Investigation of drinking- and Nile-water samples of upper Egypt

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Abstract

Nile- and drinking-water samples which were collected from Aswan to Giza during January, June and August 1987, were investigated. The water temperature, transparency and pH were measured *in situ* and the samples were analysed for the following constituents, i.e. free CO_2 (0,00 to 7,04 mg/ℓ), carbonate (0,0 to 2,0 mg/ℓ), bicarbonate (120 to 160 mg/ℓ), pH (7,00 to 8,45), nitrite (0,00 to 0,10 mg/ℓ), nitrate (0,018 to 0,360 mg/ℓ), phosphate (0,007 to 0,500 mg/ℓ), Ca^{2+} (24,05 to 36,90 mg/ℓ), Mg^{2+} (9,73 to 15,56 mg/ℓ), total hardness (TH) (102 to 112 mg/ℓ), chloride (6,5 to 11,7 mg/ℓ), sulphate (3,5 to 15,5 mg/ℓ), iron (0,00 to 0,11 mg/ℓ), organic matter (0,8 to 5,2 mg/ℓ) and total dissolved solids (125 to 230 mg/ℓ). Ionic dominance patterns did not change within the seasons although Ca, Mg, HCO_3^-, Cl^- and SO_4^{2-} in both Nile and drinking water increased from Aswan to Assiut and then decreased. No pH stratification with depth was observed. The results of both Nile and drinking water are within the reference recommended values. The divisive clustering methods were applied to identify these samples. The results of clustering analysis indicate that with the help of this technique, time variations and the type of water samples could be distinguished. The correlation coefficient values are positive and suggest that good correlations between these items and the cations exist as soluble chlorides, sulphates, phosphates, nitrates, bicarbonates and humates.

Introduction

The purpose of this paper is to document some characteristics of the chemistry of Nile and drinking water of upper Egypt. This paper supplements preliminary limnological (Zidan, 1983; Prowse and Talling, 1958) and chemical (Hurst, 1950; Klein, 1973) data of Nile basin water.

Nile water is the main drinking-water supply for the Egyptian population. Due to industrial growth in the last 30 years, especially in upper Egypt, the likelihood of contamination has increased. Thus it has become necessary to establish a comprehensive monitoring programme for chemical characterisation of the main water constituents of both Nile and drinking water. To evaluate the water quality of the Nile and drinking water, there is a need to consider the physical and chemical structure of these waters. The area covered stretches about 900 km along the Nile River. In order to investigate the water quality during the different seasons, the samples were collected in January, June and August. The reason for this choice is that January is peak (winter) season for tourism in Egypt and there are about 150 Nile craft (floating hotels) in addition to numerous port motor boats operating in Aswan and Luxor, constituting additional sources of free CO_2, organic matter, oils, fats, nitrate, and phosphate contamination to the Nile water. May is the end of this season and June is the start of the summer season. August is the end of the summer season and it was chosen to represent the water quality after the rate of cruises and craft trips on the Nile had decreased during the summer period with minimal tourism.

Description of the study area

Data presented in this paper were collected from the area between Aswan 24°N and Giza 30°N (Fig. 1). The study stations represent all upper Egypt regions.

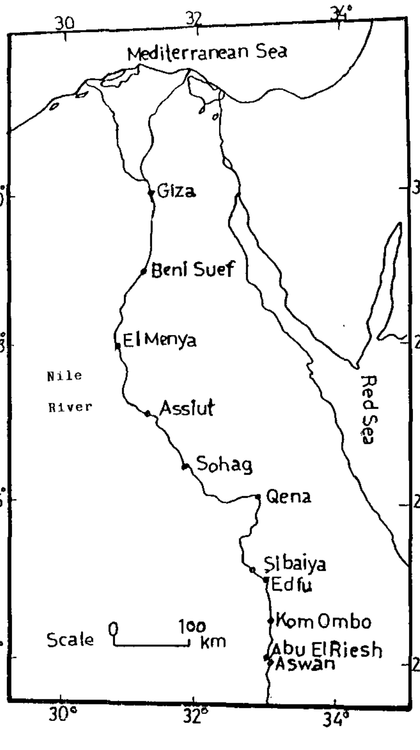

Figure 1
Locations of water sample sites on the Nile River

Methods

Sampling

Filtered Nile-water samples were collected from Aswan City (before and beyond the hotels district, beyond the Isis Hotel, before and behind the Kima Drain-Nile River confluence), Abu El Riesh, Kom Ombo, Edfu, El Sibaiya, Qena, Sohag, Assiut, El

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TABLE 1
RESULTS OF CHEMICAL ANALYSIS OF NILE RIVER WATER SAMPLES COLLECTED IN ASWAN CITY DURING JANUARY 1987

Sampling point	1			2			3			4		
Transparency, cm	235			210			215			206		
Depth, m	**0**	**4**	**10**	**0**	**4**	**10**	**0**	**4**	**10**	**0**	**4**	**10**
T, °C	16	16,5	17	16,5	16,5	17	16,5	17	18	17	17,5	18
D.O$_2$, mg/ℓ	8,08	8,56	8,72	8,72	9,20	9,20	8,56	8,40	9,04	8,72	8,80	8,12
Free CO$_2$, mg/ℓ	3,52	2,64	2,64	2,64	2,64	2,64	2,64	2,64	1,76	1,76	2,64	2,64
CO$_3^{2-}$ as CaCO$_3$, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HCO$_3^-$ as CaCO$_3$, mg/ℓ	124	124	128	128	124	128	128	128	124	124	124	120
pH	7,01	7,01	7,0	7,10	7,08	7,05	7,15	7,10	7,10	7,25	7,21	7,17
NO$_2^-$, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,004	0,0	0,0	0,0
NO$_3^-$, mg/ℓ	0,26	0,20	0,26	0,30	0,31	0,18	0,34	0,30	0,31	0,32	0,36	0,24
PO$_4^{3-}$, mg/ℓ	0,038	0,035	0,130	0,060	0,050	0,075	0,048	0,007	0,070	0,050	0,048	0,090
Ca^{2+}, mg/ℓ	27,25	25,65	25,65	24,85	24,05	25,65	25,65	24,05	24,85	24,85	24,85	24,05
Mg^{2+}, mg/ℓ	9,73	10,70	9,73	9,73	10,21	9,73	10,70	11,67	10,21	10,70	10,21	9,73
TH as CaCO$_3$, mg/ℓ	108	108	104	102	102	104	108	108	104	104	100	100
Cl$^-$, mg/ℓ	9,1	7,8	6,5	7,8	7,8	7,8	7,8	9,1	7,8	7,8	6,5	6,5
SO$_4^{2-}$, mg/ℓ	6,5	6,0	4,5	5,3	3,5	6,0	5,0	6,0	5,7	5,0	6,3	3,6
Fe, mg/ℓ	0,11	0,09	0,08	0,085	0,10	0,05	0,09	0,11	0,06	0,10	0,08	0,065
Organic matter, mg/ℓ	0,8	2,0	1,0	1,4	1,6	1,2	1,6	3,6	1,2	1,2	0,8	1,2
TDS, mg/ℓ	149	140	150	135	130	135	125	132	151	149	156	130

TABLE 2
RESULTS OF CHEMICAL ANALYSES OF NILE RIVER WATER SAMPLES COLLECTED FROM CENTRES IN ASWAN GOVERNORATE DURING JANUARY 1987

Sampling point	5		6		7		8			9		
Transparency, cm	110		190		200		175			140		
Depth, m	**0**	**4**	**0**	**4**	**0**	**4**	**0**	**4**	**10**	**0**	**4**	**10**
T, °C	16,5	16,5	17	18	17	18	16	16,5	16,5	16	17	17,5
D.O$_2$, mg/ℓ	8,16	8,32	7,60	8,24	8,40	8,80	8,40	8,40	9,12	8,32	8,72	8,80
Free CO$_2$, mg/ℓ	2,64	1,76	4,4	4,4	5,28	7,04	5,28	6,16	6,16	5,28	7,04	7,92
CO$_3^{2-}$ as CaCO$_3$, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HCO$_3^-$ as CaCO$_3$, mg/ℓ	124	126	132	132	132	132	132	132	136	136	132	140
pH	7,30	7,25	7,10	7,09	7,10	7,10	7,20	7,15	7,15	7,33	7,20	7,15
NO$_2^-$, mg/ℓ	0,015	0,050	0,090	0,100	0,010	0,010	0,0	0,003	0,0	0,030	0,0	0,005
NO$_3^-$, mg/ℓ	0,22	0,16	0,255	0,38	0,28	0,23	0,26	0,25	0,24	0,22	0,20	0,24
PO$_4^{3-}$, mg/ℓ	0,055	0,045	0,020	0,026	0,026	0,018	0,053	0,040	0,037	0,020	0,028	0,028
Ca^{2+}, mg/ℓ	24,85	24,85	24,85	24,85	25,65	25,65	28,85	27,25	27,25	29,65	28,85	27,25
Mg^{2+}, mg/ℓ	11,19	9,24	9,73	10,70	10,70	10,70	7,78	9,73	9,73	8,26	9,73	10,70
TH as CaCO$_3$, mg/ℓ	108	100	102	106	108	108	104	108	108	108	112	112
Cl$^-$, mg/ℓ	7,8	7,8	7,8	7,8	9,1	9,1	11,7	10,4	10,4	11,7	10,4	10,4
SO$_4^{2-}$, mg/ℓ	10,0	9,0	10,5	8,0	8,3	8,5	15,0	10,5	10,3	15,0	11,5	15,5
Fe, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Organic matter, mg/ℓ	2,4	1,2	3,6	4,2	1,4	1,4	3,6	4,0	5,2	4,4	4,8	2,8
TDS, mg/ℓ	150	145	142	140	169	158	145	152	157	150	155	140

