

**DYNAMICS OF NUTRIENT SALTS BETWEEN BOTTOM SEDIMENTS
AND ADJACENT WATER IN THE NOZHA HYDRODROME (EGYPT)**

BY

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Key Words: PH, Oxygen, Nutrient salts, Nozha Hydrodrome, Egypt.

ABSTRACT

The dynamics of nutrient salts between bottom sediments and the adjacent water in the Nozha Hydrodrome, Alexandria (Egypt) was estimated in the laboratory. The sediments were hauled from an area containing silty deposits (St. I) and another which is characterized by its more coarse texture (St. II). The bottles containing the sediments (6 gm dry weight/bottle) and water samples were incubated in the dark at an average temperature of 22 °C and chemical analysis of the supernatant water were performed at the beginning of the experiments and after 1,2,3,4,6,8 and 11 days.

Results indicate a high buffering capacity of water as the pH did not drop below 8.0 throughout the whole incubation period. The dissolved oxygen decreased sharply within the first 2 days to an average of 2.5 ml O₂/l and it remained low till the end of the experiments. This was associated with a rapid increase of ammonia to 1272 and 1227 µg NH₃-N/l at stations I & II respectively during the first 2 days which dropped again on the third day. The concentration of nitrate remained low during most of the incubation period. The dissolved nitrite was also low except of a peak of 2786 µg NO₂-N/l recorded in the samples of station I by the end of the experiment. The dissolved phosphate showed a steady increase throughout the incubation period, reaching 399 and 283 µg PO₄-P/l in the samples of stations I and II respectively on the eleventh day. The increase of the reactive silicate was mostly confined to the second half of the incubation period. Results indicate a high absorbing capacity of the hydrodrome sediments to phosphate, silicate and ammonia. There is also a pronounced loss of inorganic nitrogen through bacterial denitrification with the formation of molecular nitrogen gas particularly in areas with coarse bottom sediments.

INTRODUCTION

The Nozha Hydrodrome is an isolated basin, previously separated from Lake Mariut, Alexandria (Egypt) and has a total area of about 504 hectares (1200 feddans). It receives a constant supply of fresh Nile water from the Mahmoudia Canal through a feeding channel. The surplus water flows out into El-Qalaa Drain (Fig. 1). The average depth of water is about 2.7 m.

The bottom sediments of the hydrodrome is mostly silty clay which has been accumulated gradually by previous precipitation of silt introduced with the turbid Nile water (Elster & Jensen, 1960). At the neighbouring of the inlet, the bottom consists mainly of fine mud which is dark in color. Proceeding from the inlet towards the center of the hydrodrome, the texture of the bottom sediments becomes more coarse and it contains plenty of empty shells of molluscs and calcareous remains of tube worms.

In order to increase the fertility of the hydrodrome water and consequently increase its annual fish yield, the Northern Fishing company started to apply inorganic fertilizers in April, 1982 and this extended to June, 1986, prior to the present experiments. Super phosphate and ammonium sulphate or ammonium nitrate were added at weekly rates of 5 tons each. The addition of these fertilizers has increased its primary productivity as well as its annual fish yield (Wahby & Shiradach, 1985). However, as a result of the high load of inorganic fertilizers applied, big quantities of these nutrients were released in water from the bottom sediments about the second half of May, 1986, coinciding with the increase of water temperature to 28°C and this caused a bloom of blue green algae all over the hydrodrome. The dissolved oxygen was completely depleted in the subsurface water layer and hydrogen sulphide evolved from the bottom in considerable quantities causing a sudden mass mortality of fish and deterioration of water quality in early June (Dowidar and Abdel-Moati, 1989). The hydrodrome water was recovered again within 10 days by artificial aeration of water.

All these events have focused the light on the importance of studying the dynamics of nutrients between the surface sediments and the adjacent water, which is the objective of this study.

