Bull. Inst. Oceanogr. & Fish., ARE, 13 (2), 1987: 121 - 132

IMPACT OF SEWAGE DISCHARGE ON THE WATER QUALITY OF THE EASTERN HARBOUR OF ALEXANDRIA. I- ENVIRONMENTAL SURVEY.

N.M. DOWIDAR; F. EL-NADY; T. A. ABOUL-KASSIM AND A.R. ABDEL-MOATI.

Oceanography Department, Faculty of Science, Alexandria University, Egypt.

ABSTRACT

The coastal waters of Alexandria receives annualy about 183 x 10^6 m^3 of untreated sewage. About 20% of this amount is discharged to the Eastern Harbour rendering it highly fertile. The effect of waste water and sewage discharge on the physicochemical characteristics (temperature, transparency, salinity, pH and alkalinity) of the Harbour water were carefully studied and discussed.

INTRODUCTION

In recent years, the problem of sewage pollution of Alexandria coastal waters has become a point of national concern. Signs of this kind of pollution have already been observed in the last few years along the shores of Alexandria. Admittedly, the disposal of the untreated sewage, even in the open sea may be harmful concerning its possible hygienic and aesthetical effects and its impact on fauna and flora in the marine environment. The effect is directly proportional to the quantity and quality of the sewage discharged and the capacity of environment to assimilate, degrade and disperse these allochthonous pollutants.

Over 183 x 10^6 m^3 of untreated sewage and waste waters are discharged annually into the coastal waters of Alexandria through several sewers, distributed along the coast (Aboul-Kassim, 1987). Out of this amount about 35 x10^6 m^3 are discharged into the Eastern Harbout of Alexandria through several out falls, (Fig. 1). This quantity is about 2.3 times the water volume of this basin. Accordingly, the flushing rate would be about 5 months. Furthermore, due to local water circulation, the harbour receives an additional amount of sewage polluted water from the main sewage outfall (Kayet Bey) situated in its vicinity and discharges about 96 x 10^6 m^3 of raw sewage annually. This condition has rendered the water of the harbour highlyeutrophic.

The present work aims to study some physico-chemical parmeters of the harbour water and the effect of sewage pollution on these character

MATERIAL AND METHODS

The Eastern Harbour (E.H.) is a relatively shallow semi-closed basin,

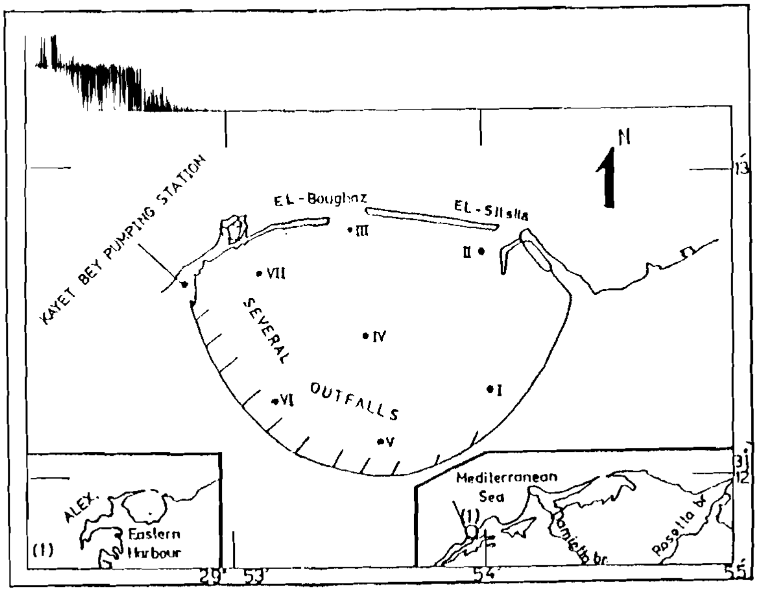

Fig. (1)
Sampled stations in the Eastern Harbour during the period 1985-1986.

situated between longitudes 29° 53' to 29° 54.4' E and latitudes 31° 12' to 31° 13' N (Fig. 1). The Harbour is sheltered from the sea by an artificial wawe-breaker, leaving two openings through which the exchange between the harbour water and the neritic Mediterranean waters takes place.

