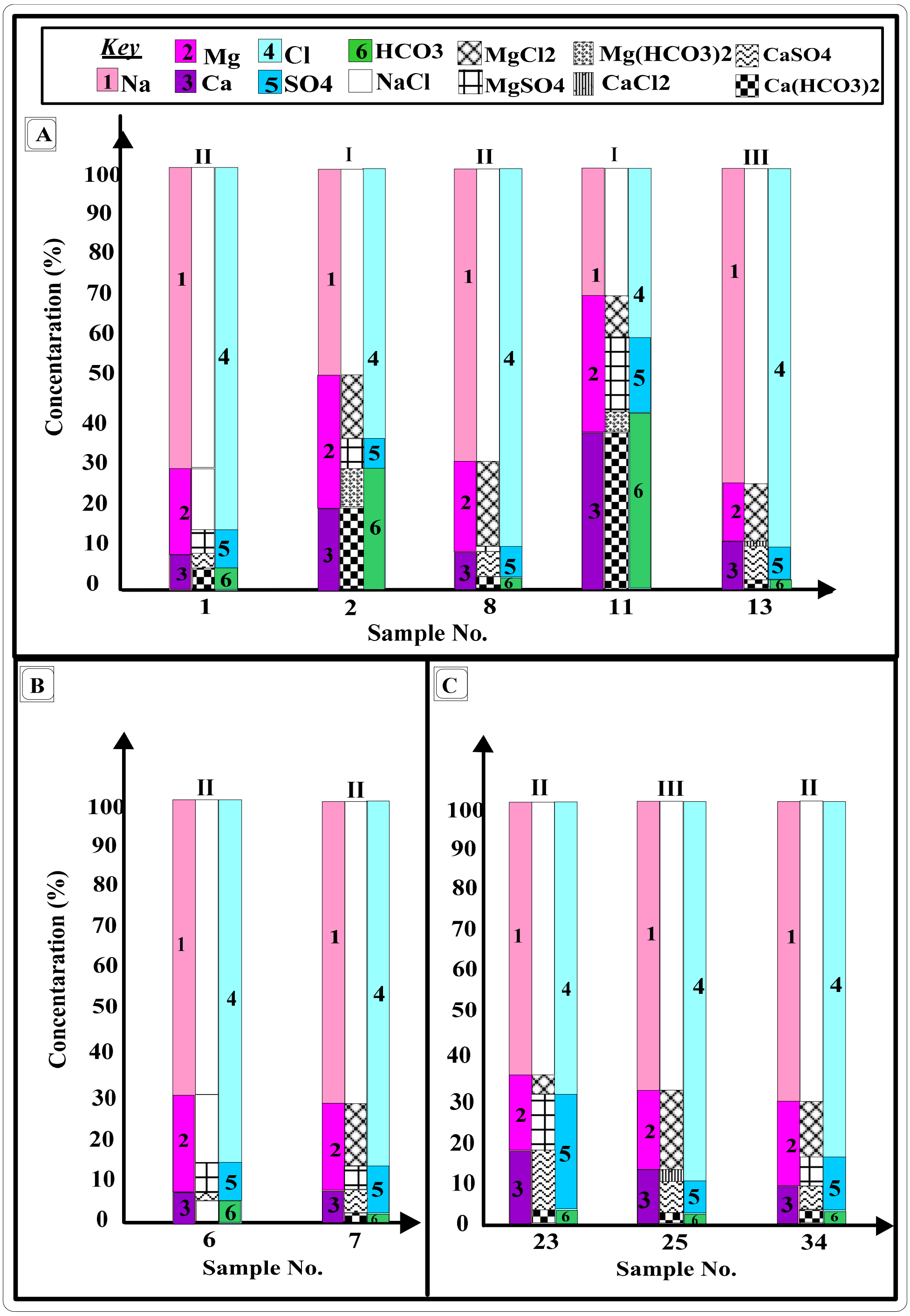

Fig. 5: Bar graphs representing groundwater samples (meq/l) in (A) Alluvial aquifer, (B) Pleistocene aquifer and (C) M. Miocene aquifer in the study area.

4.5. Ionic relations and sources of major components in groundwater

The groundwater contains major and minor ionic species that contribute to its salinity. Scatter diagrams, Fig.5 (A-E) are used to understand and distinguish between the different hydro-chemical processes that control the groundwater during its movement underground.

