EVALUATION OF GROUNDWATER SUITABILITY FOR DRINKING AND AGRICULTURE USE IN THE AREA BETWEEN EL DABAA AND RAS EL HEKMA, NORTHWESTERN COAST, EGYPT.

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ABSTRACT

Recent industrial and urban activities have led to elevated concentrations of a wide range of contaminants in groundwater, which affect the health of million people worldwide. Groundwater is the major source for drinking and agriculture uses in the Northwestern coast of Egypt. Forty five groundwater samples representing the Pleistocene and the Middle Miocene aquifers were collected from the area between El-Dabaa and Ras El-Hekma. Samples were analyzed for total dissolved solids, calcium, magnesium, sodium and five heavy metals including; aluminum, iron, manganese, copper, and lead, using the standard methods. The results show that, the total dissolved solids; calcium, magnesium and sodium concentrations have mean values of 8426, 264.5, 295.9 and 2390.1 mg/l, respectively. The heavy metals show high concentrations in groundwater of Pleistocene and Middle Miocene aquifers. The concentration of iron recorded the mean of 1.99 mg/l followed by aluminum 0.45 mg/l, while manganese recorded the lowest mean value of 0.09 mg/l. The results show that, the majority of groundwater samples in different aquifers are unsuitable for human drinking due to high concentrations of total salinity, major ions and heavy metal constituents. According to the international standards recommended by the National Academy of science (NAS) and National Academy of Engineering (NAE) the groundwater samples in the study area ranges from an excellent to not acceptable classes for the livestock and poultry uses. Most of the groundwater samples in the Pleistocene aquifer (88%) are unsuitable for domestic and laundry uses as the total hardness values are exceeding 300 mg/l, however; all the Middle Miocene groundwater are unsuitable for domestic and laundry uses. Whereas, 71% of the total samples are unsuitable for irrigation according to total dissolved solids and about 93% of groundwater samples are unsuitable for domestic and laundry uses according to total hardness. The groundwater samples tapping the available aquifers in the study area have to go through treatment and desalination processes using suitable and economical applied methods to enhance the groundwater quality and be considered as suitable for different uses.

Keywords: Groundwater quality assessment, El Dabaa area, SAR, chemical constituents.

INTRODUCTION

Groundwater is one of the major sources of drinking water all over the world, where; approximately one-third of the world's population use groundwater for drinking (Nickson *et al.*, 2005 and Bear, 1979). In the Northwestern coastal zone of Egypt, groundwater represents the major source for drinking and agricultural purposes. Quality of groundwater is equally important to its quantity and greatly influenced by hydrogeological conditions and anthropogenic activities (Prasanth *et al.*, 2012, Walton 1970, Magesh and Chandrasekar 2011). The overexploitation of groundwater in the NorthWestern Coastal Zones of Egypt has detrimentally affected its quality and quantity and may result in negative water balance due to seawater intrusion (Eissa *et al.*, 2015 a,b).

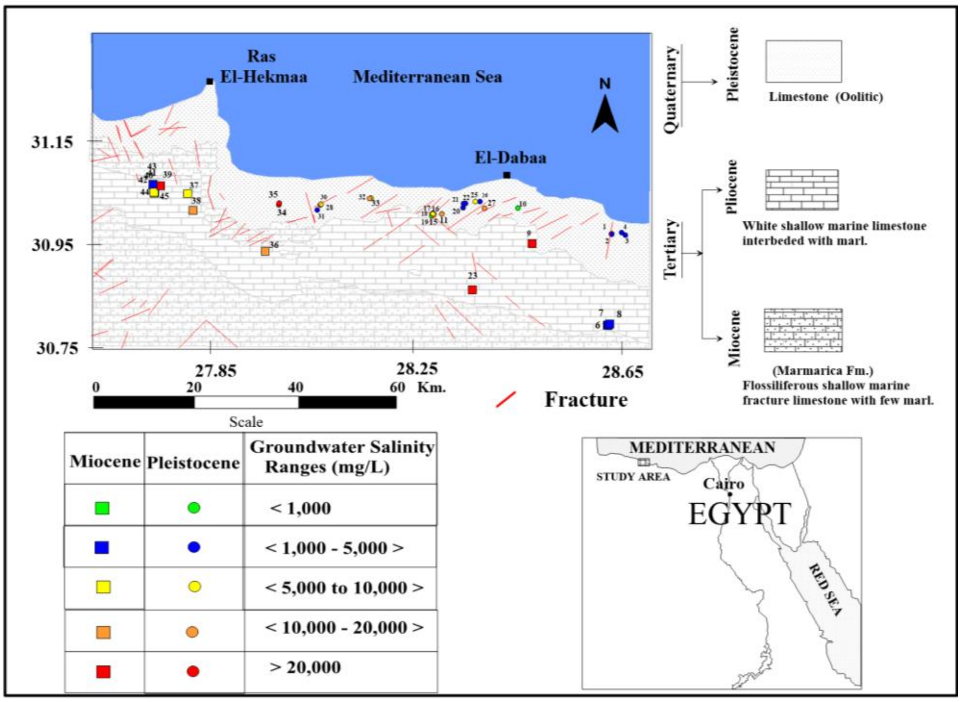
EI-Dabaa area is located in the North Western Coastal Zone of Egypt and is considered to be one of the most promising regions for land reclamation and agriculture. The study area is intensively exposed to agricultural activities due to mild weather and topography as well as its more or less available water and soil. Recently, great efforts are directed from the Egyptian government to develop the North Western Coastal Zone (Omer, 2008), where; El Dabaa has been selected as a potential site for constructing the first Egyptian nuclear power plant.

In the study area, groundwater is the sole source for drinking, agricultural, municipal and domestic purposes. El Dabaa area is located in the arid to semiarid coastal zone, where high air temperature and scarce precipitation is the dominated climate all over the year. The groundwater supplies are generally insufficient to meet the probable increases in water demands, therefore; serious strategies for water development should be established to fully exploit the surface and groundwater resources (Mohallel, 2009)**.**

Groundwater for domestic and irrigation purposes can vary greatly in quality based on type and concentrations of dissolved salts. It contains a wide variety of dissolved inorganic constituents in various concentrations, resulting from mixing with seawater and chemical interactions between water and the water-bearing rocks (Eissa *et al.*, 2016). Dissolved salts should be present in irrigation water in relatively small significant amounts. In this respect, priorities are given to the evaluation of groundwater suitability for different uses in order to manage the main water resources and ensure groundwater sustainability.

