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Evaluation of water resources in El_Minya governorate _Egypt for drinking and irrigation purposes

A.E.Farag[1], M.D.Ahmed[2]*, Magdy Hosny El-Sayed[2]
[1]Chemistry Dep., Fac. Sci., El-Minufiya University, (EGYPT)
[2]Hydrogeochemistry Department, Desert Research Center, Matrya, Cairo, (EGYPT)
E-mail : ahmeddesouky_27@hotmail.com

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ABSTRACT

The present work aims to evaluate the water resources chemicaly in El-Minya governorate for drinking. The hydrochemical characteristics, as well as evaluation of surface and groundwater also for irrigation. The study includes chemical analysis of 25 surface water samples (River Nile and, Ibrahimiya and Bahr Yousof canals and moheet drain) and 208 groundwater samples (148 samples tapping the Plio-Pleistocene aquifer and 60 samples tapping the Eocene aquifer) during Jun and September, 2005. Most of the groundwater samples of the Plio-Pleistocene and Eocene aquifers lie in the fresh zone, while the brackish water is less pronounced. There is a general direction of increasing water salinity from the River Nile to the Plateau along the study area. The higher values of water salinity is strictly confined to southwest of Samalut locality due to over-pumping activity. This reflects the impact of land reclamation projects on the groundwater figure 1.

INTRODUCTION

The study area occupies the middle portion of Nile Valley in Upper Egypt and it is located between latitudes $27^0 30'$ and $28^0 45'$ N, and longitudes $30^0 30'$and $31^0 00'$ E. The area occupies part of the Nile Valley (14-20Km width) and it is bounded by Beni-Suef governorate at the North, Assiut governorate at the South and surrounded with the Eastern desert from the East and the Western desert from the West. The studied area comprises the Eastern and Western desert fringes along the limits of El-Minya governorate. According to the present groundwater studies it can divided into two aquifers.

The plio-pleistocene aquifer

This aquifer represents the main water bearing formation in the studied area. This aquifer has a wide distribution in Nile Valley and also in the adjacent areas. The concerned aquifer is represented by Prenile sediments (Qena formation) and composed mainly of coarse, massive and thick sand and gravel. These sediments are intercalated with clay lenses. The thickness of this aquifer varies from one location to another according to the topography of the underlying Pliocene clays. The thick part (200-300m) of the middle Plio-Pleistocene exists mostly at the middle part of the valley, while, towards the valley fringes, the thickness of this aquifer becomes gradually thinner (50 to 100m.), and is bounded by fault plains. Generally, the thickness of this aquifer varies between 110m at Mallawi and 245m at Samalut[2].

The sediments of this aquifer are mostly underlain by Pliocene clay and/or Eocene fractured limestone, which form the base of Plio-Pleistocene aquifer. The Plio-Pleistocene aquifer is overlain by Holocene silt and clay layer (semi-permeable layer) in some localities nearby the River Nile. So, the groundwater of the Plio-

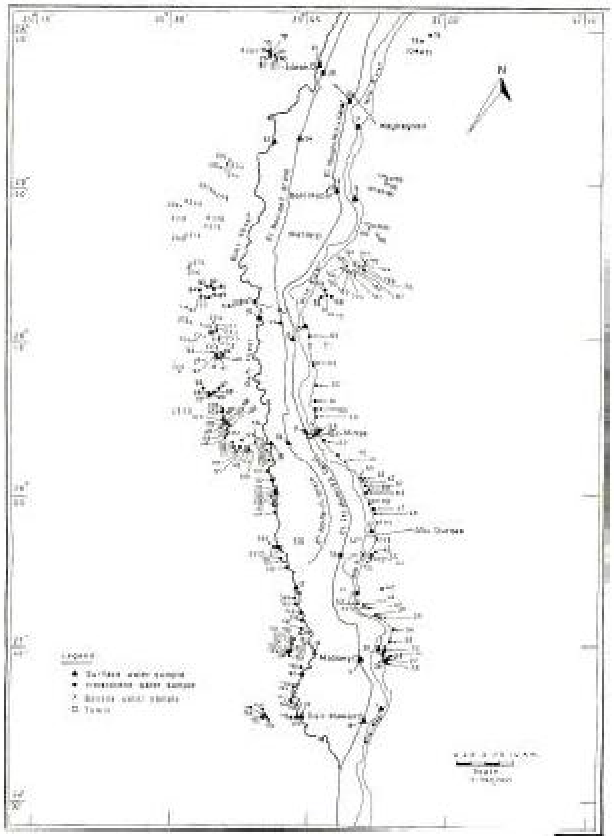


Figure 1: Well location map of the study area

Pleistocene aquifer occurs under semi-confined conditions in some localities, while being under unconfined condition in the major parts of the study area where the semi-previous silt and clay layer is absent. The present study states that the depth of water ranges between 1.5 and 26 meter from the ground surface.

The water flow in the River Nile and the main irrigation canals and drains in the area is generally from the south to the north with small and lateral distributions having other flow directions, i.e., the seepage from the River Nile and the main irrigation canals and drains to the adjacent aquifers[3].

The recharge of the Plio-Pleistocene aquifer in the studied area takes place mainly from infiltration of the surfacewater (Nile water) after irrigation of the agricultural lands, local inflow from the irrigation canals and upward recharge from the deep aquifers (Eocene and Nubian sandstone) through the fault planes existing in the region[3]. Sometimes, there is a recharge from the occasional water-runoff of the different wadis. The bulk of the present groundwater principally consists of irrigation water infiltrated before the implementation of the high Dam at Aswan, and of the groundwater seepage from the ancient aquifers.

The discharge from the Plio-Pleistocene aquifer in the Nile Valley takes place through direct and indirect routes. Among these are; the lateral seepage to the Nile, and through the drainage system, and the discharge through the wells drilled for drinking and irrigation purposes. The indirect ones are represented by evaporation and evapotranspiration from the surface water of the Nile, irrigation canals, open collector drains, and from the irrigated water before the infiltration to the aquifer, beside the evaporation of the groundwater. The major part of the subsurfacewater outflow is the discharge through the aquifer into the River Nile[4].

The Plio-Pleistocene aquifer has effective porosity that varies between 30% and 35%[6]. The transmissivity of this aquifer ranges between 3500 and 21000m^2/day[4] indicating high potentiality. The average storage coefficient amounts to about 0.15[6].

The eocene fissured limestone aquifer

The Eocene carbonate water bearing formation underlies both the Plio-Pleistocene and overlies the Nubian sandstone water bearing formation[3]. The Eocene aquifer occupies the extreme eastern and western sides of the study area.

Eocene limestone aquifer unit is represented by Samalut formation and is made up of hard, white, highly fossiliferous limestone with shale and marl intercalations. Eocene limestone is fractured and is probably affected by network of faulting system (Said, 1981). The groundwater of the Eocene aquifer occurs under unconfined conditions where it is overlain by the permeable Plio-Pleistocene sediments.

