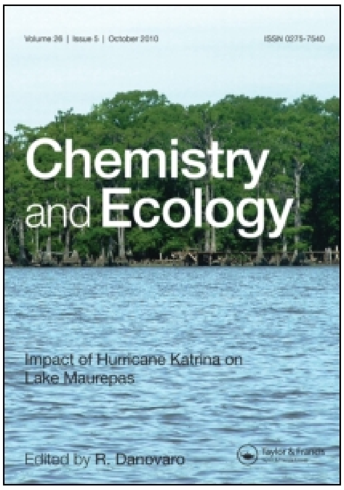

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Distribution of Alkalinity, Ph, Salinity and Carbon Dioxide Components in the Coastal Waters of Alexandria

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DISTRIBUTION OF ALKALINITY, pH, SALINITY AND CARBON DIOXIDE COMPONENTS IN THE COASTAL WATERS OF ALEXANDRIA

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The area studied is located between El-Dikheila Harbour in Elmex Bay and Mandara, at longitude 29° 47′ and 30° East and latitude 31° 8′ and 31° 17′ North. The aim of the work is to look at carbon dioxide components in this area and the effect of waste water discharged on their concentrations. Surface and bottom water samples were collected from 12 stations during January, April, August and November, 1995. Total alkalinity, salinity, temperature and pH were measured. Carbonate alkalinity, total alkalinity, partial pressure and dissolved carbon dioxide, carbonate and bicarbonate ions were calculated, since the studied area includes two different sources of pollution. It was found convenient to refer El-Mex Bay as region "A" which contains stations from I to VI and the area located between Kayet Bey outfall and Mandara which contains stations from VII to XII as region "B". When specific alkalinity is used as a tracer for El-Umum drain water it is observed that the drain water could reach Sidi Bishr area especially in August and November, while in January and April drain water did not reach this area.

Keywords: Alkalinity; pH; salinity; carbon dioxide components; Eastern Mediterranean

INTRODUCTION

The study area is located between El-Dikheila Harbour in Elmex Bay and Mandara at longitude 29° 47′ and 30° 00′ East and latitude 31° 8′ and 31° 17′ North. El-Mex Bay receives a heavy load of wastewater both directly from industrial outfalls and indirectly from Lake Maryut through the El-Umum drain. The drain discharges about 2.4×10^9 m^3 annually. The eastern part of the studied area which lie between Kayet Bey outfall and

Mandara is affected mainly by sewage discharged from the main sewer at Kayet Bey which discharges about 57 × 10^6 m^3 annually of untreated sewage and some small outfalls located on the coast of the Eastern Harbour, El-Ibrahimiya, Gleem, Sidi-Bish and Mandara.

The values of alkalinity, pH, and salinity in the studied area are used to calculate carbon dioxide components (Strickland and Parsons, 1972). The chemistry of carbon dioxide in natural waters has long interested a wide spectrum of investigators. While biologists have focused their attention on the role of carbon dioxide in photosynthetic processes, geochemists and chemical oceanographers were interested in the participation of carbon dioxide in the major geochemical cycles and also in the processes that led to the distribution of carbon dioxide in the oceans (Riley and Skirrow, 1965; Gieskes, 1974). The distribution of carbon dioxide in the surface waters is governed by six principal processes: photosynthesis, calcium carbonate formation, such advective processes as upwelling, temperature changes, evaporation and precipitation. Much work has been done to study the distribution of carbon dioxide in surface waters using the partial pressure of carbon dioxide (P_{CO_2}) as a measure (Keeling, 1968; Keeling and Waterman, 1968; Keeley and Hood, 1971). These studies have demonstrated that equilibrium rarely exists between carbon dioxide in the atmosphere and in the surface waters. Machta (1972) found that the surface mixed layer of the ocean contains about the same amount of total carbon dioxide as the atmosphere, 5 × 10^{16} mol, intermediate waters contain roughly 18 × 10^{16} mol, and the deep ocean contains 300 × 10^{16} mol.

The aim of this work is to study the distribution of temperature, pH, salinity, total alkalinity, and carbonate alkalinity and specific alkalinity, in the coastal waters of Alexandria and to calculate the carbon dioxide components for both surface and bottom water according to the equations mentioned by Strickland and Parsons (1972) using the current parameters. The second aim is to know what the effect of the discharge of different sources of pollution on the specific alkalinity and carbon dioxide components in the area.

MATERIAL AND METHODS

12 stations were sampled during January, April, August and November, 1995, from surface and bottom water of the Alexandria coast

(Figure 1). Samples were collected from surface water using a plastic sampling bottle and from the bottom layer using a Nansen reversing bottle.