GEOLOGICAL AND HYDROGEOLOGICAL SETTING

The area of study comprises an exposed sedimentary rocks ranging in geologic age from the Miocene to the Pleistocene (CONOCO, 1987). In the regional scale; the North Western Coast comprises three aquifers. The top one is the Pleistocene aquifer, underlying by the Middle Miocene aquifer and the deeper is the Lower Miocene aquifer (Figure 1). In this study; the Lower Miocene aquifer (Moghra formation) has not been represented, where all the groundwater samples have been collected from hand dug and shallow drilled wells.



Figure(1): Location and Geological map along northwestern coastal zone CONOCO, 1987

The Pleistocene aquifer extends about 10 km southward and has a wide distribution and considered to be one of the most important aquifers along the coastal strip. The groundwater exists in a free water table aquifer (Rizk, 1982). The Pleistocene aquifer is composed mainly of oolitic limestone and is characterized by less cementing materials if compared with the inland ridges, which acquire the former one more porous nature(Atwa, 1979)**.**The Pleistocene aquifer is recharged through infiltration of annual rainfall and from the runoff water comes from foreshore ridges and the elevated tableland area located in the south. The flanks of the ridges are covered by loose foreshore sand accumulations, which permit a direct infiltration and percolation of rainfall.

The groundwater in the Pleistocene aquifer attains altitude close to the mean sea level. It is a result of the local percolation in the coastal plain and the intrusion from sea water. The saltwater intrusion from the sea forms a saline water overlain by a thin sheet of fresh water (Eissa *et al.*, 2016). Such thin sheet of the fresh water is a result of a natural balance between the surplus of recharge from precipitation and the discharge through seepage to the sea (Paver & Pretorius, 1954). At El Dabaa locality, the direction of groundwater flow is due north and south. The hydraulic gradient is gentle in the northern part (0.0002), while at the southern one it reaches (0.0003) (Atwa, 1979).

The Miocene aquifer is developed as a secondary aquifer along the coastal area to the west of Alexandria and is explored at El Dabaa, Fuka, Matruh and El Sallum localities (Raslan, 1995). The Middle Miocene aquifer is subdivided into two zones and composed mainly of chalky limestone, marly limestone, dolomite and shale (Yousif *et al.*, 2016). This formation is largely fractured and exists in successive horizons separated by impervious clays with occasional bands of sandstone. (Omer, 2008).

The groundwater of the Middle Miocene aquifer is naturally discharged through pumping wells and subsurface flow toward the Mediterranean and Qattara Depression. The lateral and vertical facies changes affect the productivity of the aquifer, particularly along the coastal area. The transmissivity of the Middle Miocene aquifer ranges between10^{-4} and 10^{-2} m^2/sec. (ACSAD, 1990).

MATERIAL AND METHODS

Detailed chemical analysis of forty one groundwater samples were collected from two aquifers located in the area between El Dabaa and Ras El Hekma in March 2015 as well as four samples were collected from surface water bodies. Fifteen groundwater samples representing the Miocene aquifer, 26 samples from the Pleistocene aquifer, two rainwater samples, one seawater and one tap water. The groundwater samples have been selected based on the geographical locations and the areal extent of the investigated aquifers from inland toward the coast. Additionally; the tapping aquifers and water bearing formations were determined based on the subsurface and geological map as well as the total penetration depth. The analyses were performed according to the methods adopted by Rainwater and Thatcher, 1960 and Fishman and Friedman, 1985 and American Society for Testing and Materials ASTM, 2002 at the Centre laboratories, Desert Research Centre (DRC) in March 2015.

1. **Determination of major ions:** The analysis includes the determination of the pH, Electrical Conductivity (EC), total dissolved solids (TDS), calcium, magnesium, sodium. The electrical conductivity determined by means of EC meter using Orion 150A+, Thermo Electron Corporation, USA. The (EC) was expressed in micro mhos per centimeter (μS/cm) at 25°C and total dissolved solids (TDS) can calculate from EC by using this equation.

TDS (mg/L) = conversion factor × EC (μs/cm)

Where the conversion factor ranges between 0.55 and 0.70

The pH was measured with a3510, Jenway, UK pH meter. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by titration against Na_2EDTA by complexometric method. Calcium was determined by using murexide indicator while magnesium was estimated by subtracting the calcium value from the (Ca^{2+} + Mg^{2+}) value after determine them using Eriochrome black T in presence of suitable buffer solution and calculated by these equations (Hem, 1989).

- Total hardness (in ppm) as $CaCO_3$ =(1000x ml titrant x normality of Na_2EDTA x D) / ml sample
- Ca^{2+} hardness (in ppm) as $CaCO_3$ =(1000 x ml titrant x normality of Na_2EDTA x D)/ml sample
- Mg^{2+} hardness (in ppm) as $MgCO_3$ = total hardness - calcium hardness.

Where D is the dilution factor

Sodium (Na^+) and potassium (K^+) were determined by means of Flame Photometer, PFP 7, Jenway, UK. The detailed chemical analysis of such groundwater samples are shown in Table [1].

2. **Determination of heavy metals:** The dissolved heavy metals (Al, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb and Zn) in the collected water samples were determined by the Inductively Coupled Argon Plasma, ICAP 6500 Duo, Thermo Scientific, England. 1000 mg/L multi-element certified standard solution, Merck, Germany was used as a stock solution for instrument standardization.

Table (1): Chemical concentrations of major and heavy metals for surface water, groundwater samples collected from the area between El Dabaa and Ras El Hekma, Egypt. (March, 2015).

