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EXCHANGE OF PHOSPHORUS FORMS BETWEEN WATER AND SEDIMENT IN LAKE EDKU, ALEXANDRIA, EGYPT

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Keywords: Lake Edku, pore water, overlying water and phosphorus.

ABSTRACT

Bottom water and grab sediment samples were collected from eleven selected stations from lake Edku in spring season (May), to see the abundance and distribution of different phosphorus (P) fractions between the water and the sediments. The results showed that, the pore water recorded much higher concentrations of dissolved inorganic phosphorus (DIP) and dissolved organic phosphorus (DOP) than that in the overlying bottom water (enrichment factor, EF = 5.18 and 31.43, respectively). This means that the sediments of the lake act as a source of the two phosphorus forms. DIP constitutes the majority of total dissolved phosphorus (TDP) in the sediment pore water and in the overlying bottom water (75.40 % and 87.87 %, respectively). The rate of diffusion of DOP from the sediment pore water to the overlying bottom water is most likely greater than that of DIP. This reflects that most OP in the bottom water was diffused from the sediments, but the drainage water was the most responsible about the high level of IP in the overlying bottom water.

1. INTROCUCTION

The main natural origin of phosphorus (P) in the Nile River and the Nile Delta lakes and the soils is due to erosion, the chemical and mechanical weathering of rocks in east and central Africa (EL-Sabrouti and Sokkary, 1982). In Lake Edku another and main source of P is agricultural and other land uses. This source induced the leaching and drainage of fertilizers and other soils nutrients and the removal of soil particles (Ibrahim, 1994).

The exchange of the nutrients between the sediments and the overlying water has become a major topic in the study of the nutrient cycling. The pore water is enriched in various nutrients as compared to the overlying water as a result of diffusion and mixing processes resulting from various physical, chemical and biological factors. Hemaida (1988) studied the dynamics of nutrients between water and sediments in Lake Edku. Ibrahim (1994) studied the geochemical cycle of P in the lake. Okbah and EL-Gohary (2002) studied physical and chemical characteristics of the lake.

In the present study, the concentration of P forms are determined in the bottom water, pore water and in the grab sediment of Lake Edku through spring season (May month) to see the abundance and distribution of different P fractions between the water and the sediment.

2. AREA OF STUDY

Lake Edku (Fig. 1) lies about 30 km north east of Alexandria, south the coastline of Abu-Kir Bay between longitudes 30º 8′ & 30º 23′ E and Latitudes 31º 10′ & 31º 18′ N. It is one of the important fish sources in Egypt. The lake covers a total area of about 115 km^2, most of it particularly its eastern side is densely vegetated mostly with hydrophytes leaving a free water area of about 4200 m^2 (Okbah and EL-Gohary, 2002) with average depth of about 1 m. Its sediments are mixed with clay, silt and sand (EL-Sayed, 1993). It has only one outlet at its western extremity on Abu Kir Bay, this outlet is known as Boughaz EL-Maadia. The lake receives at its eastern side influent waters (about 3.3×10^6 m^3/d) from three main agricultural drains, namely Bousily, Edku and Barzik. The first two drains are adjoining before opening on to the north eastern side of the lake. The discharged water introduces large amounts of nutrients and terrestrial organic matter.