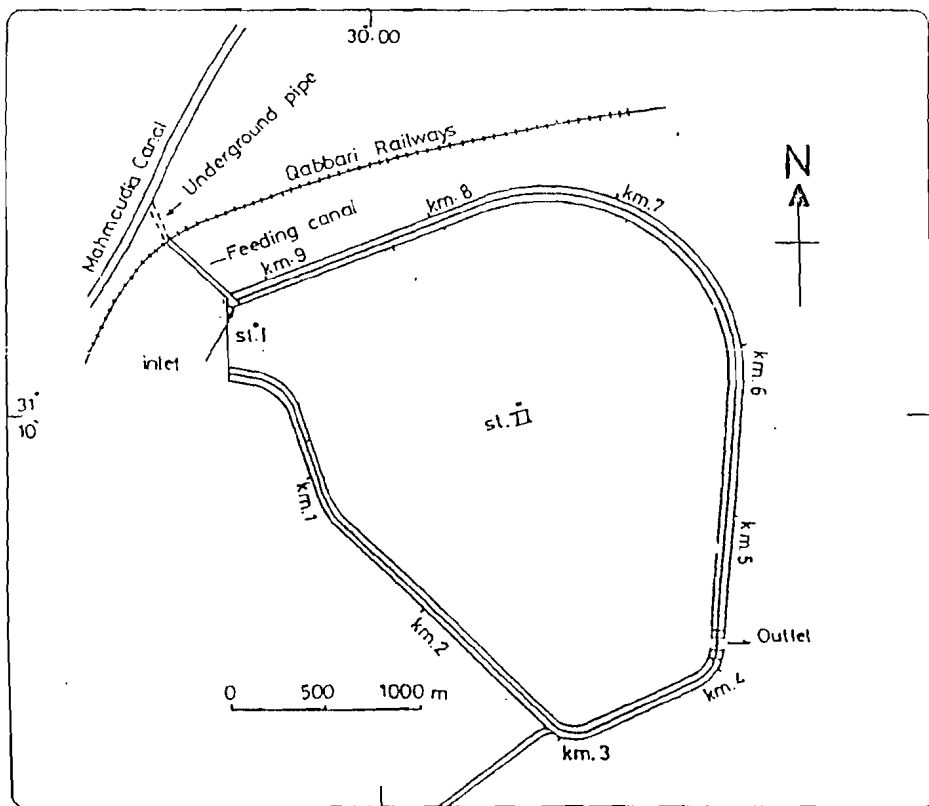


Figure 1: Position of stations in the Nozha Hydrodrome.

MATERIALS AND METHODS

Surface sediments were hauled from the area surrounding the feeding canal (Station I) and about the center of hydrodrome (Stations II) as shown in figure (1), using a modified Ekman bottom sampler. These sediments were homogenized with small amounts of water taken from the same localities and 80 ccs of sediment suspension were transferred to each of a series of brown glass stoppered bottles of 500 ccs capacity. The bottles were then filled with the hydrodrome water, stoppered well, shaken and then incubated in the dark at an average temperature of 22°C. The amount of sediment added to each bottle was calibrated to be equal to 6 gm dry weight.

Chemical analysis of the supernatant water samples were performed in duplicates at the beginning of the experiment and after 1,2,3,4,6,8 and 11 days of incubation. The parameters analysed comprised pH values, dissolved oxygen (ml O₂/l), nitrate ($\mu\text{g NO}_3\text{-N/l}$), ammonia ($\mu\text{g NH}_3\text{-N/l}$), phosphate ($\mu\text{g P}_4\text{O-P/l}$) and silicate (mg SiO₃-Si/l).

The pH values were measured by a Beckman digital pH meter. Determination of dissolved oxygen was carried out according to Winkler's method. A portion of the clear supernatant water samples were siphoned into oxygen bottles of 100 ml capacity, using a narrow plastic tubing with its end reaching the bottom of the bottle. The water was allowed to flow slowly into the oxygen bottle by situating it at lower level relative to the incubated bottle until it is completely filled with water and leaving some excess water to flow out. The water samples were then analysed for oxygen content.

