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CHEMISTRY OF THE GROUNDWATER IN DELTA WADI DAHAB, SOUTHEAST SINAI, EGYPT

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The main object of this paper is to elucidate the chemical properties of the Quaternary aquifer groundwater in Delta Wadi Dahab for uses in irrigation and domestic purposes. To achieve this goal, several chemical parameters were discussed including salinity, hardness, major constituents, ion dominance, hypothetical salts and hydrochemical coefficients through the analytical results of some selected groundwater samples. Additionally, genesis and formation of water mineralization were also discussed through the study of the main processes affecting water quality and the standard methods of groundwater classification. Eventually, the study revealed meteoric origin for groundwater, most probably affected by dissolution of salts of marine origin associated with the aquifer matrix. Furthermore, the evaluation of groundwater for different purposes showed the unsuitability of groundwater for drinking but can be used for the irrigation of certain suitable plants that tolerate high salinity.

Keywords: Chemistry, groundwater, salinity, Dahab area, southeast Sinai, Egypt.

Due to prevalence of aridity and consequent decrease of rainfall, beside, the lack of information about water resources in many areas of South Sinai (30,000 km^2), the optimum exploitation of all existing water resources is necessary. The over growing developmental activities in the coastal areas, specially at Delta Wadi Dahab basin on the Gulf of Aqaba, necessitate an increasing demand of water supply for the community at present. The exploited water potentials are generally insufficient to meet the excessive increase in water demands required for civic, agricultural, industrial and touristic activities. Groundwater is considered the only source for drinking, domestic uses and irrigation in the area, where it can be easily extracted from the occurring Quaternary aquifer

Delta Wadi Dahab is located on the western side of Aqaba Gulf between longitudes, 34° 28′ and 34° 32′ E and latitudes, 28° 28′ and 29° 32′ N

(Fig. 1.A). It has an area of 10.3 km^2. The local rainfall ranges from 10.3 to 18.9 mm/year, falling mainly during spring and autumn. The maximum temperature ranges between 31°C and 37°C in summer, while the minimum ranges between 2°C and 13°C in winter. The average annual rate of evaporation ranges from 17.4 mm to 26.8 mm, the humidity rate reaches its maximum values (45-56%) in winter months while the minimum values (25-32%) are recorded in summer.

FIELD AND LABORATORY MEASUREMENTS

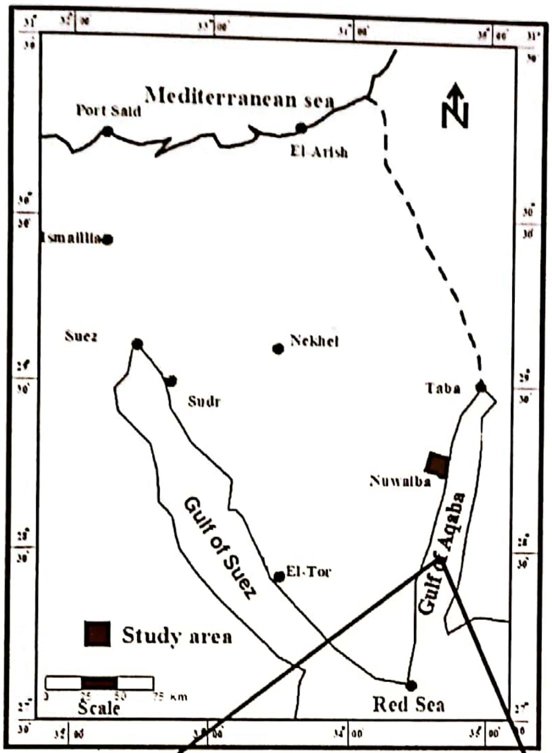
GPS is used for determination of the wells' locations (Longitudes and Latitudes) (Fig. 1-B). Measurements of the depth to water, pH, electrical conductivity (EC) and temperature for the collected water samples were carried out in the field. In the laboratory, chemical analyses were conducted for major and minor constituents according to the methods adopted by U.S. Geological survey, (Rainwater, 1960; Fishman and Friedman, 1985 and ASTM, 2002). Measurements were carried out by EC meter model Orion 150 A+, pH meter *Jenway 3510*, Flame photometer *Jenway PfP 7*, UV/Visible spectrophotometer *Thermo-Spectronic 300* and Plasma Optical Emission – mass spectrometer *(POEMS III) (Thermo Jerral Ash)*. The obtained results are expressed in mg/l (ppm), milliequivalent (epm) and %epm., for 25 groundwater samples (Fig. 1- A, B and Table 1).

AQUIFER SYSTEM

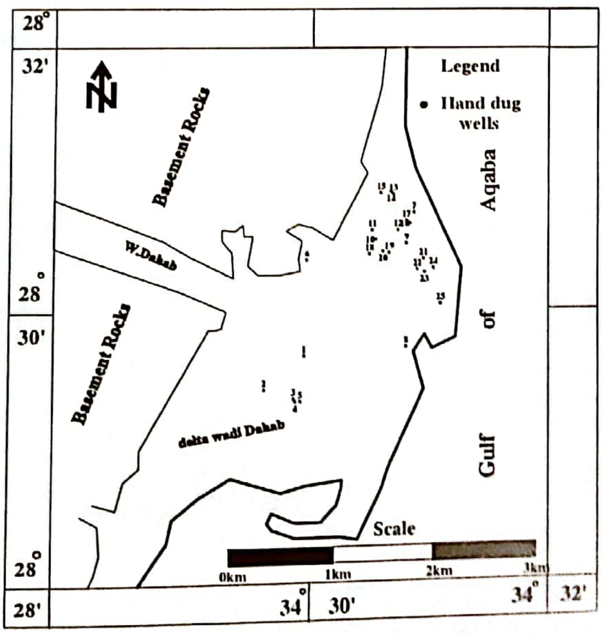
The Quaternary deposits constitute the main water bearing formation in Delta Wadi Dahab. Thus, it represents the only source for groundwater in such area. According to EL-Refaei (1992) and Shabana (1998), the following points are of interest regarding the hydrogeology of such deposits:

- Lithologically, they are formed of sand graded from fine to coarse-grains and gravels (boulders of basement rocks embedded in silty and clayey matrix) having variable thickness.
- The groundwater forms a lens-like shape above the mean sea level. The thickness of the water body reaches its maximum at the West and gradually diminishes due East direction.
- The transmissivity of the aquifer is variable and reflects the lithological variation. According to EL-Refaei, (1992), the transmissivity values range between 72m^2/day and 2326m^2/day indicating low to high potential aquifer.
- The storativity equals 9.12×10^{-2} which lies within the limit of the unconfined aquifer.

The water table map constructed by Shabana (1998) and shown in Fig.(2), indicates that the flow direction is trending from the northwest to the southeast i.e., towards the Gulf of Aqaba from the fractured basement outcrops. The subsurface seepage through the fractured basement rocks represents the main recharge source of the Quaternary aquifer in Delta Wadi Dahab.



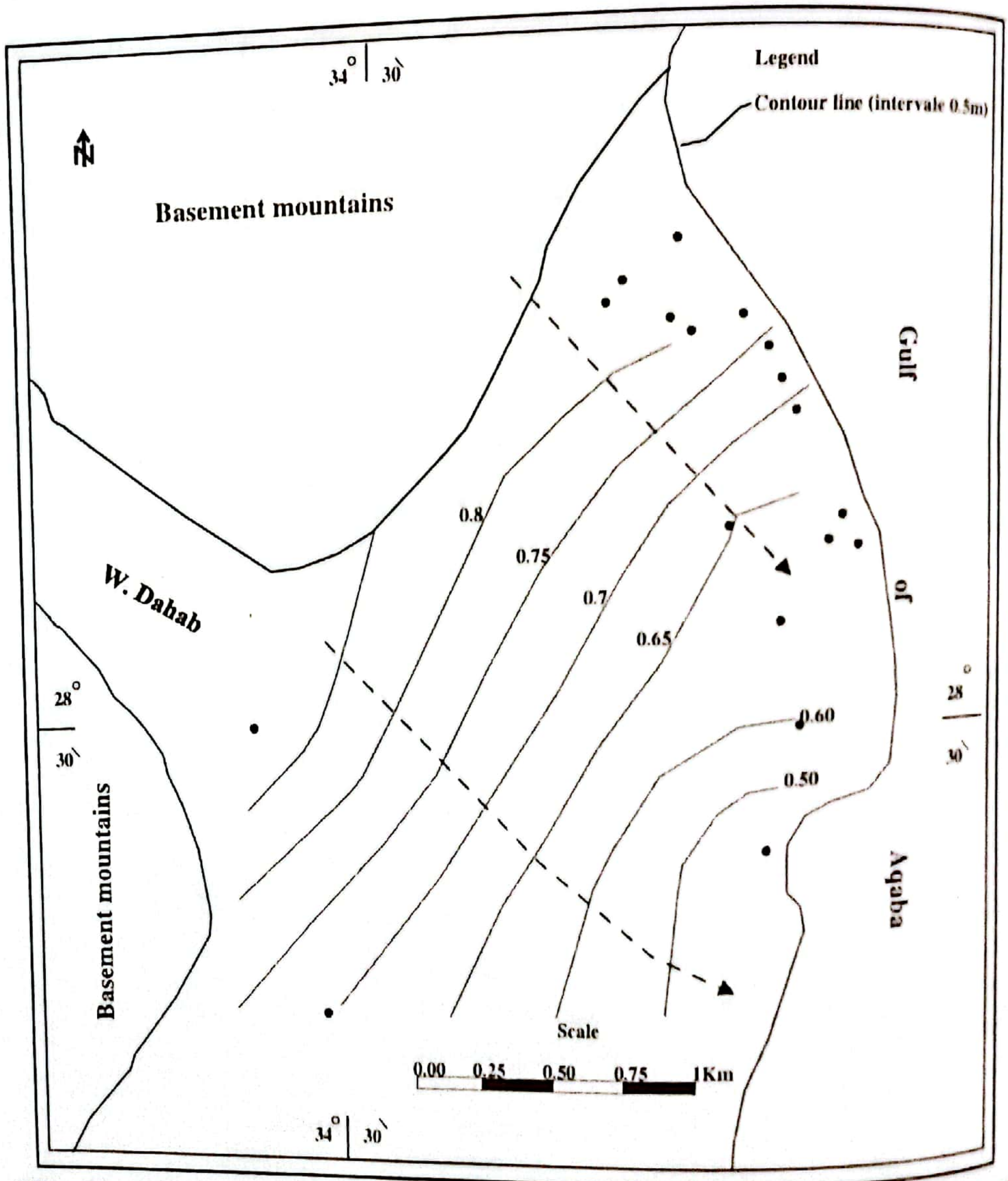
(Fig. 1-A), Key map of the studied area.