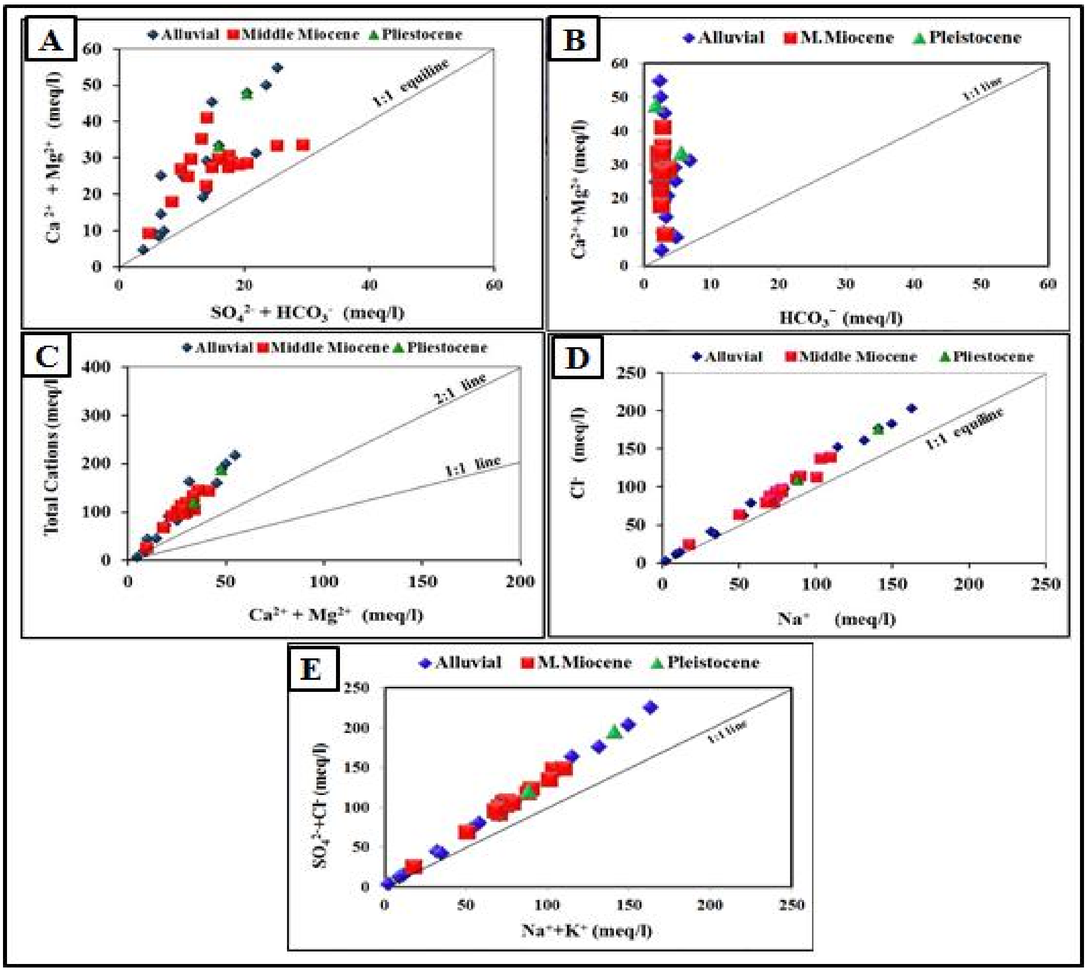

Fig. 5: Ions scatter diagrams of the investigated groundwater

1-The plot of (Ca^{2+} +Mg^{2+}) vs. (HCO_3^- + SO_4^{2-}) Fig.(5A) shows that, the whole groundwater samples are falling above the equiline, which indicate that the prevailing hydrogeochemical process is the carbonate weathering not the silicate weathering.

2-In the plot of (Ca^{2+} + Mg^{2+}) vs. HCO_3^-, Fig.(5B) . If Mg^{2+} and Ca^{2+} originate only from the dissolution of carbonates in the aquifer materials and from the weathering accessory pyroxene or amphibole minerals, this ratio would be about 0.5. The low(Ca^{2+} + Mg^{2+}) / HCO_3^- ratios (<0.5) could be the result of either Ca^{2+} +Mg^{2+} depletion by cation exchange or HCO_3^- enrichment. High ratios suggest that, the excess of alkalinity of these waters balance by alkalis (Na^+ +k^+), (Sami, 1992). However, high ratios cannot be attributed to HCO_3^- depletion, under the existing alkaline conditions, HCO_3^- does not form carbonic acid, (Spears, 1986).

3-Further, plotting of Ca^{2+}+ Mg^{2+} vs. total cations, Fig.(5 C), had shown that the ratio of (Ca^{2+} + Mg^{2+}) against total cations had fallen above line of (Ca^{2+} + Mg^{2+})= 0.5total cations, showing that these samples are rich in alkali feldspar (Sarin *et al*.,1984_; Datta and Tyagi, 1996).

