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SOME PHYSICO CHEMICAL INDICES OF EUTROPHICATION IN THE EASTERN HARBOUR OF ALEXANDRIA.

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ABSTRACT

The hydrographic conditions in the Eastern Harbour (E.H.) have been studied in the period from August 1986 to July 1987 in relation to the domestic sewage discharge, which creates eutrophic conditions. The E.H. is a strongly stratified two layer system most of the year, consisting of a dilute surface layer characterized by lower salinity, low dissolved oxygen, high dissolved phosphate and silicate, high specific alkalinity, low Secchi disc transparency and a dense phytoplankton standing crop.

The more saline bottom layer is characterized by a higher density, lower dissolved oxygen, particularly along the inner margin station, lower dissolved silicate ,lower specific alkalinity and lower phytoplankton crop.

Stratification becomes interrputed during the mixing period from November to February. The E.H. then becomes almost homohaline and homothermal, with a general rise in salinity and in the oxygen relative percent saturation. The specific alkalinity becomes nearer to that of the open sea and the pH is minimal, the phytoplankton standing crop is also at its minimum.

INTRODUCTION

The Eastern Harbour (E.H.) is a relatively shallow semi-closed basin, sheltered from the sea by a breake-water leaving two openings, "El-Boughaz and El-Silsila", through which the exchange of water between the Harbour and the neritic Mediterranean water takes place. The area of the E.H. is about 2.53 x $10^6 m^3$ with an average depth of 6 m. Accordingly, its water volume is estimated to be about 15.2 x $10^6 m^3$.

The Harbour basin is the recipient of large amounts of sewage and waste water from eleven small outfalls inside the Harbour itself, discharging annually about 35.2 x 10^6 m^3. This volume is about 2.3 times the volume of water in the E.H. . Accordingly the flushing rate would be about five months (Aboul-Kassim, 1987). On the other hand, an occasional inflow of mixed waste water takes place through El-Boughaz from the main sewer of Alexandria located about 500 m west of El-Boughaz in the open sea.

The nature of the bottom in the E.H. differs from place to place. Along its southern margin, the bottom sediments are composed of 80% black mud which smells H_2S at certain times, while the central area is covered with a mixture of mud, sand and shell remains (El-Sayed et al., 1980). The northern area near El-Boughaz is composed mainly of sand dominated by broken shells (Al-Handhal, 1979). In some places, the bottom of the Harbour is covered with extensive algal growth **Caulerpa** sp. and eel grasses **Posidonia** sp. (ElSayed et al.,1980).

MATERIAL AND METHODS

Water and phytoplankton samples were collected at regular monthly intervals in the E.H. in the period from August 1986 to July 1987. Collection was carried out from five stations inside the E.H. as well as from a station in the open sea, 1 km from El-Boughaz (Fig. 1). Samples were taken from

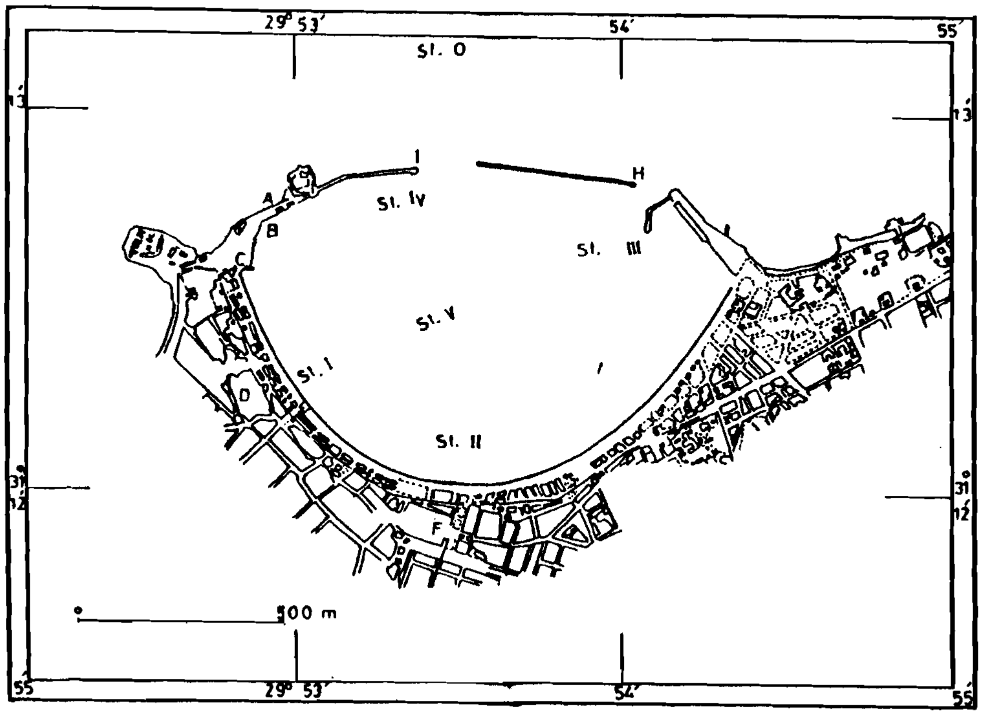

FIG. 1
The Eastern Harbour. Position of stations.

the surface and bottom layers using a plastic Ruttner sampler, except at the open-sea station (St.0), from the surface only.