(Fig. 1-B) Groundwater samples tapping the Quaternary aquifer in Delta Wadi Dahab, South Sinai, Egypt.

The recorded thickness of the water body by EL-Refaei (1992) ranges between 4.85 and 0.86m with an average of about 3m in the Delta area while the specific yield of the aquifer material amounts to 15%.

In the present study, the measured depth to water in 25 shallow water wells tapping the Quaternary aquifer, varies from 4.9m in well No. 6 to 18.2m in well No. 19 from ground surface. A map showing depth to water is constructed according to the data that is shown in table (2). Such map shows that this depth decreases generally towards the coastal area of the Gulf of Aqaba (Fig. 3).



(Fig. 2). Water level of groundwater in Delta Wadi Dahab as meters (after Shabana, 1998).

Table (1). Chemical analysis of the groundwater samples of Quaternary aquifer in Delta Wadi Dahab area in November 2005.

Well no.	pH	TDS	unit	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Total cations	CO_3	HCO_3	SO_4	Cl^{-}	Total anions
			ppm	469.9	30.67	580	15		00	81.8	233	2973	
1	6.9	2973	epm	23.45	2.52	25.22	0.38	51.57	00	1.34	4.85	45.31	51.40
			%	45.47	4.89	48.9	0.74		00	2.61	9.44	87.96	
			ppm	520.8	90.4	500	19		00	62.6	600	1500	
2	7.4	3262	epm	25.99	7.43	21.74	0.48	55.64	00	1.03	12.48	42.3	55.8
			%	46.70	13.36	39.07	0.87		00	1.84	22.36	75.8	
			ppm	513.7	76.02	825	28		16.76	78.4	287	2137.6	
3	7.2	3923	epm	25.63	6.25	35.87	0.71	68.47	0.56	1.28	5.96	60.28	68.08
			%	37.44	9.13	52.39	1.04		0.82	1.89	8.75	88.54	
			ppm	691.9	65.12	960	22		00	119.2	661	2380.5	
4	7.1	4840	epm	34.53	5.36	41.74	0.56	82.18	00	1.95	13.74	67.13	82.82
			%	42.01	6.52	50.79	0.68		00	2.36	16.59	81.05	
			ppm	618.5	71.77	1400	18		00	95.4	850	2914.9	
5	7.2	5921	epm	30.86	5.9	60.87	0.46	98.09	00	1.56	17.68	82.20	101.44
			%	31..46	6.02	62.05	0.47		00	1.54	17.43	81.03	
			ppm	368.8	37.83	840	32		00	340.7	351	1676.1	
6	7.0	3476	epm	18.40	3.11	36.52	0.82	58.85	00	5.58	7.3	47.26	60.14
			%	31.27	5.29	62.06	1.39		00	9.28	12.14	78.58	
			ppm	174.3	29.28	390	31		00	160.1	297	675.3	
7	7.6	1677	epm	8.7	2.41	16.96	0.79	28.85	00	2.62	6.19	19.04	27.85
			%	30.14	8.35	58.77	2.74		00	9.42	22.21	68.37	
			ppm	548.8	35.74	710	19		00	109.0	274	1991.8	
8	7.4	3634	epm	27.39	2.94	30.87	0.48	61.67	00	1.79	5.7	56.17	63.65
			%	44.4	4.77	50.05	0.79		00	2.81	8.95	88.24	
			ppm	523.5	55.03	740	21		00	85.2	510	1931.1	
9	7.3	3823	epm	26.12	4.53	32.18	0.54	63.35	00	1.4	10.61	54.46	66.46
			%	41.23	7.14	50.78	0.85		00	2.1	15.96	81.94	
			ppm	401.9	27.37	750	17		00	95.4	420	1688.2	
10	7.4	3352	epm	20.05	2.25	32.61	0.43	55.34	00	1.56	8.74	47.61	57.90
			%	36.23	4.07	58.92	0.78		00	2.7	15.09	82.21	
			ppm	446.2	41.69	740	17		00	68.1	400	1821.8	
11	7.4	3501	epm	22.27	3.43	32.18	0.43	58.3	00	1.12	8.32	51.37	60.81
			%	38.19	5.88	55.19	0.74		00	1.84	13.68	84.48	

Table (1). Cont.

Well no.	pH	TDS	unit	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Total cations	CO_3^{-}	HCO_3^{-}	SO_4^{-}	Cl^{-}	Total anions
			ppm	581.1	80.38	2000	40		00	231.7	980	3740.8	
12	7.5	7538	epm	29.00	6.61	86.96	1.02	123.58	00	3.8	20.38	105.49	129.67
			%	23.46	5.35	70.36	0.83		00	2.936	15.72	81.35	
			ppm	946.7	102.3	1900	33		00	139.7	600	4639.5	
13	7.3	8291	epm	47.24	8.41	82.61	0.84	139.10	00	2.29	12.48	130.83	145.60
			%	33.96	6.05	59.39	0.64		00	1.57	8.57	89.86	
			ppm	821	136.3	1650	27		00	231.7	1200	3600	
14	7.3	7550	epm	40.97	11.21	71.74	0.69	124.60	00	3.8	24.96	101.52	130.27
			%	32.88	9.00	57.57	0.55		00	2.91	19.16	77.93	
			ppm	513	74.25	1080	34		00	136.3	674	2380.5	
15	7.5	4824	epm	25.60	6.11	46.96	0.87	79.53	00	2.23	14.02	67.13	83.38
			%	32.19	7.68	59.04	1.09		00	2.68	16.82	80.5	
			ppm	229.1	28.39	520	32		00	126.1	290	971.6	
16	7.8	2134	epm	11.43	2.33	22.61	0.82	37.19	00	2.07	6.03	27.4	35.49
			%	30.74	6.28	60.79	2.19		00	5.82	16.99	77.19	
			ppm	201.7	30.36	520	28		16.76	194.2	520	796.7	
17	7.9	2211	epm	10.06	2.5	22.61	0.71	35.88	0.56	3.18	10.82	22.47	37.02
			%	28.05	6.96	63.01	1.99		1.51	8.60	29.21	60.68	
			ppm	453	29.25	600	19		00	75	250	1615.3	
18	7.1	3004	epm	22.6	2.41	26.09	0.48	51.58	00	1.23	5.2	45.55	51.98
			%	43.82	4.66	50.58	0.94		00	2.36	10.00	87.63	
			ppm	459.8	36.78	780	18		00	57.9	400	1894.7	
19	7.3	3618	epm	22.94	3.02	33.91	0.46	60.34	00	0.95	8.32	53.43	62.69
			%	38.02	5.01	56.20	0.76		00	1.51	13.27	85.22	
			ppm	459.7	33.32	740	18		00	75.0	203	1894.7	
20	7.3	3386	epm	22.94	2.74	32.18	0.46	58.31	00	1.23	4.22	53.43	58.87
			%	39.34	4.7	55.18	0.79		00	2.09	7.16	90.75	
			ppm	428.6	36	710	27		00	75	459	1627.5	
21	7.5	3326	epm	21.39	2.96	30.87	0.69	55.90	00	1.23	9.56	45.89	56.67
			%	38.25	5.3	55.22	1.23		00	2.17	16.86	80.97	
			ppm	301.5	25.29	520	20		00	71.5	200	1175.7	
22	7.5	2278	epm	15.04	2.08	22.61	0.51	40.24	00	1.17	4.16	33.15	38.48
			%	37.38	5.17	56.18	1.27		00	3.05	10.81	86.14	
			ppm	420.3	34.86	740	20		00	78.4	308	1761.1	
23	7.5	3324	epm	20.97	2.87	32.18	0.51	56.52	00	1.28	6.41	49.66	57.35
			%	37.1	5.07	56.92	0.90		00	2.24	11.18	86.58	

Table (1). Cont.

Well no.	pH	TDS	unit	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Total cations	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	Total anions
24	7.6	3265	ppm	442.5	35.33	690	22	55.54	00	61.3	478	1566.8	55.12
			epm	22.03	2.91	30.00	0.56		00	1.01	9.94	44.18	
			%	39.75	5.23	54.01	1.01		00	1.82	18.03	80.14	
25	7.7	2926	ppm	341.4	56.13	650	31	50.70	00	143.1	494	1282.6	48.78
			epm	17.04	4.62	28.26	0.79		00	2.35	10.27	36.17	
			%	33.6	9.1	55.74	1.56		00	4.81	21.05	74.14	
Rainwater	7.0	30	ppm	7.1	0.6	2.3	00	0.50	00	14.5	6.4	5.5	0.517
			epm	0.35	0.05	0.1	00		00	0.237	0.13	0.15	
			%	70	9.7	19.8	00		00	45.8	25.1	29.0	
Sea water	7.6	42232	ppm	391	1661	12690	460	718.2	00	149.7	3500	23528	738.7
			epm	19.5	136	551	11.7		00	2.45	72.8	663.5	
			%	2.9	19	76.7	1.6		00	0.3	9.85	89.8	

CHEMICAL CHARACTERISTICS OF GROUNDWATER

The chemical characteristics of the groundwater in the studied area were discussed under the following topics:

- Salinity distribution,
- Total hardness,
- Ion dominance,
- Hypothetical salt combinations,
- Hydrochemical coefficients,
- Major ions relationship between surface water and groundwater,
- Genesis and formation of groundwater mineralization.

1- Salinity Distribution

According to Chebotarev classification (1955), the salinity content in 84% of the studied water of wells belongs to the brackish class (1500mg/l-5000mg/l), while the rest 16% is related to the high saline class (above 5000mg/l). This wide variation between salinity values can be attributed to the following:

- The wide range in transmissivity values of the aquifer sediments (varies from 72m^2/day to 2326m^2/day) due to the change in lithology and thickness.
- The over-pumping of some wells due to the use of their waters in different purposes.
- The dissolution of some marine salts present in the aquifer sediments.
- The effect of evaporation particularly in the shallow dug wells.

On the other hand, to study the effect of the lapse of time and meanwhile the direction of salinity increase, two iso-salinity contour maps are constructed for water samples collected in November 1996 and November 2005 (Figs. 4, 5).

