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Distribution of the major ions in Lake Nasser II. Major cations

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Seasonal and local variations of major cations in Lake Nasser were studied. Among the factors responsible for the irregularity in the vertical distribution of cations are the movement of water masses, adsorption on and desorption from suspended matter and transport of eroded materials into the lake. The increase in the rate of evaporation in August caused the accumulation of the dissolved salts, as indicated by the high seasonal average values of sodium, magnesium and potassium. However, the minimum seasonal average calcium concentration was found in August, as the solubility of calcium carbonate concentration was found in August, as the solubility of calcium carbonatedecreases with elevation of temperature. The minimum seasonal potassium value in November coincided with the highest level of flood and the great tendency of potassium to be adsorbed on the suspended and colloidal matter enriched in the flood waters. The gradual increase in the regional average values of sodium, magnesium and potassium towards the Hith Dam coincided with the influence of the flood waters, loaded with suspended matter and containing low salt content, first on the southern part of the lake.

INTRODUCTION

The present study deals with the seasonal and regional distribution of the major cation in the water of Lake Nasser. A map of this lake, showing the position of station, is provided by SAAD and GOMA (in press), which paper deals with the seasonal variations of the major anions in this lake.

MATERIAL AND METHODS

Water samples were collected from Lake Nasser, using a hydrobiological research vessel. Sampling was carried out seasonally in April, August, November 1981 and February 1982, representing spring, summer, autumn and winter respectively. Besides, water samples were collected in May 1982 to represent late spring. Eight stations were chosen along the whole length of the lake to represent different regions (Fig. 1). Water samples were collected at several depths at each station, using a reversing Nansen water sampler, and were kept in well stoppered polyethylene bottles.

Sodium, potassium and calcium were determined according to the methods described by American Public Health Association (1975), whereas magnesium according to VOGEL, (1978). Sodium and potassium were determined, using a direct reading type Flame Photometer. Calcium and magnesium were determined by EDTA titrimetric method. The statistical analysis of results was described by Saad and Goma (submitted for publication).

RESULTS

Sodium

Sodium gave, in general, irregular vertical values. The values ranged from 20.06 mg/l at 40 m depth of station VIII in November to 44.15 mg/l at 10 m depth of station I in April. The average concentrations (averages of all depts at each station) showed noticeable local variation, fluctuating between 21.65 mg/l at station VIII in November and 40.15 mg/l at station I in April (Fig. 1). The seasonal average values (averages of all stations at each season) gave a lowest of 25.49 mg/l in May and a highest of 35.71 mg/l in April (Fig. 5). The regional average values (averages of all seasons at each station) ranged from 27.16 mg/l at station VIII to 32.84 mg/l at station I (Fig. 6). The average value for sodium obtained for lake Nasser was 30.01 mg/l (Fig. 7).

Magnesium

Magnesium generally showed irregular vertical variations. The concentrations varied from 4.86 mg/l in the surface layer (1 m depth) of station V in April to 12.15 mg/l at 40 m depth of station III in February. The average values showed noticeable local and seasonal variations, ranging from 6.32 mg/l at station VIII in November to 10.39 mg/l at station I in August (Fig. 2.) The seasonal average values gave a lowest of 7.98 mg/l in May and a highest of 9.09 mg/l in August (Fig. 5). The regional average values fluctuated between 7.81 mg/l at station VIII and 9.26 mg/l at station I (Fig. 6). The average concentration of magnesium calculated for Lake Nasser was 8.48 mg/l (Fig. 7).

