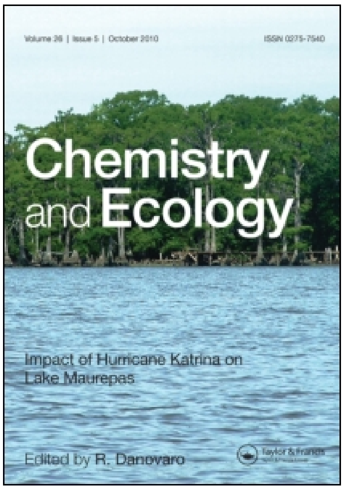

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

Dissolved Ions of Trace and Major Elements and in Suspended Sediments in the Nile, Egypt

Z. R. Komy[a]; A. A. El-samahy[a]
[a] Department of Chemistry, Faculty of Science, Sohag, Egypt

To cite this Article Komy, Z. R. and El-samahy, A. A.(1995) 'Dissolved Ions of Trace and Major Elements and in Suspended Sediments in the Nile, Egypt', Chemistry and Ecology, 11: 1, 25 — 37
To link to this Article: DOI: 10.1080/02757549508039062
URL: http://dx.doi.org/10.1080/02757549508039062

Chemistry and Ecology, 1995, Vol. 11, pp. 25–37
Reprints available directly from the publisher
Photocopying permitted by license only

DISSOLVED IONS OF TRACE AND MAJOR ELEMENTS AND IN SUSPENDED SEDIMENTS IN THE NILE, EGYPT

Z. R. KOMY and A. A. EL-SAMAHY

Department of Chemistry, Faculty of Science, Assiut University, Sohag, Egypt

(Received 17 February 1994; in final form 20 September 1994)

Dissolved ions and suspended particulates from twelve water samples from Sohag (different localities) and Aswan (behind and below the High Dam) areas were collected along the River Nile, upper Egypt, which is at present affected seriously by pressure of population, intense industrial and agricultural activities, and atmospheric fallout. Eighteen trace and nine major ions in solution and fourteen metals in suspension were analyzed to establish whether elements are of anthropogenic or natural origin. Results of this study show that the Nile water was contaminated with high concentrations of dissolved lead, and with copper, nickel and mercury to a lesser extent, suggesting that these contaminants are generated from anthropogenic activities. The other dissolved ions in the Nile are of natural origin because their metal concentrations fall within the range of the normal background and average world dissolved values for inland waters. Results show that the usual constituents of suspended particulates in the Nile seem to be some metals (Cu and Zn) adsorbed on iron and manganese oxide/hydroxide. The results also reveal that most trace and major metal particulates increase from south to north due to activities associated with the dense population living along the Nile banks. No significant differences were observed between the chemical composition of trace and major elements taken on the east and west river Nile banks.

KEY WORDS: Water quality, R. Nile, trace metals, dissolved and suspended materials.

INTRODUCTION

In spite of its vital agricultural and commercial importance, data for the quality of the Nile water are scarce, particularly for dissolved and suspended particulate concentrations of trace and toxic pollutants. However, some sporadic element analyses have been made on water samples collected from the River Nile. Kasperek *et al.* (1982) determined the composition of Nile water samples from the Nile valley and Nile Delta. They observed that the concentration of trace elements (Mn, Cr, Cd and Sb) in the Nile water increased from south to north. Accumulation of copper, zinc, cadmium and lead by aquatic macrophytes was studied by Fayed *et al.* (1985), who determined these metals in water and aquatic plants taken from the River Nile. They found that metal contents of plants collected downstream below the Aswan Dam were higher than those upstream.

The study area has a dense population (~ 3 million in 147,000 ha). It supports mainly agricultural activities with some factories producing cement, petroleum, fertilizer and aluminium in an area 70 km to the north and 50 km to the south of Sohag. This area lies in central Egypt where many factories discharge all their effluent directly to the Nile without treatment (e.g. discharges from production of oil, soft drinks, sugar, food and textile factories) as well as of agricultural activities (e.g. animal wastes, manure, fertilizers, pesticides and eroded soil). Moreover, the influence of atmospheric deposition on the levels of trace metals (particularly Pb, Cu and Cd) is found throughout the hydrological cycle. Murozumi *et al.* (1969) attributed high amounts of lead in the atmosphere to lead emission from automobiles.

The present paper provides data on the distribution of dissolved (major and trace) ions, suspended elements and their mobility within the river ecosystem so as to assess the degree of contamination. Also, the sources of elements measured in the study area are discussed.

