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# Seasonal Distribution of Total Nitrogen and Total Phosphorus in The Rosetta Estuary of The Nile and The Adjacent Mediterranean Waters

By

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## Abstract

*The Rosetta estaury of the Nile, a coastal plain type estuary, is isolated from the Rosetta branch by Edfina Barrage which controls the Nile water discharge into the sea. The maximum discharge occurs in Janyary and the minimum during April-November.The total nitrogen (TN) and total phosphorus (TP) in the estuary and adjacent sea water were studied during 1987-88 to investigate the effect of the estuarine water on the verical, regional and seasonal distribution of total nitrogenous and phosphorus compounds in the coastal region.*

*The veritcal concentrations of TN generally showed irregular variations. The lower values of TN in the euphotic zone are mainly due to the increasee in phytoplankton uptake. The minimum seasonal averages of TN in the estuarine and coastal waters were obtained in summer; mainly due to the remarkable increase in standing crop of autotrophic organisms. The annual concentration of TN calculated for the estuary was noticeably higher than that of the coastal region. This coincided with the direct effect of land-based sources of nitrogen on the estuary and deposition of organic nitrogenous compounds on the marine sediments.*

*The irregular verical distribution of TP reflects its increase or decrease in the water column. The TP fluctuation in the surface water coincided with variation in the uptake of reactive phosphorus. Those in the bottom water, however, are related to variations in the adsorption and desorption processes in abundance of suspended matter. The highest seasonal averages of TP in the estuarine and coastal waters in April are attributed mainly to the increase in the unreactive phosphorus from decomposition of organic matter acuumulated in spring. The annaual mean value of TP of the estuary was markedly higher than that of the coastal region. This reflects the direct influence of land-based sources of phosphorus on the estuary and the effect of increased salinity on the coastal sea water.*

## Introduction

Some studies on the nutrient salts have been carried out on the Egyptian coastal waters of the Mediterranean Sea. El-Rayis (1973) investigated the distribution of nutrient salts in the waters off Alexandria to the end of the continental shelf. Saad (1978) made a study on the mixed waters between Lake Edku and the Mediterranean Sea.

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Mahmoud (179) studied the effect of sewage discharge ont the water quality of the coast of Alexandria. El-Nady (1981) made a survey on some environmental parameters and nutrients in El-Mex region, the Eastern Harbour and Abu-Kir Bay. Mahmoud (1985) investigated the phosphorus and nitrogen dynamics in the polluted coastal waters off Alexandria. The problems of sewage pollution in Alexandria waters have been studied by Saad et al., (1988). Saad and Hemeda (1992) investigated the effects of pollution on the nutrient salts in the Western harbour of Alexandria.

Some investigations were also carried out on the Nile branches; Rosetta and Damietta. Abbas (1980) made a study on the limnological conditions and distribution of phytoplankton in the Rosetta of the Nile. Abdel Moati (1981) made the physicochemical studies of Damiatta branch. Saad & Abbas studied the seasonal variations of nutrients in the Rosetta Branch of the Nile (1985).

The present work was undertaken to study the regional and seasonal distribution of total nitrogen and total phosphorus in the Rosetta estuary of the Nile and in the coastal Mediterranean waters in front of this estuary, in order to investigate the influence of the estuarine waters on the vertical, seasonal and local distribution of total nitrogenous and phosphorus compounds in the coastal Mediterranean Sea water.

## Study Area

North to Cairo, the Nile bifurcates into Rosetta and Damietta branches embracing the delta between. The Rosetta branch runs northward along the west side of the Nile Delta and opens into the Mediterranean Sea at 12 km north of the city of Rosetta, Fig. (1).

The Rosetta estuary is partly separated from Rosetta branch by the installations of Edfina Barrages, which are about 500 m in length and comprises 46 gates each of about 8 m width. By opening and closing these gates at certain times of the year, the estuarine stream extends 42 km from the Barrage to the outlet. The most northen part of the estuary runs through a narrow cape that was formed by the gradual sedimentation of silt and mud carried with the Nile flood in the past. This cape is nowadays subject to gradual erosion by marine currents. This was particularly true after the construction of the High Dam as most of the silt lodd of the Nile is deposited behind the dam.

the Rosetta estuary is of the coastal plain type. From the point of view salinity stratifications, however, it fluctuates between the highly stratified type and the moderately stratified one (Hansen and Rottry, 1966).

The bottom of the estuary is made of a number successive depressions the middle of which is the deepest (~18 m). Each bend in the winding course of the channel corresponds to a rise of the bottom. In the inner part of the estuary, the bottom is made mainly of black muds, enriched with organic matter with a distinct smell of $H_2S$ gas re-

