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DISTRIBUTION OF NITROGEN AND PHOSPHORUS IN THE MEDITERRANEAN WATERS OFF THE NILE DELTA

RASPODJELA DUŠIKA I FOSFORA U MORSKOJ VODI ISPRED UŠĆA RIJEKE NIL (SREDOZEMNO MORE)

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The distribution of dissolved inorganic nitrogen and phosphorus in the pelagic waters overlying the continental shelf off the Egyptian Mediterranean coast was studied during February 1986. Nitrate is the dominating component constituting about 55% and 64% in the inshore and offshore waters, respectively. Reactive phosphorus constitutes only 5% of the total phosphorus in the area. The relative abundance of different forms of nitrogen and phosphorus was also studied at some stations. The effect of land based sources on the levels and distribution of different nitrogen and phosphorus species are evaluated and discussed.

INTRODUCTION

Prior to 1965, large amounts of nutrient rich flood water (average ca. 42.5×10^9 m^3 / y) used to discharge into the South-eastern Mediterranean from late August to November. The discharge of the flood water had raised greatly the nutrients levels of the S. E. Mediterranean waters thus furnished a fertile environment for the massive phytoplankton blooms which was developed in the area during this period. In a manner similar to a chain reaction of all trophic levels, including fish, enormously increased.

In the post High-Dam period, the biological productivity of the Egyptian Mediterranean waters has greatly declined. Such drastic change was attributed to the cessation of the Nile flood and in particular to the drop of the nutrient levels available for phytoplankton production. In the last twenty years, no reliable assessment of the nutrients concentrations in the S. E. Mediterranean waters off the Egyptian coast were made. The data given by Ichtholog 1966 (Emara, 1969) and 1969—1970 (El-Kholy and El-Wakeel, 1975) lacks accuracy because of the methods used.

The present work aims to assess the levels of inorganic and organic forms of nitrogen and phosphorus in the waters overlying the continental shelf of the Nile Delta during the winter season. It entails also relevent data on the hydrography and phytoplankton biomass during this season.

MATERIAL AND METHODS

During February 1986, twenty stations were sampled in the S. E. Mediterranean off the Egyptian coast. Stations were arranged in six sections more or less perpendicular to the coast in the area extending between Longitudes 29°45'E and 32°40'E. These sections are from West to East: El-Agami, Rosetta, Burullus, Damietta, Port Said and Tena Bay. Two additional inshore stations were sampled between Damietta and Port Said i. e. Diba and El-Gamil (Fig. 1). Each section comprised mainly three stations covering the neritic inshore (50 m), neritic offshore (between 50—100 m) and offshore waters at the edge of the continental shelf (about 200 m). At each station, surface and discrete

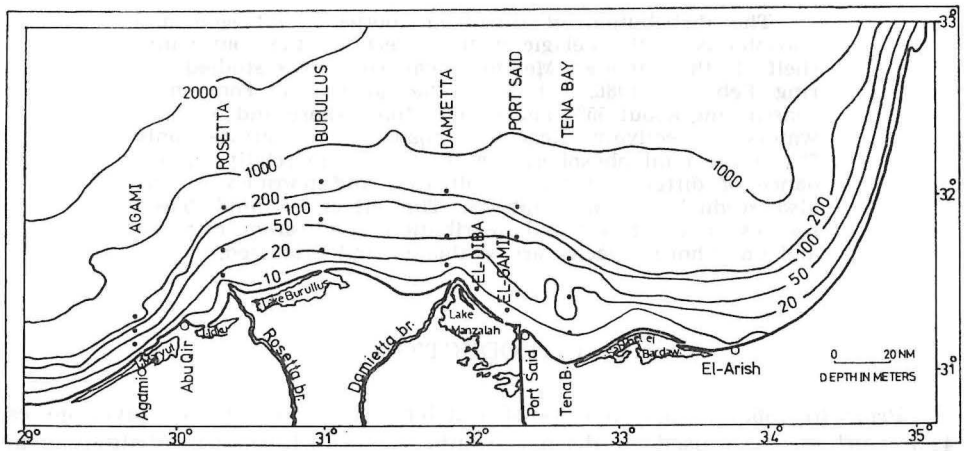

Figure 1. The studied area showing sampled stations

water samples were collected at standard depths (0, 10, 25, 50, 100, 150 and 200 m) using five liters Niskin bottles for the determination of dissolved oxygen, salinity, nutrient sals and chlorophyll *a*. Determinations of total suspended matter (TSM), particulate organic matter (POM) and the different forms of nitrogen and phosphorus were made at two inshore stations (Rosetta and El-Gamil) and one offshore station (damietta). Natrient samples were filtered on board using 0.45 μm millipore filters and stored freezed at —20°C until further analysis. Nutrient salts and chlorophyll *a* were determined colorimeterically following the procedures described by Strickland and Parsons (1972) using a Bauch and Lomb Spectronic 2000 spectrophotometer. Salinity was measured using portable induction salinometer (Be-