METHODS

Sampling and Sample Preparation

12 Nile water samples were collected in August 1989 from different locations at distances ranging from 0.2–2 km from the Cairo-Aswan highway in the Sohag area as illustrated in Figure 1. Seven samples were selected from the west side and three from the east along the River Nile within a length of 120 km. For comparison, two samples

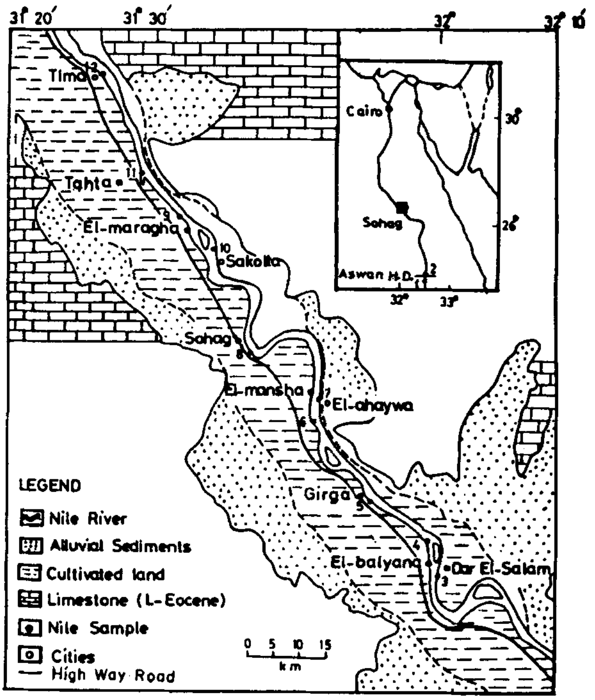

Figure 1 Locations of water sampling sites in the River Nile at Sohag and Aswan areas, Upper Egypt. (N.B: sampling sites 1 and 2 are shown in the upper map, H. D = High Dam).

were taken from Aswan (below and above the high Dam). The samples were collected in polythene bottles pre-cleaned by soaking a week in 1:1 hydrochloric acid, a week in 1:1 nitric acid and a week in bidistilled water to avoid contamination problems (Vos *et al.*, 1986). After collection, the Nile water samples (250 ml) were filtred under air pressure in a Sartorious device SM-16510 (74-mm active diameter) through a 0.45 μm filter to separate out suspended particles. The filtrates were divided into three portions; one was for anion analysis while the two others were acidified with either hydrochloric or nitric acid for major cation and heavy metal determinations. All bottles were kept in the refrigerator until analysis.

Analysis

Zinc, lead and copper were determined directly by differential pulse anodic stripping voltammetery (DPASV) in nitric acid (pH = 1.1) medium. Then pH is adjusted to pH = 9.2 by adding ammonia buffer solution. In this medium nickel was determined after adding dimethylglyoxime (DMG) to give a concentration of 10^{-4} M. A detailed description of the whole procedure is presented by Komy (1993) and also Komy *et al.* (1988). Precision and accuracy of the DPSV procedure is affected mainly by the degree to which contamination, hydrogen overvoltage, oxidation with mercury and decomposition of organic complexes can be restricted. The samples were acidified with nitric acid (pH = 1.1) to overcome all the above problems (Komy, 1993). Lead, copper, and cadmium were determined by using Zeeman Et-AAS, while zinc was measured in acetylene air flame. Trace metals (Co, Sb, As, Hg, Se, Cr, Fe, Mn, V, Sr, Al, Au and U) were determined by neutron activation analysis (NAA).

Calcium and magnesium measurements were performed by atomic absorption spectrometry (AAS), while sodium and potassium were determined by flame emission spectroscopy (FES). The instrument used was a Zeeman Et-AAS.

Sulphate, nitrate and chloride concentrations were determined by using an ion chromatograph DIONEX 4000 i, while fluoride was determined by NAA.

The measurements of pH and bicarbonate were carried out using an Orion pH electrode (Orion Research Inc., Cambridge, MA, USA). A conductivity bridge (Scientific Technical Supplies, Model D-6072, ·W. G.) was used for conductance measurement.

Suspended particulates were characterized by energy dispersive X-ray fluorescence (EDXRF).

All standard solutions of the measured anions and cations were calibrated by diluting Ventron AAS standards 1000 mg l^{-1} or Baker dilute standards. The reagent used for the preparation of solutions were Merck suprapur materials except for ammonia and ammonium chloride for which Baker analytical grade was used. The ultra pure water was prepared in a Millipore Milli-Q Water purification unit.