The depth of water of Eocene aquifer varies widely between 2m and 80m, from the ground surface and it decreases towards the East direction (East Beni-Mazar). The possible recharge of the Eocene limestone aquifer in the study area may occur from the following sources:

1. Direct recharge by downward seepage through percolation of the atmospheric precipitation and the occasional flash floods.
2. Direct recharge from the percolation of irrigation water and from the local seepage of the overlying younger aquifers. In addition, the recharge of this

TABLE 1: Chemical analyses of surface and groundwater samples in the study area in ppm

Sample no.	pH	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
Surface water										
River Nile										
1	7.72	219	28	14.58	24	5	6.06	166.35	21	14.57
2	7.85	222	28.56	9.92	25	4	12.12	140.63	22	14.57
3	7.76	187	24	12.15	23	5	6.42	145.76	19	14
4	7.82	225	24	12.39	23	5	12.12	140.36	17	14.57
5	7.88	191	28	12.15	23	5	6.06	160.19	20	14.57
6	7.80	203	28	12.15	24	5	6.06	151.16	21	14.57
7	7.80	206	28	12.15	25	5	6.06	151.16	27	14.57
Irrigation canals										
8	7.66	219	24	12.15	27	5	6.42	145.76	20	14.57
9	7.70	193	24	12.15	24	5	12.84	137.07	17	14.57
10	7.90	204	24	12.15	25	5	6.42	140.36	17	19.43
11	7.34	195	32.32	7.36	21	5	26.09	106.09	8	15
12	7.70	210	28	12.15	25	5	6.06	151.16	21	14.57
13	7.72	203	24.48	12.39	23	5	0.00	156.56	22	14.57
14	7.75	202	24.48	14.58	22	5	0.00	172.51	21	14.57
15	7.75	191	28	9.72	25	5	6.06	151.16	20	14.57
16	7.72	211	28	14.58	24	5	6.06	160.19	21	14.57
17	7.69	201	24.48	12.39	25	5	6.42	156.68	18	14.57
18	7.80	222	28.56	14.87	25	5	0.00	182.76	20	19.43
19	7.73	216	32	12.15	25	5	0.00	167.35	28	14.57
20	7.72	246	32	12.15	30	5	0.00	172.75	32	19.43
21	7.57	237	28	14.58	31	5	0.00	167.35	29	25
Drains										
22	7.20	365	40	19.44	45	16	0.00	215.94	47	50
23	7.32	571	52	29.16	88	11	0.00	275.82	200	14.75
24	7.60	524	52	24	90	6	12.12	259.13	100	68.01
25	7.48	468	48	26	74	6	12.12	210.51	120	48.58
Groundwater the (Quaternary aquifer)										
26	7.80	1025	12	60.75	260	11	6.06	496.66	240	116.6
27	7.53	525	12	51.03	90	8	6.06	264.53	130	58.3
28	7.63	487	44	36.45	65	5	18.18	323.91	10	14.57
29	7.61	445	8	48.74	65	7	6.06	237.53	120	24.29
30	7.68	402	8	41.31	55	8	24.24	134.96	120	29.15
31	7.83	249	16	26.73	25	4	24.24	161.96	18	14.57
32	7.68	455	28	31.59	63	8	6.06	215.94	140	19.43
33	7.69	374	24	29.16	54	6	6.06	161.96	130	19.43
34	8.00	1930	76	46.17	500	6	30.3	178.15	720	370
35	7.59	426	56	21.87	38	15	24.24	140.36	110	43.72
36	7.72	426	44	24.3	64	7	18.18	205.14	100	43.72
37	7.65	578	64	24.3	80	8	24.24	199.75	160	58.3
38	7.62	334	52	17.01	26	6	18.18	140.36	90	24.29
39	7.47	483	61.2	37.18	49	6	24.24	264.53	120	24.29
40	7.23	537	16	55.89	80	9	0.00	323.91	120	43.72
41	7.51	517	57.12	42.14	50	6	0.00	318.51	130	38.87
42	7.50	1102	122.4	54.53	160	8	12.12	221.8	290	267.2
43	7.41	445	20	43.74	60	8	6.06	237.53	120	34.01
44	7.30	410	8	55.89	50	9	6.06	242.93	120	19.43
45	7.71	403	53.04	27.27	36	6	12.84	199.95	100	38.87
46	7.97	400	48	24.3	51	6	25.68	188.95	90	24.29
47	7.96	424	32.64	27.27	67	4	25.68	194.35	80	34.01
48	7.72	415	32.64	39.66	55	5	12.84	221.34	100	38.87
49	7.73	438	32.64	44.62	48	7	6.42	291.52	70	48.58

To be countinue table 1

Sample no.	pH	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
50	7.88	1628	89.76	64.44	360	12	32.1	183.55	520	369.22
51	7.89	1327	102	84.27	200	15	32.1	134.96	480	286.63
52	7.82	908	36	38.88	180	17	6.42	129.56	320	145
53	7.87	1962	61.2	69.4	480	14	32.1	365.51	540	437.23
54	7.48	365	48	19.44	25	4	12.84	242.93	20	14.57
55	7.61	1151	20.4	52.05	300	5	6.42	361.44	380	165.18
56	7.98	765	40.8	14.87	190	4	44.94	448.08	120	24.29
57	7.72	728	48.96	22.31	160	8	19.26	437.28	140	38.87
58	7.63	531	69.35	27.27	60	6	24.24	226.74	120	38.87
59	7.32	500	61.2	24.79	60	7	0.00	232.14	130	48.58
60	7.66	252	36	24.3	21	2	121.12	221.34	20	14.57
61	7.57	659	8	77.76	100	9	24.24	248.33	170	106.88
62	7.60	699	69.36	42.14	100	9	0.00	367.1	180	58.3
63	7.66	320	53.04	24.79	21	4	12.12	268.68	21	14.57
64	7.67	213	36.72	12.39	23	5	12.12	156.56	21	14.57
65	7.66	406	69.36	24.79	23	5	24.24	210.54	90	14.57
66	7.70	497	12.12	39.66	100	10	32.61	318.27	59	38.87
67	7.50	977	44.44	31.91	220	18	13.04	104.43	280	245
68	7.53	771	44.44	46.63	120	18	6.52	172.4	185	175
69	7.28	614	8.08	83.73	60	10	6.52	318.27	100	91.13
70	7.63	1868	90.9	67.49	460	8	0.00	149.19	340	712.5
71	7.50	3173	248	96.8	750	25	19.56	132.61	860	1130
72	7.57	2181	165.64	78.54	480	10	6.52	165.77	680	612.13
73	7.57	1193	129.28	51.54	310	7	6.52	112.72	410	470
74	7.20	1533	113.12	44.18	230	6	13.44	106.09	340	350
75	7.48	4769	363.6	73.63	1200	19	19.56	99.46	1180	1748.9
76	7.63	1505	220	46.17	160	13	13.44	92.83	700	184.61
77	7.52	1658	251	56.45	180	19	32.61	165.77	60	242.5
78	7.62	1993	343.4	73.63	150	23	26.09	132.62	960	223.48
79	7.47	1975	258.56	61.36	300	15	19.56	152.51	620	510.11
80	7.57	1440	202	54	140	26	13.44	145.88	660	140
81	7.62	1478	173.72	41.72	210	15	6.52	139.24	660	170
82	7.74	250	16.16	14.73	35	5	20.09	125.98	30	14.57
83	7.67	273	16.16	17.18	40	7	19.56	152.51	30	14.57
84	7.75	324	16.16	17.18	55	7	19.52	192.3	34	14.57
85	7.85	282	36.36	17.18	35	4	39.14	132.16	40	14.57
86	7.75	344	48.48	17.18	35	4	32.16	179.03	40	14.57
87	7.73	410	24.24	17.18	75	6	26.09	152.51	76	38.87
88	7.52	1563	121.2	66.27	300	13	19.56	152.51	500	364.36
89	7.60	3163	251	127.44	650	26	32.61	92.83	950	981.35
90	7.48	4419	270.68	111.78	1100	16	39.14	152.41	1300	1389.4
91	7.58	2772	145.44	80.99	680	16	32.61	119.35	1000	660.71
92	7.70	1768	72.72	59.49	450	11	32.61	132.61	420	563.55
93	7.71	891	40.4	51.54	180	11	13.44	152.41	210	252.62
94	7.82	2786	129.38	90.81	660	9	19.56	119.35	1200	548.97
95	7.75	887	40.4	36.81	210	6	6.52	159.14	130	330.35
96	7.57	365	20.2	22.09	55	15	6.52	205.55	50	35
Groundwater (Quaternary aquifer)										
Sample no.	**pH**	**TDS**	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
97	7.75	316	24.24	14.73	50	11	19.56	192.3	37	10
98	7.73	387	44.44	17.18	40	7	19.56	172.4	77	25
99	7.59	353	32.32	12.27	43	13	6.52	172.4	52	25
100	7.59	553	72.73	14.73	60	10	6.52	192.3	165	29.15
101	7.75	662	56.56	19.63	110	13	19.56	165.77	230	50

