EGYPTIAN JOURNAL OF AQUATIC RESEARCH ISSN 1110-0354
VOL. 31., 1. 2005

NITROGEN AND PHOSPHORUS SPECIES OF LAKE BURULLUS WATER (EGYPT)

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Key words: Lake Burullus, Nutrients, Nitrogen, phosphorus forms.

ABSTRACT

Water samples collected from Lake Burullus were analyzed to investigate temporal and spatial variations of phosphorus and nitrogen species during the period from January to October 2003. The concentrations of dissolved inorganic nitrogen (DIN), dissolved organic nitrogen (DON), particulate nitrogen (PN) and total nitrogen (TN) were in the ranges of 4.10-107.51µmole l^{-1} ; 7.43-170.10µmole l^{-1}; 9.33-209.4µmole l^{-1} and 51.40-259.0 µmole l^{-1} respectively. DIN, DON and PN species represent 19%, 34% and 47% of the total nitrogen content, respectively.

Significant variations for the concentrations of the phosphorus forms have been found in this study. Concentrations of reactive phosphate (PO4), dissolved organic phosphorus (DOP), particulate phosphorus (PP) and total phosphorus (TP) were in the ranges of 0.76-8.40µmole l^{-1}, 0.27-10.74µmole l^{-1}, 0.26-12.81µmole l^{-1} and 3.40-21.42µmole l^{-1}, respectively. The study showed that high percentage of total phosphorus exists in the forms PP and DOP (74.1%), in addition, low levels of PO4 during spring (0.91µmole l^{-1}) and summer (0.94µmole l^{-1}). The middle basin of the lake revealed higher level of phosphorus. P: N ratios were recorded lower values (1:7 to 1:10) compared with that reported by Redfield's ratio (1:16), revealing low nitrogen content in comparison with phosphorus.

INTRODUCTION

Lake Burullus is a shallow brackish water basin. The lake lies in the north of the Nile Delta, along the Mediterranean Coast of Egypt between Long. 30° 30` & 31° 10` E and Lat. 31° 35` N. It covers an area of about 35.000 hectare with an average depth of 90 cm. The lake is connected to the Mediterranean Sea at the northern side through Boughaz El-Burg. The lake serves as reservoirs for drainage waters, which are contaminated, with anthropogenic materials (El-Sammak and El-Sabrouti, 1995a). It receives drainage waters from agricultural areas through seven drains in addition to the fresh water from Brembal Canal situated in the western part of the lake. Nitrogen and phosphorus of the lake water are found in various organic and inorganic species,. Physical and biological processes mainly control these species.

The lake receives drainage water which fluctuated between 78×106 and 272×106 m^3/month during January and July 2002, respectively (Ministry of irrigation). The amount of the drainage water discharged annually into the lake fluctuates from one year to the other, with the average of about 2.5 billion m3year-1 (Samaan *et al.,* 1989). During winter period, seawater may also enter the lake and increasing the salinity of water. Many investigators had studied the hydrographic and chemical characteristics of Lake Burullus water and sediments. Organic carbon distribution and preservation of the lake sediments was studied by El-Sammak and El-Sabrouti, 1995a. Several studies were performed on the levels and distribution of trace metals in the water a.nd sediments

(Emara, 1984; Moussa, 1984; El-Mamoney, 1988; Abdelmoneim *et al.,* 1990; Okbah, 1991 and Radwan, 2000)

The objective of the present study is to investigate temporal and spatial variations of nitrogen and phosphorus species in Lake Burullus water.

MATERIALS AND METHODS

Eleven surface water samples were collected seasonally in January (winter), April (spring), July (summer) and October (autumn) from Lake Burullus during 2003. Sampling sites were chosen covering the different parts of the lake (Fig.1). Three samples (I, II, and III) were taken from the eastern basin, near Boughaz El-Burg to reveal the influence of the sea water on the lake, Dr3, Dr4, Dr5 and Dr7 discharge in this basin. Five samples (IV, V, VI, VII and VIII) were collected from the middle basin of the lake; this basin affects by huge amount of wastewater discharges from drains 8&9. Samples IX, X and XI represented the western basin, which receives its water from two drains; drain 11 and Dr1 as well as Brimbal canal.

Water samples were taken manually by attaching a cleaned 1L-polyethylene bottle immersing to a depth 20-cm below the surface water. Dissolved inorganic nitrogen species and reactive phosphate were measured by Strickland and Parsons (1972), using a Shimadzu double beam spectrophotometer UV-150-02. The total nitrogen (TN) and total phosphorus (TP) were determined in both unfiltered and filtered samples to estimate the particulate nitrogen (PN) and particulate phosphorus (PP) using the method describe ed by (Valderrama, 1981). The dissolved organic nitrogen (DON) and the dissolved organic phosphorus (DOP) were calculated. Both TDN and TDP refer to the total dissolved nitrogen and total dissolved phosphorus in filtered samples.