Well No.	lat.	Long.	EC µs/cm	TDS, mg/l	Total hardness as CaCO3	Ca hardness as CaCO3	Na, mg/l	SAR, %	Na, %	PI, %	Mg ratio, %
surface water											
5 tab water	31.01693	28.55459	846	415.3	168.64	100.307	84	1.99	50.9	52.01	40.6
12 Rain water	31.03941	28.30633	285.9	128	83.57	66.79675	15	0.5	27.2	28.1	20.12
24 seawater	31.06921	28.3357	64400	43717	7108.7	1104.5	13600	49.58	79.77	80.61	84.5
29 Rainwater	31.05568	28.11797	505	258.02	88.28	61.092	64	2.1	60.86	61.21	30.86
Pleistocene aquifer											
1	31.01099	28.56882	4650	2988.18	628.49	230.365	800	9.81	71.16	76.86	63.42
2	31.00997	28.56891	5230	3667.03	979.35	456.555	820	8.06	62.73	67.66	53.46
3	31.00877	28.59004	4830	3863.38	1308.89	848.24	680	5.78	51.85	55.9	35.27
4	31.01272	28.58429	3370	2341.13	815.31	509.06	460	4.96	53.79	59.38	37.64
10	31.05058	28.42377	1856	891.56	291.39	93.7375	210	3.78	58.93	71.39	67.9
11	31.04149	28.30606	21800	13124.14	1788.41	548.825	4000	29.08	82.28	83.58	69.38
13	31.04093	28.29405	9570	5063.03	1272.34	496.6625	1450	12.5	70.03	73.96	61.04
14	31.04217	28.29178	3000	1686.69	545.47	291.065	410	5.4	61.18	67.38	46.72
15	31.0417	28.29208	12830	7206.81	1583.12	511.95	2150	16.61	74.2	75.96	67.73
16	31.04152	28.29291	2191	1039.13	417.45	166.6275	210	3.16	51.56	60.63	60.16
17	31.04144	28.2922	2637	1350.27	373.81	137.8025	350	5.57	65.87	73.59	63.21
18	31.04246	28.29183	4080	2246.91	438.96	166.355	680	9.98	76.34	81.06	62.18
19	31.03871	28.2904	1682	751.19	240.94	77.105	180	3.57	60.55	74.26	68.07
20	31.05119	28.3389	2875	1404.62	84.82	30.43	510	17.03	91.62	101.17	64.2
21	31.05757	28.33955	5340	2825.24	1016.38	211.94	700	6.75	59.29	64.46	79.2
22	31.05779	28.34273	2767	1291.14	624.15	92.9825	240	2.95	44.48	54.51	85.14
25	31.06063	28.35782	13310	7435.13	1305.84	307.0375	2400	20.42	79.2	81.34	76.54
26	31.06072	28.36505	7720	4402.95	1167.76	165.275	1200	10.79	68.1	71.3	85.89
27	31.05023	28.37214	16920	10196.1	1688.59	385.75	3100	23.19	79.24	80.77	77.21
28	31.05568	28.11797	4910	2712.94	539.53	107.375	840	11.12	75.84	80.72	80.15

Cont.

Well No.	lat.	Long.	EC ,µs/cm	TDS, mg/l	Total hardness as CaCO3	Ca hardness as CaCO3	Na, mg/l	SAR, %	Na, %	PI, %	Mg ratio, %
30	31.05669	28.11892	9620	5441.11	1154.01	338.4125	1650	14.93	74.63	77.36	70.74
31	31.04771	28.11316	8220	4800.69	841.18	210.4	1500	15.9	78.49	81.25	75.05
32	31.06538	28.19426	21690	14151.21	2563.44	690.025	4100	24.89	77.12	78.25	73.14
33	31.066	28.19654	10190	6565.97	1768.38	759.35	1600	11.7	65.76	67.75	57.14
34	31.05558	28.05369	34120	20860.73	3268.99	939.85	6400	34.41	80.2	81.32	71.31
35	31.05842	28.05419	43540	27870.88	4613.22	1492.4	8400	38.02	79.17	80.01	67.72
Miocene aquifer											
6	30.86948	28.56218	6780	3872.5	1510.52	691.0125	850	6.73	54.19	57.31	54.33
7	30.86898	28.56363	6860	3647.67	1503.93	635.8625	700	5.55	49.65	52.58	57.8
8	30.8712	28.56595	5030	3671.05	1991.61	1121.87	400	2.76	30.12	32.97	43.75
9	30.99567	28.446	62800	41357.5	7687	2524.2	13000	45.58	78.03	78.78	67.23
23	30.9241	28.35304	49100	25607.38	10918.88	4358.3	5600	16.48	52.49	53	60.16
36	30.98367	28.03256	24510	16444.79	4785.95	2262.825	4000	17.78	64.08	64.92	52.8
37	31.07296	27.91298	10700	6131.58	1215.52	292.1625	1750	15.43	74.62	76.64	76.02
38	31.04697	27.92068	21850	13593.25	4947.26	2196.275	2900	12.68	55.53	56.41	55.68
39	31.08489	27.87103	46900	30793.98	4339.65	1746.65	10000	46.67	83.15	83.53	59.83
40	31.08688	27.85872	8000	4567.99	946.89	311.95	1300	12.99	74.37	76.63	67.13
41	31.08725	27.85875	8330	4843	903.78	313.4875	1400	14.32	76.68	78.83	65.39
42	31.08679	27.85889	7950	4918.5	773.51	255.3375	1450	16.03	79.85	82.25	67.06
43	31.07387	27.86084	6290	3645.76	730.8	251.65	1100	12.51	76.13	78.99	65.64
44	31.07383	27.86124	12120	7639.81	1673.72	569.25	2100	15.78	72.8	74.25	66.06
45	31.07504	27.86079	13020	7734.32	1847.44	621.7625	2200	15.74	71.82	73.13	66.42

Cont.