The area of the E.H. is about 2.53 x 10^6 m^2 with an average depth of 6 m. The maximum depth recorder during the study period was 9.5 m. Accordingly its water volume is estimated at about 15.2 x 10^6 m^3.

In the present study, sampling was carried out at regular bimonthly intervals throughout the period from May 1985 to May 1986. Seven stations were selected to cover the different ecological areas of the Harbour, (Fig 1). Sixteen surface and subsurface water samples were collected using a five liter Niskin water sampler.

Transparency of water was measured at each station using a white enamelled secchi disc 30 cm in diamerter. The electrical conductivity of the Harbour water was measured using a portable induction salinometer (Beckman RS-7C). Salinity was computed from the conductivity ratio using UNESCO tables (Relis, 1965). Measurements of ph_{and} total alkalinity were determined according to Strickland and Parsons (1972)

Data of total suspended matter and chlorophyll$\underline{a}$ biomass were simultaneously measured by Aboul-Kasim (1987).

RESULTS

The absolute surface water temperature varied between a minimum of 16.9° C and a maximum of 29.2°C. The bottom values ranged between 17.0 and 28.5 °C. The annual average of the whole area was 22.2 $\pm$ 4.61°C at the surface and 22.1 $\pm$ 4.2°C near the bottom (Table 1). Figure 2 shows the monthly variations of the amplitudes and the average surface and bottom water temperatures observed in the Harbour during the study period.

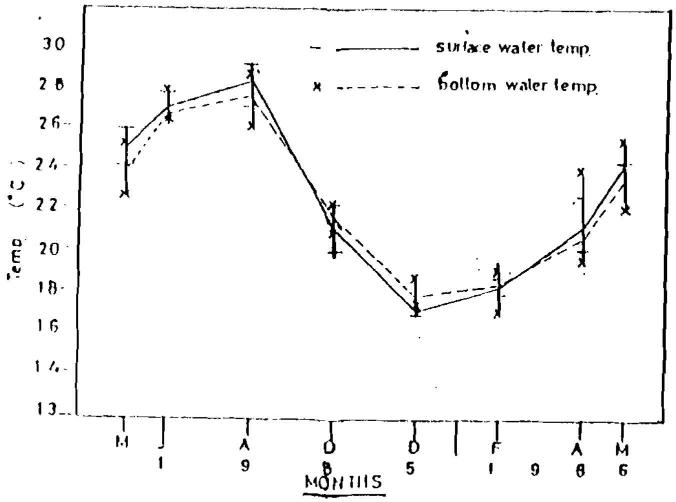

Fig. (2)
Amplitude and mean surface and bottom water temperature in the E.H. during 1985-1986.

Generally, the transparency of the Harbour water was relatively high. The annual average depth of secchi disc visibility varied between a minimum of 1.73 m at station V and a maximum of 3.79 m at station III (Table 1). The lowest values were recorded at stations (I,V and VI) subjected to the direct effect of sewage discharge. The monthlys variations of transparency in different stations of the Harbour basin showed a maximum average value (3.50 m) during April while the minimum average (1.68 m) was observed in August.

During the period of investigation, the absolute values of surface salinity in the E.H. varied between a minimum of 34.78 %° and a maximum of 39.21 %°. The horizontal distribution of salinity in the Harbour water is shown in figure 3, revealing that surplus water from the Harbour flows outward as a mixed surface layer through the main openings (stations II and III), while undiluted Mediterranean water flows into the Harbour as a subsurface layer near the bottom. The effect of sewage discharged

TABLE .

Mean values of environmental parameters in different stations of the Eastern Harbour during 1985-1986.

