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NUTRIENT LEVELS AND CHLOROPHYLL-A CONTENT IN ALEXANDRIA COASTAL WATERS.

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ABSTRACT

Data on nutrient levels and chlorophyll-a content in Alexandria coastal water were monthly collected at selected 14 stations during one year, from July 1986 to June 1987 in addition to July and August 1988. The mean nutrient content and ranges were as follows: Inorganic phosphate-P; 0.38 ug at/l, 0.00 -3.22, Ammonia-N; 6.92 ug at/l, 0.00 -122.00, Nitrite-N; 0.36 ug at/l, 0.00 -2.23, Nitrate-N; 2.96 ug at/l, 0.00 -17.62 and silicate-Si; 5.47 ug at/l, 0.06 -38.08. High values of total iron, 10 ug at/l and copper 1.8 ug at/l were recorded. The P : N : Si average ratio which is 1 : 50 : 34 in the beach water is too high when compared with the normal ocanic ratio. The average value of Clorophyll-a 4.20 mg/m^3, and the high values; 0.10 - 103.10 mg/m^3, found in the Eestern Harbour area refer to a certain eutrophication condition caused by the discharge of large amounts of nutrients from allochthonous sources.

INTRODUCTION

Eutrophication in superficial waters of coastal areas infront of Alexandria results mainly from discharges of domestic, drainage and industrial waters. Although sewage problem is local rather than global and coastal rather than oceanic, it does present a direct risk of infections to human on some beaches, during recreational warm months (El-Sharkawi, 1978 and Aubert, et al., 1988). Different amounts of effluent wastes are discharged into the coastal area of Alexandria: about 0.5×10^6 $m^3 . day^{-1}$ of domestic water outfalls throughout Kayet Bey pipelines. Eleven small sewers discharge about 10,000 to 15,000 m^3 daily of untreated sewages (Anon., 1978). The Western Harbour area receives about 6×10^6 m^3 daily of untreated industrial, drainage and domestic waters (El-Sayed et al., 1988). Al-Max area is subjected to several sources of wastes, 7.7×10^6 $m^3 . day^{-1}$ is discharged through Ummum drain from the neighbouring Lake Mariut. Several outfalls located along the eastern part of the beach were nearly closed since May, 1988 to keep the beach much suitable for recreational purposes.

Chemical characteristics of the coastal water such as temperature, salinity, pH-value, alkalinity, dissolved oxygen as well as biological oxygen demand, hydrogen sulphide and oxidizable organic matter were discussed by Nessim (1989).

The present work deals with the levels and distribution of the nutrients (N, P, Si, Fe & Cu) enriched in the coastal water subjected to different effluents and which creat a certain eutrophication condition demonstrated by chlorophyll-a biomass level. In addition the improvement of water quality of the eastern part of the beach after the construction of the new sewage project has been demonstrated.

MATERIALS AND METHODS

Fourteen stations were choosen to represent most of Alexandria beach waters starting from Abu-Qir in the east to Anfoushi in the west (Fig. 1) . Surface water samples were collected monthly during the period July, 1986 to June,