well No.	Al, mg/l	Cd, mg/l	Co, mg/l	Cr, mg/l	Cu, mg/l	Fe, mg/l	Mn, mg/l	Mo, mg/l	Ni, mg/l	Pb, mg/l	Zn, mg/l
surface water											
5 tab water	0.3235	<0.0006	<0.001	<0.01	<0.009	0.0619	<0.003	<0.001	<0.002	0.0135	0.0076
12 Rain water	0.1376	<0.0006	<0.001	<0.01	<0.009	0.0803	0.0105	<0.001	<0.002	0.0224	0.002
24 seawater	0.0338	<0.0006	0.0048	<0.01	<0.009	0.0592	<0.003	0.0063	<0.002	0.0227	<0.001
29 Rainwater	0.0343	<0.0006	0.0024	<0.01	<0.009	0.0469	<0.003	<0.001	0.0038	0.0205	0.0028
Pleistocene aquifer											
1	0.1595	<0.0006	0.0047	<0.01	<0.009	<0.02	0.2216	0.0052	0.0035	0.0258	0.0028
2	0.4372	<0.0006	<0.001	<0.01	<0.009	0.3189	0.1739	<0.001	0.0049	0.0201	0.0028
3	0.3425	<0.0006	<0.001	<0.01	<0.009	0.2493	0.008	<0.001	<0.002	0.0327	<0.001
4	0.3065	<0.0006	<0.001	<0.01	<0.009	2.096	0.0103	0.0021	<0.002	0.024	0.0316
10	0.1221	<0.0006	<0.001	<0.01	<0.009	0.3223	0.009	0.0032	<0.002	0.0216	0.0211
11	1.867	<0.0006	0.0043	<0.01	<0.009	0.9945	0.0832	0.0032	0.0064	0.1944	0.0165
13	0.0782	<0.0006	0.0046	<0.01	0.027	0.1513	0.1073	<0.001	0.0097	0.0474	0.04
14	0.0311	<0.0006	<0.001	<0.01	<0.009	0.0454	<0.003	0.0093	<0.002	0.0243	0.104
15	<0.02	<0.0006	0.0027	<0.01	<0.009	<0.02	<0.003	0.0517	0.0103	0.024	0.0154
16	<0.02	<0.0006	<0.001	<0.01	<0.009	<0.02	<0.003	0.009	<0.002	0.0179	0.0101
17	0.5544	<0.0006	<0.001	<0.01	<0.009	0.356	0.0226	0.0077	<0.002	0.0274	0.0055
18	0.1587	<0.0006	0.0022	<0.01	<0.009	0.4109	0.0085	0.0351	0.0042	0.0246	0.0046
19	0.2846	<0.0006	<0.001	<0.01	<0.009	0.2428	0.0139	0.0063	<0.002	0.0245	0.0046
20	0.2679	<0.0006	<0.001	<0.01	<0.009	0.332	0.0107	0.0026	<0.002	0.041	0.0085
21	0.0457	<0.0006	<0.001	<0.01	<0.009	0.1628	0.0166	<0.001	<0.002	0.0372	0.0139
22	0.1431	<0.0006	<0.001	<0.01	<0.009	0.2045	0.0663	<0.001	<0.002	0.0256	0.0112
25	1.678	<0.0006	0.0044	<0.01	<0.009	1.775	0.2539	<0.001	0.0059	0.0501	0.2269
26	0.1581	<0.0006	0.0029	<0.01	<0.009	0.1915	0.0068	<0.001	0.0031	0.0299	0.0096
27	<0.02	<0.0006	0.0041	<0.01	<0.009	<0.02	0.0128	0.0094	0.0081	0.0259	<0.001
28	0.0716	<0.0006	0.0028	<0.01	<0.009	0.2333	0.0081	0.0034	0.0045	0.0282	<0.001
30	0.0766	<0.0006	0.0035	0.279	<0.009	3.473	0.0068	0.0033	0.0214	0.0328	0.0041
31	0.0458	<0.0006	0.004	0.0285	<0.009	0.1876	<0.003	0.0067	0.0069	0.0274	<0.001
32	0.8618	<0.0006	0.0044	<0.01	0.0299	0.6749	0.0295	0.0239	0.008	0.0284	0.0054
33	0.2541	<0.0006	0.0041	<0.01	<0.009	0.3881	0.039	0.0035	0.0093	0.0299	<0.001
34	0.0612	<0.0006	0.0061	0.0267	<0.009	0.1275	0.004	0.0077	0.0094	0.0294	0.0028
35	<0.02	<0.0006	0.0067	<0.01	<0.009	9.612	0.1168	<0.001	0.0079	0.0515	0.0088
Miocene aquifer											
6	0.9544	<0.0006	<0.001	<0.01	<0.009	0.5606	0.1155	<0.001	<0.002	0.0363	0.0134
7	0.3194	<0.0006	<0.001	<0.01	<0.009	0.4806	0.0344	<0.001	<0.002	0.0407	0.0068
8	0.5607	<0.0006	<0.001	<0.01	<0.009	0.4708	0.0486	<0.001	<0.002	0.0331	0.0059
9	<0.02	<0.0006	0.006	<0.01	<0.009	1.727	0.0372	0.0055	0.0039	0.024	0.0056

Cont.

well No.	Al, mg/l	Cd, mg/l	Co, mg/l	Cr, mg/l	Cu, mg/l	Fe, mg/l	Mn, mg/l	Mo, mg/l	Ni, mg/l	Pb, mg/l	Zn, mg/l
23	1.379	<0.0006	0.0063	<0.01	<0.009	14.46	0.706	<0.001	0.0067	0.0348	0.1078
36	<0.02	<0.0006	0.0068	<0.01	<0.009	9.786	0.1185	<0.001	0.0074	0.0453	0.0079
37	0.0536	<0.0006	0.0037	<0.01	<0.009	17.13	0.0796	<0.001	0.0064	0.029	0.0649
38	<0.02	<0.0006	0.0039	<0.01	<0.009	0.2682	0.0173	<0.001	0.0064	0.0367	<0.001
39	<0.02	<0.0006	0.0049	<0.01	<0.009	<0.02	<0.003	0.0027	0.006	0.0354	<0.001
40	<0.02	<0.0006	0.0032	<0.01	<0.009	0.0465	<0.003	<0.001	0.0067	0.0368	0.0051
41	0.1613	<0.0006	0.0076	<0.01	<0.009	0.336	0.2339	<0.001	0.0079	0.0243	0.0055
42	0.8815	<0.0006	0.0046	<0.01	<0.009	0.6869	0.0546	<0.001	0.0091	0.0415	0.0076
43	1.465	<0.0006	0.0066	<0.01	<0.009	2.121	0.4631	<0.001	0.0109	0.0459	0.0387
44	0.6024	<0.0006	0.0051	<0.01	<0.009	0.9581	0.1175	0.0036	0.0066	0.0386	0.033
45	0.0364	<0.0006	0.0038	<0.01	<0.009	0.0529	0.0045	0.0022	0.0068	0.0292	0.0104

RESULT AND DISCUSSION

The evaluation of groundwater quality for various intend is based on the total dissolved solids (TDS), concentrations of major ions as well as the heavy metals constituents, heavy metal content and hardness.

1- **Evaluation of groundwater quality for human drinking:** Generally, water used for drinking purposes should be colorless free of turbidity, excessive amounts of dissolved salts, harmful micro-organisms and unpleasant odor or taste. To evaluate groundwater for human drinking, the groundwater salinity and concentration of major ions and heavy metals have been considered based on the basis of standards recommended by World Health Organization (WHO), 2006 and the Egyptian Standards published in 2007 (Table 2).

Table 2: Water quality guidelines for human drinking.

Constituent or Parameter	World Health Organization guidelines (ppm)	Egyptian maximum Permissible limit in (ppm)
TDS	1000	1000
Hardness as $CaCO_3$	500	500
Magnesium	--	150
Calcium	--	350
Sodium	200	200
Aluminum	0.2	0.2
Cadmium	0.003	0.005
Cobalt	--	--
Chromium	0.05	--
Copper	2.0	1.0
Iron	0.3	0.3
Manganese	0.4	0.05
Molybdenum	--	--
Nickel	0.07	--
Lead	0.01	0.05
Zinc	3	3

a- Total dissolved solids: The term salinity refers to the total dissolved concentrations of major, minor and trace constituents in water. The concentration of solutes (groundwater constituents) can vary enormously as a function of the mineral content which characterizes the aquifers matrix through which the groundwater flows. According to the chemical analyses listed in (Table 1) the Pleistocene aquifer groundwater salinity ranges from 751mg/l to 27,870 mg/l with an average value of 6006.85 mg/l while, the Middle Miocene groundwater salinity ranges from 3645 mg/l to 41357 mg/l with an average value 11897mg/l.