Total alkalinity was determined by the titrimetric method mentioned in APHA standard methods for the examination of water and waste water (1965). Salinity was measured with a Beckman salinometer, pH was measured using a pH meter. Temperature was measured at the time of sampling using a standard thermometer ranged 0–100°C accurate to ±0.1°C. The bottom water temperature was measured using the reversing thermometer fitted in the reversing Nansen bottle. Carbonate alkalinity, total alkalinity, partial pressure and dissolved carbon dioxide, carbonate and bicarbonate ions were calculated using tables in Strickland and Parsons (1972). This method is very rapid and is advantageous practically and eliminating the need for a titration process.

Since the studied area includes two different sources of pollution. First, the El-Umum drain which discharges a huge amount of brackish water annually ($2.4 \times 10^9\ m^3$) to El-Mex Bay containing agricultural,

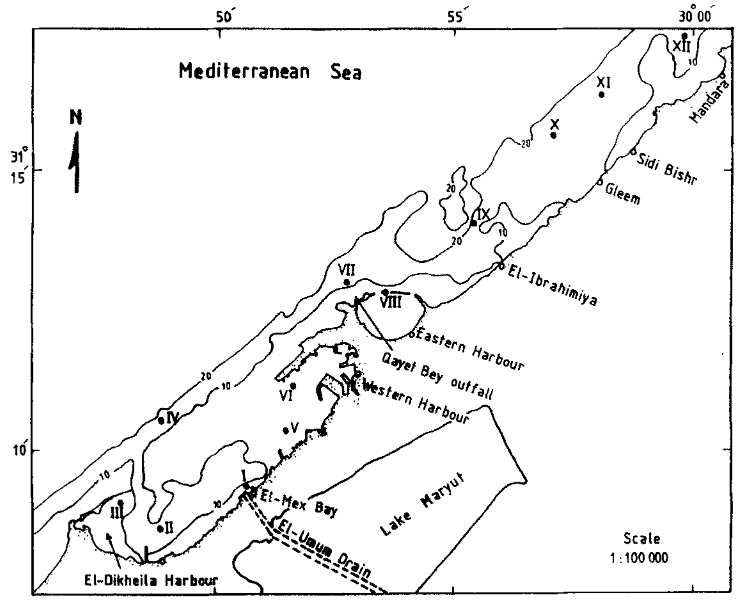

FIGURE 1 Position of sampling stations in the area investigated.

industrial and some sewage. The second source is the main sewage outfall located at Kayet Bey and some minor pipe lines discharge sewage inside the Eastern Harbour and at the eastern coast of Alexandria in front of El-Ebrahimiya, Gleem, Sidi Bishr and Mandara. It was found convenient to refer El-Mex Bay as region "A" which contains stations from number I to VI and located between El-Mex Bay and Kayet Bey outfall, and region "B" which located between Kayet Bey outfall and Mandara and contains stations from number VII to XII.

RESULTS AND DISCUSSION

Salinity

Surface and bottom distribution of salinity, pH, temperature, total alkalinity, carbonate alkalinity are tabulated in Table I. Average salinity values ranged between $25.42 \pm 4.65\text{‰}$ at the surface and $38.88 \pm 0.36\text{‰}$ at the bottom of region "A" during April and January, with an annual average of $25.89 \pm 0.38\text{‰}$ and $36.86 \pm 2.02\text{‰}$ at surface and bottom. In contrast, at region "B" they ranged between $33.95 \pm 0.31\text{‰}$ (August) and $39.5 \pm 0.20\text{‰}$ (April) at surface and from $35.32 \pm 0.23\text{‰}$ (August) to $39.82 \pm 0.11\text{‰}$ (April) at the bottom. The annual average of salinity at region "B" at both surface and bottom are 35.80 ± 2.18 and $37.07 \pm 1.84\text{‰}$. It is observed that salinity values of region "A" are lower than those at region "B"; this may attributed to the great amount of brackish water discharged to this region throughout the year through the El-Umum Drain.

Hydrogen Ion Concentration, pH

The inflow of brackish water into region "A" resulted in the decrease of surface pH to a minimum value in November, 7.98 ± 0.16 at the surface because in this month the volume of water discharged reached its maximum $208 \times 10^6\,m^3$, while in April it increased again to 8.15 ± 0.21 due to a decrease in the volume of water, $185 \times 10^6\,m^3$, in this month. The pH annual value of region "A" ranged between 8.08 ± 0.07 and 8.11 ± 0.01 in surface and bottom water. The annual value of region "B" fluctuated between 8.10 ± 0.07 and 8.05 ± 0.04 at

TABLE I Monthly and annual average concentrations of salinity (S‰), pH, temperature (Temp., °C), total alkalinity (TA, meq l^{-1}), carbonate alkalinity (CA, meq l^{-1}) and specific alkalinity, in the investigated area during January–November, 1995