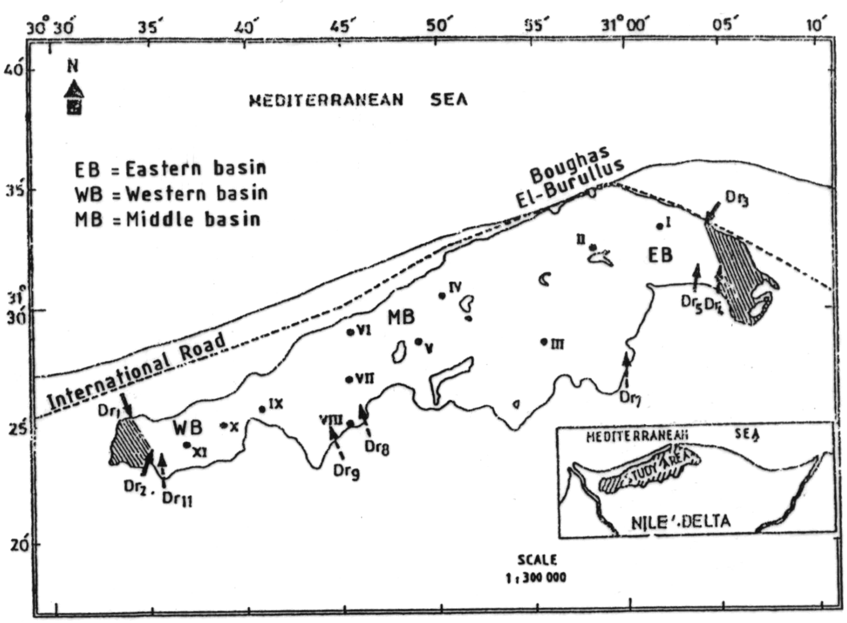

Fig. 1: Sampling stations

RESULTS AND DISCUSSION

1. Nitrogen Compounds:

1.1. Dissolved inorganic nitrogen species (DIN)

Dissolved inorganic nitrogen (NH4, NO2 and NO3) content of the Lake water is relatively high in the different basins, eastern, middle and western basins (Table 1).The concentration of ammonia, nitrite and nitrate (Fig.2) revealed wide variation. The values of ammonia fluctuated between 1.46 µmole l^{-1} in autumn and 50.60 µmole l^{-1}in winters. Nitrite showed variations from 0.16 µmole l^{-1} in spring to 31.23 in summer. The same trend was recorded for nitrate and the values are in the range of 1.02-46.7µmole l^{-1} in spring and summer, respectively.

In all parts of the lake, the highest values of DIN were recorded in the winter season with a concentration of 33.59, 40.90 and 32.77 µmole l^{-1} for eastern, middle and western basins, respectively. The relatively high concentration of inorganic nitrogen species may be attributed to the decomposition of organic matter in the lake. This was also supported by the significant negative correlation between the contents of inorganic nitrogen species and the organic matter content(r=-0.34, -0.19 and -0.41, respectively).

Generally, high level of DIN was found in the middle basin compared with that reported for the eastern and western basins, which could be attributed to the direct influence of drains No.8&9, which discharge agricultural water containing considerable amount of fertilizers. The drainage water discharged through these drains amounted to more than 960 million cubic miters per year. On the other hand, the lowest content of DIN may be due to the decreasing in the amount of wastewater in the eastern basin through the eastern El-Burullus drain and drain 7. Its volume of water was around 330 million cubic miters per year. The amount of drainage water (through the western El-Burullus drain and drain 11) in the western basin was 670 million cubic miters per year.

The wind movements is another important factor, influencing the discharge of drainage water containing nitrogen and phosphorus compounds to the lake water, Beltagy(1985) showed that the water in the most eastern part of the lake is shifted towards the west under the influence of the easterly wind. On the other hand, the westerly wind sometimes moves great quantities of water from the sea into the eastern part of the lake, at the same time; the western part becomes very shallow. The relative decrease of inorganic nitrogen species in summer and spring may be as results of nutrients consumption by phytoplankton and aquatic plants which are density populating during these seasons (Abdel-Moati *et al.,* 1988). This was confirmed by the high levels of chlorophyll-a concentrations recorded during these seasons (Table 2).

Table (1): Seasonal variations of nitrogen forms in lake Burullus during 2003 (Range and mean ± S.D)

