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CHEMICAL CONDITIONS IN BARDAWIL LAGOON
V- ENRICHMENT RATIO OF THE MAJOR CATIONS AND ANIONS.

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ABSTRACT

The waters of the Bardawil Lagoon show a positive Ca SO_4 anomally. The inner Lagoon (station 7) had a chlorinity value higher than that of normal seawater (2.04 times). The enrichment "E" in Ca^{2+}, Mg^{2+}, Na^+ and Cl^- content was higher in the western arm than in the main Lagoon. The K^+, Br^- and SO_4 and HCO_3^- were higher in their enrichment in the eastern arm than in the western arm. The SO_4^-, Br^-, Cl^- and Na^+ have decreased due to the inrush of seawater through the two Bughases.

INTRODUCTION

Water of sediment samples were taken by Yitzhak (1971) at 9 stations. At each station, two water samples were taken one just under the surface and one near the bottom. The water were analysed for major cation, anions, while the sediment were indentified by X - rays.

In this study, the water samples were taken at twelve stations to cover different limnological aspects. These samples were taken by a Ruttner sampler for surface and near bottom at each station in 1985 and during 1986. The water samples were analyzed for cations and anions (Siliem 1989 a & b).

The aim and purposes of this investigation is to carry a comparative study of the enrichment ratio of the major cations and anions in relation to the open ocean water and the data obtained by Yitzhak (1971) and the importance of this to the Lagoon water especially after digout Bughase II.

RESULTS

Results of the enrichment factor "E" variations and their mean "En" for the Bardawil Lagoon waters for the major cations and anions are given in Tables 1-3. This enrichment "E" is the ratio of each ion concentration in the Lagoon to its concentration in normal seawater.

Table 1

Enrichment ratio to open Ocean concentration (Sverdrup et al., 1942) for regional average variation of major cations and anions in Bardawil Lagoon water

W = concentration in mg /l, E = Enrichment factor, Em = Mean enrichment factor

		Ca^{+2}		Mg^{+2}		Na^{+}		K^{+}		Cl^{-}		Br^{-}		So_4		HCO_3	
		W	E	W	E	W	E	W	E	W	E	W	E	W	E	W	E
Normal Sea water (Sverdrup et al., 1942)		400	1	1.270	1	10.560	1	380	1	18.980	1	64.6	1	2.650	1	140	1
1	S	1089.62	2.72	2679.65	2.11	20700	1.96	88	2.32	29.75	1.57	86.75	1.34	2724	1.86	201.44	1.44
	B	1159.05	2.9	3279.94	2.58	24900	2.36	940	2.47	32.02	1.69	89.5	1.38	3134	1.22	196.44	1.4
2	S	1205.49	3.01	2752.80	2.17	19766.67	1.87	808.33	2.13	30.18	1.59	90.75	1.41	2756.67	1.08	195.53	1.4
	B	1315.20	3.29	3271.02	2.58	23200	2.2	941.6	2.48	35.8	1.89	92.25	1.43	2929.17	1.14	199.97	1.43
3	S	1060.12	2.65	2583.46	2.03	17391.66	1.65	775	2.04	28.52	1.5	94.75	1.47	2756.67	1.08	206.14	1.47
	B	1111.51	2.78	3128.71	2.46	20750	1.97	1066.67	2.81	34.4	1.81	94.75	1.47	2929.17	1.14	199.18	1.42
4	S	680.93	1.7	2150.05	1.69	12630	1.2	520	1.37	21.2	1.12	83.33	1.29	2158	0.84	246.8	1.76
	B	822.80	2.06	2333.14	1.84	13200	1.25	615	1.62	25.05	1.32	91.0	1.41	2268.8	0.89	244.4	1.75
5	S	815.27	2.04	2061.91	1.59	13100	1.24	645.83	1.7	23.15	1.22	76.5	1.18	2156.67	0.84	229.1	1.64
	B	882.50	2.21	2266.42	1.78	16175	1.53	858.33	2.26	28.28	1.49	90.5	1.4	2706.67	1.06	227.0	1.62

Table 1 (COnt.)

