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CHEMICAL CONDITIONS IN BARDAWIL LAGOON
1. THE MAJOR CATIONS

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ABSTRACT

Chemical characteristics of Bardawil Lagoon waters, collected for six seasons, were studied. The waters of the lagoon show a positive Ca^{2+} anomaly, caused by the dissolution of gypsum layers from the bottom. The influence of temperature and hence evaporation affects the increase in Na^{+}, K^{+}, Ca^{2+} and Mg^{2+}. Except potassium, the western arm was higher in Ca^{2+}, Mg^{2+} and Na^{+} than the eastern arm. The cation/chlorinity ratio in the lagoon was higher than in normal sea water due to the arid conditions.

INTRODUCTION

The lagoon of Sabkhat El-Bardawil, Northern Sinai (Fig. 1), is a body of sea water with an area of about 1600 km^2 (80 Km long and a maximum width of _ 18 Km). The lagoon is connected only to the Mediterranean Sea by one inlet, Boughaz I at the western arm (Yitzhak, 1971). Boughaz II at the eastern arm was represented during this study (Fig. 2). Both Boughazes are about 300 m wide and between 1 and 2 m deep at the beginning of this investigation. This depth was increased to about 6 m mechanically during carrying out this study. The depth of the lagoon ranges from a few centemeters in near shore, to a maximum depth of 2.5 m.

Few studies have been carried out on the lagoon waters. Yitzhak (1971), determined the major ions in the water and the minerals of the sediments, both samples were collected from the laggon.

A knowledge of the chemical conditions and compositions of the waters of the lagoon is necessary to help in maximization fish production. The present study deals with the determination of the major cations namely, Sodium, Potassium, Calcium and magnesum. Their chlorinity ratios as well as their seasonal and regional variations which are more or less correlated to the environmental biota in the lagoon waters through six seasons (two months for each) from the summers 1985 throughout 1986 were also determined.

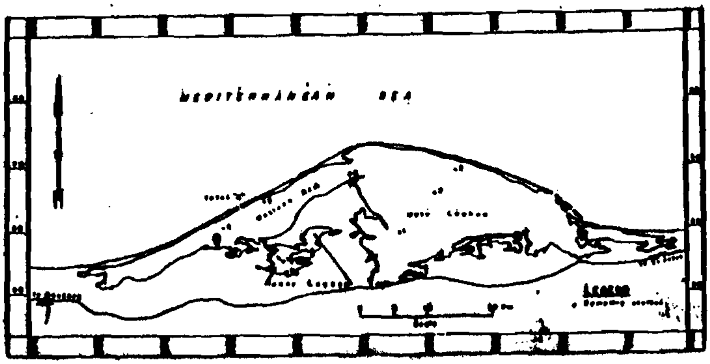

Fig. (1)
Index map of Sabkhat el Bardawil.

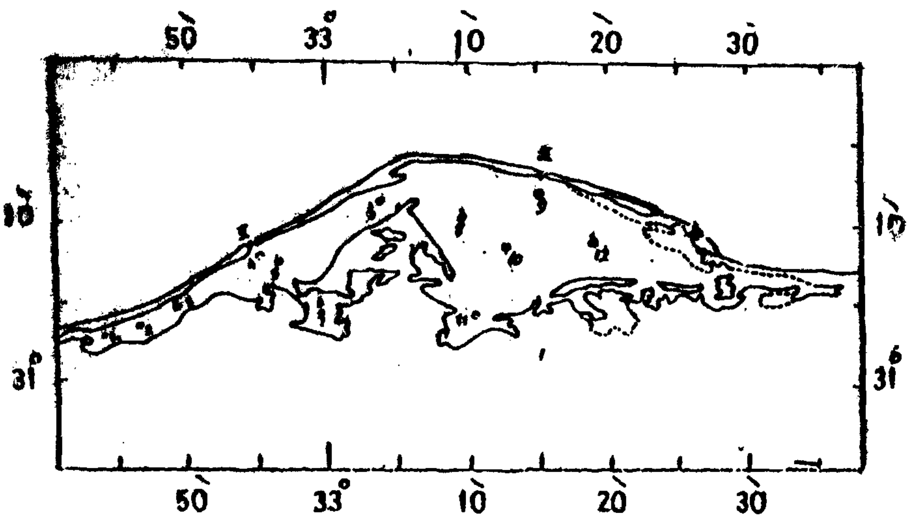

Fig. (2)
Map location of stations at Bardawil Lagoon

According to Yitzhak (1971), the climate is arid with low precipitation and high rate of evaporation in Bardawil lagoon. No streams flow into the lagoon. Maximum air temperature 31°C occurs in July, while the minimum 16°C in January. The prevailing wind in the lagoon area is north westerly during most of the year (Meteorological Dept., Cairo).

Due to the shallowness of the lagoon, the water temperature follows more or less that of the air, ranging between 31°C in summer and 16°C in winter.