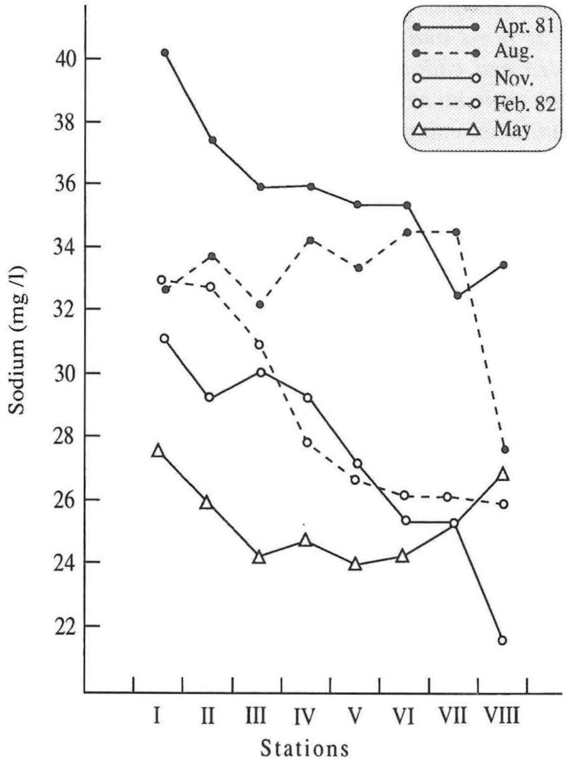

Fig. 1. Variations of the average values of sodium in Lake Nasser during 1981-1982.

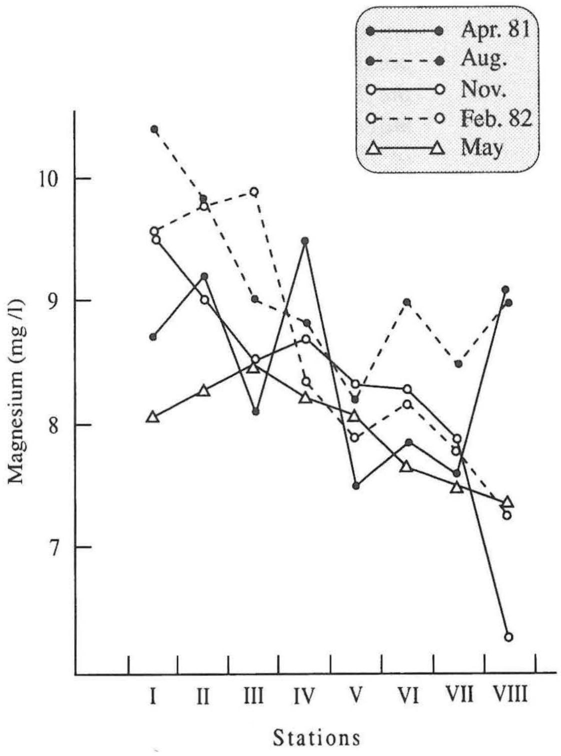

Fig. 2. Variations of the average values of magnesium in Lake Nasser during 1981-1982.

Calcium

The values generally showed irregular vertical variations, ranging from 14.43 mg/l at 10 m depth of station III in August to 29.66 mg/l in the bottom of station I that month. The average values gave noticeable local variations, fluctuating between 18.04 mg/l at station IV in August and 25.19 mg/l at station VIII that month (Fig. 3). The seasonal average values varied from 20.49 mg/l in August to 23.67 mg/l in November (Fig. 5). The regional averages ranged from 20.95 mg/l at station IV to 23.22 mg/l at station VIII (Fig. 6). The average concentration of calcium obtained for Lake Nasser was 21.99 mg/l (Fig. 7).