4-In Fig.(5 D), the plot of (Na^+ +K^+) versus Cl^- shows that ,the ratios of rCl/rNa in all groundwater samples are higher than unity ,which reflects the dominance of Cl^- over (Na^+ + K^+) resulting from the leaching and dissolution of marine deposits.

5-From Fig. (5 E), the increase in Cl^-+SO_4^{2+} corresponds to alkalis (Na+K) simultaneously with the increase in ionic strength suggesting the presence of Na_2SO_4 and K_2SO_4 in the soils beside the effect of leaching and dissolution of sulfate and chloride from rocks of marine origin.

6-Gibbs (1970) diagram is constructed to show which of the hydrochemical processes (precipitation, water-rock interaction or evaporation) is controlling groundwater chemical composition. Log TDS values are plotted against major cations ((Na^+ + K^+)/ Na^+ + K^+ + Ca^{2+}) and major anions (Cl^- / Cl^- + HCO_3^-) separately, Fig. (6). The plots indicate that, the groundwater chemistry in the area is mainly controlled by evaporation process beside water-rock interaction factor because the annual rainfall and ground water recharge are insignificant. Also, the evaporation increases salinity as a result of Na^+& Cl^- increase, (Wen *et al*., 2005).

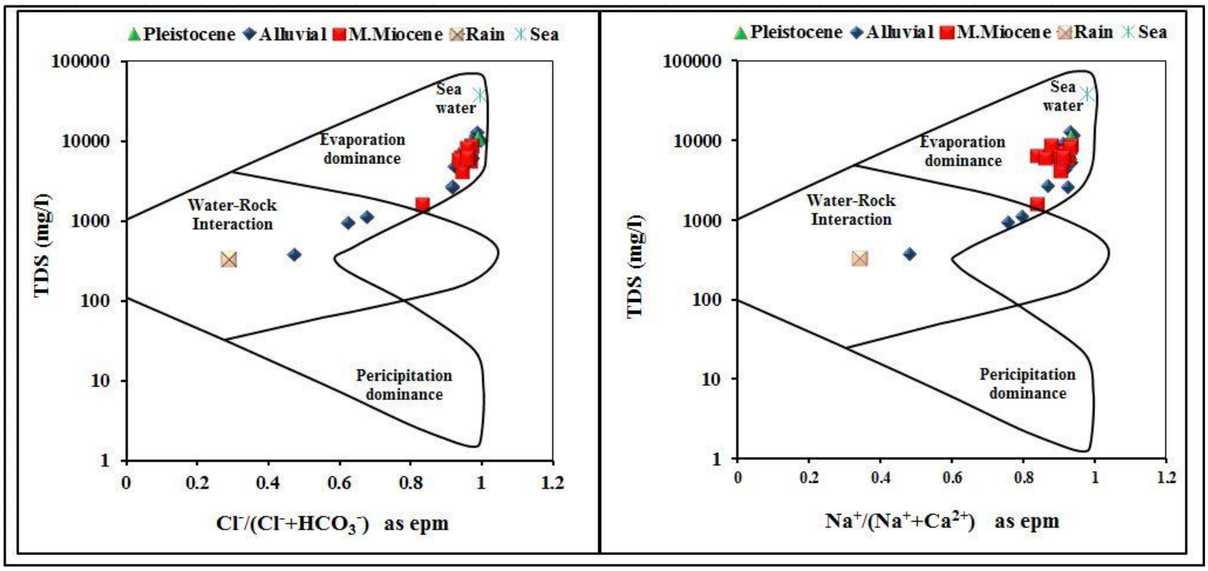

Fig. 6: Mechanisms governing groundwater chemistry (Gibbs,1970)

7-The data of the chemical analysis of groundwater are plotted on **Piper's (1953)** tri-linear diagram Fig.(7). It shows that, the majority of groundwater samples (94 %) occupy the upper right side of the diamond figure (sub-areas7), where the water is dominated by primary salinity character (SO_4^{2-}+ Cl^-) > (Na^+ + K^+), and where calcium and magnesium chloride and sulfate salts do exist in groundwater samples. This reflects the leaching and dissolution processes. On the other hand, only two groundwater samples (No. 2&11) occupy the sub-area 9, where no one cation-anion pair exceeds 50 percent.