MATERIALS AND METHODS

a- Materials

The samples used for the present study were collected from twelve stations chosen to represent the different regions of the lagoon (Fig. 2); these are :

1) Six stations (1-6) at the western arm.
2) One station (station 7) at the inner lagoon.
3) Five stations (8-12) at the eastern arm (main lagoon)

Samples were collected in well stoppered polyethylene bottles of about 1 l capacityat; one just below the water surface and one near the bottom at each station. Sampling was carried out during Aug., Sept., and Nov., in 1985 and Jan., Feb., Apr., May, July, Oct., and Nov., of 1986, with a total of 240 samples for the determination of sodium, potassium, calcium, and magnesium contents for the Bardawil waters.

b- Methods of Analysis

Determination of sodium, potassium, calcium and magnesium were analyzed according to Anon. (1965). For sodium and potassium, the samples were diluted in different proportions and measurements were made by Flamephotometry. Calcium and magnesium were determined titrimetrically using murexide powder as indixator for the first and E.B.T. for the latter.

RESULTS

Sodium Determination

The values of sodium content expressed in mgl^{-1} for water samples during six seasons are given in table 1. The sodium content of the surface and bottom water samples, respectively, varied between an average maximum of 18,791.67 mg l^{-1} and 22,137.5 mg l^{-1} in January. It also differs from one region to another due to the continuous dig out and dilution of the lagoon waters by the Mediterranean Sea water. This appears from the annual average values which vary from a maximum of 20,700 mg l^{-1} and 29,900 mg l^{-1} at station 1 surface and bottom respectively, and

TABLE 1

The sodium content in mg/l^{-1} in the Bardawil Lagoon water

		Station												Seasonal
		1	2	3	4	5	6	7	8	9	10	11	12	Average
August	Surface	-	19100	19100	13400	18600$^+$	16700	9400$^-$	-	11200	14000	13800	11500	14680.0
1985	Bottom	[illegible]	19400	20.000	15.000	1980u	18500$^{\pm}$	13600	-	20000$^+$	19400	19400	17100	18220.0
November	Surface	24750	22250	16250	16250$^-$	15500	11500	15000	22250	15500$^+$	18000$^+$	24750$^-$	23500	18791.67$^-$
1985	Bottom	27500	25250	23500	18750$^+$	25250$^+$	13750	18000	26750$^+$	18000	20400$^+$	24750$^+$	26750	22137.5
January	Surface	11250$^-$	11250$^-$	11500$^-$	10750$^-$	10750	11500	12000	11500$^-$	10750	11000	10550$^-$	10500$^-$	11108.33
1986	Bottom	12750$^-$	11750$^-$	13750$^-$	10750	11000$^-$	11500$^-$	12500$^-$	13750	11550	11250	10750$^-$	10750$^-$	11837.5
April	Surface	32250$^+$	31500$^+$	29800$^+$	10750$^+$	12000	10750$^-$	12250	14500	10750	13750	13000	29500$^+$	18375.0
	Bottom	32250$^+$	35000$^+$	34000$^+$	11500	15000	13500	19500	16500	17500	13750	14250	32250$^+$	21250.0
July	Surface	10500	16500	11500$^-$	-	10500$^-$	14250	18750$^+$	12500	10500$^-$	11600	11250	10750	12600
	Bottom	28000	28000	13750	-	13000	17000	19500	13500$^-$	10500$^-$	11650	12500	10750	16195.45
October	Surface	24750	18000	16500	12000	11250	18750$^+$	16000	18750	14250	10250$^-$	21250	18000	16645.0
	Bottom	24000	20000	19500	10000$^-$	13000	17500	22750$^+$	18750	15000	10500$^-$	21250	18750	17583.33
Annual Average	Surfac	20700$^+$	19766.67	17391.6	12630	13100	13908.3	13900	15950	12158.3$^-$	13100	15766.67	17291.67	15471.95
Value	Bottom	24900$^+$	23200.0	20750	13200	16175	15291.67	17641.67	17850	15425	14491.67	17150	19391.67	17955.56

N.B. The maximum values are designated by (+) and the minimum values by (-)

a minimum of 12,158.33 mg l^{-1} at station 9 surface and 13,200 mg l^{-1} at station 4 bottom, with an annual average value of 15,471.95 mgl^{-1} for the surface and 17,955.56 mg l^{-1} for the bottom. Yitzhak (1971), determined the sodium content of the loagoon and stated that, the sodium content varies between a minimum of 14,140 mg l^{-1} in the western arm for both surface and bottom water samples, to a maximum of 22,200 mg l^{-1} and 24,670 mg l^{-1} in the main lagoon for the surface and bottom respectively.

Potassium Determination

The potassium content expressed in mg l^{-1} for the lagoon water is given in table 2. The potassium content varies seasonally from an average maximum value of 1,129.17 mg l^{-1} and 1,312.5 mg l^{-1} for the surface and bottom, respectively in autumn 1083, to a minimum of 464.58 mg l^{1} in winter and 501.58 mg l^{-1} in autumn 1986 for both surface and bottom. The annual average potassium content at the surface varies from a maximum of 937.5 mg l^{-1} to a minimum of 250 mg l^{-1} at stations 7 and 4. At bottom, it varies from a maximum of 1,066.67 mg l^{-1} to a minimum of 615 mg l^{-1} at stations 3 and 4, respectively. These variations are mainly due to the climatic effect. Hutchinson (1957), cole (1975 and 1979), stated that, desert waters, are similar by being high in electrolytes and are quite different from the dilute waters of humid regions. The effect of evaporation, precipitation of compounds and the relative changes in ionic abundance are related to the chemical limnology of the arid land (Hutchinson, 1957, Bayly and Wiliam, 1973 and Cole, 1975 and 1979).