ckman Model RS7-C). Total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) were determined using the simultaneous persulphate oxidation method described by Valderrama (1981). The determination of total dissolved phosphorus (TDP) and total phosphorus (TP) were carried out according to the procedure of Koroleff (1977). Other forms of nitrogen and phosphorus were calculated by subtraction.

RESULTS AND DISCUSSION

Salinity

The horizontal distribution of surface salinity is shown in Fig. 2. As evident, variations in surface salinity of the coastal waters are affected by the discharge of fresh and brackish water from land based sources, which amounts to about 17.7×10^9 m^3 annually. Out of this amount about 3.5×10^9 m^3 of Nile water are discharged through Rosetta branch during the winter season (December—February). This explains the low salinity recorded at the inshore station of Rosetta section. Between the two Nile branches, the salinity of the coastal area bordered by the 50 m isobath is less than 39.0‰ which virtually reflects the effect of land runoff. Further seaward, the salinity increase more or less gradually reaching 39.6‰. East of

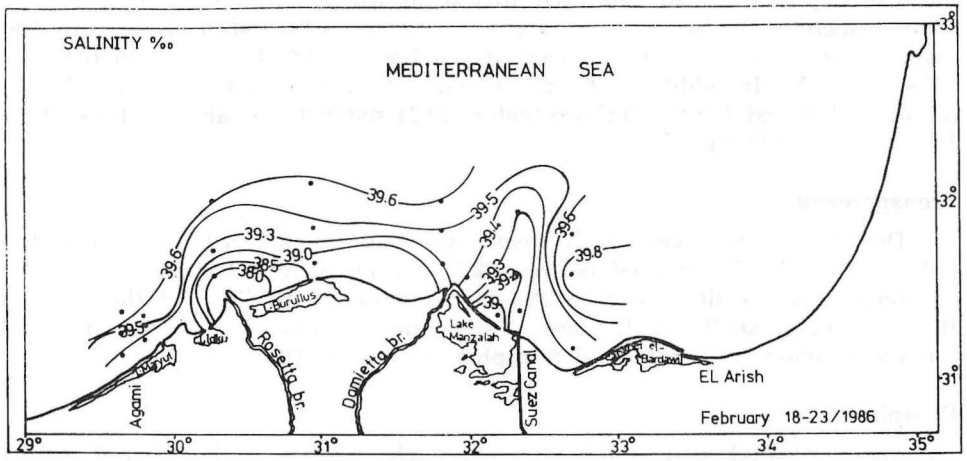

Figure 2. Horisontal distribution of surface salinity ($S \times 10^{-3}$) in the S. E. Mediterranean during February 1986.

Damietta, the direct effect of the outflowing water of Lake Manzalah (average 0.43×10^9 m^3/month) seems to be localized to a small area off the lake--sea connection (salinity 38.9‰). However, the tongue of comparatively low salinity (39.3‰) oposite to El-Gamil opening may represent further extension of mixed water. The relatively high salinity observed off El-Tena Bay probably represents the Eastern Mediterranean water driven to the area under the effect of north-easterly winds which frequently prevail during this sea-

son. On the other hand, the salinity at the most westerly section was higher than that off the Nile delta and increased more or les gradually seaward reaching 39.6‰ at the offshore stations.

The vertical distribution of salinity at the offshore stations is represented in Fig. 3. The pattern indicates that the salinity of the upper 25 m is slightly higher than the subsurface layers. Off the Nile Delta, vertical variations of salinity between 25 and 150 m were rather limited. Below 150 m, a layer of comparatively high salinity. This layer may correspond to Nielsen's intermediate layer of maximum salinity (H a l i m *et al.*, 1967).

Temperature

The absolute surface values observed during this cruise varied between 17.0°C and 19.2°C. The vertical profiles (Fig. 3) shows that the whole water column is nearly homothermal indicating effective vertical mixing during the winter season.

Dissolved oxygen (D. O.)