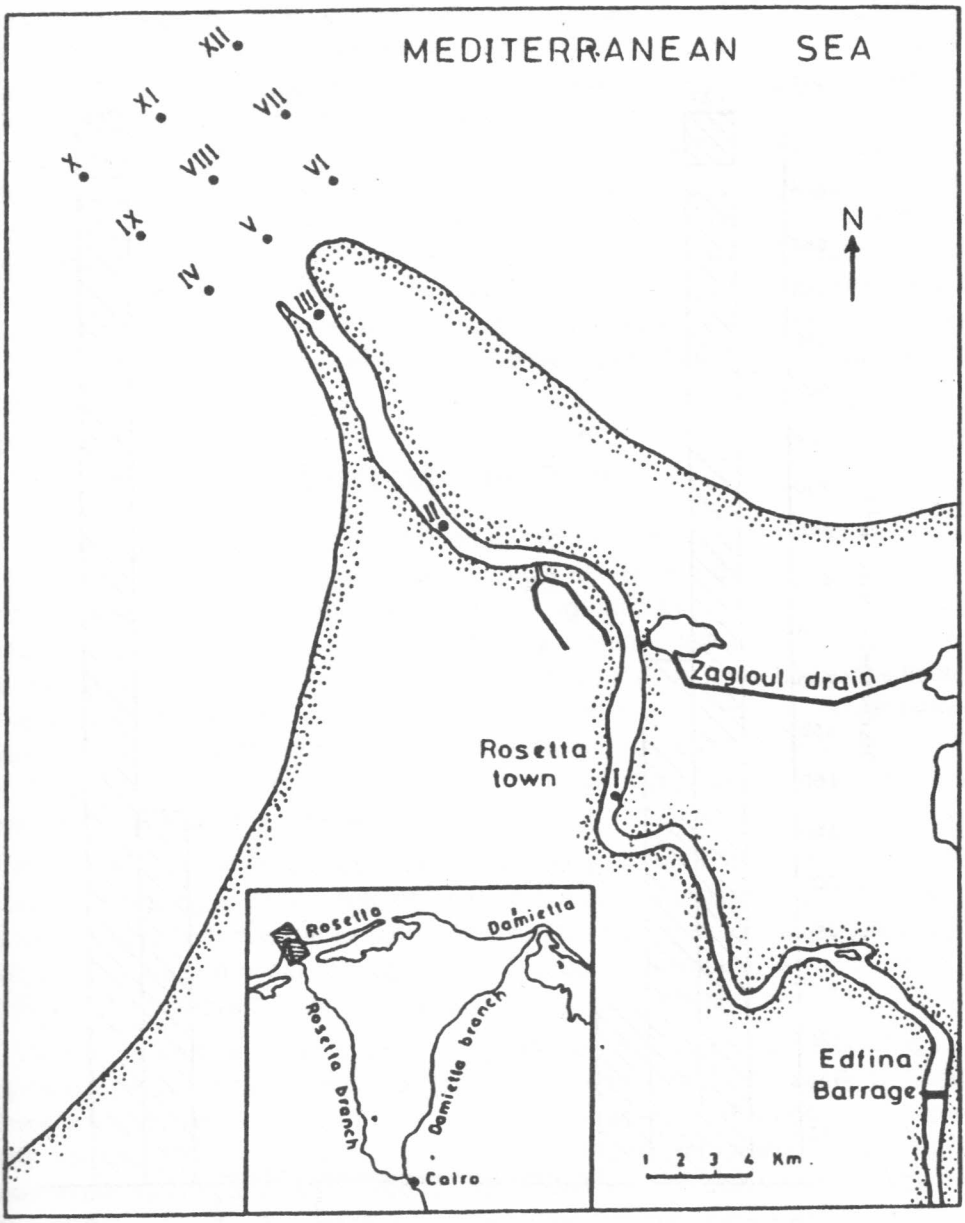


**Fig. (1)**
Map of the study area showing Position of stations.

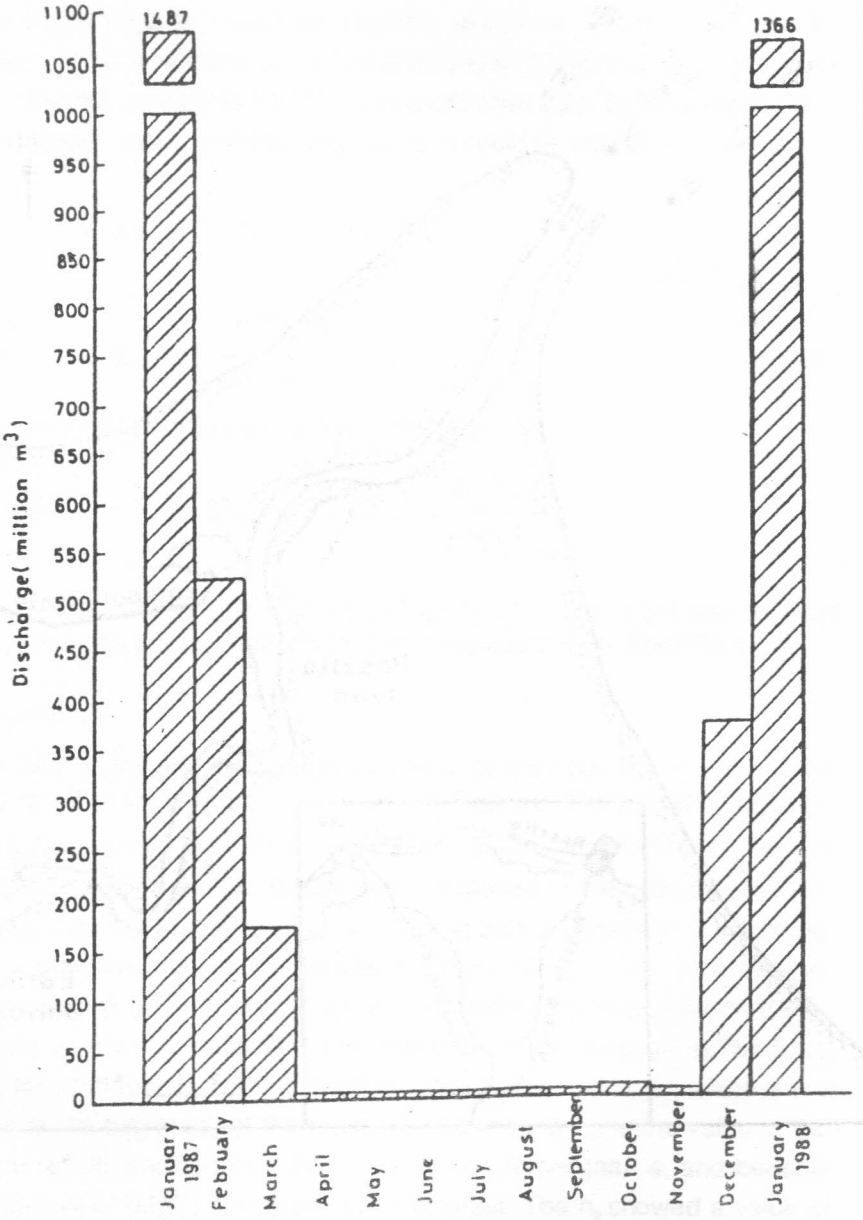


**Fig. (2)**

Monthly variations of water discharge from January 1987 to January 1988.

flecting the discharge of organic wastes. Down stream, it gradually changes into sandy-muds that are greyish in colour and without detectable smell. (Zaghloul, 1976).

The Rosetta estuary derives its characteristic features from the powerful outflow of the fresh Nile water at restricted times every year through the Edfina Barrage. The amounts of water discharged through this barrage during 1897-1988 werre obtained from the Irrigation Department, Fig. (2). The maximum discharge (1487 million $m^3$) occurred in January 1987. when all the gates of the barrage were opened. Half of these gates were closed in February, and thus the discharge decreased to about 522 million $m^3$ followed by another decrease to 113 million $m^3$ in March. Then, it decreased sharply during the period April - November giving values of 6 million $m^3$ with a slight increase to 10 million $m^3$ in October, However, a sharp increase in the discharge followed in December (374 million $m^3$) when about half of the gates were opened again. In January 1988 when all the gates were opened again, the discharge reached 1366 million $m^3$.

## Materials and Methods

The study area was distinguished into two regions, the estuarine region (Region A) and the marine coastal region (Region B). In the estuarine region, three stations (I, II and III) were selected between the Edfina Barrage and the Rosetta mouth, Fig. (1). Water samples were collected at these stations from the surface and the bottom. In the marine coastal region, nine stations were chosen along three horizontal sections parallel to the shoreline; three stations along each section, Fig. (1). Water samples were collected at the shallower stations from the surface and bottom water layers. At the deeper stations (X, XI, and XII), however, sampling was carried out from the surface, middle and bottom water layers.

Samples were collected seasonally in April, Jully, October 1987 and January 1988 to represent spring, summer, autumn and winter seasons respectively. A Nansen bottle was used to collect water samples. The surface samples were collected at 20 cm below the surface to avoid floating matter. The bottom samples, however, were collected at 50 cm above the bottom to avoid disturbance fo the sediments.