Calcium Determination

The calcium content of the Bardawil lagoon waters is expressed in mg l^{-1} and given in table 3. The calcium content varies seasonally from an average maximum of 1,753.08 and 1,923.84 mg l^{-1} in winter, to a minimum of 455.42 and 449.99 mg l^{-1} in autumn 1986 for both surface and bottom, respectively. It varies regionally from an average maximum of 1,205.49 and 1,315.2 for surface and bottom at station 12. The variation of Calcium content in the lagoon waters was observed with depth and location. This can be attributed to changes in temperature influence, the rate of $CaCO_3$ shell and spicules precipitation that organisms, (Sverdrup et al., 1942 and Cole 1975 and 1979). The skeletal organisms (Murix sp) were observed in great quantity at different localities and caused a problem for fishing operations. In addition, calcium inters into combination with anions other than carbonate, some of these being found in high concentration in arid lakes. Reid (1967), stated that, in Swiss Alps several lakes are rich in $CaSO_4$, which could has been derived from local deposits. Yitzhak (1971), indicated that, the calcium content of the lagoon water, varies between a minimum of 680 mg l^{-1} for both surface and bottom in the western, to a maximum of 900 and 1000 mg l^{-1} for both surface and bottom respectively at the main lagoon. The continuous dig out at Boughazes I and II may rises the vlaues of main data than that found by Yitzhak (1971), who found anomaly in calcium in the lagoon waters caused by the dissolution of gypsum layers from the bottom.

TABLE 2

The Potassium Content in mg/l^{-1} in the Bardawil Lagoon water.

Month		Station 1	2	3	4	5	6	7	8	9	10	11	12	Sea Av
August 1985	S	-	850	750	575	525	875	850	-	862.5	795	795	650	79
	B	-	1200	1225	675	1100	1175	975	-	1012.5^{+}	1150	800	1012.5	10
November	S	1300^{+}	1200^{+}	1000	800^{+}	900	1150^{+}	11250	1200^{+}	1000^{+}	1400^{+}	1350^{+}	1000^{+}	1129
	B	1400^{+}	1300^{+}	1300	1000^{+}	1400^{+}	1350^{+}	1500^{+}	1400^{+}	1000	1400^{+}	1350^{+}	1350^{+}	131
January 1986	S	400^{-}	400^{-}	400^{-}	400	400	400^{-}	650^{-}	600^{-}	400^{-}	425	650	450^{-}	464
	B	450^{-}	450^{-}	450^{-}	550	580	450^{-}	650^{-}	650^{-}	450	650	650	450^{-}	533
April	S	1200	1000	1150^{+}	475	1000^{+}	950	1400^{+}	1000	800	1000	1000	700	97
	B	1200	1200	2000^{+}	525	1000	1300	1400	1100	800	1000	1000	800	111
July	S	775	775	775	-	675	625	725	625	700	750	780	650	71
	B	900	800	800	-	675	775	875	650^{-}	750	750	800	650	76
October	S	725	625	575	350^{-}	375^{-}	750	750	625	450	312.5^{-}	625^{-}	500	55
	B	750	700	625	325^{-}	425	565.33^{+}	476.35	347.89	304.41^{-}	325^{-}	625^{-}	550	501
Annual Average value	S	880	808.33	775	520^{-}	645.83	791.67	937.5^{+}	810	702.08	780.42	866.67	658.33	76
	B	940	941.67	1066.67^{+}	615^{-}	858.89	935.89	979.39	829.58	719.49	879.17	870.83	802.08	86

N.B. The maximum values are designated by (+) and the minimum values by (-)
S = surface B = bottom.

TABLE 3

The calcium content in mg/l^{-1} in the Bardawil Lagoon water.

		Station												Seasonal
		1	2	3	4	5	6	7	8	9	10	11	12	Average
August 1985	Surface	-	1348.04	1400.27	887.13	1113.26	1217.6^{+}	2209.13^{+}	-	1095.87	1243.61^{+}	1313.3	1026.75^{+}	1285.5
	Bottom	-	1548.13	1643.8	930.62	1321.0	1435.06^{+}	1948.21^{+}	-	1348.09	1417.67^{+}	1408.97	1156.75^{+}	1415.83
November	Surface	1087.17	791.46	684.92	521.84	656.65	462.45^{-}	547.02	602.29	460.9	1043.68	847.99	595.77	691.55
	Bottom	1400.27	1087.17	734.93	641.43	739.28	684.92	1000.2	621.86	526.19	1195.89	880.61	595.77	842.13
January 1986	Surface	2308.61^{+}	3078.14^{+}	2565.12^{+}	1026.05^{+}	1539.07^{+}	1154.3	1799.58	1538.07^{+}	1410.82^{+}	1923.84	1795.18^{+}	397.79	1753.08^{+}
	Bottom	2308.16^{+}	3078.14^{+}	2565.12^{+}	1539.7^{+}	1539.7^{+}	1154.3	2052.1	1667.33^{+}	1410.82^{+}	2566.12	2052.1^{+}	1154.3	1923.84^{+}
April	Surface	484.77^{-}	513.02^{-}	513.02	586.51	484.77	513.02	613.02	484.77	513.02	484.77	484.77	556.60	508.50
	Bottom	484.77^{-}	641.28^{-}	513.02	584.77	556.51	556.51	641.28	484.77	556.51	484.77	484.77	556.50	549.45
July	Surface	741.28	741.28	784.28	-	684.77	756.51	841.28	713	713	713	731	584.77	726.02
	Bottom	775.54	775.64	800	-	720	756.51	860	713	713	713	731	684.77	684.53
October	Surface	826.25	761.02	413.12^{-}	413.12^{-}	413.12	565.33	478.35^{-}	347.89^{-}	304.41^{-}	391.38^{-}	340.68^{-}	210.42^{-}	455.42^{-}
	Bottom	826.25	761.02	413.12^{-}	431.12^{-}	413.12^{-}	413.12^{-}	565.33^{-}	347.89^{-}	304.41^{-}	391.38^{-}	340.68^{-}	210.42^{-}	449.99^{-}
Annual Average	Surface	1088.62	1205.49^{+}	1060.12	680.93	815.27	778.21	1064.73	737.2	749.60	966.72	915.89	645.30^{-}	893.17
value	Bottom	1159.8	1315.2^{+}	1111.51	822.8	882.5	827.4	1176.19	766.38	809.84	1121.14	980.02	726.42^{-}	976.96