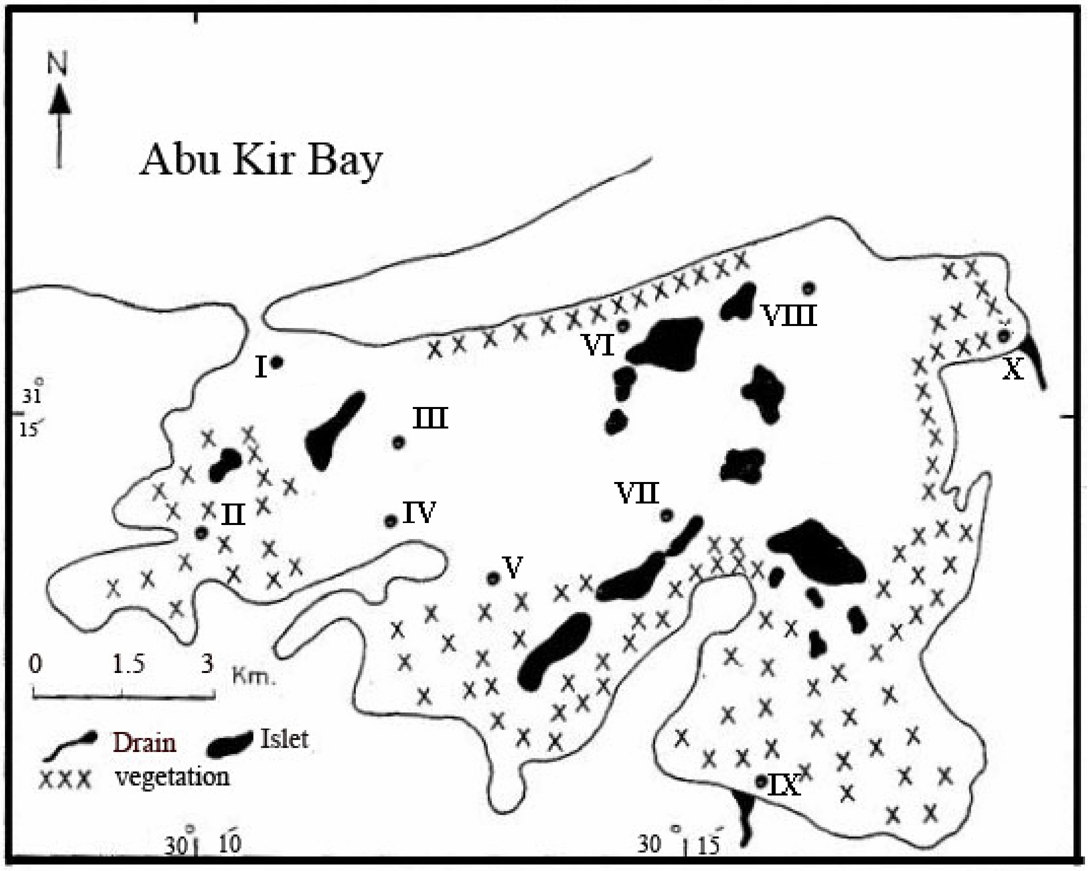

Fig. (1): Lake Edku and station positions.

3. MATERIALS AND METHODS

Bottom water samples were collected from eleven selected stations (Fig. 1) in May 2006 using a plastic Ruttner water sampler. Hydrogen ion concentration (pH) was determined using a portable pH meter. Dissolved oxygen (DO) was measured by the method described by Winkler method (Strickland and Parsons, 1972) and chlorosity by to Mohr,s titration method.

Samples for phosphorus forms and chlorophyll-a determination were filtered immediately after collection using Whattman GF/C glass fiber filter and measured according to Grasshoff (1976) and Strickland and Parsons (1972), respectively.

Grab sediment samples were collected from the same stations using patterson grab sampler. Portion of each sediment sample was used for extraction of the pore water by centrifugation directly after sampling. The supernated (pore) waters were filtered through Wattman GF/C glass fiber filter and used for determination chlorosity and phosphorus forms as mentioned before in the bottom water. The other portion of the grab sediments was dried and grounded for determination of the phosphorus forms according to Aspila *et al* (1976).

4. DATA TREATMENT

- The obtained results are summarized by the computation of the following statistical parameters: average, standard deviation and correlation matrices using excel program.
- The distribution of the studied parameters are drawing using excel program.
- Enrichment factors between the pore water and the overlying bottom water are calculated according to the following equation:

Enrichment factor = sediment pore water / overlying bottom water

- The percentage for each of inorganic phosphorus (IP) and organic phosphorus (OP) in bottom water, pore water and sediment to the corresponding total phosphorus (TP) are calculated.
- Eutrophication of the lake was determined according to Vollenwider, 1968 and Giovanardi and Tromellini, 1992.

5. RESULTS AND DISCUTION

The concentrations of hydrogen ion concentration (pH), dissolved oxygen (DO), chlorophyll-a (Chl-a), Chlorosity, inorganic phosphorus (IP), organic phosphorus (OP) and total phosphorus (TP) in Lake Edku were listed in Table 1.

5. 1. Physico-chemical characteristics of the lake in bottom and sediment pore waters

5.1.1. Hydrogen ion concentration (pH)

The pH values ranged between 7.43 at St. 1 and 8.71 at Sts. IV and V with average 8.18. The low levels of pH are observed far from the discharged water and near to the lake sea connection, while the high levels were observed in the central of the lake which was enriched with DO. Generally, the pH values of the bottom water vary within very narrow limits, reflecting the shallowness of the lake and mixing of the water and also referring to the buffer capacity of natural waters (Krauskopf, 1967).

5.1.2. Dissolved oxygen (DO)

The concentration of DO varied between 2.28 mgO_2/L at St. XI and 20.16 mgO_2/L at St.II with average 13.00 mgO_2/L. Fig. 2 showed that, the eastern part of the lake in front of the outlets had the lowest level of DO (<4.00 mgO_2/L), this reflects the pollution of the discharged water at this part of the lake and the more consumption of DO used in decomposition of organic matter and plant. Ibrahim (1994) pointed out that the eastern basin of the lake has the low values of DO. Also St.I (near EL-Maadia opening) had low level of DO (8.76 mgO_2/L). Hemaida (1988) reflect that to the mixing with the polluted water of the low oxygen content entering the lake from Abu-Kir Bay. Faragallah (2004) also found that spring season has relatively low DO (8.62 mgO_2/L) inside Boughaze EL-Maadia. The rest of the lake characterized by high oxygenated water (> 16 < 20.17 mgO_2/L) probably due to the shallowness of the lake and its vertical mixing. DO gives positive correlation with chlorosity (r = 0.66) and negative correlation with DIP, DOP and DTP (r = 0.63, 0.60 and 0.66, respectively).