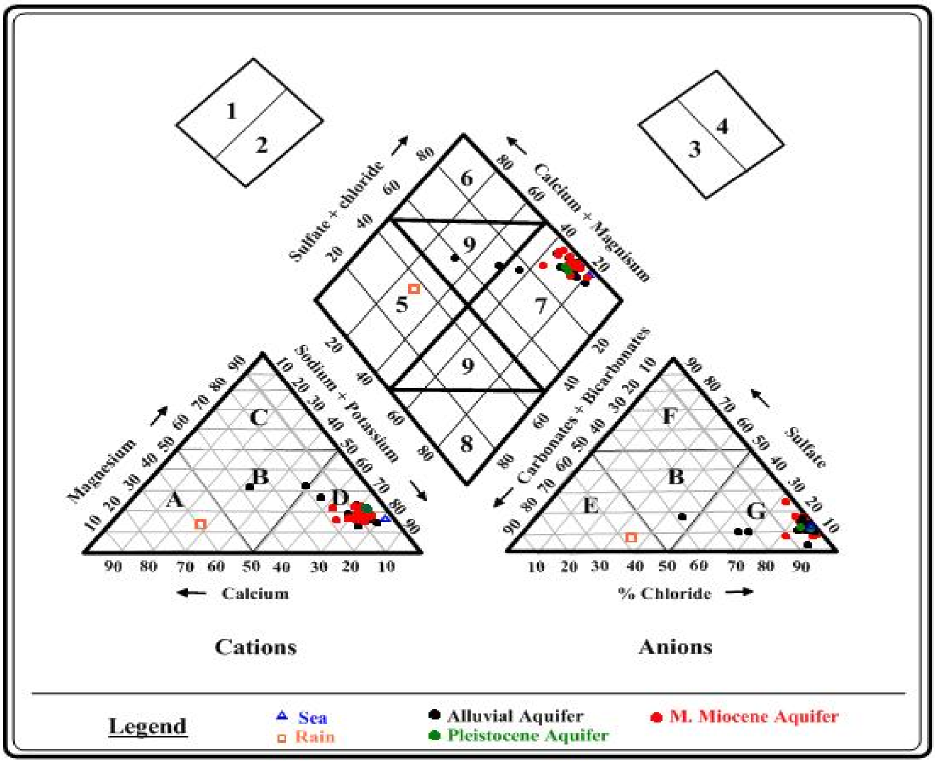

Fig. 7 : Piper's tri-linear diagram.

4.6. Evaluation of groundwater quality for human drinking

Depending on the World Health Organization (WHO), (2011) and Egyptian organization for Standardization and quality, (2007) in water for human drinking, Table (4), and according to the TDS, a major part of (94%) of total groundwater samples is unsuitable for human drinking (>1000mg/l), whereas, only 6% of total samples represented by two samples are suitable.

Table 4 : Water quality guidelines for human drinking

Parameter	WHO	Egyptian standard	Range	Mean	No. of samples within the permissible limit	%
Salinity	1000	1000	372 - 12926	6097	2	6 %
pH	6.5 – 8.5	6.5 –9.5	6.7 – 11.7	8	32	97 %
Sodium	200	200	57 - 3780	1763	1	3 %
Calcium	350	-	47.8 – 321.2	166	33	100%
Magnesium	150	-	27.51 – 499.8	232.9	7	21 %
Chloride	250	250	101.4 - 7200	3305	1	3 %
Sulfate	250	400	58 -1300	538	7	21 %
Hardness as CaCO3	500	-	120-804	415	24	73%
Manganese	0.05	0.1	0.002-0.18	0.052	28	85 %
Iron (total)	0.3	0.3	0.0015 - 3.85	0.905	24	73%
Strontium	-	-	1.63 – 33.45	14.72	33	100 %
Boron	-	0.3	0.097 – 4.02	1.76	1	3 %

4.7. Determination of the best sites for establishment of groundwater desalination plants.

The possibility of producing drinking water from brackish and saline groundwater depends on different parameters as total dissolved salts (TDS), type of hypothetical salts, of Ca-HCO_3 type water with low concentration of heavy & trace metal as Fe^{2+} , Mn^{2+} , SiO_2 and B^{3+} and Sr^{2+} . One of the major problems affecting the performance and age of reverse osmosis membranes during desalination process of brackish groundwater is the hardness, where the presence of high ions concentrations from Ca^{2+}, Mg^{2+} and, SO_4^{2-}, HCO_3^- that cause high scaling, which in turns block the membrane and reduces the quantity of the produced desalted water. Consequently, before establishing any RO desalination plant (Shawky *et al*., 2012), the best water points must be chosen. In addition, the groundwater samples must pretreatment first before desalination. Therefore, the chemical analyses of the collected 33 ground water samples indicated that; 29 groundwater samples representing 88 % of the total samples had salinity below 10,000 ppm, 6 samples (18%) had boron concentration below 1 mg/l, 28 samples (85%) contained manganese below 0.05 mg/l and 24 samples (73%) had the iron concentration below 0.3 mg/l. The detailed analyses of the groundwater indicated the feasibility and promising opportunities of establishing RO in the study area. Sites of groundwater salinity below 10,000 (brackish) and having high Ca, Mg, Fe and Mn require pre-filtration unit before the RO unit due to the fouling effect of these ions to the membranes.