Menya, Beni Suef and Giza at the surface and 10 m depth for the Aswan Governorate (Aswan City, Abu El Riesh, Kom Ombo, Edfu, and El Sibaiya), and at the surface and 4 m depth for the other Governorates, during the study period (January, June and August 1987) using a water sampler (Goodwin and Goddard, 1974). Drinking-water samples were collected in the same study time from the Aswan City filters (7 filters and 3 wells), Abu El Riesh, Kom Ombo, Edfu and Sibaiya Filters (Aswan Governorate) and Qena, Sohag, Assiut, El Menya, Beni Suef and Giza Filters.

Analysis

Physical and chemical analysis were performed following methods outlined in *Standard Methods* (1980), Merck (1980), Vogel (1982) and Welcher (1965).

Field measurements were done on temperature, transparency, dissolved oxygen, pH, free CO_2, carbonates, nitrites, and phosphates. The pH was measured using an Orion Research Model 211 digital pH meter. Transparency was determined with a Secchi disc. Temperature was immediately measured *in situ* using a standard thermometer (100°C) and CO_2, HCO_3^- and CO_3^{2-} were determined *in situ* by titration with HCl; dissolved oxygen *in situ* by the Winkler method; NO_2^-; PO_4^{3-}; SiO_2 (*Standard Methods*, 1980); SO_4^{2-} (Merck, 1980); NO_3^- (Caron and Raquet, 1963) *in situ* spectrophotometrically by Spectronic 21 Spectrophotometer (1 cm fused silica cell, no. 1102227H, USA), Cl^- by $Hg(NO_3)_2$ method (Vogel, 1982); Ca^{2+} and Mg^{2+} titrimetrically by EDTA (Welcher, 1965); Fe by atomic absorption spectrophotometry, Pye Unicam Sp 1900; TDS by filtering 1 *ℓ* water and drying; and organic matter by chromic acid digestion.

Clustering analysis

There are two statistical classification methods, i.e. the divisive clustering method and the classical clustering method. The main difference between classical classification and clustering is that the former refers mainly to predefined classes, while clustering is an aid to identify these classes and uses the divisive clustering method belonging to the hierarchical classification methods. It depends on an initial cluster being subdivided into 2 groups, each group being further subdivided into smaller and smaller clusters. In the clustering method, chemical concentrations of 12 constituents (i.e. variables) of water samples were tested to identify classes according to the water quality. The first step in clustering analysis is data standardisation before applying clustering models. One of the methods used is the Z-transformation technique which depends on subtracting the mean value of each variable and dividing the results by the standard deviation equations:

$$Z(ij) = \frac{X(ij) - X(j)}{S(j)} \qquad (1)$$

$$S(j) = \sqrt{1/(n-1)\,[X(ij) - X(j)]^2} \qquad (2)$$

The next step for classification is to determine the dissimilarity between the objects found by determining the Euclidean distance. The Euclidean distance can be evaluated by applying the following equation:

$$d(i,l) = Z(ij) - Z(l,j) \qquad (3)$$

Results and discussion

Results of physical, chemical, statistical (r, SD and SE) and divisive clustering analyses are reported in Tables 1 to 9 and represent graphically in Figs. 2 to 14. The figures show the vertical and horizontal variations in phosphate, sulphate, chloride, Ca, Mg, total hardness, bicarbonate, organic matter, dissolved oxygen, total dissolved solids, pH and nitrate values (Figs. 2 to 13) and clustering dendrographs (Fig. 14). Figures 8 to 14 show box-and-whisker plots of the Nile and drinking water of Aswan, Quena, Sohag, Assiut, El Menya, Beni Suef and Giza during January, June and August 1987, for the analysed constitutents.

There was little change in the water temperature, either vertically or horizontally, and thermal stratification was absent during January (15 to 20°C) but during June, the temperature increased vertically with depth and horizontally with distance (20,5 to 27,5°C). In August, the temperature showed slight vertical and horizontal decreases in both depth and distance (23,5 to 27,5°C). Increased surface water temperature may have been due to the effect of the absorption of sunlight and abundance of solid particles floating on the water, whereby heat was absorbed more rapidly than by the water itself. These particles radiated the heat again to the surrounding water medium (Husseiny, 1967). The drinking-water (from filters, artesian wells and mixed water) temperature was in the range 16 to 26; 22 to 31 and 25 to 31°C during January, June and August, respectively. The higher temperature may be explained on the basis that the water from deep wells comes from different sources and this agrees well with the fact that the temperature of water increases with increasing depth. In addition, direct sunlight on water pipes increases the water temperature.

Transparency decreased regularly along the distance between Aswan and Giza, while it showed a sharp drop at Sibaiya during the study period.

The sharp decrease in transparency at Sibaiya may be ascribed to the effect of phosphate dust falling from phosphate jaw crushers which caused turbidity to water during the charging and transportation of phosphate ores by ships. Here, the jaw crusher of El Nassr company phosphate mines is very close to the Nile River. The dissolved oxygen values were in the range 7,6 to 9,36; 2,4 to 6,2; and 1,28 to 5,32 mg/*ℓ* for surface and bottom water, during January, June and August, respectively. However, the oxygen values increased with distance between Aswan and Giza. Increased dissolved oxygen content in January may be related to the decrease in temperature, leading to a dissolution of a great amount of atmospheric oxygen in the water (Hurst, 1950), while a decrease in dissolved oxygen may be attributed to the breakdown of organic matter by biological organisms which use up oxygen from the water and may be due to the effect of high temperatures during June and August. The dissolved oxygen content of drinking water was in the range 1,20 to 9,92 mg/*ℓ* in January, June and August, 1987. CO_2 contents of Nile River and drinking-water samples were in the range 1,76 to 7,92; 0,88 to 6,16 and 0,88 to 10,6 mg/*ℓ*, and 1,76 to 24,64; 1,76 to 10,56 and 0,88 to 10,56 mg/*ℓ* in January, June and August. However, it decreased from south to north. An increase in CO_2 in January at Abu El Riesh, Kom Ombo, Edfu, and El Sibaiya, in June at Sohag, and in August beyond the Isis Hotel, beyond the Kima Drain-Nile River confluence, Qena (bottom), Sohag (bottom), Assiut, El Menya (surface), Beni Suef (surface) and Giza may be related to the respiration of dense growths of aquatic weeds. Lower free CO_2 values may be attributed to its consumption as a

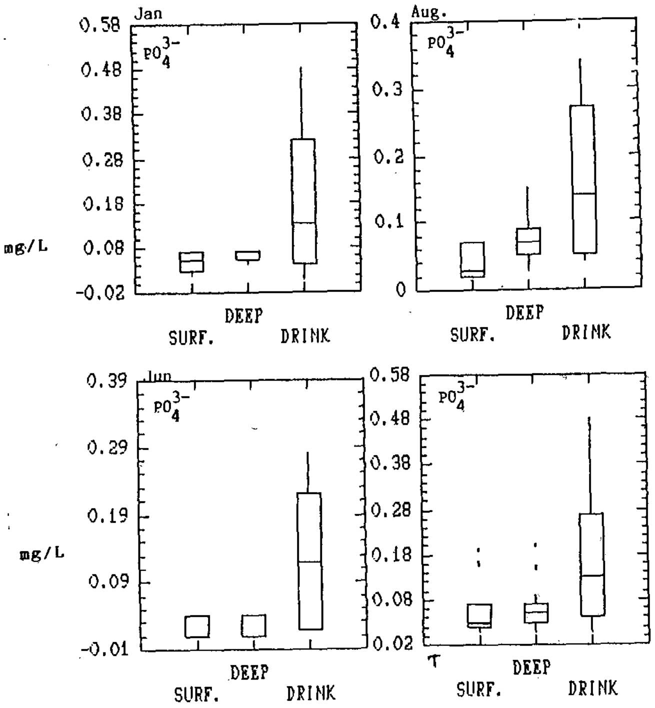

Figure 2
Box-and-whisker plots for phosphate concentrations in surface and deep water of the Nile River and in drinking water

