Technical note

Physical and chemical properties of Aswan High Dam Lake water

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Abstract

During the period 1 July 1980 to 24 July 1980 water samples were collected from nineteen stations between Daal Cataract in Sudan and the High Dam wall in the most southern part of Egypt. The study dealt with measuring electrical conductivity, temperature and pH; and with the determination of dissolved oxygen, CO_3^{2-}, HCO_3^-, Cl,SO_4^{2-}, SiO_2, Na, Ca, Mg, total hardness(TH) and total dissolved solids (TDS) in the entire body of water in order to follow up the physical and chemical changes and their effects on the water quality, on the growth of the microorganism communities and hence, on fish living in the lake.

The study revealed that the temperature ranged from 29,1 to 19,0 °C in the Sudan and 28,2 to 19,2 °C on the Egyptian side; conductivity in the range 3,40 to 2,30 mS/m, pH range 8,9 to 8,0; dissolved oxygen in the range 8,0 to 1,0 mg/ℓ; TDS: 193 to 138 mg/ℓ; Cl : 9,7 to 4,2 mg/ℓ; free CO_2:0 mg/ℓ CO_3^{2-}:15 to 0 mg/ℓ; HCO_3^-:174 to 103,7 mg/ℓ; SO_4^{2-}:13,5 to 6,35 mg/ℓ; SiO_2: 15 to 7 mg/ℓ; Ca:24,39 to 17,6 mg/ℓ; Mg : 9,7 to 8,3 mg/ℓ; Na : 33,6 to 17,6 mg/ℓ; and TH : 135,27 to 53,70 mg/ℓ for surface and bottom waters. On the basis of the results there was a stratification in the water masses of the lake.

Introduction

The High Dam Lake, which is one of the largest man-made lakes in the world, is the reservoir created as a result of the construction of the High Dam in the southernmost part of Egypt and extends beyond Daal Cataract in the northern part of Sudan. In the study of lakes, many disciplines such as physics, chemistry, geology, hydrology, and biology are combined and a knowledge of several of these sciences may be necessary in order to solve any particular problem. The distribution of certain chemical components in water bodies may provide useful information regarding water movements, or may give an indication of the factors controlling the fertility of the water masses for the growth of microorganisms and fish. Physico-chemical studies of the waters of the lake show how anaerobic and aquatic plants grow and how the sediments of the lake have been produced and give a clue to their geochemistry and mineralogy, or may give information on such features (Riley and Skirrow, 1965).

The physical and chemical changes (Awadallah, 1984, Sherif *et al.*, 1978; 1980) and distribution of nutrient components in waters (Nessiem, 1972; Elewa, 1976) and trace elements in sediments (Sherif *et al.*, 1981) of the High Dam Lake and nutrient components in Nile River water (Zidan, 1983; Ahmed, 1983) were studied.

Sampling and methods

Water samples were collected from different localities (nineteen) at variable depths (surface, 25%, 50%, 65% and near bottom) by means of a water sampler (Nansen bottle) (Goodwin and Goddard, 1974). Water samples were filtered and the filtrate was analysed for Ca^{2+} and Mg^{2+} by EDTA (Welcher, 1965); Cl- by $AgNO_3$ (Vogel; 1982); free CO_2, HCO_3^{2-} *in situ* by HCl (Merck, 1980; American Public Health Association, 1980); SO_4^{2-} *in situ* by $BaCl_2$; SiO_2 by the molybdate method; Na^+ by flame photometry (Stainton, *et al.*, 1977; Molins and Rial, 1962; Cheng *et al.*, 1953; Mackereth *et al.*, 1978; Merck, 1980; Furman, 1966) and dissolved oxygen *in situ* by the Winkler method (American Public Health Association, 1980) whereas temperature was measured *in situ* by thermometer, pH *in situ* by Beckman H-5 pH meter and electrical conductivity *in situ* with the aid of a 3965 A Conductance Bridge (Thomass-Serfass. Philadelphia, USA). Total dissolved solids (TDS) were determined by evaporating, in a platinum dish, one litre of the previously filtered water and weighing the residue. The samples were collected during the period 1 July 1980 to 24 July 1980 and their positions are shown on Fig. 1.