To be countinue table 1

Cont. TABLE 1

Groundwater (Quaternary aquifer)										
Sample no.	pH	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
102	7.59	503	18.26	14.73	120	10	39.14	172.4	110	38.87
103	7.90	440	20.2	17.18	85	17	32.61	218.81	52	25
104	7.97	1669	40.4	19.63	500	7	19.56	165.77	520	390
105	7.84	2349	113.12	47.09	900	19	19.56	159.14	1050	885
106	8.00	2093	32.32	12.27	680	8	39.14	119.35	620	535
107	7.58	1416	52.52	19.63	400	22	13.44	225.44	380	365
108	8.00	2293	52.52	34.36	680	12	32.61	152.51	860	460
109	7.75	1929	40.4	24.54	600	15	26.09	205.55	490	525
110	8.00	2758	113.12	68.72	750	19	39.14	106.09	600	1025
111	7.93	2186	44.44	24.54	660	19	58.7	132.61	620	605
112	7.69	2945	218.16	112.9	600	27	39.14	152.51	900	865
113	7.54	3362	160	80.19	900	24	32.61	132.61	1050	960
114	7.70	2497	113.12	31.91	700	24	39.14	145.88	650	762.73
115	7.83	3023	234.32	132.53	600	29	19.36	119.35	1040	834.95
116	7.84	1711	76.76	73.63	380	19	16.31	182.34	700	320.64
117	8.00	626	20.2	27	160	16	26.09	265.23	31	170
118	8.00	920	52.52	56.45	180	15	32.61	165.77	200	265
119	8.00	303	20.2	22.09	45	11	32.61	198.92	8	20
120	7.91	423	12.12	44.18	60	15	39.14	165.77	75	55
121	7.77	415	20	26.73	70	13	39.14	179.03	55	38.87
122	7.71	745	8.08	51.54	160	17	32.61	221.52	220	110
123	7.78	325	32.32	22.09	30	9	19.56	179.03	29	25
124	7.80	757	40.4	24.54	180	7	6.52	198.92	190	170
125	7.74	453	36.36	31.91	60	12	13.41	225.44	120	30
126	7.72	270	20.2	19.63	40	9	19.56	165.77	20	25
127	7.79	274	32.64	12.39	25	6	0.00	199.47	18	14.57
128	7.89	326	36	31.59	25	5	6.52	159.58	65	43.72
129	7.60	274	32.64	9.91	20	8	19.26	134.96	17	14.57
130	7.90	628	40.8	34.7	110	11	6.42	307.71	150	53.44
131	7.67	406	36	36.45	40	9	32.1	207.4	90	19.43
132	7.90	453	69.36	24.79	42	9	32.1	183.55	100	38.87
133	7.70	608	61.2	29.74	110	6	19.26	307.71	140	58.3
134	7.74	831	32	29.16	210	8	19.26	480.47	190	43.72
135	7.79	419	52	26.73	37	4	32.1	188.95	90	24.29
136	8.00	320	48.96	19.83	34	5	25.68	205.14	36	19.43
137	7.97	344	72	9.72	30	4	12.84	237.53	38	19.43
138	7.80	381	44.88	14.87	33	6	32.1	178.15	21	14.57
139	7.97	570	44	19.44	99	30	19.26	210.54	180	24.29
140	7.59	276	44	14.58	25	4	19.26	167.35	23	19.43
141	7.75	411	52	24.3	40	5	25.68	194.35	90	19.43
142	7.77	666	61.2	29.74	110	20	44.94	259.13	170	43.72
143	7.80	249	24.48	14.87	20	2	12.84	139.63	23	9.72
144	7.80	424	28	17.01	80	4	25.68	275.32	32	19.43
145	8.00	686	36.72	27.27	160	2	44.94	248.33	150	82.59
146	7.90	558	24.48	34.7	100	13	44.94	253.73	125	29.15
147	7.90	829	44.88	64.44	130	6	12.84	334.71	260	82.59
148	7.70	577	24.48	37.2	110	5	38.52	259.13	130	29.15
149	8.00	469	69.36	12.39	40	14	25.68	145.76	90	48.58
150	7.90	457	44	41.31	56	9	12.84	219.42	65	95
151	7.68	545	36	24.3	80	11	19.26	152.93	90	82.59
152	7.77	553	56	38.88	60	11	12.84	215.94	120	77.87
153	7.60	546	69.36	27.27	40	5	12.84	208.86	100	58.3
154	7.76	553	52	41.31	60	15	12.84	261.08	130	55

To be countinue table 1

Sample no.	pH	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
155	7.73	544	48	31.59	45	6	25.68	86.38	60	121.45
156	7.94	541	77.52	17.35	40	8	19.26	113.37	170	53.44
157	7.97	563	48	31.59	65	15	19.26	91.78	180	92.31
158	7.52	428	57.12	22.31	30	8	25.68	159.58	90	34.01
159	7.80	442	68	24.3	30	8	25.68	205.14	90	34.01
160	7.95	638	56	29.16	90	6	32.1	237.53	130	48.58
161	7.80	906	32.64	74.36	150	2	12.84	418.26	260	43.72
162	7.60	1347	12	43.74	380	1	12.84	490.14	500	97.16
163	7.50	428	52	29.16	25	4	51.36	237.53	19	9.72
164	7.90	491	12	65.61	60	5	25.68	302.32	95	34.01
165	7.61	743	36	12.15	25	2	6.42	189.1	13	9.72
166	7.80	333	36	14.58	40	4	19.26	210.54	15	14.57
167	7.61	1377	138.7	71.88	190	21	6.42	189.1	450	291.49
168	7.30	788	88	36.45	110	15	25.68	242.93	200	130
169	7.79	574	40	19.44	100	9	6.42	26834	105	48.58
170	7.60	588	60	26.73	100	10	25.68	242.93	110	82.59
171	7.80	454	48.96	19.84	70	5	32.1	188.95	90	34.01
172	7.82	371	36.72	17.35	55	8	19.26	199.75	70	24.29
173	7.70	1262	142.8	74.36	160	17	6.42	205.14	500	218.62
Groundwater (Eocene aquifer)										
174	7.58	673	28	48.6	130	10	12.2	226.7	180	116.6
175	7.40	1846	124	99.6	340	21	24.24	209.47	500	514.97
176	7.39	430	8	60.75	40	11	0.00	280.72	100	30
177	7.30	3055	392	155.5	400	11	19.26	70.18	950	1049.4
178	7.65	408	48	24.79	40	8	24.24	119.56	90	68.01
179	7.73	2114	44.44	34.36	660	12	26.09	205.55	490	660
180	7.75	1075	40.40	34.36	300	6	13.44	172.4	110	450
181	8.00	3633	133.3	84.27	1000	9	13.44	125.98	1140	1140
182	7.53	409	16.16	19.63	90	5	6.52	152.51	14	125
183	7.65	361	16.16	19.63	55	9	26.09	106.09	7	80
184	7.60	431	12.12	19.63	80	9	6.52	128.98	14	110
185	7.67	1283	44.44	34.36	380	7	6.52	225.44	82	580
186	7.90	527	12.12	31.91	120	5	19.56	165.77	7	175
187	7.68	1615	73.44	54.53	400	9	6.52	185.66	320	580
188	7.75	754	8.08	44.18	170	5	13.44	179.03	70	245
189	7.67	437	20.20	24.54	72	4	13.44	125.98	15	125
190	7.53	1756	96.96	64.4	440	10	13.44	179.03	240	745
191	7.50	1642	121.2	39.66	380	10	6.52	172.4	285	615
192	7.73	420	16.16	27	55	5	6.52	198.92	8	70
193	7.78	384	20.20	24.54	70	5	12.86	137.07	18	121.36
194	7.78	401	16.16	27	80	5	6.52	172.7	8	130
195	7.83	861	8.08	41.72	240	7	13.44	179.03	40	380
196	7.47	548	20.20	34.36	120	6	19.56	159.14	41	190
197	7.45	621	28.28	31.91	115	9	13.44	198.92	33	180
198	7.27	1667	52.52	44.18	460	17	6.52	218.81	190	710
Groundwater (Eocene aquifer)										
Sample no.	**pH**	**TDS**	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
199	7.57	1144	60.6	61.97	240	7	6.52	198.92	145	450
200	7.36	2053	246.4	76.84	320	20	6.52	185.66	560	655
201	7.84	4003	173.7	109.4	1100	19	39.14	145.88	760	1630
202	7.82	2408	28.28	31.91	840	15	6.52	145.88	140	1205
203	7.69	2605	105.0	86.75	700	15	26.09	119.35	340	1225
204	7.82	2097	72.72	81.79	570	15	26.09	145.88	170	1000
205	7.54	2010	72.72	73.63	570	15	6.52	198.92	150	950