Analytical Quality Control

Twelve samples containing major ions (including bicarbonate) were measured and the ionic balance was checked. The mean and standard deviation of the ratio of the summation of the measured meq l^{-1} of cations to that of the measured meq l^{-1} of cations is 0.92 ± 1.27. To check the accuracy of DPSV measurement of zinc, lead, copper and nickel, we participated in a laboratory intercomparison with IAEW-4 simulated fresh water. The test portion was analyzed six times for zinc, lead, copper and nickel. The results were 50.7, 24.1, 25.4 and 2.27 $\mu g\,l^{-1}$ for zinc, lead, copper and nickel, respectively, for reference values of 50.0, 25.0, 25.0 and 2.5 $\mu g\,l^{-1}$. The agreement between our results and the recommended values is very satisfactory and to test precision, the test was applied to compare the results obtained by DPSV and AAS; no significant differences were observed ($p = 0.05$, 0.01 and 0.05) for zinc, lead and copper, respectively (Komy, 1993).

RESULTS AND DISCUSSION

Dissolved Trace Elements

In Table I, the mean values, standard deviation and range of concentrations for 18 different major and trace ions in soultion in Nile waters are shown. To our knowledge, no such studies on dissolved trace elements have been reported previously for this region. Hence our results are compared with "normal background" values in fresh water (Förstner and Wittmann, 1981) and average world dissolved (AWD) values (Martin and Meybeck, 1979) to assess the extent of pollution in the Nile, using these background values as guidelines for water quality control and as indicators of the extent and possible consequences of contamination when they are exceeded.

Table I Mean concentration, standard deviation and range of dissolved trace and major elements in Nile waters.

	Concentration of trace elements ($\mu mol\,l^{-1}$)					*Concentration of major ions* ($\mu mol\,l^{-1}$)			
	n	$\bar{x}$	SD	range		n	$\bar{x}$	SD	range
Zn	12	0.205	0.067	0.122 – 0.382	pH*	12	7.67	0.16	7.5 – 8.0
Pb	12	0.105	0.038	0.047 – 0.171	Ec**	12	289	37	200 – 321
Cu	12	0.126	0.038	0.092 – 0.201	HCO_3	12	2.11	0.35	1.51 – 2.72
Ni	12	0.056	0.010	0.036 – 0.070	hardness	12	0.39	0.06	0.31 – 0.49
Co	12	0.004	0.001	0.002 – 0.005	Na	12	0.78	0.09	0.56 – 0.92
Cd	12	0.007	0.003	0.003 – 0.011	K	12	0.12	0.04	0.01 – 0.16
Sb	12	0.002	6E-4	0.002 – 0.003	Ca	12	0.48	0.09	0.37 – 0.65
AS	12	0.032	7E-3	0.027 – 0.040	Mg	12	0.30	0.03	0.25 – 0.34
Hg	12	0.001	0.003	9E-4 – 0.003	SO_4	12	0.15	0.03	0.10 – 0.17
Se	12	0.013	0.009	0.004 – 0.038	Cl	12	0.25	0.05	0.13 – 0.31
Cr	12	0.063	0.026	0.004 – 0.096	F	12	0.03	0.01	0.02 – 0.04
Fe	12	2.78	1.52	0.895 – 4.476	NO_3	12	0.02	0.01	0.006 – 0.033
Mn	12	0.052	0.01	0.037 – 0.055					
V	12	0.136	0.017	0.118 – 0.177					
Sr	10	1.325	0.806	0.342 – 2.853					
Al	10	10.49	6.988	2.222 – 11.11					
Au	12	4.8E-5	1.7E-5	3E-5 – 8.6E-5					
U	12	0.0032	0.001	0.0013 – 0.0059					

SD = standard deviation, $\bar{x}$ = mean value, ** as conductance ($\mu S\,cm^{-1}$),
* as pH units n = no of samples

The results show that the concentrations of trace metals (Pb, Hg, Ni, Cd, Se, V and Cr) in the study area are higher than normal background values with variations extending 10- to 100-fold, while copper, cobalt, zinc and arsenic varied by only 5-fold at most. The results also show that concentrations of lead, nickel and cobalt in the study area are higher than average world dissolved values for surface inland waters, with 21.7, 1.5 and 1.2 times AWD values, respectively, while zinc, copper, antimony and manganese are less than AWD values. Komy (1993) gives concentrations of trace elements in groundwater for lead, cadmium and nickel (0.049, 0.0033 and 0.0052 μmol l^{-1}, respectively). A comparison of data for Nile water (Table I) and published groundwater composition shows that concentrations of lead, cadmium and nickel in the Nile are higher than in groundwater, suggesting that these elements do not move from groundwater to the Nile. These results are also confirmed by study of the hydraulic relationship between the Nile and groundwater. Abdel-Moneim (1992) indicates that, after construction of the Aswan High Dam and the regulation of water levels in the Nile, water supply for irrigation has increased throughout the year, and consequently the groundwater level in the Nile valley aquifer has increased with the result that water drains towards the Nile which has become a water sink (drain) rather than a water source for groundwater. The concentrations of dissolved lead, copper and nickel in the River Nile are high, demonstrating contamination. These high concentrations of dissolved ions may possibly be attributed to motor vehicle exhaust fumes from the Cairo-Aswan highway, agricultural activities, and municipal and industrial effluents. Moreover, the high concentration of lead may be due also to regional atmospheric fallout, while high concentrations of dissolved cadmium and selenium result from a high level of oil combustion, cement production and detergent use.