		NH_4-N	NO_2-N	NO_3-N	DIN	DON	TDN	PN	TN
		(μmole l^{-1})							
Eastern Basin	Winter	4.82-17.40 10.25±7.32	1.88-13.40 5.79±6.74	6.85-29.70 17.56±12.60	13.55-51.64 33.59±21.4	9.07-12.10 10.99±3.26	25.64-63.45 44.58±20.3	12.55-25.76 18.41±7.91	51.40-76.0 62.99±4.23
	Spring	1.79-2.63 2.07±10.40	0.16-0.46 0.34±0.16	1.47-2.17 1.83±0.80	4.10-4.49 4.24±0.93	59.30-69.51 63.6±1.25	63.4-74.0 67.84±4.67	50.6-245.0 117.9±101.3	164.0-211.0 185.74±15.3
	Summer	5.29-15.46 8.76±3.92	0.39-1.25 0.81±0.63	5.70-10.21 7.69±6.51	12.49-26.04 17.26±12.01	15.27-39.01 28.25±8.72	41.33-51.5 45.51±13.7	13.5-40.63 31.2±20.30	64.0-84.3 76.71±10.2
	Autumn	2.63-3.83 2.96±0.83	1.25-2.42 1.77±0.75	4.56-5.42 4.95±0.35	9.08-10.47 9.68±0.43	10.23-19.45 13.33±1.78	19.38-29.40 23.01±4.62	29.10-56.92 41.77±19.2	58.5-76.3 64.78±4.3
	Annual	6.01±3.55	2.18±2.15	8.01±5.89	16.19±11.06	29.04±21.0	45.24±15.8	52.3±38.0	97.56±80.3
Middle Basin	Winter	3.36-50.60 13.65±17.82	1.07-9.72 3.08±3.14	10.79-44.70 24.17±37.2	18.37-105.0 40.90±58.6	7.43-43.3 17.93±19.81	30.0-121.0 58.83±71.4	9.33-39.23 30.33±21.5	64.60-154.4 89.16±95.71
	Spring	2.71-4.42 3.14±0.82	0.46-14.10 3.52±2.36	1.02-20.27 5.89±4.72	4.32-38.79 12.55±11.63	74.89-170.1 112.33±95.2	83.4-184.70 124.88±119.4	23.6-148.70 65.12±84.1	107.0-259.0 190.0±21.1
	Summer	5.0-29.58 12.10±14.30	0.47-31.23 6.78±10.3	3.24-46.70 15.34±17.21	8.97-107.51 34.22±45.1	26.64-42.7 36.84±24.6	40.3-157.8 71.06±49.8	17.67-57.2 30.8±38.2	62.17-89.81 101.9±10.41
	Autumn	1.46-32.54 8.85±10.62	1.09-8.32 3.01±2.07	4.41-19.06 11.4±6.10	8.21-59.92 23.26±7.08	8.76-19.33 14.25±3.21	20.63-79.00 37.51±11.24	60.20-209.4 128.73±27.0	81.5-233.8 166.24±28.9
	Annual	9.44±4.03	4.1±1.56	14.2±6.7	27.73±10.79	45.34±39.6	73.1±32.2	63.7±40.1	136.82±42.4
Western Basin	Winter	3.32-37.60 14.81±19.23	2.50-5.17 4.11±3.92	11.54-17.62 13.85±11.54	20.56-54.31 32.77±3.52	13.39-16.52 14.67±1.71	34.67-70.83 47.44±13.9	26.77-44.93 38.29±11.7	63.60-114.0 85.73±31.2
	Spring	2.04-2.92 2.47±0.14	0.51-1.36 0.82±0.37	1.78-2.10 1.95±0.52	4.33-6.38 5.24±0.94	63.32-91.7 79.66±10.4	69.7-96.0 84.9±9.26	15.8-72.0 46.27±12.3	111.8-141.7 131.17±40.2
	Summer	5.42-6.42 5.96±0.82	0.31-1.77 0.84±0.62	6.55-7.93 7.04±1.03	13.0-14.79 13.84±1.73	27.3-35.41 31.62±5.43	41.0-50.2 45.50±6.41	25.0-29.82 27.14±1.71	70.82-75.2 72.60±10.30
	Autumn	1.50-3.42 2.65±0.61	1.30-6.24 3.12±1.58	5.49-17.80 10.76±3.10	10.21-25.54 16.53±10.18	10.36-19.20 13.44±4.70	24.20-36.30 29.97±5.23	28.3-72.9 48.1±7.14	52.50-109.2 77.97±18.30
	Annual	6.47±5.01	2.22±1.44	8.4±4.44	17.10±99.6	34.85±26.9	51.94±20.2	40.0±8.26	91.87±50.1

Table (2): Seasonal variations of phosphorus forms in lake Burullus during 2003 (Range and mean ± S.D)