The dissolved nitrite was determined by diazotization with sulfanilamide and coupling with *p*-naphthylamine (Strickland and Parsons, 1965).

Estimation of dissolved nitrate was carried out by the same procedure after reducing it to nitrite by passing the water samples through a reductor (cadmium filling coated with metallic copper) (Strickland and Parsons, 1965).

The dissolved ammonia was determined according to Koroleff (1969) by using the modified indophenol blue method. Estimation of the reactive phosphate was carried according to Grasshoff (1976). Determination of reactive silicates was based on the method of Robinson & Thompson (1948) as modified by Grasshoff (1976).

RESULTS

Hydrogen ion concentration :-

The initial pH value of water samples from station I was 8.56 and it appeared more or less constant during the first 3 days of incubation and this coincided with an increased rate of release of ammonia. The pH dropped on the fourth day and it remained relatively low throughout the rest of the incubation period, except of a slight increase observed on the sixth day (Table 1 and Fig. 2).

The water samples of station II sustained an initial pH of 8.89. It showed a gradual small decrease throughout the whole incubation period, reaching 8.03 on the eleventh day.

Dissolved oxygen:-

The initial concentration of the dissolved oxygen in the water samples of station I was 8.44 ml O₂/l. It decreased sharply to 3.15 ml O₂/l after one day incubation and slightly on the second day. This was accompanied with a rapid increase of ammonia. Other slight increase in dissolved oxygen appeared in the following two days and it remained mostly constant throughout the rest of the incubation period (Table 1 and Fig. 2).

The initial concentration of dissolved oxygen in the water samples of station II was 9.72 ml O₂/l. It also decreased sharply during the first 2 days of incubation to 2.51 ml O₂/l parallel to the sharp increase in dissolved ammonia. Further decrease to 1.79 ml O₂/l appeared in the fourth day, followed by another gradual small increase till the eighth day to reach 3.29 ml O₂/l. It decreased again by the end of the experiment to 1.22 ml O₂/l.

Inorganic nitrogen compounds:-

The initial concentration of dissolved ammonia in the water samples of station I was 36.6 µg NH₃-N/l. It increased rapidly to 1272.4 µg NH₃-N/l on the second day and disappeared totally on the third one (Table 1 and Fig. 3). Another gradual increase was recorded during the following four days, reaching 737.1 µg NH₃-N/l. It dropped again by the end of the experiment to 267.6 µg NH₃-N/l. The initial concentration of dissolved nitrite in the same samples was 49.9 µg NO₂-N/l. It remained at more or less

Table (1): Chemical parameters measured in the incubated glass stoppered bottles filled with hydrodrome water mixed with sediments from stations I and II. The nitrogen to phosphorus ratios (by weight) are also illustrated.

Station	Parameter	pH	ml/l O ₂	mg/l SiO ₃ -Si	µg PO ₄ -P/L	µg NH ₃ -N/l	µg NO ₃ -N/l	µg NO ₂ -N/l	Total N	N:P	
Station I	day of collection	8.56	8.44	5.12	92.9	36.6	67.2	49.9	153.7	1.65:1	
	1st day of incubation	8.53	3.15	5.73	202.5	998.8	16.8	76.3	1091.9	5.4:1	
	2nd day of incubation	8.49	2.51	5.82	237.9	1272.4	47.0	60.5	1379.9	-5.8:1	
	3rd day of incubation	8.55	3.44	4.74	297.3	0.0	35.3	54.2	89.5	0.3:1	
	4th day of incubation	8.15	4.58	3.67	282.4	170.1	0.0	56.7	226.8	1.25:1	
	6th day of incubation	8.43	4.58	8.07	386.1	385.4	55.9	102.7	544.0	1.41:1	
	8th day of incubation	8.19	3.72	9.01	384.9	737.1	0.0	1122.6	1859.7	4.83:1	
	11th day of incubation	8.01	4.15	13.47	398.6	267.6	0.0	2786.3	3053.9	7.66:1	
	Station II	day of collection	8.89	9.72	6.20	96.9	50.0	0.0	66.8	116.8	1.21:1
		1st day of incubation	8.71	5.65	5.91	93.2	928.2	419.2	68.1	1415.5	15.2:1
		2nd day of incubation	8.60	2.51	4.55	84.8	1227.0	74.1	28.2	1329.3	15.7:1
3rd day of incubation		8.55	2.36	3.00	120.8	0.0	12.9	36.2	49.1	0.41:1	
4th day of incubation		8.43	1.79	4.60	130.8	0.0	22.1	35.7	57.8	0.44:1	
6th day of incubation		8.32	2.44	5.44	188.9	49.0	40.2	16.1	105.3	0.56:1	
8th day of incubation		8.26	3.29	9.29	234.6	262.8	5.6	42.5	310.9	1.33:1	
11th day of incubation		8.03	1.22	9.06	283.0	245.8	0.0	164.5	410.3	1.45:1	