The distribution of trace ions in the River Nile (Figure 2A & 2B) shows that the level of concentrations of Pb, Cu, Ni, Mn, Se, Cd and Co in the Sohag area is higher than in the Aswan area and is associated with the high population density (~ 3 million in 174,000 ha) of the Sohag area. The quality of Nile River water is possibly affected by the increased discharge of waste waters from agricultural, domestic, industrial effluent and atmospheric fallout. Figure 3 (A & B) shows downstream variations of dissolved trace ions with distance (km), 0 km being the first station below the High Dam. Most of the trace ions increase downstream from south (Aswan) to north (Sohag). This finding is in agreement with the results reported by Kasperek *et al.* (1982). No significant differences were observed between the results of dissolved trace ions in samples taken from east and west Nile banks in the Sohag area.

Major Ions

Table I shows the mean value, standard deviation, and range for 9 major ions in solution, hardness, conductivity and pH values measured in the study area. Since no data have been published previously, our results are compared with data for the Danube river (Förstner and Wittmann, 1981). The results show that concentrations of sodium (0.78 mmole l^{-1}) and potassium (0.12 mmole l^{-1}) in the Nile are 2.3 and 1.7 times higher than in the Danube (0.35, 0.075 mmole l^{-1}, respectively). It can be seen in Figure 2(C) that the concentration levels of calcium, sodium, potassium, sulphate and chloride in the Sohag area are all higher than in the Aswan area. In Figure 3(C-E) we

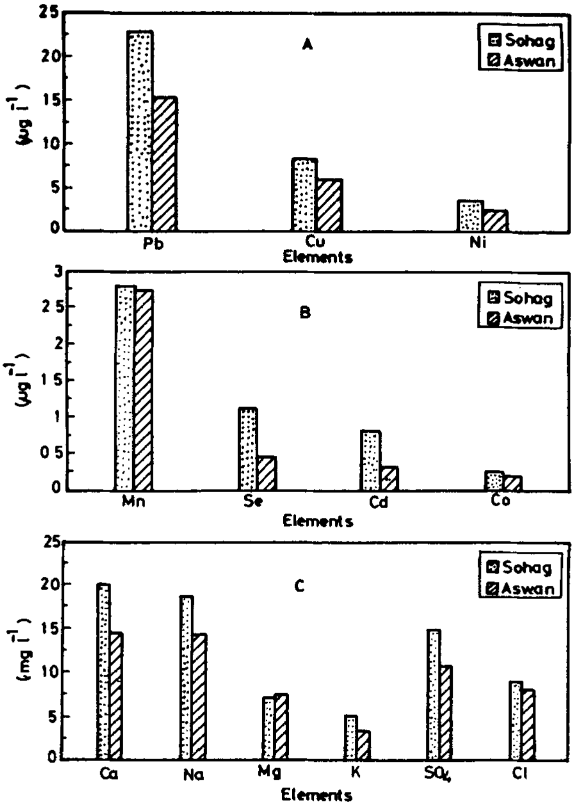

Figure 2 Comparison of concentrations of dissolved trace and major elements in Sohag and Aswan areas for A-lead, copper and nickel, B-manganese, selenium, cadmium and cobalt, C-calcium, sodium, magnesium, potassium, sulphate and chloride.

show the variations in hardness, alkalinity, salinity and pH values which also increase downstream from Aswan. These findings suggest that the higher levels of salinity, hardness and pH measured in the lower Nile are due to industrial wastes (from factory production of soaps, oil and soft drinks) and municipal and agricultural wastes.

Figure 4 shows the relative concentrations of the different major ions in the Nile water. It is clear that the major cations are in the order Ca > Na > Mg > K. Potassium is usually low in concentration; it is derived from the weathering of mineral deposits or decay of organic materials. The major anions are in the order $HCO_3 > SO_4 > Cl > F > NO_3$.

Suspended Sediments

Since no significant results are published for the chemistry of suspended sediments in the Nile, our results are compared with the published chemical composition of world river average suspended sediments (WAS) and world surficial rocks (WSR) exposed to chemical weathering according to the values compiled by Martin and Meybeck (1979) and shown in Table II.