		PO_4-P	DOP	TDP	PP	TP	N/P	Chlorophyll-a
		µmole/ l					Ratio	µg/ l
Eastern Basin	Winter	1.30-4.12	0.80-2.18	2.10-6.30	1.30-3.72	3.40-8.52	10.4-12.5	28.90-31.80
		2.21±0.82	1.5±0.73	3.77±3.00	2.41±1.08	6.19±3.02	15.2	30.50±2.13
	Spring	0.78-1.04	0.27-0.82	1.05-1.86	2.01-7.99	3.87-9.30	4.3-5.3	35.90-74.12
		0.91±0.39	0.50±0.35	1.41±0.91	4.05±2.89	7.23±4.15	4.7	49.80±10.52
	Summer	1.22-1.89	0.46-6.32	1.68-8.21	7.19-10.21	10.50-15.40	10.2-13.9	35.60-92.70
		1.48±0.85	4.65±1.82	6.13±3.87	8.74±1.23	14.87±2.57	11.7	65.60±13.02
	Autumn	0.84-8.40	0.34-3.57	1.18-11.97	0.54-4.45	5.63-13.50	1.3-10.8	35.60-47.40
		4.23±3.14	2.09±1.38	6.32±4.42	2.17±2.01	8.49±3.92	2.3	41.90±5.36
	Annual	2.21±1.26	2.20±0.81	4.41±1.74	4.34±2.64	8.75±2.55	7.3	46.95±8.21
Middle Basin	Winter	0.90-7.80	0.78-3.71	1.68-10.76	1.36-5.94	3.80-16.70	13.5-20.4	17.30-76.30
		3.71±4.23	2.15±1.61	5.86±6.18	2.12±3.11	8.76±6.15	11.1	38.70±20.31
	Spring	1.26-5.87	1.13-10.74	2.91-16.61	0.26-4.57	6.91-18.79	3.4-6.6	28.40-172.50
		2.6±1.73	5.64±3.92	8.24±5.84	2.34±2.11	10.58±3.88	4.8	70.70±35.00
	Summer	0.76-5.88	0.41-4.54	1.51-10.42	3.20-7.26	7.56-17.68	11.8-18.3	45.10-104.30
		2.23±1.83	2.09±1.32	4.32±3.98	5.04±3.45	10.27±4.93	15.4	70.50±20.30
	Autumn	1.26-3.92	0.67-7.26	2.14-11.21	3.40-12.81	5.54-21.42	6.5-15.3	37.26-71.10
		2.94±1.78	2.74±2.51	5.68±3.95	6.26±4.53	10.19±5.82	7.9	51.00±15.24
	Annual	2.87±0.62	3.14±1.41	6.00±1.44	3.94±1.78	9.95±0.70	9.7	57.73±16.32
Western Basin	Winter	0.63-4.70	1.11-1.66	2.24-6.36	1.84-6.54	4.20-12.90	11.6-32.6	23.70-52.20
		2.19±2.75	1.46±0.53	3.65±2.74	5.78±2.37	7.30±5.13	14.9	37.20±8.25
	Spring	1.09-9.91	2.50-8.63	3.59-18.54	0.76-3.37	6.96-19.30	0.74-3.9	53.26-124.70
		2.17±2.25	4.96±3.64	8.14±4.61	3.01±0.82	13.58±6.72	2.4	65.79±34.20
	Summer	0.89-1.02	0.48-1.03	1.50-1.95	2.79-6.69	4.55-8.19	14.5-14.6	59.30-85.32
		0.94±0.24	0.79±0.47	1.74±0.53	5.50±2.15	6.04±3.81	14.3	69.50±7.00
	Autumn	1.17-5.33	0.97-2.60	2.14-7.54	1.76-2.37	4.28-9.30	4.8-8.7	30.40-55.07
		2.57±1.32	0.93±0.51	3.49±1.87	2.91±0.81	6.58±2.34	6.4	44.50±5.02
	Annual	1.97±0.61	2.04±1.60	4.26±3.41	4.12±1.06	8.38±3.04	8.7	54.25±17.58

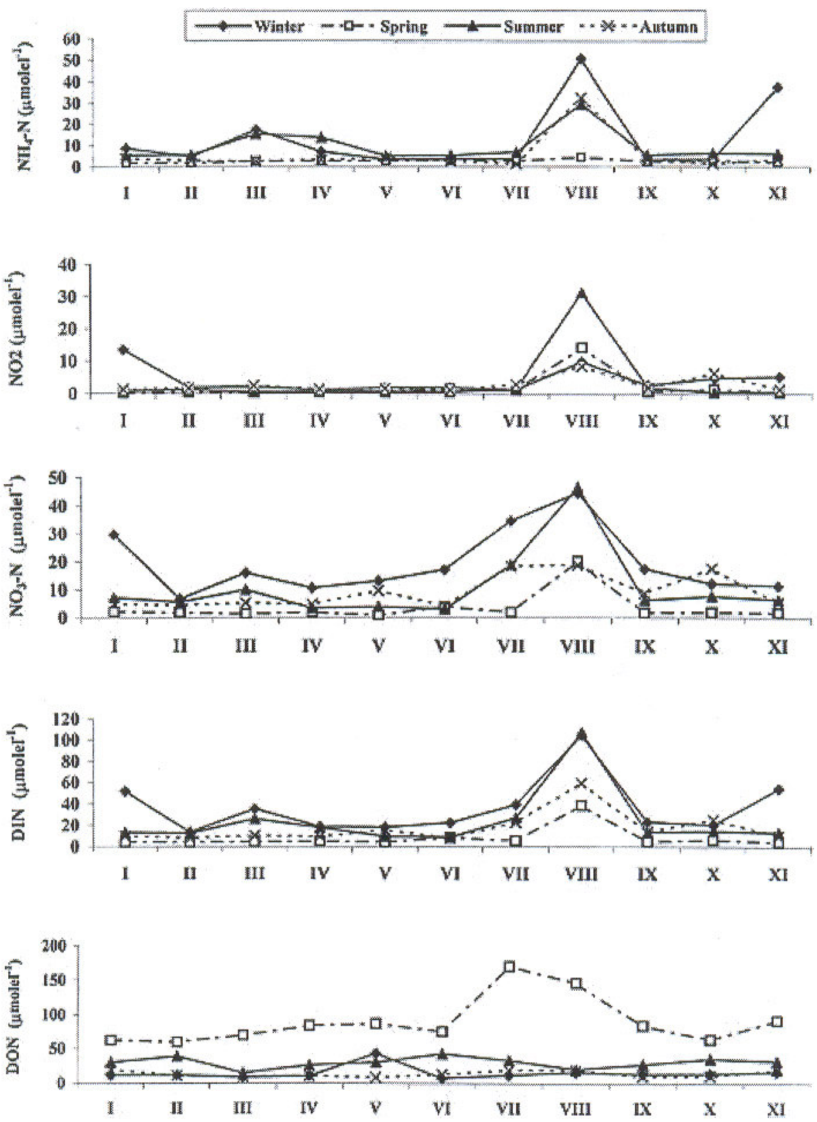

Fig.2: Regional and seasonal variations of NH_4-N, NO_2-N, NO_3-N, dissolved inorganic nitrogen (DIN) and dissolved organic nitrogen (DON), in Lake Burullus water during 2003

1.2. Dissolved organic nitrogen (DON)

Dissolved organic nitrogen (DON) can be one of the important sources of nitrogen for phytoplankton growth (Otsuki *et al.,* 1993).