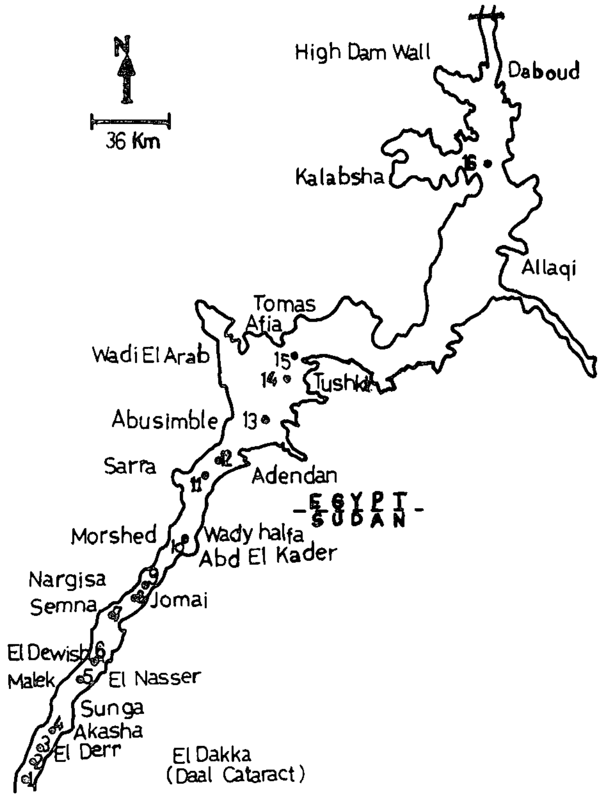

Figure 1
Lake Nasser — Lake Nubia

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TABLE 1
Vertical and horizontal variations of physical and chemical components of the water samples of the High Dam Lake

Locality:	Daal Cataract			El Dakka			El Derr			Akma			Malek El Nasser			El Dewaishat			Atirry			Semna		
Sampling date:	1.7.1980			3.7.1980			4.7.1980			5.7.1980			6.7.1980			7.7.1980			8.7.1980			9.7.1980		
Item	Depth in metre			Depth in metre			Depth in metre			Depth in metre			Depth in metre			Depth in metre			Depth in metre			Depth in metre		
	0	15	30	0	4,5	9	0	12	24	0	10	20	0	15	30	0	15	30	0	16	32	0	20	40
T, °C	29	28,2	28	29,1	28,7	8,8	28	27,7	27,6	28	27,9	27,9	27,9	27,7	27,3	8,3	28,2	28,2	28,3	28,3	28,2	28,3	28,0	28,2
λ, mS/m	2,85	2,80	2,80	3,05	2,90	2,90	3,40	3,40	3,35	3,00	3,00	3,00	3,00	3,00	3,00	3,05	3,05	3,05	3,05	3,05	3,05	3,05	3,05	3,05
pH	8,9	8,8	8,7	8,55	8,57	8,55	8,6	8,5	8,6	8,55	8,5	8,48	8,5	8,48	8,48	8,3	8,25	8,25	8,2	8,2	8,2	8,2	8,2	8,2
CO_3^{2-}, mg/ℓ	6,0	3,2	6,0	6,0	6,0	6,0	3,5	3,6	3,5	6,0	6,0	6,0	6,0	6,0	6,0	3,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HCO_3^-, mg/ℓ	128	134	134	155	155	154	154	156	155	158,6	155,8	155,6	156	155,6	155	162	164,8	164,7	167,8	167,8	167,8	167,8	167,8	167,8
SO_4^{2-}, mg/ℓ	7,1	7,1	7,1	7,2	7,2	7,15	7,2	7,8	7,4	6,4	9,0	9,2	9,21	8,1	9,2	9,5	11,1	8,0	11,5	13,9	11,0	11,5	11,5	11,5
O_2, mg/ℓ	7,6	7,5	7,4	6,3	6,25	6,4	6,5	6,9	7,0	6,45	6,85	7,0	6,0	6,0	6,0	6,0	6,0	5,8	5,7	5,8	5,8	5,8	5,8	5,8
TDS, mg/ℓ	180	189	182	176	186	179	184	178	178	178	182	186	185	186	175	192	188	169	190	188	188	192	188	190
Ca, mg/ℓ	13,3	8,0	35,1	20,8	20,8	20,8	22,8	22,8	22,8	21,6	21,6	21,6	20,8	21,6	20,8	20,8	20,8	20,8	20,8	20,8	20,8	20,8	20,8	20,8
Mg, mg/ℓ	14,3	8,1	11,6	9,2	9,2	9,2	9,5	9,5	9,5	8,3	8,3	8,3	8,7	8,3	8,7	9,2	9,2	9,2	9,2	9,2	9,2	9,2	9,2	9,7
TH, mg/ℓ	91,98	53,7	53,27	89,73	89,73	89,73	95,95	95,95	95,95	88,02	88,02	88,02	87,67	88,02	87,67	89,73	89,73	89,73	89,73	89,73	89,73	89,73	89,73	89,73
Na, mg/ℓ	26,9	24,2	36,9	30,6	31,7	31,7	17,1	36,8	36,8	32,4	33,7	32,7	32,2	31,6	32,2	30,5	31,0	29,6	32,4	33,5	32,2	32,6	32,6	31,7
SiO_2, mg/ℓ	15,2	15,1	15,2	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	14,0	14,0	14,0	14,0	14,0	14,0	13,0	14,0	11,0	11,0	13,0	11,0
Cl, mg/ℓ	4,7	7,7	6,0	8,5	8,5	8,5	6,8	8,7	8,2	8,5	8,5	8,5	7,8	7,8	7,8	7,8	7,8	7,8	7,8	7,8	7,8	8,2	8,2	8,2