St. No.	Maximum depth (M)	Depth of samples (M)	Water Temp. (°C)	Transp. (M)	Salinity ‰	PH	T.Alk. meq/l	Sp. Alk.
I	4.0	0.0	22.20	2.43	36.89	8.15	2.47	0.121
		3.5	22.20		38.01	7.98	2.38	0.113
II	5.5	0.0	21.83	2.71	37.25	8.17	2.45	0.119
		5.0	22.50		37.84	8.22	2.42	0.116
III	9.0	0.0	22.15	3.73	37.48	8.22	2.43	0.117
		5.0	21.92		37.69	8.12	2.42	0.115
		8.5	21.73		38.62	8.08	2.35	0.110
IV	6.5	0.0	22.17	3.13	37.07	8.26	2.46	0.120
		3.0	21.00		38.04	8.11	2.41	0.114
		6.0	21.33		38.22	8.04	2.40	0.114
V	4.0	0.0	22.47	1.73	36.94	8.19	2.47	0.121
		3.5	22.37		37.38	8.12	2.40	0.116
VI	2.5	0.0	22.20	1.93	37.04	8.18	2.47	0.121
		2.0	22.67		37.03	8.19	2.45	0.119
VII	5.5	0.0	22.30	2.31	37.53	8.24	2.44	0.117
		5.0	22.10		38.40	8.06	2.37	0.117
Areal		Surface	22.20	2.65	37.17	8.20	2.64	0.120
		St.Dev.(±)	±4.60	±0.67	±0.91	±0.16	±0.15	±0.009
Aver-		Bottom	22.10		37.32	8.08	2.39	0.114
age.		St.Dev.(±)	±4.20		±0.42	±0.07	±0.15	±0.008

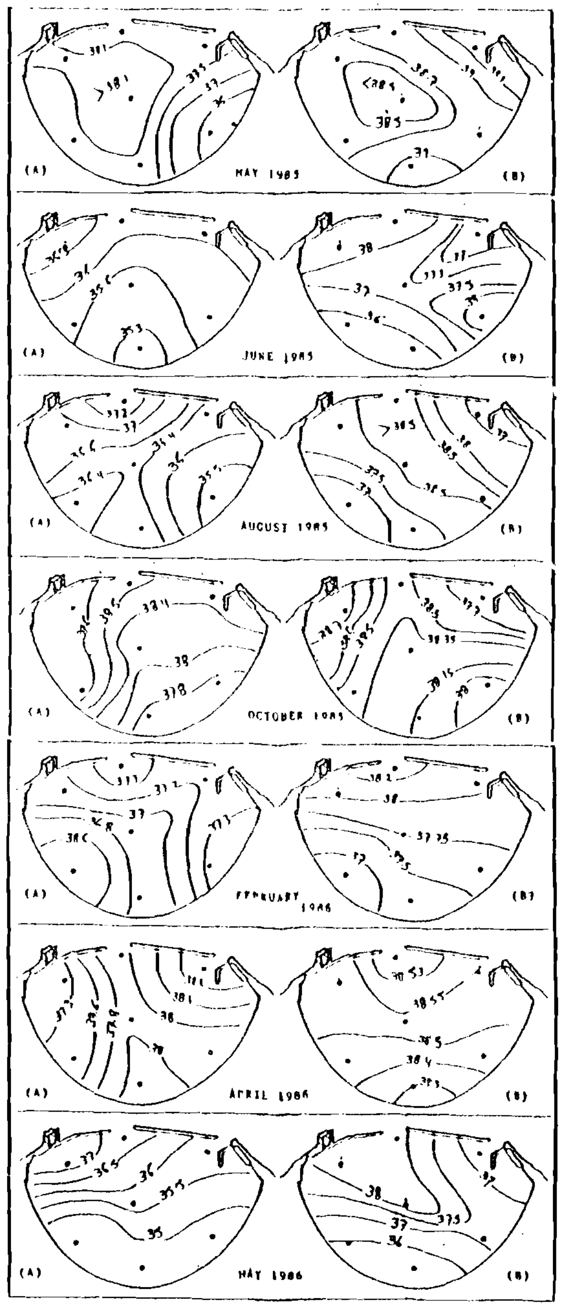

Fig. (3)
Areal distribution of salinity (‰) in A) surface and B) bottom waters of the Eastern Harbour during 1985-1986.

into the southern region of the Harbour was clear as it lowered the values of salinity at stations I (average 36.89 %°), V (36.94 %°) and to a less extent at station VI (Table 1).

Figure 4 shows the monthly variations of salinity of the Harbour water. Three distinct peaks are clearly recognized during May, October and April 1985. On the average, the seasonal variations in salinity of the bottom layer generally followed those of the surface water (Fig 4).

