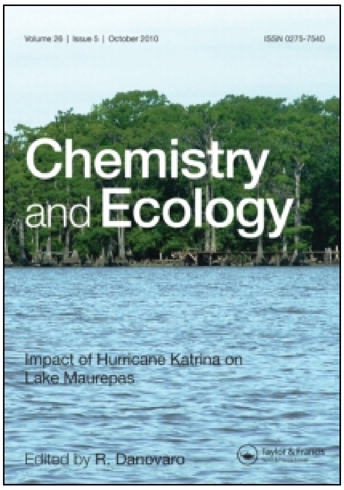

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The Effect of Sewage Discharge On Water Quality Off the Coast of Alexandria in Spring and Summer

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THE EFFECT OF SEWAGE DISCHARGE ON WATER QUALITY OFF THE COAST OF ALEXANDRIA IN SPRING AND SUMMER

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Water samples were taken from 7 transects at El-Anfushy, Eastern Harbour, El-Ebrahymea, Stanly, Gleem, Sidi-Bishr and El-Asafra along the coast off Alexandria. The area lies between latitude 31°10′ and 31°20′ N and longitude 29°55′ and 30° E. Nitrate, nitrite, ammonium, urea, dissolved inorganic phosphate, silicate and pH values were measured with average values 1.13, 0.43, 1.41, 1.21, 1.71, 7.16 $\mu mol\ l^{-1}$, respectively. The investigated area is considered to be eutrophic. Levels of nutrients measured in 1991 are all significantly higher than those found in the same area in 1976.

KEY WORDS: Sewage discharges, nutrients, eutrophication, eastern mediterranean.

INTRODUCTION

Alexandria is the principal summer resort of Egypt. It is a relatively densely populated region of the eastern Mediterranean, with more than 4 million inhabitants, receiving an additional one million tourists in summer who come to use the beaches for recreation. Alexandrian coastal waters are highly polluted with untreated sewage and other wastes. In the study area, sewage and runoff water are discharged mainly through outfalls direct to the sea without treatment. El-Anfushy and Eastern Harbour areas are affected by the main discharge at Kayet Bey. This outfall discharges about $57 \cdot 10^6\ m^3$ annually. Within the Eastern Harbour, there are 11 outfalls discharging untreated sewage. At Sporting, to the east of the Harbour, there is a small pipeline which discharges $21 \cdot 10^3\ m^3$ a year. The sewage outfall at Gleem is just at sea level and discharges $36 \cdot 10^3\ m^3$ a year. At Sidi-Bishr, there are three pumping stations, at Miami, Beer Masoud and El-Asafra, with annual discharges of $13 \cdot 10^3\ m^3$, $47 \cdot 10^3\ m^3$, and $6 \cdot 10^3\ m^3$.

The coastal water off Alexandria is one of the most pollution stressed sites in the Mediterranean. Abdel-Moati (1991) found that the free connection with the open sea and the regular flushing of the coastal waters by the annual input of $4.5 \cdot 10^3\ m^3$ of bottom neritic south-eastern Mediterranean water provides self purification for the area (about 2 km^2), with an estimated residence time of 162 days, indicating that a long-term build up of pollutants is prevented. The mixing of fresh and saline waters within a few kilometres from discharge points leads also to sedimentation of large amounts of suspended material. This is a rapid means of pollutant transfer to deeper water and consequent burial in sediments, limiting pollutant hazards to a few kilometres from shore.

The concentrations of inorganic phosphorus in surface waters of the Mediterranean are extremely low, 0.03 μmol l^{-1} $P\text{-}PO_4$ or less as expresed as orthophosphate, while typical concentrations for eutrophic coastal waters are >0.15 μmol l^{-1}, and for highly eutrophic systems even >0.30 μmol l^{-1}. Concentrations of inorganic nitrogen compounds in Mediterranean surface waters are 0.01 μmol l^{-1} $N\text{-}NO_3$ for nitrate, 0.5 μmol l^{-1} $N\text{-}NH_4$ for ammonium, and 0.1 μmol l^{-1} $N\text{-}NO_2$ for nitrite. In eutrophic waters these concentrations are usually higher by at least a factor of two, and in highly eutrophic waters by a factor or more than 5. In waters directly polluted by sewage or substantially polluted by river discharges, the concentrations of nitrate and ammonium are often even higher, above 35 μmol l^{-1} $N\text{-}NO_3$ and 20 μmol l^{-1} $N\text{-}NH_4$ (Unesco, 1988).

The aim of this work was to assess the effect on water quality of sewage discharged to the coastal water off Alexandria and to measure the degree of eutrophication (i.e., nutrient enrichment) especially during spring and summer.

MATERIALS AND METHODS

Water samples were collected from 7 transects perpendicular to the coast off El-Anfushy, Eastern Harbour, El-Ebrahymea, Stanly, Gleem, Sidi-Bishr and El-Asafra. The area lies between latitude 31°10′ and 31°20′ N and longitude 29°55′ and 30° E. Sampling was carried out twice, in May (spring) and in July (summer) of 1991. For each transect there were 3 stations (Fig. 1). At stations 1, 4, 7, 10, 13, 16 and 19 (Sector C), samples were taken of the surface water at the beach. At stations 2, 5, 8, 11, 14, 17 and 20 samples were taken at the surface and at 10 and 20 m depth (Sector B). At stations 3, 6, 9, 12, 15, 18 and 21, samples were taken at the surface and at 10, 20 and 30 m depth (Sector A). All samples were treated immediately with 0.5% chloroform to prevent, or at least minimize, any changes, and were kept in well stoppered polyethylene bottles. In the laboratory, samples were frozen at extreme low temperature (−20°C). Nitrate, nitrite, ammonium, urea, dissolved inorganic phosphate and silicate were measured spectrophotometrically according to the methods described by Grasshoff (1983), using a Shimadzu spectrophotometer UV-150-20. Results are expressed here as μmol l^{-1}. The detection levels were: for nitrate (0.05–45 μmol l^{-1}), nitrite (0.01–10 μmol l^{-1}), ammonium (0.05–90 μmol l^{-1}), urea 0.1–10 μmol l^{-1}), dissolved inorganic phosphate (0.01–28 μmol l^{-1}) and silicate (0.05–85 μmol l^{-1}).