Locality:	Kegnarty			Morshed			Jomai			Amka				Sarra						Adendan				
Sampling date:	10.7.1980			11.7.1980			12.7.1980			13.7.1980				15.7.1980						16.7.1980				
Item	Depth in metre			Depth in metre			Depth in metre			Depth in metre				Depth in metre						Depth in metre				
	0	20	40	0	20	40	0	13	26	0	10	20	30	0	10	20	30	40	50	0	10	20	30	40
T, °C	28,1	28,0	27,9	28,8	28,2	27,8	28,4	28,3	28,5	28,7	28,5	28,4	27,8	28,4	27,8	27,4	21,4	29,4	19,0	28,8	28,3	27,6	21,2	19,2
λ, mS/m	3,00	3,00	3,00	3,00	3,00	3,00	2,80	2,80	2,80	2,70	2,70	2,70	3,00	2,70	2,65	2,65	2,60	2,65	2,60	2,70	2,65	2,80	2,70	2,70
pH	8,1	8,1	8,0	8,5	8,35	8,25	8,5	8,35	8,35	8,5	8,5	8,45	8,2	8,35	8,40	8,30	8,25	8,10	8,00	8,4	8,45	8,40	8,20	8,00
CO_3^{2-}, mg/ℓ	3,0	0,0	0,0	6,0	0,0	0,0	9,0	3,0	6,0	9,0	6,0	9,0	0,0	12	9	6	0,0	0,0	0,0	15,	12,	6,0	0,0	0,0
HCO_3^-, mg/ℓ	161,7	167,8	167,8	155,6	173,8	173,8	140,3	146,4	140,3	131	137	134	164,7	127	128	134,2	146,4	146,4	146,4	119	125	137,3	149,5	149,5
SO_4^{2-}, mg/ℓ	11,9	11,0	10,8	9,4	10,0	9,7	10,8	11,0	8,9	8,5	12	11	9,75	7,7	13,5	12,2	10,8	9,7	8,9	8,2	12	11,2	10,6	7,2
O_2, mg/ℓ	5,6	6,0	5,6	5,6	5,8	5,8	6,5	6,2	6,0	6,5	6,1	5,8	4,2	7,6	6,0	5,0	3,2	3,2	2,6	7,2	5,8	4,2	3,6	1,8
TDS, mg/ℓ	188	192	190	177	180	178	164	172	162	160	162	157	178	146	150	158	151	193	154	152	142	158	146	148
Ca, mg/ℓ	20,8	20,8	20,8	20,8	20,8	20,8	19,2	19,2	18,4	18,4	18,4	18,4	20,04	19,2	17,6	18,4	18,4	22,4	22,4	18,4	18,4	18,4	22,4	24,0
Mg, mg/ℓ	9,2	9,7	9,7	9,7	9,7	9,7	9,2	9,7	9,2	9,2	9,2	8,7	9,7	8,8	9,7	9,2	9,2	8,8	8,8	9,2	9,2	9,7	9,7	9,7
TH, mg/ℓ	89,73	91,78	91,78	91,78	91,78	91,78	85,73	87,79	83,74	83,74	83,74	81,68	89,89	84,09	84,55	83,74	83,74	92,07	92,07	83,74	83,74	85,79	85,79	99,97
Na, mg/ℓ	32,8	31,5	31,7	32,3	33,0	28,3	30,0	26,4	27,7	26,4	27,6	27,3	25,8	26,7	27,5	18,8	18,9	18,6	18,6	21,9	20,4	19,4	18,4	18,4
SiO_2, mg/ℓ	11	15	12	13	14	12	14	11	13	13	13	13	13	13,1	13,1	12	13,4	12	12	14	13,2	11	11,5	12
Cl, mg/ℓ	8,2	8,2	8,3	7,8	7,8	7,8	7,1	6,4	7,1	7,1	6,4	7,1	7,8	6,4	6,4	6,4	6,4	5,0	5,0	7,1	6,4	6,0	4,3	4,2