To be countinue table 1

Groundwater (Eocene aquifer)										
Sample no.	**pH**	**TDS**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**CO_3^{2-}**	**HCO_3^{-}**	**SO_4^{2-}**	**Cl^{-}**
206	7.66	2631	65.45	80.63	750	12	20.09	125.98	380	1204.8
207	7.90	1602	60.60	61.36	420	11	32.61	139.24	260	650.91
208	7.76	981	44.44	46.63	210	20	45.65	139.24	100	378.64
209	7.80	1023	40.4	46.63	260	10	19.56	152.51	110	425
210	7.68	1212	121.2	49.09	220	10	39.14	124.01	320	330.35
211	7.45	1098	80.8	41.72	240	9	6.52	159.14	210	390
212	7.75	1442	177.8	57.01	220	11	26.09	132.61	540	291.49
213	7.82	1438	52.52	44.18	370	20	13.44	139.24	140	645
214	7.60	809	32.32	46.63	180	7	32.61	152.51	110	280
215	7.33	962	48.48	46.63	210	13	26.09	139.24	210	300
216	7.63	1150	92.92	44.62	210	17	13.44	179.03	410	205
217	7.70	824	52.52	39.27	160	7	6.52	139.24	220	225
218	7.67	1536	80.8	49.09	400	9	26.09	112.72	170	660
219	7.79	624	36.36	34.36	130	5	13.44	139.24	55	225
220	7.60	1383	92.92	56.45	300	12	19.56	86.2	460	364.36
221	7.50	2452	222.2	86.75	440	13	19.56	139.24	1020	514.96
222	8.00	1331	80.8	49.57	300	9	26.09	139.24	320	440
223	7.88	1536	48.48	27	420	10	32.61	152.51	520	340.1
224	8.00	808	36.36	31.91	200	6	19.56	152.51	120	270
225	7.60	1672	76.76	54	440	16	26.09	165.77	410	525
226	7.52	1967	109.1	68.72	440	13	19.56	152.51	640	514.96
227	7.39	1355	88.88	66.9	270	10	26.09	132.61	380	408
228	7.82	1634	145.4	88.36	280	13	19.56	192.3	420	480.96
229	7.98	665	36.36	29.45	140	9	19.56	152.51	70	225
230	8.00	711	48.48	31.91	130	5	32.61	152.51	85	210
231	7.91	339	24	26.73	45	5	19.26	169.7	24	60
232	7.86	425	28	31.59	60	5	12.84	166.23	34	97.16
233	7.40	1293	76	48.6	310	11	12.84	202.34	175	505.25

aquifer may occur from the Nile water passing the Plio-Pleistocene aquifer especially the area affected by the fault plains.

Groundwater of the fissured limestone aquifer is of lower potentiality than that of the Nubian sandstone aquifer[3]. The discharge of this aquifer occurs essentially through the pumping wells for irrigation purposes, as well as the seepage towards the Nile through the fractures[7].

1. Evaluation of surface and groundwater quality for human drinking

Applying the water quality guidelines for human drinking uses[5] and the chemical data (TABLE 1), it is clear that;

A. River Nile and its canals water (Ibrahimiya, and Bahr Yousof canals) are suitable for drinking, since they have water salinity and concentrations of major ions less than that of the permissible limits (1200mg/l). Likewise, most groundwater samples of the Plio-Pleistocene and Eocene aquifers (77% and 52%, respectively), are suitable for drinking since they have water salinity and concentrations of major ions less than that of the permissible limits. In contrast, the rest of the groundwater samples of Eocene and Plio-Pleistocene aquifers (48% and 23%, respectively), are unsuitable for drinking because they have water salinity and concentrations of major ions more than that of the permissible limits (1200mg/l).

B. The majority of the surface (River Nile and its canals) and groundwater samples of both aquifers (62% and 66%), respectively, are suitable for drinking since they have concentrations of soluble heavy metals and trace constituents (Fe^{3+}, Cd^{2+}, Co^{2+}, Cu^{2+}, Cr^{3+}, Pb^{2+} and Ni^{2+}) less than the permissible limits. On the other hand, the rest of the surface and groundwater samples (38% and 34%, respectively), are unsuitable for drinking because they have soluble iron concentrations more than that of the permissible limits (0.3mg/l), so they must be treated by available techniques before use for drinking.

TABLE 2 : The evaluation of groundwater samples in the different aquifers of the study area according to Doneen's method (plio-pleistocene aquifer)