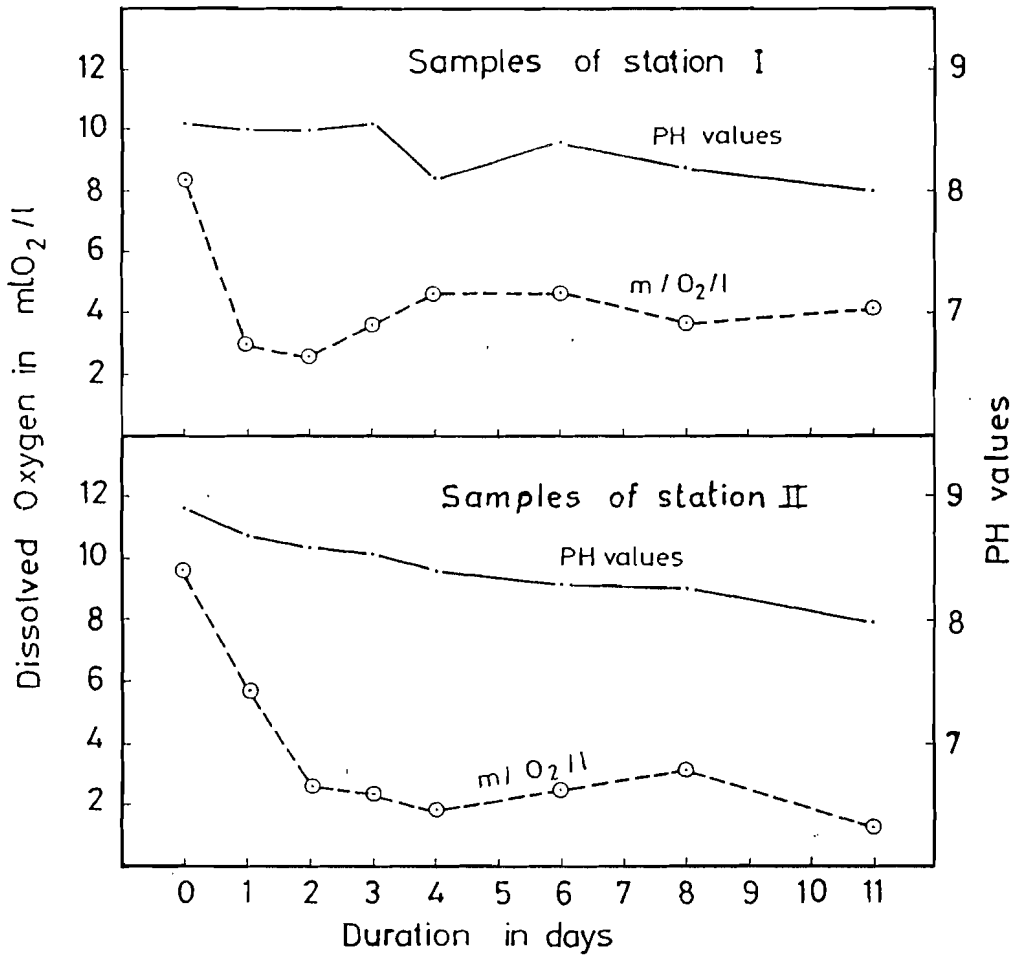


Figure 2: PH values and dissolved oxygen measured during the incubation period of water samples mixed with bottom sediments taken from stations I and II.