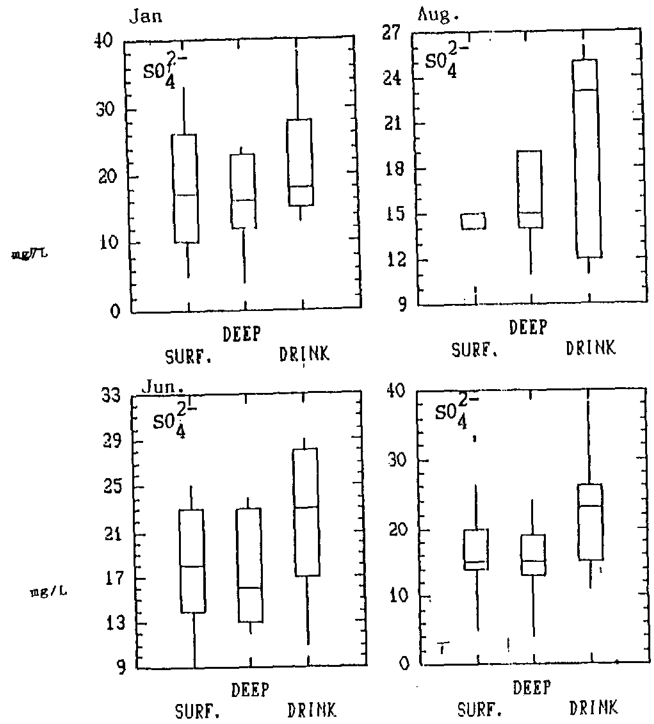

Figure 3
Box-and-whisker plots of sulphate concentrations of surface and deep water of the Nile River and of drinking water

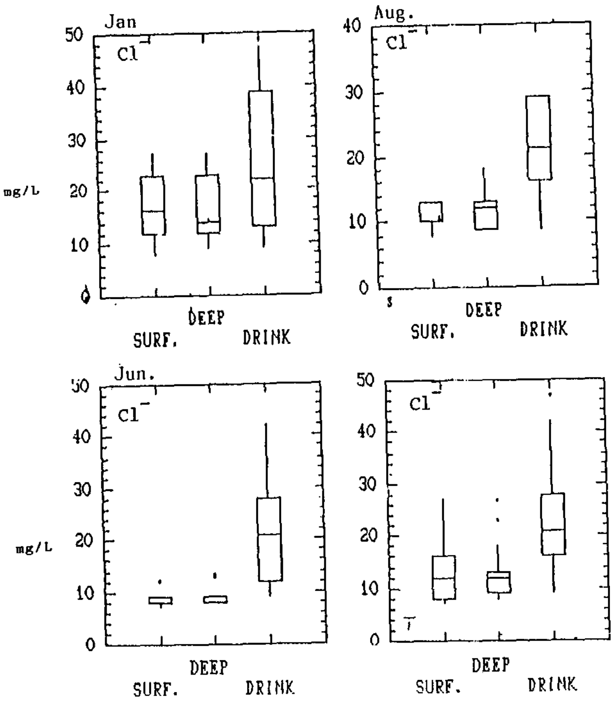

Figure 4
Box-and-whisker plots of chloride concentrations of surface and deep water of the Nile River and of drinking water

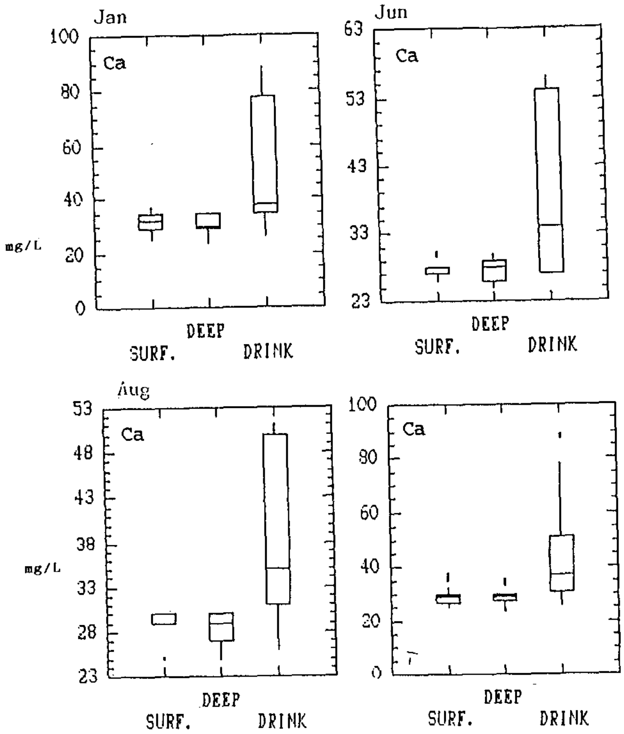

Figure 5
Box-and-whisker plots of calcium concentrations of surface and deep water of the Nile River and of drinking water

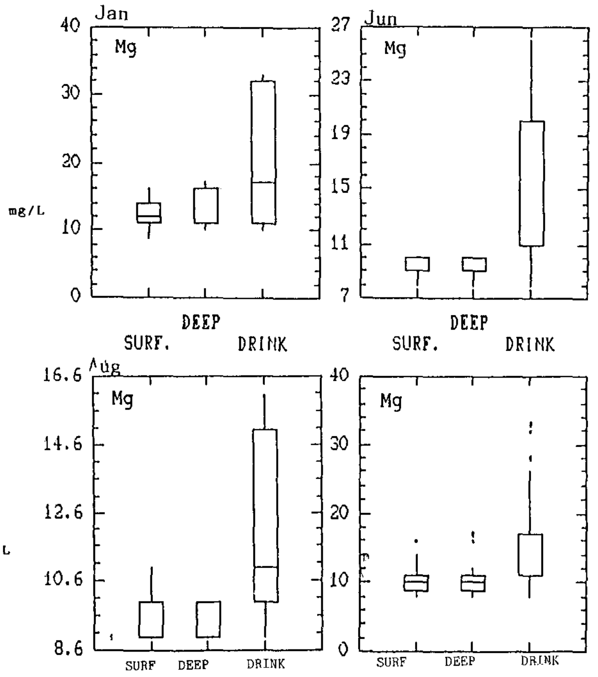

Figure 6
Box-and-whisker plots of magnesium concentrations of surface and deep water of the Nile River and in drinking water

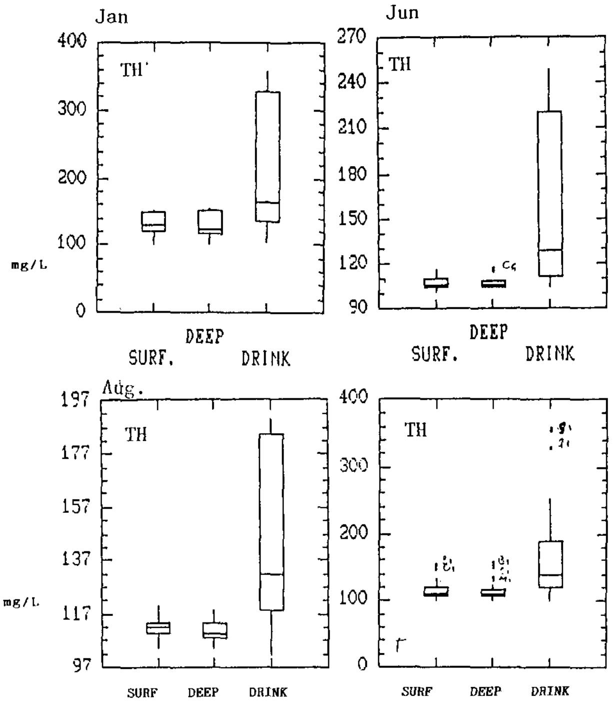

Figure 7
Box-and-whisker plots of total hardness (TH) in surface and deep water of the Nile River and in drinking water