Water temperature was measured with an ordinary thermometer. The pH value was recorded immediatly using a portable pH-meter. Transparency of the water was measured using a white enamelled Secchi disc 30 cm in diameter. The average depth of disappearance and reappearance of the disc was recorded. Total alkalinity was measured by titration against standard HCl. Salinity was calculated from the electrical conductivity of the samples as measured by a Beckman Salinometer. Dissolved oxygen (DO) was measured according to the winkler method. Oxygen percent saturation was computed using UNESCO tables (Anon., 1973), Stability of the water was calculated according to Fofonoff and Millard (1983) and from the equation :

$$\text{difference of } \sigma_T / \text{ difference of depth}$$

Dissolved phosphate and reactive silicate were determined colorimetrically according to the methods described by Strickland and Parsons (1972).

SOME HYDROGRAPHIC FEATURES

1- Temperature and Salinity:

The E.H. waters are strongly stratified most of the time except from November to February (Fig. 2), consisting of a dilute surface layer of mixed runoff and a more saline bottom layer. The highest surface water temperature occurred in July (30°C) and the lowest in January (14.5°C).

Thermal stratification was rarely detected. From August to November 1986, the bottm water was slightly warmer (0.5c^{O}) than the surface layer. From April to June 1987, it was cooler by 2°C, where the difference decreased to 1°C during July. Salinity is always lowest along the inner margin of the E.H., with a weak horizontal gradient towards the outlets. Surface salinity ranged from 28.3 - 31.2‰ to 38.8‰ during the period of observation. Salinity variations in the bottom water are much more restricted (Fig. 3). The bottom layer showed a narrower range. Except for two readings, it ranged from 36.6 to 39.?‰. Fluctuations in salinity showed that a strong vertical gradient persisted from August to October, 1986. The haloclyne disappears from November to February, with development of almost homohaline and homothermal conditions and a general rise in salinity (38.7 to 37.9‰ respectively in November and February at the central station). Stratification is reestablished from March to July and surface salinity drops to lower values. It is during winter that the flux from the outfalls is reduced to its yearly minimam. Summer stratification therefore is interrupted from November to February to become reestablished from March onwards. Stability values are minimal or nil during the homohaline - homothermal period. This sequence affects the vertical distribution of other parameters. Surface salinity at the open sea station (St.0) ranged from 36.23 to 39.00‰ with higher values in winter. Comparison with earlier observations (Table 1) points to a decrease in the average surface salinity in the last decade with the increased volume of waste water discharge.