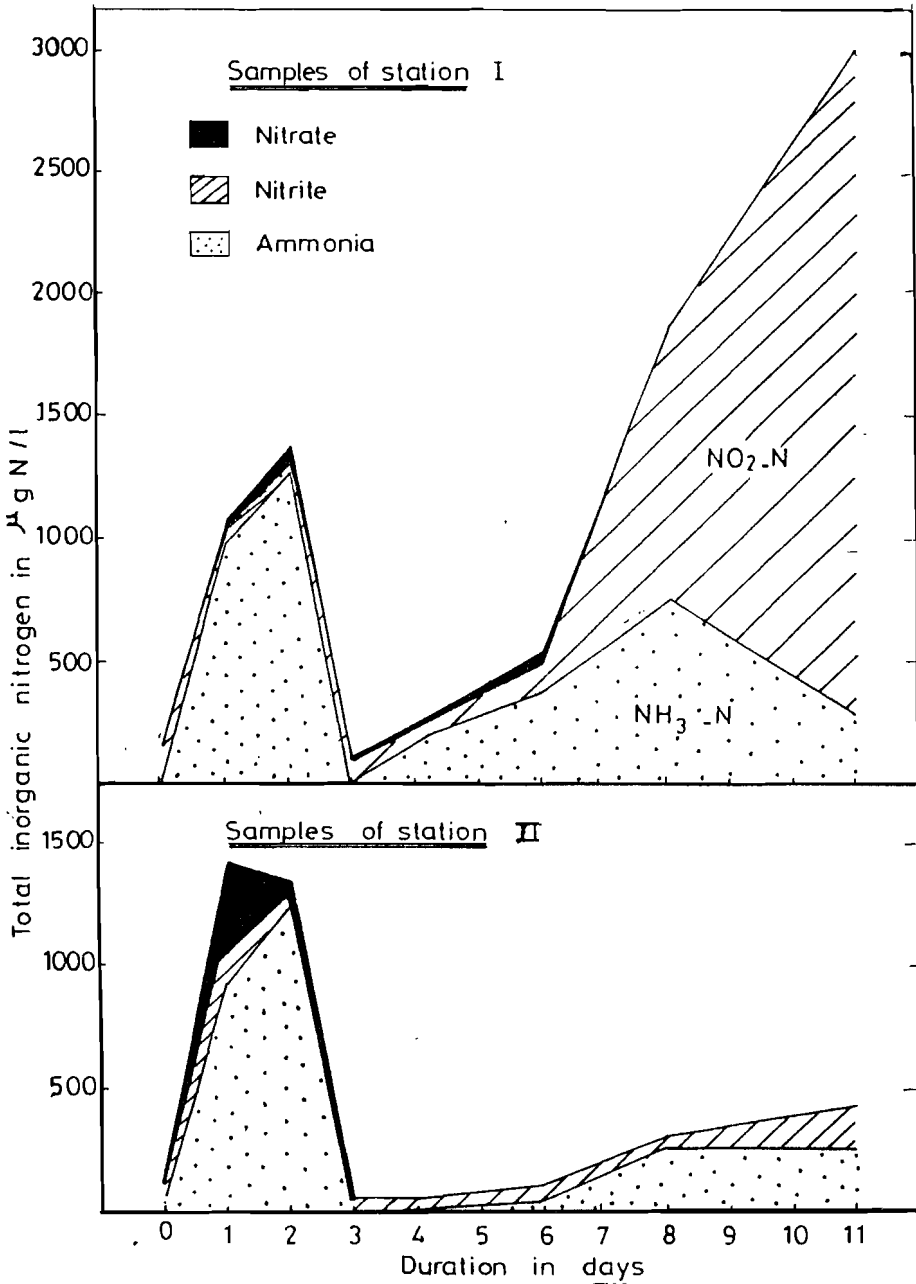


Figure 3: Nitrate, nitrite and ammonia measured during the incubation period of water samples mixed with bottom sediments taken from stations I and II.