RESULTS AND DISCUSSION

The surface distribution, at the beach (Sector C), of nitrate, nitrite, ammonium, urea, dissolved inorganic phosphate and silicate is illustrated in Figure 2. It can be seen that phosphate, ammonium and silicate values in May are higher than in July.

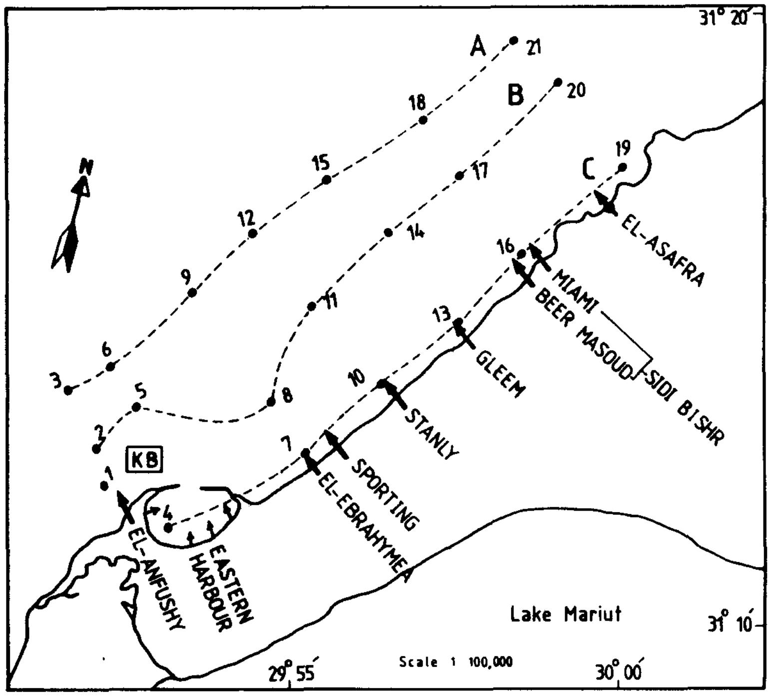

Figure 1 Position of sampling stations in the area investigated. Sectors A and B lie off-shore. Sector C (surface water samples only) were taken at the shore. Seven transects perpendicular to the shore are represented by points 1 – 21. KB = Kayet Bey. Arrows represent sewage outfalls at the coast.

Nitrate, nitrite and urea concentrations in May were lower than in July except at Stanly and Gleem. This might be due to oxidation of ammonium to nitrite or nitrate, or to the breakdown of amino acids or proteins by bacteria with urea as one of the by-products. It could be due to an increase in rate of assimilation in July by the increase of phytoplankton. El-Sherief (1994) found that total phytoplankton num-bers were 24094 ± 5182 in July. It could also be due to a monthly change in the discharge of sewage to the coastal area (Table I).

The vertical distribution of nitrate, nitrite and ammonium in the coastal waters of Alexandria in spring and summer is shown in Table II and illustrated for Sectors A and B in Figure 3a.

Nitrate

Nitrate constitutes about 26% of the total inorganic nitrogen in May and 56% in July when concentrations are higher; this may be attributed to oxidation of ammonium to nitrate or to the preferential uptake of ammonium by phytoplankton. In Abu-Qir Bay, where Mahmoud and Abdel-Hamied (1991) found a peak of nitrate followed by a peak of ammonium, nitrate contributed only about 14% of the total inorganic nitrogen, with a range in concentration of 1.77 to 16.56 $\mu mol\ l^{-1}$.

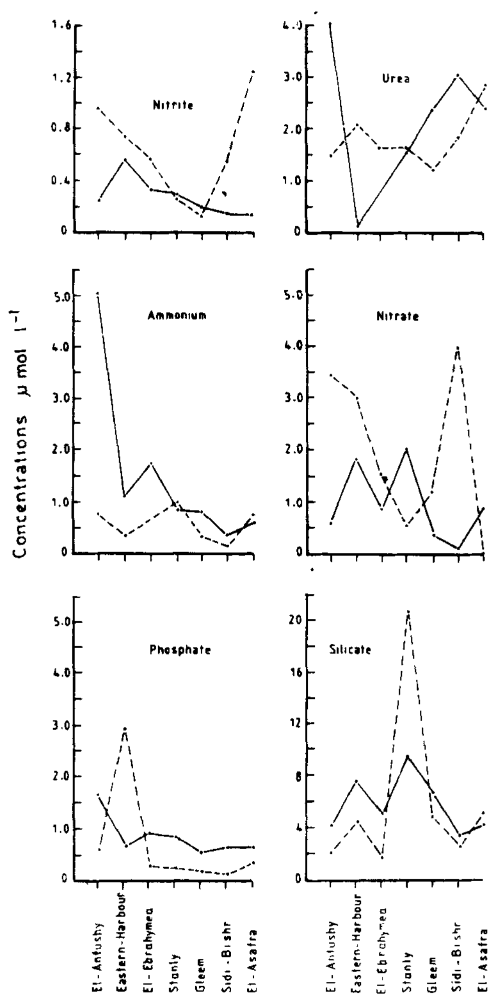

Figure 2 Surface water samples from Sector C at the seven coastal stations analyzed for ammonium, nitrate, nitrite, phosphate and silicate in May (---) and July (——), 1991.

The vertical distribution of nitrate (Fig. 3a) indicates an increase in nitrate concentration with depth in Sector B, while in Sector A, concentrations decreased with depth (both in May and July). Nitrate concentration varied widely from zero at many sites and depths in May and July to a maximum of 31.49 μmol l^{-1} in May in surface water in El-Asafra. Average nitrate concentrations in the investigated area showed remarkable local or regional variations as well as monthly differences. The average values ranged from 0.001 ± 0.003 to 5.29 ± 10.75 μmol l^{-1} El-Anfushy and El-Asafra in May and from 0.65 ± 0.84 to 2.03 ± 1.59 μmol l^{-1} at Sidi-Bishr and El-Ebrahymea in July. Low average values in summer were matched with relatively high temperature.