Determination of total nitorgen and total phosphorus, was made according to the technique described by Koroleff (1977) and modified by Valderrama (1981). Simultaneous oxidation was obtained by using oxidizing reagent (sodium peroxodisulphate, boric acid and sodium hydroxide). Four ml of this reagent were added to 30 ml of unfiltered water sample and autoclaved for 30 minutes in a pressure cooker. After complete oxidation, the nitrogen compounds were determined as nitrate and the phosphorous compounds as inorganic phosphate. The method described by Grasshoff (1976) for nitrate determination is based on the reduction of nitrate in a glass column containing copperized cadmium fillings. The sample was treated as nitrite and was determined according to Grasshoff (1976). The developed colour was measured spectrophotometrically at wave length 540 nm. The concentration of nitrate was caluculated

after correction of nitrite value. Determination of inorganic phosphate was carried out according to Grasshof (1976). The developed blue colour was measured spectrophotometrically at 880 nm.

# Results

### Total nitrogen (TN) content

The vertical values of total nitrogen are presented in Figure (3) and the average values are listed in table (1).

**Table (1) : Seasonal and regional variations of the average values of total nitrogen (ug at-N/l) in the study area during 1987 - 1988**

| Region | Station | Average station depth (m) | April | July | Oct. | Jan. | Regional averages |
|---|---|---|---|---|---|---|---|
| | | | 1987 | | | 1988 | |
| A | I | 7.5 | 66.35+ | 51.2 | 118.2 | 92.40+ | 82.04+ |
| | III | 6.5 | 61.50 | 52.3+ | 105.4- | 75.30 | 73.63 |
| | III | 4.5 | 57.60- | 23.45- | 122.35+ | 60.30- | 65.93- |
| Seasonal average | | | 61.82 | 42.32- | 115.32+ | 76.0 | 73.87 |
| B | IV | 6.5 | 44.70 | 43.85 | 98.25 | 88.40+ | 68.80 |
| | V | 5.5 | 37.45- | 47.80 | 70.70 | 80.10 | 59.01 |
| | VI | 5.6 | 64.30 | 35.35 | 55.55 | 67.10 | 55.58 |
| | VII | 6.5 | 85.75+ | 26.65 | 34.35 | 57.75 | 51.10 |
| | VIII | 6.5 | 68.85 | 55.95+ | 29.10- | 75.60 | 57.38 |
| | IX | 7.6 | 52.70 | 29.75 | 35.05 | 57.50 | 43.75 |
| | X | 10.5 | 49.66 | 28.87 | 39.0 | 43.17 | 40.17 |
| | XI | 10.5 | 70.97 | 52.90 | 127.37+ | 43.33 | 73.64+ |
| | XII | 10.5 | 61.97 | 52.37 | 118.63 | 28.30- | 65.32 |
| Seasonal average | | | 61.82 | 42.32- | 115.32+ | 76.0 | 73.87 |

N.B. For each of Region A & B, the maximum values are designated by (+) and the minimum by (-).