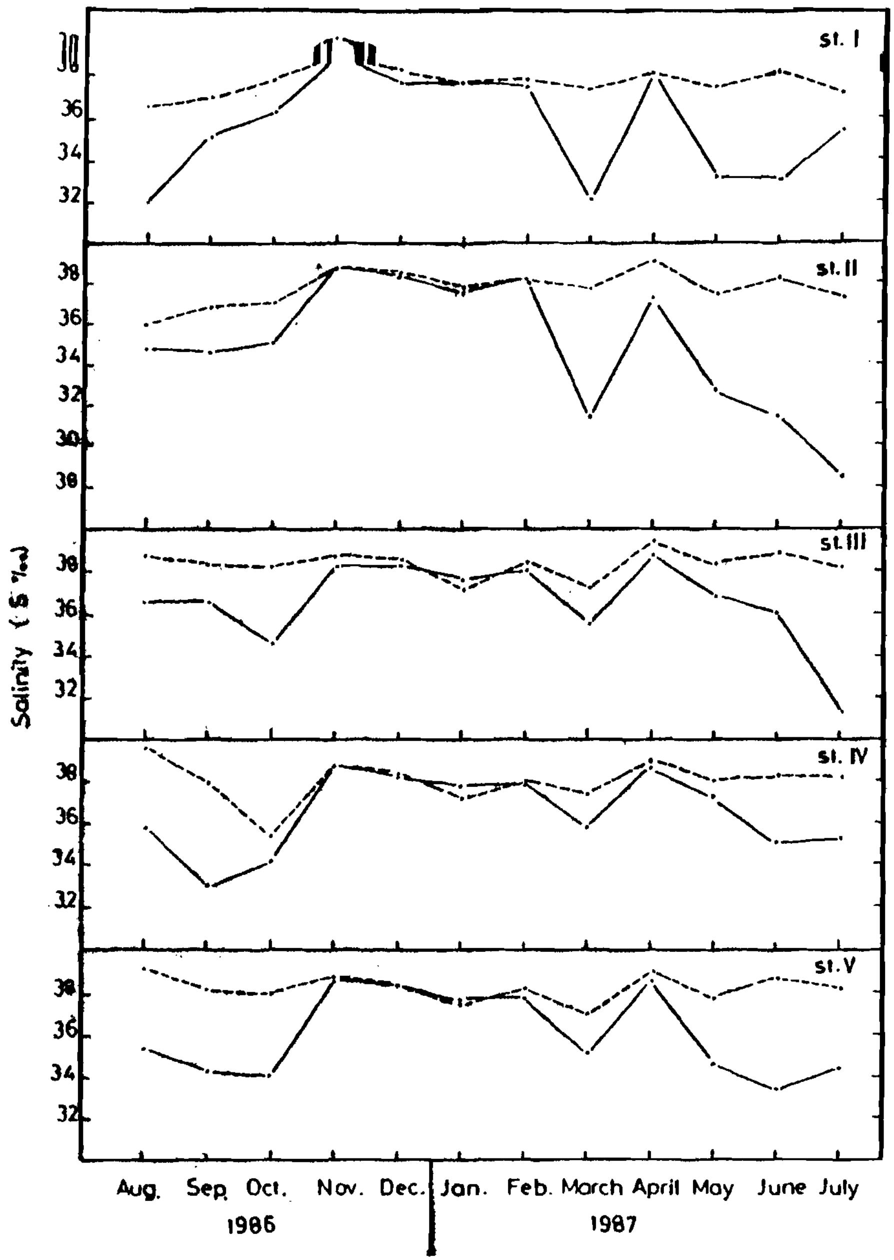

FIG. 2
Monthly variations of water salinity in the surface water (._____.) and bottom layer (. ____ .) at the different stations of the EAstern Harbour.

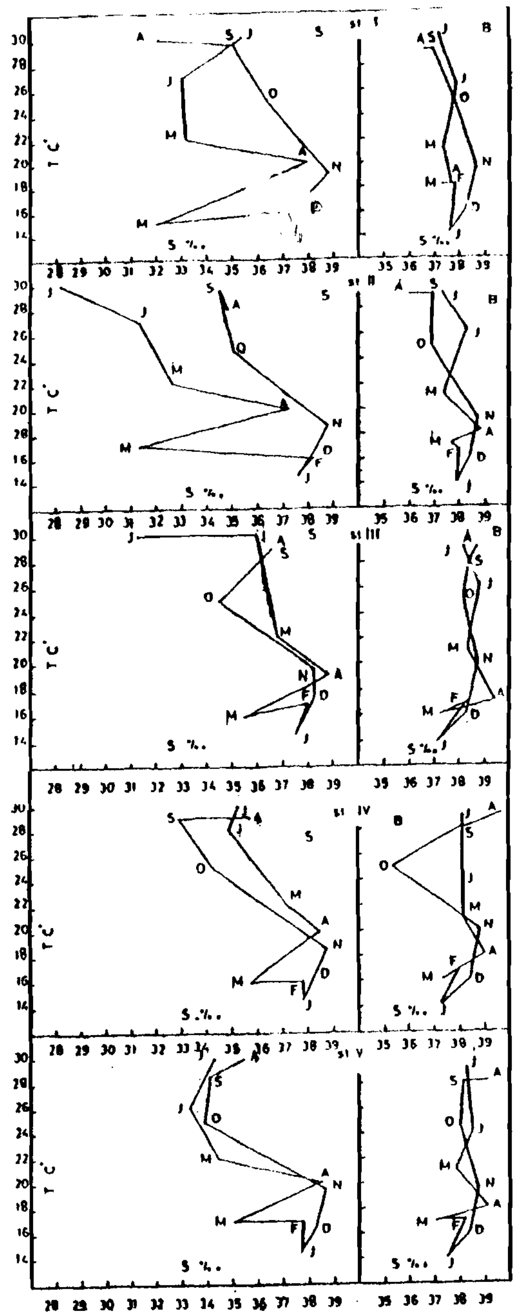

FIG. 3
Temperature/Salinity diagram at the different stations in both surface water (S) and bottom layer (B) in the Eastern Harbour.

Table (1)

Mean and range of surface and bottom salinity in the E.H. from 1979 to 1987.