According to the values of total dissolved solids (TDS), water could be categorized into fresh, brackish and saline waters (Chebotarev, 1955**)**. In the study area, the majority of groundwater samples are categorized as saline (44 %) and brackish (41 %) water class while minorities are considered as freshwater class (15%). In general, most of the freshwater samples are recorded within the Pleistocene aquifer (23%). The majority of freshwater groundwater dominates the Pleistocene oolitic aquifer is mainly due to the prevalence of fractures, joints and faults that facilitate the surface water percolation and enhancing the annual recharge. Additionally, the oolitic elevated ridges act as a barrier for surface water flow and consequently enhance the entrapment of recharge water. On the other hand the samples with high salinity that reflect the effect of leaching and seawater intrusion.

Comparing the chemical data for the groundwater in the study area (Table 1) with the maximum standard guidelines recommended for human drinking by the World Health Organization (WHO, 2006), it can be deduced that; 92% of the Pleistocene groundwater samples are unsuitable for drinking except, wells No. 10 and 19 are permissible. However, in the Middle Miocene aquifer, all the groundwater samples are unsuitable for drinking.

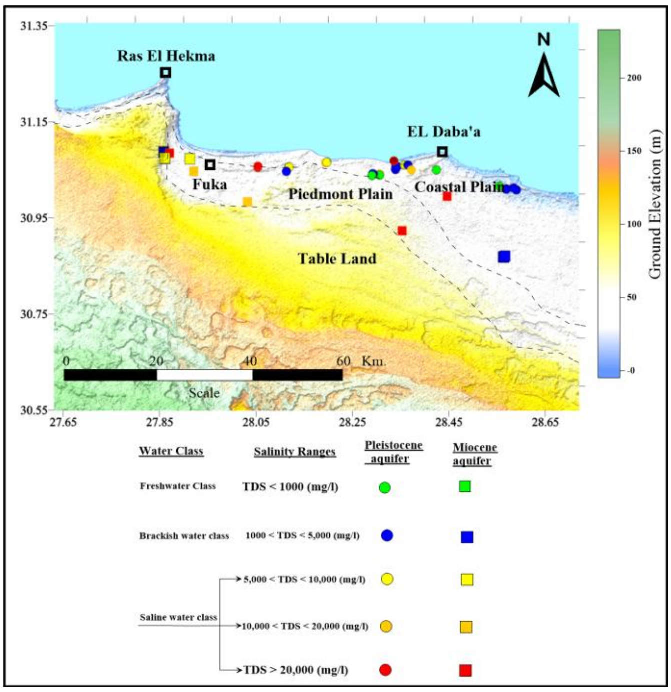


Figure 2: Groundwater salinity distribution map for Pleistocene and Middle Miocene aquifers.

b- Heavy metals: Heavy metals are not biodegradable and tend to accumulate in living organisms. Many heavy metals are known to be toxic or carcinogenic. The heavy metals of particular concern in groundwater include Aluminum, Cadmium, Cobalt, Chromium, Copper, Iron, Manganese, Molybdenum, Nickel, Lead and Zinc. In this study, the dissolved concentrations of Cadmium, Cobalt, Copper, Chromium, Manganese, Molybdenum, Nickel, and Zinc in groundwater samples tapping the Miocene and the Pleistocene aquifers are less than the World Health Organization permissible limits. By evaluating the other elements Concentrations with World Health Organization (WHO, 2006), shows that

38% of Aluminum and 46% of Iron concentrations in the Pleistocene aquifer are exceeding the permissible limit. On the other hands 47% of Aluminum and 73% Iron in the Middle Miocene aquifer are exceeding the permissible limit. While Lead in all groundwater samples is more than the permissible limit.

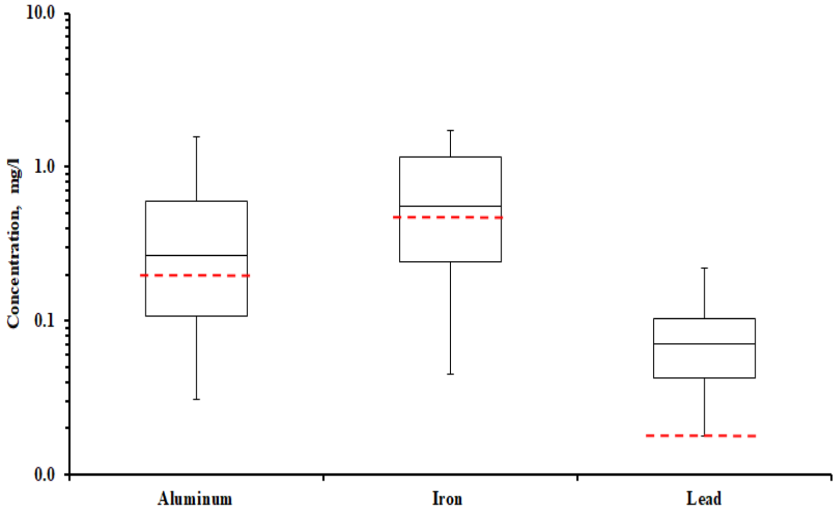


Figure 3: Box-Whisker plot of Aluminum, Iron and Lead concentrations for groundwater samples in the Pleistocene aquifer related to the Permissible limit, - - - is the Permissible limit.