Month	*Regions*		*S* ‰	*pH* °C	*Temp.* meq l^{-1}	*TA* meq l^{-1}	*CA* (ratio)	*Specific Alkalinity*
January	A	s	26.228 ± 7.173	8.105 ± 0.164	17.367 ± 0.386	2.587 ± 0.377	2.525 ± 0.3650	0.189 ± 0.051
		b	38.875 ± 0.362	8.095 ± 0.028	17.483 ± 0.261	2.700 ± 0.119	2.609 ± 0.1180	0.126 ± 0.005
	B	s	34.500 ± 3.688	8.104 ± 0.046	16.733 ± 1.115	2.653 ± 0.206	2.581 ± 0.1930	0.139 ± 0.007
		b	37.690 ± 3.342	8.085 ± 0.041	16.617 ± 0.534	3.040 ± 0.249	2.956 ± 0.2580	0.148 ± 0.029
April	A	s	25.415 ± 4.467	8.154 ± 0.205	21.100 ± 0.356	3.507 ± 0.333	3.441 ± 0.3610	0.263 ± 0.075
		b	38.862 ± 0.295	8.122 ± 0.023	19.867 ± 0.160	2.620 ± 0.038	2.531 ± 0.0390	0.122 ± 0.002
	B	s	39.500 ± 0.204	8.095 ± 0.042	20.917 ± 0.604	2.787 ± 0.082	0.128 ± 0.0037	0.128 ± 0.004
		b	39.817 ± 0.109	8.095 ± 0.039	19.750 ± 0.472	2.700 ± 0.200	0.123 ± 0.0013	0.123 ± 0.001
August	A	s	26.298 ± 2.449	8.100 ± 0.249	30.100 ± 0.337	3.533 ± 0.224	0.249 ± 0.0420	0.249 ± 0.042
		b	35.080 ± 0.457	8.097 ± 0.281	28.800 ± 0.000	2.720 ± 0.052	0.140 ± 0.0040	0.140 ± 0.004
	B	s	33.950 ± 0.312	8.207 ± 0.173	29.450 ± 0.577	2.927 ± 0.257	0.156 ± 0.0140	0.156 ± 0.014
		b	35.315 ± 0.229	8.022 ± 0.110	28.683 ± 0.211	2.660 ± 0.045	0.137 ± 0.0030	0.137 ± 0.003
November	A	s	25.608 ± 4.602	7.978 ± 0.160	23.667 ± 0.399	3.711 ± 0.377	0.249 ± 0.0620	0.249 ± 0.062
		b	34.617 ± 0.661	8.108 ± 0.046	24.067 ± 0.249	2.848 ± 0.081	0.153 ± 0.0060	0.153 ± 0.006
	B	s	35.266 ± 0.391	8.006 ± 0.068	24.417 ± 0.297	2.977 ± 0.119	0.153 ± 0.0070	0.153 ± 0.007
		b	35.465 ± 0.094	8.000 ± 0.114	24.433 ± 0.197	2.875 ± 0.044	0.146 ± 0.0030	0.147 ± 0.003
Annual Average	A	s	25.887 ± 0.383	8.084 ± 0.065	23.059 ± 4.642	3.335 ± 0.439	3.271 ± 0.4400	0.238 ± 0.029
		b	36.859 ± 2.017	8.106 ± 0.011	22.554 ± 4.308	2.722 ± 0.082	2.653 ± 0.1180	0.135 ± 0.012
	B	s	35.804 ± 2.184	8.103 ± 0.071	22.879 ± 4.668	2.836 ± 0.127	2.751 ± 0.1240	0.144 ± 0.011
		b	37.072 ± 1.843	8.051 ± 0.040	22.371 ± 4.845	2.815 ± 0.151	2.732 ± 0.1580	0.139 ± 0.010

s = surface; b = bottom.

surface and bottom, and pH values fluctuated between 8.0 ± 0.07 and 8.21 ± 0.17 in August and November at surface and between 8.0 ± 0.11 (November) and 8.09 ± 0.04 (April) in bottom water. The increase of pH values of bottom water of region "A" and its decrease in region "B" may be due to the extent to which carbon dioxide content of the bottom water is modified by biological activity. Although variations in the salinity affected the pH values, the predominant factor that affected pH in our studied area is the total carbon dioxide content or its partial pressure.

Temperature

Average temperature values at region A ranged between 17.37 ± 0.39°C and 30.1 ± 0.34°C in January and August at surface, while at the bottom they ranged from 17.48 + 0.26°C to 28.8 ± 0.0°C in the same months. At region "B", the surface temperature is lower than in region "A" and ranged from 16.73 ± 1.11°C to 29.45 ± 0.58°C. The bottom water temperature ranged between 16.62 ± 0.53°C and 28.68 ± 0.21°C in January and August. Higher and lower values of temperature at both regions are coincident with air temperature. The annual average values of temperature at both regions at the surface are 23.05 ± 4.64°C (region A) and 22.88 ± 4.67°C (region B), while at the bottom water they are 22.55 ± 4.31°C (region A) and 22.37 ± 4.85°C (region B).