Seasonal distribution of dissolved organic nitrogen in Lake Burullus showed values ranging between 7.43 µmole $l^{-1}$and 170.1 µmole l^{-1} in winter and spring, recorded at sites VI and VII, respectively (Fig. 2). The average minimum and maximum values of DON in the three basins of the lake fluctuated between 10.99 µmole l^{-1} in winter at the eastern basin and 112.33 µmole l^{-1} in spring at the middle basin (Table 1)

The highest average concentrations of DON in all basins were recorded in spring, where it reached to 63.6 µmole l^{-1} in the eastern basin compared with 112.3 µmole l^{-1} in the middle basin and reached to 79.66 µmole l^{-1} in the western basin (Table1). This could be interpreted on the basis of DIN assimilation by phytoplankton and aquatic plants during the warm seasons that lead to a rapid removal of the DIN species.

As shown in Fig.5, the average concentrations of DON constitute about 29.8, 33 and 37.9% of the total nitrogen, while DIN constitute about 16.6, 20.3 and 18.6% of total nitrogen in the eastern, middle and western basin, respectively The high content of DON (36.4 µmole l^{-1})compared with the lower one for DIN (20.34µmole l^{-1}) is due to the fact that the organic nitrogen seems to be assimilated by the aquatic organisms at a much slower rate than that of the inorganic species (Fahmy *et al.,* 1996). In addition, some organic matter containing nitrogen usually resists bacterial change and remains in the water or sinks to the sediments as bottom humus (Riley and Chester, 1971).

In general, the present data demonstrated that DON is an important form as a source of nitrogen compounds in the lake water.

1.3 Particulate nitrogen (PN):

In addition to the dissolved organic and inorganic nitrogen compounds, the lakes also contain a considerable amount of particulate nitrogen associated with organisms and products of their metabolism and decay. Fig.3 shows the seasonal variation of PN content in the lake water. The levels of PN were widely fluctuated between a minimum of 9.3 µmole l^{-1} in winter and maximum of 209.4 µmole l^{-1} in autumn at site V.

Table1 shows the distribution of PN in the three basins of the lake water. In the eastern basin, the high level of PN was recorded in spring (117.9 µmole l^{-1}) and decrease in winter (18.41 µmole l^{-1}), the increasing of PN may be attributed to the high productivity of phytoplankton during spring, chlorophyll-a concentrations ranged from 47.80 to 70.7 µg l^{-1}. The particulate nitrogen distribution in the middle basin was high in spring and autumn and decrease in winter and summer periods, the maximum value (128.73 µmole l^{-1}) in autumn and minimum content (30.33 µmole l^{-1}) in winter. In the western basin PN concentration ranged from 27.14 µmole l^{-1} to 48.1 µmole l^{-1} (Table 1).

In general, the PN concentrations of the lake water was relatively high in the middle basin with an annual average of 63.7 µmole l^{-1} (46.6% of TN) compared with the lower values of the eastern basin (52.3 µmole l^{-1}; 53.6% of TN) and western basin (40.0 µmole l^{-1}; 43.5% of TN)

1.4 Total nitrogen (TN)

Total nitrogen concentration in the investigated area showed wide variation, ranging between 51.4 µmole l^{-1} at site II in winter and 259.0 µmole l^{-1} at site VIII in spring (Fig.3).

As shown in Table1, the greater values of TN exhibited in spring season, and is restricted to the middle basin (190.0 µmole l^{-1}), while the lowest level was recorded in the eastern basin (63.0 µmole l^{-1}). The high level of TN is attributed to the high content of both DON and PN. Generally, Lake Burullus showed lower content of total nitrogen in comparison with the values reported for Lake

Edku, the annual average concentration of TN in Lake Edku increased 1.5 fold than that recorded in the eastern and western basin, while similar to that found in the middle basin of Lake Burullus (Okbah and El-Gohary, 2002)

2. Phosphorus compounds:

2.1 Reactive phosphate (PO4-P)

The seasonal distribution of PO4 at Lake Burullus is shown in Fig. 4. The values ranged between 0.63 and 9.91µmole l^{-1} in winter and spring, respectively at site X. High values of PO4 were recorded at sites I, VII, VIII, X and XI, revealing the effect of drainage water that enriched with fertilizers containing phosphorus compounds.

Regional annual average concentration of PO4 was higher in the middle basin (2.87 µmole l^{-1}; 28.8% of TP), comparing with lower one (1.97µmole l^{-1}; 23.5% of TP) for the western basin (Table 2 & Fig. 5).