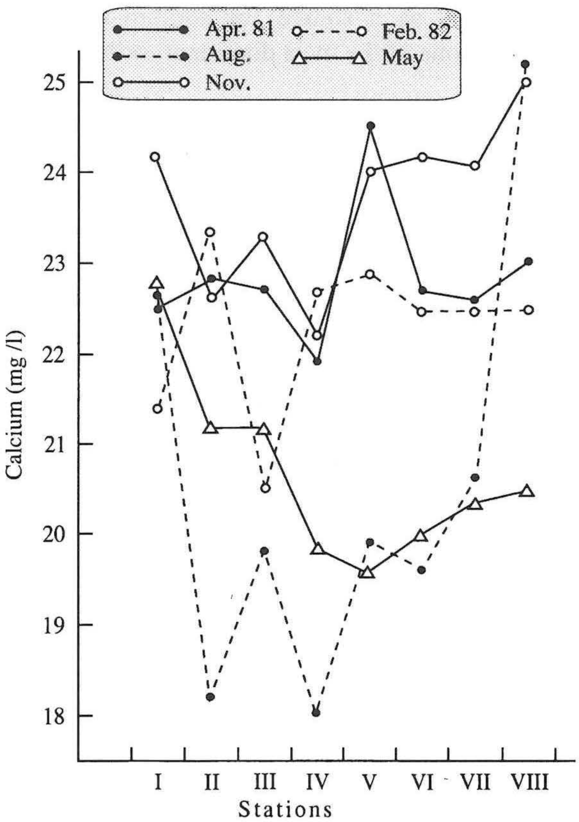

Fig. 3. Variations of the average values of calcium in Lake Nasser during 1981-1982.

Potassium

The vertical distribution of potassium was generally irregular, although similar values were observed at several depths. The values fluctuated between 5.32 mg/l at 40 m depth of station VIII in November and 16.40 mg/l at 10 m depth of station I in April. The average values showed pronounced variations, ranging from 6.80 mg/l at station VIII in November to 13.28 mg/l at station I in April (Fig. 4). The seasonal

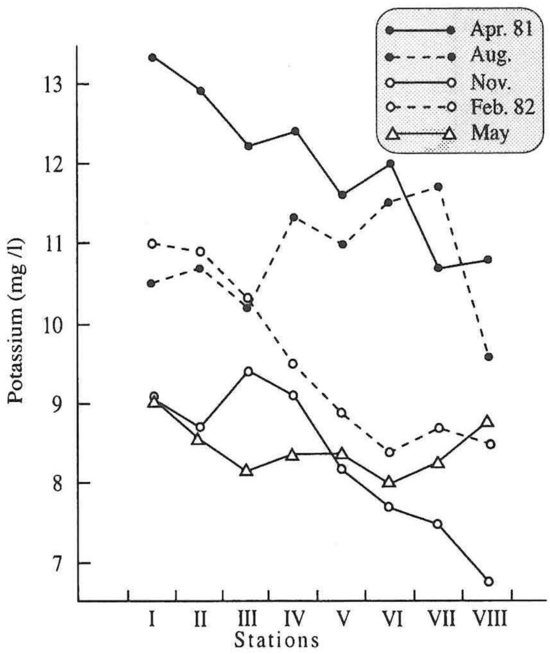

Fig. 4. Variations of the average values of potassium in Lake Nasser during 1981-1982.

average concentrations gave a lowest of 8.32 mg/l in November and a highest of 11.97 mg/l in April (Fig. 5). The regional averages varied from 8.88 mg/l at station VIII to 10.59 mg/l at station I (Fig. 6). The average value calculated for Lake Nasser was 9.81 mg/l (Fig 7).

DISCUSSION

Sodium Variations

The monovalent cation sodium is the sixth most abundant element in the lithosphere. This alkali metal is very reactive and soluble; when leached from the rocks, its compounds tend to remain in solution. For this reason, it is at least the third most abundant metal in lakes and streams, and in many instances it ranks first (COLE, 1983).

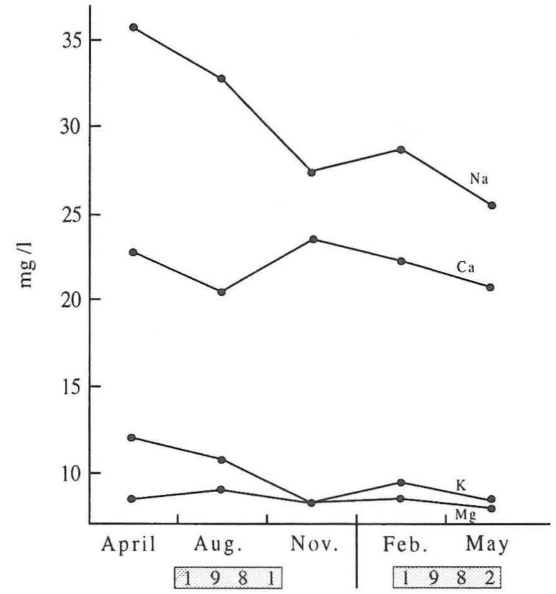

Fig. 5. Seasonal average values of cations in Lake Nasser during 1981-1982.