Magnesium Determination

The magnesium content of the water samples of the chosen stations are given in table 4. Again it is reasonable to expect that variations in the magnesium content of the lagoon waters with position and depth might occur. Similar to calcium, the seasonal average of magnesium varies at surface and bottom from a maximum of 5,087.23 mg l^{-1} and 5,531.87 mg l^{-1} in winter to a minimum of 1,610.35 mg l^{-1} and 1,827.3 mg l^{-1} at surface and bottom. It varies regionally between an average maximum value of 2,752.8 mg l^{-1} and 3,271.02 mg l^{-1} for both surface and bottom at station 2 to a minimum of 20,61.91 mg l^{-1} and 22,66.42 mg l^{-1} at station 5 for surface and bottom, respectively. Reid (1967) and Cole (1974 and 1979), confirmed that, magnesium occur in high concentration in saline hot lake in the arid eastern region of Washington and found a layer of gypsum lying below the epsomite stratum. In addition, the dig out of the Boughazes of the lagoon increases the magnesium content of the lagoon water than that found by Yitzhak (1971). According to him, magnesium varies between a minimum of 1,550 mg l^{-1} and 1,940 mg l^{-1} for both surface and bottom in western arm, to a maximum of 2,888 mg l^{-1} and 2,918 mg l^{-1} at the main lagoon for the surface and bottom, respectively.

Sodium and Potassium/Chlorinity Ratio

The average sodium chlorinity and average potassium chlorinity ratios are calculated from the average results of sodium, potassium and chlorinity and the data are given in table 5. The average sodium chlorinity ratio for the lagoon waters at surface and bottom layers are 0.5779 and 0.5939, respectively. These ratios are higher than the average ratio of 0.5555 for sea water given by Culkin (1965). Robinson and Knapman (1941) and Lyman and Fleming (1940) agree exactly with the value 0.5556. The latter value is somewhat higher than the average of 0.5509 given by Thompson and Robinson (1932), but is in fair agreement with the ratio of 0.5549 obtained by Webb (1939). The average potassium chlorinity ratio for the brine water is 0.0285 and 0.0256 which is again higher than the average ratio of 0.0209 for sea water (Culkin 1965). Previously published results range from 0.0191 (Anderson and Thompson, 1932 and Miyake, 1939 a) to 0.0213 (Fukai and Shiokawa, 1955) suggesting that considerable variations do occur.

Variation of sodium/chlorinity ratio.

The seasonal and regional variations of the sodium/chlorinity ratio are given in table 5. The average sodium/chlorinity ratio varies between a maximum of 0.7776 and 0.7456 for the surface and bottom layers in autumn and spring, respectively and a minimum of 0.4653 and 0.4759 in summer and winter. The seasonal variation of sodium/chlorinity ratio and chlorinity values for stations 2 and 6 (table 6) are illustrated in Fig. 3.

Regionally, the sodium/chlorinity ratio varies from one station to another (table 5) according to the influence of sea water inrushing into the lagoon