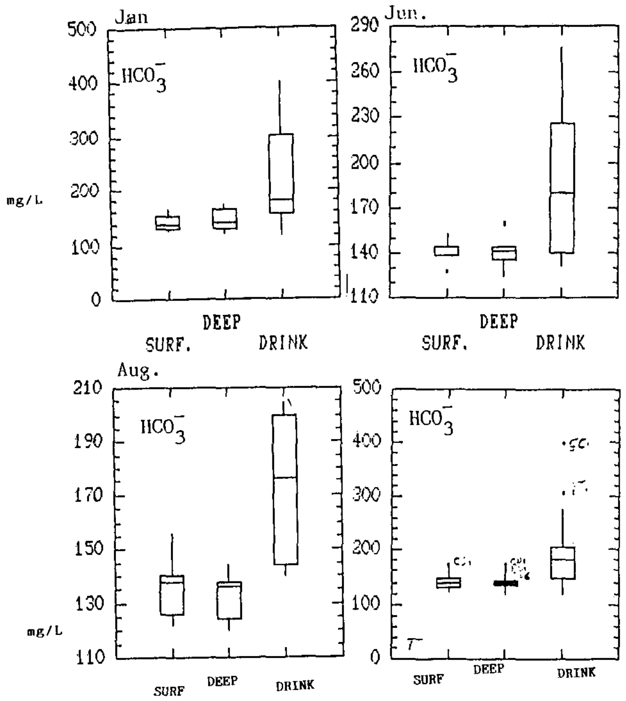

Figure 8
Box-and-whisker plots of bicarbonate concentrations in surface and bottom water of the Nile River and in drinking water

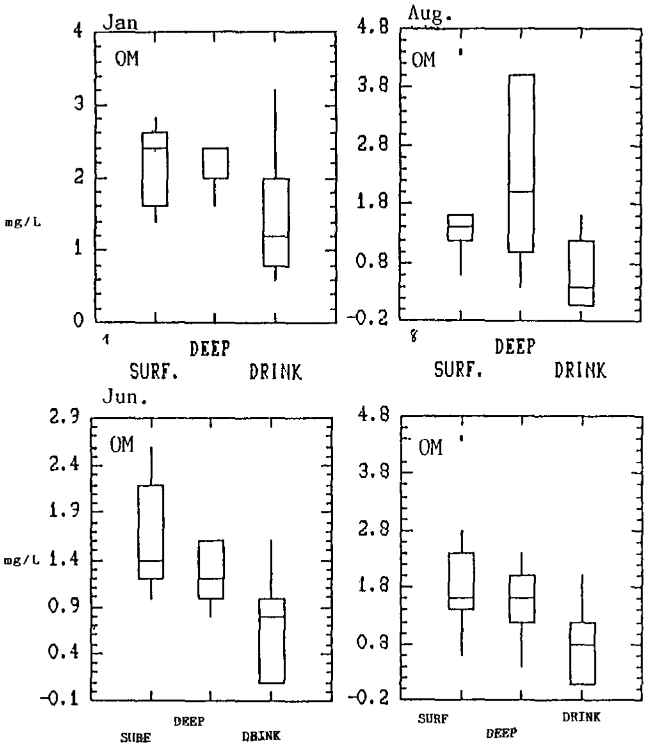

Figure 9
Box-and-whisker plots of organic matter contents in surface and deep water of the Nile River and in drinking water

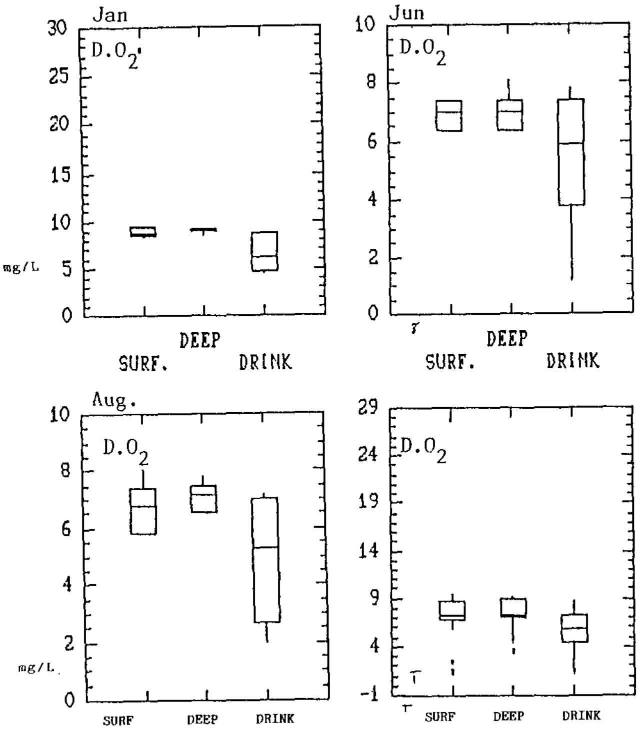

Figure 10
Box-and-whisker plots for dissolved oxygen contents in surface and deep water of the Nile River and in drinking water

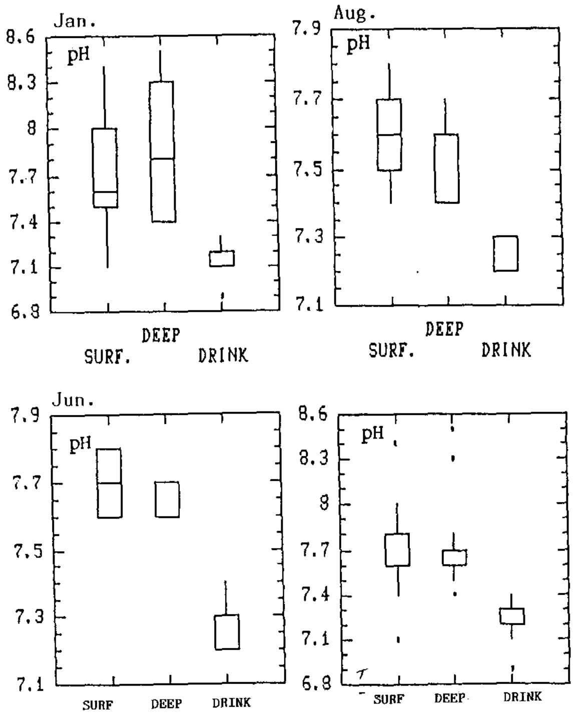

Figure 12
Box-and-whisker plots for pH measurements in surface and bottom water samples of the Nile River and in drinking water

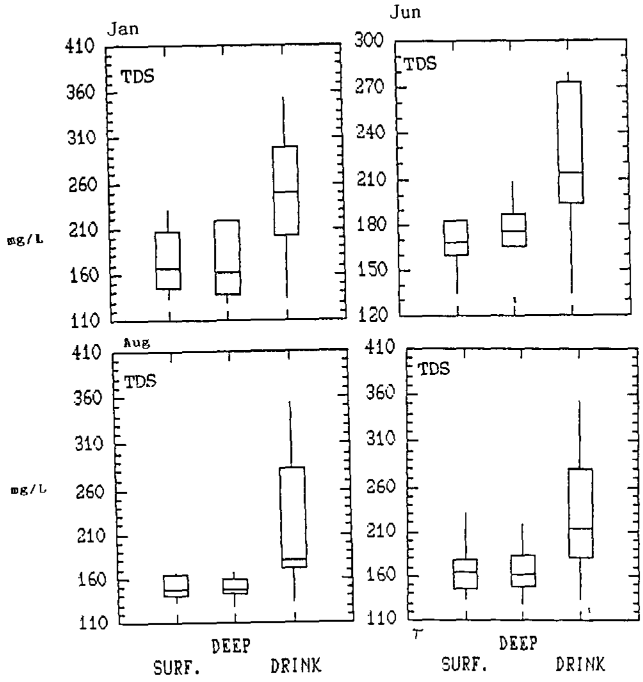

Figure 11
Box-and-whisker plots for total dissolved solids concentration in surface and bottom water of the Nile River and in drinking water

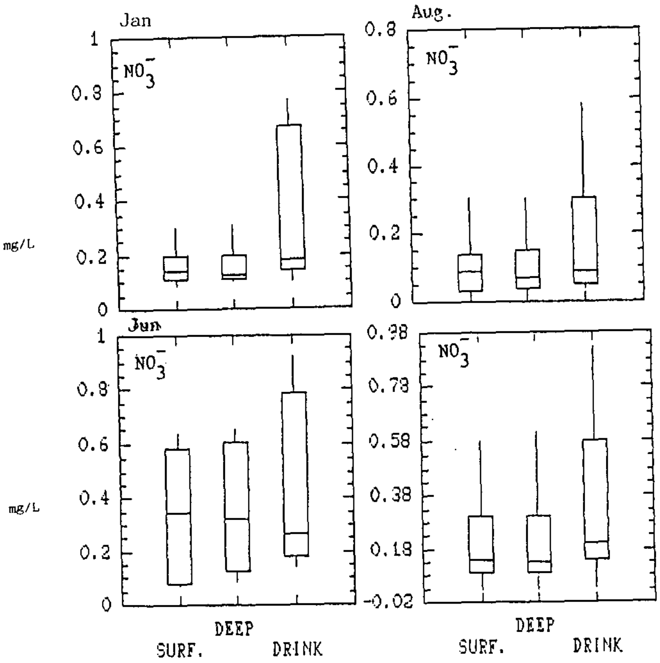

Figure 13
Box-and-whisker plots for nitrate concentrations in surface and deep water samples of the Nile River and in drinking water