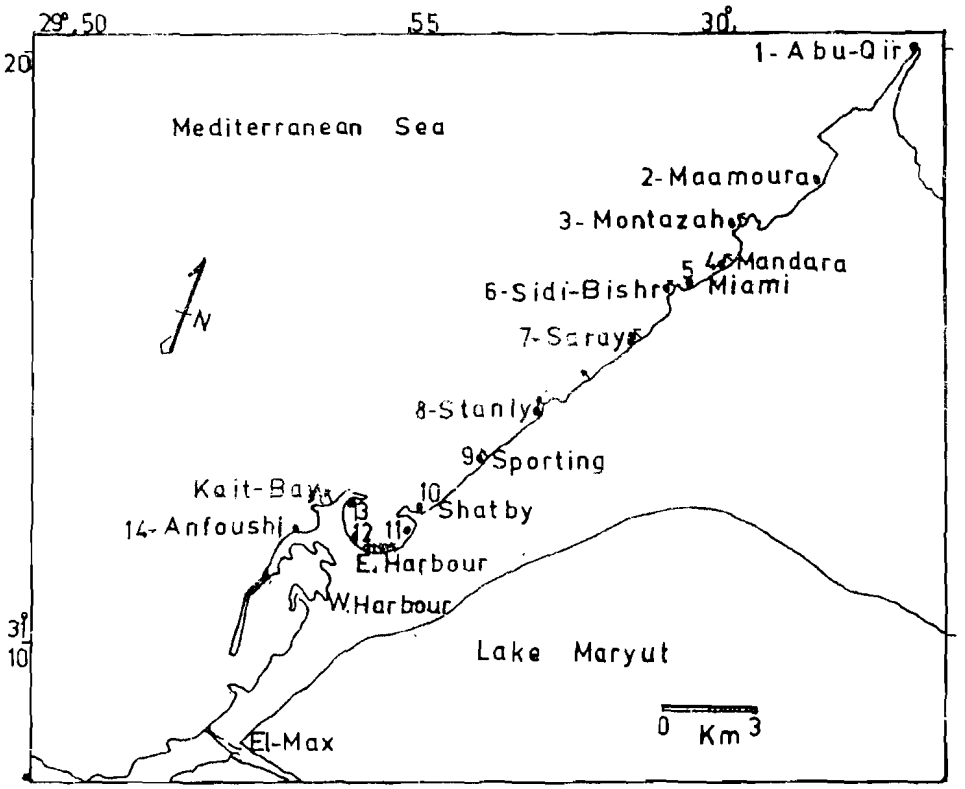

Fig .1

Alexandria Beach sampling stations (1-14) and waste water outfalls.

1987 in addition to July and August, 1988. The collection was done at 5 to 50 m away from the shore where the water depth ranged between 2 and 4 m.

Phosphate, ammonia, nitrite, nitrate, and silicate were determined colourimetrically according to methods described by Grasshoff (1976). A Schimadzue double beam Spectrophotometer UV-150-02 was used for the nutrient measurments. Total iron was determined according to orthophenanthroline method (Armstrong, 1957), copper was analyzed according to carbamate method (Strickland and Parsons, 1968). Chlorophyll-a level was measured using acetons as a solvent according to Strickland and Parsons, 1968).

RESULTS AND DISCUSSIONS

a) Phosphate-P

Phosphorus is considered as a potential pollutants. It is brought into the coastal water mainly by sewage and when present in high concentration it causes a certain eutrophication condition. Its amount in the beach water was found between 0.02 and 3.22 ug at/l with an annual average of 0.38 ug at/l. The areal distribution gave irregular pattern. Two peaks at least were recorded in most localities during December and March. Summer and spring samples gave the highest averages, around 0.50 ug at/l while autumn and winter data showed the lowest averages, being 0.33 and 0.22 ug at/l respectively. The monthly or seasonally variations were probably contributed to many factors such as rate of sewage discharge, uptake by algae and regeneration. The importance of the allochthonous source of phosphate was demonstrated by the strong inverse correlation found between salinity and phosphorus. This correlation tends to be much stronger during summer - autumn perriod ($r = -0.8285$, p 0.001). Similar relations were found by Aboul-Kassim (1987) in the Eastern Harbour, Nessim & Zaghloul (1990) in Kayet Bey area and Zaghloul & Nessim (1991) in the Western Harbour. Additional evidence explain the allochthonous origin of P is realized from the significant positive correlation found between P and oidizable organic matter ($r = 0.3276$, p 0.001). During the period, August - November, this correlation becomes much stronger ($r =$ 0.6980, p 0.001).

The significant inverse correlation found between P and dissolved oxygen ($r = -0.3551$, p 0.001) indicated the oxidation process of organic matter brought in domestic water.

The highly polluted area adjacent to the sewers gave the highest averages, e. g. st. 11 (1.25 ug at/l). The western part of the beach extending between st. 10 and st. 13 and subjected markedly to sewage discharge reflects high P-average (0.84 ug at/l) which is 4 times greater that of the eastern part of the beach. The coastal waters of Maamoura away from the outfalls recorded the lowest average (0.13 ug at/l).

b) Ammonia - N

Ammonia is the main constituent of dissolved inorganic nitrogen (68 %) and principally brought into the sea by the sewage effluents. Its cocentration varied widely from zero to 122.00 ug at/l with an annual average of 6.90 ug at/l.

Regarding the monthly averages; July represents the lowest content being 0.77 ug at/l while December value was the highest (15.13 ug at/l). The summer average content, in general, reflected the minimum value (3.08 ug at/l), influenced with phytoplankton uptake while the autumn average represented the maximum (10.97 ug at/l).