Table (2). Well locations and depth to water of groundwater samples at Delta Wadi Dahab area (November 2005).

Well No.	EC mg/L ppm	Lat. N	Long. E	Depth to water(m)	Well No.	EC mg/L ppm	Lat. N	Long. E	Depth to water(m)
1	5490	34° 30'01"	28° 29' 68"	--	14	12380	34° 30' 71"	28° 30 91"	4.9
2	4920	34° 29'69"	28° 29 43"	14.75	15	8400	34° 30' 63"	28° 30 90"	--
3	7170	34° 29'93"	28° 29 36"	11.7	16	3750	34° 30' 87"	28° 30 67"	8.1
4	8240	34° 29'94"	28° 29 34"	11.55	17	3550	34° 30' 84"	28° 30 69"	8.8
5	9850	34° 29'98"	28° 29 34"	11.7	18	5460	34°30' 54 "	28° 30 44"	18.2
6	6020	34° 31'03"	28° 30 40"	7.0	19	6200	34° 30' 70"	28° 30 45"	15
7	2750	34° 30'90"	28° 30 75"	6.4	20	6470	34° 30' 65"	28° 30 46"	--
8	6490	34° 30'84"	28° 29 74"	8.7	21	5820	34° 30' 98"	28° 30 40"	8.3
9	6590	34° 30'84"	28° 30 52"	11.4	22	4220	34° 30' 93"	28° 30 32"	9.05
10	5800	34° 30'59"	28° 30 55"	16.3	23	6090	34° 30' 99"	28° 30 30"	8.05
11	6830	34°30' 56"	28° 30 62"	16	24	5790	34° 31' 06"	28° 30 33"	7.2
12	12250	34° 30' 77"	28° 30 62"	--	25	4820	34° 31' 12"	28° 30 06"	6.2
13	13930	34° 30' 73"	28° 30 89"	5.3					

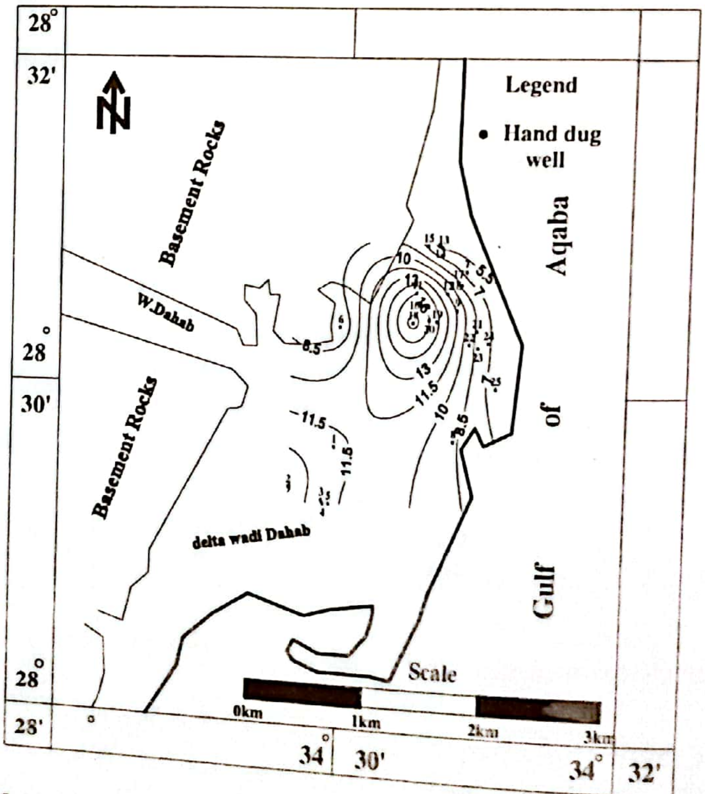


Fig. (3) Depth to water contour map of Quaternary aquifer in Delta Wadi Dahab, as meters (November 2005).

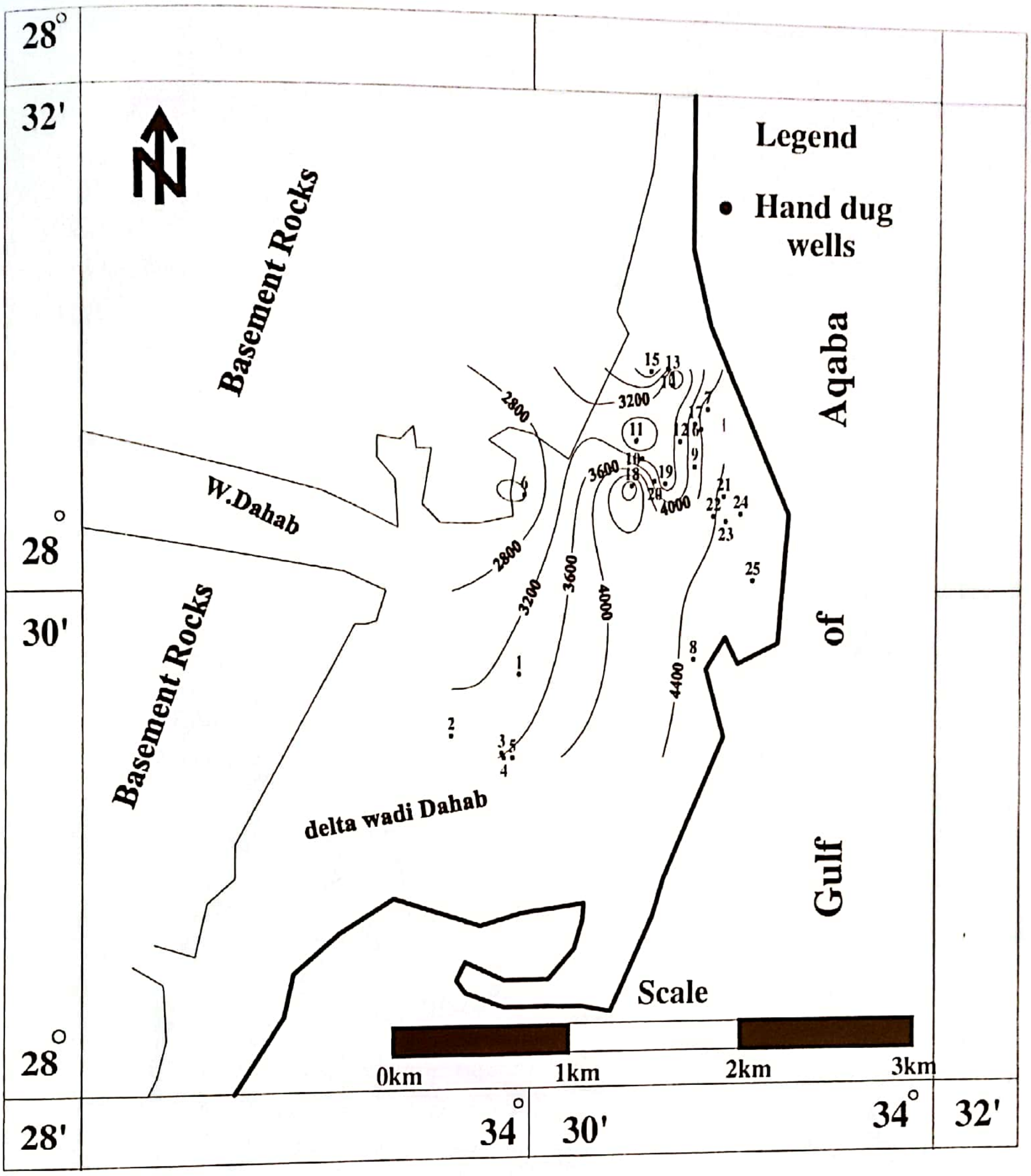


Fig. (4). Iso-salinity contour map of the Quaternary aquifer in Delta Wadi Dahab, as ppm, mg/l (November 1996).

The comparison of the two maps shows more or less similar behaviour regarding the direction of salinity increase which is confirmed by the direction of groundwater flow towards the Gulf of Aqaba and also the slight change in salinity values except for some wells in November 2005. Notably, the changes in climatic conditions are considered main factors affecting the water salinity in this semi-arid region.

2- Total Hardness

The obtained mean values of total hardness (TH), permanent and temporary hardness are 1400, 1300 and 100mg/las $CaCO_3$, respectively. All groundwater samples show permanent hardness rather than temporary hardness. The total and permanent hardness increase as the water salinity increases while it decreases as the temporary hardness increases (Table 3).

This is mainly attributed to the effect of leaching and dissolution of salts leading to the increase of hardness with particular importance to the effect of NaCl concentration (effect of ionic strength) on increasing solubility of Ca^{2+} and Mg^{2+} in water (Hem, 1989). Also, the hardness of the groundwater increases with long residence time and the Ca^{2+} and Mg^{2+} concentrations are apt to change due to cation exchange reactions. Moreover, the fertilizers, the presence of carbonate sediments and gypsum in the aquifer matrix cause an increase in the hardness of groundwater. The determined values indicate that the majority of groundwater (88%) is very extremely hard and the rest samples (12%) are very hard water types (Stuyfzand, 1986).