Sample no.	Total cation in epm	Permeability index	Evaluation	Sample no.	Total cation in epm	Permeability index	Evaluation
26	17.18	5.79	CLASS III	100	7.70	2.54	CLASS I
27	8.91	3.00	CLASS II	101	9.55	3.80	CLASS II
28	8.15	1.45	CLASS I	102	7.60	2.24	CLASS I
29	7.00	1.93	CLASS I	103	6.55	1.25	CLASS I
30	6.39	2.07	CLASS I	104	25.55	16.41	CLASS III
31	4.19	0.60	CLASS I	105	49.14	11.18	CLASS III
32	6.94	2.01	CLASS I	106	32.40	21.54	CLASS III
33	6.10	1.90	CLASS I	107	22.19	13.83	CLASS III
34	29.49	17.93	CLASS III	108	35.33	21.92	CLASS III
35	6.63	2.38	CLASS I	109	30.51	19.91	CLASS III
36	7.16	2.27	CLASS I	110	44.40	35.15	CLASS III
37	8.88	3.31	CLASS II	111	33.43	23.52	CLASS III
38	5.28	1.62	CLASS I	112	46.96	33.76	CLASS III
39	8.40	1.93	CLASS I	113	54.33	38.00	CLASS III
40	9.10	2.48	CLASS I	114	39.33	28.28	CLASS III
41	8.64	2.45	CLASS I	115	49.43	34.37	CLASS III
42	17.76	10.55	CLASS III	116	26.90	16.33	CLASS III
43	7.62	0.42	CLASS I	117	10.60	5.12	CLASS III
44	7.45	0.28	CLASS I	118	15.48	9.56	CLASS III
45	6.61	2.14	CLASS I	119	5.06	0.65	CLASS I
46	6.77	1.62	CLASS I	120	7.23	2.33	CLASS I
47	6.89	1.79	CLASS I	121	6.57	1.67	CLASS I
48	7.41	2.14	CLASS I	122	12.04	5.39	CLASS III
49	7.56	2.10	CLASS I	123	4.96	1.01	CLASS I
50	25.74	15.83	CLASS III	124	12.04	6.77	CLASS III
51	21.10	13.08	CLASS III	125	7.35	2.10	CLASS I
52	13.26	7.42	CLASS III	126	4.59	0.91	CLASS I
53	29.99	17.95	CLASS III	127	3.89	0.60	CLASS I
54	5.18	0.62	CLASS I	128	5.61	1.91	CLASS I
55	18.47	8.61	CLASS III	129	3.52	0.59	CLASS I
56	11.62	1.93	CLASS I	130	9.95	3.07	CLASS II
57	11.44	2.55	CLASS I	131	6.76	1.48	CLASS I
58	8.47	2.35	CLASS I	132	7.56	2.14	CLASS I
59	7.88	2.72	CLASS I	133	10.44	3.10	CLASS II
60	4.76	0.62	CLASS I	134	13.33	3.21	CLASS II
61	11.37	4.78	CLASS II	135	6.50	1.62	CLASS I
62	11.51	3.52	CLASS II	136	5.68	0.92	CLASS I
63	5.70	0.63	CLASS I	137	5.80	0.94	CLASS I
64	3.98	0.63	CLASS I	138	5.05	0.63	CLASS I
65	6.63	1.35	CLASS I	139	8.87	2.56	CLASS I
66	8.47	1.71	CLASS I	140	4.58	0.79	CLASS I
67	14.87	9.62	CLASS III	141	6.46	1.48	CLASS I
68	11.73	6.86	CLASS III	142	10.80	3.00	CLASS II
69	10.15	3.92	CLASS II	143	3.37	0.51	CLASS I
70	30.30	23.63	CLASS III	144	6.38	0.88	CLASS I
71	53.59	40.19	CLASS III	145	11.08	3.89	CLASS II
72	35.86	24.34	CLASS III	146	8.76	2.12	CLASS I
73	19.43	13.41	CLASS III	147	13.35	5.04	CLASS III
74	24.35	17.52	CLASS III	148	9.19	2.18	CLASS I
75	76.87	61.60	CLASS III	149	6.58	2.31	CLASS I
76	22.07	12.49	CLASS III	150	8.26	3.36	CLASS II
77	25.48	13.71	CLASS III	151	7.56	3.27	CLASS II

To be countinue table 2

Sample no.	Total cation in epm	Permeability index	Evaluation	Sample No.	Total cation in epm	Permeability index	Evaluation
78	30.30	16.30	CLASS III	152	8.88	3.45	CLASS II
79	31.38	20.84	CLASS III	153	7.60	2.69	CLASS I
80	21.27	10.82	CLASS III	154	8.99	2.90	CLASS I
81	21.62	11.66	CLASS III	155	7.10	4.05	CLASS II
82	3.67	0.72	CLASS I	156	7.24	3.28	CLASS II
83	4.14	0.72	CLASS I	157	8.20	4.48	CLASS II
84	4.79	0.76	CLASS I	158	6.19	1.90	CLASS I
85	4.85	0.83	CLASS I	159	6.90	1.90	CLASS I
86	5.46	0.83	CLASS I	160	9.26	2.72	CLASS I
87	6.04	1.89	CLASS I	161	14.32	3.94	CLASS II
88	24.88	15.48	CLASS III	162	20.75	7.94	CLASS III
89	51.94	37.56	CLASS III	163	6.18	0.47	CLASS I
90	70.95	52.71	CLASS III	164	8.73	1.95	CLASS I
91	43.90	29.04	CLASS III	165	3.93	0.41	CLASS I
92	28.37	20.26	CLASS III	166	4.84	0.57	CLASS I
93	14.36	9.31	CLASS III	167	21.63	12.90	CLASS III
94	42.85	27.97	CLASS III	168	12.56	5.75	CLASS III
95	14.33	10.67	CLASS III	169	8.17	2.46	CLASS I
96	5.60	1.51	CLASS I	170	9.80	3.47	CLASS II
97	4.88	0.67	CLASS I	171	7.25	1.90	CLASS I
98	5.55	1.51	CLASS I	172	5.86	1.41	CLASS I
99	4.91	1.25	CLASS I	173	20.63	1.62	CLASS I

TABLE 3 : The evaluation of groundwater samples in the different aquifers of the study area according to Doneen's method (Eocene aquifer)

Sample no.	Total cation in epm	Permeability index	Evaluation	Sample No.	Total cation in epm	Permeability index	Evaluation
174	11.30	5.16	CLASS III	204	35.53	29.97	CLASS III
175	29.70	19.73	CLASS III	205	34.86	28.35	CLASS III
176	7.42	1.89	CLASS I	206	42.82	37.93	CLASS III
177	50.03	39.48	CLASS III	207	26.62	21.06	CLASS III
178	6.38	2.85	CLASS I	208	15.70	4.07	CLASS II
179	34.05	23.71	CLASS III	209	17.41	13.13	CLASS III
180	18.04	13.84	CLASS III	210	19.91	12.65	CLASS III
181	57.30	44.02	CLASS III	211	18.13	13.18	CLASS III
182	6.46	3.67	CLASS II	212	23.41	13.84	CLASS III
183	5.04	2.33	CLASS I	213	22.86	19.65	CLASS III
184	5.93	3.25	CLASS II	214	13.46	9.04	CLASS III
185	21.75	17.21	CLASS III	215	15.72	10.65	CLASS III
186	8.58	5.01	CLASS III	216	17.87	10.05	CLASS III
187	25.78	19.69	CLASS III	217	12.99	8.64	CLASS III
188	11.56	7.64	CLASS III	218	25.69	20.38	CLASS III
189	6.26	3.68	CLASS II	219	10.42	6.92	CLASS III
190	29.53	23.51	CLASS III	220	22.63	15.06	CLASS III
191	26.09	20.31	CLASS III	221	37.69	25.14	CLASS III
192	5.55	2.06	CLASS I	222	21.39	15.74	CLASS III
193	6.20	3.61	CLASS II	223	23.16	15.00	CLASS III
194	6.63	3.75	CLASS II	224	13.29	8.86	CLASS III
195	14.45	11.13	CLASS III	225	27.82	19.07	CLASS III
196	9.21	5.78	CLASS III	226	30.56	21.18	CLASS III
197	9.27	5.42	CLASS III	227	21.94	15.46	CLASS III
198	26.69	22.00	CLASS III	228	27.03	17.94	CLASS III
199	18.74	14.20	CLASS III	229	10.56	7.07	CLASS III
200	33.04	24.30	CLASS III	230	10.82	6.81	CLASS III
201	65.99	53.88	CLASS III	231	5.48	1.94	CLASS I
202	40.95	35.44	CLASS III	232	6.73	3.09	CLASS II
203	43.20	38.08	CLASS III	233	21.55	16.07	CLASS III

TABLE 4 : Relative standards of effective irrigation water salinity according to Doneen[1]

Soil conditions	Grades of effective salinity as me/l		
	Class (I)	Class (II)	Class (III)
Soil with low permeability, less leaching and slow shallow drainage.	<3	3-5	>5
Soil with moderate permeability, limited leaching, slow and deep drainage.	<5	5-10	>10
High permeable soil with deep and easy drainage.	<7	7-15	>15

TABLE 5: Evaluation of the groundwater samples of different aquifers in the study area for irrigation according to the effective water salinity as me/l, Doneen[1]

Soil conditions	Soil with low permeability, less leaching and slow shallow drainage	
	Plio-pleistocene El Minya	Eocene El Minya
Class (I)	53%	26%
Class (II)	13%	12%
Class (III)	34%	62%
Soil conditions	**Soil with moderate permeability, limited leaching, slow and deep drainage**	
	Plio-pleistocene El Minya	**Eocene El Minya**
Class (I)	65%	20%
Class (II)	9%	20%
Class (III)	26%	60%
Soil conditions	**Soil with High permeable soil with deep and easy drainage**	
	Plio-pleistocene El Minya	**Eocene El Minya**
Class (I)	70%	30%
Class (II)	11%	25%
Class (III)	19%	45%

2. Evaluation of surface and groundwater for irrigation purpose

For this purpose we use the fowling methods:

1. Evaluation of groundwater for irrigation according to the effective salinity classification[1]

This classification takes into consideration main factors upon which the infiltration and permeability rates of soil depend.