The concentrations of PO4 showed a decreasing trend in both spring and summer seasons of the lake water, suggesting that at higher temperature and regeneration in the lake, the metabolic activity increases and affect PO_4 content (Edmond *et al.,* 1985)

Significant positive correlation was observed between the dissolved phosphate concentrations and the amount of suspended particulate matter in the lake water ($r=0.53$; $p<0.05$; $n= 44$). Sanders *et al.,* 1997 showed that the removal of PO_4 by suspended particulate matter ranged from 30 to 80% of phosphate input. Many studies have demonstrated that the interactions of DIP with suspended particulate matter represent one of the most important mechanisms affecting the behavior of phosphorus (Pratska *et al.,* 1998)

2.2 Dissolved organic phosphorus (DOP)

The regional variation of DOP was found in Fig. 4, the highest value was recorded at site VIII (10.74 µmole l^{-1}) while the lowest one (0.27 µmole l^{-1}) was recorded at site I.

The seasonal variations of DOP in the three basins of Lake Burullus are given in Table1. The average values revealed wide variations. In spring season, the minimum value (0.50 µmole $l^{-1)}$ was recorded at the eastern basin while the maximum content (5.35 µmole l^{-1}) at the middle basin

The annual average concentrations of DOP were, 2.14 µmole l^{-1} (24.6% of TP), 3.14 µmole l^{-1} (31.6% of TP), 2.29 µmole l^{-1} (27.30% of TP) for the eastern, middle and western basins, respectively.

According to Conley *et al.* (1995), DOP might contribute a significant fraction of the total dissolved phosphorus. The present study showed that the contribution of DOP to the total phosphorus was relatively high.

2.3 Particulate phosphorus (PP)

The results as shown in Fig.4 revealed wide variation in the content of PP. It ranged from 0.26 to 12.81 µmole l^{-1}. The annual mean concentrations of PP during this study were 4.34, 3.94 and 4.12 µmole l^{-1} for the eastern, middle and western basins, respectively.

Abdel-Moati (2001) showed that the ferric oxyhydroxide formed under oxic conditions have a high adsorption capacity for particulate phosphorus. The percentage of PP in the present study ranged from 50% to 40% of TP for the three basins (Fig. 5).

The distribution of PP did not show the same trend of the PN in the three basins. In addition, no relationship was found between PP and PN in the present study. In contrast, significant relationship between PP and suspended matter ($r= 0.53$, $P< 0.05$, $n= 44$) were found. Bad relationship between PP and chlorophyll-a was observed. The high level of PP may be resulted from phosphorus that is associated with the suspended particulate matter, and transported by wastewater through the drains.

Generally, PP can be regulates the concentrations of dissolved phosphate in the lake water.

2.4 Total phosphorus (TP)

The total phosphorus concentrations were generally high in the lake water (Fig.4).

It ranges from 3.40µmole l^{-1} in winter (eastern basin) to 21.42 µmole l^{-1} in autumn (middle basin).

The highest annual mean concentration of total phosphorus in the present study was recorded in the middle basin (9.95µmole l^{-1}) compared with lower values 8.69, 8.39µmole l^{-1} for eastern and western basins, respectively. The concentrations of TP in the eastern basin ranged from 3.40µmole l^{-1} in winter to 15.40µmole l^{-1} in summer (Fig. 4). In the middle basin it varied from 3.80µmole l-1 in winter to 21.42µmole l^{-1} in autumn. In the western basin, the content of TP ranged between 4.20µmole l^{-1} in winter and 19.30 µmole l^{-1} in spring.

TP concentrations averaged 9.01 µmole l^{-1} over the study period, 26% of which only was in the form of inorganic PO_4, indicating that most of TP was found in particulate and dissolved organic phosphorus (Fig.5). This pattern supports the idea that a large fraction of TP is transported in suspension bound to sediment particles (Perez *et al.,* 2003).

In general, the huge amounts of wastewater drainage into the lake led to high content of phosphorus and nitrogen compound especially in the particulate form. The inputs of drainage water into the lake through the drains are significant forcing mechanisms that lead to water movement and re-suspension of sediments of shallow lakes.

3. Phosphorus: Nitrogen Ratio:

Dissolved inorganic phosphorus and dissolved inorganic nitrogen are very important compounds in the growth and reproduction of phytoplankton.When present in large content, it causes eutrophication and may be considered as a potential pollutant (Riley and Chester,1971).

Table 2 showed the regional and seasonal variations of P: N ratios in the three basins, it ranged from 1: 0.74 in spring and 1: 32 in winter (western basin). The annual mean ratios of P: N (Table 2) was found to be 1: 7 for eastern basin; 1: 10 for middle basin and 1: 9 for western basin. According to the results reported by Redfield et al., 1963, P: N ratio is 1:16, indicating that the P:N ratio of the present study is lower than that of Redfield ratio and reflecting lower nitrogen content in comparison with phosphorus in lake water.