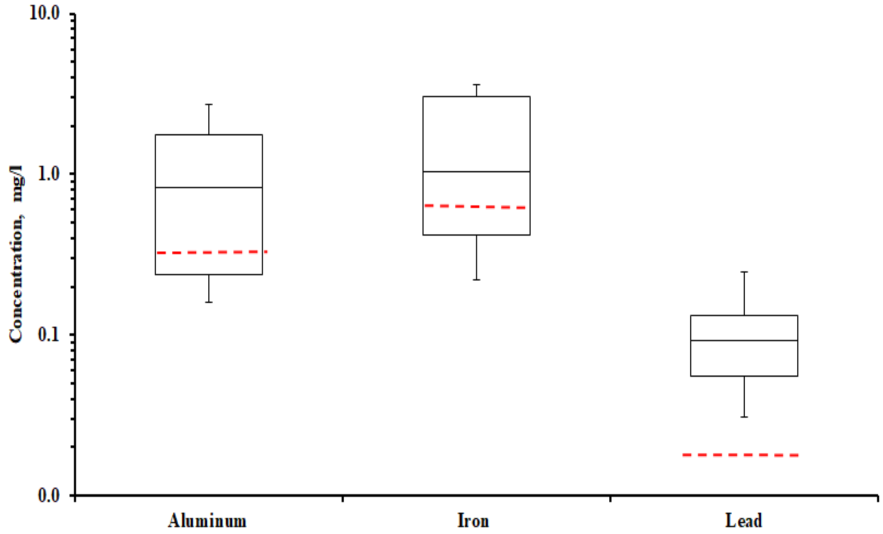


Figure 4: Box-Whisker plot of Aluminum, Iron and Lead concentrations for groundwater samples in the Middle Miocene aquifer related to the Permissible limit, - - is the Permissible limit.

Evaluation of groundwater quality for livestock and poultry: Water required for domestic purposes on farms includes that consumed by livestock and poultry is subjected to quality limitations and international standards recommended by the National Academy of Science (NAS) and National Academy of Engineering (NAE) (1973).

Table (3): Guide to the use of saline waters for livestock and poultry (National Academy of science (NAS) and National Academy of Engineering (NAE), 1973)

Salinity, mg/l	Classification	Characters
Less than 1000	**Excellent**	Excellent for all classes of livestock and poultry
1000 to 3000	**Very satisfactory**	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them or watery dropping in poultry.
3000 to 5000	**Satisfactory**	Satisfactory for livestock, but may causes temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing water faces, increased mortality and decreased growth, especially in turkeys.
More than 5000mg/l	**Not acceptable**	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cow, horses or sheep, or for the young of these species

To evaluate the suitability of groundwater for livestock and poultry the chemical analyses data shown in (Table 1) are compared with the standards recommended limits represented in Table (4). It is clear that, in the Pleistocene groundwater samples, 8% of total groundwater samples have an excellent class, 38% are considered as very satisfactory, 15% are satisfactory and 38% are considered as water having a risk class. In the Middle Miocene aquifer, 47% of groundwater is satisfactory and 53% are considered as groundwater having risk for livestock and poultry.

Table (4): Evaluation of the groundwater samples for drinking of livestock and poultry in the study area.

Salinity in mg/l	Characters	Pleistocene aquifer		Miocene aquifer	
		Sample NO	%	Sample NO	%
Less than 1000	**Excellent**	2	8%	-	-
1000 to 3000	**Very satisfactory**	10	38%	-	-
3000 to 5000	**Satisfactory**	4	15%	7	47%
More than 5000mg/l	**Not acceptable**	10	38%	8	53%

Evaluation of groundwater for domestic and laundry uses: In general, water used in laundry and domestic purposes should be soft or moderately hard. The total groundwater hardness in the Pleistocene aquifer ranges between 84.8 mg/l and 4613.2 mg/l with an average value of 1204.6 mg/l. In the Miocene aquifer, total hardness ranges between 730.8 mg/l and 10918.9 mg/l with an average value of 3051.8 mg/l. The hardness values for all groundwater samples have been compared with the permissible limits recommended by (Sawyer and Mc Carty, 1967) represented by Table (5). Most of the groundwater samples in Pleistocene aquifer (88%) are unsuitable for domestic and laundry uses as the total hardness values are exceeding 300 mg/l, however; all the Middle Miocene groundwater are unsuitable for domestic and laundry uses

Table (5): Suitability of water for laundry usage according to its total hardness, (Sawyer and McCarty, 1967).

Classification	Total hardness(mg/l as $CaCO_3$)
Soft	< 75
Moderately hard	75 – 150
Hard	150 – 300
Very hard	>300

Evaluation of groundwater for irrigation: Water quality problems in irrigation include high salinity and excessive toxicity elements. High salinity occurs when there is an accumulation of salts in soils. Some water contains high enough concentrations of certain elements to retard or even eliminate the growth of some plants such as, total salinity, chlorides and sodium are common toxic substances.

For the better understanding of the suitability of water for agriculture uses; important factors have to be considered including; the sodium adsorption ratio (SAR), sodium hazards, Sodium percentage **(Na %), Permeability index (PI) and magnesium ratio.:** The assessment of water quality is discussed under the following topics are very important factors that have been used to evaluate the suitability of water for irrigation to avoid the adverse effect on soil and plant productivity.

1- **Sodium Adsorption Ratio (SAR):** Sodium adsorption ratio (SAR) is a measure of the suitability of water for use in agricultural irrigation because sodium concentration can reduce the soil permeability and soil structure (Todd, 1980). High value of SAR implies that sodium in the irrigation water may replace calcium and magnesium ions in the soil, potentially causing damage to the soil structure.

The SAR value is defined as follows:

$$SAR\ (\mathrm{epm}) = \frac{\mathrm{Na}}{\sqrt{(\mathrm{Ca} + \mathrm{Mg})/2}}$$

Where: all ionic concentrations are expressed in meq/l.

A monogram is widely used for the evaluation of waters for irrigation purposes. This monogram consists of a plot of specific conductivity (in µmhos/cm) which is a function of the total dissolved solids concentration against SAR. The water is classified into four classes based on salinity (C_1, C_2, C_3 and C_4) and four classes based on SAR (S_1, S_2, S_3 and S_4) giving a total of sixteen possible quality classes (C_1-S_1, C_1-S_2, C_1-S_3 …etc.) (Table 6).

Table (6): Classification and Interpretation of the Water Quality According to the (U.S. Salinity Laboratory Staff, 1954).

A) Based on salinity concentrations

Conductivity (EC)	Degree	Range (ppm)	Usage
C1	Low salinity	100-250	Used for irrigation with most crops on most soil
C2	Medium salinity	250-750	Used if moderate leaching occurs
C3	High salinity	750-2250	Cannot be used with restricted drainage
C4	Very high salinity	2250-5000	Not suitable for irrigation under ordinary condition

B) Based on Sodium concentrations

Sodium ion Content (SAR)	Degree	Range (ppm)	Usage
S1	Low Sodium	0-10	Can be used for all soils
S2	Medium Sodium	10-18	Preferably used with good permeability
S3	High Sodium	18-26	Good soil management essential
S4	Very high Sodium	26-100	Unsuitable for irrigation except at low salinity

2- Sodium hazard

By applying the US. Salinity hazard diagram on the groundwater classification it is obvious that; 54%, 100% of groundwater samples in the Pleistocene and Middle Miocene aquifer respectively; are plotted out of the diagram because they have Electrical conductivity (EC) values that are more than 5000 µmhos/cm. The groundwater samples plotted out of the diagram are considered unsuitable for irrigation; while 8% of samples in the Pleistocene aquifer are classified by moderate water class (C4-S2) and the rest of samples (38%) are represent good water for irrigation (C3-S1 & C4-S1).