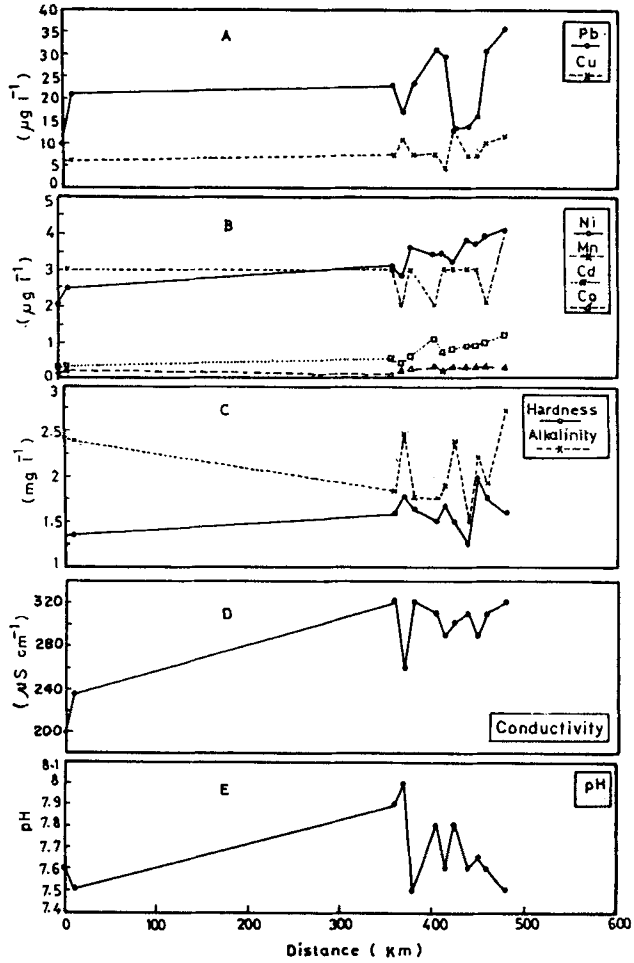

Figure 3 Downstream variation of dissolved ions in River Nile from Aswan to Sohag for A-lead and copper, B-nickel, manganese, cadmium and cobalt, C-hardness and alkalinity, D-conductivity, E-pH value (Distance (km) measured from the Aswan Dam).

A comparison is first made with particulate composition of the Amazon and Yukon (Gibbs, 1977) since they are large unpolluted river systems. Gibbs (1977) made a rather complete study of the mechanisms of trace metal (Cr, Mn, Fe, Co, Ni and Cu) transport phases along two major river basins; one is tropical (Amazon) and the other is subarctic (Yukon). The two rivers are widely different in their environment. Results of elemental concentrations and distributions in the various transporting phases of the transition metals showed that crystalline particles are the major transport mechanism, followed by adsorption on hydrous metallic coatings. In spite of the two river basins having different geological and climate characteristics, an impressive similarity was found in the percentage distribution in the different transporting phases of the Amazon and Yukon river systems, leading to the conclusion that the amounts and distribution of the

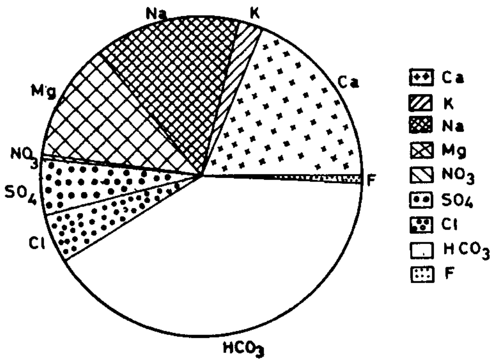

Figure 4 Relative proportion of different cations and anions (Ca, K, Na, Mg, NO_3, SO_4, Cl, HCO_3 and F meq l^{-1}) in River Nile water.

Table II Element concentrations of suspended sediments in the River Nile and from published work for WAS, WSR and 3 major rivers ($\mu g\, g^{-1}$).

	This Work		*Published Work*			
Elements	$\bar{x}$	*WAS*	*WSR*	*Amazon*	*Yukon Rivers*	*Yellow*
K	3162	20000	24400	18000	—	—
Ca	11256	21500	45000	40000	—	60000
Fe	24100	48000	35900	55000	63000	32000
Mn	2200	1050	720	1030	1270	—
Ti	3496	4160	3800	7000	—	4000
V	109	170	97	232	—	—
Cr	62	100	71	193	115	72
Ni	24	90	49	105	136	38
Cu	55	100	32	266	416	33
Zn	82	350	127	426	—	75
Rb	51	100	112	138	—	—
Sr	128	150	278	309	—	220

$\bar{x}$ = mean value, WAS = world average suspended, WSR = world surficial rocks, — = no data

elements are fundamental characteristics of natural (non-polluted) river systems. Besides, considering that both river systems represent large parts of the continent and contain a wide variety of rock types, it seems reasonable that their elemental compositions are rather close to values obtained for the world average.