6	S	778.21	1.95	2617.50	2.06	13908.33	1.32	791.67	2.08	23.3	1.73	77.5	1.2	2765	1.08	232.13	1.66
	B	827.40	2.07	2857.82	2.25	15291.67	1.45	935.89	2.46	29.2	1.54	93.0	1.44	3098.33	1.21	226.67	1.62
7	S	1064.73	2.66	2473.77	1.95	13900	1.32	937.5	2.47	31.9	1.68	118.75	1.84	3315	1.3	196.47	1.40
	B	1176.19	2.94	3053.87	2.40	17691.67	1.67	979.39	2.58	36.05	1.9	121.75	1.88	3455.83	1.35	219.3	1.57
8	S	737.20	1.84	2363.90	1.86	19950	1.51	810.0	2.13	27.1	1.43	105	1.63	2894	1.13	232.85	1.66
	B	766.38	1.92	2675.44	2.11	17850	1.69	829.58	2.18	28.38	1.5	113.75	1.76	3038	1.19	228.84	1.63
9	S	794.6	1.87	2382.68	1.88	12158.33	1.15	702.08	1.85	22.51	1.19	103.75	1.61	2715	1.06	225.43	1.61
	B	809.84	2.02	2787.18	2.19	15425	1.46	719.49	1.89	27.79	1.46	112.5	1.74	3132.5	1.22	223.7	1.6
10	S	966.72	2.42	2580.32	2.03	13100	1.24	780.42	2.05	25.04	1.32	103.5	1.6	2780.83	1.09	265.43	1.9
	B	1121.14	2.80	2948.34	2.32	14490	1.37	879.17	2.31	29.48	1.55	112	1.73	2838.33	1.11	266.03	1.9
11	S	915.89	2.29	2715.83	2.14	15766.67	1.49	866.67	2.28	26.21	1.38	100.75	1.65	2667.5	1.04	213.27	1.52
	B	980.02	2.45	2693.32	2.12	17150	1.62	870.83	2.29	29.95	1.58	109.0	1.69	3106.67	1.21	216.11	1.54
12	S	645.33	1.61	2272.3	1.79	17291.67	1.64	658.33	1.73	24.36	1.28	97.75	1.51	2877.5	1.12	224.67	1.6
	B	726.42	1.82	2584.14	2.03	19391.67	1.84	802.08	2.11	26.35	1.39	107.5	1.66	3417.5	1.34	225.33	1.61
Em	S	898.17	2.23	2469.51	1.94	15471.95	1.46	764.65	2.01	26.77	1.39	95.48	1.48	2718.9	1.06	222.88	1.59
	B	976.96	2.44	2824.53	2.22	17955.56	1.7	866.26	2.28	30.23	1.59	102.85	1.59	3096.11	1.21	222.75	1.59

Table 2

Mean Enrichment ratio to open Ocean concentration (Sverdrup et al., 1942) for regional average variation of major cations and anions in Bardawil Lagoon waters

Yitzhak (1971)									Author 1985-1986								
Western arm			Inner Lagoon			Main Lagoon			Western arm			Inner Lagoon			Main Lagoon		
Em			Em			Em			Em			Em			Em		
St. No 1	S	B	St. No 1	S	B	St. No 1	S	B	St. No 1	S	B	St. No 1	S	B	St. No 1	S	B
--	--	--	7	2.3	2.3	--	--	--	1	1.82	2.0	7	1.83	2.04	8	1.65	1.75
--	--	--	8	2.3	2.3	2	2.1	2.2	2	1.83	2.06	--	--	--	9	1.53	1.70
6	1.4	1.3	9	2.2	2.3	3	2.2	2.2	3	1.74	1.98	--	--	--	10	1.71	1.89
5	1.2	1.4	--	--	--	1	2.0	2.0	4	1.37	1.52	--	--	--	11	1.71	1.81
--	--	--	--	--	--	--	--	--	5	1.43	1.67	--	--	--	12	1.54	1.73
4	1.4	1.9	--	--	--	--	--	--	6	1.57	1.76	--	--	--	--	--	--
Em	1.33	1.53	--	2.3	2.3	--	2.1	2.13	--	1.63	1.83	--	1.83	2.04	--	1.63	1.78

S = Surface B = Bottom

Table 3

Enrichment ratio to open Ocean concentration (Sverdrup et al., 1942) for Seasonal average variation of major cations and anions in Bardawil Lagoon water