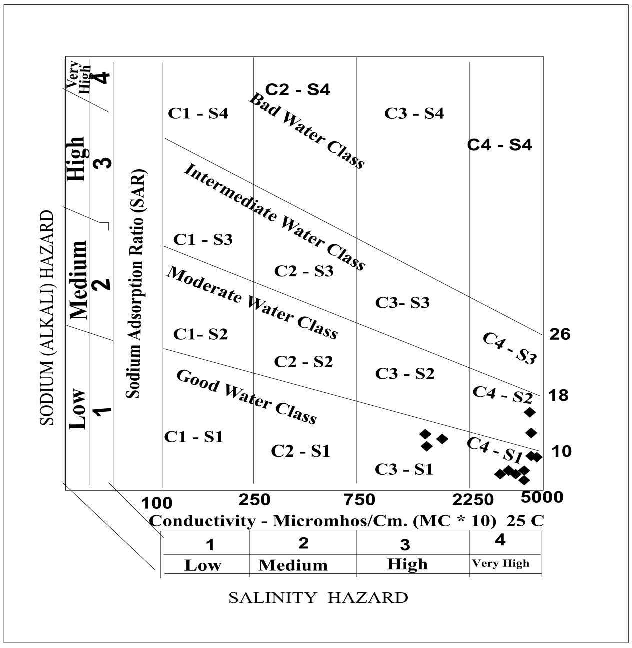


Figure 5: US.Lab.of irrigation water for the Pleistocene groundwater samples.

3- Sodium percentage (Na %): The sodium in irrigation waters is usually denoted as a percent of sodium (%). According to (Wilcox, 1955), in all natural waters, the Na% is a common parameter to assess its suitability for irrigation purposes. The sodium percent (Na %) value was obtained by using the following equation.

$$Na\% = \frac{(\mathbf{Na} + \mathbf{K})\ \mathbf{x\ 1000}}{\sqrt{(\mathbf{Ca} + \mathbf{Mg} + \mathbf{Na} + \mathbf{K})}}$$

Table 7. Classification of groundwater based on Na% (Wilcox, 1955)

Water quality	Sodium (%)
Excellent	<20
Good	20-40
Permissible	40-60
Doubtful	60-80
Unsuitable	>80

Comparing the sodium percent for the groundwater samples in the study area with the suitability for irrigation (Table 7) it is clear that; 54%, 100% of groundwater samples in the Pleistocene aquifer and Middle Miocene aquifer respectively; are outside the diagram because they have Electrical conductivity (EC) exceed 5000 µmhos/cm and are unsuitable for irrigation. While, 8 % of groundwater samples in the Pleistocene aquifer fall in the permissible to doubtful filed, 12% fall in the doubtful to unsuitable filed and 27% are considered to be unsuitable.

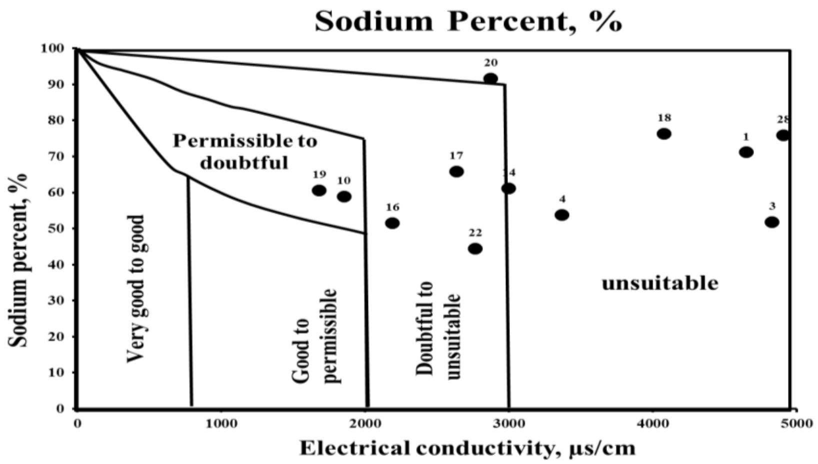


Figure 6.: Classification of irrigation water quality, with respect to EC and sodium percent.

4- **Permeability Index (PI):** The permeability index (PI) was developed by (Doneen, 1964) and it has been used mainly to evaluate water suitability for irrigation uses. The PI was calculated by the following equation where all the ions are expressed in meq/l. PI was classified into three classes Class I and class II waters are considered to be good and suitable for irrigation while class III water is unsuitable for irrigation.

$$\mathbf{PI = [Na + (HCO3)^{0.5} + 100/[Na + Ca + Mg]}$$

The PI values recorded in the Pleistocene aquifer vary from 55 to 101.17, with an average value of about 73.91.in the Miocene aquifer; it varies from 33 to 83.5 with an average value of 68.01. A classification based on PI as represented in Figure (7), was proposed by World Health Organization for assessing the suitability of groundwater for irrigation purposes. According to the permeability index values,55 % of groundwater samples in the Pleistocene aquifer are out of curve because they have Electrical conductivity (EC) more than 5000 µmhos/cm, 4 % of the samples fall under the class 3, only 42 % belongs to class 1 (Fig. 7). On other hand, all groundwater samples in the Middle Miocene aquifer are out of curve because they have Electrical conductivity (EC) more than 5000 µmhos/cm.