Permeability index = Na+√HCO3×100/Ca+Mg+Na

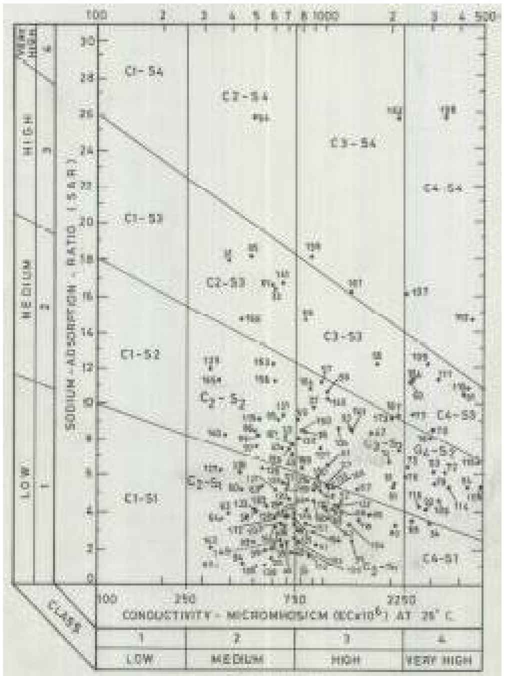
Where all values in TABLES 2 and 3.

Applying this classification, (TABLE 4), for the groundwater of the aquifers in the study area, and TABLES 2 and 3 the following can be deduced:

1. Some of the groundwater samples of the plio-pleistocene aquifer (34%) can be classified as water of the third grade (class III) of irrigation water, while (13%) of the groundwater samples can be classified in (class II) the rest of the groundwater samples (53%) can be classified as water of the first grade (class I) in case of soils of low permeability. In case of irrigating soil with moderate permeability, (9%), (26%) and (65%) of groundwater samples can be classified as water of the second grade (class II), (class III) and (class I) of irrigation water, respectively, grade (class I). On the other hand, some of groundwater samples (11%) can be classified as water of the second grade (class II) of irrigation water while (70%) and (19%) of groundwater samples can be classified as water of the first and third grade (class I), (class III), respectively, for irrigating soils of high permeability.
2. Some of the groundwater samples of the Eocene aquifer (62%) can be classified as water of the third grade (class III) of irrigation water, while (12%) of the groundwater samples can be classified in (class II) the rest of the groundwater samples (26%) can be classified as water of the first grade (class I) in case of soils of low permeability. samples of the limestone aquifer (60%) can be classified as water of the third grade (class III) of irrigation water, while (20%) of the groundwater samples can be classified in (class II) the rest of the groundwater samples (20%) can be classified as water of the first grade (class I). samples of the Eocene aquifer (45%) can be classified as water of the third grade (class III) of irrigation water, while (25%) of the groundwater samples can be classified in (class II) the rest of the groundwater samples (30%) can be classified as water of the first grade (class I)

In general, the majority of the groundwater samples in the study area (42%) can be classified as water of the third grade (class III) of irrigation water, while 13% and 45% of the water samples can be classified as water of the second grade (class II) and first grade (class I) of irrigation water, respectively.

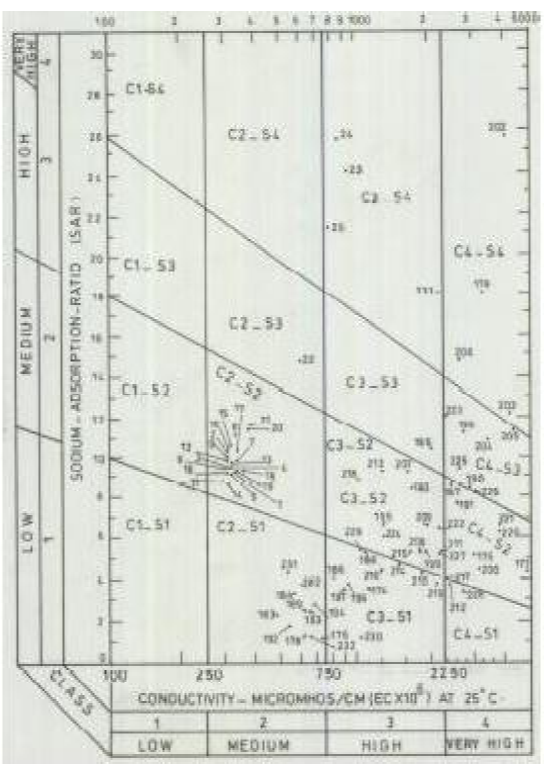
And second grade (class II) of irrigation water, respectively. On the other hand, the groundwater samples (26%) can be classified as water of the third grade (class III) of irrigation water, while (58%) and (16%) of groundwater samples can be classified as water of the first grade (class I) and second grade (class II) of irri-



Sodium (Alkali) Hazard

Salinity Hazard

Figure 2 : The water quality classes according to the U. S. salinity laboratory staff of (plio-pleistocene aquifer)



Sodium (Alkali) Hazard

Salinity Hazard

Figure 3 : The water quality classes according to the U. S. salinity laboratory staff of (Eocene aquifer) and surface water

gation water, respectively, for irrigating soils of high permeability.

In brief, regardless of soil types, the majority of groundwater samples in the study area can be classified as water of the third grade (class I) of irrigation water, while the rest of groundwater samples can be classified as water of the first grade (class III) and second grade (class II) of irrigation water.

2. The U.S. Salinity Laboratory staff classification[8]

This method consists of plot specific conductivity for water (in micro mhos/cm) as a function of the total dissolved solids(TDS) against sodium adsorption ratio (SAR) expressed in milli equivalent/lit i.e Na/√(Ca+ Mg)/2

By applying this classification to the groundwater samples in the area of study, (Figures 2 and 3), we can conclude the following:-

1. Most of the groundwater samples (49%) of the plio-pleistocene aquifer are good water for irrigation (C2-S1, C3-S1 and C4-S1), while about (37%) of the samples are moderate water for irrigation (C3-S2 and C4-S2) and (11%) of the samples are intermediate water for irrigation (C3-S3 C2-S3- C4-S3- C2-S4- C3-S4and C4-S4). On the other hand, the rest of the groundwater samples (3%) are unsuitable water for irrigation (C_2-S_4, C_3-S_4 and C_4-S_4) (TABLE 8).
2. About 37% of the groundwater samples of the Eocene aquifer are good water for irrigation (C2-S1, C3-S1 and C4-S1) while about (35%) of the samples are moderate water for irrigation (C3-S2 and C4-S2) and (15%) of the samples are intermediate water for irrigation (C3-S3 C2-S3- C4-S3- C3-S4and C4-S4) (TABLE, 9). On the other hand, the rest of the groundwater samples (13%) are unsuitable for irrigation (C_3-S_4 and C_4-S_4).
3. River Nile and its canals waters (Ibrahimiya, and Bahr Yousof canals) are moderate water for irrigation C2-S2 (TABLE 7).