TABLE 3
RESULTS OF CHEMICAL ANALYSIS OF NILE RIVER WATER SAMPLES COLLECTED FROM QENA TO GIZA GOVERNORATES DURING JANUARY 1987

Locality	**Qena**		**Sohag**		**Assiut**		**El Menya**		**Beni Suef**		**Giza**				
Depth (m)	**0**	**4**	**0**	**4**	**0**	**4**	**0**	**4**	**0**	**4**	**0**	**4**	**Mean**	**SD**	**SE**
T, °C	20	20	19	19,4	18	18,5	17	18	15,5	17	15	16	17,28	1,130	0,292
D.O_2, mg/ℓ	8,96	8,56	8,8	8,88	8,16	9,20	9,36	9,04	8,64	9,04	8,48	9,12	8,656	0,296	0,077
Free CO_2, mg/ℓ	1,76	0,88	0,0	0,0	1,76	0,0	0,88	6,16	2,64	0,0	1,70	2,46	3,131	1,83	0,472
CO_3^{2-} as $CaCO_3$, mg/ℓ	0,0	0,0	8	12	0,0	4	0,0	0,0	0,0	4	0,0	0,0	1,200	2,713	0,700
HCO_3^- as $CaCO_3$, mg/ℓ	132	140	132	132	146	144	152	156	164	164	172	172	137,51	14,358	3,707
pH	7,5	7,5	8,4	8,45	7,96	8,3	7,6	7,4	7,9	8,31	7,5	7,4	7,428	0,428	0,111
NO_2^-, mg/ℓ	0,013	0,008	0,010	0,004	0,010	0,010	0,005	0,008	0,010	0,040	0,021	0,018	0,017	0,024	0,006
NO_3^-, mg/ℓ	0,20	0,20	0,14	0,10	0,15	0,13	0,12	0,11	0,11	0,16	0,09	0,11	0,212	0,073	0,019
PO_4^{3-}, mg/ℓ	0,25	0,50	0,20	0,040	0,050	0,050	0,070	0,060	0,070	0,065	0,070	0,070	0,077	0,084	0,022
Ca^{2+}, mg/ℓ	28,85	28,85	30,46	28,85	32,06	30,46	32,06	33,66	35,27	35,27	36,9	35,27	28,411	3,778	0,975
Mg^{2+}, mg/ℓ	11,67	10,7	10,7	10,7	12,67	11,67	11,67	10,7	15,56	16,54	13,61	15,56	11,121	1,837	0,474
TH as $CaCO_3$, mg/ℓ	120	116	120	116	132	124	128	132	152	156	148	152	116,579	16,284	4,204
Cl^-, mg/ℓ	11,7	11,7	15,6	13	15,6	14,27	15,6	15,6	23,4	23,4	27,3	27,3	12,291	5,839	1,508
SO_4^{2-}, mg/ℓ	9,5	11,5	17	12	26	23	25	26	26	19	33,5	24	13,365	7,838	2,024
Fe, mg/ℓ	0,06	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,027	0,038	0,010
Organic matter, mg/ℓ	2,8	2,4	2,6	2	1,6	2,2	2,4	2	2,4	2,4	2,2	2	2,256	1,057	0,273
TDS, mg/ℓ	145	154	150	163	188	211	191	178	208	220	230	320	162,755	27,988	7,227

TABLE 4
RESULTS OF CHEMICAL ANALYSES OF DRINKING-WATER SAMPLES COLLECTED DURING JANUARY 1987

Locality	**Aswan City**										**Centres in Aswan Governorate**			
Sampling points	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
T, °C	18	18	19	18,5	22	19	19	26	24	26	18,5	21	19	19
D.O_2, mg/ℓ	7,28	8,80	9,28	8,88	9,92	8,80	8,88	2	6,56	2,72	8,80	8,24	8,24	8,56
Free CO_2, mg/ℓ	3,52	4,40	4,40	8,80	4,40	4,40	4,40	14,96	16,72	24,64	5,28	12,32	6,16	6,16
CO_3^{2-} as $CaCO_3$, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
HCO_3^- as $CaCO_3$, mg/ℓ	120	120	128	116	124	116	120	252	260	364	124	132	132	136
pH	7,09	7,01	7,12	6,98	7,10	6,90	6,90	6,95	6,85	6,90	7,10	7,22	7,25	7,20
NO_2^-, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,010	0,0	0,0	0,0	0,0
NO_3^-, mg/ℓ	0,79	0,22	0,20	0,24	0,55	0,21	0,67	0,33	0,20	1,4	0,4	0,23	0,28	0,24
PO_4^{3-}, mg/ℓ	0,030	0,010	0,007	0,026	0,007	0,012	0,040	0,055	0,150	0,400	0,055	0,042	0,065	0,040
Ca^{2+}, mg/ℓ	26,45	24,05	25,65	25,65	24,05	24,85	25,65	86,57	72,14	76,95	25,65	27,25	27,25	27,25
Mg^{2+}, mg/ℓ	9,73	10,21	10,21	8,26	10,70	9,73	10,21	28,21	20,42	26,26	11,67	9,73	9,73	10,70
TH as $CaCO_3$, mg/ℓ	106	102	106	100	104	102	104	332	264	300	112	108	108	112
Cl^-, mg/ℓ	9,1	9,1	10,4	7,8	10,4	10,4	9,1	72,65	64,87	80,44	7,8	12,97	11,70	10,4
SO_4^{2-}, mg/ℓ	10,5	7,5	13	9	8	11	15	68,5	55	48	8	8,5	8	13
Fe, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,36	0,36	0,0	0,0	0,0	0,0	0,0
Organic matter, mg/ℓ	1,2	2	2	2	1,2	2,4	2	0,8	1,2	1,6	2	2,8	3,6	2
TDS mg/ℓ	130	156	125	135	162	135	134	475	425	505	140	162	160	155

11 = Abu El Riesh, 12= Kom Ombo, 13 = Edfu, 14 = Sibaiya filters

TABLE 5
RESULTS OF CHEMICAL ANALYSIS OF DRINKING-WATER SAMPLES COLLECTED DURING JANUARY 1987

Locality	Qena	Sohag	Assiut	El Menya	Beni Suef	Giza	Mean	SD	SE
T, °C	21	20	20	16	19	18	20,050	2,573	0,575
D.O$_2$, mg/ℓ	8,4	4,48	4,8	6,16	8,80	8	7,380	2,177	0,487
Free CO$_2$, mg/ℓ	1,76	4,4	4,4	15,84	4,4	2,64	7,700	5,856	1,310
CO$_3^{2-}$ as CaCO$_3$, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,000	0,000	0,000
HCO$_3^-$ as CaCO$_3$, mg/ℓ	304	400	180	248	168	156	185,00	86,189	19,373
pH	7,2	7,15	7,3	7,1	7,1	7,2	7,081	0,128	0,029
NO$_2^-$, mg/ℓ	0,050	0,050	0,240	0,011	0,008	0,010	0,018	0,053	0,012
NO$_3^-$, mg/ℓ	0,77	0,18	0,14	0,18	0,20	0,10	0,376	0,309	0,069
PO$_4^{3-}$, mg/ℓ	0,28	0,32	0,48	0,13	0,04	0,01	0,110	0,139	0,031
Ca^{2+}, mg/ℓ	78,55	88,18	35,27	54,5	36,9	38,5	42,566	23,152	5,177
Mg^{2+}, mg/ℓ	32,10	33,07	14,60	28,21	10,70	16,54	16,050	8,356	1,869
TH as CaCO$_3$, mg/ℓ	328	356	148	252	136	164	172,200	90,915	20,329
Cl$^-$, mg/ℓ	46,80	18,20	13	27,30	22,08	39	24,676	22,728	5,082
SO$_4^{2-}$, mg/ℓ	27	13	17	28	18	38	21,200	17,273	3,862
Fe, mg/ℓ	0,0	0,0	0,0	0,0	0,0	0,0	0,036	0,108	0,024
Organic matter, mg/ℓ	0,8	1,2	0,8	0,6	1,6	3,2	1,750	0,797	0,178
TDS, mg/ℓ	353	300	202	285	250	213	230,100	118,288	26,450