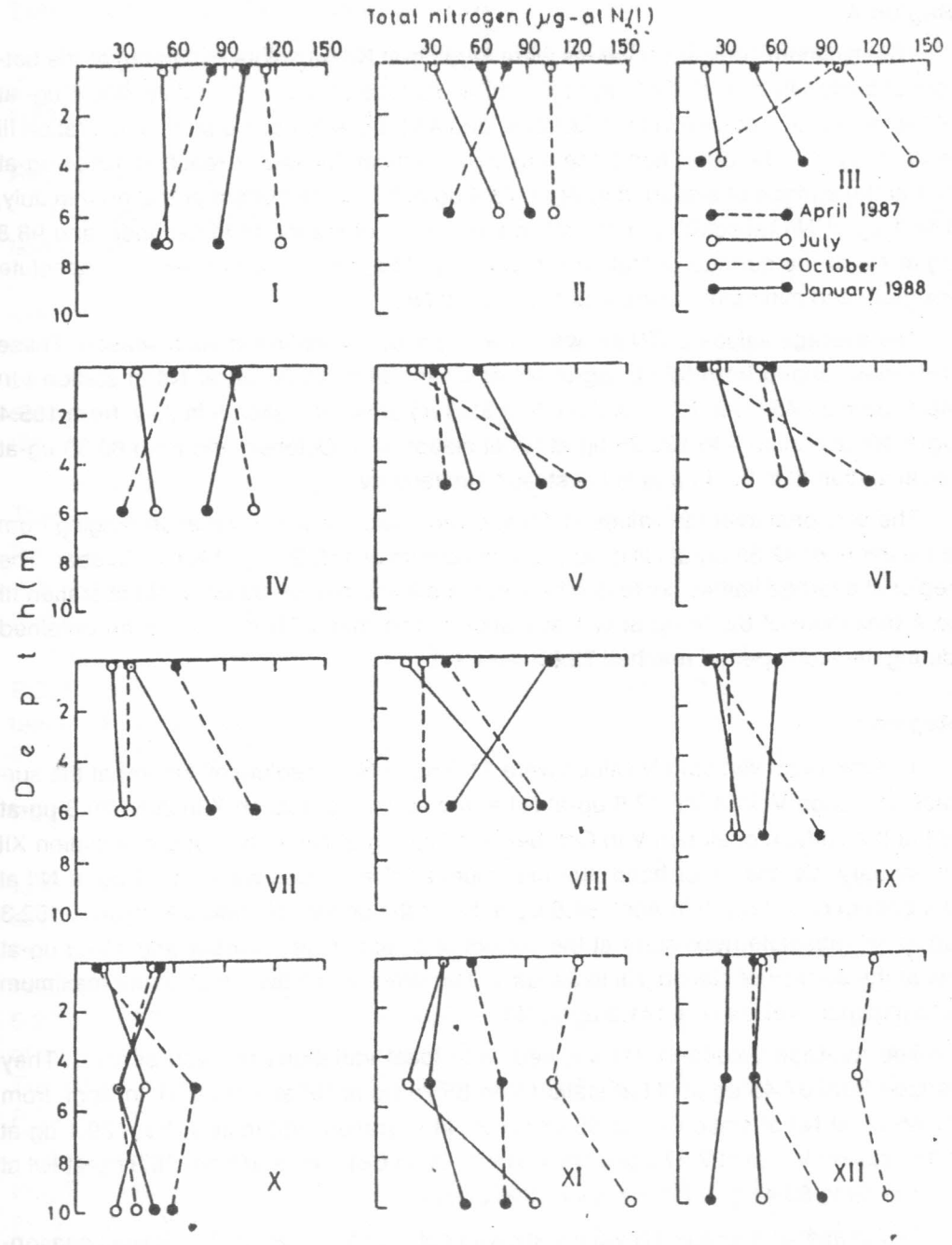


**Fig. (3)**

Seasonal variation of the vertical values of total nitrogen in the study area during 1987 - 1988.

**Region A**

The minimum vertical TN values were 14.8 ug-at N/l (absolute minimum) at the bottom of station III in April, 18.3 ug-at N/1 at the surface of station III in July, a00.6 ug- at N/l at the surface of station III in October, and 43.9 ug-at N/l at the surface of station III in January. On the other hand, the maximum vertical TN values reached 100.4 ug-at N/1 at the surface of station III in April, 73.9 ug-at N/l at the bottom of station II in July, 144.1 ug-at N/l (absolute maximum) at the bottom of station III in October, and 98.8 ug-at N/l at the surface of station I in January. The difference between the absolute mximum and minimum values was 129.3 ug-at N/l.

The average values of TN showed noticeable local variation in each season. These averages ranged from 57.60 ug-at N/l at station III to 66.35 ug-at N/l at station I in April, from 23.45 ug-at N/l at station III to 52.3 ug-at N/l at station II in July, from 105.4 ug-at N/l at station II to 122.35 ug-at N/l at station III in October, and from 60.30 ug-at N/l at station III to 92.4 ug-at N/l at station I in January.

The seasonal average values of TN showed a wide range of variation ranging from a minimum of 42.32 ug-at N/l in July to a maximum of 115.32 ug-at N/l in October. The regional average values fluctuated between a minimum of 65.93 ug-at N/l at station III to a maximum of 82.04 ug-at N/1 at station I. The mean TN concentration obtained during the study period reached 73.87 ug-at N/l.