One of the remarkable features observed during this cruise was the comparatively low D. O. content of the study area (Fig. 3), despite the low temperature. The average D. O. saturation varied between 78% and 83% in the inshore and offshore waters, respectively, coinciding with the relative increase of organic load deposited to coastal waters from land sources. The total suspended matter content waried between 0.36 and 0.22 mg/l in the inshore and offshore waters, respectively, of which POM constituted between 66% and 70%. In addition, the phytoplankton biomass (expressed as chlorophyll *a)* observed for the inshore waters (0.71 mg/m^3) was about 3 times that for open sea (0.22 mg/m^3).

Transparency

Due to the relatively high suspended load in the inshore waters, the values of secchi disc ranged between 2.5 and 4.0 meters. In open sea water the secchi disc readings reached 28—33 m increasing to 43 m at the edge of the continental shelf which places the oceanic waters of the Eastern Mediterranean among the highly oligotrophic regions of the world.

Phosphorus

The horizontal distribution of reactive phosphorus in the surface waters during the study period showing a gradual decrease seaward. The average concentrations were 0.072, 0.062 and 0.041 μ mol. dm^{-3} in the inshore, middle and offshore stations, respectively. In the inshore waters low value were recorded in front of Rosetta branch of the Nile and Lake Manzalah outlet. Such low values are probably due to adsorption of phosphorus on the large amounts of suspended solids discharged into these areas. The water at both stations was highly turbid (secchi disc about 3 m) and the average TSM was maximum i. e. 0.37 and 0.34 mg/l, respectively.

The vertical distribution of reactive phosphorus in the offshore stations showed a remarkable feature. Except for Damietta where the maximum

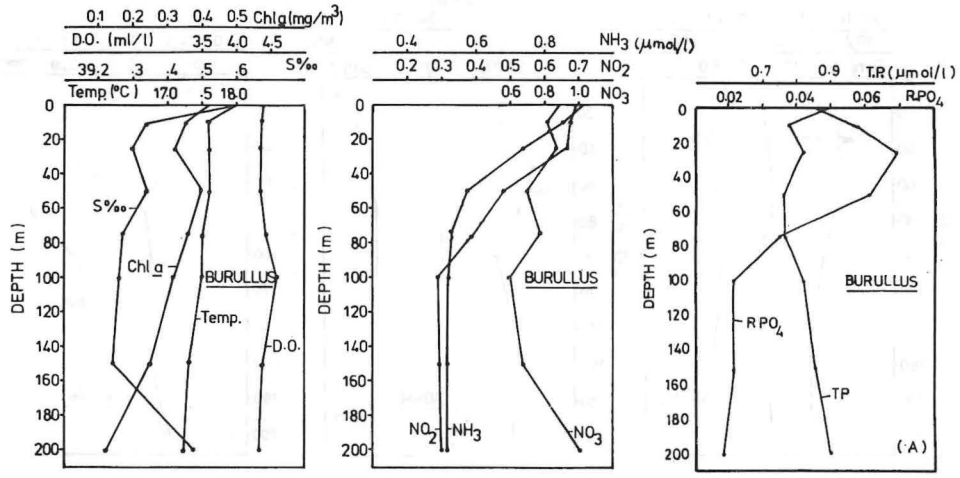

Figure 3 A. Vertical distribution of different studied parameters in the offshore station of Burullus during February 1986.

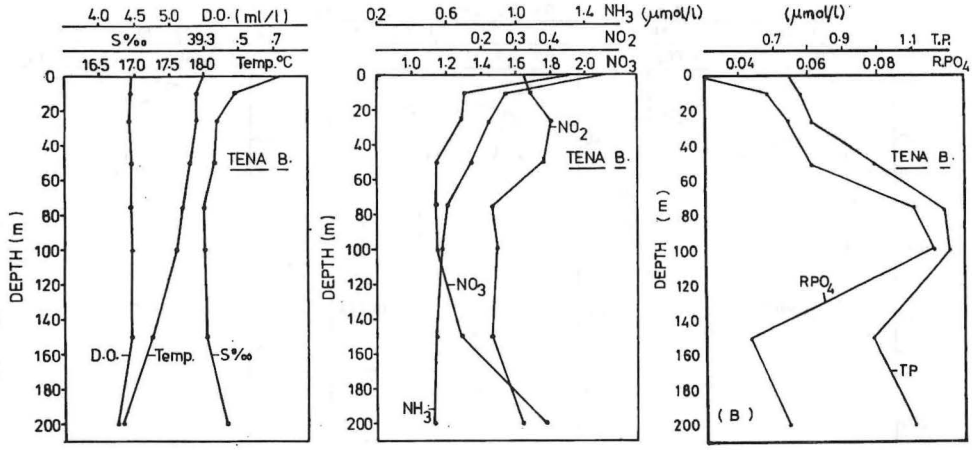

Figure 3 B. Vertical distribution of different studied parameters in the offshore station of Tena bay during February 1986.