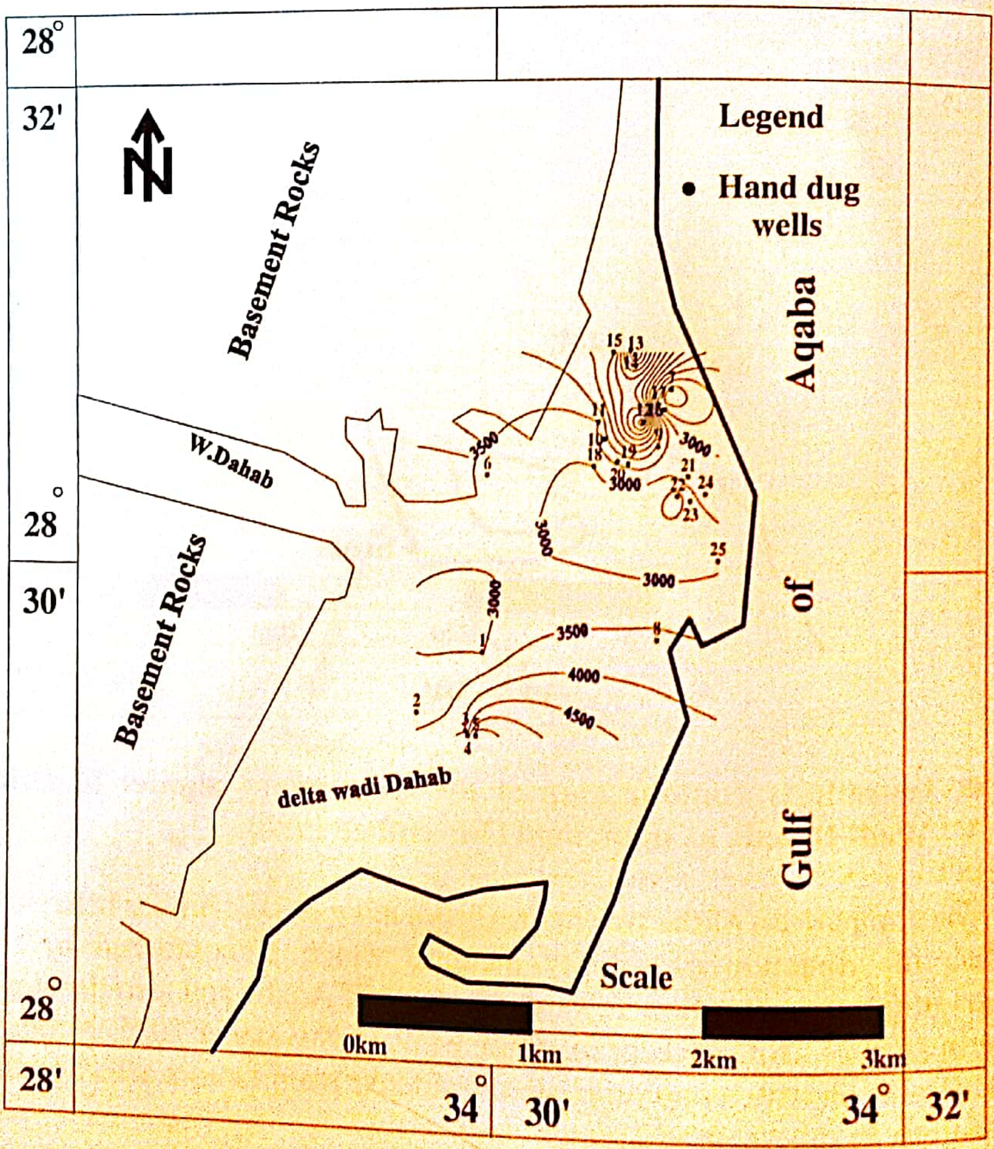


Fig. (5). Iso-salinity contour map of the Quaternary aquifer in Delta Wadi Dahab (ppm, mg/l) (November 2005).

Table (3). Total, temporary and permanent hardness of groundwater samples of Quaternary aquifer in Delta Wadi Dahab area.

Well No	TH (ppm)	TH as m mole/l	Temporary (ppm)	Permanent (ppm)	Well No	TH	TH as m mole/l	Temporary (ppm)	Permanent (ppm)
1	1300	13.0	67	1233	14	2611	26.1	190	2421
2	1673	16.7	51	1621	15	1587	15.9	112	1475
3	1596	16.0	92	1504	16	689	6.9	103	586
4	1996	20.0	98	1898	17	629	6.3	187	441
5	1840	18.4	78	1762	18	1252	12.5	61	1190
6	1077	10.8	279	797	19	1300	13.0	48	1252
7	556	5.6	131	424	20	1285	12.9	61	1224
8	1518	15.2	89	1428	21	1219	12.2	61	1157
9	1534	15.4	70	1464	22	857	8.6	59	798
10	1116	11.2	78	1038	23	1193	11.9	64	1129
11	1286	12.9	56	1230	24	1251	12.5	50	1200
12	1782	17.8	190	1592	25	1084	10.8	117	966
13	2785	27.9	115	2671	average	1400	14.0	100	1300

3- Ion Dominance

The sequence of major ions in the groundwater follow two main orders:

-$Cl^- > SO_4^{--} > HCO_3^-$ / $Na^+ > Ca^{++} > Mg^{++}$
(detected in 96 % of water samples).

--$Cl^- > SO_4^{--} > HCO_3$ / $Ca^{++} > Na^+ > Mg^{++}$
(detected in 4% of water samples).

Such sequence are directly affected the increase of salinity in all groundwater samples where chloride - sodium and chloride – calcium water types are dominating.

4- Hypothetical Salt Combinations

The hypothetical salt combinations of the groundwater, according to the Bar graph representation are distinguished into three assemblages as follows, (Fig. 6):-

Assemblage I NaCl, $MgCl_2$, $CaCl_2$, $CaSO_4$ and $Ca(HCO_3)_2$ (92% of the total samples).

Assemblage II NaCl, $MgCl_2$, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$ (4% of the total samples).

Asemblage III NaCl, Na_2SO_4, $MgSO_4$, $CaSO_4$ and $Ca(HCO_3)_2$ (4% of the total samples).

Assemblage I is encountered in most of the investigated groundwater samples (92%) while assemblage II and III characterize only (8%) of total samples regardless their salinities (medium to high saline). Both assemblages I and II represent an advanced stage of chemical development, while assemblage III represents an intermediate stage of chemical development. In spite of the similarity of assemblages I and II with sea water assemblage, this similarity is attributed to the dissolution of soluble salts in the catchment area of Wadi Dahab basin, which is characterized by the Cenomanian rocks (marine environment) and the basement rocks (rich in mafic minerals).

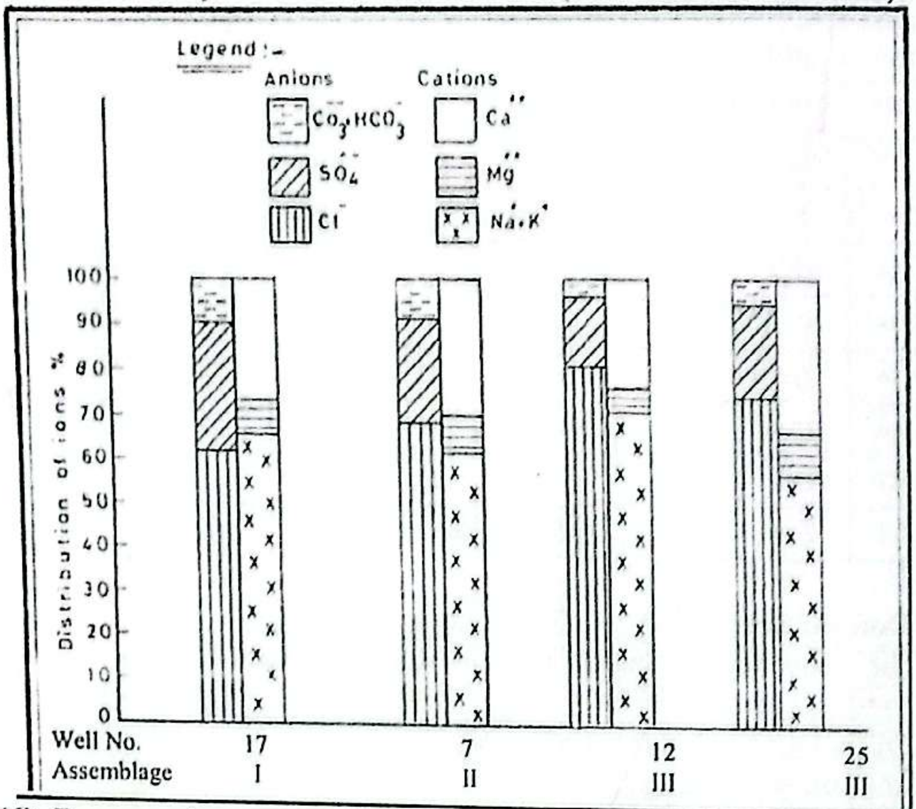


Fig. (6). Bar-graph representing the assemblage groups of groundwater of the Quaternary aquifer in Delta Wadi Dahab area.

5- Hydrochemical Coefficients

The hydrochemical coefficients represent the sodium imbalance in the groundwater (rNa^+ / rCl^-), the excess of sulphate (rSO_4^{--} / rCl^-), the rate of evaporite dissolution (rCa^+ / rMg^{++}), the activity of base exchange ($rCl^- - Na^+ / rCl^-$) and the contamination index coefficient ($rCl^- / rCO_3^- + rHCO_3^-$). The computed values revealed more sodium over chloride with a mean value close to that of rainwater, more calcium over magnesium, more chloride over sulphate, less base exchange activity and high contamination rate.

Detailed discussion of such coefficients listed in table (4), is given in the following:

1- The average value of rNa^+/rCl^- becomes very near to that of rainwater which indicates meteoric water origin with a partial leaching of old marine deposits evidenced by the rich content of chlorides in the groundwater samples.

2- The ratio of rCa++/rMg++ is very far from that of sea water (0.14) but it is very near to rainwater standard (7.14). This may indicate carbonate salt dissolution or CO_2-$CaCO_3$ interaction where the water bearing formation contains carbonate salt as (Aragonite, Calcite and Chalice).

3- The low value of (rSO_4^{--}/rCl^-) ratio in all groundwater samples indicates the low content of sulphate salts in the leached sediments.

4- The base exchange index ($rCl^-r(Na^+ + K^+)/rCl^-$) has almost positive value which indicates inactive base exchange process.

5- Regarding the value of ($rCl^- / rCO_3^- + rHCO_3^-$) ratio, it indicates high contamination water type according to (Simpson, 1946) and (Todd, 1959) categories for the values of this ratio.

6- The chloride-bromide (Cl/Br) and iodide-bromide (I/Br) ratios aim to define if the groundwater has marine contamination or not. The determined values in the groundwater with regard to their values in both rainwater and sea water as listed in table (5), indicate that both ratios in the groundwater are nearly similar to those of sea water which means that the groundwater is affected by sea water or marine salts dissolution of aquifer sediments.

Table (4). Range and average values of hydrochemical coefficients in the groundwater of the Quaternary aquifer in Delta Wadi Dahab.

Hydrochemical coefficient	Groundwater range		Groundwater mean	Rainwater	Sea water
rNa^+/rCl^-	0.51	1.006	0.68	0.65	0.83
rCa^{2+}/rMg^{2+}	3.49	9.39	6.15	7.14	0.14
rSO_4^{2-}/rCl^-	0.08	0.48	0.13	0.82	0.10
$\{rCl^- - (Na^+ + K^+)\}/rCl^-$	-0.04	0.47	0.18	0.35	0.16
$Cl^-/r(HCO_3^-)$	6.01	57.14	21.5	0.65	220

Table (5). Range and average values of Br^- and I^- concentrations (mg/l) in the groundwater of the Quaternary aquifer in Delta Wadi Dahab.