TABLE 6
CORRELATION COEFFICIENT VALUES OF NILE RIVER WATER SAMPLES, JANUARY 1987

	T,°C	D.O$_2$	CO$_2$	CO$_3^{2-}$	HCO$_3^-$	pH	NO$_2^-$	NO$_3^-$	PO$_4^{3-}$	Ca	Mg	TH	Cl$^-$	SO$_4^{2-}$	Fe	OM	TDS
T,°C	1,0	-0,084	-0,387	0,412	-0,273	0,400	-0,400	-0,047	0,668	-0,125	-0,214	-0,167	-0,235	-0,126	0,80	-0,021	-0,246
D.O$_2$		1,00	-0,225	0,222	0,428	0,358	-0,651	-0,522	0,220	0,526	0,297	0,460	0,444	0,422	0,066	-0,190	0,364
CO$_2$			1,00	-0,521	-0,087	-0,560	0,159	0,371	-0,455	-0,203	-0,347	-0,271	-0,242	-0,137	-0,285	-0,461	-0,171
CO$_3^{2-}$				1,00	0,138	0,892	-0,040	-0,505	0,087	0,334	0,263	0,316	0,290	-0,308	-0,009	0,254	0,454
HCO$_3^-$					1,00	0,454	0,122	-0,733	0,026	0,955	0,856	0,961	0,962	0,919	-0,512	0,156	0,939
pH						1,00	-0,033	-0,729	0,224	0,629	0,535	0,618	0,578	0,603	-0,433	0,035	0,559
NO$_2^-$							1,00	0,135	-0,170	-0,027	0,112	0,038	0,029	0,081	-0,433	0,460	0,025
NO$_3^-$								1,00	-0,202	-0,852	-0,595	-0,787	-0,790	0,848	0,556	0,045	-0,773
PO$_4^{3-}$									1,00	0,140	0,084	0,120	0,083	0,024	0,240	0,00	-0,055
Ca										1,00	0,808	0,966	0,962	0,939	-0,501	0,136	0,918
Mg											1,00	0,931	0,883	0,704	-0,273	-0,123	0,875
TH												1,00	0,972	0,886	-0,432	0,031	0,943
Cl$^-$													1,00	0,886	-0,476	0,098	0,930
SO$_4^{2-}$														1,00	-0,648	0,189	0,916
Fe															1,00	-0,534	-0,527
TOM																1,00	-0,042

TABLE 7
CORRELATION COEFFICIENT VALUES OF NILE RIVER WATER SAMPLES, JUNE 1987

	T,°C	D.O_2	CO_2	CO_3^{2-}	HCO_3^-	pH	NO_2^-	NO_3^-	PO_4^{3-}	Ca	Mg	TH	Cl^-	SO_4^{2-}	Fe	OM	TDS
T,°C	1,00	0,909	0,596	-0,108	0,745	0,061	-0,791	-0,256	-0,525	0,372	0,462	0,532	0,592	0,841	-0,200	0,098	0,571
D.O_2		1,00	0,502	0,043	0,579	0,185	-0,721	-0,114	-0,475	0,421	0,279	0,473	0,562	0,738	-0,102	0,152	0,513
CO_2			1,00	-0,626	0,660	-0,517	-0,495	-0,416	-0,356	0,285	0,163	0,341	0,373	0,637	-0,218	-0,094	0,480
CO_3^{2-}				1,00	-0,320	0,876	0,005	0,574	0,070	0,269	0,125	0,250	0,277	-0,208	-0,031	0,470	0,041
HCO_3^-					1,00	-0,112	-0,794	-0,307	-0,522	0,563	0,541	0,696	0,747	0,915	-0,253	-0,030	0,664
pH						1,00	-0,207	0,666	-0,065	-0,209	0,108	0,205	0,365	-0,080	0,001	0,264	0,050
NO_2^-							1,00	0,059	0,689	-0,491	-0,362	-0,572	-0,666	-0,737	0,210	0,132	-0,611
NO_3^-								1,00	0,187	-0,159	0,078	-0,087	-0,109	-0,363	-0,037	0,332	-0,138
PO_4^{3-}									1.00	-0,298	-0,127	-0,301	-0,395	-0,376	0,020	0,086	-0,203
Ca										1,00	-0,202	0,872	0,745	0,579	-0,212	0,227	0,561
Mg											1,00	0,653	0,624	0,609	-0,334	0,447	0,722
TH												1,00	0,893	0,760	-0,351	0,396	0,802
Cl^-													1,00	0,734	-0,140	0,429	0,726
SO_4^{2-}														1,00	-0,280	0,066	0,803
Fe															1,00	-0,139	-0,297
OM																1,00	0,127
TDS																	1,00

TABLE 8
CORRELATION COEFFICIENT VALUES OF NILE RIVER WATER SAMPLES, AUGUST 1987

	T,°C	D.O_2	CO_2	CO_3^{2-}	HCO_3^-	pH	NO_2^-	NO_3^-	PO_4^{3-}	Ca	Mg	TH	Cl^-	SO_4^{2-}	Fe	OM	TDS
T,°C	1,00	0,915	0,34	0,00	0,632	0,541	-0,289	-0,246	-0,162	0,708	0,715	0,848	0,781	0,834	0,323	-0,239	0,708
D.O_2		1,00	0,427	0,00	0,569	0,678	-0,150	-0,153	-0,304	0,633	0,837	0,878	0,727	0,839	0,363	-0,089	0,665
CO_2				1,00	0,354	-0,066	0,604	0,305	-0,159	-0,070	0,700	0,356	0,445	0,221	0,469	0,612	0,455
CO_3^{2-}						0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HCO_3^-					1,00	0,192	-0,197	-0,346	-0,131	0,677	0,702	0,833	0,939	0,773	0,159	-0,117	0,756
pH						1,00	-0,397	-0,097	-0,268	0,668	0,347	0,607	0,347	0,634	-0,165	-0,139	0,414
NO_2^-							1,00	0,744	-0,051	-0,620	0,127	-0,291	-0,210	-0,385	0,408	0,794	-0,060
NO_3^-								1,00	-0,259	-0,301	-0,152	-0,276	-0,230	-0,197	0,360	0,794	0,130
PO_4^{3-}									1,00	-0,137	-0,277	-0,251	-0,245	-0,381	-0,381	-0,093	-0,472
Ca										1,00	0,404	0,835	0,761	0,897	-0,102	-0,307	0,713
Mg											1,00	0,837	0,770	0,708	0,358	0,118	0,634
TH												1,00	0,915	0,958	0,154	-0,127	0,804
Cl^-													1,00	0,893	0,246	-0,014	0,891
SO_4^{2-}														1,00	0,218	-0,150	0,857
Fe															1,00	0,252	0,293
OM																1,00	0,215
TDS																	1,00

TABLE 9
CORRELATION COEFFICIENT VALUES OF NILE RIVER WATER SAMPLES, JANUARY 1987

	T,°C	D.O$_2$	CO$_2$	CO$_3^{2-}$	HCO$_3^-$	pH	NO$_2^-$	NO$_3^-$	PO$_4^{3-}$	Ca	Mg	TH	Cl$^-$	SO$_4^{2-}$	Fe	OM	TDS
T,°C	1,00	-0,602	0,611	0,00	0,516	-0,386	0,023	0,452	0,361	0,621	0,416	0,552	0,780	0,699	0,641	-0,277	0,769
D.O$_2$		1,00	-0,630	0,00	-0,732	0,169	-0,321	-0,258	0,635	0,765	-0,696	-0,749	-0,700	-0,704	-0,475	0,453	-0,784
CO$_2$				1,00	0,477	-0,467	-0,188	0,351	0,283	0,488	0,390	0,458	0,699	0,641	0,463	-0,206	0,699
CO$_3^{2-}$					0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HCO$_3^-$						-0,111	0,184	0,326	0,723	0,943	0,930	0,951	0,695	0,565	0,275	-0,503	0,839
pH						1,00	0,452	-0,311	0,170	-0,203	-0,053	-0,149	-0,392	-0,412	-0,470	-0,170	-0,339
NO$_2^-$							1,00	-0,126	0,740	0,105	0,154	0,125	-0,056	-0,040	-0,116	-0,345	0,045
NO$_3^-$								1,00	0,325	0,254	0,228	0,246	0,406	0,197	-0,120	-0,210	0,368
PO$_4^{3-}$									1.00	0,581	0,602	0,596	0,392	0,257	-0,023	-0,471	0,531
Ca										1,00	0,944	0,992	0,810	0,743	0,530	-0,533	0,916
Mg											1,00	0,978	0,687	0,621	-0,330	-0,507	0,810
TH												1,00	0,744	0,706	0,461	-0,554	0,888
Cl$^-$													1,00	0,944	0,647	-0,322	0,954
SO$_4^{2-}$														1,00	0,783	-0,342	0,881
Fe															1,00	-0,314	0,620
OM																1,00	-0,480
TDS																	1,00