Table I Volume of water discharged to the investigated area through the main sewer at Kayet Bey (1991).

Month	*Volume of water* $10^3\ m^3$
January	5465
February	4844
March	5277
April	5031
May	5324
June	5318
July	5516
August	5645
September	4709
October	4291
November	5066
December	5306

Nitrite

Nitrite is the least abundant nitrogenous species in the coastal water, about 14% and 19% of the total inorganic nitrogen in May and July. Mahmoud and Abdel-Hameid (1991) found that nitrite contributed only 1.47% of total inorganic nitrogen in Abu-Qir Bay.

The vertical distribution of nitrite in the investigated area (Fig. 3a) showed an increase with depth especially along Sector A in both May and July, while along Sector B in May it decreased with depth. Variation in the vertical nitrite profiles occurred between the two months at many sites. Minimum values of 0.09 and 0.14 μmol l^{-1} were found in May and July at several sites. Maximum values of 1.62 and 1.58 μmol l^{-1} were found at mid-depth (10 m) and at the bottom (30 m) at Stanly in May and July. The average values showed local variations between the two months, from 0.26 ± 0.07 μmol l^{-1} at El-Asafra to 0.51 ± 0.48 μmol l^{-1} at Stanly in May and from 0.43 ± 0.26 μmol l^{-1} at Eastern Harbour to 0.50 ± 0.31 μmol l^{-1} at El-Ebrahymea in July.

Ammonium

The most abundant nutrient in the area is ammonium, contributing about 46% of the total inorganic nitrogen. The vertical distribution of ammonium shows that in Sector B in May and July, it decreased with depth, while in Sector A, concentrations of ammonium decreased from El-Anfushy to Gleem, and then increased to El-Asafra. In July, it also decreased with depth.

Variation in the vertical profile of ammonium appeared in both sampling months at many sites. The values varied widely from a minimum of 0.78 μmol l^{-1} at 30 m depth at Gleem to zero μmol l^{-1} in July at many sites and depths. In May a maximum of 17.46 μmol l^{-1} was found at El-Anfushy, and in July 3.54 μmol l^{-1} at the surface at El-Ebrahymea. Average values were 1.50 ± 0.44 μmol l^{-1} at El-Ebrahymea to 4.09 ± 5.49 mol l^{-1} at El-Anfushy in May and 0.19 ± 0.28 μmol l^{-1} at El-Anfushy to 1.22 ± 1.12 μmol l^{-1} at El- Ebrahymea in July.

Table II Mean and ranges of concentrations of inorganic nitrogen compounds (N-NH_4, N-NO_2, N-NO_3), urea-N, phosphate (P-PO_4), silicate (Si-SiO_4), pH and N:P ratio, May and July, 1991. Values are given (except pH) as μmol l^{-1}.

Transects		*NH_4*	*NO_2*	*NO_3*	*Urea*	*PO_4*	*Si*	*pH*	*N/P*
					May, 1991				
El-Anfushy	M	4.09 ± 5.49	0.37 ± 0.13	0.001 ± 0.003	1.62 ± 0.33	0.65 ± 0.23	4.20 ± 4.20	8.11 ± 0.02	1:0.001
	R	1.16 – 17.46	0.32 – 0.59	0.0 – 0.01	0.96 – 2.06	0.22 – 1.06	2.76 – 7.6	8.06 – 8.14	
Eastern Harbour	M	1.65 ± 0.35	0.46 ± 0.24	0.36 ± 0.55	1.70 ± 0.83	1.81 ± 1.02	9.15 ± 6.61	8.11 ± 0.04	1:0.2
	R	0.97 – 2.04	0.14 – 0.95	0.0 – 1.68	0.75 – 3.27	0.48 – 2.55	4.41 – 24.86	8.08 – 8.11	
El-Ebrahymea	M	1.50 ± 0.44	0.34 ± 0.17	0.09 ± 0.24	not analysed	3.22 ± 2.43	9.63 ± 8.43	8.06 ± 0.05	1:0.04
	R	0.26 ± 2.52	0.05 – 0.59	0.0 – 0.69	not analysed	0.66 – 6.73	3.5 – 20.80	7.96 – 8.11	
Stanly	M	2.76 ± 0.22	0.51 ± 0.48	1.11 ± 1.21	1.07 ± 0.61	2.58 ± 2.05	17.43 ± 16.87	8.09 ± 0.02	1:0.43
	R	1.21 – 6.84	0.23 – 1.62	0.03 – 3.78	0.26 – 1.94	0.92 – 6.56	5.36 – 50.65	8.05 – 8.13	
Gleem	M	1.70 ± 0.68	0.46 ± 0.24	0.04 ± 0.09	1.55 ± 0.27	3.47 ± 5.83	4.51 ± 0.63	8.11 ± 0.001	1:0.01
	R	0.78 – 3.007	0.14 – 0.95	0.0 – 0.26	1.06 – 1.89	0.53 – 17.73	3.69 – 4.26	8.09 – 8.12	
Sidi-Bishr	M	2.31 ± 1.21	0.41 ± 0.14	not detected	1.54 ± 0.22	1.94 ± 1.59	8.07 ± 6.57	8.09 ± 0.03	not detected
	R	1.12 – 4.17	0.18 – 0.68	not detected	1.21 – 1.81	0.57 – 4.93	3.69 – 20.44	8.03 – 8.15	
El-Asafra	M	1.65 ± 0.26	0.26 ± 0.07	5.29 ± 10.75	not analysed	1.94 ± 1.59	9.58 ± 7.29	8.10 ± 0.01	1:2.73
	R	1.31 – 2.09	0.14 – 0.36	0.0 – 31.49	not analysed	0.57 – 4.93	3.90 – 23.40	8.08 – 8.12	
					July, 1991				
El-Anfushy	M	0.19 ± 0.28	0.47 ± 0.64	0.81 ± 0.67	1.14 ± 0.24	0.44 ± 0.22	7.49 ± 4.36	8.00 ± 0.10	1:1.84
	R	0.0 – 0.97	0.05 – 2.03	0.0 – 1.54	0.92 – 1.57	0.26 – 0.88	2.6 – 15.5	7.81 – 8.12	
Eastern Harbour	M	0.29 ± 0.34	0.43 ± 0.26	1.20 ± 3.39	1.19 ± 0.22	0.74 ± 0.33	6.90 ± 2.88	7.96 ± 0.14	1:1.60
	R	0.0 – 0.97	0.09 – 0.63	0.0 – 10.22	0.91 – 1.57	0.18 – 1.06	2.81 – 11.39	7.74 – 8.12	
El-Ebrahymea	M	1.22 ± 1.12	0.50 ± 0.31	2.03 ± 1.59	0.78 ± 0.29	0.84 ± 0.53	5.66 ± 1.67	7.94 ± 0.08	1:2.62
	R	0.29 – 3.54	0.18 – 1.08	0.0 – 5.03	0.44 – 1.38	0.26 – 1.89	4.06 – 8.22	7.92 – 8.02	
Stanly	M	0.45 ± 0.42	0.49 ± 0.42	1.29 ± 1.60	1.09 ± 0.34	3.89 ± 8.60	6.80 ± 6.09	8.02 ± 0.11	1:0.33
	R	0.0 – 1.16	0.23 – 1.58	0.0 – 4.58	0.70 – 1.86	0.01 – 24.95	1.72 – 19.34	7.85 – 8.15	
Gleem	M	0.21 ± 0.19	0.26 ± 0.18	0.97 ± 0.79	1.16 ± 0.48	0.36 ± 0.30	3.83 ± 1.49	8.02 ± 0.11	1:2.69
	R	0.0 – 0.49	0.09 – 0.54	0.0 – 2.40	0.23 – 1.86	0.04 – 1.01	1.98 – 6.55	7.83 – 8.12	
Sidi-Bishr	M	0.65 ± 0.55	0.47 ± 0.19	0.65 ± 0.84	0.75 ± 0.18	1.74 ± 2.71	4.68 ± 2.88	8.00 ± 0.02	1:0.37
	R	0.0 – 1.75	0.27 – 0.77	0.0 – 1.99	0.49 – 0.93	0.09 – 8.32	1.46 – 6.4	7.98 – 8.04	
El-Asafra	M	0.81 ± 0.72	0.47 ± 0.28	1.93 ± 2.87	0.94 ± 0.45	0.28 ± 0.15	2.30 ± 1.77	7.96 ± 0.12	1:6.89
	R	0.01 – 1.99	0.23 – 1.13	0.0 – 8.79	0.75 – 1.46	0.04 – 0.53	1.30 – 4.39	7.75 – 8.11	