TABLE 4

The Magnesium Content in mg/l^{-1} in the Bardawil Lagoon water

		Station												Seasonal
		1	2	3	4	5	6	7	8	9	10	11	12	Average
August 1985	Surface	-	2902.89	3219.24	2163.75	2585.95	2691.49	1948.12		2638.72	3219.24	3377.56	2744.27	2749.09
	Bottom	-	3852.53	4221.95	2269.3	3060.91	3272.01	3166.46	-	2777.04	3219.24	3377.56	2955.37	3217.24
November	Surface	1182.15^{-}	1733.64	2500.19	1550.25	1662.39	2315.48	2369.57	2217.84	1884.05	2932.59	2190.14	1762.66	2025.08
	Bottom	1926.26^{-}	2105.7	2667.74	2045.01	1936.82	2526.57	3087.3	2393.32	1891.96^{-}	3034.53	2961.96	2316.8	2407.83
January 1986	Surface	5603.33^{+}	6537.22^{+}	4825.09^{+}	4202.5^{+}	3502.08^{+}	5214.21^{+}	5214.0^{+}	4435.97^{+}	4280.32^{+}	4280.32^{+}	4202.5^{+}	4749.26^{+}	5087.23^{+}
	Bottom	7782.4^{+}	7704.58^{+}	5368.86^{+}	4435.97^{+}	3579.9^{+}	5214.21^{+}	5369.36^{-}	5214.21^{+}	5758.48^{+}	5758.48^{+}	4980.74^{+}	5214.21^{+}	5531.87^{+}
April	Surface	2100.25	1330.85^{-}	1011.21^{-}	933.89^{-}	1478.66	1712.13	1712.13^{-}	1556.48	1634.3^{-}	1634.3^{-}	1328.01^{-}	1400.83	1610.35^{-}
	Bottom	2023.4	1356.61^{-}	2023.42^{-}	1556.48^{-}	1867.78	2101.25	1945.6^{-}	1789.59^{-}	2177.07	1739.95^{-}	1634.3	1712.13	1827.3^{-}
July	Surface	1867.78	1789.95	1556.45	-	1400.83^{-}	1634.3^{-}	1712.13	1458.66^{-}	1945.6	1634.3^{-}	1789.95	1712.13	1682.01
	Bottom	1945.6	2179.07	2101.25	-	1556.68^{-}	1789.95^{-}	2023.42	1789.95	2179.07	1945.6	1867.75	2023.42	1945.55
October	Surface	2638.72	2216.52	2388.04	1899.88	1741.55	2137.36	1886.68	2150.56	1913.07	1718.14	3406.8	1264.64^{-}	2118.75
	Bottom	2797.04	2427.62	2388.04	1358.94^{-}	1596.4	2242.91	2731.07	2190.14	1939.46	1992.23	1337.6^{-}	1282.88^{-}	2023.69
Annual Average value	Surface	2679.65	2752.80^{+}	2583.46	2150.05	2061.91^{-}	2617.5	2473.77	2363.9	2382.68	2580.32	2715.83	2272.3	2469.51
	Bottom	3229.94	3271.02^{+}	3128.71	2333.14	2266.42^{-}	2857.82	3053.87	2675.44	2787.18	2948.34	2693.32	2584.14	2824.53

TABLE 5

Seasonal and regional variation of sodium, Potassium, Calcium and Magnesium chlorosity ratio in the Bardawil Lagoon water.

			Station 1	2	3	4	5	6	7	8	9	10	11	12	Seasonal Average
Sodium	Annual Average	Surface	0.6958	0.6549	0.6094	0.5957	0.5668	0.5962	0.4357	0.5805	0.5401	0.5233	0.6015	0.7098	0.5779
"Na"		Bottom	0.7776^{+}	0.6032	0.5269	0.5719	0.5269	0.5237	0.4093^{-}	0.6290	0.5581	0.4915	0.6726	0.7359	0.5939
Potassium "K"	Annual Average Value	Surface	0.0296	0.0267	0.0272	0.0245^{-}	0.0278	0.03339^{+}	0.0293	0.0299	0.0312	0.0311	0.03330	0.0270	0.0285
		Bottom	0.0294	0.0263	0.03100	0.02455^{-}	0.0320^{+}	0.0320^{+}	0.0271	0.0292	0.0259	0.0298	0.0290	0.0304	0.0286
Calcium "Ca"	Annual Average Value	Surface	0.0366	0.0399^{+}	0.0372	0.0321	0.0352	0.0334	0.0333	0.0271	0.0333	0.0386	0.0349	0.02647^{-}	0.0333
		Bottom	0.0362	0.0367	0.0323	0.0328	0.0312	0.0283	0.0326	0.0260^{-}	0.0291	0.0388^{+}	0.0327	0.0276	0.0323
Magnesium "Mg"	Annual Average Value	Surface	0.0908	0.0912	0.0906	0.1014	0.0890	0.1123^{+}	0.0775^{-}	0.0872	0.1098	0.1098	0.1036	0.0833	0.0922
		Bottom	0.1008^{+}	0.0914	0.0909	0.0931	0.0501^{-}	0.0978	0.0447	0.0942	0.1003	0.1000	0.0889	0.0881	0.0934

Seasonal average

Months	Sodium		Potassium		Calcium		Magnesium	
August 1985	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
August 1986	0.4653^{-}	0.5122	0.0238	0.0291	0.0407	0.0398	0.0871	0.0985
November	0.7774^{+}	0.7325	0.0467^{+}	0.0434^{+}	0.0286	0.0279	0.0838	0.0796
January	0.4880	0.4759^{-}	0.0204^{-}	0.0216	0.0771^{+}	0.0773^{+}	0.2239^{+}	0.2226^{+}
April	0.7231	0.7466^{+}	0.0382	0.0389	0.01999^{-}	0.0131	0.0633	0.0641
July	0.4198	0.4977	0.0237	0.0235	0.0241	0.0218	0.0580^{-}	0.0898^{-}
October	0.6262	0.6004	0.0209	0.017^{-}	0.0171^{-}	0.0156^{-}	0.0797	0.0700
Annual average	0.5779	0.5839	0.0285	0.0286	0.0333	0.0323	0.0922	0.0934

N.B. The maximum values are designated by (+) and the minimum values by (-).

and again the effect of the arid conditions of that lagoon. It varies from a maximum of 0.7098 and 0.7776 at stations 12 and 1 for the surface and bottom waters, respectively, to a minimum of 0.4357 and 0.4893 at station 7 for both surface and bottom. The annual average sodium/chlorinity ratio for the arid lagoon water is 0.5779 and 0.5939 at surface and bottom, respectively. No significant variation in potassium/chlorinity ratio was found with depth or geographical position (Culkin and Cox, 1966).