In Table II, our results indicate that suspended sediments collected along the River Nile are enriched especially in manganese when compared with WAS. In contrast, a large depletion of the potassium and calcium content of the suspended sediments is evident, while the average composition of the suspended sediments collected in the study area compared to WSR exposed to chemical weathering shows a depletion in potassium, calcium and strontium. These results are confirmed by Meybeck's (1977) data on the average dissolved content of some major rivers, corresponding to more than 50% of the total world discharge. He noticed a significant depletion in potassium and calcium in the suspended matter, while on the contrary, the major cations were found in solution. In addition, there was evidence that calcium depletion in tropical river material was more pronounced. In general, due to the importance of chemical weathering resulting in greater dissolved transport, particulate material is usually depleted of its more soluble compounds. Comparison with the values reported for the Amazon and Yukon rivers shows a systematically lower content either in potassium, calcium and iron or in trace metals (Table II). It can also be seen from Figure 5 (A), that calcium and potassium behave differently along the course of the River Nile with concentrations increasing below Aswan, probably due to a resuspension of coarse particles which seem to settle out downstream.

It is also apparent from Table II that the content of most trace elements measured in the Nile suspended sediments are lower than the WSR, this being a clear indication that the (pollution) input of elements from anthropogenic sources is not significant by comparison with natural geochemical inputs. Comparison between chemical composition of suspended sediment in the River Nile and Amazon, Yukon and Yellow Rivers

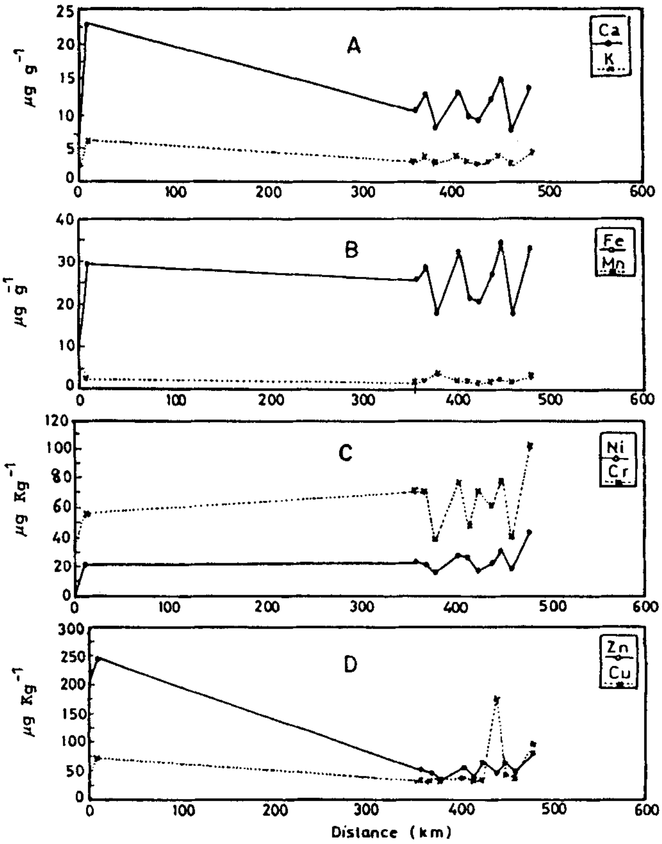

Figure 5 Downstream values for elements in suspended sediments in River Nile: A) calcium and potassium, B) iron and manganese, C) nickel and chromium, D) copper and zinc.

indicate that present Nile values of trace metals are rather close to those of the Yellow River.

Downstream values for Fe, Mn, Cr, Ni, Cu and Zn for suspended sediments are given in Figure 5 (B – D). Although the values are more or less erratic, heavy metals determined in the samples collected immediately below the Aswan High Dam are present at a systematically different level. In the Sohag area, variations in trace element content are easily attributable to local anthropogenic, agriculture and industrial influences.

The geographic variability of elements in the suspended particulates differ between elements. The coefficient of variation, $(SD/\bar{X}) \times 100$, (SD and $\bar{X}$ are the standard deviation and mean concentrations in suspended matter) is calculated (Table III). It is found that $SD/\bar{X}$ values (highly variable) for copper (1.07) and vanadium (1.30), 1.84 – 2.11 (moderately variable) for Cr, Ti, Co, Ni, K and Ca and (little variation) for iron (2.22), strontium (2.60) zinc (2.79), manganese (3.16), rubidium (3.78), and yttrium (4.63). In a comprehensive review by Martin and Meybeck (1979), the average values for concentrations in the suspended particulates of 20 major rivers were compared. It was found that copper, zinc, nickel and strontium were highly variable elements but chromium varied moderately, while most rare earth elements (such as Fe, Rb and Y) did not vary much. The results indicate that the more variable elements in the River Nile (Cu, V, Cr, Co, Ni, Ti, Ca and K) are carried in solution, while rare earth elements (Fe, Mn, Rb, Y) are carried mostly in the particulate phase.