N/P = N-NO_3 : P-PO_4 R = Range   M = Mean ± standard deviation
A, data for May 1991; B, data for July 1991

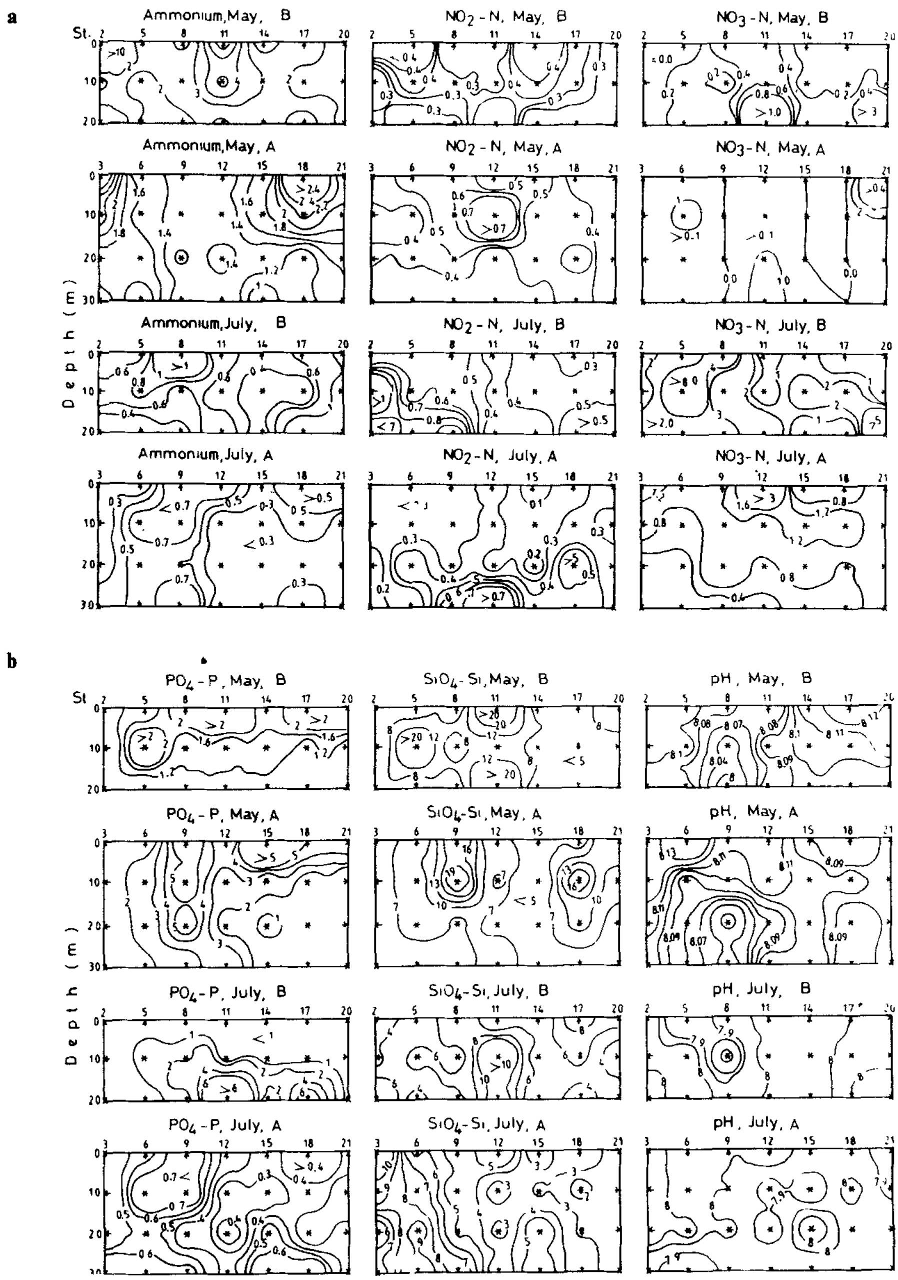

Figure 3a, b

Urea

Dissolved organic compounds is sea water, including urea, originate from several autochthonous and allochthonous land-based sources. Urea is a constituent of human urine and also of the urine of some aquatic animals. It dissociates to ammonia c