Total Alkalinity and Carbonate Alkalinity

In the case of total alkalinity and carbonate alkalinity surface samples have higher annual average value in region "A", 3.335 ± 0.439 meq l^{-1} (total), and 3.27 ± 0.44 meq l^{-1} (carbonate) than the bottom ones, 2.722 ± 0.082 meq l^{-1} and 2.653 ± 0.118 meq l^{-1}. On the other hand, region "B" surface and the bottom water have almost the same annual average values 2.836 ± 0.127 and 2.751 ± 0.124 meq l^{-1} at surface and 2.815 ± 0.151 and 2.732 ± 0.158 meq l^{-1} at the bottom. It can also be observed that region "A" has a higher total and carbonate alkalinity content than region "B" due to the effect of brackish water discharged with a higher content of total and carbonate alkalinity from the El-Umum drain. The low values in the bottom waters are ascribed to the loss of calcium carbonate by organisms possessing calcareous skeleton.

Whether or not calcium carbonate dissolves again while sinking through the water column depends upon the degree to which the water is saturated with these compounds. Higher levels of alkalinity may be attributed to the lower dissolved oxygen content in the El-Umum drain water. The lower oxygen content is an indicator of the higher content of carbon dioxide and hence greater solubility of calcium carbonate.

In El-Mex Bay, especially in the near-shore stations which are affected greatly by the discharge of brackish water, the water contains relatively larger quantity of calcium carbonate, and in the region of marked dilution there is a great increase in alkalinity. This may be attributed to the volume of brackish and waste water discharged to the Bay or possibly due to the decomposition of the bottom organic matter by biological processes.

Specific Alkalinity

The term "specific alkalinity" which is calculated as milliequivalents per unit chlorinity, this is introduced to facilitate the comparison of the alkalinities of various bodies of water. According to Koczy (1956) different water masses frequently have characteristic alkalinities, which usually lie in the range 0.119–0.130. Such variety appears to be associated in some complex fashion with difference in the calcium content in the waters. The annual average values of specific alkalinity at surface water in region "A" is 0.238 ± 0.029 decreasing with depth to 0.135 ± 0.012, while in region "B" which is not affected by brackish water discharge, specific alkalinity values are constant at both surface and bottom water and are almost equal to 0.144 ± 0.011 and 0.139 ± 0.01. Higher values at the surface water of region "A" are attributed to low chlorinity values in comparison with higher chlorinity values of region "B".

The specific alkalinity of region "B" indicates that this area represents almost true sea water. In normal sea water, different water masses frequently characterise specific alkallinities which usually lie in the range 0.119–0.130 with a mean value of 0.126. In brackish water the ratio may be increased tremendously if the river water is high in bound carbonate compounds.

Total carbon dioxide content, partial pressure of carbon dioxide, P_{CO_2}, dissolved carbon dioxide, bicarbonate and carbonate ions concentration have been calculated for both surface and bottom samples according to the equations mentioned in Strickland and Parsons (1972). Average monthly values for surface and bottom samples are given in Table II.

Total Carbon Dioxide

The annual average value of total carbon dioxide in surface and bottom water in region "A" is 2.792 ± 0.431 mM and 2.507 ± 0.123 mM and in region "B" the values were 2.630 ± 0.139 mM and 2.644 ± 0.199 mM. Higher content of total carbon dioxide in the bottom water of region "B" than "A" may be attributed to respiration and decomposition by microbiological agents leading to the production of carbon dioxide in addition to the circulation of water, and plays an important role in the distribution of total carbon dioxide or may reflect possibly the dissolution of calcium carbonate skeletal material.

Undissociated Dissolved Carbon Dioxide (Dissolved CO_2)

This content in the investigated area is very low especially in the bottom water of region "B"; its annual value is $0.017 \times 10^{-3} \pm 3.269 \times 10^{-3}$ mM. In the surface water of regions "A" and B its concentrations are $0.0209 \times 10^{-3} \pm 4.982 \times 10^{-3}$ mM and $0.0236 \times 10^{-3} \pm 7.044 \times 10^{-3}$ mM. At region "B" surface values reached their maximum in August, 0.034 ± 0.04 mM. This is coincident with a maximum temperature of 29.45 ± 0.577°C, a minimum salinity of 33.95 ± 0.31‰, maximum pH 8.207 ± 0.173. On the other hand, undissociated dissolved carbon dioxide within region "B" reached its minimum content in April and November.