In the E.H., the absolute pH values of the surface water fluctuated between 7.80 and 8.58 at stations VI and IV, while of the bottom samples, the minimum and maximum values varied between 7.56 and 8.43 at stations V and VI, respectively. The overall average pH values amounted to 8.20 ± 0.16 and 8.08 ± 0.07 for the surface and bottom water layers, respectively (Table 1).

The distribution of pH values in the Harbour water during the study period (1985-86) showed a general trend of increasing values in a north and / or northwest direction. In some months this pattern may be reversed, e.g. in August as a result of extermely high chlorophyll content at stations subjected to sewage discharge (Aboul-Kassim,1987). Figure 5 shows the monthly variations of pH in both surface and bottom waters of the Harbour basin.

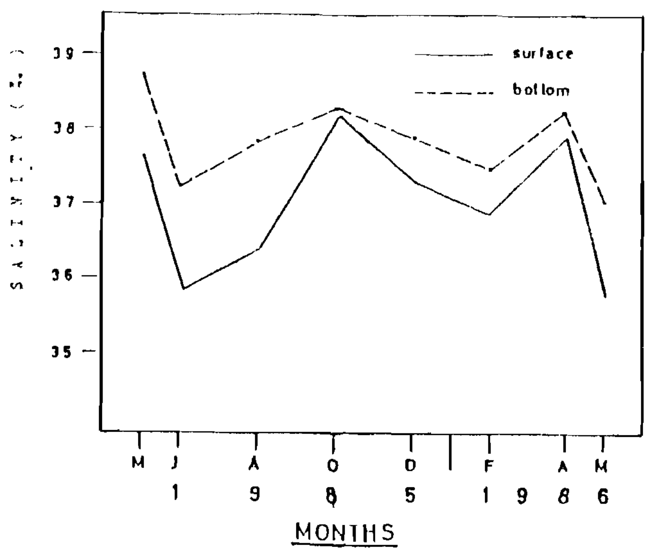

Fig. (4)
Monthly variation of salinity (‰) in both surface and bottom waters in the Eastern Harbour during the period 1985-1986.

Spatial and seasonal variations in total alkalinity (meq/l) of the E.H. were rather limited. The values varied between a minimum of 2.10 and 2.08 meq/ at stations I and III and a maximum of 2.37 and 2.64 meq/l at stations I and VI for surface and bottom waters, respectively. The vertical variations, in general, showed a decrease with depth, with the difference rarely exceeding 0.3 meq/l. The overall averages for the surface and bottom waters were 2.46 and 2.39 meq/l, respectively (Table 1).

The seasonal variations of alkalinty values (Fig. 5) were slightly mare pronounced than spatial variations. The monthly averages were high in warm months but low in cold ones(except February). This trend coincided with the maximum sewage water discharge through sewer outfalls recorded during summer as well as maximum phytoplankton production during August and February.

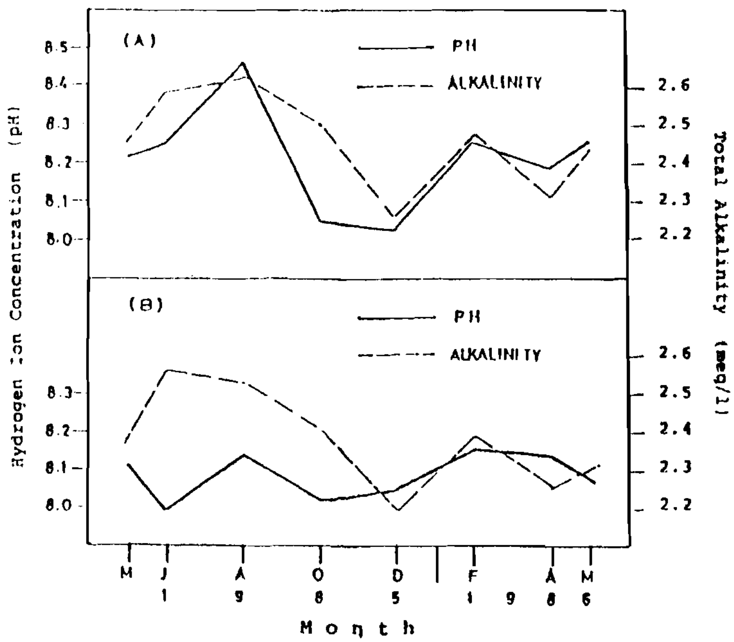

Fig. (5)
Monthly variations of pH and total alkalinity (meq/l) in both a) surface and b) bottom waters of the Eastern Harbour during 1985-1986.