Hydrochemical coefficient	Groundwater range		Groundwater mean	Rainwater	Sea water
Cl^-/Br^-	60	125.1	81	128	137
I^-/Br^-	0.0003	0.0061	0.0013	0.03	0.003

6- Major Ions Relationship between Surface Water and Groundwater

To define the relationship between rainwater and sea water from one side and groundwater in the other side, a relation distribution diagram is constructed for the mean percentages of major ions in the groundwater and those in rainwater and sea water (%). This relation is discussed in the following (Figure 7):

- The average percentage of Ca^{++} ions in groundwater is 36.5% higher than both rainwater and sea water. This increased concentration of calcium ion is due to the rich content of calcareous materials in the aquifer sediments that dominated by silt and clay. On the other hand, Mg^{++} ion are very low (6.4%) relative to Ca^{++} ions in rain and sea water (10 to 20%, respectively), which may be attributed to its replacement in aqueous solutions by ion exchange.
- The concentration percentage of Na^{+} ion ranges from 39.9% to 71.2% with an average percentage 57% which is three times its average in rainwater and much less than sea water. This increased content of sodium in the groundwater is due mostly to leaching and dissolution processes of saline deposits.
- The chloride content is 81.5% as a main value which is more closer to its value in sea water.
- The sulfate content has an average value between rainwater and sea water (15%).
- The average of bicarbonate concentration is very low and amount to 3.4% which is much lower than that of rainwater but very near to sea water.

It can be concluded from the above discussion that the concentrations of the different ions (cations and anions) in the groundwater are controlled by a complicated system of hydrochemical processes (e.g., ion exchange, salt dissolution and mixed) which resulted from the interaction between the aquifer sediments (varieties of continental and marine sediments mixed with weathered materials of basement rocks) and infiltration rainwater (resent and old) or intruded sea water along the coastal area in particular.

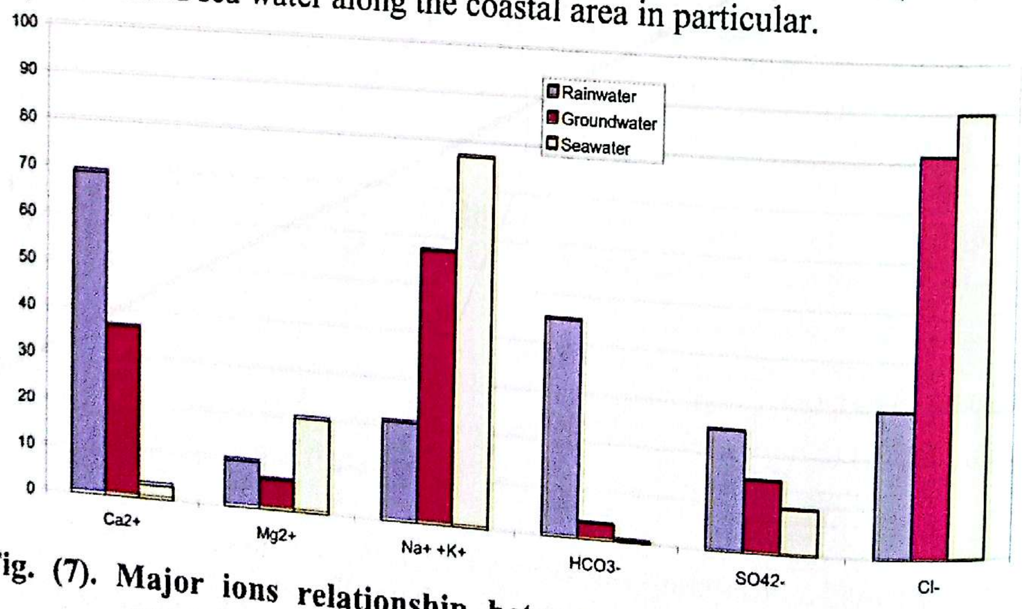


Fig. (7). Major ions relationship between sea water, rainwater and groundwater of Quaternary aquifer in Delta Wadi Dahab.

7- Genesis and Formation of Groundwater Mineralization

Different methods have been proposed for genesis and classification of groundwater quality. Some are based on anions while others make use of both anions and cations. In the present work four methods are used for classification of Quaternary groundwater in the Delta Wadi Dahab as follow:-

7-1 Trilinear plotting method (Piper's diagram, 1944)

This system of classification represents an analysis by three plotting points, one for cations, another for anions and the third point plotted in the upper diamond shaped field which indicates the character of water as represented by the relationships among Ca^{++}, Mg^{++}, Na^{+}, K^{+}, CO_3^{--}, HCO_3^{--}, SO_4^{--} and Cl^{-} ions.

From the plotted data shown in figure (8), the following could be noticed:

- All water samples are plotted in area (4) of the diamond shaped field where strong acids exceed weak acids, i.e., $(SO_4^{--}+Cl^{-}) > (CO_3^{--}+HCO_3^{-})$.
- 92% of the plotted points (23 samples) is located in sub-area (7) (primary salinity) close to the sea water sample. This indicates that the chemical composition of the groundwater samples is more or less resembles that of sea water which can be attributed to the effect of the Gulf of Aqaba water or the dissolution of marine salts encounter in the aquifer sediments.
- One sample is located in the secondary salinity sub-area (6) and one more is located in sub-area (9) near the location of rainwater which indicated rainwater origin.

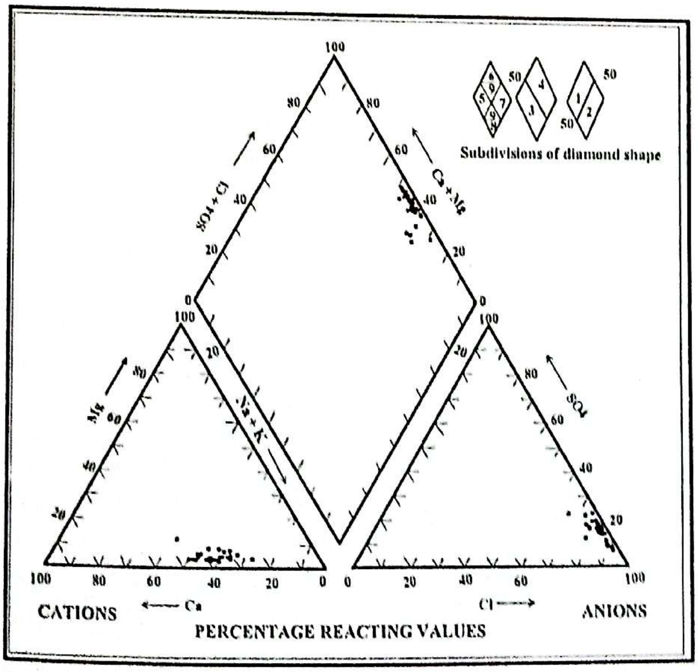


Fig. (8). Trilinear diagram for the groundwater chemical analyses of the Quaternary aquifer in Delta Wadi Dahab.

7-2 Modified Durov's diagram (1948)

This diagram aims to elucidate the role of metasomatic changes in the development of groundwater mineralization. It is based on plot of anions and cations (expressed in % epm) on expanded equilateral triangle constructed on two sides of a square into which the positions of cations and anions are projected. From the constructed diagram, shown in figure (9), for the investigated water samples, the following remarks are concluded:

- The general trend of major metasomatic changes begins from the $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ subsquares (calcite and magnesite) and ending by the NaCl subsquare (halite).
- The majority of groundwater samples is plotted together with sea water in the NaCl subsquare which means that most samples display more developed stage of mineralization i.e., they are subjected to different processes of metasomatism through its path from the recharge area to the delta until they reach such advanced stage of mineralization.
- Two only of water samples occupy the $MgCl_2$ subsquare (bischofite) which indicate that a part of the aquifer deposits belongs to marine environment.
- Notably, rainwater subjected partly to dissolution, occupies the $CaSO_4$ subsquare (gypsum and anhydrite).

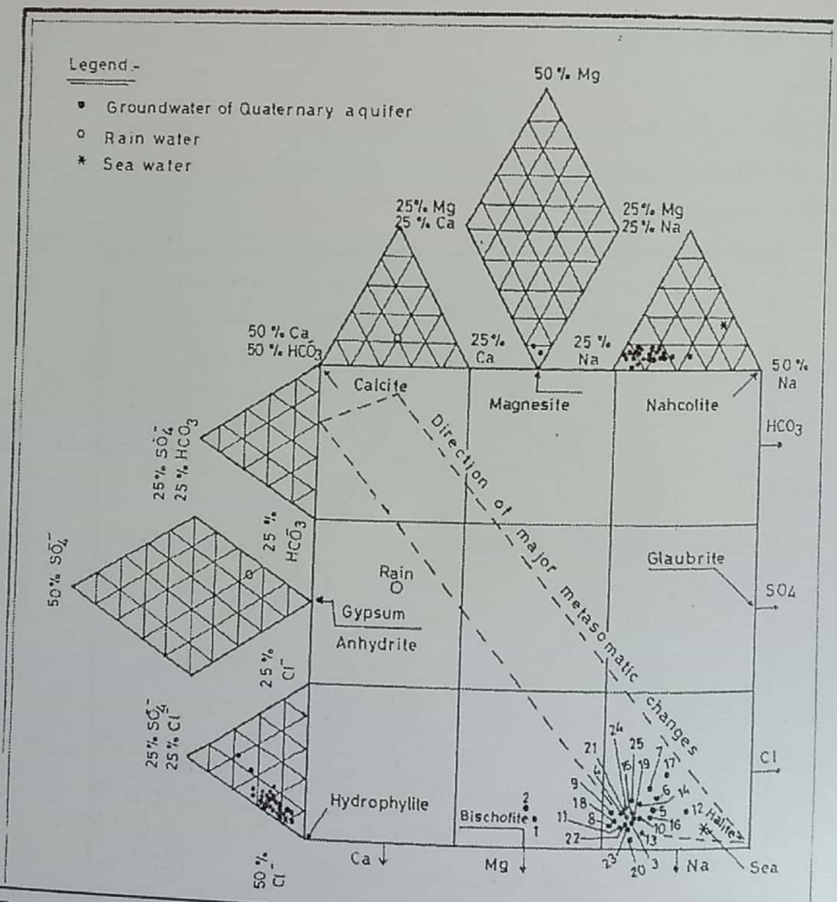


Fig. (9). Durov's diagram for representation of the Quaternary aquifer groundwater samples.