Partial Pressure of Carbon Dioxide, P_{CO_2}

The values of P_{CO_2} are of interest due to several reasons, most of which centre around the significance of the variations in this parameter and the possibility that the values of P_{CO_2} serve as an indicator of chemical and physical changes. The dynamics of the carbon dioxide system in sea water can be studied by the use of P_{CO_2} and pH, which is the most precise way to study the changes due to biological activity and

TABLE II Monthly and annual average concentrations of total carbon dioxide (T CO_2), partial pressure (P_{CO_2}, pressure), dissolved (d CO_2), bicarbonate $(HCO_3)^-$ and carbonate ions $(CO_3)^{2-}$ in mM, in the investigated area during January–November, 1995

Month	*Regions*		TCO_2	P_{CO_2}	$d\,CO_2$	$[HCO_3]^{-1}$	$[CO_3]^{2-}$
January	A	s	2.055 ± 0.466	$4.405 \times 10^{-4} \pm 1.611 \times 10^{-4}$	0.01420 ± 0.0087	2.261 ± 0.3160	0.1540 + 0.0820
		b	2.500 ± 0.141	$3.95 \times 10^{-4} \pm 1.496 \times 10^{-4}$	0.01450 ± 0.0055	2.212 ± 0.1060	0.2030 + 0.0095
	B	s	2.504 ± 0.128	$4.947 \times 10^{-4} \pm 0.851 \times 10^{-5}$	0.01850 ± 0.0033	2.227 ± 0.1370	0.1798 + 0.0290
		b	2.906 ± 0.377	$5.37 \times 10^{-4} \pm 9.47 \times 10^{-5}$	0.02080 ± 0.0038	2.499 ± 0.2920	0.2040 + 0.0190
April	A	s	2.938 ± 0.285	$5.61 \times 10^{-4} \pm 2.58 \times 10^{-4}$	0.01930 ± 0.0077	2.956 ± 0.5620	0.2420 + 0.1030
		b	2.354 ± 0.037	$4.25 \times 10^{-4} \pm 0.06 \times 10^{-4}$	0.01370 ± 0.0014	2.133 ± 0.0899	0.2100 + 0.0059
	B	s	2.505 ± 0.093	$4.74 \times 10^{-4} \pm 0.67 \times 10^{-4}$	0.01595 ± 0.0021	2.248 ± 0.0996	0.2220 + 0.0140
		b	2.418 ± 0.050	$4.54 \times 10^{-4} \pm 0.54 \times 10^{-4}$	0.01610 ± 0.0020	2.188 ± 0.0500	0.2110 + 0.0140
August	A	s	3.046 ± 0.191	$8.71 \times 10^{-4} \pm 5.82 \times 10^{-4}$	0.02210 ± 0.0148	2.783 ± 0.5110	0.3350 + 0.1540
		b	2.477 ± 0.189	$7.9 \times 10^{-4} \pm 4.578 \times 10^{-4}$	0.02196 ± 0.0126	2.099 ± 0.3310	0.2630 + 0.1350
	B	s	2.670 ± 0.287	$0.122 \times 10^{-4} \pm 0.146 \times 10^{-4}$	0.03400 ± 0.0400	2.167 ± 0.2130	0.3270 + 0.1060
		b	2.487 ± 0.092	$7.827 \times 10^{-4} \pm 2.12 \times 10^{-4}$	0.02200 ± 0.0060	2.143 ± 0.1210	0.2070 + 0.0490
November	A	s	3.130 ± 0.275	$0.103 \times 10^{-4} \pm 3.69 \times 10^{-4}$	0.02800 ± 0.0080	3.040 ± 0.5370	0.3200 + 0.2680
		b	2.696 ± 0.056	$5.72 \times 10^{-4} \pm 8.7 \times 10^{-4}$	0.01800 ± 0.0030	2.377 ± 0.0710	0.2360 + 0.0250
	B	s	2.841 ± 0.088	$8.07 \times 10^{-4} \pm 2.13 \times 10^{-4}$	0.02600 ± 0.0070	2.780 ± 0.5430	0.2030 + 0.0300
		b	2.763 ± 0.074	$7.95 \times 10^{-4} \pm 2.59 \times 10^{-4}$	0.02500 ± 0.0080	2.410 ± 0.0980	0.1960 + 0.0420
Annual Average	A	s	2.792 ± 0.431	$7.25 \times 10^{-4} \pm 2.35 \times 10^{-4}$	$0.02090 \pm 4.982 \times 10^{-3}$	2.749 ± 0.3210	0.2630 + 0.0720
		b	2.507 ± 0.123	$5.47 \times 10^{-4} \pm 1.59 \times 10^{-4}$	$0.01700 \pm 3.269 \times 10^{-3}$	2.205 ± 0.1070	0.2280 + 0.0240
	B	s	2.630 ± 0.139	$7.49 \times 10^{-4} \pm 3.02 \times 10^{-4}$	$0.02360 \pm 7.044 \times 10^{-3}$	2.356 ± 0.2470	0.2320 + 0.0560
		b	2.644 ± 0.199	$6.47 \times 10^{-4} \pm 1.43 \times 10^{-4}$	$0.02120 \pm 3.53 \times 10^{-3}$	2.310 ± 0.1490	0.2050 + 0.0055

s = surface; b = bottom.