DISCUSSION

Due to the shallowness of the Harbour and the pronounecd effect of wind, seasonal variations in the water temperature were directly affected by solar radiation and seasonal changes in air temperature. During the study period, thermal stratification was rarely detected in the Harbour basin. However, in periods of clam weather, thermal stratification may occur to a limited extent. The occurrence of a homothermal water column is a general characte of the E.H., particularly in winter. This is mostly related to the effective mixing processes in this shallow basin.

The area of the E.H.,as a part of SE Mediterranean, represents a warm tropical or subtropical region. The annual average temperature is about 22.2°C, with an amplitude of 11.9°C. This is nearly comparable to the condition in the coastal waters of Alexandria (Table 2).

The transparency of the E.H. was relatively high. The annual average of secchi disc visibility (2.65 $\pm$ 0.67 m) is comparable or sometimes lower than found in other inshore areas (Table 2). Generally, low values were recorded at stations located in front of sewage pipelines. The remarkable high transparency at station III is mostly due to its low phytoplankton standing crop and total suspended matter (Aboul Kassim, 1987) as well as being rerlatively far from the direct effect of waste water discharged inside the Harbour.

Using simultaneous secchi disc readings and submarine photometer in the E.H., Halim et al. (1980) indicated that the relative light intensity or irradiance at the depth of secchi disc disappearance is about 35 % of surface illumination. Those authors suggested that the mean depth of 1 % light intensity, i.e. lower limit of photic zone, is about 4.32 times the secchi disc depth.

According to Halim et al. (1980), the empirical relation derived by Poole and Atkins (1929) relating K, the extinction coefficient, with the secchi depth in meters (D), i.e. $k=1.7/D$, can not be applied to the shallow eutrophic Harbour water. They proposed a new constant, i.e. $k=1.06/D$. Applying this equation, the average K values for the Harbour water amounted to 0.43 (Table 3). On the other hand, Moustafa (1985) derived the empirical relation between K and secchi disc readings and showed that these equations gave results of K which were about 11-16 % lower than the Poole and Atkins (1929) equation. Table 3 shows the K values estimated according to the equation given by Halim et al. (1980), Moustafa (1985) and Poole and Atkins (1929) together with the corresponding estimated euphotic zone. It is obvious that the calculated K for the Harbour water using the equation of Poole and Atkins (op. cit.) gave results comparable with that of the inshore Egyptian waters (Moustafa, 1985) and deviated significantly from that of Halim et al. (1980). As a result, the average depth of euphotic zone is comparatively much higher than the computed average from the two other methods.

A highly significant inverse correlation ($r=-0.5401$, $p<0.001$) was found between secchi disc depth and chlorophyll a. The empirical regression equation relating both variables is:

$$\ln Z_{SD} = 1.1018 - 0.600 \ln \text{Chl. } a$$

where, Z_{SD} is the secchi disc depth in meters. This relation showed that water transparency in Harbour is affected by factors other than

TABLE 2

Mean and range different environmental parameters in the Eastern Harbour in comparison with other areas.