Table 1 (continued)

Locality:	Abu Simble						Tushki			
Sampling date:	20.7.1980						21.7.1980			
Item	Depth in metre 0	10	20	30	40	50	Depth in metre 0	10	20	30
T, °C	28,6	28,0	28,0	21,0	19,4	19,2	28,7	28,8	24,4	20,4
λ, mS/m	2,40	2,40	2,50	2,50	2,50	2,45	2,40	2,40	2,40	2,45
pH	8,5	8,5	8,25	8,25	8,15	8,15	8,5	8,5	8,35	8,3
CO_3^{2-}, mg/ℓ	12	9	0,0	0,0	0,0	0,0	12	15	3,0	3,0
HCO_3^-, mg/ℓ	112,8	119	152,5	140,3	140,3	140,3	104,8	106,8	131,2	131,2
SO_4^{2-}, mg/ℓ	9,8	12,0	11,1	9,2	8,8	7,6	8,6	7,0	7,0	7,0
O_2, mg/ℓ	8,0	7,2	2,0	3,4	2,6	2,4	7,0	6,4	4,4	3,2
TDS, mg/ℓ	143	153	162	145	150	158	140	152	153	155
Ca, mg/ℓ	17,6	17,6	19,2	22,4	24,0	24,0	17,6	17,6	20,0	20,8
Mg, mg/ℓ	8,3	8,3	9,2	8,2	8,7	8,7	8,7	8,7	9,2	8,7
TH, mg/ℓ	78,04	78,04	85,73	89,61	95,65	95,65	78,04	78,04	87,73	87,67
Na, mg/ℓ	23,7	23,5	22,4	20,4	18,4	18,4	21,1	21,3	22,2	18,5
SiO_2, mg/ℓ	12	11,5	11,1	11	10,9	11	11	11,1	11,2	11
Cl, mg/ℓ	4,4	4,6	4,6	4,3	4,5	4,35	4,6	4,7	4,7	4,6

Locality:	Wadi El Arab				Gerf Hussein					Kalabasha		
Sampling date:	22.7.1980				23.7.1980					24.7.1980		
Item	Depth in metre 0	10	20	30	Depth in metre 0	10	20	30	40	Depth in metre 0	10	20
T, °C	28,6	27,9	24	19,8	29	27,9	23,2	20	19	29,3	27,3	24
λ, mS/m	2,40	2,35	2,45	2,40	2,40	2,45	2,45	2,30	2,40	2,30	2,30	2,30
pH	8,5	8,45	8,25	8,2	8,9	8,7	8,4	8,4	8,2	8,6	8,5	8,4
CO_3^{2-}, mg/ℓ	12	12	0,0	0,0	15	12	0,0	0,0	0,0	6,6	3,0	0,0
HCO_3^-, mg/ℓ	122	109,8	137,2	140,0	103,7	109,8	140,5	140,3	140	125	137	140
SO_4^{2-}, mg/ℓ	10	11,5	7,2	6,8	8,2	10,0	9,6	8,5	8,3	10,0	9,8	9,0
O_2, mg/ℓ	7,2	6,2	1,8	1,2	7,0	6,4	2,4	1,8	1,2	7,5	6,6	2,6
TDS, mg/ℓ	155	146	158	152	138	140	148	156	152	142	154	150
Ca, mg/ℓ	19,2	20,0	22,4	22,4	19,2	19,2	22,4	22,4	22,4	20,8	20,8	20,8
Mg, mg/ℓ	9,2	9,2	8,7	8,5	9,2	9,2	8,7	8,7	8,7	9,7	9,7	9,7
TH, mg/ℓ	85,73	87,73	91,66	90,84	85,73	85,73	91,66	91,66	91,66	91,78	91,78	91,78
Na, mg/ℓ	23,7	20,0	18,4	18,5	24,7	22,9	20,0	17,5	16,3	23,1	20,0	16,2
SiO_2, mg/ℓ	11	11,5	11,2	11	12	11,2	12,1	12	11	12	11,5	11
Cl, mg/ℓ	4,3	4,4	4,35	4,45	4,5	4,4	4,35	4,3	4,5	4,6	4,5	4,5