The regional distribution of ammonia showed that the Eastern Harbour water particularly at st. 11 maintained great amounts of ammonia during the year, which is 9 times greater than that of the eastern part of the beach. Abu-Qir and Shatby areas gave also nearer high averages. Ammonia free water was found at different localities during several months in the eastern part e.g. (sts. 3 - 9) during February and (sts. 2 - 6) during August. In general, the ammonia content in the eastern part (sts. 2 - 9), the less polluted area, did not exceed 1/5 of the concentration in the Eastern Harbour water. The mean value recorded in the Eastern Harbour was 5 times greater than that obtained by Mahmoud (1979), 10 years before. The beach water, in general, is highly enriched with ammonia when compared with the offshore water in front of Alexandria (El-Rayis, 1973).

The significant inverse correlation found between ammonia and salinity ($r = -0.5020$, $p < 0.05$) in June and the positive correlation with oxidizable organic matter ($r = 0.9551$, $p < 0.001$) in December indicate the allochthonous origin of Ammonia.

c) Nitrite - N

Nitrite represented only 3 % of dissolved inorganic nitrogen in Alexandria coastal waters. Its amount varied from 0.03 to 2.23 ug at/l with an annual average of o.34 ug at/l. The coastal area which receives different amounts and types of wastes reflects irregular NO_2-N pattern among the year.

According to seasonal average, autumn value was the highest (0.45 ug at/l) while spring was the lowest (0.25 ug at/l), winter and summer gave intermediate values. Reffering to monthly average January was the lowest, o.10 ug at/l, and November was the highest being 0.92 ug at/l.

It is noticed that the polluted areas, poor in dissolved oxygen showed high values of nitrite content (0.50 - 0.68 ug at/l) e. g., Abu-Qir, Shatby and the Eastern Harbour areas. The nitrite peak coincided with the ammonia peak suggesting either the input of nitrite in sewage or active nitrification (Thomas et al., 1988). A significant positive correlation between ammonia with nitrite was found (r =

0.3713, p 0.001). The significant inverse correlation (r = -0.4413, p 0.001) found between nitrite and dissolved oxygen during summer (July & August) demonstrate the oxidation of most of these unstable ions under well oxygenated condition as reported by Nessim and Tadros (1986). Low nitrite averages were found consequently in the less polluted area (Maamoura - Sporting) accompanied well oxygenated condition and high salinity, Maamoura water reflects the lowest average, being 0.10 ug at/l.

Regarding the annual average obtained since ten years before this study by Mahmoud (1979), the Eastern Harbour water tends to double its nitrite content while the amount at Maamoura decreased to one half.

The coastal water, in general, is enriched in nitrite when compared with the offshore waters.

During summer 1988, after the construction of the new sewage system, nitrite content in the eastern part was decreased to 1/3 of its value of the 1986 summer as a result of the non arrival of domestic waters to this area.

d) Nitrate-N

The average ratio of nitrate in the coastal water of Alexandria was 29 % of dissolved inorganic nitrogen. Its amount is widely varied from 0.00 to 17.63 ug at/l with an annual average of 2.96 ug at/l which is 75 times greater than that of the offshore values found by Asaad (1981).

The nitrate distribution showed much regular pattern than nitrite, exhibiting one major peak which occurred in December in the eastern part of the studied area (sts. 1 - 7) and in November in the western part (sts. 8 - 14). Additional peaks were recorded during May or June at a few localities. It is noticed that the major peaks coincided with very low contents of chlorophyll-a.

Abu-Qir area, subjected to considerable amounts of industrial and domestic wastes showed maximum average (5.26 ug at/l). The nitrate content decreased gradually westwards reaching its minimum average of 1.76 ug at/l at st.4.

Complete depletion of nitrate was detected during spring in the Eastern Harbour area associated with high level of chlorophyll-a (up to 87.80 mg/m^3). This may explain the exhaustion of nitrate ions by phytoplankton bloom during this period.

The nitrate maximum value (17.62 ug at/l) recorded in Maamoura water during June 1987 was accompanied by super saturation condition of dissolved oxygen (135.46 %) and a sharp drop in salinity (28.278 $\%_o$) demonstrating its origin. The strong inverse correlation (r = -0.9412, p 0.001) found between nitrate and salinity during this month confirms the suggestion.