carbonate dissolution effect (Martin, 1970). Krogh (1910) determined the partial pressure of carbon dioxide in a series of samples from the sea surface between Scotland and Canada, indicating a P_{CO_2} amounting to 30×10^{-5} atmospheres. Buch (1939) has made similar observations during summer months. In this study, the P_{CO_2} in the surface water was found experimentally and by calculation varied with an average some 5% less than in the atmosphere. Buch (1939) found that P_{CO_2} to be around 29×10^{-5} atmosphere in temperate regions and 15×10^{-5} in Arctic waters. Shriadah (1982) also found in Alexandria that the P_{CO_2} in the Eastern Harbour is 0.5068×10^{-3} atmosphere.

The monthly average values of P_{CO_2} in the two regions is more or less equal but in August the surface water of region "B", the P_{CO_2} content reached its minimum average value, $0.122 \times 10^{-4} \pm 0.146 \times 10^{-4}$ atmosphere. This is coincident with a very high content of undissociated dissolved carbon dioxide, maximum temperature 29.45 ± 0.577°C, pH = 8.207 ± 0.173 and minimum salinity 33.95 ± 0.31‰. This may be attributed to an increase in the quantity of phytoplankton in this month. El-Sherief (1994) found that plankton reached a maximum quantity in August. This means that in August carbon dioxide is consumed by phytoplankton decreasing its concentration and the pH increases because carbon dioxide system is shifted to produce carbon dioxide. In November in region "A", P_{CO_2} content decreased to a minimum value $0.1028 \times 10^{-4} \pm 3.69 \times 10^{-4}$ atmosphere, correlated with a low pH value (7.978 ± 0.16), high content of undissociated dissolved carbon dioxide (0.028 ± 0.008 mM) and low salinity (25.608 ± 4.602‰).

Carbonate and Bicarbonate Ions

Due to the close relationship between bicarbonate and carbonate content in sea water, they are better to be discussed together. As shown in Table II, bicarbonate is more generally abundant than carbonate in the whole investigated area. The annual average values of bicarbonate in region "A" are 2.749 ± 0.321 mM and 2.205 ± 0.107 mM at surface and bottom water. Carbonate content in surface and bottom are 0.263 ± 0.072 mM and 0.228 ± 0.024 mM at the same area. In region "B", bicarbonate content in both surface and bottom are more or less equal, 2.356 ± 0.247 mM and 2.310 ± 0.149 mM. The annual average values of carbonate in both surface and bottom of the same region are

0.232 ± 0.056 mM and 0.205 ± 0.005 mM. In region "A", bicarbonate content is 10 times greater than carbonate in both surface and bottom water, while in region "B" the ratio is 11 times higher. In both regions, the general trend of bicarbonate is to decrease with depth. Limited carbonate data are due mainly to the presence of carbon dioxide in excess converting it into bicarbonate. The monthly variation of bicarbonate and carbonate ions are related to the duration of the high discharge of the El-Umum drain and elevated temperature during summer.

Figures 2, 3 and 4 illustrate the horizontal distribution of salinity, alkalinity and specific alkalinity in regions "A" and "B". It is observed that region "A" is characterized by having lower salinity, higher alkalinity and specific alkalinity in the investigated period than that of region "B" (Table I). It is also observed that specific alkalinity in region "B" is affected by sewage outfalls located at the beaches and the main sewage outfall at Kayet Bey is more or less constant in both surface and bottom water at 0.14 meq l^{-1}. In region "A", which is affected greatly by brackish water from the El-Umum drain, specific alkalinity