5.1.3. Chlorophyll-a (Chl-a)

Chl-a concentration ranged between 1.70 mg/m^3 at St.X and 12.37 mg/m^3 at St. IV with average 6.81 mg/m^3. Fig .2 showed that the western and the center of the lake (from St.I to St. V) had high concentration of Chl-a (> 7.6 mg/m^3), but the rest of the lake (from St. VI to St. XI) especially in front of the discharged water in the eastern side had low concentrations. This means that Chl-a decrease from the west of the lake to the east.

According to preliminary classification of trophic state of shallow marine water bodies (Vollenwieder, 1968 and Giovanardi and Tromellini, 1992) based on the level of chlo-a, transparency and DTP, lake Edku can be considered as eutrophic.

Table (1): The concentration of pH, DO, Chlor-a, Chlorosity, IP, OP and TP in Lake Edku

	Bottom water							Pore water				Enrichment Factor (EF)				Sediment		
Station	pH	DO mgO_2/l	Chlor-a mg/m^3	Chlorosity g/l	DIP uM	DOP uM	TP uM	Chlorosity g/l	DTP uM	DOP uM	TP uM	Chlorosity	DTP	DOP	TP	IP ppm	OP ppm	TP ppm
I	7.43	8.76	7.64	0.70	1.26	0.38	1.64	1.11	3.70	0.07	3.77	1.59	2.94	0.18	2.30	526	171	697
II	8.01	20.16	8.79	0.70	1.45	0.12	1.57	1.11	17.43	7.72	25.15	1.59	12.19	64.33	16.02	493	125	618
III	8.64	16.22	10.75	0.56	1.21	0.11	1.32	1.11	1.47	0.38	1.85	1.98	1.22	3.46	1.40	385	101	486
IV	8.71	18.53	12.37	0.70	1.32	0.04	1.36	0.65	9.24	3.76	13.00	0.93	7.00	94.00	9.56	622	83	705
V	8.71	18.83	12.05	0.63	0.84	0.15	0.99	1.76	3.17	1.23	4.40	2.79	3.77	8.20	4.44	576	197	773
VI	8.20	18.20	4.82	0.63	1.52	0.47	1.99	0.83	11.09	5.26	16.35	1.32	7.30	11.19	8.22	778	208	986
VII	7.70	19.50	2.27	0.56	3.10	0.20	3.30	0.83	14.52	4.97	19.49	1.48	4.68	24.85	5.91	635	169	804
VIII	8.20	9.12	6.32	0.63	0.84	0.22	1.06	1.96	2.11	0.41	2.52	3.11	2.51	1.86	2.38	429	136	565
IX	8.10	7.49	4.03	0.42	3.04	0.68	3.72	1.11	25.88	9.75	35.63	2.64	8.51	14.34	9.58	694	234	928
X	8.10	3.90	1.70	0.42	3.93	0.36	4.29	1.39	2.31	0.07	2.38	3.31	0.59	0.19	0.56	803	256	1059
XI	8.10	2.28	4.15	0.45	4.62	0.41	5.03	1.67	28.79	5.38	34.17	3.71	6.23	13.12	6.79	643	106	749
Min	7.43	2.28	1.70	0.42	0.84	0.04	0.99	0.65	1.47	0.07	1.85	0.93	0.59	0.18	0.56	385	83	486
Max	8.71	20.16	12.37	0.70	4.62	0.68	5.03	1.96	28.79	9.75	35.63	3.71	12.19	94.00	16.02	803	256	1059
SD±	0.402	6.757	3.798	0.109	1.328	0.192	1.432	0.418	9.77	3.3716	12.83	0.9274	3.468	30.21	4.597	133.5	57.12	176.4
Average	8.17	13.00	6.81	0.58	2.10	0.29	2.39	1.23	10.88	3.55	14.43	2.22	5.18	21.43	6.11	599	162	761