Regarding the monthly average, November and December values represented the highest, being 8.13 and 8.27 ug at/l respectively while during the rest of the year the averages did not exceed 3.00 ug at/l.

According to the annual averages, the value of Mahmoud (1979) increased during the last ten years at Stanly area (4 times) and at Maamoura (6 times) while the concentration in the Eastern Harbour showed insignificant variation.

Similar to the nitrite condition, nitrate mean value decreased in the eastern part of the beach during summer 1988 to only 1/3 of its value of 1986 summer.

e) Silicate-Si

Complete depletion of silicate from the studied area did not occur during the period of sampling, where the values fluctuated widely between 0.06 and 23.08 ug at/l, with an annual average of 4.41 ug at/l. The uptake of silicate by diatoms during winter affected the silicate content, the average being 3.48 ug at/l. In warm seasons; spring and summer, the mean values increased again to reach 5.35 and 5.47 ug at/l respectively, while the autumn average was little higher than winter.

Contrary to the phosphate condition, a sharp drop in silicate content was detected in the beach water during September reaching its minimum average of 0.21 ug at/l.

A significant inverse correlation was found between salinity and silicate during summer and autumn months ($r = -0.3031$, $p < 0.001$) which demonstrate the effect of the influx of fresh and drainage water into the coastal area.

Except the Si-Peak at Stanly area (Fig. 2), the western localities subjected to large amounts of sewage and fresh waters, gave higher averages than those of the eastern part. The maximum average was found at st. 12 while the minimum at st. 4, being 6.39 and 3.08 ug at/l, respectively.

f) Nutrient ratios

The "limiting nutrient" concept long played an important role in aquatic environment. Smith (1979) found that the phytoplankton yeild depends mainly on N / P ratios; 15-17: 1 indicates that P is the critical controlling factor, from 9-10: 1 indicates that the yeild varied with N and 21: 1 shows that P is the primary cotrolling factor. In Italien coastal water, Chiaudani and Vighi (1978) stated that the marine algae are considered to be P-limited when the N / P ratio is higher than 6 and N-limited when the N / P ratio is lower than 4.5 . Accordingly, P limitation of biomass formation was the most common results of the present investigation where the mean N / P ratio reached 50: 1 (Tables 1 & 2) and deviated much from the normal oceanic ratio (16 : 1) found by Richards (1958).