occurred at 10 m, the concentrations of reactive phosphorus increased below 10 m reaching its maximum between 25—50 m, 25—75 m or 75—100 meters. Below 100 or 150 m depth, variations in phosphorus concentrations were generally not significant (Fig. 3).

The concentrations of total phosphorus (TP) were much higher than those of reactive phosphorus. The surface values varied between 0.75 and 1.98μ mol dm^{-3}. High values were recorded in the inshore water with an

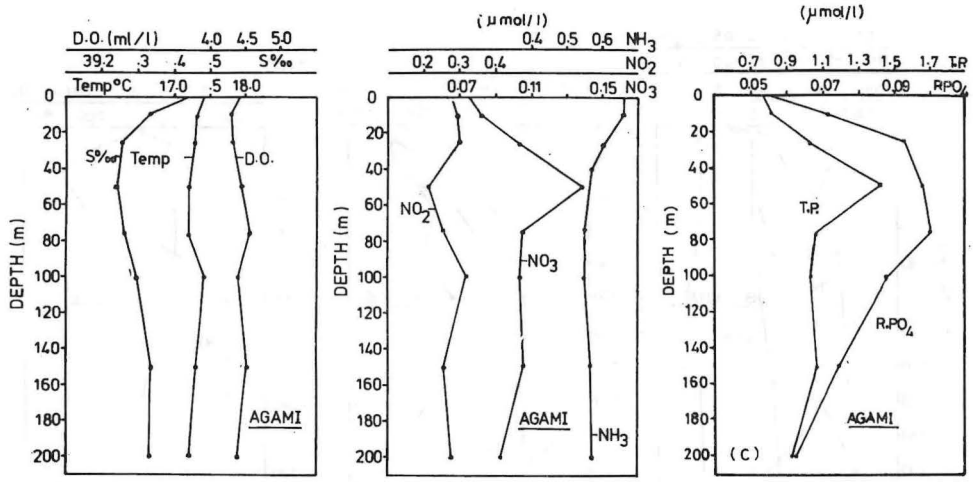

Figure 3 C. Vertical distribution of different studied parameters in the offshore station of Agami during February 1986.

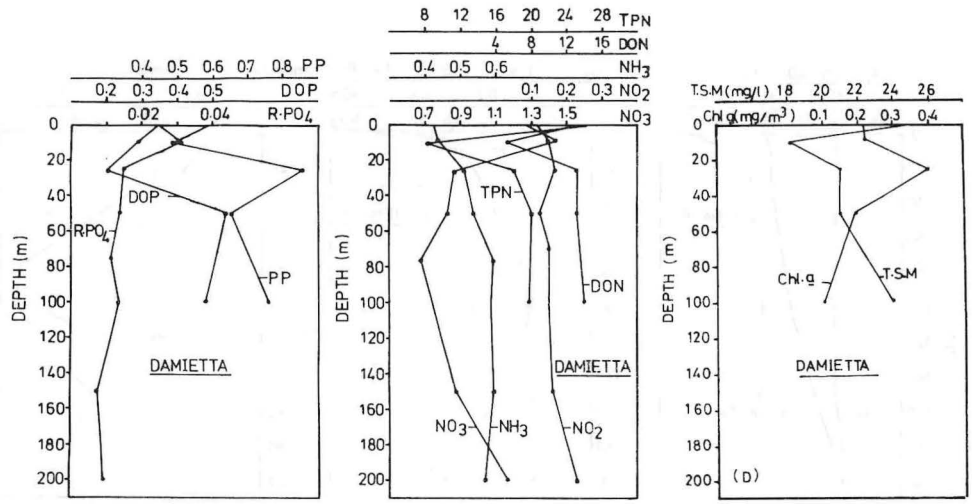

Figure 3D. Vertical distribution of different studied parameters in the offshore station of Damietta during February 1986

average 1.375 μ mol dm^{-3}, the corresponding average in the offshore water was 0.845 μ mol dm^{-3}. Contrary to reactive phosphorus, maximum values of TP occurred in the inshore stations of Rosetta and El-Gamil.