constant lower values during the first 6 days, followed by a rapid increase throughout the second half of the incubation period, attaining 2786.3 $\mu\text{g NO}_2\text{-N/l}$ on the eleventh day. For dissolved nitrate, its initial value was 67.2 $\mu\text{g NO}_3\text{-N/l}$. It remained also relatively low during the first 6 days and was depleted in the following incubation period.

The initial concentration of dissolved ammonia in the water samples of station II was 50 $\mu\text{g NH}_3\text{-N/l}$. It showed a rapid increase to 1227 $\mu\text{g NH}_3\text{-N/l}$ after 2 days incubation, followed by complete depletion on the third and fourth days. The dissolved ammonia increased again on the second half of the incubation period, reaching 245.8 $\mu\text{g NH}_3\text{-N/l}$ by the end of the experiment. The initial concentration of dissolved nitrite in these samples was 66.8 $\mu\text{g NO}_2\text{-N/l}$. Its concentration remained relatively low throughout the whole incubation period except a higher value of 164.5 $\mu\text{g NO}_2\text{-N/l}$ recorded on the eleventh day. No dissolved nitrate was detected in the initial samples of station II, but it increased to 419.2 $\mu\text{g NO}_2\text{-N/l}$ on the second day parallel to the ammonia peak. The dissolved nitrate dropped again and it remained low till the end of the experiment.

Dissolved phosphate:-

The initial concentration of dissolved phosphate in the water samples of station I was 92.9 $\mu\text{g PO}_4\text{-P/l}$. It increased gradually to reach 386.1 $\mu\text{g PO}_4\text{-P/l}$ on the sixth day and it remained within this high level till the end of the incubation period (Table 1 & Fig. 4).

The initial value of dissolved phosphate in the water samples of station II was 96.6 $\mu\text{g PO}_4\text{-P/l}$. Its concentration remained more or less constant during the first two days, followed by a steady increase throughout the rest of the incubation period, reaching 283 $\mu\text{g PO}_4\text{-P/l}$ on the eleventh day.

Dissolved Silicate:-

The initial concentration of dissolved silicate in the water samples of station I was 5.12 mg $\text{SiO}_3\text{-Si/l}$. Its concentration remained more or less constant during the first 2 days, followed by a pronounced decrease on the third and fourth ones. A gradual increase was then traced, reaching 13.47 mg $\text{SiO}_3\text{-Si/l}$ by the end of the incubation period.

The initial silicate content in the water samples station II was 6.20 mg $\text{SiO}_3\text{-Si/l}$. It decreased during the first three days of incubation followed by a gradual increase till the eighth day and its concentration remained within this high level by the end of the experiment with an average of 9.17 mg $\text{SiO}_3\text{-Si/l}$.