Mean	Range	Date of observation	REferences
S 35.83	28.2 - 38.3	1986 - 1987	Present work
B 37.96	35.4 - 39.7		
S 33.17	34.87 - 38.77	1985 - 1986	Aboul Kassim, 1987
B 37.92	35.47 - 39.21		
S 36.84	35.13 - 39.46	1980 - 1981	Shriadah (1982)
B 37.43	36.42 - 39.31		
S 37.43	37.01 - 39.19	1979 - 1980	El-Nady (1981)
B 38.13	37.13 - 39.20		

2- Dissolved Oxygen :-

Dissolved Oxygen in the E.H.showed wide fluctuations in both surface and bottom water becoming at times almost depleted . The surface DO ranged between a minimum of 0.14 ml 0_2. L^{-1} (3.1% saturation, St.II in August) to 10.7 ml 0_2. L^{-1} (213.2% saturation, St. V in May). Its fluctuations are caused by the interaction of several factors: the input of waste water with its high organic load causes a drop in DO leading to depletion in the bottom water. This happened in both summer 1986 and 1987; and is more obvious at the inner stations I & II (Fig.4). The excessively high phytoplankton blooms have the opposite effects depletion or near-depletion in August - September 1986 (St.I - III) is followed by supersaturation in October. Vertical mixing in November - February accompanied by an inflow of sea - water leads to a general rise in DO% and the bottom water becomes better oxygenated than the surface layer.

It is important to note that on the average DO in the bottom water of the E.H. has been progressively decreasing in the last few years (Table 2).

3- Reactive Phosphate:-

Surface phosphate in the E.II. ranges from depletion to 5.8 ugm. at.L^{-1} Phosphate shows very wide fluctuation with abnormally high peaks. Its fluctuations are governed by the interaction of two factors: the input of waste water and the uptake by the heavy blooms. The drop in salinity from

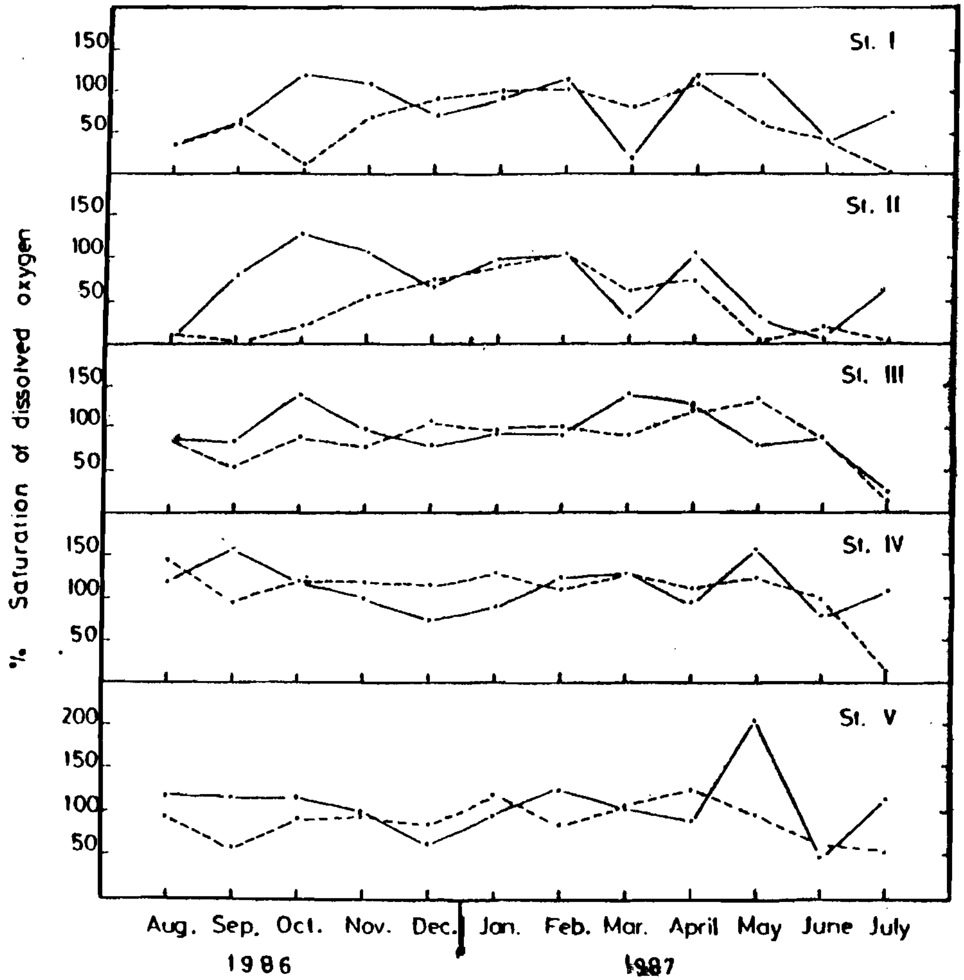

FIG. 4
Monthly variations of percentage saturation of dissolved oxygen in the surface water (. ___ .) and bottom layer (. ____ .) of the different stations in the Eastern Harbour.