The vertical distribution of TP showed a more or les remarkable increase at subsurface levels. However, the depth of maximum varied at different stations (Fig. 3), coinciding to a great extent with the subsurface phytoplankton biomass maximum layer which frequently appeared in the southeastern Medi-

terranean waters off the Egyptian coast. This indicates that most of the particulate fraction of phosphorus (particulate phosphorus) which comprises a significant portion not less than 40% of total phosphorus is mostly biogenic in nature. In the inshore and offshore waters, particulate phosphorus constitutes on the average between 80 and 48%, respectively (Table 2). The inshore station sampled opposite to the Nile River estuary is characterised by remarkably high PP concentrations varying between 0.676 and 1.278 μmol dm^{-3} with an average of 0.913 μ mol dm^{-3}. Most of this PP is expected to be non-biogenic. The average PP in the offshore waters was 0.67 μ mol dm^{-3} with the maximum at 25 m depth (Fig. 3d).

The concentrations of dissolved organic phosphorus (DOP) was much higher than that of dissolved inorganic phosporus (DIP) and constituted 91% to 97% of TDP at different depths. Its concentration was comparatively higher in the inshore than in offshore stations.

a — Dissolved inorganic forms:

Table 1 shows the average surface values of nitrate, nitrite and ammonia in the studied area. As seen nitrate is the dominating component and showed slight decrease seaward in nearly all sections. The overall average of surface values was 1.13 μ mol dm^{-3}. Amonia was the second important component of dissolved inorganic nitrogen forms. The average surface values were remarkably high in the coastal waters i. e. 1.02 μ mol dm^{-3} with a gradual decrease towards the offshore waters i. e. 0.68 μ mol dm^{-3}. The overall mean in the area was 0.88 μ mol dm^{-3}. Nitrite, which is the intermediate oxidation state, was the least in the order of abundance. Likewise, its concentration showed a gradual decrease seaward with an average of 0.41 μ mol dm^{-3} in the whole area. The average concentrations of dissolved

Table 1. Average concentration (μm01/dm^3) of dissolved inorganic nitrogen and total phosphorus in the study area during February 1986. (S = average surface; MWC = mean of water column)

		Inshore	Middle	Offshore
Nitrate	AS	1.27	1.07	1.04
	MWC	1.35	1.00	0.89
Nitrate	AS	0.48	0.35	0.39
	MWC	0.43	0.40	0.30
Ammonia	AS	1.02	0.92	0.68
	MWC	0.79	0.99	0.64
Reactive	AS	0.07	0.06	0.04
Phosphorus	MWC	0.08	0.08	0.05
Total	AS	1.38	1.22	1.06
Phosphorus	MWC	1.48	1.50	0.85

inorganic nitrogen (DIN) in the surface waters of the area amounted to 2.42 μ mol dm^{-3} varying between 2.77 μ mol dm^{-3} in the inshore zone and 2.14 μ mol dm^{-3} in the offshore waters.

The vertical distribution of DIN forms is shown in Fig. 3. Apart from local variations in the upper 25 or 50 m at different stations, nitrate increased significantly below 100 m reaching its highest values near the bottom.

This pattern is more obvious at stations located of the Nile delta and clearly demonstrates the role of the regenerated nutrients from the rich bottom sediments of the Nile cone. On the other hand, the vertical profiles of ammonia (Fig. 3) indicate that in most cases higher concentrations were observed in the upper eutrophic layer of the water column. Ammonia in this layer is derived mainly from phyto- and zooplankton execretory products.

b — Dissolved organic nitrogen

Determination of DON was carried out on sampled collected from the upper 100 m layer at the offshore station of Damietta as well as two shallow inshore stations (Rosetta and El-Gamil). In the offshore water the values of DON varied between 5.1 μ mol dm^{-3} at 10 m depth (corresponding to minimum chlorophyll *a* concentration) and a maximum od 14.87 μ mol dm^{-3} at the bottom of the photic zone (Fig. 3d). Except for the minimum value mentioned, variations in the DON in the upper 100 m layer were not signifi-

Table 2. Total suspended matter, particulate organic matter, chloropyll *a* and relative abundance (%) of the different components of nitrogen and phosphorus at selected stations in the study area