Enrichment factor (EF) = Sediment pore water / Bottom water

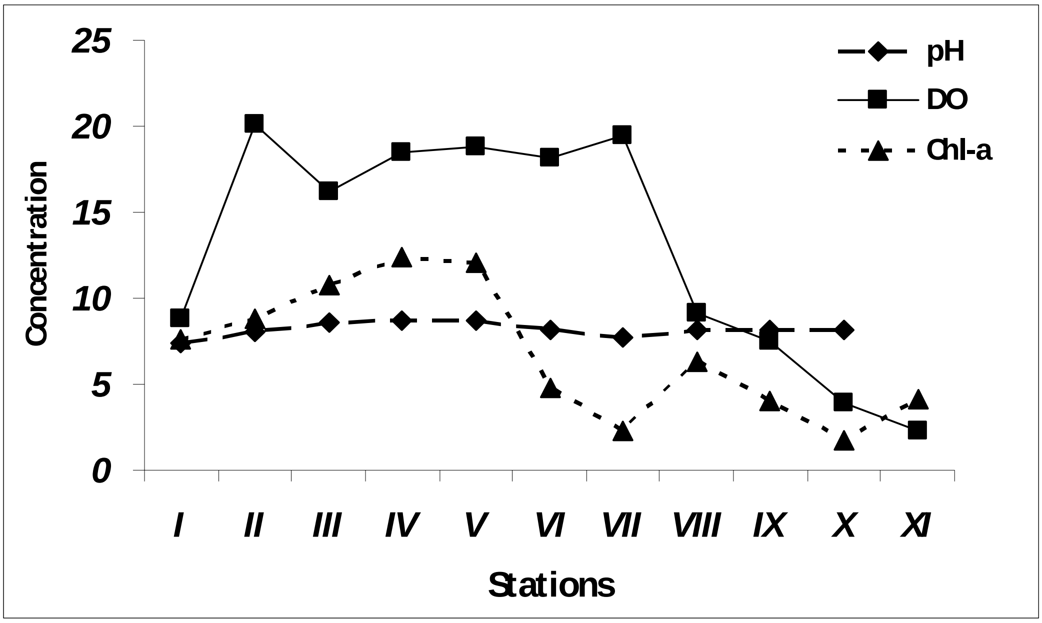

Fig. (2): The distribution of pH, DO (mgO2/l) and Chl-a (mg/m3) in the bottom water of Lake Edku.

5.1.4. Chlorosity

Chlorosity in the bottom water fluctuated from 0.42 g/l at Sts IX and X to 0.70 g/l at Sts. I, II and IV with average 0.58 g/l. Generally, the high concentration of chlorosity was found in the west of the lake and decrease towards the east (Fig.3). This means that lake – sea communication was characterized by high level mainly due to the high chlorosity of sea water introduced to the lake from the neighboring Abu-Kir Bay.

Levels of chlorosity in the sediment pore water were generally higher than those in the bottom water (EF = 2.22). The maximum of 1.96 g/l was observed at St. VIII, while the minimum of 0.65 g/l was observed at St. IV with average 1.23 g/l. Fig. (3) showed increase in the diffusion rates of chloride ions at St V and east of the lake (from St.VIII to St.XI) than those in the other stations. Ibrahim (1994) pointed out that, the high rate of chlorosity in the pore water seems to induce rate of diffusion of pore water chloride ions to the overlying lake water.

5. 2. Phosphorus forms

Phosphorus is an essential nutrient for the maintenance of life in marine and fresh water system. As such, it is very important to investigate processes adding phosphate to water bodies. One major factor is the addition of phosphate to the pore water within bottom sediments and its consequent diffusion to the overlying water. Thus, the determination of phosphorus content of the grab sediments is of considerable importance. This arises from its role in controlling the productivity and other various biological processes as well as its role in eutrophication (Lee, 1973).

5.2.1. Phosphorus forms in bottom and sediment pore waters

5.2.1.1. Dissolved inorganic phosphorus (DIP)

DIP is very important element limiting the growth and reproduction of phytoplankton (Riely & Chester, 1971). DIP when present in a large content it causes eutrophication and may be considered as a potential pollutant.

The concentration of DIP in the bottom water varied from 0.84 µM at Sts. V and VIII to 4.62 µM at St. IX with average 2.10 µM. The horizontal distribution of DIP (Fig. 5) indicated that, the eastern basin (Sts. IX, X and XI) which has polluted discharged water has the highest levels of DIP (>3.03 and <4.63 µM), while the other stations in the western and central basins of the lake has mostly low concentrations (<1.53 µM). Ibrahim (1994) pointed out that DIP is generally increase from the western to the eastern of the lake and respect this observation to the up take processes en route before reaching the sea. Hemaida (1988) observed that the concentrations of the eastern basin are mostly high due to the effect of the drainage water enriched with DIP, contrary to the western basin affected by sea water poorer in phosphate. DIP represented 87.87 % of DTP, mostly due to the effect of the drainage water enriched with phosphorus compounds. The distribution of DIP (Fig.5) is reverse to that of DO and Chl-a.