Variation of potassium/chlorinity ratio.

The average values of potassium/chlorinity ratio are given in table 5. They varies between a maximum of 0.0467 in autumn and a minimum of 0.0204 and 0.017 in winter and autumn, respectively. The seasonal variation of both potassium/chlorinity and chlorinity values for stations 2 and 6 (table 6) are presented graphically in Fig. 3.

The potassium/chlorinity ratio is more or less correlated with chlorinity values. Like the sodium/chlorinity ratio, it decreases in winter and increase in autumn. Regionally, the potassium/chlorinity ratio varies, for surface and bottom layers, between a maximum of 0.0339 and 0.0320 at station 6 which is far from Boughas I and unaffected directly by sea water creeping. This means that potassium/chlorinity is more or less correlated with chlorinity values. The minimum values for the surface and bottom layers, were 0.0245 and 0.02455 at station 4 which is affected directly by the sea water as shown in table 5. It must be noticed that the effect of sea water is restricted only to the nearer stations and being neglected to the farthest one (table 5). In fact there is a slight regional variation among the different stations, representing the desert lagoon. The annual average ratio for surface and bottom is 0.0285 and 0.0286, respectively.

Calcium/chlorinity ratio.

The calcium/chlorinity ratio obtained from the determined calcium and chlorinity values is given in table 6. The average calcium/chlorinity ratio for arid lagoon water ranges between 0.0379 and 0.02647 with an average value of 0.0286 at surface which is less than the value 0.0333 at bottom, both are higher than the ratio 0.02106 for oceanic waters (Culkin and Cox, 1966). Culkin and Cox (1966), confirmed that, the mean Ca/Cl%., ratio for all the deep samples collected for, the North Pacific, South Pacific, North Atlantic, Southern and Indian Oceans, was higher than for surface samples. They added that, in the Mediterranean Sea, the mean ratio was higher for the surface water than that for the deep one, the reason is not known.

Variation of Calcium/chlorinity ratio.

The average seasonal and regional Ca/Cl %. ratios are given in table 5. Contrary to the sodium and potassium, the average Ca/Cl %. ratio varies seasonaly from a maximum of 0.07771 and 0.7773 in winter for surface and bottom, to a minimum of 0.0171 and 0.0155 in autumn

Table (6)

Sodium, Potassium, Calcium and magnesium chlorinity ratio at stations 2 and 6 at Bardawil Lagoon water.

		Station 2					Station 6				
		Chlorinity %	Na^+/cl %	K^+/cl %	Ca^{+2}/cl %	Mg^+/cl %	Chlorinity %	Na^+/cl %	K^+/cl %	Ca^{+2}/cl %	Mg^+/c
August	surface	41.44	0.4609	0.0209	0.0325	0.0700	25.56	0.6534	0.0342	0.0482	0.10
1985	Bottom	47.98	0.4043	0.0250	0.0323	0.0803	43.5	0.4253	0.0276	0.0330	0.07
November	Surface	21.93	1.0146	0.0647	0.0361	0.0790	19.04	0.6040	0.0603	0.0243	0.12
	Bottom	30.31	0.8331	0.0429	0.0359	0.0694	24.89	0.5524	0.0542	0.0275	0.10
January	Surface	25.3	0.4447	0.0168	0.1217	0.2584	20.72	0.5650	0.0193	0.0553	0.25
	Bottom	25.3	0.4644	0.178	0.1217	0.3045	20.72	0.5550	0.0217	0.0557	0.25
April	Surface	27.39	1.1500	0.0365	0.0187	0.0487	21.51	0.4998	0.0444	0.0238	0.079
	Bottom	31.21	1.1214	0.0384	0.0205	0.0434	27.84	0.4849	0.0467	0.0200	0.075
July	Surface	32.72	0.5042	0.0237	0.226	0.0547	25.96	0.5489	0.0240	0.0291	0.062
	Bottom	36.46	0.7575	0.0216	0.0210	0.0589	28.15	0.6039	0.0275	0.0268	0.063
October	Surface	30.62	0.5878	0.0204	0.0248	0.724	27.47	0.6826	0.0273	0.0205	0.77
	Bottom	33.02	0.6057	0.0212	0.0230	0.0735	28.71	0.6095	0.0197	0.0125	0.078
Annual	Surface Average	30.18	0.6549	0.0268	0.0399	0.0912	23.30	0.5969	0.0339	0.0333	0.112
Value	Bottom	35.8	0.6480	0.0263	0.0367	0.0914	29.20	0.5237	0.0320	0.0283	0.097