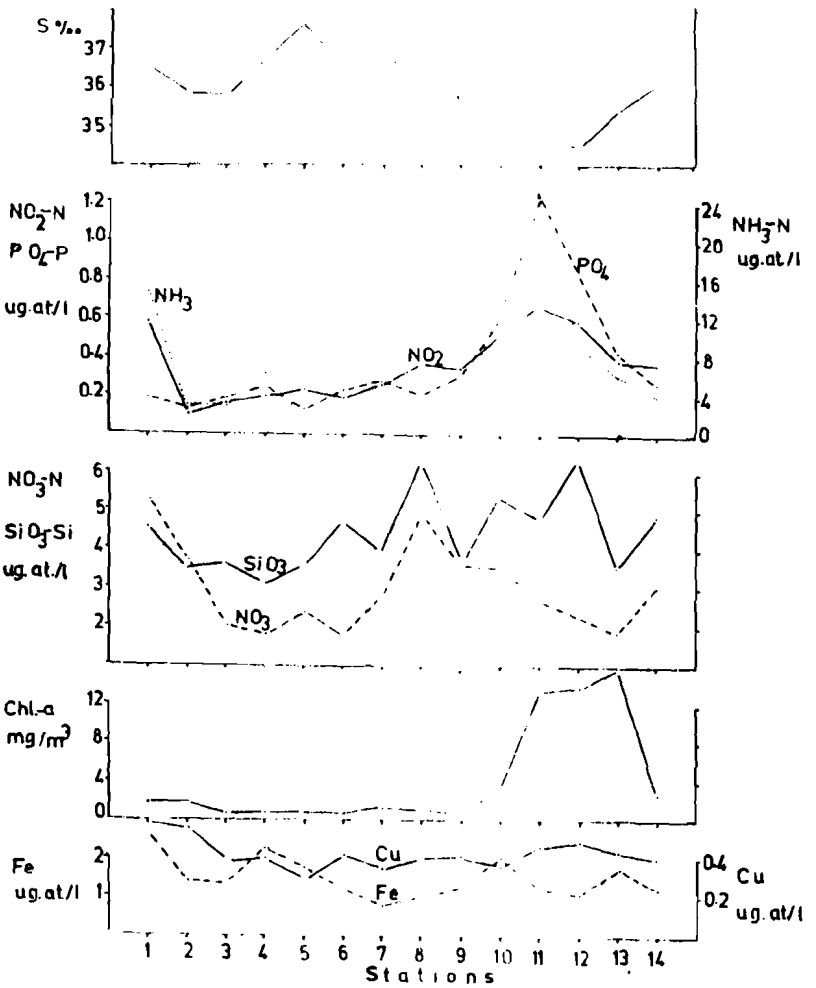

Fig. 2

Annual averages of studied parameters along Alexandria Beach (stations 1-14).

Table 1.

Monthly average ratios (P : N : Si) in Alexandria coastal water during 1986-1987.

Month	P	N	Si
July, 1986	1	7.4	27.1
Aygust	1	13.8	21.1
September	1	22.3	1.0
October	1	68.5	52.1
November	1	62.9	4.4
December	1	67.3	7.0
January, 1987	1	162.0	160.4
February	1	44.2	52.9
March	1	31.8	7.9
April	1	86.0	32.7
May	1	14.8	31.7
June	1	15.0	21.2
Annual average	1	50	34

Table 2.

Annual average ratios (P : N : Si) along Alexandria coastal water.

Station	P	N	Si
1- Abu-Qir	1	102.7	53.3
2- Maamour	1	78.8	63.0
3- Montazah	1	15.8	32.5
4- Mandara	1	65.1	28.4
5- Miami	1	43.5	48.2
6- Sidi-Bishr	1	42.6	33.2
7- Saray	1	53.2	38.8
8- Stany	1	39.8	36.9
9- Sporting	1	67.0	65.3
10- Shatby	1	34.0	18.3
11- Eastern	1	65.0	7.4
12-	1	45.0	17.9
13- Harbour	1	43.3	20.6
14- Anfoushi			
average	1	50	34

The N / P ratio, in general showed temporaly as well as spatial variation. Based on monthly average, the N / P ratios detected during the growing period, July - August, and May June, 1987, were relatively low and did not exceed the normal oceanic ratio (Table 1). During the rest months N / P ratios were relatively high (22.3 - 162.0 : 1) and may indicate potential P limitation.

The annual N / P ratio averages for the most studied stations were exceeded than 21 : 1 (Table 2) and according to Smith (1979) P becomes the primary controlling factor. Montazah beach water showed N / P ratio average closely nearer to normal oceanic ratio. At the highly polluted localities, e. g. the Eastern Harbour the N / P values were low (< 4.5) during summer months. N limitation may occur consequently due to strong loading with water having a low N / P ratio (sewage). Such condition was rarely occurred at the less polluted eastern part of the beach.

The Si / P ratio average was widely fluctuated between 1 : 1 (September) and 160.4 : 1 (January) with an annual average of 34 : 1 (Table 1). This mean is higher than that found in the Western Harbour by Nessim and Tadros (1986) or in the offshore water (El-Rayis, 1973).

The high N : Si : P ratio mean recorded during January, 162 : 160.4 : 1 was coincided with a sharp drop either in P or salinity. However, the very low Si / P ratio average recorded during September (1 : 1) was accompanied with high salinity.

g) Total iron

Since iron is associated with land drainage effluents it is usually found in considerable amounts in the coastal waters, Iron in trace amounts is essential for algal nutrition. Many authors suggested that the addition of iron increases C^{14} uptake by several folds (Menzel and Ryther, 1961). The discharged polluted water from industrial factories (Abu-Qir area) and drainage waters pass through sewers and pipelines made of iron along the shore. With time the pipelines become eroded by effluents and this may increase the concentration of iron passing to the coastal area with sewage and drainage waters.

The annual average of total iron, 1.52 ug at/l is nearly 70 times greater than that given by Chester and Stoner (1974) for normal sea water.

A remarkable exhaustion of iron by phytoplankton bloom during spring may cause a sharp drop in its concentration from maximum average of 2.95 ug at/l detected during May to its minimum mean of 0.78 ug at/l in June 1987.