Stations	Dep. (M)	TSM mg/l	POM mg/l	Chl. *a* mg/l^3	NITROGEN DON/TDN	NITROGEN TPN/TN	PHOSPHORUS DOP/TDP	PHOSPHORUS PP/TP
Rosetta	0	0.28	0.24	0.637	79	41	97	75
(Inshore)	8	0.40	0.24	0.523	78	61	93	60
	16	0.42	0.19	0.378	88	81	92	60
El-Gamil	0	0.24	0.20	0.708	90	39	94	48
(Inshore)	10	0.44	0.26	0.724	90	35	95	50
Damietta	0	0.26	0.17	0.216	88	63	94	61
(Offshore)	10	0.20	0.18	0.229	71	53	91	60
	25	0.21	0.17	0.403	89	81	93	80
	50	0.21	0.15	0.190	90	83	87	54
	100	0.24	0.10	0.102	91	56	97	60

cant. The average value of the whole water column was 11.73 μ mol dm^{-3}. At the inshore stations the highest concentrations of DON were recorded at El-Gamil where the average amounted to 23.15 μ mol dm^{-3} while in the inshore station of Rosetta the average value represents the minimum recorded i. e. 9.76 μ mol dm^{-3}. The present results indicate that the contribution of DIN to the total nitrogen budget in the south eastern Mediterranean is very small. The ratio of DON/TDN varies between 78 and 91% (Table 2). On the other hand, except for the condition at the inshore station of El-Gamil, PN contributes 61—67% of TN at the inshore and offshore stations, respectively.

From the foregoing, it is obvious that the dissolved inorganic fraction of either nitrogen or phosphorus constitutes a smaller percentage of the total concentration. In the present study, it was found that reactive phosphorus constitutes on the average about 5% of the total phosphorus in the whole area. Likewise, dissolved inorganic nitrogen constitutes on the average about 6% of the total nitrogen. However, the ratio of TN:TP varied between 26 and 37 indicating that the total concentration of phosphorus in the area is

comparatively lower than that of nitrogen. Hence, it is most probable that in the southeastern Mediterranean waters phytoplankton growth is limited by phosphorus rather than nitrogen. The ratio DIN:DIP may substantiate this assumption (Table 3). A remarkable feature observed during this cruise was the comparatively high particulate phosphorus content relative to DIP in the whole area probably due to adsorption of phosphorus ions on the fine particules suspended in the water during this season. As previously mentioned, the content of TSM was remarkably high during this season; this is mostly due to the resuspention of bottom sediments and detritus caused by various active mixing processes appearing during this season.

Table 3. N : P ratio in the surface water of the study area

LOCATION RATIO	Inshore	Middle	Offshore
DIN/DIP+	38.5	37.9	52.2
NO3/DIP+	17.7	17.2	25.6
DON/DOP*	35.1	—	35.6
TDN/TDP*	36.9	—	38.1
TPN/TPP*	25.3	—	43.9
TN / TP*	31.3	—	41.6
TN/TP*	31.3	—	41.6

+ = Average surface water for the whole area.
* = Surface values for El-Gamil inshore station & Damietta offshore.

As revealed from the present study the average relative abundance of different components of total nitrogen and phosphorus in the offshore water may be expressed as folows: NO_3: 4.3%; NO_2: 0.5%; NH_3: 1.8%; DON: 42%; TPN: 66.3% and DIP: 3.0%; DOP: 35.4%; PP: 62.4×.

Table 3 shows the N:P ratio of different components of nitrogen and phosphorus in the area. Obviously NO_3/PO_4 ratio is nearly similar to that found in living plankton. The other ratios are considerably high particularly because of the elevated nitrogen concentrations. Strickland (1972) mentioned that concentrations of DON and DOP can be as high as 15 μ mol dm^{-3} and 0.8 μ mol dm^{-3} at the surface with a surprising absence of correlation with plant productivity. In the southeastern Mediterranean the maximum concentration of DON and DOP i. e. 23 μ mol dm^{-3} and 0.639 μ mol dm^{-3} was recorded in the inshore water of El-Gamil area. In the offshore waters these concentrations were much lower.

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KRATKI SADRŽAJ

Izučavana je raspodjela anorganskog dušika i fosfora tijekom veljače 1986. godine u vodama kontinentalnog platoa mediteranske obale Egipta. Nitrat je dominantna komponenta i iznosi između 55 i 64% u priobalnom i otvorenom moru. Reaktivni fosfor tvori samo 5% od ukupnog fosfora u ovom području. Također je izučavana raspodjela različitih oblika dušika i fosfora te utjecaj kopna na tu raspodjelu.