Location		Temperature (C°)		Transparency (m)		Salinity (‰)		pH		Reference
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	
E.H.	S	22.2	16.9-29.2	2.65	0.6-4.5	33.17	34.78-38.77	8.20	7.80-8.58	Present study
	B	22.1	17.0-28.5			37.92	35.47-39.21	8.08	7.65-8.43	
E.H.	S	21.8	16.6-28.5	-	-	36.84	35.13-39.46	8.14	7.68-8.40	Shriadacn(1982)
	B	21.3	16.5-27.0			37.43	36.42-39.31	8.04	7.51-8.35	
E.H.	S	20.1	14.4-28.6	-	-	37.43	37.01-39.19	-	-	El-Nady (1981)
	B	20.3	15.6-28.4	-	-	38.13	37.13-39.20	-	-	
E.H.		-	-	-	0.5-3.5	-	-	-	-	Halim et at(1980)
W.H.		21.1	15.1-27.8	2.14	0.1-3.6	36.97	26.25-39.36	7.64	7.00-8.81	Hemeda (1982)
In front of	S	-	-	1.70	0.5-5.5	36.05	35.24-37.21	7.87	7.50-8.35	Mahmoud (1983)
El-Boughaz	B	-	-			38.66	36.94-39.66	8.03	7.00-8.30	
Abu-Qir	S	22.4	15.4-29.5	-	-	37.65	35.95-39.10	8.11	7.20-8.72	El-Deeb (1979)
Bay	B	-	-			-	35.00-39.00	8.15	7.10-8.90	
S.E.Mediterranean		-	-	-	2.0-46.0	-	-	-	-	Moustafa (1985)

TABLE 3

The extinction coefficient and depth of the euphotic in the E.H. computed by 3 different equations using secchi disc reading obtained durlng the study period.

Station	(1) K(m^{-1})	(1) Euphotic depth	(2) K(m^{-1})	(2) Euphotic depth	(3) K(m^{-1})	(3) Euphotic depth
I	0.44	10.57	0.74	6.59	0.62	7.39
II	0.39	11.79	0.63	7.35	0.56	8.19
III	0.28	16.48	0.45	10.28	0.41	11.26
IV	0.34	13.61	0.54	8.49	0.49	9.39
V	0.61	7.52	0.98	4.69	0.86	5.35
VI	0.55	8.39	0.88	5.23	0.78	5.94
VII	0.38	12.22	0.60	7.62	0.54	8.48
Mean	0.43	11.53	0.69	7.18	0.61	8.02

(1) Halim et.al (1980) $(K = 1.06/D)$
(2) Poole and Atkins (1929) $(K = 1.7/D)$
(3) Moustafa (1985) $(\ln K = 0.37 - 0.948 \ln Z_{SD})$

chlorophyll, i.e. inorganic suspensoids, dead organisms or dissolved organic substances (Gelbstoff).

An expected significant inverse correlation ($r = -0.6026$, $p < 0.001$) existed also between the secchi disc depth and total suspended matter in the E.H. (Aboul Kassim, 1987). From the empirical regression equation relating both variables, i.e. $\ln Z_{SD} = 1.1792 - 0.0176 \times TSM$, it appeared that if $TSM = 0$, the corresponding secchi depth calculated in the Harbour water would be 0.54 m. This may underscore the importance of other factors such as the dissolved organic and inoranic compounds.

The salinity of the E.H. is mostly controlled by the amount of sewage water discharged into the basin and the rate of mixing and exchange of the Harbour water with the adjoining coastal waters of the Mediterranean Sea. During the last 10 years, salinity values of the Harbour were decreasing gradually by more than 4‰ due to nearly doubling the amount of sewage and waste water discharged to the Harbour during this period.

According to the wind regime in the area, the surface currents in the coastal waters are mostly onshore driving surface water into the Harbour. The surface salinity of the coastal Mediterranean water adjoining the E.H. (average 35.0 - 37.0 ‰) is lower than the normal value of the open water (38.8 - 39.4 ‰) (Mahmoud, 1985) being diluted by the sewage pumped into the area through the main pumping station. However, the salinity of the bottom layer is generally over 39.0 %° (Mahmoud, 1985). On the other hand, the Harbour receives more than its volume of sewage water annually. This would decrease the salinity of the E.H. considerably below that of the adjacent Mediterranean water (flushing rate about 5 months).

Despite the comparatively large volume of sewage discharged into the Harbour, its average salinity (37.55 $\pm$ 0.78 %°) is not much lower than that of the coastal waters of Alexandria (Table 2). This clearly indicates that the Harbour water is continuously mixed with that of the adjacent Mediterranean water, a condition which results in the still healthy condition of the Harbour environment. The surplus amount of water flows out to the sea through the two outlets as a surface mixed layer, the salinity of which varies between 35.71 and 38.54 %° depending upon the amount of sewage water, the direction and strength of the prevailing wind and the rate of mixing inside the Harbour. On the other hand, the subsurface water of the adjacent Mediterranean (salinity > 39.0 %°) area flows into the Harbour as a bottom layer of high salinity. Further inside the Harbour, this water gradually loses its identity as it is mixed with the overlying diluted water. The highest average salinity recorded in the bottom layer of the E.H. > 38.0 %° occurred in May 1985, October 1985 and April 1986.