In conclusion, all surface waters (100%) and, the majority of groundwater samples (90%) are suitable for irrigation under ordinary conditions while the rest of groundwater samples (10%) are suitable for irrigation under special conditions. In fact, the water suitability is associated with soil properties and crop type. There-

TABLE 6: The water quality classes according to the U. S. salinity laboratory staff method[8]

Conductivity	Quality	Range	Usage
C1	Low salinity water	100-250	Can be used for irrigation of most crops in most soils with little likelihood that soil salinity develops.
C2	Medium salinity water	250-750	Can be used if a moderate amount of leaching occurs.
C3	High salinity water	750-2250	Cannot be used on soil with restricted drainage even with adequate drainage, special management for salinity control may be required and plants with good salt tolerant should be selected.
C4	Very high salinity	>2250	Is not suitable for irrigation under ordinary conditions, but may be used occasionally under special conditions as the soils must be permeable, and drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching.
SAR	**Quality**	**Range**	**Usage**
S1	Low sodium water	0-10	Can be used for irrigation of almost all soils with little changes of the development of harmful levels of exchangeable sodium.
S2	Medium sodium water	10-18	Will represents an appreciable sodium hazard in fine-textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil.
S3	High sodium water	18-26	May produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching and organic matter condition.
S4	Very high salinity	26-100	Is generally unsatisfactory for irrigation purposes except at low and perhaps land perhaps medium salinities.

Note: 1. The C2-S3 and C3-S3 water can be improved by adding gypsum to the soil; 2. The C2-S4 may be improved by the addition of gypsum to the water.

TABLE 7 : Evaluation of groundwater samples in the different aquifers of the study area for irrigation purposes according to U. S. salinity laboratory staff

Sample no.	Salinity class	SAR class	Evaluation class	Sample no	Salinity class	SAR class	Evaluation Class
Sufacewater							
1	C2	S2	Moderate	14	C2	S2	Moderate
2	C2	S2	Moderate	15	C2	S2	Moderate
3	C2	S2	Moderate	16	C2	S2	Moderate
4	C2	S2	Moderate	17	C2	S2	Moderate
5	C2	S2	Moderate	18	C2	S2	Moderate
6	C2	S2	Moderate	19	C2	S2	Moderate
7	C2	S2	Moderate	20	C2	S2	Moderate
8	C2	S2	Moderate	21	C2	S2	Moderate
9	C2	S2	Moderate	22	C2	S3	Intermediate
10	C2	S2	Moderate	23	C2	S4	Bad
11	C2	S2	Moderate	24	C2	S4	Bad
12	C2	S2	Moderate	25	C2	S4	Bad
13	C2	S2	Moderate				

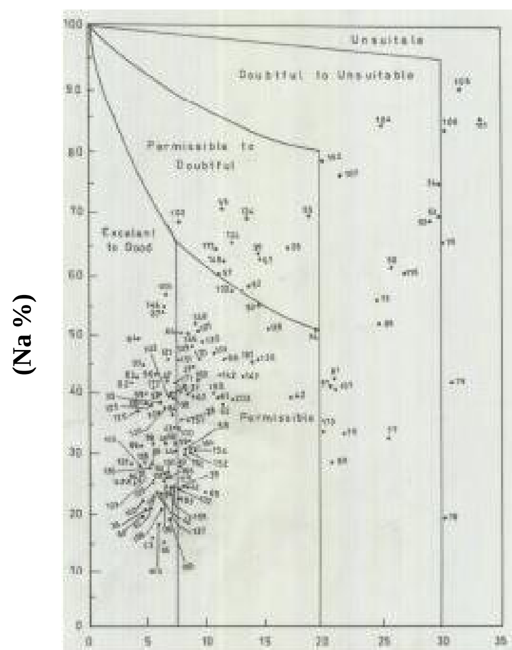


Figure 4 : Wilcox classification plio-pleistocene aquifer

fore, at least some, if not all, groundwater in the study area can be used for irrigation but the expected yield productivity will not reach the optimum level, TABLE 10.

3. Wilcox classification

Wilcox classification[9], suggested that, the definition of sodium percentage relative to common cations percentage is expressed in the following equation:

$$Na\ \% = \frac{Na^{+}}{Ca^{++} + Mg^{++} + Na^{+}} \times 100$$

This classification is based on the relationship be-

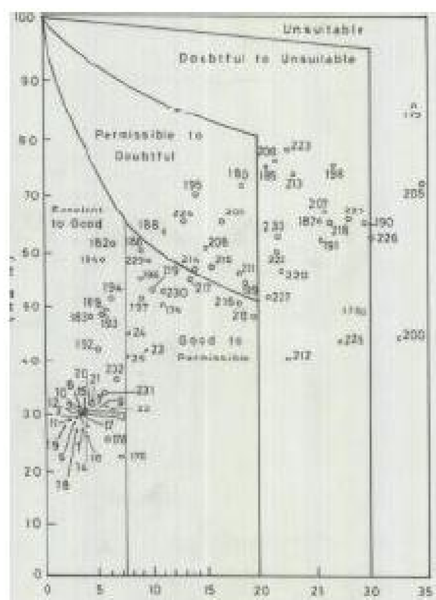
TABLE 8 : Evaluation of groundwater samples in the different aquifers of the study area for irrigation purposes according to U. S. salinity laboratory staff . s method of quaternary aquifer

Sample no.	Salinity class	SAR class	Evaluation class	Sample no.	Salinity class	SAR class	Evaluation cass
			Plio-pleistocene				
26	C3	S1	Good	101	C3	S2	Moderate
27	C3	S1	Good	102	C2	S1	Good
28	C3	S1	Good	103	C2	S1	Good
29	C2	S1	Good	104	C4	S3	Intermediate
30	C2	S1	Good	105	C4	S2	Moderate
31	C2	S3	Intermediate	106	C4	S2	Moderate
32	C2	S2	Moderate	107	C4	S4	Bad
33	C2	S1	Intermediate	108	C4	S4	Bad
34	C4	S1	Bad	109	C4	S3	Intermediate
35	C2	S1	Good	110	C4	S3	Intermediate
36	C2	S1	Good	111	C4	S3	Intermediate
37	C3	S2	Moderate	112	C4	S4	Bad
38	C2	S1	Good	113	C2	S1	Good
39	C3	S2	Moderate	114	C4	S2	Moderate
40	C3	S1	Good	115	C4	S2	Moderate
41	C3	S1	Good	116	C4	S2	Bad
43	C2	S2	Moderate	117	C3	S1	Good
44	C2	S1	Good	118	C3	S1	Good
45	C2	S1	Good	119	C2	S2	Moderate
46	C2	S1	Good	120	C2	S1	Good
47	C2	S2	Moderate	121	C4	S4	Bad
48	C2	S1	Good	122	C3	S1	Good
49	C2	S1	Good	123	C2	S1	Good
50	C4	S3	Intermediate	124	C3	S2	Moderate
51	C3	S2	Moderate	125	C2	S1	Good
53	C4	S2	Moderate	126	C2	S1	Good
54	C2	S4	Bad	127	C2	S1	Good
55	C3	S4	Intermediate	128	C2	S1	Good
56	C3	S2	Moderate	129	C2	S2	Moderate
57	C3	S2	Moderate	130	C3	S2	Moderate
58	C3	S4	Intermediate	131	C2	S2	Moderate
59	C3	S2	Moderate	132	C3	S2	Moderate
60	C2	S1	Good	133	C3	S1	Good
61	C3	S2	Moderate	134	C3	S1	Good
62	C3	S1	Good	135	C2	S1	Good
63	C2	S1	Good	136	C2	S1	Good
64	C2	S1	Good	137	C2	S1	Good
65	C2	S2	Moderate	138	C2	S1	Good
66	C3	S1	Good	139	C3	S4	Bad
67	C3	S2	Moderate	140	C2	S1	Good
68	C3	S1	Good	141	C2	S1	Intermediate
69	C3	S1	Good	142	C3	S1	Good
70	C4	S3	Intermediate	143	C2	S1	Good
71	C2	S1	Good	144	C2	S1	Good
72	C4	S2	Moderate	145	C3	S2	Moderate
73	C4	S2	Bad	146	C3	S1	Good