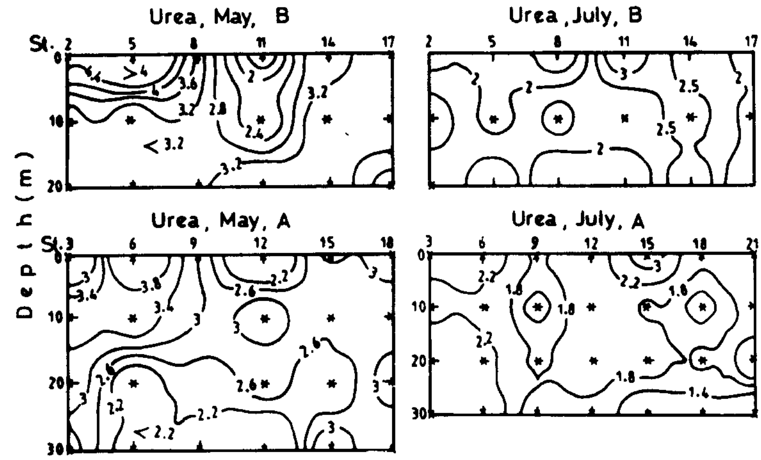

Figure 3 The depth distribution in May and July, 1991, of inorganic nitrogen compounds (a), phosphate and silicate and pH (b) and urea (c) at stations along sectors A and B.

and cyanate at great dilution. Bacteria break down amino acids to produce urea and it is also formed from the breakdown of proteins via purines and pyrimidines. The possibility that urea could be a significant source of nitrogen for growth of marine phytoplankton was suggested by Harvey (1940); Remsen (1971) found concentrations of urea in US coastal sea water from Cape Cod to Cape May, ranging from 0.12 μmol l^{-1} to 5.6 μmol $1l^{-1}$.

Eastern Harbour has the highest concentration with 3.27 μmol l^{-1} and the lowest concentrations 0.26 μmol l^{-1} (30 m) at Stanly in May. In July the highest urea content, 1.86 μmol l^{-1}, is at Stanly and Gleem while the lowest, 0.23 μmol l^{-1}, is at Gleem. The average urea ranged from 1.54 ± 0.22 to 1.07 ± 0.61 μmol l^{-1} at Sidi Bishr and Eastern Harbour in May and from 0.75 ± 0.18 to 1.19 ± 0.22 μmol l^{-1} at Sidi-Bishr and Eastern Harbour in July. The vertical distribution of urea in May and July is illustrated in Figure 3c. In May and July, along Sector B, concentrations decreased with depth, while in May, along Sector A, it increased from the surface to 10 m depth then decreased. In contrast, in July, along Sector A, it decreased from the surface to 10 m. Surface water content of urea is much higher than that in bottom water, indicating an allochthonous origin.

Dissolved Inorganic Phosphate

The minimum value of phosphate found in May was 0.22 μmol l^{-1} at El-Anfushy (10 m) and the maximum 17.73 μmol l^{-1} at Gleem (surface). In July the minimum (0.04 μmol l^{-1}) was found at Gleem, Stanly and El-Asafra and the maximum (24.95 μmol l^{-1}) at Stanly (20 m). The average values showed considerable regional differences, varying from 0.65 ± 0.23 μmol^{-1} at El-Anfushy to 3.47 ± 5.83 μmol l^{-1} at Gleem in May and from 0.28 ± 0.15 μmol l^{-1} at El-Asafra to 3.89 ± 8.6 μmol l^{-1} at Stanly in July.

The vertical profile of phosphate in May and July is illustrated in Figure 3b; in May it decreased with depth along Sectors A and B, and in July along Sector B. In contrast, at Stanly and Sidi Bishr, phosphate concentration in bottom water was higher than at the surface.

Nitrogen to Phosphorus Ratio

Riley and Skirrow (1967) showed that a relatively constant N:P ratio of 15:1 was found statistically on a world scale. Chiaudani and Vighi (1978) found that marine algae in the Mediterranean are P-limited at a N:P ratio of 6:1, and N-limited at a ratio of < 4.5; in the range of 4.5–6.0:1 the two nutrients are near their optimal assimilative proportion.

For coastal waters off Alexandria in spring and summer of 1991, the N:P ratio (Table II) ranged from 0:0 at El-Anfushy and Sidi Bishr, to 1:3 at El-Asafra in May, while in July it was 1:0.33 to 1:7 at Stanly and El-Asafra. These very low ratios show that phosphate is higher than nitrate, especially at El-Anfushy, Sidi Bishr and El-Asafra. Except at Stanly in July where N:P ratio was $> 6:1$, the area was N-limited. Emara *et al.* (1992) found N:P ratio in Eastern Harbour ranged from 1:9 to 1:4.5, while at El-Mex Bay it was 1:22 and 1:5. Mahmoud and Abdel-Hamied (1991) found a N:P ratio between 2:1 and 10:1 in Abu-Qir Bay. Saad and Hemeda (1992 b) found monthly average N:P: ratio of 0.7:1 and 7.2:1 in the Western Harbour.

Silicate

Concentrations of silicate varied widely from a minimum of 2.76 μmol l^{-1} (as SiO_2) at El-Anfushy and 1.3 μmol l^{-1} at El-Asafra inn May and July, with a maximum of 50.65 μmol l^{-1} (May) and 19.34 μmol l^{-1} (July) at Stanly. Average values show considerable regional variations from 4.20 ± 1.5 to 17.43 ± 16.87 μmol l^{-1} in May at El-Anfushy and Stanly, and from 2.3 ± 1.77 to 7.47 ± 4.36 μmol l^{-1} at El-Asafra and El-Anfushy. Concentration in May are higher than in July.