7-3 Schoeller's semi logarithmic diagram (1962)

The chemical compositions of groundwater samples are represented on the semi logarithmic diagram by connecting lines between major ions. Each line represents the chemical composition of single sample. Accordingly, the plot of chemical data of some selected groundwater samples, as shown in (Fig.10), indicates one category of chemical properties, i.e., $Na^{+}>Ca^{++}>Mg^{++}$ / $Cl^{-}>SO_4^{--}>HCO_3^{-}$ with the exception of some deviation of sample No.17 and 2. Moreover, the comparison with the lines of both rainwater and sea water indicates near relation to sea water composition rather than rainwater (as evident from the figure).

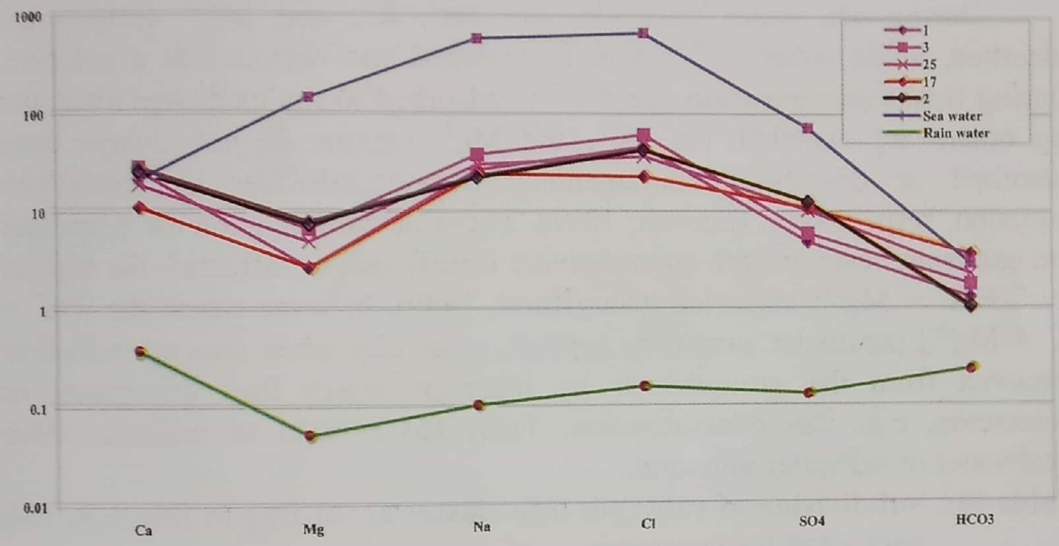


Fig. (10). Semi-logarithmic graph diagram for the groundwater of Quaternary aquifer in Delta Wadi Dahab.

7-4 Stuyfzand water classification (1986 and 1989)

In this method, the groundwater quality is studied through the evaluation of the geochemical processes to which groundwater have been subjected such as mixing and ion exchange processes that result from the freshwater and saltwater. In addition, the determination of the sum of {Na^{+}, K^{+} and Mg^{2+}} deficit or surplus compared to ($Ca^{2+}+Mg^{2+}$) are taken as diagnostic criteria.

The explanation of water type classes will be discussed on the base of the empirical cation exchange reaction. The groundwater types affected by leaching and dissolution processes of marine salts and mixing between the different water zones in the Quaternary aquifer (leading to an increase in water salinity) are possibly accompanied by cation exchange processes (related to clay minerals assemblage, dominated by montmorillonite, illite, hydrous mica and kaolinite as well as amorphous inorganic materials) that lead to slight decrease in water salinity (equation 1) as follows:

$$\text{1) } Ca + [\alpha Na. + \beta K + (1 - \tfrac{1}{2}\alpha - \tfrac{1}{2}\beta)\, Mg]\text{-clay} \underset{\text{Salt water intrusion}}{\overset{\text{Freshwater intrusion}}{\rightleftarrows}} [Ca]\text{-clay} + \alpha\, Na + \beta K + (1 - \tfrac{1}{2}\alpha - \tfrac{1}{2}\beta)\, Mg$$

An additional formula is applied in order to differentiate between freshwater or saltwater intrusion.

$$[Na^{+} + K^{+} + Mg^{2+}] \text{ corrected} = [Na^{+} + K^{+} + Mg^{2+}] \text{ measured} - (1.049)\, Cl^{-}$$

The factor 1.049 is equal to ($[Na^{+} + K^{+} + Mg^{2+}]/Cl^{-}$) in me/l (epm) for the sea water at Dahab area.

During sea water intrusion, the Na^{+}, K^{+}, and Mg^{2+} cations are adsorbed, while some Ca^{2+} cation is desorbed and becomes in a solution. During freshwater intrusion, the Ca^{2+} is adsorbed to the exchange sites and the others are expelled. Na^{+}, K^{+}, and Mg^{2+} cations do not always been adsorbed or desorbed simultaneously during saltwater or freshwater intrusion, respectively, (Laeven, 1991). These deviations from the empirical ion exchange reactions are quantitatively insufficient to influence the sign of $[Na^{+} + K^{+} + Mg^{2+}]$ corrected, (Stuyfzand, 1989). In some cases, the $[Na^{+} + K^{+} + Mg^{2+}]$ parameter cannot be applied, especially when ions are added or removed from the groundwater by other processes than adsorption or desorption, e.g., de- mineralization. Table (6) is used to indicate either freshwater or saltwater intrusion.

Table (6). Subdivision of subtypes into classes according to [Na + K +Mg] corrected for sea water .

Class	Code	Condition (me/l)
$[Na^{+} + K^{+} + Mg^{2+}]$ deficit	-	$[Na^{+} + K^{+} + Mg^{2+}]$ corr. $< -\sqrt{Cl/2}$
$[Na^{+} + K^{+} + Mg^{2+}]$ equilibrium	0	$-\sqrt{Cl/2} \leq [Na^{+} + K^{+} + Mg^{2+}]$ corr $\leq \sqrt{Cl/2}$
$[Na^{+} + K^{+} + Mg^{2+}]$ surplus	+	$[Na^{+} + K^{+} + Mg^{2+}]$ corr. $> \sqrt{Cl/2}$

Where the codes denotes;
(-) often points at a (former) saltwater intrusion (somewhere)
(0) mostly indicates sufficient flushing water or stagnant condition
(+) often points at a (former) freshwater intrusion (somewhere)

It is assumed that all Cl ions originate from the sea, this fractionation of the major constituents of sea water upon spraying can be neglected, and that chloride behaves conservatively. The class boundaries at $\pm \sqrt{(Cl/2)}$ are compromise between the expected errors in chemical analysis, (Stuyfzand, 1986).

This classification method can trace saltwater intrusion, as well as freshwater intrusion, due to cation exchange. The majority of groundwater points (88% of investigated samples), that gives a deficit of $[Na^{+}+K^{+}+ Mg^{2+}]$

indicate an intrusion of saline water. On the other hand, few groundwater samples (Nos.7, 17 and 18, or 12%) displayed equilibrium of [Na^{+}+K^{+}+Mg^{2+}] which is influenced by increasing contamination from saltwater, i.e., code 0 mostly indicates sufficient flushing by freshwater (dilution) to marine facies groundwater types.

The geographical distribution of the groundwater types extrapolated from Stuyfzand (1986) is shown in Fig. (11). The apex of Delta Wadi Dahab, has code (-) except groundwater samples Nos. 7, 16 and 17. Locations of these groundwater samples are indicating an intrusion of saline water (over-pumping and depth of pumping where these water points reached to the hydrogeologic zone of brackish and saline water.

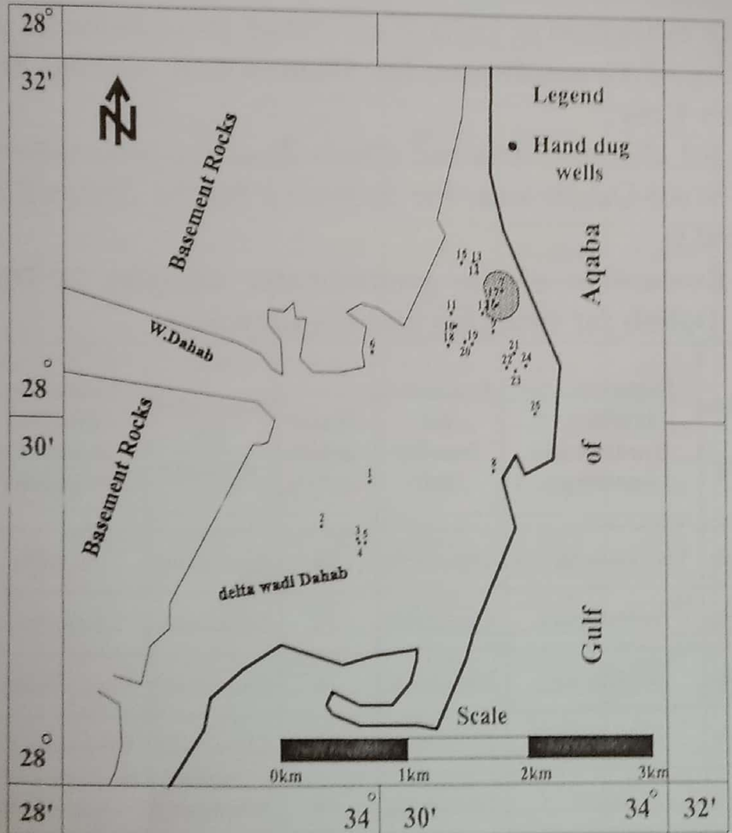


Fig. (11). Zonation of the groundwater of Quaternary aquifer in Delta Wadi Dahab according to Stuyfzand, 1986.

From the above mentioned results, it is clear that the very limited water types classes (o) (12%) indicate freshwater flushing by infiltrating surface runoff water through the different faults in north direction. While the water type class (–) has a dominant distribution that reached 88% of total investigated samples, indicating an intrusion of saline water, whereas the sea water intrusion does not take place until 1998, (Fig. 2). This confirmed that the general groundwater flow from Northwest to Southeast directions and it has meteoric water origin of mineralization affected by dissolved marine salts.