To be countinue right column

Sample no	Salinity class	SAR class	Evaluation class	Sample no	Salinity class	SAR class	Evaluation cass
			Plio-pleistocene				
74	C3	S2	Moderate	147	C3	S2	Moderate
75	C2	S1	Good	148	C3	S1	Good
76	C4	S2	Moderate	149	C2	S1	Good
77	C4	S3	Intermediate	150	C3	S2	Moderate
78	C4	S2	Moderate	151	C2	S2	Moderate
79	C4	S2	Moderate	152	C3	S1	Good
80	C3	S1	Good	153	C2	S1	Good
81	C3	S2	Moderate	154	C3	S1	Good
82	C2	S1	Good	155	C2	S2	Moderate
83	C2	S1	Good	156	C2	S1	Good
84	C2	S1	Good	157	C3	S1	Good
85	C2	S1	Intermediate	158	C2	S2	Moderate
86	C2	S2	Moderate	159	C2	S1	Good
87	C2	S1	Intermediate	160	C3	S1	Good
88	C4	S1	Bad	161	C3	S4	Bad
89	C2	S1	Good	162	C3	S4	Bad
90	C2	S1	Good	163	C2	S2	Moderate
91	C4	S3	Intermediate	164	C3	S2	Moderate
92	C4	S2	Moderate	165	C2	S2	Moderate
93	C3	S2	Moderate	166	C2	S1	Good
94	C4	S2	Moderate	167	C3	S4	Intermediate
95	C3	S1	Good	168	C3	S1	Good
96	C2	S2	Moderate	169	C2	S1	Good
97	C2	S2	Moderate	170	C2	S1	Good
98	C3	S1	Good	171	C2	S1	Good
99	C2	S1	Good	172	C2	S1	Good
100	C3	S1	Good	173	C3	S2	Moderate

(Na %)



Total concentration (meq/l)

Figure 5 : Wilcox classification (Eocene aquifer) and surface water

TABLE 9 : Evaluation of groundwater samples in the different aquifers of the study area for irrigation purposes according to U. S. salinity laboratory staff's method Eocene aquifer

Sample no.	Salinity class	SAR class	Evaluation class	Sample no.	Salinity class	SAR class	Evaluation Class
			Eocene				
174	C3	S1	Good	204	C4	S3	Intermediate
175	C4	S2	Moderate	205	C4	S3	Intermediate
176	C2	S1	Good	206	C4	S4	Bad
177	C4	S2	Moderate	207	C3	S2	Moderate
178	C2	S1	Good	208	C3	S2	Moderate
179	C4	S4	Bad	209	C3	S2	Moderate
180	C3	S2	Moderate	210	C3	S1	Good
181	C2	S1	Good	211	C2	S1	Good
182	C2	S1	Good	212	C4	S1	Good
183	C2	S1	Good	213	C3	S2	Moderate
184	C2	S1	Good	214	C3	S1	Good
185	C2	S1	Good	215	C3	S2	Moderate
186	C3	S1	Good	216	C3	S1	Good
187	C4	S2	Moderate	217	C4	S2	Moderate
188	C3	S1	Good	218	C3	S2	Moderate
189	C2	S1	Good	219	C3	S1	Good
190	C4	S3	Intermediate	220	C4	S2	Moderate
191	C4	S2	Moderate	221	C4	S2	Moderate
192	C2	S1	Good	222	C3	S2	Moderate
193	C2	S1	Good	223	C4	S3	Intermediate
194	C2	S1	Good	224	C4	S3	Intermediate
195	C2	S1	Good	225	C4	S3	Intermediate
196	C3	S1	Good	226	C2	S1	Good
197	C3	S1	Good	227	C2	S1	Good
198	C4	S3	Intermediate	228	C4	S1	Good
199	C3	S2	Moderate	229	C3	S1	Good
200	C4	S2	Moderate	230	C3	S1	Good
201	C2	S1	Good	231	C2	S1	Good
202	C4	S4	Bad	232	C2	S1	Good
203	C4	S4	Bad	233	C2	S1	Good

TABLE 10 : Evaluation of the surface and groundwater in the study area for irrigation according to Richard's[8]

Suitability of the surface and groundwaters for irrigation	The percentages of the surface water and groundwater in the study area		
	Surface water	Plio-Pleistocene	Eocene
Good water class	0.00	49	37
Moderate water class	100	37	35
Intermediate water class	0.00	11	15
Unsuitable water class	0.00	3	13

tween sodium percentage and total cations concentrations (where cations concentrations are in me/l), governing the suitability of waters for irrigation.

By applying this classification on the groundwater and surface samples of different aquifers in the study

TABLE 11: Evaluation of the different aquifers groundwater samples in the study area for irrigation according to Wilcox[9]

Suitability of groundwater for irrigation	plio-pleistocene in El- Minya	Eocene in El- Minya	Surface water
Excellent to good	41%	18%	88%
Good to permissible	29%	17%	12%
Permissible to doubtful	8%	17%	0.0%
Doubtful to unsuitable	12%	30%	0.0%
Unsuitable	10%	18%	00%

area figures 4 and 5, we can conclude the following;

1. About 41% groundwater samples of the plio-pleistocene aquifer in El Minya are excellent to good water for irrigation, 29% of samples are good to permissible, 8% of samples are permissible to doubtful, 12% of samples are doubtful to unsuitable and the else are unsuitable.
2. About 18% of the groundwater samples of the Eocene aquifer are excellent to good water for irrigation, 17% of samples are good to permissible, 8% of samples are permissible to doubtful, 17% of samples are doubtful to unsuitable and the else are unsuitable.
3. About 88% of surfacewater are excellent and 12% are good to permissible.

Generally, about 68% of the groundwater samples in different aquifers in the study area {78% and 43% of plio-pleistocene and fractured limestone aquifers, respectively} are considered suitable for irrigation, while the rest of the groundwater samples (32%) in different aquifers in the study area {22% and 57% of the alluvium and fractured limestone aquifers, respectively} are unsuitable for irrigation, TABLE 11.

CONCLUSION

There are two aquifers detected in El Minya governorate; Plio-Pleistocene and Eocene aquifers. The groundwater sources in the study area have great advantages due to the low cost of production and their high reliability during emergencies where the depth to water ranges from 2 to 82.6m.

Most of the groundwater samples of the Plio-Pleistocene and Eocene aquifers lie in the fresh zone, while the brackish water is less pronounced. The fresh water type in the Plio-Pleistocene and Eocene aquifers is due to the continental origin of the water bearing formation in case of the Plio-Pleistocene aquifer and flushing for the water bearing formation in case of the Eocene aquifer.

The presence of brackish water type in the Plio-Pleistocene aquifer is due to the Pliocene marine deposits intercalated with Plio-Pleistocene matrix, carbonate materials that was transported from the limestone plateau by weathering as well as over- pumping activities especially at southwest Samalut locality, while in the Eocene aquifer; the presence of the brackish water type is due to marine deposits.

There is a general direction of water salinity increase from the River Nile to the Plateau in all the study area, i.e., there is recharge from the Nile River, its canals and drains to the groundwater of the Plio-Pleistocene aquifer. The higher values of water salinity is strictly confined to southwest of Samalut locality due to over-pumping activity. This reflects the impact of land reclamation projects on the groundwater quality. The majority of the surface and groundwater samples in the study area are suitable for drinking. All surface waters and, most of groundwater samples are suitable for irrigation under the ordinary conditions while the rest of groundwater samples are suitable for irrigation under special conditions.

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