Moreover, Table III shows that there are large differences of trace metal concentration in suspended particulates and dissolved ions. The suspended particulates' ability to accumulate trace metals under oxygenated conditions are evaluated using

Table III Mean concentration of trace elements in suspended particulates (mg l^{-1}) and dissolved (mg l^{-1}) in the river Nile, and their distribution coefficient (Kd).

			Suspended Concentration			*Dissolved Concentration*	*Distribution Coefficient*
	n	$\bar{x}$	*SD*	*Range*	(*CV*/100)	$\bar{x}$	*Kd*
Zn	12	1.56	0.56	0.75 – 3.02	2.79	0.0134	1.16×10^2
Cu	12	1.12	1.04	0.25 – 4.47	1.07	0.00798	1.40×10^2
Ni	12	0.47	0.23	0.29 – 0.86	2.04	0.0033	1.42×10^2
Cr	12	1.34	0.72	0.21 – 2.34	1.86	0.00329	4.07×10^2
Co	12	2.57	1.28	0.00 – 4.61	2.01	0.00024	1.07×10^4
V	12	2.28	1.75	0.00 – 4.21	1.30	0.00695	3.28×10^2
Mn	12	45.2	14.3	29.4 – 82.6	3.16	0.00284	1.59×10^4
Sr	12	3.56	1.37	1.02 – 5.83	2.60	0.116	30.70
Rb	12	1.02	0.27	0.58 – 1.41	3.78	nm	—
Y	12	0.88	0.19	0.50 – 1.09	4.63	nm	—
Fe	12	535	241	200 – 958	2.22	0.185	2.89×10^3
Ti	12	75.8	40	2.15 – 149	1.89	nm	—
K	12	63.6	34.6	4.5 – 110	1.84	4.76	13.36
Ca	12	232	110	19.4 – 303	2.11	19.1	12.15

nm = not measured, $\bar{x}$ = mean values. SD = standard deviation, n = no of samples, CV = coefficient of variation

Table IV Correlation matrix between the elements determined in the suspended sediments in the River Nile.

	K	*Ca*	*Ti*	*Cr*	*V*	*Mn*	*Fe*	*Ni*	*Cu*	*Zn*	*Rb*	*Sr*
K	1	0.99	0.62	0.48	0.62	−0.32	0.80	0.35	0.22	0.12	0.27	0.71
Ca		1	0.59	0.47	0.65	−0.30	0.78	0.29	0.28	0.10	0.29	0.72
Ti			1	0.82	0.89	−0.56	0.96	0.72	0.23	−0.56	−0.26	0.42
Cr				1	0.73	−0.33	0.81	0.79	0.21	−0.26	0.10	0.61
V					1	0.09	0.95	0.69	0.33	0.33	0.41	0.76
Mn						1	−0.50	0.28	0.02	0.60	0.64	0.21
Fe							1	0.72	0.26	−0.39	−0.06	0.59
Ni								1	0.25	0.07	0.57	0.74
Cu									1	0.09	0.24	0.37
Zn										1	0.79	0.40
Rb											1	0.76
Sr												1

a distribution coefficient (Kd):

$$\mathrm{Kd} = \frac{\text{metal concentration in particulate matter (mg l}^{-1}\text{)}}{\text{metal concentration in dissolved ions (mg l}^{-1}\text{)}}$$

It is clear from Table III that the distribution coefficient for measured elements decreases in the order Mn > Co > Fe > Cr > V > Cu > Ni > Zn > Sr > K > Ca. The high Kd values of manganese and iron can be attributed to the oxidation of Mn(II) to Mn (IV) and iron (II) to iron (III)in the weakly alkaline medium (pH = 7.67) accompanied by hydrolysis to precipitate the hydroxy oxides to the suspended particulates. The higher Kd value of Co than for other trace elements in the River Nile can be attributed to most mobile fractions of Co bound to particulates in sorbed precipitated or coprecipitated forms (hydrous Fe/Mn oxides and carbonate or in an organically complexed form) (Förstner and Wittmann, 1981).

Correlations between the measured elements in Nile suspended sediments are shown in Table IV. There is a positive high correlation between potassium, calcium and strontium and between potassium, calcium and iron, suggesting a mixed transport phase for calcium; possibly the suspended sediments might be derived from carbonates and from clay minerals. High correlations are also observed between iron and trace metals (Ti, V, Ni and Cr) and a slighter correlation of manganese with zinc and rubidium, indicating the importance of the mechanism of trace metal transport adsorbed on oxides/hydroxide coating in the suspensions of the Nile.