The pH of the E.H. water always lies on the alkaline side. The overall average, i.e. 8.14 $\pm$ 0.13, is comparable with those recorded for other Egyptian inshore waters including previous records in the E.H. (Table 2). The surface values were slightly higher than those near the bottom. This may be explained by the high photosynthetic activity at the surface and relatively high organic load of the bottom water and surface sediments.

The relatively high pH values recorded in warm months are mostly correlated ($p<0.001$) with the rise in water temperature. The significant correlation, between chlorophyll a content and pH may indicate that the pH of the environment could be used as a good indicator for production levels.

Variations in the total alkalinity of the Harbour water are mostly controlled by the physical and chemical processes taking place in the water body. The annual average of total alkalinity amounted to 2.42 $\pm$ 0.14 meq / l. A significant inverse correlation was observed between total alkalinity and salinity of the Harbour water ($r= -0.4015$, $p<0.001$). The higher total alkalinity values recorded in summer may be related to the increased photosynthetic rate during this season.

The average specific alkalinity values [total alkalinity (meq/l)/chlorinity %°] calculated for the E.H., i.e. 0.117 $\pm$ 0.009 (Table 1) were slighty low compared with 0.126 accepted for oceanic water (Koczy, 1956 and Morcos, 1970).

REFERENCES

Aboul-Kassim, T.A., 1987. **Cycles of carbon, nitrogen and phosphorus in the marine environment in Alexandria region.** M.Sc. Thesis, Faculty of Science, Alexandria University, Egypt, 340 P.

El-Deeb, M.K.Z., 1977. **Hydrography and chemistry of Abu Qir Bay.** M.Sc. Thesis, Faculty of Sicence, Alexandria University, Egypt, 273 P.

El-Nady, F.E., 1981 **Survey of some heavy metals in Alexandria waters and its effect** on some marine animals. PH. Thesis, Faculty of Science, Alexandria University, Egypt, 325 P

Halim,Y.,A. Khalil and A.Handhal, 1980. Diatoms flora of a eutrophic bay, the Eastern Harbour of Alexandria. **Acta Adriatica**, 21 (2): 271-298.

Hemeda, E.I.M., 1982. **Chemical studies on the water of the Western Harbour of Alexandria.** M.Sc. Thesis, Faculty of Science. Alexandria University, Egypt,187P.

Koczy,F.F (1956) The specific alkalinity. Deep-Sea Res., 3 (4): 279-288.

Mahmoud, T.H., 1985. **Phosohorus and nitrogen dynamics in polluted coasted coastal warers off Alexandria.** PH. D. Thesis, Faculty of Science, Alexandria University, Egypt.

Morcos, S.A., 1970 Chemical compsition of sea water and the variation of calcium and alkalinity.J. **Cons.Perm.Int.Explor.Mer**, 33 (2):126-133.

Moustafa,H .M.M., 1985 **Phytoplankton production and biomass in the SouthEastern Mediterranean waters off the Egyptian coast.**M.Sc. Thesis, Faculty of Science, Alexandria University. 125 P.

Poole. H.H. and W.R.G. Atkins 1929 Photoelectric measurements of submarine illumination throughout the year. **J.Mar. Biol.Ass.U.K.**, 16:297-324.

Relis,M., 1965 **Instruction manual for model Bekman RS-7C Portable Induction Salinometer.** U.S.Patent No.2,542,057.

Shriadah, M.M.A., 1982 **Studies on chemical composition of the Eastern Harbour.** M.sC. Thesis, Faculty of Science, Alexandria University, Egypt, 271 P.

Strickland, J.D.H. and T.R. Parsons, 1972 **A practical hand-book of sea water analysis. Fish. Res. Bd. Canada, Bull. 167, 2nd ed., 310 p.**