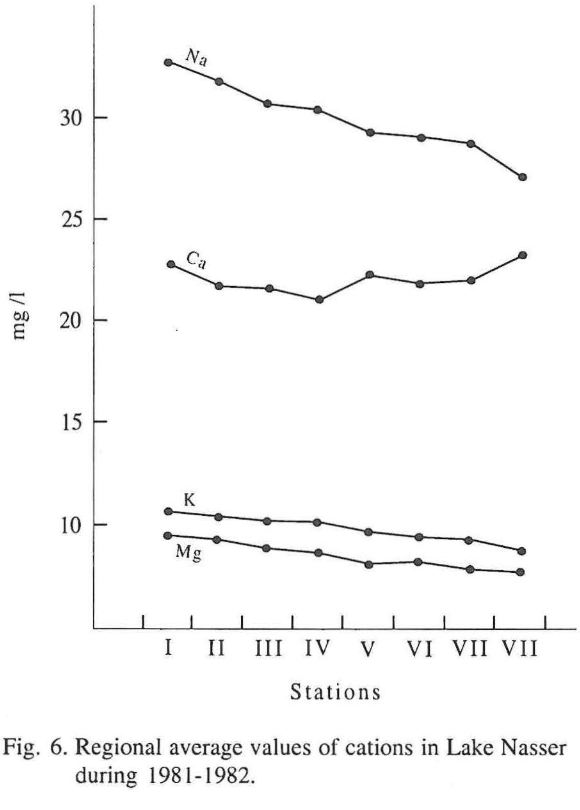

Fig. 6. Regional average values of cations in Lake Nasser during 1981-1982.

Among the four major cations, sodium is by far the most abundant in Lake Nasser. This may be due to the fact that sodium does not play any decisive role in vital processes of bio-

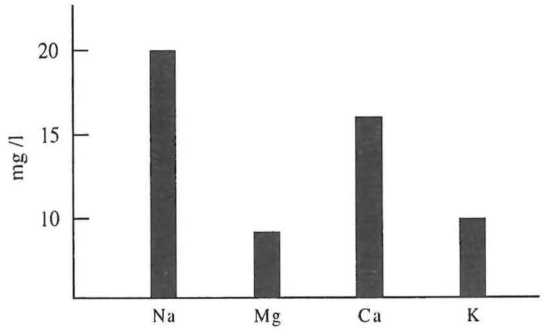

Fig. 7. Mean annual values of cations in Lake Nasser.

coenoses; variations in its concentrations in the lake waters should be connected mainly with its run-off from the catchment area (MISZTAL, 1980). According to GOLTERMAN (1975), the rainfall in the catchment areas of the rivers is considered as a source for sodium chloride, which is one of the most dominant sodium compounds.

The irregularity in the vertical values of sodium in the water of Lake Nasser might be due to the influence of movement of water masses, adsorption on and desorption from suspended matter, transport of eroded material from the surrounding areas to the lake. According to LASHEEN (1981), the stratification period on Lake Nasser extends from May to September. This is in agreement with the vertical distribution of water temperature in May and August. The thermal stratification caused a noticeable variation in the vertical concentrations of sodium; the sodium values in August and at some stations in May vere obviously higher in the upper water layer (above 20 m depth) than in the bottom layers. Also, SHERIF *et al.* (1978) pointed out that alkali metal concentrations are generally higher in surface than in bottom.

The relatively high seasonal average value in August (Fig. 5) might be attributed to the increase in the rate of water evaporation and consequently the accumulation of dissolved salts by the elevation of temperature, as indicated from the maximum seasonal average temperature values that month (SAAD and GOMA, in press). According to OLSEN and SOMMERFELD (1977), the slight increase of sodium in late summer might be attributed to evaporative concentration.