Vertical profiles of dissolved silicate (Fig. 3b) show an increase with depth in May and July, especially in Sector B (surface to 10 m) from Eastern Harbour to El-Ebrahymea, while along Sector A in May, silicate increased from west to east especially at the transects from El-Ebrahymea and Sidi-Bishr. In contrast, silicate along Sector A in July decreased from west to east.

Hydrogen Ion Concentration (pH)

The pH of sea water is affected by temperature, the level of dissolved oxygen, photosynthetic activity of aquatic flora, and the amounts of organic constituents present. Waste discharges to coastal water also affect pH. In the investigated area, pH was always alkaline. Its value decreased with depth in Sectors A and B in May and July (Fig. 3b), varying from a minimum of 7.96 at El-Ebrahymea, to a maximum of 8.15 at Sidi Bishr in May, while in July it varied more widely from 7.74 at Eastern Harbour to 8.15 at Stanly. Average pH values showed some slight regional variation, with values from 8.06 ± 0.05 to 8.11 at the transects El-Ebrahymea, Eastern

Harbour, El-Anfushy and Gleem. In contrast, in July, average values ranged from 7.94 ± 0.08 at El-Ebrahymea and 8.02 ± 0.11 at Stanly and Gleem.

The higher levels of nitrate, nitrite and ammonium found in the investigated area have been attributed to many factors such as their production by the oxidation of organic nitrogen compounds (Fiadeiro and Strickland, 1968; Hart and Currie, 1960; Barber, 1977; Treguer and Corre, 1979), by zooplankton and animal excretion (Smith, 1977; Ward *et al.*, 1984), and by nitrate and nitrite reduction in the relatively oxygen-poor bottom water (Calvert and Price, 1971). The extracellular release of nitrite from phytoplankton is also reported (Vaccaro and Ryther, 1960). The lower levels of nitrate, nitrite and ammonium may be attributed to uptake by phytoplankton, since ammonium is the form of nitrogen preferred by plankton, but after its depletion to less than 0.15 μmol l^{-1}, nitrate and nitrite will be utilized (Unesco, 1988; El-Sherief, 1994).

The increase and decrease in the concentrations of urea in the area could be attributed to a change in the rate of urea dissociation or to uptake of urea by phytoplankton. Carpenter and Watson (1972) and McCarthy (1972) found that urea can support growth of phytoplankton in coastal and some off-shore waters.

The variation in the inorganic phosphorus content may be due to the decomposition of particulate organic matter at the surface, absorption to suspended particulates and to bottom sediments (Tsunogai *et al.*, 1979), its excretion by organisms at the sea surface (Goering and Wallen, 1967), and the progressive decay of descending phytoplankton (Hammer, 1971).

Irregular profiles of silicates were found at several sites, possibly related to variation in silicate uptake by solution of diatom frustules (Stefansson, 1968), as well as water column turbulence. El-Sherief (1994) found that diatoms were the predominant component of the phytoplankton in July, constituting about 84% of the totals but in May were only 29%.

A high pH value could be the result of photosynthesis by abundant phytoplankton, while sewage discharge to the coastal water will result in a decrease in pH values.

The main factor that affects the distribution of nitrate, nitrite, ammonium, urea, inorganic phosphorus, silicates and pH is the sewage discharged to the area without any treatment.

CONCLUSION AND SUMMARY

Regional variations in average values for nitrate, nitrite, ammonium, phosphate and pH in the coastal waters of Alexandria during the spring and summer of 1976 (Mahmoud, 1979) and in the present study (1991) are shown in Figure 4. It can be seen that concentrations of nutrients have increased greatly during the last 15 years, especially for phosphates, where concentrations have increased 11-fold. Nitrate, nitrite and ammonium have also doubled. This might be due to the continued discharge of wastes to the coastal waters without treatment and a higher uptake of the inorganic N species than phosphate in N-limited areas. In Alexandria coastal waters the N:P ratio in 1976 was 1:6 (Mahmoud, 1979), while in 1991 it was 1:0.6, attributed

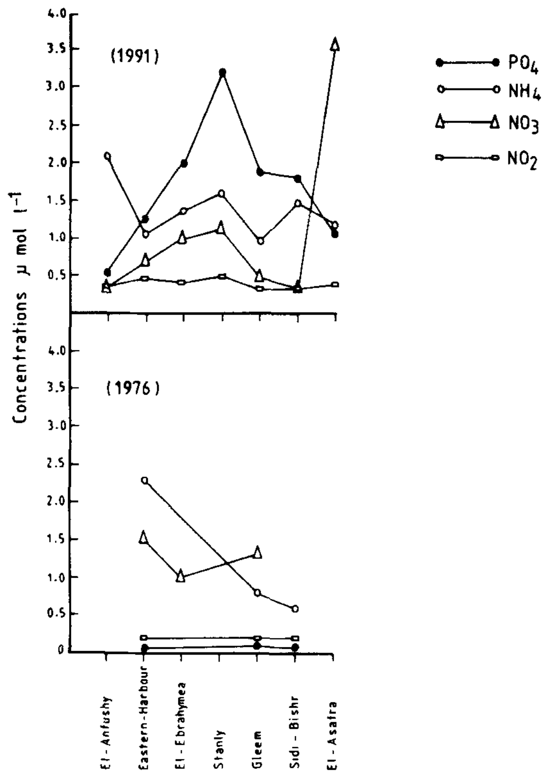

Figure 4 Variations in the average concentrations of ammonium, nitrate, nitrite and phosphate (μmol l^{-1}) found in the coastal water off Alexandria in May and July of 1976 and 1991.

to the increase in phosphate. Average pH in 1976 was 8.14 while in 1991 the average was 8.04, possibly due to increased discharge of sewage. El-Anfushy has the highest levels of ammonia, while Stanly has the highest levels of phosphate and El-Asafra has the highest levels of nitrate. According to Unesco (1988) reports, coastal waters off Alexandria are eutrophic due to the discharge of untreated sewage, with average phosphate concentrations of 1.72 μmol l^{-1}, nitrate 1.13 μmol l^{-1}, nitrite 0.43 μmol l^{-1} and ammonia concentration 1.41 μmol l^{-1}. In 1976, the same nutrients were significantly lower at 0.15, 0.88, 0.2 and 1.14 μmol l^{-1}.