TABLE 10
CORRELATION COEFFICIENT VALUES OF NILE RIVER WATER SAMPLES, JUNE 1987

	T,°C	D.O$_2$	CO$_2$	CO$_3^{2-}$	HCO$_3^-$	pH	NO$_2^-$	NO$_3^-$	PO$_4^{3-}$	Ca	Mg	TH	Cl$^-$	SO$_4^{2-}$	Fe	OM	TDS
T,°C	1,00	-0,569	0,315	-0,324	0,578	-0,516	-0,044	0,203	0,402	0,616	0,491	0,584	0,595	0,768	-0,044	-0,290	0,599
D.O$_2$		1,00	-0,362	0,196	-0,796	0,513	-0,237	-0,220	-0,798	-0,765	-0,759	-0,777	-0,677	-0,573	-0,004	-0,564	-0,738
CO$_2$			1,00	-0,367	0,665	-0,467	-0,203	0,054	0,585	0,573	0,667	0,617	0,552	0,410	0,250	0,329	0,606
CO$_3^{2-}$				1,00	-0,186	0,792	0,208	-0,219	-0,185	-0,146	-0,164	-0,155	-0,145	-0,163	0,118	0,445	-0,144
HCO$_3^-$					1,00	-0,519	0,114	0,354	0,897	0,968	0,960	0,983	0,918	0,755	0,229	-0,428	0,973
pH						1,00	-0,105	-0,106	-0,488	-0,464	-0,470	-0,475	-0,443	-0,471	0,266	0,652	-0,460
NO$_2^-$							1,00	-0,434	0,322	-0,024	0,126	0,027	-0,128	-0,231	-0,329	-0,025	-0,038
NO$_3^-$								1,00	0,239	0,401	0,248	0,365	0,457	0,471	0,375	-0,134	0,417
PO$_4^{3-}$									1.00	0,852	0,864	0,872	0,752	0,508	0,240	-0,359	0,838
Ca										1,00	0,918	0,991	0,965	0,839	0,313	-0,385	0,993
Mg											1,00	0,964	0,875	0,652	0,226	-0,425	0,928
TH												1,00	0,952	0,790	0,289	-0,406	0,989
Cl$^-$													1,00	0,878	0,417	-0,360	0,978
SO$_4^{2-}$													1,00	1,00	0,221	-0,364	0,837
Fe															1,00	0,309	0,342
OM																1,00	-0,372
TDS																	1,00

TABLE 11
CORRELATION COEFFICIENT VALUES OF NILE RIVER WATER SAMPLES, AUGUST 1987

	T,°C	D.O$_2$	CO$_2$	CO$_3^{2-}$	HCO$_3^-$	pH	NO$_2^-$	NO$_3^-$	PO$_4^{3-}$	Ca	Mg	TH	Cl$^-$	SO$_4^{2-}$	Fe	OM	TDS
T,°C	1,00	-0,316	0,296	0,00	0,414	-0,418	0,246	0,417	0,386	0,491	0,520	0,494	0,500	0,453	0,281	-0,052	0,471
D.O$_2$		1,00	-0,601	0,00	-0,519	0,235	-0,168	0,106	-0,535	-0,551	-0,483	-0,558	-0,536	-0,439	-0,778	0,191	-0,524
CO$_2$			1,00	0,00	0,583	-0,286	0,294	-0,004	0,468	0,638	0,578	0,639	0,612	0,556	0,719	-0,099	0,620
CO$_3^{2-}$				1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HCO$_3^-$					1,00	-0,482	0,235	0,157	0,891	0,980	0,568	0,974	0,964	0,951	0,570	-0,372	0,981
pH						1,00	-0,154	-0,137	-0,454	-0,462	-0,275	-0,468	-0,474	-0,381	-0,259	0,397	-0,472
NO$_2^-$							1,00	0,070	0,451	0,272	0,020	0,265	0,162	0,139	0,481	0,413	0,219
NO$_3^-$								1,00	0,262	0,180	-0,052	0,154	0,112	0,212	-0,177	0,295	0,187
PO$_4^{3-}$									1,00	0,872	0,328	0,860	0,804	0,787	0,639	-0,158	0,864
Ca										1,00	0,671	0,998	0,976	0,962	0,571	-0,325	0,988
Mg											1,00	0,705	0,698	-0,694	0,304	-0,307	0,622
TH												1,00	0,979	0,964	0,566	-0,343	0,984
Cl$^-$													1,00	0,976	0,541	-0,418	0,984
SO$_4^{2-}$														1,00	0,443	-0,331	0,969
Fe															1,00	-0,076	0,544
OM																1,00	-0,343
TDS																	1,00

result of the reaction between free CO_2 produced within the water body and $CaCO_2$ in the sediments and transferred into water as $Ca(HCO_3)_2$ and photosynthetic production of oxygen, hydrocarbons and carbohydrates by utilisation of CO_2. Carbonates are absent except in January at Sohag, Assiut (bottom) and Beni Suef (bottom) where the Nile showed abnormal values. This may be because the Nile River is close to limestone mountains present in these places. However, the drinking water is carbonate-free. Bicarbonate showed horizontal and vertical increases from south to north. The increase in bicarbonate may be ascribed to dissociation of H_2CO_3 into HCO_3^- and H^+, and the reaction between CO_2 and OH to produce HCO_3^- (Kern, 1960). The relative decrease in HCO_3^- may be attributed to the uptake of combined CO_2 into HCO_3^- by algae and CO_2-H_2O interaction during the photosynthetic processes (Klein, 1973), and sedimentation of dissolved bicarbonates on the surface of suspended particles (Morel, 1983).

There was a slight horizontal and a slight vertical increase in pH values from the south to the north. This increase may be related to photosynthesis and growth of aquatic plants (Allem and Samaan, 1969; El Wakeel and Wahby, 1970) particularly in Sohag, Assiut, El Menya and Beni Suef, or may be attributed to industrial effluents being discharged into the river, while the pH of drinking water is the same. Nile River water in Aswan Governorate is nitrite-free while it showed low figures in Qena-Giza. The absence or decrease of nitrite may be principally due to the increase of its oxidation rate to nitrate and reduction of nitrate to ammonia as well as its uptake by plankton. However, the drinking water was nitrite-free. Nitrate decreased horizontally and vertically from the south to the north. However, Nile River water of Aswan Governorate showed slightly high nitrate concentrations. The slight increase in nitrate concentrations may be ascribed to nitrification of NH_3 and NO_2^- produced by the biochemical decomposition of descending dead plankton into nitrate by nitrifying bacteria, and transformation of organic nitrogen to ammonia and nitrifying ammonia to nitrate. The decrease in nitrate concentration in January and August may be attributed to biological uptake in the photic zone and recycling from the hypolimnion (Goldman and Horn, 1983). The high nitrate concentrations in drinking water may be due to the fact that water from artesian wells is also used for drinking purposes. Horizontal and vertical distribution of phosphate showed a smaller decrease in January than in June and in August. The decreased phosphate concentration may be attributed to the higher rate of decay of phytoplanktons and release of the adsorbed phosphate from the sediment of the Nile River bed. On the other hand, the increase of phosphate was consistent with low pH and dissolved oxygen. The decrease and depletion of phosphate may be related to its adsorption on hydrous Fe_2O_3 and Al_2O_3, its consumption by algae, bacteria or aquatic weeds (Kramer et al., 1972; Harvey, 1955). Chloride showed horizontal increases and vertical decreases in January, June and in August. However, the highest values were reached in January. This may be related to some biological assimilation processes. Drinking water showed high concentrations of chloride, particularly water taken from Aswan wells. High chloride concentrations in drinking water may result from the chlorine added as a disinfection agent. Also, sulphate concentrations increased horizontally and decreased vertically from the south to the north. Increased sulphate concentrations may result from industrial effluents discharged into the river while the relative decrease of sulphate concentrations in bottom water may be attributed to reduction into sulphide as a result of the considerable effect of