DIP in the sediment pore water ranged from 1.47 µM at St. III to 28.79 µM at St XI with average 10.88 µM. Generally DIP in the sediment pore water is higher than that in the overlying bottom water (average enrichment factor, EF = 5.18 times) revealed to increase in regeneration and accumulation rates of DIP in the pore waters of the bottom sediments except in front of Edku Drain (St. X). This reflected that the benthic flux of DIP in this station is expected to change its direction (downward) from the overlying water to the sediment pore water. Ibrahim (1994) pointed out that the source of DIP in the pore water of Lake Edku could be partly due to its mineralization from the buried organic matter containing P. The other part could be from release of adsorbed P onto the surface of clays or/and iron oxides precipitates, of the retained pore water there and dissolution of iron oxides.

In the pore water DIP constitutes 75.40 % of DTP. This referred to the increase in the upward diffusion rate of the pore water with DIP.

5.2.1.2. Dissolved organic phosphorus (DOP)

DOP in the bottom water ranged between 0.04 µM at St.IV and o.68 µM at St. IX with average 0,29 µM. DOP representing 12.13 % of TP referring to the low rate of production of DOP. Ibrahim (1994) indicated that a large majority of TP in lake Edku is inorganic phase (67 %). This reflects the use of inorganic fertilizers in the agricultural lands of the drainage basin.

The horizontal distribution of DOP (Fig. 5) showed that St. IX has the maximum value. This could be due to the preference of inorganic form of phosphorus by authogenic plants at this station. Also due to the release of DOP into the ambient water by living organisms as excretes as well as from damaged cells as degradable soluble organic matter.

In the sediment pore water, DOP changed from 0.07 µM at Sts. I and X to 9.75 µM at St. IX with average 3.55 µM. Generally, DOP in the pore water is higher than that in the overlying bottom water (EF is about 21.43). In the pore water, the horizontal distribution of DOP (Fig. 5) is mostly similar to that of DIP, where Sts. II, IV, VI, VII, IX and XI has the highest levels, also in front of Edku drain (St. X) the concentration of DOP in the pore water (o.07 µM) is less than that in the overlying bottom water (0.36 µM).

The difference between the concentration of DIP in the bottom water and that in the pore water was 8.78 µM, while the difference between the corresponding values for the DOP was 3.26 µM. This observation suggests that the rate of diffusion of DOP from the sediment pore water to the overlying bottom water was most likely greater than that of DIP. This reflects that most OP in the bottom water were diffused from the sediment, but the drainage water was mostly responsible about the high level of IP in the overlying bottom water.

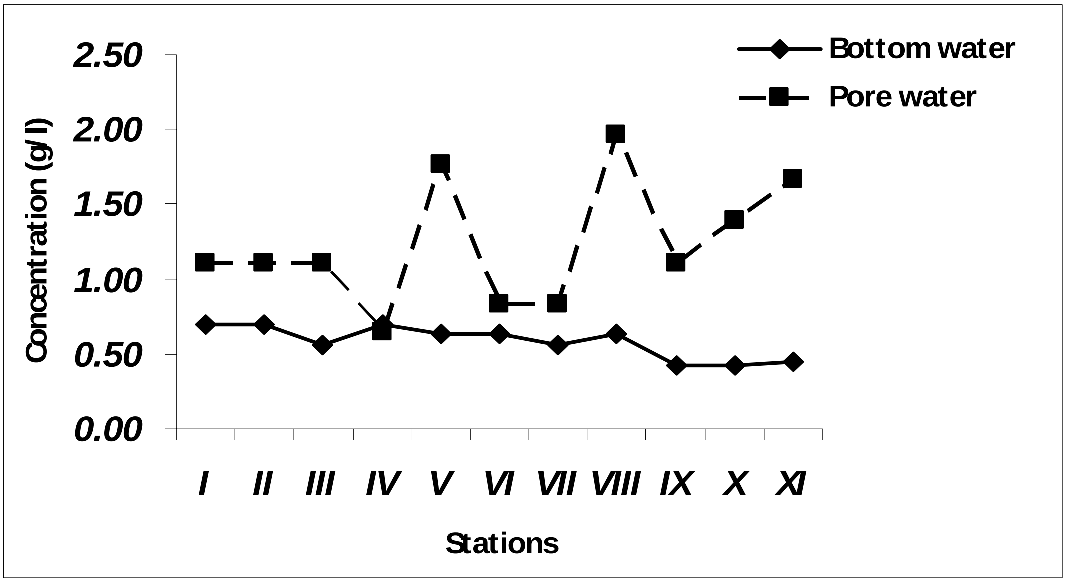

Fig. (3).The distribution of Chlorosity in bottom and sediment pore waters of Lake Edku.