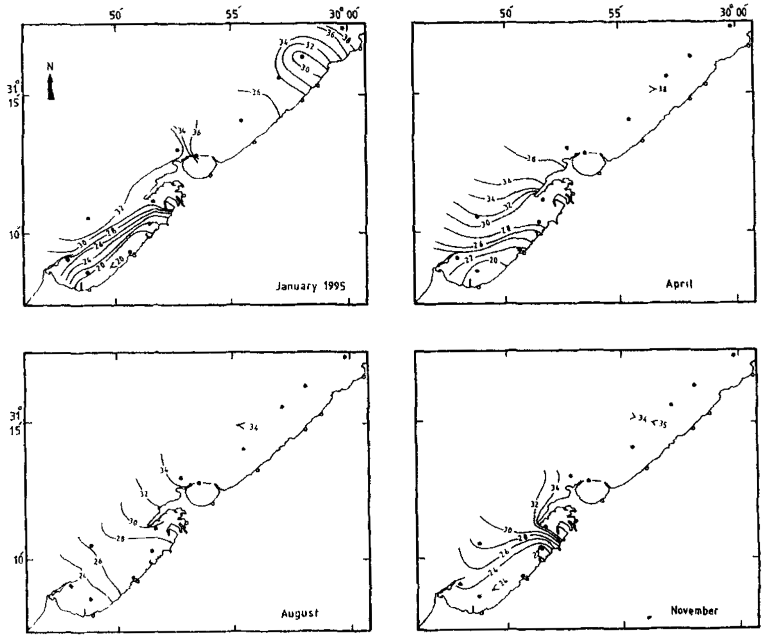

FIGURE 2 Horizontal distribution of salinity (S‰), in January, April, August and November 1995 in the coastal water of Alexandria.

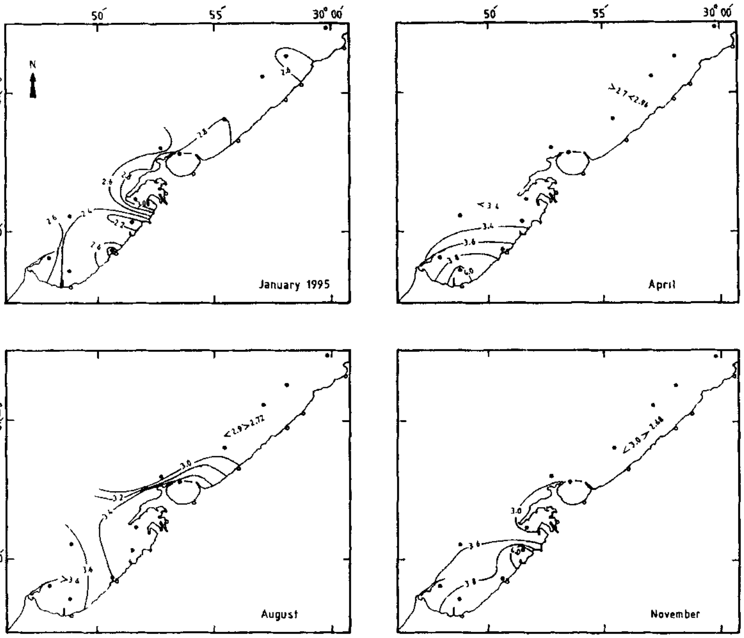

FIGURE 3 Horizontal distribution of alkalinity (meq l^{-1}) in January, April, August and November 1995 in the coastal area of Alexandria.

in the surface water doubles that in the bottom one. According to Wong (1988), sea water approximates to shelf molar sodium chloride solution with a rather uniform alkalinity of about 2.3 meq l^{-1}, but the composition of river water can be much more variable. Average river water usually dilutes calcium bicarbonate solution (Garrels and MacKenzie, 1971). Since bicarbonate is the dominant contributor to alkalinity in river and sea water, thus although average river has lower alkalinity, it should have a much higher specific alkalinity than sea water. As a result, specific alkalinity may serve as a tracer for characterizing the riverine end-member in the mixing between river and sea water. Park (1966) and Park *et al.* (1969) have used specific alkalinity to demonstrate successfully the extent of the penetration of the outflow of the Columbia River into the adjacent marine waters off the coast of Oregon. Pelletier and Lebel (1979) and Sharp *et al.* (1982) have also shown that alkalinity may be used to identify the influence of the waters from the St Lawrence River and Delaware River on the

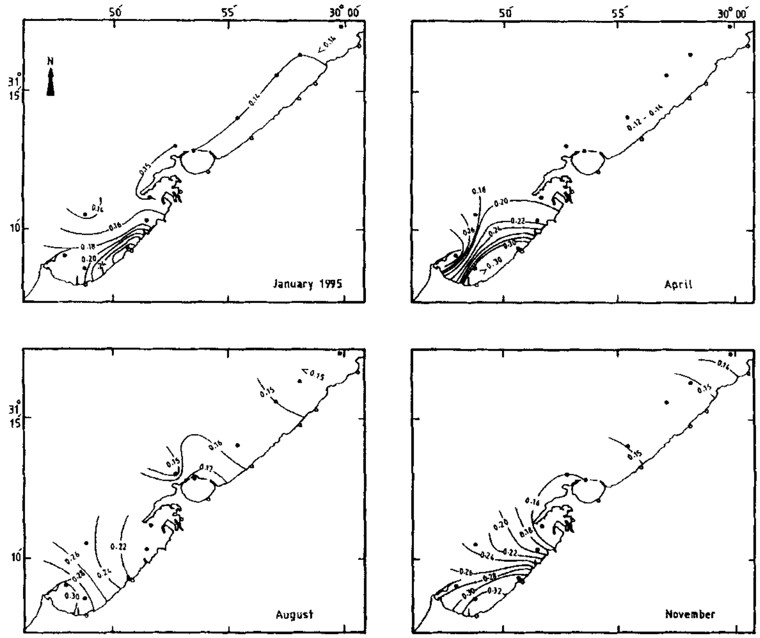

FIGURE 4 Horizontal distribution of specific alkalinity in January, April, August and November 1995 in the coastal water of Alexandria.