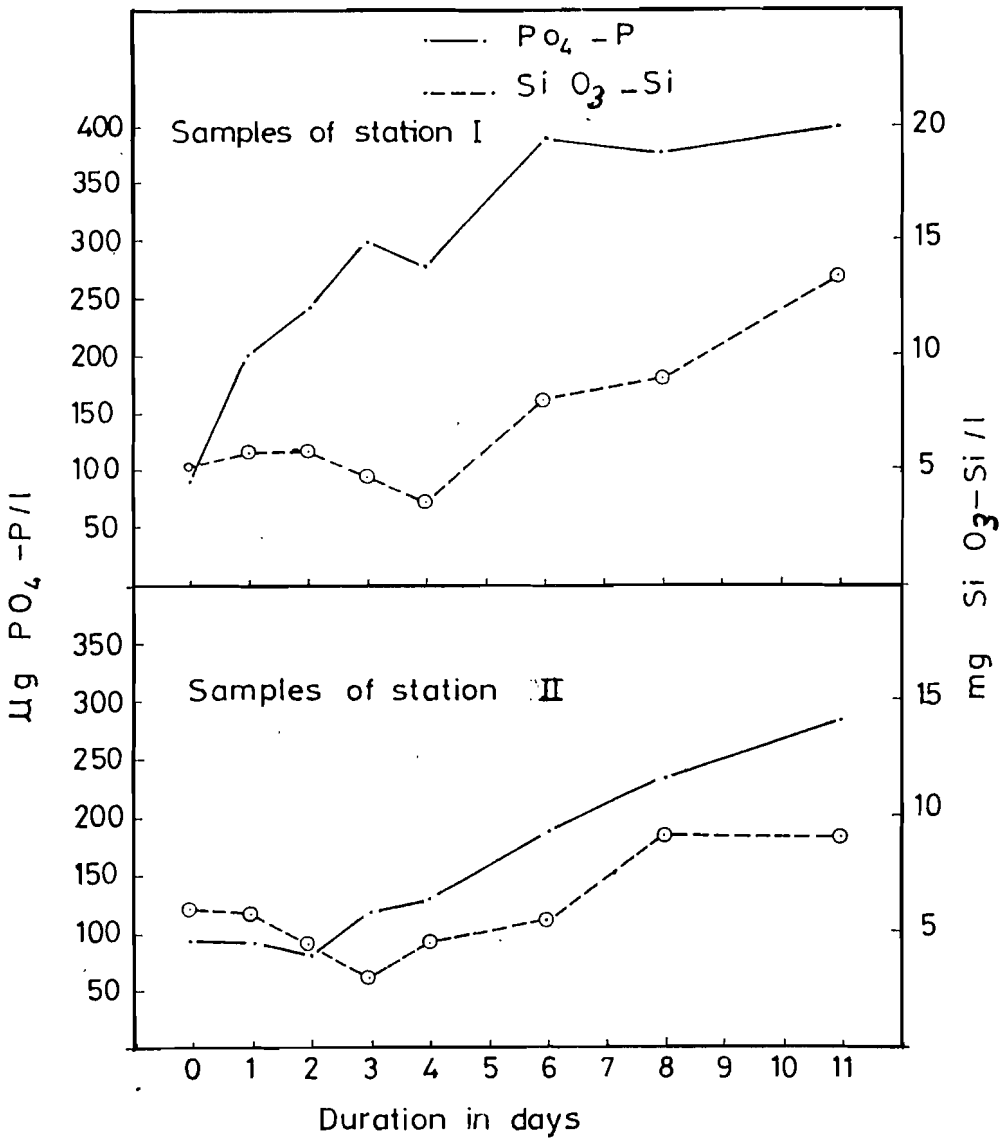


Figure 4: Dissolved phosphate and silicate measured during the incubation period of water samples mixed with bottom sediments taken from stations I and II.

DISCUSSION

The muds of ponds and shallow lakes have been described to be the chemical laboratory through which the release of nutrients adsorbed on the soil particles can be brought again in water. The oxidation of organic matter accumulated on the bottom through bacterial activities produces also a constant supply of nutrients as an end product.

Several factors such as the amount of dissolved oxygen, pH values as well as the redox potential of the upper sediments were established to have controlling effects on the dynamics of these nutrients (Pearsall and Mortimer, 1939 and Mortimer, 1941 & 1942). The colloidal ferric ions and colloidal humic substances form together a highly absorptive layer for both acidic ions (Phosphate and silicate) and basic ions (ammonia, calcium and magnesium) while nitrite and nitrate are not adsorbed. When dissolved oxygen is depleted, ferric ions is reduced to ferrous and the adsorbed ions are released into water in considerable quantities (Husomi *et al.*, 1981). Also the changes of pH just on the acidic side causes retention of big portions of these ions by ferric hydroxide but at pH 8.6 or more most of them are easily washed out from the muds (Ohle, 1938).