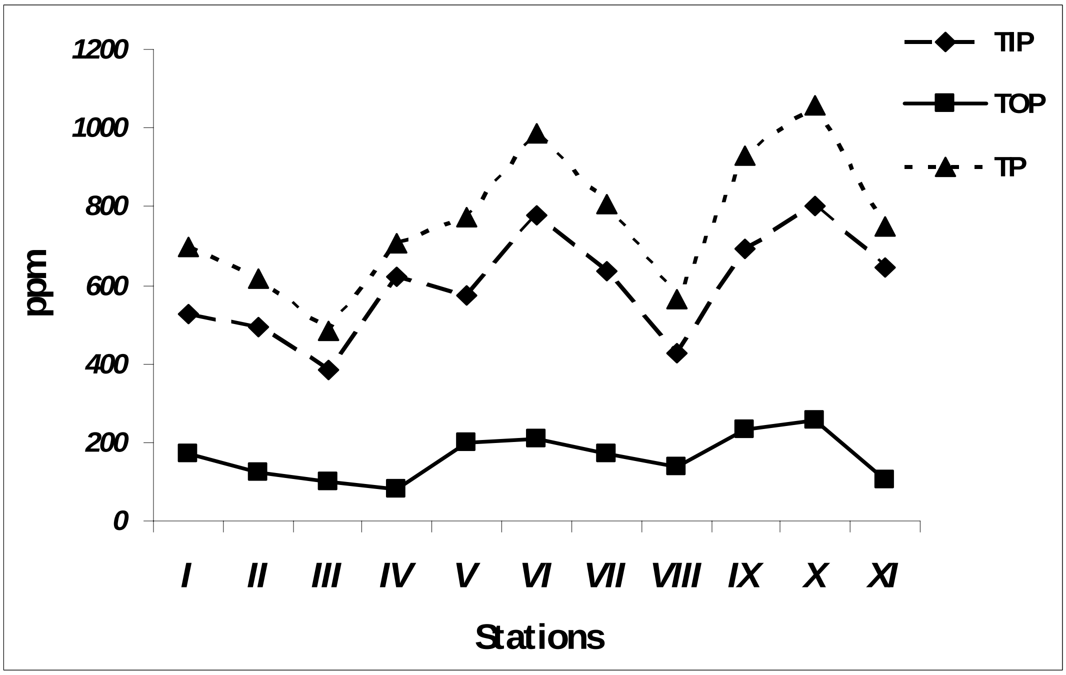

Fig. (4): The distribution of phosphorus forms (TIP, TOP and TP) in grab sediment of Lake Edku.