**Region b**

The minimum vertical TN values were 11.3 ug-at N/l (absolute minimum) at the surface of station VI in April, 17.6 ug-at N/l at the surface of station X in July, 20.3 ug-at N/l at the surface of station V in October and 22.9 ug-at N/l at the bottom of station XII in January. On the other hand, the maximum vertical values were 117.3 ug-at N/l at the bottom of station VI in April, 94.8 ug-at N/l at the bottom of station XI in July, 152.3 ug-at N/l (absolute maximum) at the bottom of station XI in October and 105.3 ug-at N/l at the surface of station VIII in January. The difference between absolute maximum and minimum values was 141.0 ug-at N/l.

The average values of TN showed wide local variations in each season. They ranged from 37.45 ug-at N/l at station V to 85.75 ug-at N/l at station VIi in April, from 26.65 ug-at N/l at station VII to 55.95 ug-at N/l at station VIII in July, from 29.1 ug-at N/l at station VIII to 127.37 ug-at N/l at station XI in October, and from 28.3 ug-at N/l at station XII to 88.4 ug-at N/l at station IV in January.

The seasonal average TN values showed noticeable variation. The lowest seasonal average value was recorded in July (41.5 ug-at N/l) and the highest (67.55 ug-at N/l) in October. The regional average values fluctuated between a minimum of 40.17 ug-at N/l at station X to a maximum of 73.64 ug-at N/l at station XI. The mean TN concentration obtained during the study period amounted to 57.19 ug-at N/l.

**Total phosphorus (RP) content**

The vertical values of TP are represented in Figure (4) and the average values are given in table (2). In all months, the vertical values showed irregular variations and increased or decreased with depth at the majority of stations.

**Regions A**

The minimum vertical values of TP reached 3.45 ug-at $PO_4$-P/l at the bottom of station II in April, 3.03 ug-at $PO_4$-P/l at the bottom of station III in July, 2.73 ug-at $PO_4$-P/l (absolute minimum) at the bottom of station III in October, and 4.14 ug-at $PO_4$-P/1 at the bottom of station II in January. On the other hand, the maximum vertical values were 11.7 ug-at $PO_4$-P/l (absolute maximum) at the surface of station III in April, 7.52 ug-at $PO_4$-P/1 at the surface of station III in july, 7.50 ug-at $PO_4$-P/l at the bottom of station II in October, and 8.0 ug-at $PO_4$-P/l at the surface of station I in January. The difference between absolute maximum and minimum values was 8.97 ug-at $PO_4$-P/l.

The average TP values generally showed noticeable local variation in each season. These averages ranged from 5.18 ug-at $PO_4$ P/l at station I to 9.33 ug-at $PO_4$-P/l at station III in April, from 4.14 ug-at $PO_4$-P/l at station II to 5.28 ug-at $PO_4$-P/l at station III in July, from 3.09 ug-at $PO_4$-PI at station III to 6.23 ug-at $PO_4$-P/l at station II in October, and from 5.12 ug-at $PO_4$-P/l at station II to 7.58 ug-at $PO_4$-P/l at station III in January.

The seasonal average values of TP varied remarkably from a lowest of 4.44 ug-at $PO_4$-P/l in October to a highest of 6.74 ug-at $PO_4$-P/l in April. The regional average values of TP ranged from 5.18 ug-at $PO_4$-P/l at station I to 6.32 ug-at $PO_4$-P/l at station III. The mean value of TP obtained during the study period was 5.60 ug-at $PO_4$-P/l.

**Region B**

The minimum vertical values of TP were 2.75 ug-at $PO_4$-P/l at the surface of station XI in April, 1.06 ug-at $PO_4$-P/l at the surface of station IX XII in July, 1.41 ug-at $PO_4$-P/l at the bottom of station VII in October, and 0.92 ug-at $PO_4$-P/l (absolute minimum) at the bottom of station VIII in January. On the other hand, the maximum vertical values reached 11.35 ug-at $PO_4$-P/l (absolute maximum) at the surface of station VIII in April, 5.20 ug-at $PO_4$-P/l at the bottom of station VI in July, 8.20 ug-at $PO_4$-P/1 at the bottom of station X in October, and 5.30 ug-at $PO_4$-P/l at the bottom of station V in January. The difference between the absolute maximum and minimum values was 10.43 ug-at $PO_4$-P/l.

the average values of TP varied from 3.32 ug-at $PO_4$-P/l at station XII to 8.28 ug-at $PO_4$-P/l at station VIII in April, from 1.26 ug-at $PO_4$-P/l at station XII to 4.50 ug-at $PO_4$-P/l at station VI in July, from 1.58 ug-at $PO_4$-P/l at station VII to 4.93 ug-at $PO_4$-P/l at station IV in October, and from 1.36 ug-at $PO_4$-P/l at station IV to 5.13 ug-at $PO_4$ P/l at station V in January.

The lowest seasonal average value was recorded in July (2.29 ug-at $PO_4$-P/l) and the highest (5.11 ug-at $PO_4$-P/l) in April. The regional average values of TP ranged