decomposition of adjacent coastal water. Although the range of specific alkalinity in the open oceans is small as a result, alkalinity and specific alkalinity have become a widely accepted oceanic tracers (Koczy, 1956; Sen Gupta and Pylee, 1968; Turekian *et al.*, 1971; Fiadeiro, 1980). In the investigated area, specific alkalinity could serve as a tracer for characterizing the brackish water from the El-Umum drain in region "A", while sewage waste water in region "B" comes from sewage outfalls. If specific alkalinity is used in the investigated area as a tracer for the El-Umum drain water, the drain water could reach Sidi Bishr area to the east of the drain causing an increase in its specific alkalinity, especially in August and November, and a decrease in its salinity. In January and April, drain water did not reach region "B" and its specific alkalinity is more or less constant.

Comparing data for total alkalinity, specific alkalinity and carbon dioxide components in other studies in different areas are shown along with results of the present study in Table III. It can be seen that

TABLE III Concentrations of total alkalinity, carbonate alkalinity, specific alkalinity and carbon dioxide components reported from the same area (average values). Data from the present study are included for comparison

Ecosystem	*Total alkalinity*	*Carbonate alkalinity*	*Specific alkalinity*	*Total CO_2*	*Dissolved CO_2*	P_{CO_2}	*carbonate ion*	*bicarbonate ion*	*References*
Abu Qir Bay	2.479	–	0.1202	–	–	–	–	–	Tayel and Shriadah, 1992
Western Harbour	3.0201	–	0.1458	–	–	–	–	–	Shriadah, 1992
Eastern Harbour	2.7192	–	0.1274	–	–	–	–	–	Shriadah and Emara, 1992
El-Mex Bay	3.4087	–	0.3493	–	–	–	–	–	Shriadah and Emara, 1992
Eastern Harbour	2.53–2.72	2.43–2.65	0.1272	2.19–2.49	10.96×10^{-3}–26.65×10^{-3}	0.3481×10^{-3}–0.8223×10^{-3}	0.1737–0.2440	1.9317–2.2873	Shriadah, 1982
Region A s	3.335	3.271	0.23750	2.792	0.0209×10^{-3}–	7.251×10^{-4}	0.263	2.749	Present study
b	2.722	2.653	0.13525	2.507	0.0170×10^{-3}	5.47×10^{-4}	0.228	2.205	
Region B s	2.836	2.751	0.1440	2.630	0.0236×10^{-3}	7.49×10^{-4}	0.232	2.356	Present study
b	2.815	2.732	0.1385	2.644	0.0212×10^{-3}	6.472×10^{-4}	0.205	2.310	

s = surface; b = bottom.

there are quite substantial differences that can be attributed to differences in waste water content. El-Mex Bay and Western Harbour are affected mainly by a discharge of brackish water from the El-Umum drain mainly agricultural and industrial wastes, while Abu Qir Bay is mainly affected by industrial waste and the Eastern Harbour is affected by sewage discharged to it through minor outfalls and the main outfall at Kayet Bey. Total alkalinity values in region “A” of the present study (3.335 and 2.722 meq l^{-1}) are more or less equal to that of the Western Harbour and El-Mex Bay (3.020 meq l^{-1} and 3.4087 meq l^{-1}). In Abu Qir Bay and the Eastern Harbour total alkalinity content (2.479 meq l^{-1} and 2.719 meq l^{-1}) are more or less equal to that of region “B”, and its concentration is lower in region “A”. Specific alkalinity measurements are constants for Abu Qir Bay, Western Harbour, Eastern Harbour and region “B”. Shriadah and Emara (1992) found that specific alkalinity of El-Mex Bay is 0.3493 which is much higher than its values for the previously mentioned areas. This may be attributed to increase in the volume of brackish water discharged in that time. Shriadah (1982) and the present study used the same tables of Strickland and Parsons (1972) to calculate carbon dioxide components of the Eastern Harbour because this method is rapid and is practically advantageous. It is observed that total carbon dioxide, partial pressure of carbon dioxide, carbonate and bicarbonate ion content are more or less equal at the Eastern Harbour and in regions “A” and “B”. Dissolved carbon dioxide content in the studied areas is less than that in the Eastern Harbour.

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