August to October 1986 is accompained by a peak in surface phosphate (2.6 to 5.8 ugm.at.L^{-1}). The bloom of phytoplankton rapidly takes up most of the a valiable phosphate, reducing its concentration to less than 0.5 ugm.at.L^{-1} in November. A similar trend is observed in March and May - June (Fig.5). The high phosphate content in March and in May - June follows an abrupt drop in salinity. This high phosphate content is again rapidly reduced by the heavy phytoplankton bloom developing at the same time.

Table (2)

Mean and Range of surface and bottom DO in the E.H. from 1979 to 1987.

Mean	Range	Date of observation	References
S 4.68	0.14 - 10.66	1986 - 1987	Present work
B 4.00	0.00 - 6.75		
S 5.09	2.96 - 10.52	1985 - 1986	Aboul-Kassim, 1987
B 3.42	0.00 - 5.71		
S 4.95	2.66 - 8.21	1980 - 1981	Shriadah, 1982
B 4.89	2.7 - 7.60		
S 6.79	3.46 - 11.07	1979 - 1980	El-Nady, 1981
B 5.75	1.51 - 10.83		

Except for St.1, surface phosphate was usually higher than bottom phosphate. This relation ship between higher phosphate content and lower salinity together with its higher concentration in surface than in bottom water are consistent with its terrigenous origin in the E.H.

4-Reactive Silicate :-

Surface silicate also showed very wide fluctuations in the E.H., ranging from depletion to 31.24 ugm.at. L^{-1}. Three factors govern silicate fluctuations : the input of drainage waters, the uptake by heavy diatom blooms and intermixing with sea water poor in silicate. The drop in salinity in August - Septmber is accompanied by a peak in surface silicate particularly at the inner stations I& II(16.51 to 31.24 ugma .L^{-1} at St I and 22.25 to 20.12 ugm.at.L^{-1} at St.II) as shown in Figure (6). The bloom of phytoplankton rapidly takes up silicate lowering its concentration 2.72 ugm.at.L^{-1} in October. A similar increase is recorded in May June , following an abrupt drop in salinity, rapidly reduced by the diatom blooms at the same period. During the homohaline - homothermal period of higher salinity (December - February) silicate dropped to a minimum and became depleted particularly at St. IV in February in the bottom layer. Surface silicate was much higher than in the bottom layer, since the latter ranged from 0.00 to only 16.27 ugm.at.L^{-1}. This is attributed to the inflow of fresh water with higher silicate content, spreading on the surface layer.