For comparison, data for nutrient levels in other studies in the region are shown along with results of the present study in Table III.

It can be seen that there are quite substantial differences that can be attributed to differences in waste water content, i.e., El-Mex Bay is affected by the discharge of El-Umum drain which contains mainly industrial, agricultural and sewage wastes, while Eastern Harbour, Kayet Bey and the coastal water of the eastern region off Alexandria are affected mainly by sewage discharged from the main outfall at Kayet Bey.

Inorganic nitrogen components in the present study (ammonium 0–17.46 μmol l^{-1}, nitrate 0–31.49 μmol l^{-1}, and nitrite 0.14–1.62 μmol l^{-1}) are lower than values

Table III Concentrations of inorganic nitrogen compounds ($N-NH_4, N-NO_3, N-NO_2$), urea–N, phosphate ($P-PO_4$), silicate ($Si-SiO_4$) and pH reported from the same area. Data (ranges) from the present study are included for comparison.

Ecosystem	*Ammonium*	*Nitrate*	*Nitrite*	*Urea*	*Phosphate*	*Silicate*	*pH*	*References*
Alexandria Coastal Water	1.71 – 2.0	0.18 – 3.2	0.03 – 0.83	–	–	–	7.0 – 8.4	Mahmoud (1979)
Eastern Harbour	–	–	–	–	–	–	7.7 – 8.25	Shriadah (1982)
Kayet Bey	0.0 – 93.0	0.25 – 33.0	–	–	0.1 – 0.89	–	7.5 – 8.2	Mahmoud (1986)
El-Mex Bay	–	–	–	–	0.0 – 35.9	–	–	
Western Harbour	–	–	–	–	–	–	7.05 – 8.35	Nessim and Tadros (1986)
Eastern Harbour	1.41 – 60	0.0 – 1.0	1.4 – 3.69	–	2.2 – 8.0	–	7.7 – 8.25	El-Deek and Mahmoud (1988)
Abu-Qir Bay	8.99 – 22.13	1.77 – 16.56	4.98 – 15.43	–	0.82 – 1.94	–	–	Mahmoud and Abdel-Hamied(1991)
Eastern Harbour	0.1 – 88	0.0 – 103.5	0.0 – 1.68	–	0.44 – 17.6	–	–	Emara *et al.*
El-Mex Bay	0.49 – 67.4	0.46 – 40.5	0.32 – 21.6	–	0.35 – 9.37	–	–	(1992)
Eastern Harbour	–	–	–	–	–	0.0 – 31.23	–	Zaghloul and Halim (1992)
Western Harbour	–	0.01 – 8.96	0.1 – 6.11	–	0.11 – 2.89	2.8 – 62	7.0 – 8.81	Saad and Hemeda (1992 a and b)
Western Harbour	–	–	–	0.19 – 2.45	–	–	–	El-Deek (1994)
Gamasa	2.31 – 11.37	4.58 – 18.74	0.20 – 2.51	0.25 – 3.91	0.65 – 6.03	0.40 – 10.13	–	El-Deek *et al.*
Ras El-Bar	3.92 – 13.73	1.43 – 24.78	0.11 – 11.30	0.21 – 3.29	0.68 – 21.06	0.35 – 10.84		(1994)
Port Said	6.33 – 24.43	0.50 – 18.20	0.07 – 7.90	0.26 – 5.15	0.12 – 27.37	1.80 – 16.76		
El-Anfushy to El-Asatra	0.0 – 17.46	0.0 – 31.49	0.14 – 1.62	0.26 – 3.26	0.04 – 24.95	1.30 – 50.65	7.85 – 8.15	Present study

reported elsewhere for the Eastern Harbour, Kayet Bey, El-Mex Bay and Abu-Qir Bay, attributed to the increased discharge of untreated wastes. Phosphate concentrations, however, are higher (0.04–24.95 μmol l^{-1}) than reported in the other studies except at Port Said and El-Mex Bay (0.12–27.37 and 0–35.9 μmol l^{-1}). Silicate in the present study (1.3–50.65 μmol l^{-1}) is generally higher than reported elsewhere in the area but equal to the level found in the Western Harbour (2.8–62 μmol l^{-1}). Urea in the present study (0.26–3.26 μmol l^{-1}) is equal to that found in the other studies except for Port Said (0.26–5.15 μmol l^{-1}). pH values are in the same range as in other studies, due to the strong buffer capacity of sea water.

References

Abdel-Moati, A. R. (1991) Pollution problems of Alexandria coast, strategies and future. Program and Abstracts of International Symposium on Geophysical Hazards in Developing Countries and their Environmental Impacts. August 4–9, 1991. Perugia, Italy, 5 pp.

Barber, R. T. (1977) The Joint-I Expedition of the Coastal Upwelling Ecosystems Analysis Programme. *Deep Sea Research*, **24**: 1– 6.

Calvert, S. E. and Price, N. B. (1971) Upwelling and nutrient regeneration in the Benguela Current. *Deep Sea Research*, **18**: 505–523.

Carpenter, E. J. and Watson, S. W. (1972) Utilization of urea by some marine phytoplankters. *Limnology and Oceanography*, **17**: 265–269.

Chiaudani, G. and Vighi, M. (1978) Metodologia standarde di saggio algare per lo studio della contaminazione delle acque marine. *Quaderni dell'Instituto di Ricerca Sulle Acque*, **39**: 120 pp.

El-Deek, M. S. (1994) The water pollution of the Western Harbour by phenolic compounds, anionic detergents and urea. *Bulletin High Institute Public Health*. **24**: 945–965.