The regional average concentrations showed a gradual increase northward toward the High Dam (Fig. 6). This might be due to the influence of the flood waters first on the southern part of the lake. The data obtained by ENTZ (1976) showed impact of the incoming flood waters on the salinity of Lake Nasser. The data of ENTZ for November 1970 illustrate that the salinity values of the older water near the Dam were significantly higher and the flood waters with relatively low salt contents reached about 250 km south of the High Dam. The inflows to Lake Nasser carry salts from water sheds of both the blue and white Nile. The white Nile has the higher concentration of total dissolved solids (TALLING, 1976), but the flood is composed primarily of the flow from the blue Nile, brings water of low salt concentration to the southern end of Lake Nasser. It has been stated by ENTZ and LATIF (1974) that about 80% of the Nile flood comes from the flood of the blue Nile. The inflow of salts at a given time of year thus varies with both the size and the stage of the flood. The gradual increase of sodium concentration northward in Lake Nasser; i. e. the relative decrease in sodium values in the southern part of this lake might be explained also by the influence of the flood water loaded by clay and suspended also by the tendency of sodium to be adsorbed on them (EL-WAKEEL *et al.*, 1970). BEADLE (1981), pointed out that the flow rate of the incoming floodwater greatly decreases as it enters at the southern end of the High Dam Lake. The heaviest silt immediately falls to the bottom and progressively lighter particles are deposited as the water mass advances. The northern half of the lake is so far free of silt.

The seasonal sodium: chloride average ratio varied from 2.3 in May to 4.5 in April (Table 1). These coincided with the minimum and maximum seasonal average values of sodium in these months, respectively (Fig. 5).

The correlation between each major cation and the rest of cations and all anions in Lake Nasser is given in the correlation matrix provided by SAAD and GOMA (in press) and the significant correlations of the cations are presented in Fig. 8, in the form of "correlation constellation". Sodium was found to be in a highly positive correlation with magnesium, potassium and sulphate (p<0.001)). It was also positively

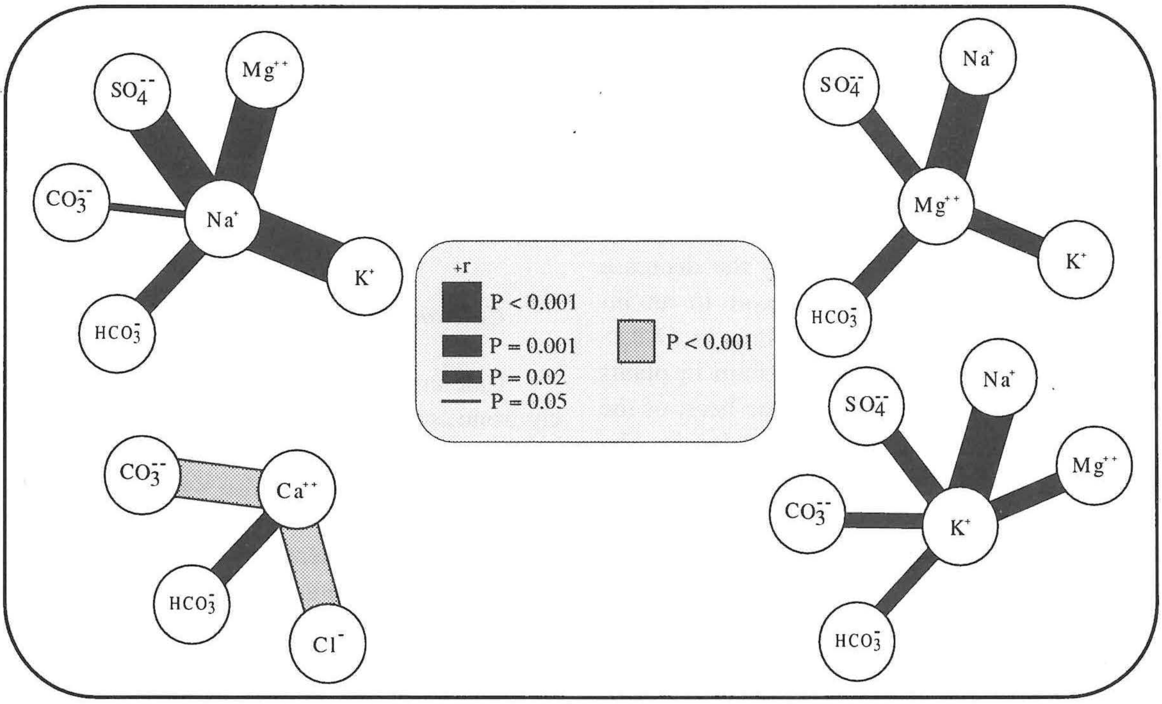

Fig. 8. Correlation constellation for each cation and other major elements in Lake Nasser during 1981-1982.