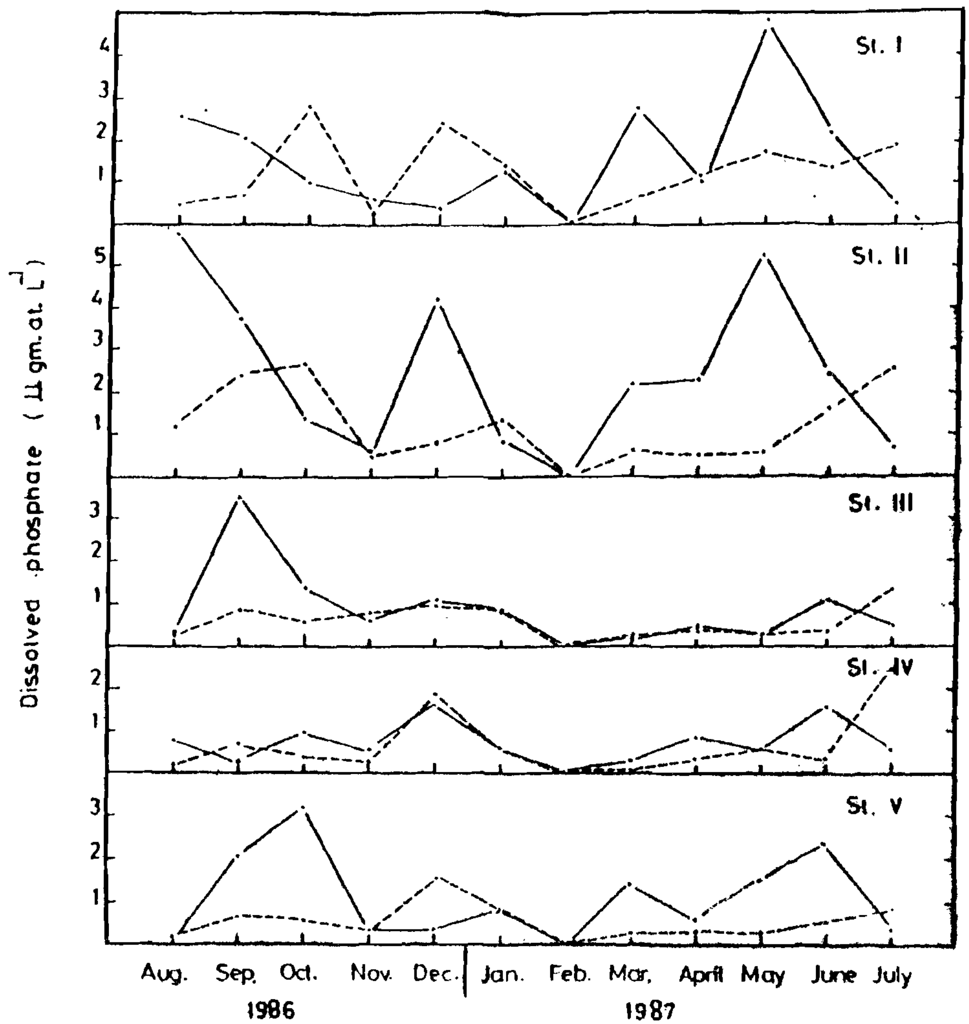

FIG. . 5
Monthly variations of dissolved phosphate in the surface water (. ___ .) and bottom layer (. ___ .) of the different stations in the Eastern HArbour.

5- Hydrogen ion concentration :-

Although the pH of the E.H. water was always on the alkaline side, its range of fluctuation was relatively wide. Surface water fluctuated between 7.4 and 8.7 and the bottom water between 7.4 and 8.5. There was a distinct drop in the pH of both surface and bottom waters during the mixing period,

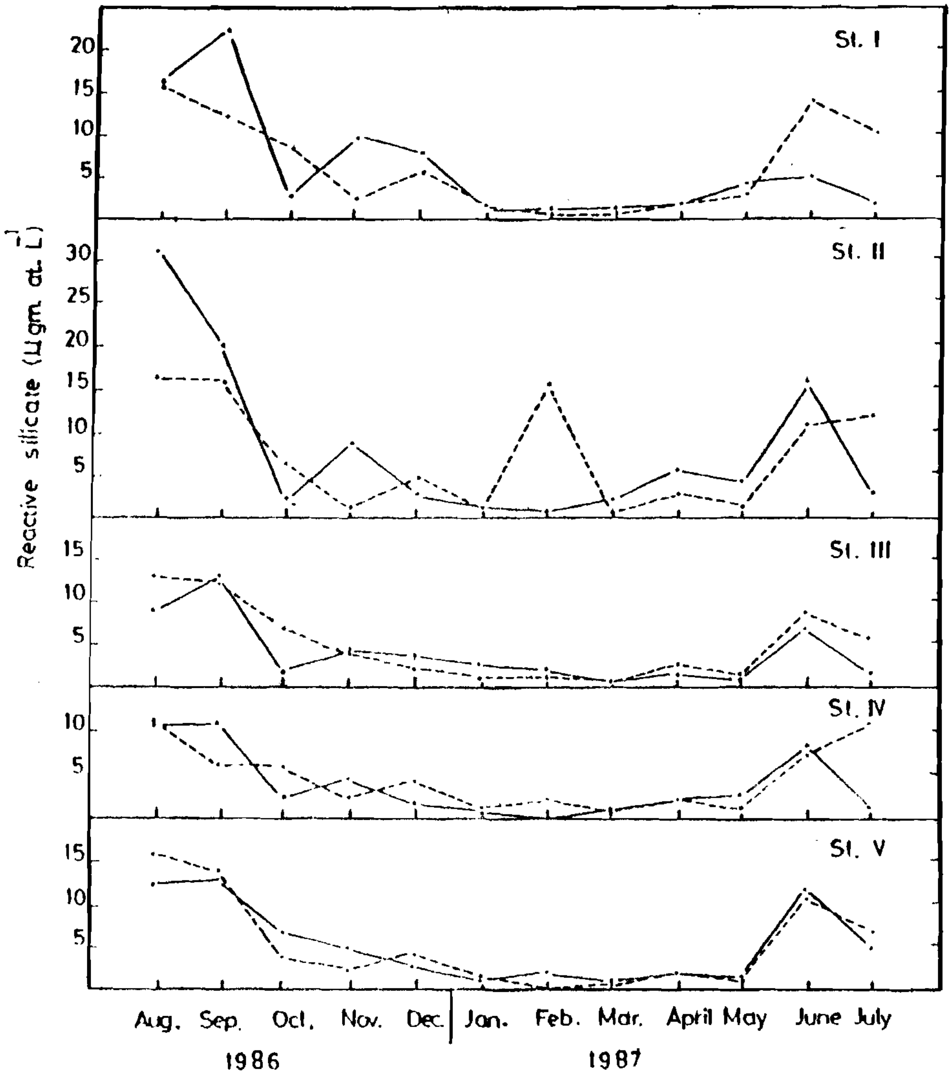

FIG. 6

Monthly variations of dissolved silicate in the surface water (. ___ .) and bottom layer (. ____ .) of the different stations in the Eastern Harbour.