Preparation of solutions

All the chemicals used were of AnalaR grade (99,9%, Riedel de Haën, E Merck, BDH or Aldriche). The reagent, standard, indicator (Vogel, 1982) and buffer solutions (Britton, 1956) were prepared in accordance with recommended methods.

Results and discussion

The data obtained are recorded in Table 1 and represented in Fig. 2. The figures illustrate the changes in temperature (T,°C), conductivity (mS/m), pH, dissolved oxygen, CO_2, CO_3^{2-}, HCO_3^-, SiO_2, Na, Ca, Mg, SO_4^{2-}, and Cl with depth and with distance from Daal Cataract to near the High Dam wall.

The temperature of the water slightly decreased horizontally and vertically between Daal Cataract and Amka in Sudan while the water temperature on the Egyptian side showed a slight horizontal increase and a vertical decrease between Sarra and Kalabsha. High temperature values may be attributed to the effect of solar radiation and have the advantage of increasing the amount of photosynthetic activity and utilisation of CO_2 in the photosynthetic production of oxygen, carbohydrates and increasing pH. This behaviour was confirmed by the absence of free CO_2, by the dissolved oxygen and pH data. Electrical conductivity values of the surface water were higher in Sudan (El Dakka to Morshed) than in Egypt (Sarra to Kalabsha). However, there was no vertical variation in conductivity values in Sudan and also not in Egypt. This may have been due to the effect of the pressure of the water column. This was also in accordance with the temperature values, and the sodium, bicarbonate, calcium and magnesium behaviour.

Dissolved oxygen values decreased vertically and horizontally from Daal Cataract up to Morshed, then increased vertically and decreased horizontally from Jomai to Kalabsha. The changes in oxygen content may be related to the water temperature and photosynthesis (Willoughby, 1976). It may be also related to the concurrent changes in the formation and decomposition of organic compounds and to the uptake of inorganic carbon and release of nutrient elements (i.e. N,P,...) (Hurst, 1950). The high content of dissolved oxygen may be attributed to the high rate of biosynthesis, photosynthesis production, uptake of inorganic carbon, and nutrient ions on the surface where these components are present in high concentrations ($CO_2 + H_2O \rightarrow CH_2O + O_2$). On the other hand, the low oxygen values in the deeper waters could be ascribed to the increase of organisms living in the lake. In addition, the penetration of light energy over distance was limited, as the physical circulation of the bottom water masses was so restricted (advective and diffusive processes were not effective in ventilating lower waters) that replenishment of dissolved oxygen in the deeper waters did not take place.

There was a slight decrease in pH values vertically and horizontally between Daal Cataract and Kegnarty. This may be attributed to the relative decrease in the production of phytoplankton blooms and the decomposition of organic matter in the bottom which led to the release of CO_2 gas, producing a decrease in pH values from the surface to the bottom (Naguib, 1958). Water masses were also poorly ventilated. Between Morshed and Wadi El Arab, surface waters almost had the same pH values. Constant pH values of surface waters may be related to a distribution of phytoplankton populations. However, waters of Gerf Hussein and Kalabsha showed slight increases in pH values. This may be as a result of the buffer action attributed to the dissolved CO_2, and CO_3^{2-} and HCO_3^- ions.

Sodium first increased, then decreased and finally reached a constant level vertically and horizontally from Daal Cataract to near the High Dam. Increased sodium levels in water may be as a result of its solubility in water and the high sodium content of rocks surrounding the lake. Decreases in sodium levels encountered during the study, may be due to its consumption by microorganisms and fish as NaCl.