El-Deek, M. S. and Mahmoud, Th.H. (1988) The effect of sewage pollution on the constitution of sea water in the Eastern Harbour, Alexandria. The First National Conference on Environmental Studies and Research. Jan. 1988,Cairo, Egypt, 519–525

El-Deek, M. S., Abdel-Hameid, O. H. and Fattouh, F. A. (1994) Environmental studies of sea water along the Egyptian Mediterranean beaches between Port-Said and Gamasa. *Bulletin High Institute Public Health*. **24**: 263–277.

El-Sherief, Z. M. (1994) Effect of sewage discharge on phytoplankton population in east of Alexandria coastal waters (Egypt). Proceedings of the 4th International Conference for Environmental Studies and Research. *Towards a Better Environment*. Institute of Environmental Studies and Research, Ain-Shams University, Cairo, pp. 184–193.

Emara, H., Shriadah, M. A., Mahmoud, Th.H. and El-Deek, M. S. (1992) The effect of sewage and industrial wastes on the chemical characteristics of the Eastern Harbour and El-Mex Bay waters of Alexandria, Egypt. Proceedings of an International Conference in *Marine Coastal Eutrophication*, Bologna, Italy 21–24 March, 1990, 773–784.

Fiadeiro, M. and Strickland, J. D. H. (1968) Nitrate reduction and the occurrence of a deep nitrite maximum in the ocean off the west of South America. *Journal Marine Research*, **26**: 187–201.

Grasshoff, K. (1983) *Methods of Sea Water Analysis*. Second Extended Edition, Verlage Chemie, New York, 317pp.

Hammer, U. T. (1971) Limnological studies of the lakes and streams of the upper Qu'Appelle River system, Saskatchewan, Canada. I Chemical and physical aspects of the lakes and drainage system. *Hydrobiologia*, **37**: 473–507.

Hart, J. T. and Currie, R. I. (1960) The Benguela Current. *Discovery Reports*, **31**: 123–298.

Harvey, H. W. (1940) Nitrogen and phosphorus required for the growth of phytoplankton. *Journal Marine Biological Association*. U.K., **24**: 115–123.

Goering, J. J. and Wallen, D. (1967) The vertical distribution of phosphate and nitrite in the upper one-half meter of the south east Pacific Ocean. *Deep Sea Research*, **14**: 29–33

Mahmoud, Th. H. (1979) The effect of sewage discharge on the water quality of the coast of Alexandria. M.Sc. Thesis, Alexandria University, 135 pp.

Mahmoud, Th. H (1986) Phosphorus and nitrogen dynamics in the polluted coastal waters off Alexandria. Ph.D. Thesis, Alexandria University, 301 pp.

Mahmoud, Th. H. and Abdel-Hamied, O. H. (1991) The distribution and the relationship between nitrogen and phosphorus compounds in Abu-Qir Bay, Alexandria, Egypt. *Bulletin High Institute Public Health*, **21:** 359–370.

McCarthy, J. J (1972) The uptake of urea by natural populations of marine phytoplankton. *Limnology and Oceanography*, **17**: 738–748.

Nessim, R. B. and Tadros, A. B. (1986) Distribution of nutrient salts in the water and pore-water of the Western Harbour of Alexandria. *Bulletin Institute of Oceanography and Fishery, Egypt*, **12**: 165–174.

Remsen, C. C. (1971) The distribution of urea in coastal and oceanic waters. *Limnology and Oceanography*, **16**: 732–740.

Riley, J. P. and Skirrow, G (1967) *Chemical Oceanography*, Vol. I Academic Press, London, Second Ed., 712 pp.

Rowe, G. T., Clifford, C. H. and Smith, K. L. Jr (1977) Nutrient regeneration in sediments off Cap Blanc, Spanish Sahara. *Deep Sea Research*, **24**: 57–63

Saad, M. A. H. and Hemeda, E. I. M. (1992a) Effect of pollution on the Western Harbour of Alexandria. I. Environmental characteristics. Proceedings of an International Conference in *Marine Coastal Eutrophication*, Bologna, Italy 21–24 March, 1990, pp.737–753

Saad, M. A. H. and Hemeda, E. I. M. (1992b) Effect of pollution on the Western Harbour of Alexandria. II. Nutrient salts. Proceedings of an International Conference *Marine Coastal Eutrophication*, Bologna, Italy 21–24 March, 1990, pp. 755–772.

Shriadah, M. M. A. (1982) Studies on the chemical composition of the Eastern Harbour, Alexandria. M.Sc. Thesis, Alexandria University, 143 pp.

Smith, V. H. (1977) Nutrient dependence of primary productivity in lakes. *Limnology and Oceanography*, **24**: 1051–1064.

Stefansson, U. (1968) Dissolved nutrients, oxygen and water masses in the northern Irwinger Sea. *Deep Sea Research*, **15**: 541– 575.

Tréguer, P. and Le Corré, P. (1979) The ratios of nitrate, phosphate and silicate during uptake and regeneration phases of Moroccan upwelling regime. *Deep Sea Research*, **26**: 163–184.

Tsunogai, S., Kusakabe, M., Iizumi, H., Korke, I. and Hattori, A. (1979) Hydrographic features of the deep water of the Bering Sea. *Deep Sea Research*, **26**: 641–659.

Unesco (1988) Eutrophication in the Mediterranean Sea receiving capacity and monitoring of long-term effects, Bologna, Italy, 26 March (1987). Unesco Reports in Marine Science, No.49, 195 pp.

Vaccaro, R. E. and Ryther, J. H. (1960) Marine phytoplankton and the distribution of nitrite in the sea. *Journal Conservation International Exploratoin Mer*, **25**: 260–271.

Ward, B. B., Tabbat, M. C. and Perry, M. J. (1984) Contribution of phytoplankton and nitrifying bacteria to ammonia and nitrite dynamics in coastal water. *Journal Continental Shelf Research*, **3**: 383–398.

Zaghloul, F. A. and Halim, Y. (1992) Long-term eutrophication in a semi-enclosed bay: the Eastern Harbour of Alexandria in *Marine Coastal Eutrophication*. Proceedings of an International Conference, Bologna, Italy, 21–24 March 1990, 727–735.