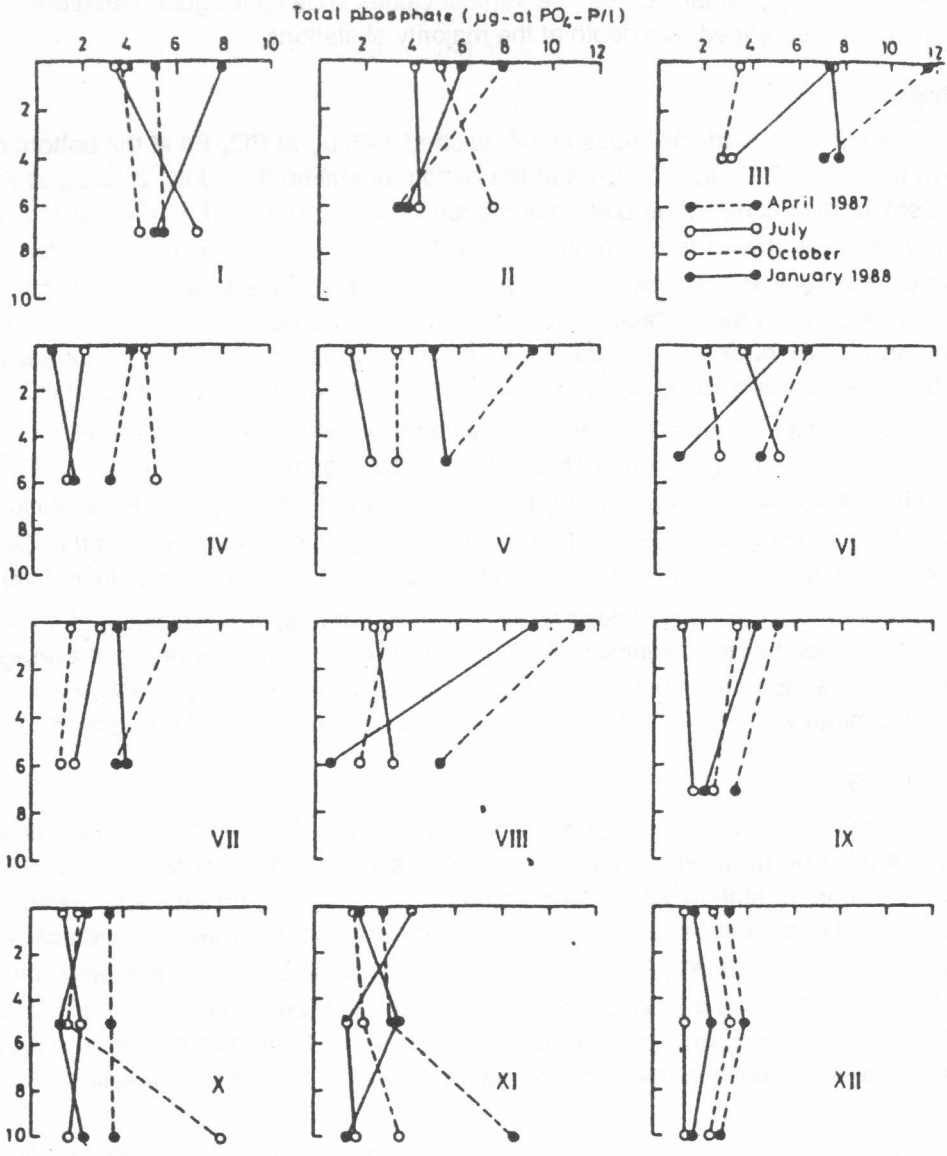


**Fig. (4)**

**Seasonal variation of the vertical values of total phosphorus in the study area during 1987 - 1988.**

**Table (2) : Seasonal and regional variations of the average values of total phosphorus (ug at-$PO_4$ - P/l) in the study area during 1987 - 1988**

| Region | Station | Average station depth (m) | April | July | Oct. | Jan. | Regional averages |
|---|---|---|---|---|---|---|---|
| | | | 1987 | | | 1988 | |
| A | I | 7.5 | 5.18- | 5.06 | 4.0 | 6.47 | 5.18- |
| | III | 6.5 | 5.70 | 4.14- | 6.23+ | 5.12- | 5.24 |
| | III | 4.5 | 9.33+ | 5.28+ | 3.09- | 7.58+ | 6.32+ |
| Seasonal average | | | 6.74+ | 4.83 | 4.44- | 6.39 | 5.60 |
| B | IV | 6.5 | 3.80 | 18.1 | 4.93+ | 1.36 | 2.95 |
| | V | 5.5 | 7.28 | 1.87 | 3.35 | 5.13+ | 4.41 |
| | VI | 5.6 | 5.45 | 4.50+ | 2.35 | 2.85 | 3.79 |
| | VII | 6.5 | 4.93 | 2.43 | 1.58- | 3.98 | 3.23 |
| | VIII | 6.5 | 8.28+ | 2.96 | 2.48 | 5.09 | 4.70+ |
| | IX | 7.6 | 4.48 | 1.41 | 2.59 | 3.18 | 2.92 |
| | X | 10.5 | 3.57 | 1.85 | 4.02 | 2.12 | 2.89 |
| | XI | 10.5 | 4.92 | 2.53 | 2.50 | 2.27 | 3.06 |
| | XII | 10.5 | 3.32- | 1.26- | 2.85 | 1.95 | 2.35- |
| Seasonal average | | | 5.11+ | 2.29- | 2.96 | 3.10 | 3.37 |

N.B. For each of Region A & B, the maximum values are designated by (+) and the minimum by (-).

from 2.35 ug-at $PO_4$-P/l at station XII to 4.70 ug-at $PO_4$-P/l at station VIII. The mean TP concentration obtained during the investigation was 3.37 ug-at $PO_4$-P/l.