Results of the present experiments revealed that the incubated water samples persisted on the alkaline side during the whole incubation period, with a general trend of a gradual decrease from pH 8.56 (Station I) and 8.89 (Station II) at the beginning of the experiment to pH 8.02 by the end of the incubation period which indicates a high buffering capacity of water. According to the findings of Ohle (1938), the persistence of pH values exceeding 8.0 during the whole incubation period would reduce the adsorptive capacity of the surface muds and consequently the formed ions of ammonia, phosphate and silicate can be easily washed out from the sediment when the other conditions are suitable for such release.

The sharp decrease of dissolved oxygen within the first two days of incubation from 8.44 to 3.15 ml mg O₂/l in the samples of station I and from 9.22 to 2.51 ml O₂/l in the samples of station II was accompanied with a sharp increase of dissolved ammonia. This indicates rapid oxidation of organic matter present in sediments and ammonification of amino acids by denitrifying bacteria. The presence of dissolved oxygen in the water samples throughout the rest of the incubation period, although at lower concentration, would permit the persistence of ferric ions and thus the adsorptive capacity of muds for ions is still functioning.

The concentrations of the total inorganic nitrogen compounds (NO_3 , NO_2 and NH_3) at the beginning of the experiment were 154 and 117 $\mu\text{g N/l}$ in the samples of stations I and II respectively. The peaks of 1380 $\mu\text{g N/l}$ was recorded for station I after 2 days incubation, and 1416 $\mu\text{g N/l}$ for station II after one day incubation. By the end of the incubation period, a peak of 3054 $\mu\text{g N/l}$ was recognized for samples of station I and it consisted mainly of nitrite (2786 $\mu\text{g NO}_2/\text{l}$) while its concentration at station II remained low with only 165 $\mu\text{g N/l}$. Such reduction in the total inorganic nitrogen in the samples of station II appears to result mostly through bacterial denitrification and formation of molecular nitrogen gas which represents a considerable loss in inorganic nitrogen.

The initial concentration of the reactive phosphate was 92.9 and 96.9 $\mu\text{g PO}_4\text{-P/l}$ in the samples of stations I and II respectively. These values increased to 389.6 and 283 $\mu\text{g PO}_4\text{-P/l}$ for the 2 stations by the end of the experiments. The higher phosphate content released from the bottom sediments of station I is attributed to the fact that it contains more silt which adsorb more inorganic phosphate.

The ratios by weight of inorganic nitrogen to phosphorus (N:P) at the beginning of the incubation period were 1.7:1 and 1.5:1 for samples of stations I and II respectively. These ratios became 7.7:1 for station I and 1.5:1 for station II on the eleventh day. The N:P ratio recorded at station I by the end of the experiment represents their normal ratio in the plankton (Fleming, 1940), while the decreased inorganic nitrogen in the samples of station II emphasizes its loss through denitrification as mentioned previously.

The initial concentration of dissolved silicate was 5.1 and 6.2 $\text{mg SiO}_3\text{-Si/l}$ in the samples of stations I and II respectively and it increased to 13.5 and 9.1 $\text{mg SiO}_3\text{-Si/l}$ by the end of the experiments. Its variations during the incubation period was generally similar to that of the dissolved phosphate.

Results of the present experiments illustrate that the adsorbing capacity of the hydrodrome sediments to phosphate, silicate and ammonium ions is high, particularly the former ion. There is also a possibility of a big loss of inorganic nitrogen as molecular nitrogen gas through bacterial activities especially when nitrogen fertilizers are applied in excess while the inorganic phosphorus can be adsorbed on the bottom. Consequently, it is recommended that the application of these fertilizers should proceed at lower concentrations and within short intervals in order to obtain optimum growth rate of phytoplankton and in the same time avoiding any loss of the added nitrogen fertilizers.

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