Novemper to January, from about 7.2 to 8.5. The phytoplankton standing crop was minimal at the sametime. Higher pH values are recorded during the blooming periods. The maximum vertical gradeint reached 0.4 pH units in July, while in other months it rarely exceeded 0.1.

6- Specific Alkalinity:-

The specific alkalinity in the E.H. (table 3) is always higher than in the open sea, 0.126 according to Morcos (1970). However, the period November 1986-February 1987, characterized by vertical mixing together with a general rise in salinity is also characterized by specific alkalinity values nearer to the open sea value and with a very small difference of only 0.003 between surface and bottom. Before and after this mixing period, stratification and a general rise in specific alkalinity is observed . From August to October and from March to July , the surface specific alkalinity is about 0.022 higher than bottom water specific alkalinity and both are much higher than in November to February. Elevated surface specific alkalinity, largely exceeding the normal offshore values, together with a higher vertical gradient appear therefore to be another Index of mixing with land drainag

Table (3)

Mean and range of specific alkalinity in the surface and bottom water in the E.H. during different periods in 1986-1987.

Mean	Range	Period of observations
S 0.158	0.138 - 0.186	August 1986 - October 1986
B 0.136	0.123 - 0.147	
S 0.140	0.132 - 0.149	November 1986 - February 1987
B 0.137	0.133 - 0.147	
S 0.171	0.136 - 0.224	March 1987 - July 1986
B 0.148	0.170 - 0.185	

7- Transparency and depth of photic layer:-

The Secchi disc transparency at the open sea station (St.0) was higher than in the E.H. It ranged between 3 m. (May) and 10 m. (January) at St .0, while in the E.H. it ranged from a minimum of about 15 cm. (St.I, May) during the highest phytoplankton blooms (15.5 x 10^6 cells. L^{-1}) to an absalute maximum of 500 cm (St.III, April) during the period of low standing crop (Fig. 7).