Chloride concentrations increased, then decreased and reached a constant value with depth and with distance between Daal Cataract and the High Dam (Holdern, 1970). Chloride is an essential element for plant growth and photosynthesis, and it stimulates the activity of several enzymes and regulates osmotic pressure of extracellular fluids (Oser, 1979). It is the chief anion of the gastric juice which is derived from blood chloride and is normally realeased during the later stages of digestion in fish (Malik and Srivastava, 1982).

Carbonate concentration showed vertical and horizontal fluctuation. Surface waters had the same carbonate concentration between Daal Cataract and Morshed, then the concentration increased and

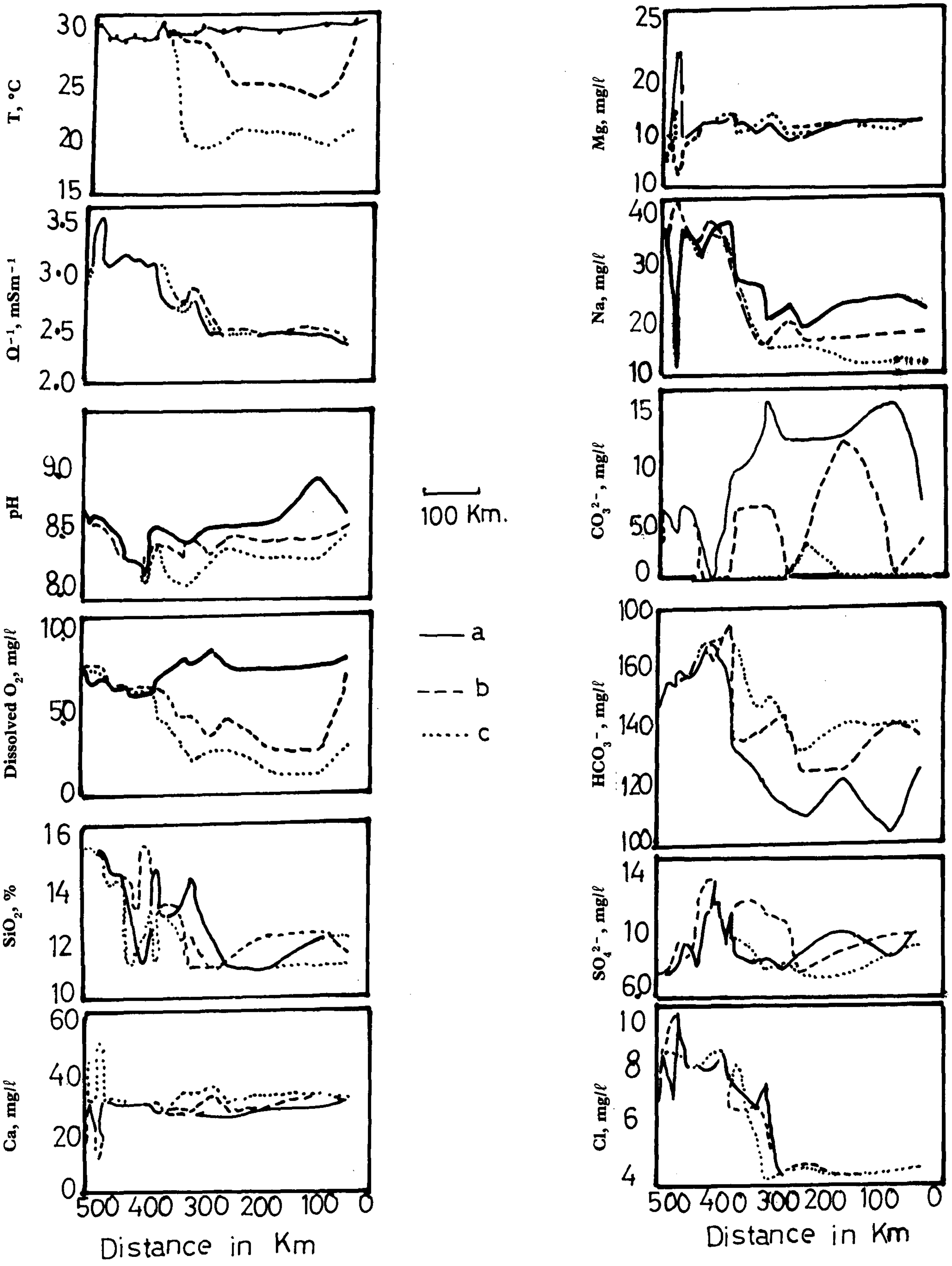

Figure 2
Vertical and horizontal variation of physical and chemical parameters of water samples of Aswan High Dam of a)surface; b)50%; and c)near-bottom