Sites suffering from high salinity, i.e. >10000 are the worst sites to establish RO plants on it as this will expose the membrane to a very high dose of ions that will foul the membrane, cause fast aging, increase the energy consumption and the overall costs (Sahachaiyunta *et al*., 2002) ,so it is advisable to establish plants in the groundwater sites of brackish water content with a suitable pre-treatment sequence and periodically clean the membrane by the aid of acid or base to maintain the RO membranes for longer time (Aly *et al*., 2012).

The TDS value increases from south to north in the same direction of groundwater flow , so the best sites should be inland and in west and at east of Sidi Barrani coast sites) at Al-Kour valley, the water points (9,10,12,18,&27) which have low TDS, Sr^{2+} & B^{3+} concentrations.

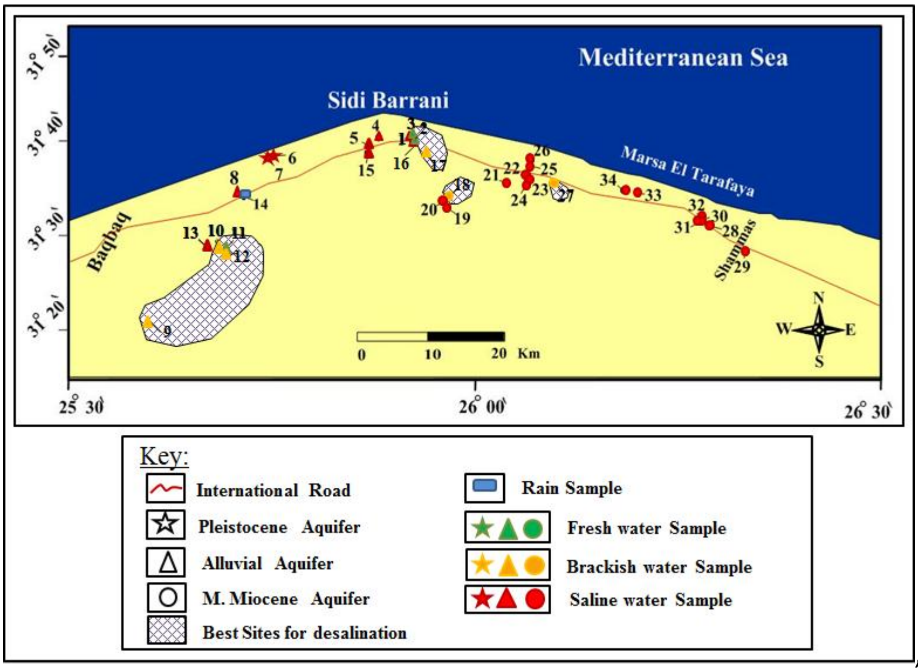

Fig. 8: Salinity zonation map and best sites for desalination

5-Conclusion and recommendations

In conclusion, (94%) of total groundwater samples is unsuitable for human drinking , whereas, only 6% of total samples represented by two samples are suitable., while some groundwater samples are suitable for livestock drinking. The quality of water varies greatly depending on lithology variation, rate of recharge. Applying RO plants in this area is necessary and promising for the settlement of Bedouins, desert reclamation, overcoming the overpopulation around the River Nile and establishing touristic villages on the beautiful Mediterranean coast. It is the key solution to the problem of high salinity in these communities to provide freshwater that is the vein of life.

In Sidi Barrani area 27% of the investigated groundwater samples exceed the maximum recommended limit of Fe^{2+} (0.3 mg/l) and 82 % of groundwater samples exceed the maximum recommended limit of boron (B^{3+}) in drinking water (1 mg/l), respectively. So, the groundwater must be pretreated to eliminate the high iron and boron concentration before allowing water to pass on RO membranes. Also, the problem of increasing silicate in water samples not only affect the human health but also, the higher probability of forming silicate scaling which will harm a lot the membrane elements resulting in shortage lifetime.

The best sites for groundwater desalination process in the area of study are that characterized with lower and constant TDS, shallow depth to groundwater , higher water production and with Ca-HCO3 chemical type as shown in Fig.8).

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