correlated with bicarbonate (p = 0.001) and carbonate (p = 0.05). However, there was no significant correlation between sodium and each of calcium and chloride.

Magnesium Variations

According to GOLDMAN and HORNE (1983), magnesium is usually present in aquatic system in large amounts relative to organisms needs, so this element does not play a major role in limiting the growth of distribution of animals or plants in most waters. Magnesium is needed by all cells for phospate transfer involving adenosine triphosphate and diphosphate (ATP and ADP).

Magnesium on the annual average values (Fig. 7), ranks fourth of the cations in Lake Nasser. According to MUNAWAR (1970), carbon dioxide reacts more readily with calcium salts than with magnesium salts converting large quantities of calcium into soluble bicarbonate. This author added that this preferential behaviour of carbon dioxide is possibly responsible for the comparatively low percentages of magnesium in alkaline waters.

The irregularity in the vertical distribution of magnesium might be attributed to the effects of various physico-chemical and biological processes.

The minimum seasonal average value of magnesium observed in May (Fig. 5) might be due to the abundance of phytoplankton. HANNAN and BROZ (1976) attributed the decrease in magnesium in Canyon reservoir to an increase in chlorophyll *a*. According to GOLDMAN and HORNE (1983), magnesium in plants serves as the transition metal at the heart of the reactive center in the chlorophyll molecule. The maximum seasonal average value of magnesium in August (Fig. 5) is attributed mainly to the highest water temperature in summer which increased the rate of water evaporation (SAAD and GOMA, in press) and consequently caused the accumulation of dissolved salts in the lake water. OLSEN and SOMMERFELD (1977) attributed the slight increase in magnesium concentration during late summer to evaporative concentration.

The regional average values of magnesium showed a gradual increase northward towards the High Dam (Fig. 6). This phenomenon, as in case of sodium, coincided with the influence of the flood waters, loaded with suspended matter and containing low salt concentration, which enters the lake at its southern region.

The seasonal variations of the average magnesium: chloride ratio ranged from 0.7 in May to 1.1 in April and November (Table 1). These coincided with the maximum and minimum seasonal average values of chloride these months, respectively (SAAD and GOMA, in press).

Magnesium gave a high positive correlation with sodium ($p<0.001$). It was also positively correlated with potassium, bicarbonate and sulphate (p = 0.001). However, there was no significant correlation between magnesium and each of calcium, chloride and carbonate.

Table 1. Variations of the seasonal average sodium, magnesium, calcium and potassium: chloride ratio, in Lake Nasser during 1981-82

	April	Aug.	Nov.	Feb.	May
	1981			1982	
Na: Cl	4.5+	3.4	3.7	3.1	2.3-
Mg: Cl	1.1+	0.9	1.1+	0.9	0.7-
Ca: Cl	2.9	2.1	3.2+	2.4	1.9-
K: Cl	1.5+	1.1	1.1	1.0	0.8-

The minimum values are designated by (-) and the maximum by (+).

Calcium Variations

Calcium plays the main role in the aquatic environment with regard to the reactions with carbon dioxide (the only source of carbon for primary production) and also with regard to the dependence of the pH on these reactions (MISZTAL, 1980). This element is regulated by the solution and precipitation af a solid phase (GOLDBERG, 1965). The behaviour of calcium is of considerable interest.

Based on the annual averages, (Fig. 7), calcium occupies the second order of abundance after sodium among cations. According of GOLTERMAN (1975), calcium forms 50% of the cations in the upper stream of the river Nile.