reached a constant value at Sarra-Gerf Hussein. However, it decreased with depth. The increase in the carbonate content may be as a result of the reaction of the bicarbonate with water (H_2O + $HCO_3^- \rightarrow CO_3^{2}$ + H_3O^+). This is in accordance with the high pH values. Decreased carbonate may be ascribed to dilution effect, acid-base reactions, CO_3^{2-} -CO_2-H_2O reaction, aeration, and biological activity effects. Absence or complete depletion of carbonate may be accompanied by an increase in bicarbonate. This may be due to the complete interaction of CO_2 (resulting from the decomposition of organic matter and the atmosphere) and CO_3^{2-} in the presence of water, $CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2$.

Bicarbonate increased regularly with distance and with depth between Daal Cataract and Morshed, then decreased and reached a constant value. An increase in HCO_3^- may be due to the reaction of CO_2 and OH^- ($CO_2 + OH^- \rightarrow HCO_3^- + H^+$) and the dissociation of CO_3^{2-} into HCO_3^- ($CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$). A decrease in bicarbonates may be attributed to the utilisation of bicarbonate carbon dioxide for photosynthesis processes of algae and diatoms (Entz, 1972).

Soluble silicates were the same between Daal Cataract and Amka, then slightly decreased and became constant. The changes in silicate concentration could have been caused partly by biological effect and partly by upwelling of deep water of high silicate content combined with the effect of water movements, turbulence, temperature, pH and salinity. High soluble silicate concentration on the Sudan side may be related to soluble silicates coming from the surrounding weathered feldspar rocks which break down, or to a high abundance of phytoplankton population or rapid circulation which dissolved amorphous silicates. A decreased silicate concentration may be attributable to its consumption by diatoms, fungi, algae, phytoplankton, zooplankton, fish tissues and aquatic plants.

Water between Daal Cataract and Jomai showed similar values for calcium, then calcium slightly decreased. However, at El Derr it was high and at Abu Simble and Gerf Hussein, it increased with depth. The same results appear with Mg, indicating that Ca and Mg were uniform through the water column. Ca and Mg are essential elements (Volkovic, 1975) and play significant roles in photosynthesis of chlorophyll, carbohydrate metabolism, fatty acids, amino acids, proteins, alcohols, phenols and nucleic acids. Increased calcium and magnesium concentrations could have been due to regional variations of the surrounding rocks or may be due to some degradation of organisms containing Ca and Mg. A decrease in Ca and Mg may be attributed to their uptake by microorganisms and fish (Bowling, 1976).

Sulphate concentrations increased between Daal Cataract and Sarra, then slightly decreased and reached constant concentrations with depth and with distance. However, at some depths, the concentration changed, indicating that the water masses were stratified. High sulphate concentration may be attributed to the bacterial oxidation effect of the detrital organic phase (Owens and Wood, 1968), whereas the decrease of [SO_4^{2-}] with depth could have been due to the effect of the abundance of active sulphate-reducing bacteria and the effect of the decomposition of the phytoplankton which tends to produce anaerobic regions where sulphate-reducing bacteria thrive (Holdern, 1970).

Conclusion

The ionic composition of the surface water was very similar in the Sudan and in Egypt, and the ionic composition of the water in general was dominated by bicarbonate, reactive silica, calcium and magnesium, Na and Cl. The following ionic dominance order mostly previaled: Na > Ca > Si > Mg : $HCO_3 > SO_4$ > Cl.

However, there were marked changes in some physical and chemical properties of the water (Awadallah, 1984, Sherif *et al.*, 1978; 1980) of the High Dam Lake due to regional variations, physical circumstances, biological (Latif and Rashid, 1972), biochemical, geochemical and biogeochemical (El Dardir, 1984) processes occurring in the Lake. These processes influence the distribution of the physical and chemical components (Sherif *et al.*, 1980; Moalla, 1985), the microorganism populations, the fish communities, the sedimentation of trace elements (Sherif *et al.*, 1981), the properties of irrigation water (Sherif *et al.*, 1981) and the fertility of the Egyptian soil (Sherif *et al.*, 1981).

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