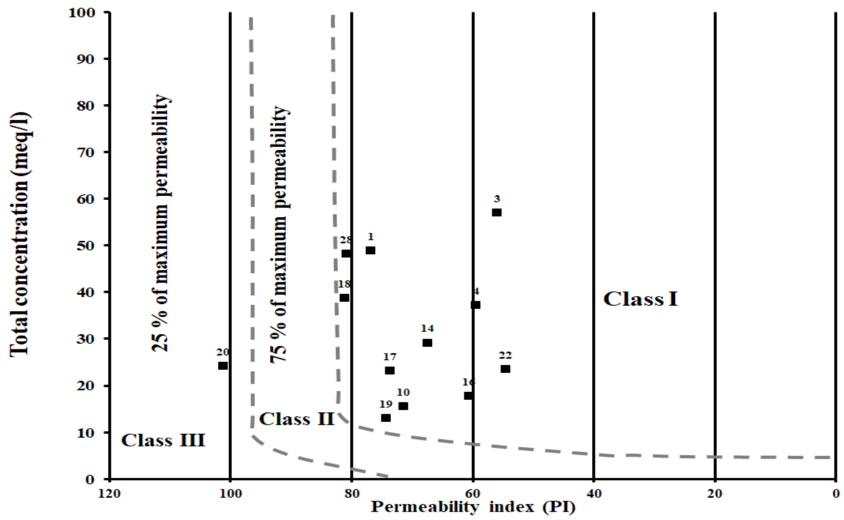


Figure 7.: Classification of irrigation water based on permeability index for the Pleistocene groundwater samples

5- Magnesium ratio: In most waters, calcium and magnesium maintain a state of equilibrium and the ratio namely index of magnesium hazard (MH) was developed by (Paliwal, 1972). The high magnesium hazard value (>50 %) has an adverse effect on the crop yield as the soil becomes more alkaline.

$$\textbf{Magnesium ratio} = \textbf{Mg x 100/ (Ca + Mg)}$$

In Pleistocene aquifer, the magnesium hazard values fall in the range of 36.0 to 85.89% while the (MH) ratio in the Middle Miocene aquifer varies from 44 to 76.02%. According to the calculated MH values in Table 1; 12 % of groundwater samples in the Pleistocene aquifer are suitable for irrigation and 88 % falls in the unsuitable category while 7% of the Middle Miocene groundwater are suitable and 93% can cause an adverse effect on the agricultural yield.

CONCLUSION

Groundwater is the sale source for drinking and agriculture uses in the NorthWestern coast of Egypt. The results show, the total dissolved solids have a mean value of 8426 mg/l are exceeding the recommended international standard limit for human drinking. The majority of groundwater samples in the Pleistocene aquifer (92%) and all groundwater samples in the Middle Miocene aquifer are unsuitable for drinking. According to the World Health Organization standard limits. 38% of aluminum and 46% of iron concentrations in the Pleistocene aquifer are exceeding the permissible limit. On the other hand, 47% of aluminum and 73% iron in the Middle Miocene aquifer are exceeding the permissible limit. The concentration of Manganese and Copper in all groundwater samples tapping the Pleistocene and Middle Miocene aquifer are less than the permissible limit while Lead in all groundwater samples is more than the permissible limit. To evaluate the suitability of groundwater for livestock and poultry, 8% of the Pleistocene groundwater samples, have an excellent class, 38% are considered as very satisfactory, 15% are satisfactory and 38% are considered as water having a risk class. However, 47% of the Middle Miocene groundwater is satisfactory, 53% are considered as groundwater having a risk for livestock and poultry. According to the total hardness in groundwater of the Pleistocene aquifer, about 88% are unsuitable for domestic and laundry uses, however, all the Middle Miocene groundwater are unsuitable for domestic and laundry uses. Based on sodium adsorption ratio (SAR), sodium percentage (Na %), magnesium hazard (MH) and permeability index (PI), 71% of total samples are unsuitable for irrigation.

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تقييم صلاحية المياه الجوفية للشرب والزراعة للمنطقة ما بين رأس الحكمة والضبعة–الساحل الشمالي الغربي– مصر

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المستخلص

أدت الأنشطة الصناعية والحضرية الأخيرة إلى زيادة تركيزات الملوثات في المياه الجوفية، مما يؤثر على صحة مليون شخص في جميع أنحاء العالم. تعتبر المياه الجوفية هي المصدر الرئيسي للشرب و الزراعة في الساحل الشمالي الغربي لمصر. حيث تم جمع خمسة وأربعين عينة من المياه الجوفية من المنطقة الواقعة بين الضبعة ورأس الحكمة تمثل خزاني البليستوسين والميوسين الاوسط، وقد تم اجراء بعض التحليلات للعينات المجمعه مثل: الاملاح الذائبه الكليه والكالسيوم والماغنيسيوم والصوديوم وخمسة عناصر ثقيلة مثل: (الألومنيوم، الحديد، المنجنيز، النحاس، الرصاص) وذلك باستخدام الطرق العالميه المعمليه المستخدمه في تحليل عينات المياه. ومن النتائج وجد أن متوسط تركيزات العناصر الذائبه الكليه، الكالسيوم، الماغنيسيوم و الصوديوم ٨٤٢٦ ، ٢٦٤,٥ ، ٢٩٥,٩ ، ٢٣٩٠,١ مليجرام/ لتر على التوالي.كما وجد ايضا ان كل عينات المياه الجوفيه في الخزانين اعلي من الحدود المسموح بها وذلك بناء علي الحدود القصوي المسموح به للعناصر الثقيلة حيث ان متوسط تركيز الحديد ١,٩٩ مليجرام / لتر متبوعا بالألومنيوم ٠,٤٥ مليجرام/ لتر، بينما سجلت المنجنيز أدنى قيمة متوسطة ٠,٠٩ مليجرام/ لتر. كما لوحظ من النتائج أن غالبية عينات المياه الجوفية في الخزانين الجوفيين غير صالحة للشرب الادمي بسبب التركيزات العالية من الاملاح والأيونات الرئيسية والمكونات المعدنية الثقيلة. وفقا للمعايير الدولية التي أوصت بها الأكاديمية الوطنية للعلوم والأكاديمية الوطنية للهندسة ، كما ان عينات المياه الجوفية في منطقة الدراسة تتراوح من ممتازة إلى غير مقبولة لاستخدامات الماشية والدواجن. ومعظم عينات المياه الجوفية في الخزان البليستوسين (٨٨٪) غير مناسبة للاستخدامات المنزلية حيث تتجاوز قيم الصلادة الكلية ٣٠٠ مليجرام / لتر. وكذلك كل المياه الجوفية الموجوده في خزان الميوسين غير مناسبه للاستخدامات المنزلية. في حين أن ٧١٪ من مجموع العينات غير صالحة للري وفقا للاملاح الذائبه الكليه وحوالي ٩٣٪ من عينات المياه الجوفية غير مناسبة للاستخدامات المنزلية وفقا للصلادة الكلية. لذلك ينصح بعملعملياتمعالجة وتحلية للمياه

الجوفيه باستخدام طرق مناسبة واقتصادية مطبقة لتحسين نوعية المياه وصلاحيتها للاستخدامات المختلفة.

كلمات مفتتاحيه: تقييم نوعية المياه الجوفية – منطقة الضبعة وراس الحكمه – نسبة امتزاز الصوديوم – المكونات الكيميائيه