The irregularity in the vertical distribution of calcium in Lake Nasser might bi due to its involvement with the biosphere and with carbonate system in the waters (WILSON, 1975). MOBERG and REVELLE (1937) have demonstrated the existence of vertical differences in the calcium: chlorinity ratio, which they attributed to removal of calcium in the surface layers through biological activities. The increase in calcium content in the bottom layers of most stations is a good evidence for the solution of calcareous deposits accumulated on the lake bottom (SAAD and HUSSEIN, 1978).

In August, the minimum seasonal average calcium value (Fig. 5) might be due to the maximum seasonal average water temperature that month (SAAD and GOMA, in press). According to COLE (1983), the solubility of calcium carbonate decreases as the temperature rises from 0°C to 35°C. The low seasonal average calcium value observed in May (Fig. 5) coincided with the abundance of phytoplankton. SAAD and HUSSEIN (1978) found a negative correlation between chlorophyll *a* and calcium. Thus, the net effects of increasing chlorophyll *a* will be a decrease in calcium content. The maximum seasonal average calcium value found in November (Fig. 5) might be attributed on the effect of flood, where in this month the lake reached its maximum water level (SAAD and GOMA, in press). GURASIO *et al.* (1980) and ENTZ and LATIF (1974) pointed out that the flood is composed primarily of flow from the blue Nile, which carries water rich in calcium according to TALLING (1976).

The maximum regional average value of calcium obtained at station VIII (Fig. 6), resulting from the maximum averages in August and November (from the beginning to the end of the flood period), illustrates the influence of the flood-water on this location. The abnormal relative high regional average value at station V (Fig. 6) might be due to the very low densities of phytoplankton, as has been pointed out by ENTZ and LATIF (1974). The minimum regional average concentration at station IV, (Fig. 6), resulting from the lowest calcium averages in most months, might be related to position of this station in the narrowest region of the lake, where mountains are found in both sides. It seems that air-borne dust falling on the bottom of these mountains and the other non calcareous deposits from both sides of the lake are transported by water movements to be deposited on the lake bottom, preventing the direct contact between the calcareous deposits and the overlying water.

The seasonal average calcium: chloride ratio varied from 1.9 in May to 3.2 in November (Table 1). These coincided with the maximum and minimum seasonal averages of chloride in these months, respectively (SAAD and GOMA, in press).

Calcium was found to be high negatively correlated with chloride and carbonate ($p<0.001$). It was positively correlated with bicarbonate ($p = 0.001$). However, there was no significant correlation between calcium and each of sodium, magnesium, potassium and sulphate.

Potassium Variations

Potassium plays a minor role for the growth of phytoplankton. This element is required for all cells, mainly as enzyme activator and is present in larger amounts inside the cells of aquatic biota than in the surrounding medium (GOLDMAN and HORNE, 1983). Potassium is weathered from various feldspars rocks, but does not remain in solution, as it combines easily with other products of weathering, being removed from solution by adsorption on clay. There are some evidences that highly concentrated waters with potassium are lethal to many aquatic animals (COLE, 1983). Regarding the annual average values (Fig. 7), potassium ranks third of cation in Lake Nasser.

The irregularity in the vertical concentrations of potassium might be attributed to its adsorption on or desorption from suspended matter, following the abundance of suspended particles at certain areas and in specific periods. In August, the upper layer (above 20 m depth) had, in general, noticeably higher values of potassium. This, as in case of sodium, coincided with elevation of temperature in summer and the existence of thermal stratification during this season (SAAD and GOMA, in press).

The minimum seasonal average value of potassium in November (Fig. 5) can be related to the influence of the flood, attaining its maximum that month (SAAD and GOMA, in press) in transporting huge amounts of suspended particles on which considerable quantities of potassium were adsorbed. According to MORCOS (1968), potassium has a great tendency to be adsorbed on the suspended and colloidal matter in the rivers.

The regional average values of potassium tended to increase gradually northward towards the High Dam (Fig. 6). This, as in case of sodium and magnesium, resulted from the influence of the flood-waters carrying a large amount of suspended materials and silt, on which potassium is adsorbed in considerable quantities.