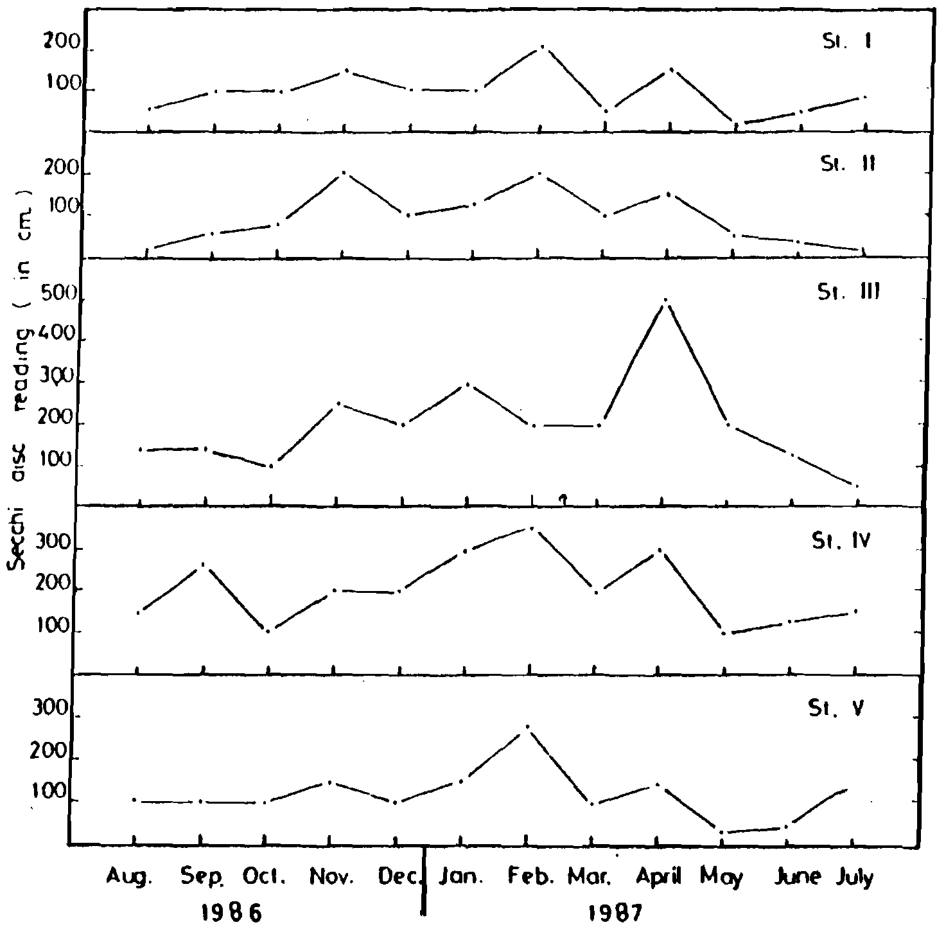

FIG. 7
Monthly variations of the Secchi-disc readings at the different stations of the Eastern Harbour.

Transparency was lowest at stations I & II (average 96 & 95 cm. respectively). Station IV, located next to the harbour main outlet, attained the highest transparency (average 205 cm.). Compared to earlier observations, the annual average Secchi disc transparency in the E.H., 1.43 m., appears to be on the decrease (table 4).

Table (4)

Mean and range of Secchi- disc transparency (m) in the E.H. from 1972-1987.

Mean	Range	Date of observation	References
1.43	0.15 - 5.00	1986 - 1987	Present work
2.65	0.6 - 5.5	1985 - 1986	Aboul-Kassim, 1987
----	0.5 - 3.5	1977 - 1978	Halim et al, 1980
2.62	1.3 - 4.0	1972 - 1973	Sultan, 1975

Using simultaneous Secchi disc reading 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 disappearence to be about 35% of surface illumination, The authors concluded that the depth of 1% light intensity, i.e lower limit of the photic zone, is about 4.32 times the Secchi disc depth.

The thickness of the photic layer was calculated using this factor. The photic layer was very thin near the inner margin due to the high turbidity caused by the outfalls, particularly at St.II (it reached to 0.86 m in August) increasing gradually towards St.V, reaching down to the bottom at the two outlest. During the homohaline-homothermal period (November to February) the photic zone reached down to the bottom at all stations. while the standing crop was minimal. In May the photic zone was very thin at the turbid St.I (0.65 m). Although it slightly increased at St.II and St.V (2.2 and 1.7m). it remained very low, as a result of the dense bloom of the Dinoflagellate **Alexandrium minutum** . In July the effect of the outfalls reappears particularly at St. II,where the photic zone drops to 0.65 m.

DISCUSSION

The continuous input of a large volume of domestic waste water to the E.H., a semi - closed bay, creates eutrophic conditions which are well characterized by the physico - chemical parameters. The E.H. is a strongly stratified two layer system most of the year, cosisting of a dilute surface layer chrraterized by lower salinity, low dissolved oxygen, abnormally high level of both dissolved phosphate and silicate, high specific alkalinity,low Secchi disc transparency and a heavy phytoplankton standing crop.

The more saline bottom layer is characterized by a higher density, lower dissolved oxygen falling to complete depletion sometimes, particùlarly along the inner margins stations (I & II), lower dissolved phosphate and silicate, lower specific alkalinity and lower phytoplankton crop.

This stratified two - layer system becomes interrupted during the mixing period from November to February. The E.H. then become vertically almost homohaline and homothermal with a general rise in salinity and oxygen percent saturation. The bottom water becomes better oxygenated than the surface water, with lower dissolved silicate and higher values of dissolved phosphate.The specific alkalinity is nearer to that of the open sea and the pH is minimal, The phytoplankton standing crop is also at its minimum, after February, stratification is restored.

There appears to be a trend in gradual deterioration of the conditions in the E.H. over the last decade. Compared to earlier observations, (Sultan (1975), El-Handhal (1979), Halim et al ., (1980), El-Nady (1981), Shriadash (1982) and Aboul-Kassim (1987), the waters of the E.H. show a decrease in the average surface salinity,a decrease in dissolved oxygen and also in the Secchi disc transparency in the last decade, with the increased input of waste water .

In conclusion, indices of eutrophication are the following: There is a two layer system with very high stability except for the period from November to February; There is a pronounced vertical gradient, all parameters decreasing in the bottom layer except for salinity. Dissolved oxygen in the bottom layer shows wide fluctuations, becoming depleted at times. The phosphate level is abnormally high . Both phosphate and silicate are always higher in surface than in bottom waters. The specific alkalinity in the mixing period is nearer to that of the open sea. Except for the mixing period, there is a gradient between the two layers and the value is much higher than that of the open sea , Low Sechi disc transparency. The phytoplankton crop is exceptionally dense.

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