Regionally, Abu-Qir area which is affected by different types of effluents showed the highest absolute value of 10.60 ug at/l and average of 2.66 ug at/l. The second polluted area with iron is Mandara area, st. 4, (2.24 ug at/l) followed by Shatby water (2.06 ug at/l). Stanly beach, on the other hand, gave its water the lowest average, being 0.78 ug at l

The total iron content in February was relatively low or completly depleted which was in a good agreement with the finding of Aboul-Nagha (1981) at the same region. Buljan (1954) suggested that the decrease of iron content in the sea water may be attributed to precipitation as hydrated ferric hydroxide or as hydrosol after decomposition of organic complexes, as well as to scavening by calcium carbonate, clay minerals and biogen suspended matter and biological assimilation.

h) Copper

Similar to iron, high concentration of copper appears to be associated with the industrial and domestic wastes and high amount of organic matter. Copper reaches the coastal water from large number of industrial processes around Alexandria city e. g., paper manufacture, wood preservation, agricultural chemicals and leaching of marine paints in addition to the sewage as a copper source. The concentration of copper in the coastal water varied from 0.08 to 1.78 ug at/l with an annual average of 0.42 ug at/l. Spring average represented the lowest value while the winter mean was the highest, being 0.31 and 0.57 ug at/l.

As the case with iron, Abu-Qir water contained the maximum average of copper, 0.60 ug at/l. The effect of Abu-Qir industrial effluents extends westwards under wind influence till Maamoura (Anon., 1991) where the mean value of Cu was 0.55 ug at/l. The minimum average of Cu was observed in Miami water (0.30 ug at/l). The Eastern Harbour area showed intermediate content (0.44 - 0.49 ug at/l).

i) Chlorophyll-a

Except at the Eastern Harbour area, the Alexandria coastal water showed considerable concentrations of chlorophyll-a varied between 0.10 and 11.89 mg/m^3. In the Eastern Harbour water high values were detected (>100 mg/m^3) as well as high average was calculated, being 14.34 mg/m^3 which is two times greater than that found by Aboul-Kassim, (1987) in the same area during the year 1985-1986.

The seasonal distribution of chlorophyll-a in the coastal water is similar to the finding of Aboul-Kassim (1987) which is characterized by two major peaks during August, 1986 and May, 1987, and a minor peak in February.

The mean value of chlorophyll-a in the Eastern Harbour, the highly biologically productive area-is 14 times greater than that of the eastern studied part, 8 times of Abu-Qir value, 6 times of Anfoushi and 4 times of Shatby value (Fig. 2). The high standing crop of phytoplankton in the coastal water is mainly attributed to the continous supply of untreated sewage effluent rich in different nutrient salts. The good positive correlation found between chlorophyll-a and oxidizable organic matter ($r = 0.4653$, p 0.001) and the negative correlation calculated between chlorophyll-a and salinity ($r = -0.2217$, p 0.05) demonstrate that the flourishing of phytoplankton in the beach water depends mainly on allochthonous supply.

It is evident that the chlorophyll-a peak recorded during May, 1987 was coincided with maximal averages of total iron, oxidizable organic matter and dissolved oxygen while the August chlorophyll-a peak occurred during the highest water temperature. It is also noticed that N : P ratios detected during these two months (May and August) were nearly close to the normal oceanic ratio.

CONCLUSIONS

According to the mean values of the studied chemical parameters, the beach water in front of Alexandria could be divided into two parts; the western part with considerable pollution (high averages) represented by sts. 10 - 14 and Abu-Qir area and the eastern less polluted part characterized by low averages, sts. 2 - 9.

A considerable improvement in water quality from the chemical point of view is noticed after the construction of the new sewage system in May 1988 which keeps domestic water to dispose away from the eastern part of the beach. A remarkable reduction (20 - 50 %) in the concentration of nutrients and heavy metals was detected during summer 1988. The oxidizable organic matter was dropped in its amount to 32 % while salinity increased by 1.662 $\%_o$ on average (Nessim and Tadros, 1989).

Miami and Stanly beaches, located in the eastern part and away from direct sewage discharge showed their waters have minimum dilution effect where salinity averages were found above 37 $\%_o$ (Nessim & Tadros, 1989). Miami samples sustained minimum averages of each ammonia and copper while Stanly gave minimum means of both oxidizable organic matter and total iron.

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