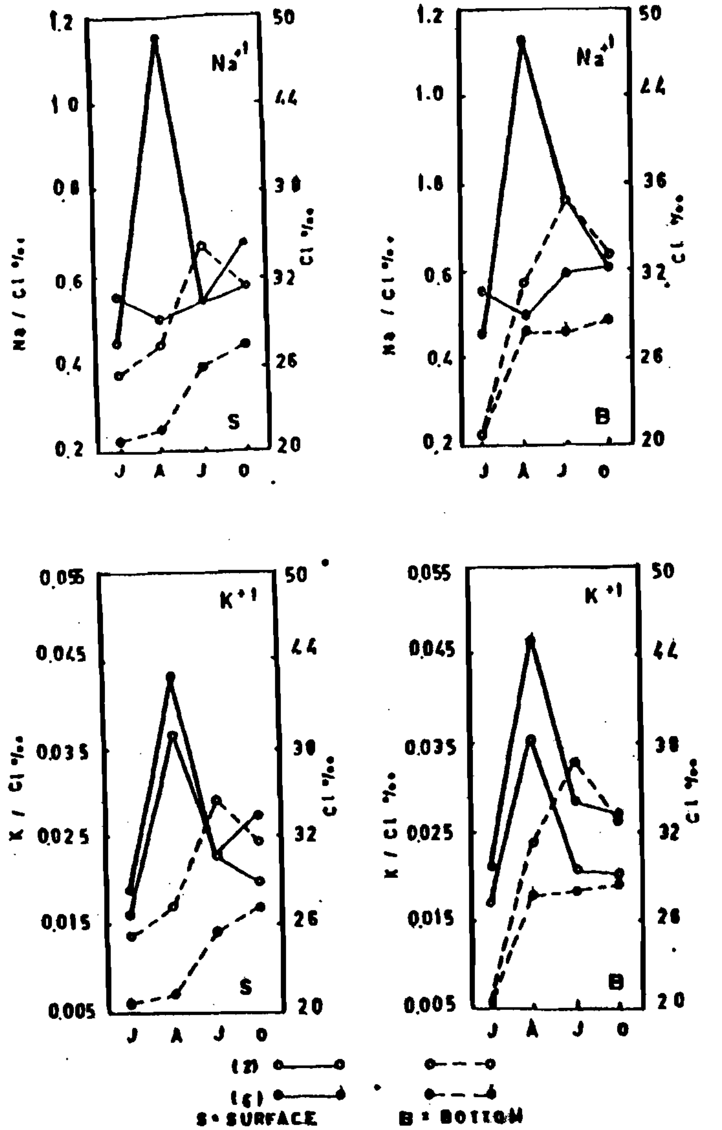

Fig. (3)
seasonal variation of cations chlorinity ratio (Na & K) and
chlorinity at stations 2 & 6 in Bardawil Lagoon
surface and bottom water.

respectively. Culkin (1965) and Wilson (1975) confirmed that, in some areas the Ca/cl % ratio may differ significantly than of sea water. Consisting high values were stated in several parts of the Northern Indian Ocean (Sen Gupta, et al., 1978; Naqvi and Reddy, 1979; Noronha, et al., 1981). The seasonal variation of the calcium/chlorinity ratio and chlorinity values for stations 2 and 6 (table 6) are presented in Fig. 3. It is clear that Ca/Cl %. is contrary to the chlorinity variation in the lagoon waters. These results confirm Ditmar (1884) and Qasim (1977), that deep water generally contains more calcium, relative to chloride, than do surface water. This can be explained as due to (a) extraction of calcium from surface water by animals forming calcareous shells and (b) Some re-solution of shells of dead animals in the lower layer where the solubility of calcium carbonate is increased by the lower temperature. Regionally the calcium/chlorinity ratio varies slightly in the twelve stations. It ranges between a maximum of 0.0399 and 0.0380 at stations 2 and 1 for surface and bottom water respectively, to a minimum of 0.02647 at the surface of station 12 and 0.0269 at the bottom of station 8. It can be noticed from table 6 that the calcium/chlorinity ratio increases in the western arm and shows a slight decrease in the eastern arm.

Magnesium/chlorinity ratio.

The magnesium chlorinity ratios obtained from the determined values of magnesium and chlorinity values are given in table 5. The magnesium/chlorinity ratio in the arid lagoon water varies from a minimum of 0.0775 and a maximum of 0.1123. Both are higher than the average value of 0.0333 for both surface and bottom which is less than the average value for sea water. Culkin and Cox (1966), confirmed that, the mean value of the magnesium/chlorinity was not significantly different for the different oceans.

Variation of magnesium/chlorinity ratio.

The average seasonal and regional values of magnesium/chlorinity ratios are given in table 6. This average ratio varies between a minimum values of 0.0559 and 0.0598, for just subsurface and near bottom respectively in summer, to a maximum of 0.02239 and 0.2224 for surface and bottom layers respectively in winter. This coincides with the observations for calcium i.e. both cations increase in winter and decrease at higher temperature, in summer, for calcium and in autumn for magnesium. This is obviously due to the geological and biological activity of both elements (Sverdrup et al., 1942; Reid, 1967 and Culkin and Cox, 1966). The seasonal variations of the Mg/Cl %. ratio and chlorinity ratio for stations 2 and 6 are presented graphically in Fig. 4. Regionally, there are variations in the magnesium/chlorinity ratio from one station to another, where there is a slight increase at the main lagoon. The regional average values of the magnesium/chlorinity ratio are 0.01123 and 0.1008. The annual average ratio for the lagoon is 0.0922 & 0.0934 at the surface and bottom waters.