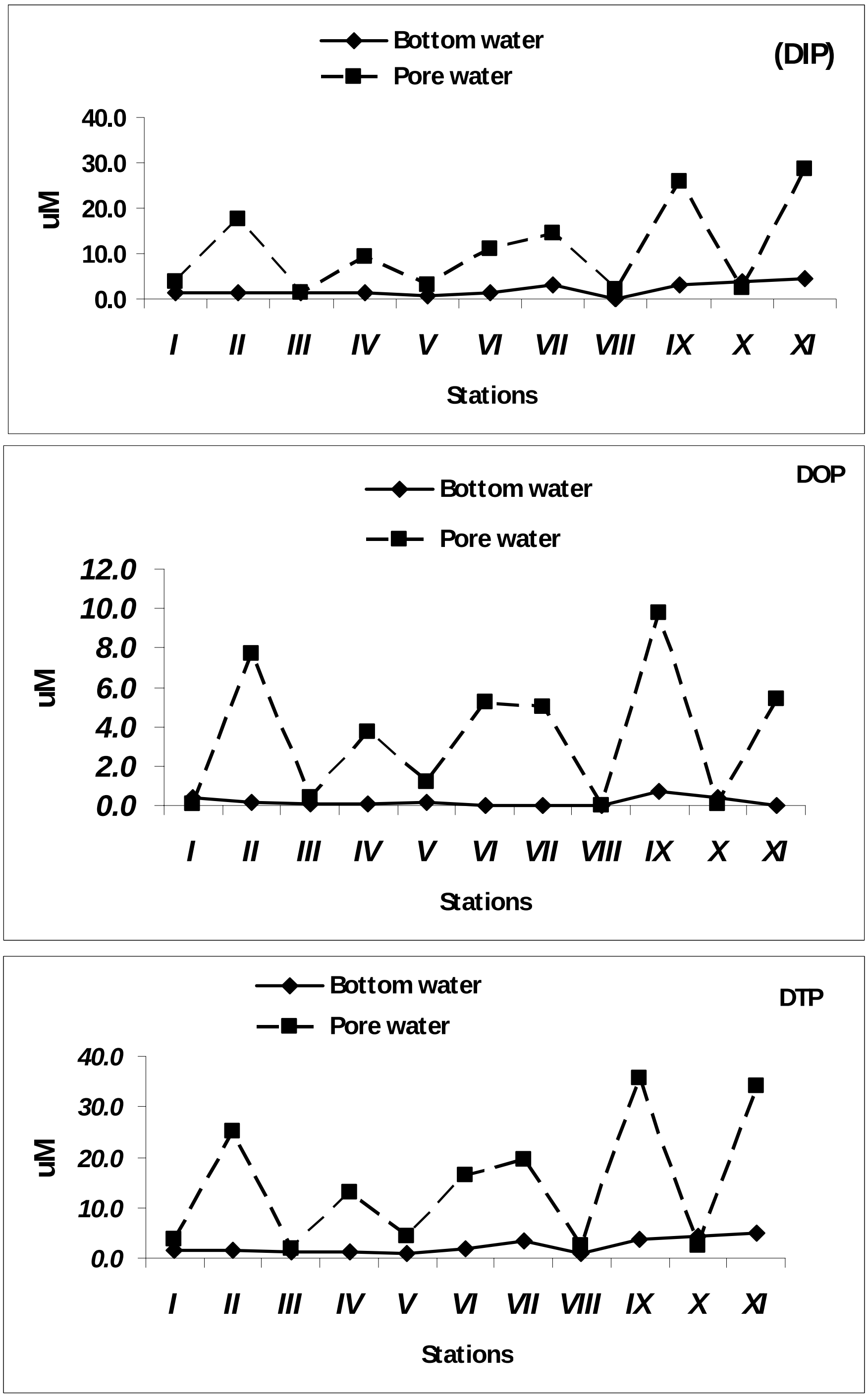

Fig. (5): The distribution of phosphorus forms (DIP, DOP and DTP) in bottom and sediment pore waters of Lake Edku.

5.2.1.3. Dissolved total phosphorus (DTP)

DTP in the bottom water ranged between 0.99 µM at St. V and 5.03 µM at St. XI with average 2.39 µM. The horizontal distribution of DTP (Fig. 5) was similar to that of IP (r = 0.99), where the concentration increases from western of the lake to the eastern.

The pore water has levels of DTP ranged from 1.85 µM at St. III to 35.63 µM at St. IX with average 14.43 µM which was higher than that in the overlying bottom water (2.39 µM).

The correlation matrix (Table 2) showed negative correlation between chl-a and each of DIP (r = 0.75), DOP (r = 0.65) and DTP (r = 0.78). This means that the introduced of P forms to the water lake can be decreased by phytoplankton consuming.

5.2.2. Phosphorus forms in grab sediment

TIP in the lake sediment varied from low level 385 ppm at St. III and high level 803 ppm at St. X with average 599 ppm. TOP concentration had the minimum value 83 ppm at St. IV and maximum value 256 ppm at St. X with average 162 ppm. TP changed from 486 ppm at St. III to 1059 ppm at St X with average 761 ppm.

The distribution pattern of TIP was quite similar to that of TP (Fig. 4), where it represented 78.7 % from TP. This fact is confirmed more from their good relationship with each other (r = 0.97). Faragallah (2004) pointed out that TIP in the sediments of Abu-Kir Bay constituted more than 57 up to 93 % of TP. This finding refers to the possible incorporation of phosphorus into the surfaces of inorganic particulate matter mostly by adsorption before incorporation with the bottom sediments. The same was also notice by Balba (1985) for the sediments of lake Edku where TIP formed 92 % of TP.

Stations I, II, and III (which near to the lake sea connection) has moderately low levels of TP (< 700 ppm), TIP (< 530 ppm) and TOP (< 175 ppm). Ibrahim (1994) showed the same manner and respect this to the coarseness of the sediment.

Stations from IV to VII has moderately high levels of phosphorus forms. This may be due to the bottom is densely vegetated by rooted plants which is very effective in pumping sediment phosphorus.

Station X (infront of Edku Drain) has the maximum levels of phosphorus forms. Hemaida (1988) noticed that higher phosphorus values in lake Edku were found in areas directly affected by drainage water and mostly covered by fine sediments enriched with organic matter. On the other hand, lower values were found in areas near the lake-sea connection, and these were cover by coarse sediment.

Fig. 4 shows that the distribution of TIP was similar to that of TOP, this means that the organically bound phosphorus was almost important as the IP. Also, the decomposition and excreta of indigenous organisms (particularly hydrophytes) should contribute a significant portion of OP. This increase of OP can partly be referred to a principle allogenic contribution from the neighboring agricultural lands. Glase and Barlow (1986) mentioned that phytine which comprises about 50 % of OP in soils is commonly leached by water and comes an important part of the influent drainage waters.