The seasonal variations of the average potassium: chloride ratio ranged from 0.8 in May to 1.5 in April (Table 1). These are related to the maximum and relatively low seasonal average values of chloride in these months, respectively (SAAD and GOMA, in press).

Potassium showed a high positive correlation with sodium ($p<0.001$) and it was also positively correlated with magnesium and sulphate ($p = 0.001$), bicarbonate and carbonate ($p = 0.02$). However, no significant correlation appeared between potassium and each of calcium and chloride.

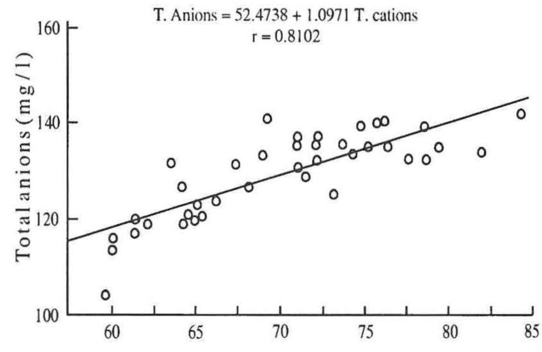

Fig. 9. Relation between the average values of total cations and total anions in Lake Nasser.

The correlation coefficient, computed for the relationship between the total cations and total anions in Lake Nasser was positively high (0.8102). The correlation is significant at the level ($p<0.001$). The relationship between total cations and anions (Fig. 9) illustrates that the total anions were higher than the total cations. This is in agreement with the results obtained by GOMA (1987) on the stretch of the Nile at Aswan and ABDEL-MOATI (1981) on the down -stream of the Nile (Damietta branch).

CONCLUSIONS

Based on the annual average concentrations of cations, sodium ranked first, followed by calcium, potassium and magnesium. The thermal stratification caused noticeable variations in the vertical distribution of sodium and potassium, i. e. the concentrations of these cations in August were, in general, notably higher in the upper water layer (above 20 m depth) than in the bottom layers). The sodium: chloride ratio exceeded that of each of the other cations with chloride. The minimum seasonal average value of potassium accompanied by the maximum seasonal average concetration of calcium found in November coincided with the influence of the Nile flood, attaining its maximum that month, in transporting large amounts of waters enriched with calcium, as well as suspended particles on which considerable quantities of potassium were adsorbed.

Sodium was found to be positively correlated with magnesium, potassium, sulphate, bicarbonate and carbonate. Magnesium was positively correlated with potassium, bicarbonate and sulphate. Calcium was high negatively correlated with chloride and carbonate and positively correlated with bicarbonate. Potassium was positively correlated with sulphate, bicarbonate and carbonate. The relationship between total cations and anions illustrates that the total anions were higher than the total cations.

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Raspodjela glavnih iona u jezeru Nasser
II. Glavni kationi

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KRATKI SADRŽAJ

Izučavana su sezonska i lokalna kolebanja glavnih kationa u jezeru Nasser. Od čimbenika koji djeluju na nepravilnost okomite raspodjele kationa treba spomenuti kretanje vodenih masa, adsorpciju na i desorpciju sa suspendiranih čestica i donos erodiranog materijala u jezero. Pojačano isparavanje tijekom kolovoza prouzročilo je gomilanje otopljenih soli, na što su ukazale visoke sezonske prosječne vrijednosti natrija, magnezija i kalija. Međutim, najniža prosječna vrijednost kalcija zabilježena je u kolovozu kad se topljivost kalcijevog karbonata smanjivala porastom temperature. Minimalna sezonska vrijednost kalija u studenom javljala se istodobno s najvišim vodostajem, a kalij je pokazivao izrazitu tendenciju adsorpcije na suspendirani i koloidni materijal, koji je pristigao poplavnim vodama. Postupni porast lokalnih prosječnih vrijednosti natrija, magnezija i kalija u smjeru Velike brane javljao se istodobno s djelovanjem poplavnih voda, opterećenih suspendiranim materijalom, a s vrlo niskim sadržajem soli, koji se javljao prvo u južnom dijelu jezera.