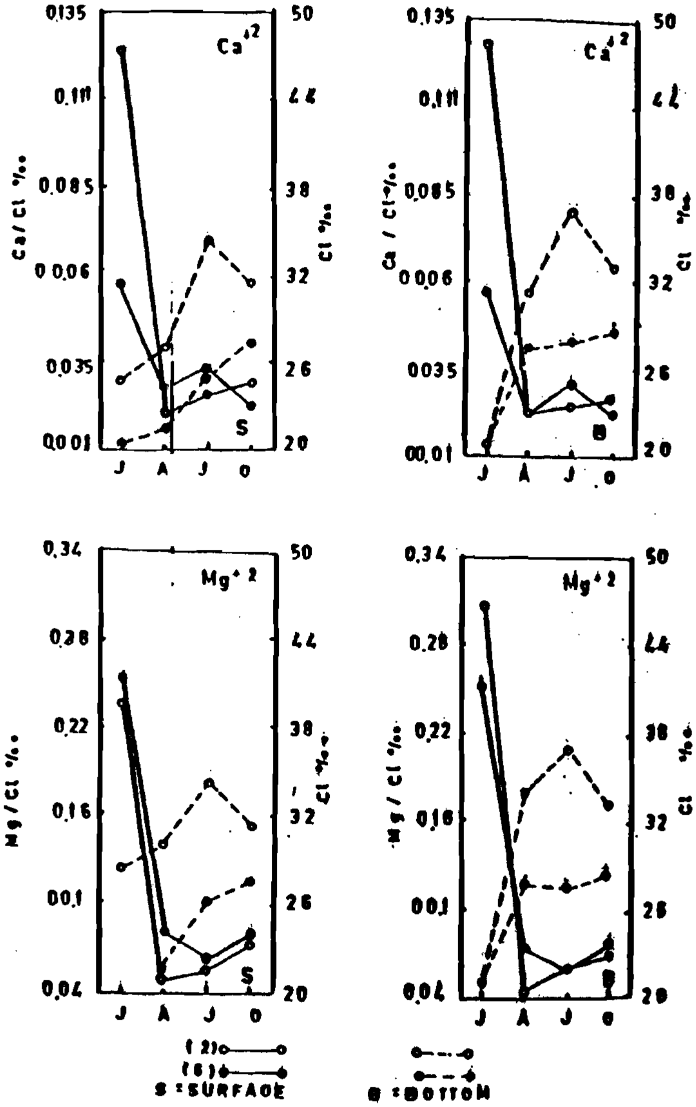

Fig. (4)
Seasonal variation of cations chlorinity ratio (Ca & Mg)
and chlorinity at stations 2 & 6 in Bardawil
Lagoon Surface and bottom water.

SUMMARY AND CONCLUSION

The concentrations of sodium, potassium, calcium and magnesium in the lagoon water are determined at twelve stations representing the different regions of the desert lagoon during summer and autumn of 1985 and the year 1986.

The significance of sodium, potassium, calcium and magnesium appears most prominantly in their essential roles in the metabolism of the various groups of aquatic plants and animals (Welch, 1952). It seems, that the more calcium and magnesium in water, other things being the same, the greater the productivity. According to Miller (1931), calcium is required by all green plants except by the lower algae. While magnesium is an important component of the chlorophyll molecule (Reid, 1967). Cole (1975) stated that, sodium might be a minor factor in eutrification.

The sodium content varies seasonaly and regionally with an annual average value of 15471.95 mg l^{-1} for surface and 17955.56 mg l^{-1} for bottom. The potassium content varies also seasonaly and regionally following the sodium variation, with an annual average content of 746.65 mg l^{-1} and 866.26 mg l^{-1} for the surface and bottom layers. The potassium concentration in the lagoon water comprises about 4.94 % and 4.8 % that of sodium for the surface and bottom waters, compared with 3.6 % in sea water. The average of Na/Cl% ratio varies between a maximum in autumn for the surface water and in spring for the bottom layer, and minimum in summer and winter for the surface and bottom waters. The K/Cl%. ratio increases in autumn for the surface and decreases in winter and autumn for the bottom layer. The annual average Na/Cl% ratio of 0.7776 and 0.7456 for the surface and bottom water of the Bardawil lagoon is higher than the average of 0.5555 given for sea water. The K/Cl% ratio has an annual average ratio of 0.0285 and 0.0286 at the surface and bottom layers which is again higher than the average value of 0.0208 for sea water.

The calcium content in the lagoon water show anormaly, caused by the dissolution of Gypsum layer from the bottom which was precepitated in the past Yitzhak, (1971). The calcium values reaches its maximum in winter, 1753.08 mgl^{-1} and 1923.04 mgl^{-1} for both surface and bottom respectively and a minimum in autumn 455.42 mgl^{-1} and 449.99 mg^{1} for surface and bottom also. According to Cole (1975), the solubility of $CaCO_3$ decreases as the temperature rises (0°-35C°). The annual average content of calcium varies between 893-17 mgl^{-1} for surface and 976.96 mgl^{-1} for the bottom. The Ca/Cl %. ratio for the lagoon water has an average value of 0.0333 and 0.0323 which is higher than the ratio of 0.02126 for oceanic water. It also varies regionally following the distribution of Gypsum in the bottom sediments (Yitzhak, 1971).

The magnesium content in the lagoon water has an average of 2469.5 and 2824.5 mgl^{-1} for the surface and bottom waters. The Mg/Cl %. ratio is contrary to chlorinity values, with annual average value of 0.0922 and 0.0934 for the surface and bottom waters. These ratios again are higher than the average ratio of 0.06692 for sea water. The Mg/Cl %. ratio varies slightly from one region to another.

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