CONCLUSIONS

Unfortunately, no data has been reported previously on the relationships of dissolved and suspended elements in the Nile. Hence, comparison with normal background values in fresh water, AWD, WSR, WAS and in three major rivers may improve our ability to assess the degree of metal contamination.

These studies indicate that the concentration of dissolved lead in the Nile is higher than background values and AWD by >100 and >20 times, respectively, while nickel and cobalt are moderately high (by 11, 4.8 and 1.5, 1.2 times, respectively). This suggests a pollution input by lead, nickel and cobalt to the Nile. Their high concentrations may possibly be due to motor vehicle exhaust fumes from the Cairo-Aswan highway, from industrial and agricultural activities, and from local atmospheric fallout. The remaining dissolved trace ions in Nile water are at lower concentrations than background values and AWD, suggesting that these elements originate from natural sources. Moreover, it is found that the concentration of dissolved major (sodium and potassium) ions is higher than in the Danube river due to agricultural and industrial wastes in the study area. No significant differences were found between the chemical composition of dissolved metals collected on the east and west river banks in the Sohag area.

Analysis of suspended material showed that the trace metal concentrations are close to values published from two unpolluted rivers (Amazon and Yukon) with quite different geological and climatic characteristics. Trace metal distribution in the study area seems to be more dependent on pollution inputs along the course of the river than on chemical weathering process. In spite of the observed increase in trace metals to the north, concentrations are similar to those of non-polluted rivers and lower than weathering of world surficial rocks.

Suspended sediment samples collected above the high Dam showed a different elemental composition, i.e. they usually exhibit a much lower concentration of potassium, calcium and iron. Most transition metals were close to the detection limits below the high Dam, due to the settling out of resuspended coarse particles. The main constituents of the suspended particles collected at this location seem to be some trace metals (Cu and Zn) adsorbed on Fe and Mn hydroxide.

It is concluded that calcium, iron and trace elements (Ti, Mn, Y and Rb) originate from soil mineral leaching (natural processes) while others (Zn, Cu, Ni, Co and V) originate from local anthropogenic sources.

ACKNOWLEGEMENT

The authors are grateful to Prof. R. Van Grieken, University of Antwerp (U. I. A.), Belgium who provided the possibility of carrying out the analyses in his laboratory.

References

Abdel-Moneim, A. A. (1992) Numerical simulation and groundwater management of the Sohag aquifer, the Nile valley, Egypt, PhD Thesis, Department of Civil Engineering, Strathclyde University, United Kingdom, 220 pp.

Fayed, S. E. and Abd-el Shafy, H. I. (1985) Accumulation of Cu, Zn, Cd and Pb by aquatic macrophytes, *Environmental International*. **11**, 77–88.

Förstner, U. and Wittmann, G. T. (1981) *Metal Pollution in the Aquatic Environment*, Springer Verlag-Berlin, 2nd Ed, 486 pp.

Gibbs, R. J. (1977) Transport phases of transition metals in the Amazon and Yukon rivers. *Geological Society of America Bulletin*. **88**, 829–843.

Kasperek, K., Iyengar, G. V. and Feinendegen, L. E. (1982) Multielement analysis of fingernail, scalp hair and water samples from Egypt (a preliminary study). *The Science of the Total Environment*. **22**, 149–168.

Komy, Z. R. (1993) Determination of trace metals in Nile and gorund water by differential pulse stripping voltammetry. *Microchimica Acta.* **111**, 239–249.

Komy, Z. Roekens, E. and Van Grieken, R. (1988) Analysis of rain water by differential pulse stripping voltammetry in nitric acid medium. *Analytica Chimica Acta* **204**, 179–187.

Martin, J. M. and Meybeck, M. (1979) Elemental mass-balance of material carried by major world rivers. *Marine Chemistry* **7**, 173–206.

Meybeck, M. (1977) Dissolved and suspended matter carried by rivers: composition, time and space variations, and world balance. In: H. L. Golterman (editor), *Interactions between Sediments and Fresh Waters.* Junk, Amsterdam, pp. 25–32.

Murozumi, M., Chow, T. J. and Patterson, C. C. (1969) Chemical concentrations of pollutant lead aerosols, terrestrial dusts and sea salts in Greenland and Antarctic snow strata. *Geochimica et Cosmochimica Acta* **33**, 1247–1294.

Vos, L., Komy, Z. R., Reggers, G., Roekens, E. and Van Griekin, R. (1986) Determination of trace metals in rain water by differential pulse stripping voltammetry. *Analytica Chimica Acta* **184**, 271–280.