EVALUATION OF GROUNDWATER QUALITY FOR DIFFERENT PURPOSES

The suitability of particular water for drinking, domestic, laundry and irrigation is controlled by many factors. In the following study, the evaluation of water quality for various intended uses is based on, the total dissolved solids (TDS), and the concentration of major, minor and trace components. Following the Egyptian standards for drinking and domestic uses, adapted by Higher Committee for Water (1995) and World Health Organization (1996) standards for drinking water and the character of water used by livestock and poultry according to Mckee and Wolf (1963) as well as the suitability for laundry usage by Durfor and Becker (1964), a discussion for evaluation of Delta Wadi Dahab groundwater is given below:

A- Suitability of Groundwater for Human and Animal Drinking and Laundry Uses

From the chemical data and standards of the groundwater evaluation in Delta of Wadi Dahab area, the following can be deduced as present in tables 7, 8 and 9.

Table (7). Evaluation of the groundwater samples in Delta of Wadi Dahab for drinking and laundry uses.

Water points	Evaluation for drinking	Evaluation for drinking of livestock and poultry	Evaluation for laundry use	Water points	Evaluation for drinking	Evaluation for drinking of livestock and poultry	Evaluation for laundry use
1	Unsuitable	Very satissfactory	Unsuitable	14	Unsuitable	Unfit	Unsuitable
2	Unsuitable	Satissfactory	Unsuitable	15	Unsuitable	Satissfactory	Unsuitable
3	Unsuitable	Satissfactory	Unsuitable	16	Unsuitable	Very satissfactory	Unsuitable
4	Unsuitable	Satissfactory	Unsuitable	17	Unsuitable	Very satissfactory	Unsuitable
5	Unsuitable	Safety	Unsuitable	18	Unsuitable	Satissfactory	Unsuitable
6	Unsuitable	Satissfactory	Unsuitable	19	Unsuitable	Satissfactory	Unsuitable
7	Unsuitable	Very satissfactory	Unsuitable	20	Unsuitable	Satissfactory	Unsuitable
8	Unsuitable	Satissfactory	Unsuitable	21	Unsuitable	Satissfactory	Unsuitable
9	Unsuitable	Satissfactory	Unsuitable	22	Unsuitable	Very satissfactory	Unsuitable
10	Unsuitable	Satissfactory	Unsuitable	23	Unsuitable	Satissfactory	Unsuitable
11	Unsuitable	Satissfactory	Unsuitable	24	Unsuitable	Satissfactory	Unsuitable
12	Unsuitable	Unfit	Unsuitable	25	Unsuitable	Very satissfactory	Unsuitable
13	Unsuitable	Unfit	Unsuitable				

Table (8). Chemical analysis of minor elements (mg/l) of the groundwater samples of Quaternary aquifer in Delta of Wadi dahab.

Well No.	Fe^{3+}	B^{+++}	Cd^{2+}	Co^{3+}	Cr^{3+}	Cu^{2+}	Pb^{2+}	Ni^{2+}	Mn
1	0.0498	0.4335	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	<0.004
2	0.4123	1.333	0.0044	<0.003	<0.006	0.0502	0.0402	0.0063	1.051
3	0.0216	0.6498	<0.002	0.0095	<0.006	<0.03	<0.01	<0.004	<0.004
4	0.3894	1.194	<0.002	<0.003	<0.006	0.0556	<0.01	<0.004	0.0811
5	0.6989	1.372	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	0.0992
6	2.682	0.6229	<0.002	0.0057	<0.006	<0.03	0.1294	<0.004	0.5810
7	1.167	1.905	<0.002	0.0166	<0.006	0.0616	0.5779	0.0104	0.2670
8	3.401	0.5191	<0.002	0.0057	<0.006	<0.03	<0.01	0.0082	5.681
9	0.9361	0.6398	<0.002	0.0104	<0.006	0.1034	0.3819	<0.004	0.0808
10	2.844	0.6258	<0.002	<0.003	<0.006	<0.03	<0.01	0.0056	0.1234
11	1.018	0.5493	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	0.0659
12	1.611	3.161	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	0.1100
13	1.937	0.9396	<0.002	0.0069	<0.006	0.0387	<0.01	<0.004	0.1354
14	1.078	1.188	<0.002	0.0085	<0.006	0.0419	<0.01	<0.004	0.4763
15	0.4585	1.591	<0.002	0.0047	<0.006	<0.03	0.1845	<0.004	0.0220
16	0.5607	1.536	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	0.0647
17	1.339	1.947	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	0.0791
18	2.055	0.3918	<0.002	<0.003	<0.006	<0.03	0.3144	0.0079	0.3181
19	1.224	0.3688	<0.002	0.0047	<0.006	<0.03	<0.01	0.0051	0.0703
20	0.8947	0.6458	0.0381	0.0490	<0.006	<0.03	0.0349	0.0472	0.6983
21	1.758	0.5899	1.872	0.0040	<0.006	<0.03	0.0244	0.0065	0.0696
22	1.202	0.4677	0.0053	0.0074	<0.006	<0.03	<0.01	<0.004	0.0385
23	0.0974	0.5293	0.0757	<0.003	<0.006	<0.03	<0.01	<0.004	<0.004
24	0.4403	0.5233	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	0.0410
25	0.3024	1.103	<0.002	<0.003	<0.006	<0.03	<0.01	<0.004	0.0108

Table (9). Trace constituent concentrations (mg/l) of the groundwater samples of Quaternary aquifer in Delta of Wadi Dahab.

Well No.	Mo	Sr	Ti	V	Zn	Al	Ba	Be
1	<0.02	13.26	<0.003	0.0381	0.0356	<0.1	0.1252	<0.0005
2	<0.02	1.110	<0.003	0.0314	0.3398	0.2137	0.0981	<0.0005
3	<0.02	15.35	<0.003	0.0435	0.2909	<0.1	0.1490	<0.0005
4	<0.02	16.79	<0.003	0.0844	0.0788	<0.1	0.1013	<0.0005
5	<0.02	20.05	<0.003	0.0346	0.1180	<0.1	0.1134	<0.0005
6	<0.02	9.982	<0.003	0.0482	0.0929	<0.1	0.2563	<0.0005
7	<0.02	4.367	<0.003	0.0641	0.1220	<0.1	0.0557	<0.0005
8	<0.02	16.50	<0.003	0.0359	0.1636	<0.1	0.2607	<0.0005
9	<0.02	15.07	<0.003	0.0391	0.0701	<0.1	0.1459	<0.0005
10	<0.02	12.74	<0.003	0.0373	0.1288	<0.1	0.1423	<0.0005
11	<0.02	15.07	<0.003	0.0383	0.0131	<0.1	0.1409	<0.0005
12	<0.02	16.21	<0.003	0.0409	0.0268	<0.1	0.1410	<0.0005
13	0.0720	29.06	0.0496	0.3000	0.0461	1.145	0.2021	<0.0005
14	0.0433	26.32	<0.003	0.3721	0.1003	0.2834	0.1822	<0.0005
15	<0.02	17.75	<0.003	0.0374	0.2003	<0.1	0.1281	<0.0005
16	<0.02	6.535	<0.003	0.0495	0.5439	<0.1	0.0459	<0.0005
17	<0.02	6.017	<0.003	0.0528	0.0365	<0.1	0.0626	<0.0005
18	<0.02	15.93	<0.003	0.0372	0.0707	<0.1	0.1509	<0.0005
19	<0.02	18.03	<0.003	0.0375	0.0596	<0.1	0.1523	<0.0005
20	<0.02	17.00	<0.003	0.0364	0.1128	<0.1	0.1780	<0.0005
21	<0.02	13.32	<0.003	0.0351	0.1887	<0.1	0.1151	<0.0005
22	<0.02	10.14	<0.003	0.0390	0.0449	<0.1	0.1381	<0.0005
23	<0.02	15.49	<0.003	0.0375	0.0251	<0.1	0.1184	<0.0005
24	<0.02	15.23	<0.003	0.0380	0.0354	<0.1	0.1052	<0.0005
25	<0.02	11.77	<0.003	0.0487	0.0087	<0.1	0.0782	<0.0005

1- According to the total dissolved solid, all groundwater are unsuitable for human drinking. But the concentrations of the trace elements Ni^{2+}, Cr^{3+}, Cu^{2+}, Co^{3+}, Pb^{2+}, Cd^{2+} and also PO_4 are considered far below the drinking water permissible limits. Therefore, all water samples are suitable for human drinking from the phytotoxicity of trace elements and PO_4 after desalination or distillation.

2- Concerning the drinking of livestock and poultry, the groundwater samples are located at 24%, 60%, 4% and 12% which represent very satisfactory, satisfactory, reasonable safety and unfit classes, respectively. This means that, the majority of groundwater (88%) is suitable for livestock and poultry, (Table 7). Also, their components and heavy metals as well as trace elements are less than the permissible limits.

3- The total hardness in all groundwater samples is unsuitable for laundry uses because they have very hard class (Table 7).
4- The concentration of minor and trace elements shows that, the iron content ranges between 0.022 and 3.1mg/l with a mean value of 1.14 mg/l. In the majority of groundwater samples (92%), iron is higher than the permissible level (0.3mg/l) in drinking water, and the rest groundwater samples (8%) are lower than the permissible level (Table 8).
5- The boron content ranges between 0.36 and 3.16 mg/l with a mean value of 0.993mg/l. In most groundwater samples (60%), it is below the permissible level (1.0mg/l) in drinking water while some groundwater samples (40%) have more boron than the permissible level (Table 8).

B- Suitability of Groundwater for Irrigation

The suitability of the groundwater samples for irrigation processes in the study area is classified into two types according to Sodium Adsorption Ratio (SAR) (Fig. 12 and Table 10) and salinity levels, (Table 11), Richards (1954).

The first type shows two water samples are located in (C_4-S_2) class. The water of this class represents moderate water while four water samples are located in (C_4-S_3) class related to intermediate water. The water of such classes is not suitable for irrigation under ordinary conditions due to high salinity. On the other hand, nineteen water samples are located outside such diagram because they have salinity more than 5000 μmhos/cm.

Table (10). Suitability of the groundwater for agricultural in the Delta Wadi Dahab.