# Discussion

### Total Nitrogen Variations

Total nitrogen includes organic and inorganic nitrogen in both forms (dissolved and particulate). There are high concentrations of total nitrogen in all freshwater sources of the estuaries (Fisher ***et al.***, 1988). Larsson ***et al.***, (1985) found that 30% of the total nitrogen inputs to the sea was from direct precipitation; half as nitrate from fossil fuel combustion, and half as ammonium from livestock forming. Of the river inputs to the sea, 70-80% are in organic forms indicating a high proportion of humic substances. However, Ahl (1984) and Tylor (1984) found that the organic portion can be less than 10% from areas with intensive agriculture. Bacteria convert the organic nitrogen compounds into inorganic nitrogen species and eventually to nitrate. Phytoplankton normally synthesizes its proteins from nitrate, nitrite and ammonium. Bacteria usually use these forms of nitrogen only when organic nitrogen is not available (Riley and Chester, 1971).

The vertical values of TN showed irregular variations in Regions A and B in general, Fig. (3). The lower values of TN in the euphotic zone are mainly due to the increase in uptake by phytoplankton. Also, the larger net losses of nitrogen from the water column can be attributed to sedimentation and denitrification in the sediments (Jenkens and Kemf, 1984). On the other hand, the plankton regenerates substantial amounts of TN. However, the nitrogen regenerated in bottom sediments appears to be recycled tightly within the benthic community rather than being exchanged with the overlying water (Nixon ***et al.,*** 1975). In much deeper water, the organic inputs to the bottom come largely from sinking phytoplankton cells, zooplankton fecal pellets and other pelagic detritus. However, the level of all nitrogen containing compounds is determined by the effects of fixation, assimilation, denitrification, regeneration and other processes in the complex nitrogen cycle. Hartwig , 1974; Rowe ***et al.***, 1975 and Nixon ***et al.***, (1975).

The minimum seasonal average TN values were obtained in summer (42.32 and 41.50 ug-at N/l) in Region A and B respectively, Table (1). This may be due to the remarkable increase in standing crop of autotrophic organisms. Zaghloul (1976) found that the quantity of phytoplankton reached the level which increased the rate of uptake in summer. According to Meybeck ***et al.*** (1988), primary production is responsible for the remarkable spring and summer river depletion of nutrient. This TN minimum reflects the appreciable contibution of nitrate and nitrite species to the TN, as indicated from the low seasonal averages of these nutrients in July (Hassan, 1993). Nixon ***et al.***, (1975) pointed out that the levels of inorganic nitrogen were relatively low during summer, but increased substantially by time till October. The nutrient concentration decreases in summer in the upper layer above the thermocline after exhaustive use by

phytoplankton. According to Vegelia and Vaissiere (1984), the water column enriched with nutrients, especially those of deeper water origin from the begining of the vertical mixing process in early autumn the end of winter. The present data of TN suggest the same explanation as confirmed from the maximum seasonal averages obtained in October and the obviously high seasonal averages in January in both Regions A and B, Table (1). This may be due to river phytoplankton species encountering brackish waters where halophilic species may release easily degradable dissolved organic matter that may be converted into inorganic nutrients (Morris ***et al.***, 1978).

The annual mean value of TN in Region A (73.87 ug at N/l) was noticeably higher than that of Region B (57.19 ug at N/l). This reflects the direct effect of the land-based sources of nitrogen (mainly domestic wastes, Nile discharge from Edfina Barrage and agricultural runoff) on Region A and deposition of organic nitrogen compounds on the marine sediments (Fisher ***et al.***, 1988). The net loss of nitrogen from the water column is probably due to sedimentation and denitrification in the sediments ( Jenkins & Kemp, 1984).

**Total Phosphorus Variations**

Phosphorus compounds play a key role in photosynthesis and other processes in plants. Some species of phytoplankton are able to utilize dissolved organic phosphates. According to Riley and Chester (1971), the distribution of the various forms of phosphorus in the sea is broadly controlled by biological and physical agencies. When dead organisms sink to the sea floor, much of their phosphorus will be subsequently regenerated to the water. However, a proportion of it will eventually undergo digenetic changes and converted into phosphate minerals. Adsorption of phosphorus particularly on iron and aluminum hydroxide can be considered as abiotic process responsible for depletions of phosphate (Liss, 1976; Lucotte & D'Anglejan, 1983). This loss of phosphorus from the sea is balanced by phosphate from rock-weathering which enters the sea in river water.

The vertical values of TP showed an irregular distribution in general. This irregularity reflects the increase or decrease in TP content in the water column. The TP fluctuations in the surface waters reflect the variations in the uptake of reactive phosphorus, while those in the bottom waters are mainly related to the increase in suspended matter and, consequently, variations in adsorption and desorption processes affected by the prevailing environmental conditions. Besides, the increase in TP in the water column possibly resulted from the increase in decay of the descending plankton (Hammer, 1971; Kramer ***et al.***, 1972 and Saad, 1973).

Total phosphorus was subject to seasonal fluctuations as shown in table (2) with the highest values recorded in April in both regions A and B (6.74 and 5.11 ug-at $PO_4$-P/l respectively). Such increase in TP concentrations is mainly due to the increase in the unreactive form which might originate from the decomposition of the organic matter accumulated in considerable amounts in spring. This is confirmed by the relatively low and minimum seasonal averages of reactive phosphorus values in Regions A and

B (Hassan, 1993). According to Riley and Chester (1971), during the winter, most of the phosphorus is present as phosphate but this decreases rapidly in spring when it is utilized by phytoplankton. Also, zooplankton and fish grazing on the abandant phytoplankton in spring release considerable amounts of phosphorus to the water in their excretions as both phosphate and organic phosphorus compounds. The latter become the predominant form of dissolved phosphorus in spring when phosphate decrease in the euphotic zone. The low TP in Region A occurred in October (4.44 ug-at $PO_4$-P/l), and in July (2.29 ug-at $PO_4$-P/l) in Region B. The low value of TP in October is mainly due to the decrease in reactive phosphorus (Hassan 1993). The low value in summer accompanied by high value of reactive phosphorus (Hassan, 1993) is probably due to the decrease in unreactive phosphorus. Wollast (1983) found that the bacterial degration of organic matter is maximum in summer, which may be responsible for the release of phosphate. Also, some species of phytoplankton in both their normal and phosphorus-deficient states are able to utilize dissolved organic phosphates (e.g. glycerophosphate and nucleotides).