Table (2): correlation matrices in lake edku.

	pH	DO	Chlor-a	Chlorosity	DIP	DOP	DTP
pH	1.00						
DO	0.31	1.00					
Chlor-a	0.63	0.53	1.00				
Chlorosity	0.04	0.66	0.67	1.00			
DIP	-0.32	-0.63	-0.75	-0.83	1.00		
DOP	-0.43	-0.60	-0.65	-0.59	0.49	1.00	
DTP	-0.35	-0.66	-0.78	-0.85	0.99	0.59	1.00

Bottom water

	Chlorosity	DTP	DOP	DTP
Chlorosity	1.00			
DTP	-0.13	1.00		
DOP	-0.36	0.88	1.00	
DTP	-0.19	0.99	0.93	1.00

Sediment pore water

	TIP	TOP	TP
TIP	1.00		
TOP	0.66	1.00	
TP	0.97	0.82	1.00

Grab sediment

6. CONCLUSION

- The effect of the discharged effluents from the land based sources on the lake was restricted in vicinity of Edku and Barzik drains.
- The levels of transparency, chl-a and DIP indicating that, the lake was in eutrophic state.
- The concentrations of DIP, DOP and TDP in the sediment pore water were higher than those in the overlying bottom waters. This reflects the role of diagenetic processes prevailed in the sediment pore waters in providing the overlying bottom water with different forms of phosphorus through the diffusion and other factors.
- The rate of diffusion of DOP from the sediment pore water to the overlying bottom water was most likely greater than that of DIP.
- The pore water and the overlying bottom water had concentrations of phosphorus much less than that in grab sediments. This means that most of phosphorus in the sediments were non labile i.e. not have ability to regenerate from the sediments to the pore water and subsequently to the overlying bottom water.

REFERENCES

Aspila, K., Agemain, H. and Chau, A.: 1976, A semi-automated method for the determination of inorganic, organic and total phosphate in sediments. *Analyst*, 101: 187-197.

Balba, A.: 1985, Fifty years of phosphorus studies in Egypt, Adv. *Soil and Water Res.,* No.5, Special volume, 118p.

El-Sabrouti, M.A. and Sokkary, A.A.: 1982, Distribution of clay minerals and their diagenesis in sediments of Lake Edku. *J. Mar. geol.,* 45.

EL-Sayed,M.A.: 1993, Sediment characteristics and phase association and mobility of Fe, Mn, Zn, Cu. Pd and Cd in core sediments from Lake Edku. Journal King Abdul Aziz University, *Marine Science*, 4: 19 – 35.

Faragallah, H. M.: 1995, Sediment-water interface chemistry in the Eastern Harbour, Alexandria, Egypt. M.Sc., Thesis, Fac. Sci., Alexandria University, 277p.

Faragallah, H. M.: 2004, Chemical fractionation of phosphorus and some heavy metals in suspended matter in water column and in sediment in Abu-Kir Bay, Egypt. Ph.D. Thesis, Fac. Sci., Alexandria University, 347p.

Giovanardi, P. and Tramellini, E.: 1992, Statistical assessment of trophic conditions. Application of the OECD methodology to the marine environment, Sci. *Total Environ.,Suppl.,* 1992: 211-233.

Glase, M. S. and Barlo. P.: 1986, The role of lake water in enhancing sorption of phosphorus by stream particulates, in: sediments and water interactions, P.G.Sly (ed),spriner-verlag, p. 451-459.

Grasshoff, K.: 1976, Methods of sea water analysis with contribution by T.Almgreen; R.Dawson; Ehrhadt, S.H. Fonselius, B. Josefsson; F. Koroleff; K. Kremling. Aufl. Weinheim, New York: Verlag Chemie, pp.317.

Hemaida, H.: 1988, The dynamic of nutrients between water and sediments in Lake Edku. M.Sc., Thesis, Fac. Sci., Alexandria University, 198p.

Ibrahim, M.: 1994, Geochemical cycle of phosphorus in Lake Edku. M.Sc., Thesis, Fac. Sci., Alexandria University, 143p.

Krauskopf, K.B.: 1967, Introducyion to Geogchemistry: New York, MCG raw. Hill Book Company, Inc. Chaps. 7,11. and 20. 721p.

Okbak,M.A. and EL-Gohary, S.: 2002, Physical and chemical characteristics of Lake Edku water, Egypt.Medit. *Mar. Sci.,* vol. 3/2, p. 27-39.

Strickland, J. and Parsons, T.: 1972, A practical handbook of sea water analysis. *Bull. Fish. Res. Bd. Canada.,* 167: 310p. M 15-M21.

Vollenwieder, R.: 1968, Water management research. Scientific fundamental of eutrophic of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication.Technical Report DCDE. Directorate for Scientific Afairs, Paris, 194p.