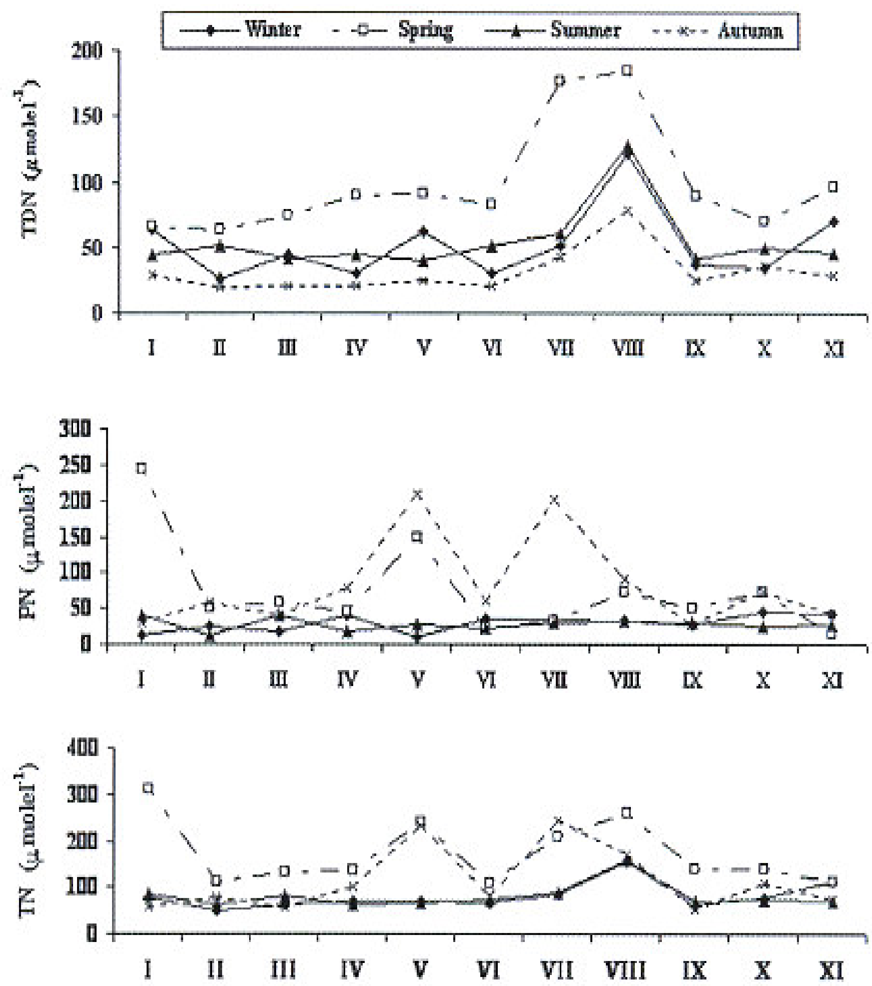

Fig.3: Regional and seasonal variations of total dissolved nitrogen (TDN), particulate nitrogen (PN) and total nitrogen (TN) in Lake Burullus water during 2003.