The regional variations of TP are probably due to local waste discharge (Lakshminarayana, 1965; Saad, 1973; Hannan and Young 1974; Casey, 1975). Phosphorus is mainly brought into the basin by rivers and from municipal and industrial sources, while agriculture and atmospheric contributions are minor (Wulff & Rahm 1988).

The annual mean value of TP in Region A was 5.60 ug-at $PO_4$-P/l, while in Region B it was 3.37 ug-at $PO_4$-P/l, Table (2). According to Eisma and Bennekom (1978), phosphate show maxima in the salinity range 0.0 - 25‰. At salinities above 25‰, the concentrations of phosphate decrease with increasing salinity gradually. This is due to a change in the mixing process and to phytoplankton growth. According to Sharp ***et al.***, (1984), there was a large decrease in TP at salinities > 5%, probably as a result of precipitation with dissolved iron. At higher salinities, TP was either nearly conservative or constant, other than the geochemical loss of TP during initial mixing of freshwater with seawater.

The annual mean TP calculated by Abbas (1980) for Rosetta stretch (stations X - XIV) was 4.9 ug at $PO_4$-P/l, while that for Damietta branch was 3.07 ug $PO_4$-P/l (Abdel Moati, 1981).

The total nitrogen: total phosphorus ratio shows a range where either phosphorus or nitrogen could limit phytoplankton growth (Wulff and Rahm, 1988). The relative changes in TN:TP ratios suggest an increased primary production, where more phosphorus and nitrogen are utilized and bound to organic matter. Table (3) shows the TN:TP ratio for Regions A and B calculated from their average values. The average ratios for Region A ranged from 4.3 at station III in July to 39.6 at station III in October, and in Region B from 5.1 at station V in April to 65 at station IV in January. In both Regions, the low average ratio in April is due to the high average values of TP in this season; i.e., 6.74 and 5.11 ug-at $PO_4$-P/l) in Regions A and B respectively. On the other hand, the maximum seasonal average ratio in Region A (28.7) in October is related to

the high average value of the TN (115.3 ug-at N/l) in this season, while in region B it was 22.8 in january. A large proportion of the TN is related to stable organic components (Mempkowiak, 1985; Wulff ***et al.***, 1987) and is also a poor indicator of a possible phosphorus limitation. This means that nitrogen has generally increased more than phosphate.

It is a fact that nitrogen and phosphorus are removed from water in almost constant proportion as a result of phytoplankton growth (Harbey, 1926). Cooper (1937) showed that water from different localities contained these two elements in approximately constant proportions; i.e., the atomic N/P ratio is about 15. Table 3 shows that the annual average ratio of TN:TP in Region A was 15. In Region B, however, the annual average ratio was 19.9, which is comparable to the normal ratio. Smith (1979) found that the phytoplankton ield depending mainly on N/P ratio > 15-17 indicates that phosphorus is the critical controlling factor; From < 9-10 indicates that the yield varied with nitrogen, and > 21 shows that phosphorus is the primary controlling factor.

**Table (3) : Seasonal and regional variations of the average total nitrogen: total phosphorus ratio in the study area during 1987 - 1988**

| Station | Average depth (m) | April | July | Oct. | Jan. | Regional average |
|---|---|---|---|---|---|---|
| | | 1987 | | | 1988 | |
| I | 7.5 | 12.8:1+ | 10.1:1 | 29.6:1 | 13.8:1 | 16.6:1+ |
| III | 6.5 | 10.8:1 | 12.6:1+ | 16.9:1- | 14.7:1 | 13.8:1- |
| III | 4.5 | 6.2:1- | 4.3:1- | 39.6:1+ | 8.0:1- | 14.6:1 |
| Seasonal average | | 9.9:1 | 9.0:1- | 28.7:1+ | 12.2:1 | 15.0:1 |
| IV | 6.5 | 11.8:1 | 24.4:1 | 19.9:1 | 65.0:1+ | 30.3:1+ |
| V | 5.5 | 5.1:1- | 25.6:1 | 21.1:1 | 15.6:1 | 16.9:1 |
| VI | 5.6 | 11.8:1 | 7.9:1 | 23.6:1 | 23.5:1 | 16.7:1 |
| VII | 6.5 | 17.4:1+ | 11.0:1 | 21.7:1 | 14.5:1- | 16.2:1 |
| VIII | 6.5 | 8.3:1 | 18.9:1 | 11.7:1 | 14.9:1 | 13.5:1- |
| IX | 7.6 | 11.8:1 | 21.1:1 | 13.5:1 | 18.1:1 | 16.1:1 |
| X | 10.5 | 13.9:1 | 15.6:1 | 9.7:1- | 20.4:1 | 14.9:1 |
| XI | 10.5 | 14.4:1 | 20.9:1 | 50.9:1+ | 19.1:1 | 26.3:1 |
| XII | 10.5 | 16.7:1 | 41.6:1+ | 41.6:1 | 14.5:1- | 28.6:1 |
| Seasonal average | | 12.4:1- | 20.8:1 | 21.6:1 | 22.8:1 | 19.9:1 |

N.B. For each of Region A & B, the maximum values are designated by (+) and the minimum by (-).

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