Water group	Sample No.	EC mhos/cm	SAR	Class	Agriculture suitability
I	1,3,4,5,6,8,9,10,11,12,13, 14,15,18,19,20,21,23,24	5460-13930	7.0-20.6	Out of scale	Unsuitable
II	2,7	2750-4920	5.3-7.2	Moderate water class C_4S_2	V. High salinity-medium Na hazard requires highly permeable soil with high leaching. Suitable for high salt tolerant crops.
III	16,17,22, 25	3550-4820	7.7-9.0	Intermediate water class C_4S_3	V. High salinity and Na hazard. To be used only in highly permeable soil considerable leaching and drainage are required. Suitable for high salt tolerant crops.

The second classification according to salinity levels, for crops types is shown in table (11). From this table, the majorty of the groundwater samples (76%) has salinity levels range from 4000 to 10000μ mhos/cm and they are suitable for semi-tolerant crop types while (12%) have salinity levels range from 10000 to 16000 μ mhos/cm and are suitable for tolerant crops types. On the other hand, few groundwater samples (12%) have salinity levels less than 4000μ mhos/cm are suitable for all crop types.

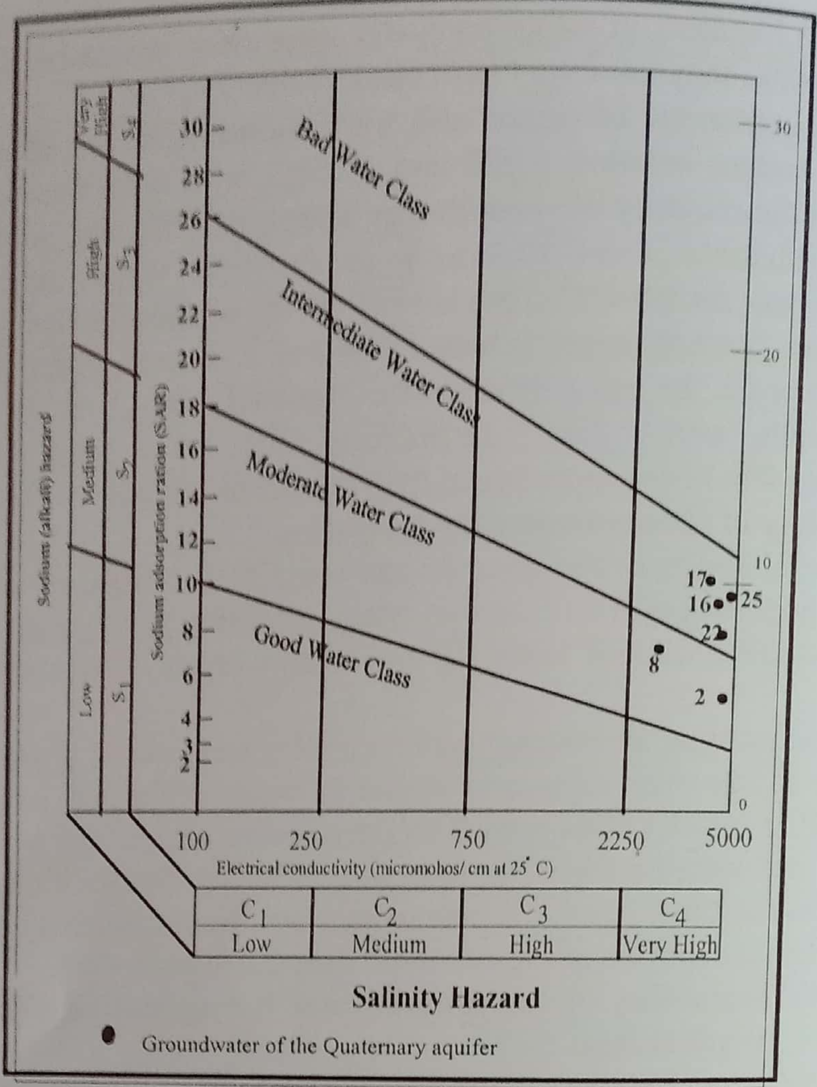


Fig. (12). Diagram for the classification of irrigation water (U.S. Salinity Laboratory staff, 1954)

Table (11). Evaluation of the groundwater samples for Crops and their salt tolerance in Delta Wadi Dahab according to Richards (1954).

Sensitive crops Salinity < 4 mmhos /cm		Semi-tolerant crops 4-10 mmhos /cm		Tolerant crops 10-16 mmhos /cm	
Number of samples	%	Number of samples	%	Number of samples	%
3	12	19	76	3	12

C- Boron Content

Among the factors that should be taken into consideration for irrigation water is the boron content. (Wilcox, 1955) gave a classification for boron content due to its importance for plant growth and its effect on many of the physiological activities of plant tissue. Boron is an essential micro – nutrient to proper plant nutrition, however, a small excess over the needed amounts is toxic to some plants. Therefore, plant species vary in both boron requirement and also in their tolerance to excess boron. Accordingly, a classification based on boron requirement for different kinds of crops is shown as follows (Table 12).

Based on the guidelines, the groundwater samples (25 samples) can be divided into the following classes:

Table (12). Classification of groundwater for irrigation according to its boron content (mg/l).

Class of water	Sensitive crops	Semi -tolerant crops	Tolerant crops
	Boron concentration (mg/l)		
Excellent	--	1,3,21,10,11,7,22,12,24, 25,9,23,19,20	1,3,20,19,14,23,9, 21,25,24, 12,22,7,11,10
Good	1,3,21,10,11,7,22,12, 24,25,9,23, 19,20	14,15,4,6,2	15,4,6,2,5,17,16,8,18
Permissible	14	2,5,17,16,8,18	--
Doubtful	4,15	--	13
Unsuitable	6,2,5,17,16,8,19,13	13	--

The groundwater of studied area has a wide range of boron concentration (0.3688 - 3.161mg/l). Thus, all groundwater samples in Delta of Wadi Dahab are suitable for irrigating different crop types, including tolerant, semi sensitive and sensitive crops. In details, 70% of the water samples are good for all crops because they have boron content ranges from 0.33 to 0.67mg/l while 30% of the water samples are suitable for different crops of semi sensitive and tolerance because they have boron content greater than 0.67mg/l.

In conclusion, the evaluation of groundwater in the studied area for irrigation according to the already established classifications shows that the majority of groundwater is suitable for irrigation. However, this does not mean that the unsuitable waters cannot entirely used. In fact, the water suitability is associated with soil nature and crop type. Therefore, at least some, if not all, groundwater samples in the study area can be used for irrigation but the expected yield productivity may not reach the optimum level.

SUMMARY AND CONCLUSION

The present study was carried out to evaluate the chemistry and water quality in an important groundwater resource of the Delta Wadi Dahab, i.e., the Quaternary aquifer. The main object is to assess the quality of this groundwater aquifer for different uses. To achieve this purpose a number of 25 groundwater samples were collected and chemically analysed for major elements and some trace elements. Interpretation of the results led to the following conclusions:

- The study revealed that there are two water salinity levels, one is the brackish water (up to 5000 mg/l) which occupies the western part of the

Delta and the second is the saline water (up to 8290 mg/l) which dominates the coastal plain at the eastern part. The brackish water type constitutes most groundwater of the sampled wells (84%).

- The distribution and relationship of major elements indicated that the aquifer sediments represent the major source of such elements in groundwater. These elements are provided through leaching and dissolution processes of evaporates and old marine sediments which are detected from the different hydrochemical coefficient and types of hypothetical salt assemblages.
- It was proved that the groundwater was subjected to several stages of metasomatic changes for long period of time until it reaches the present most advanced stage of mineralization, represented by the sequence $Cl^- > SO_4^{2-} > HCO_3^-$ in all groundwater samples.
- The application of the international methods for water uses evaluation revealed the unsuitability of water for drinking and laundry due to its high salinity and hardness regardless of its low content of trace elements. In addition, it is suitable for irrigation under certain conditions of soil and plant types.

RECOMMENDATIONS

From the aforementioned study, the following recommendations are worked out:

- Drilling of wells near the coastal area of the delta should be forbidden to avoid highly saline groundwater supply.
- Drilling operation should be directed to the western part of the delta close to the fractured basement rocks to catch directly the percolated rainwater.
- The extraction of groundwater from wells should be controlled to minimize stalinization.
- Carrying out desalinization for groundwater and sea water is a necessity to cover the excessive use of water in different purposes.
- Carrying out periodical chemical analyses for groundwater to follow up the changes in groundwater salinity and compositions.

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كيميائية المياه الجوفية فى دلتا وادى دهب، جنوب شرق سيناء، مصر

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الهدف الرئيسي من هذا البحث هو الوصول إلي الخواص الكيميائية لخزان المياه الجوفي الرباعي بمنطقة دلتا وادي دهب وذلك بغرض إستخدام هذه المياه لاغراض الزراعة والاغـراض المنزليه. وللوصول لهذا الهدف فقد تم دراسة العديد من المكونات الكيميائية للمياه وتشتمل علـي الملوحه ،العسر، المكونات الاساسيه، الأيونات السائدة، الأملاح الافتراضية ونسبة الأملاح. وذلك من خلال التحليل الكيميائي لعدد من عينات المياه الجوفيه المجمعة من منطقـة الدراسـة. هـذا بالإضافة الي دراسة أصل وتكوين معادن المياه وذلك من خلال دراسة العمليات التي تؤثر علـي نوعية المياه وأهم طرق تصنيف هذه المياه.

- ثبت أن المياه ذات أصل متعدد التمعدن ربما نتجت من عمليات الخلط بين ميـاه حديثـة وأخري قديمة بجانب تأثير عمليات الغسيل والإذابة لصخور بحرية قديمة وأخري قاريـة حديثة لفترات زمنية طويلة أدت في النهاية إلى وصول النوعية الكيميائيـة للميـاه إلـي المرحلة الأكثر تطوراً وهي $Cl^{-} > SO_4^{2-} > HCO_3^{-}$.
- من هذا اتضح عدم صلاحية المياه للشرب بالنسبة للإنسان نظراً لارتفاع ملوحتها عن الحد المسموح بالرغم من أن محتواها من العناصر النادره أقل من المسموح به عالميـاً كـذلك فان المياه عسرة جداً بحيث لا يمكن استخدامها للغسيل أما بالنسبة للري فان معظم الميـاه مناسبة للري تحت ظروف معينة تشمل نوعية التربة ونوعية النباتات المنزرعه.
- في النهاية تم تقديم عدة توصيات منها وهي الأهم أنه لابد من ايجاد مصادر أخرى للميـاه لمواجهة الزيادة المستمرة لاستخدامات المياه وذلك بضرورة تحلية مياه البحر بجانب تحلية المياه الجوفية المستغلة (Desalinization).