TABLE 12
SUMMARY OF THE DENDROGRAPH OBTAINED BY CLUSTERING ANALYSIS

Cluster	Symbol	Indication			Month
1	ST1	Sohag	-	drinking w.	Jan
	ST6				June
	QT1	Qena	-	drinking w.	Jan.
	QT6				June
	MT1	El Menya	-	drinking w.	Jan.
2	SD1	Sohag	-	deep w.	Jan.
	SS1		-	surf. w.	
	AD1	Assiut	-	deep w.	
	AS1		-	surf. w.	
	BD1	Beni Suef	-	deep w.	
	BS1		-	surf. w.	
	GD1	Giza	-	deep w.	
	GS1		-	surf. w.	
	MS1	El Menya	-	surf. w.	
	GT1	Giza	-	drinking w.	
3	BT1	Beni Suef	-	drinking w.	Jan
	BT6				June
	AT1	Assiut	-	drinking w.	Jan.
	AT6				June
	MT6	El Menya	-	drinking w.	June
	GT6	Giza	-	drinking w.	June
4	QD6	Qena	-	deep w.	June
	QS6		-	surf. w.	
	ND6	Aswan	-	deep w.	
	NS6		-	surf. w.	
	NT6		-	drinking w.	
	NT1		-	drinking w.	Jan.
5	QD1	Qena	-	deep w.	Jan
	QS1		-	surf. w.	
	ND1	Aswan	-	deep w.	
	NS1		-	surf. w.	
	MD1	El Menya	-	deep w.	
6	SS6	Sohag	-	surf. w.	June
	SD6		-	deep w.	
	AS6	Assiut	-	surf. w.	
	AD6		-	deep w.	
	MS6	El Menya	-	surf. w.	
	MD6		-	deep w.	
	BS6	Beni Suef	-	surf. w.	
	BD6		-	deep w.	
	GS6	Giza	-	surf. w.	
	GD6		-	deep w.	

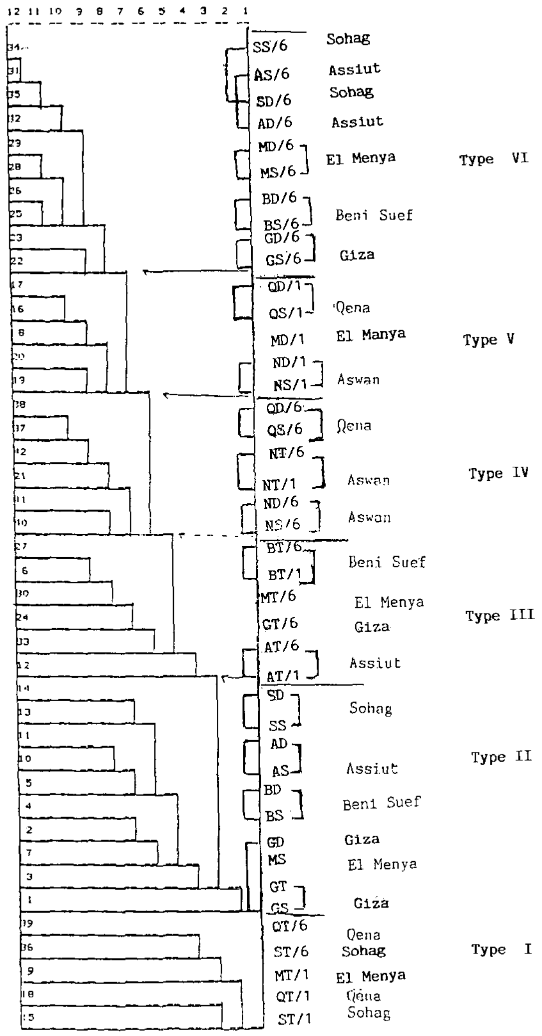

Figure 14
Dendrograph of water samples (clustering by divisive method)

reducing bacteria, protein synthesis and subsequent precipitation of detrital organic matter and its decomposition into H_2S and insoluble sulphides (Beauchamp, 1953). However, drinking water contained higher concentrations of sulphate, particularly those in Aswan City (wells no. 8, 9 and 10), during the study period, but pumping from the wells has now been discontinued due to their undesired water quality. Ca, Mg, TH and TDS showed a horizontal increase and a slight vertical decrease from the south to the north in the Nile River and drinking water during the study period and along the distance Aswan-Giza. However, the highest values were obtained in January. The relative increase of Ca and Mg (TH and TDS) in January may be attributed to the increase in $CaCO_3$ and $MgCO_3$ solubility with the decrease in water temperature, while the relative decrease in Ca and Mg concentration in June and August may be attributed to photosynthetic precipitation of Ca as $CaCO_3$ and Mg as $Mg(OH)_2$, adsorption of Ca on $Mg(OH)_2$, decreasing $CaCO_3$ and $MgCO_3$ solubility as a result of temperature increase and loss of CO_2 [$Mg(HCO_3)_2 \rightarrow MgCO_3+H_2O+CO_2$]. However, Aswan (wells no. 8, 9 and 10), Qena, and Sohag utilised water wells and so water showed higher Ca, Mg, TH and TDS values. Iron and organic matter were very low in both Nile and drinking water.

TABLE 13
COMPARISON OF NILE WATER WITH OTHER STANDARDS

	(1)		(2)	(3)	(4)
Item	**Highest desirable level**	**Maximum permissible level**	**Approximate level above which trouble may arise**	**Approximate level above which trouble may arise**	**Data for Nile River water**
$D.O_2$,mg/ℓ			5	5	2,6 - 12,88
pH	7 - 8,5	6,5 - 9,2		6,5 - 9,2	7,18 - 8,77
Ca^{2+},mg/ℓ	75	200	200	200	23,24 - 38,47
Mg^{2+}, mg/ℓ	30	150	30-125	150	7,30 - 17,02
TH as CaCO, mg/ℓ	100	500	100-500	500	90-162
Cl^-, mg/ℓ	200	600	600	200 - 600	5,83 - 29,16
SO_4^{2-}, mg/ℓ	200	400	250	200 - 400	4,5 - 37,5
NO_3^-, mg/ℓ	45		50 - 100	45	0,04 - 2,86
Cu, mg/ℓ	0,05	1,5	0,05	1	0,002 - 0,022
Zn, mg/ℓ	5	15	5	1	0,002 - 0,028
Fe, mg/ℓ	0,1	1	0,1	1	0,0 - 0,34
Mn, mg/ℓ	0,05	0,5	0,05	0,5	0,006 - 0,087

Legend:
(1) International World Health Organisation
(2) European World Health Organisation
(3) Ministry of Health (A.R.E)
(4) Average values of chemical components of Nile River Water

Statistical analysis

Correlation coefficient values between water quality variables (Tables 7 and 8) were all positive and between 0,41 and 0,989, indicating that the metals determined in Nile River and drinking water exist as significant pairs in soluble form.

Clustering analysis

As indicated on the graphs (Figs. 2 to 13), the middle line inside the box represents the median value and the whiskers extend out to the extreme (minimum and maximum) values. The outliers appear as separate points as the whiskers extend only to points within 1,5 times the interquartile range. The chemical constituents can be divided into 3 groups. The first contains phosphate, sulphate, chloride, calcium, magnesium and total hardness, the values of which are higher in drinking water than in the corresponding values of surface and deep water. Also, the values obtained in January are higher than those in June and August. The second group includes pH, dissolved oxygen and organic matter. These values are lower in the case of drinking water than in Nile water. The third group contains only nitrate. The values are nearly the same in Nile and drinking water. The distribution range between drinking water is much higher than in Nile-water samples. This may be that TDS values are higher due to mixing the underground (well) water with the drinking (filtered water from Nile) water or using well water directly in some governorates. The drinking-water quality at Qena and Sohag is the same in January and June. These samples are completely different. The drinking water in these districts is a mixture of well and filtered water which increases the concentration of the chemical components of the water as shown in Tables 4 to 6 from those of Aswan, Assiut, El Menya, Beni Suef and Giza (most of the outliers belong to these samples). The second class of drinking water includes the samples taken from Assiut, El Menya, Beni Suef and Giza (cluster no. 3). The third class of drinking water contains the water samples collected from Aswan in January and June (cluster no. 4), and Nile-water samples collected from Aswan and Qena in June which indicates that the quality of drinking water of Aswan is very similar to the water quality of the Nile. The Nile-water samples collected from Sohag to Giza were divided into 2 clusters according to the sampling time (clusters no. 2 and 6 for samples collected in January and June 1987). Due to some technical problems, the results of January and June for clustering analysis were included while August was not included. This classification, however, is a promising method for the identification of water samples though it was necessary to employ other statistical methods, e.g. box-and-whisker plots to obtain the valid clustering results and to gain clarity about the distribution of the constituents between the samples.

Conclusion

The water quality (Nile and drinking water) of upper Egypt differs remarkably between individual areas, and the total dissolved salts content in the drinking water (except Aswan) is higher than in the corresponding Nile water. However, the chemical components in Nile and drinking water are within the required safety baseline levels (Table 10). Clustering analysis using Z-transformation and Euclidean distance techniques for the divisive method (Table 8) is a fairly successful technique for sample characterisations.

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