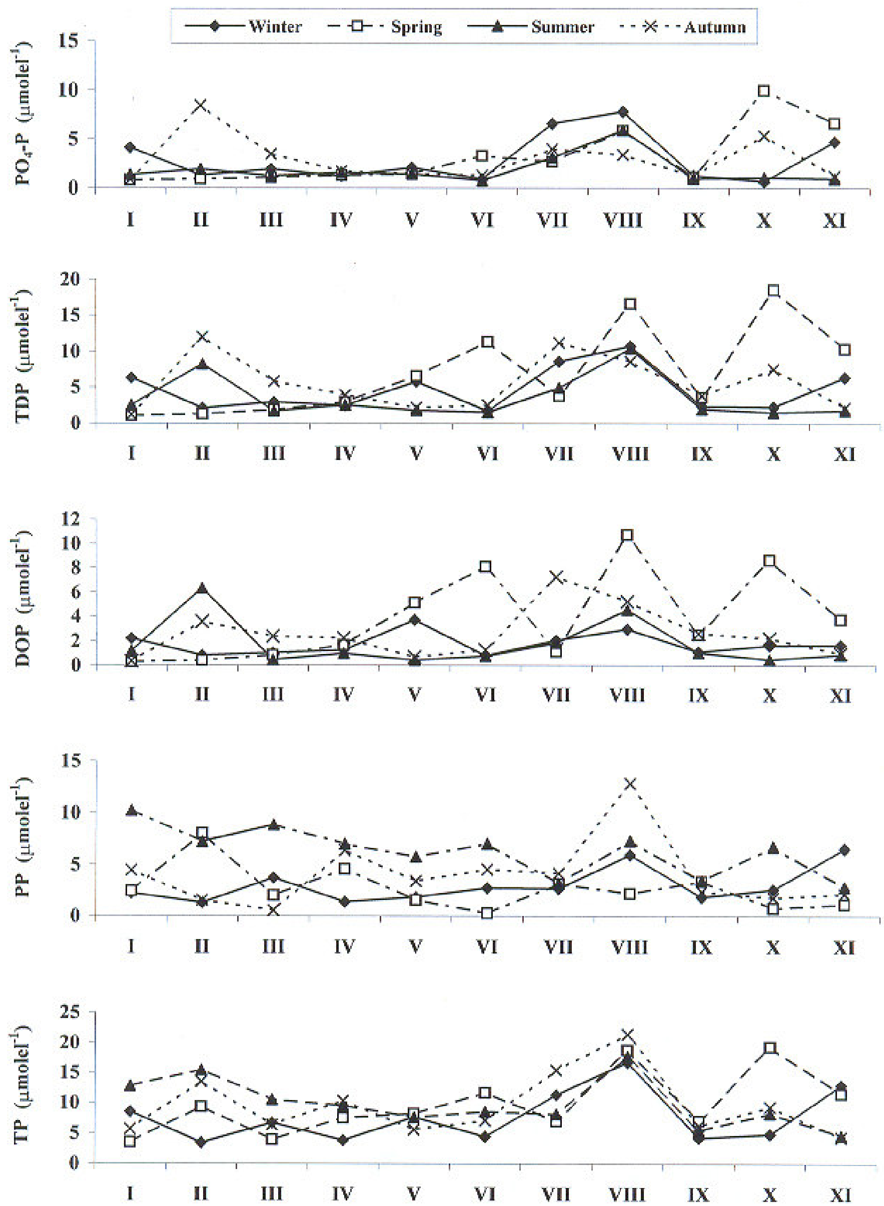

Fig.4. Regional and seasonal variations of PO_4-P (total dissolved phosphorus (TDP), dissolved organic phosphorus (DOP), particulate phosphorus (PP) and total phosphorus (TP) in Lake Burullus water during 2003

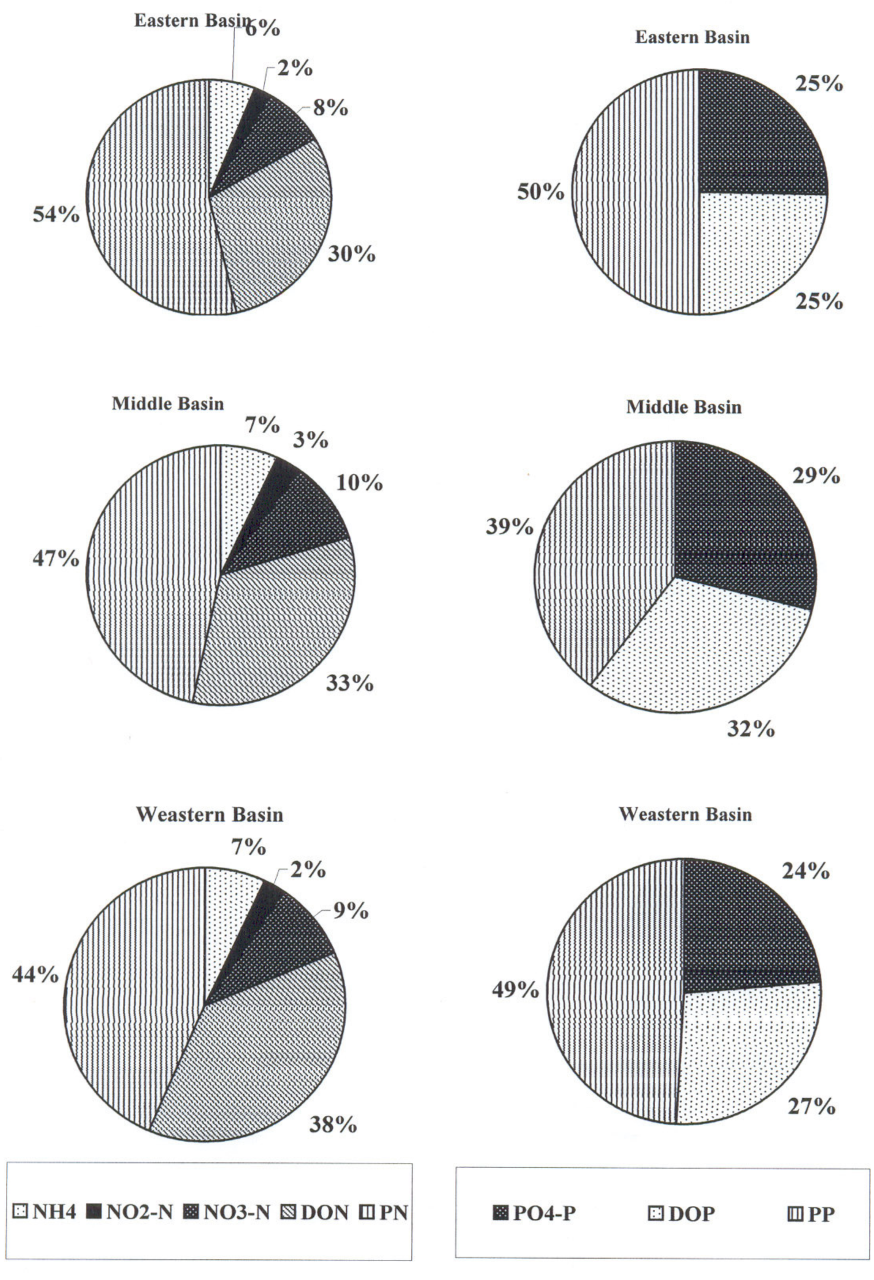

Fig. (5): The relative percent of nitrogen and phosphorus in Lake Burullus water 2003

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