		Ca^{+2}		Mg^{+2}		Na^{+}		K^{+}		Cl^{-}		Br^{-}		SO_4		HCO_3	
		W	E	W	E	W	E	W	E	W	E	W	E	W	E	W	E
Normal Sea water (Sverdrup et al., 1942)		400	1	1.270	1	10.560	1	380	1	18.980	1	64.6	1	2.650	1	140	1
Aug.	S	1285.5	3.21	2749.09	2.16	14680	1.39	752.75	1.98	31.55	1.66^{+}	-	-	2236	0.84	233.9	1.67
1985	B	1415.83	3.54	3217.24	2.53	18220	1.73	1032.5	2.72	35.53	1.87^{+}	-	-	2780.5	1.05	242.28	1.73
Nov.	S	691.85	1.73	2025.08	1.59	18791	1.78	1129.17	2.97	24.17	1.27	-	-	1870	0.7	146.71	1.05^{-}
	B	842.13	2.11	2407.83	1.9	22137.5	2.1	1312.5	3.45^{+}	30.22	1.59	-	-	2065	0.78	146.51	1.05^{-}
Jan.	S	1753.08	4.83^{+}	5087.53	4.01^{+}	11108.33	1.05^{-}	464.58	1.22^{-}	22.72	1.2^{-}	83.75	1.3^{-}	2376.25	0.9	250.37	1.79
1986	B	1923.84	4.81^{+}	5531.87	4.35^{+}	11837.5	1.12	533.33	1.4^{-}	24.87	1.31^{-}	97.08	1.5	2802.92	1.06	250.7	1.79
Apr.	S	508.5	1.27^{-}	1610.35	1.27^{-}	18375	1.74^{-}	972.92	2.56^{+}	25.41	1.34	96.58	1.5	3275.83	0.24	296.23	2.11^{+}
	B	545.45	1.36	1827.3	1.44	21250	2.09^{+}	1110.42	2.92	28.50	1.50	102.25	1.58	3689.17	1.39	295.82	2.11^{+}
Jul.	S	726.02	1.82	1682.01	1.32	12600	1.18	714.09	1.88	30.07	1.58	110.27	1.71^{+}	3058.64	1.15	252.91	1.81
	B	684.53	1.71	1945.55	1.53^{-}	16195.45	1.53	765.91	2.02	32.54	1.71	117.73	1.82^{+}	3099.55	1.17	254.91	1.82
Oct.	S	1155.42	2.89	2118.75	1.67	16645.83	1.58	555.21	1.46	26.58	1.40	91.33	1.41	3466.67	1.31	157.17	1.12
	B	449.99	1.12^{-}	2023.69	1.29	17583.33	1.66	501.58	1.32	28.90	1.52	94.33	1.46^{-}	4139.5	1.56	152.17	1.09
Em	S	893.17	2.23	2469.77	1.94	15471.95	1.47	764.65	2.01	26.77	1.39	95.48	1.48	2718.9	1.06	222.88	1.59
	B	976.96	2.44	2824.53	2.22	17955.56	1.7	866.26	2.28	30.23	1.59	102.85	1.59	3096.11	1.27	222.75	1.59

W = concentration in mg/l , E = Enrichment factor , Em = mean enrichment factor.

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

S = Surface B = Bottom

DISCUSSION

According to Siliem (1989 a & b), the concentrations of Na^+, K^+ and Mg^{2+} are affected only by evaporation. This is confirmed by the enrichment factor "E" (Tables 1 and 2). In the same time, the enrichment "E" for Ca^{2+}, Mg^{2+}, Na+ and Cl^- contents is slightly higher in the western arm than in the main Lagoon. However, K^+, Br^-, SO_{4-} and bicarbonate alkalinity were higher in their enrichment in the eastern arm than in the western arm (Table 2). Erikson (1960 & 1961) pointed out that shallow lying ground water and lake water should have the same relative composition of the seawater ions Na^+, K^+, Mg^{2+} and Cl^- as precipitation, while a significant Ca^{2+} excess occurs in calcium-rich areas. Variations in the content levels depend on the intensity of evaporation in comparison with preciptation. Gorham (1961) thoroughly discussed five principal environmental factors; climate, geology, topography, biota and time, which interact to determine ionic composition of atmospheric precipitation, soil solutions, lake and river waters.

The seasonal variations (Table 3) show that Na^+ enrichment observed in spring (1.74) was followed by autumn (1.58). While K^+ enrichment reached its maximum in spring (2.56) and decreased towards the other season. The enrichment factors for Ca^{2+} and Mg^{2+} were alike; l.e. they increased in winter, decreased in spring and again increased during summer and autumn.

Hutchinson (1957), Cole (1975 & 1979) stated the presence of gypsum ($CaSO_4$) as sedimentary beds precipitate in the presence of high salinity (Table 3). This is in acceptance with the data obtained and indicated by the high chlorinity and low SO_{4-} content during summer and autumn 1985. This mean that the arid region of closed basins is more expansive. Again Cole added that desert waters are similar by being high in electrolytes and are quite different from dilute waters of humid regions. This coincided previously by Yitzhak (1971), who calculated the enrichment factor for the ions Na^+, K^+ and Mg^{2+} and at whose concentrations are believed to be influenced by evaporation in the Lagoon and points to a positive anomaly in both Ca^{2+} and SO_4 concentration in inner Lagoon (station 7). This is more or less in accordance with our data.

Table 3 shows that the Cl^- enrichment factor is contrary to Ca^{+2} and Mg^{+2} enrichment factors and more or less correlated to Na^+ and K^+. Comparison for Em for Ca^{+2} and the "E" for the other cations in the same sample shows that there is anomaly in Ca^{2+}. From Fig.1 we observe the effect of digging of the new Bughase II, being in the lower enrichment values Ca^{2+}, Na^+, Cl^-, Br^-, SO_{4-} and the high value of HCO_3 than that found by Yitzhak (1971). The higher enrichment values of Ca^{2+}, Mg^{+2}, K^+, and HOC_3 are indication to the waters of productive Bardawil Lagoon (Welch, 1952; Hickling, 1962; Reid, 1967; Siliem, 1974 & 1984).

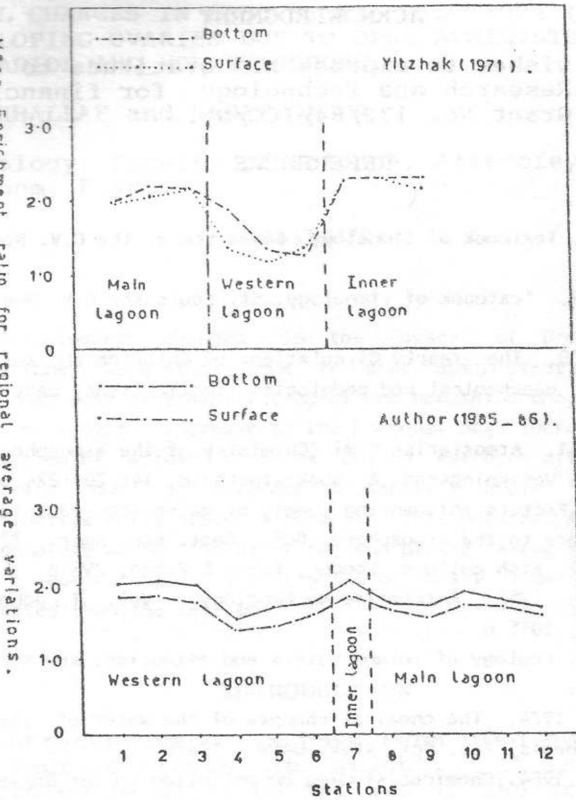

FIG. 1
Mean Enrichment ratio for regional average variations of major cations and anions in Bardawil Lagoon waters

SUMMARY AND CONCLUSION

Twelve stations were selected to cover the different parts of the Bardawil Lagoon, from the middle of 1985 and through 1986. Waters were collected and analyzed to determine the cations and anions enrichment and the effect of the new digout of Bughase II.

The Bardawil Lagoon waters show a positive Ca^{2+} and Mg^{2+} anomaly. The inner Lagoon had chlorinity higher than the western and eastern arms. The enrichment "E" for Ca^{2+}, Mg^{2+}, Na^{+} and Cl^{-} was higher in the western arm than that found in the eastern arm. However, K^{+}, Br^{-}, SO_{4-} were higher in their enrichment in the main Lagoon than in the western arm. As a result of the inrush of the Mediterranean Sea water through Bughases I & II, SO_4, Br^{-}, Cl^{-} and Na^{+} have decreased.

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