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# WATER QUALITY ASSESSMENT OF RIVER NILE FROM IDFO TO CAIRO

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## ABSTRACT

Water quality of the River Nile from Idfo to Cairo and trace elements of the Nile water were seasonally investigated from autumn 2000 to summer 2001. Eleven sites were selected along the main channel of the River Nile. In addition, six stations in front of some shore-line activities were also sampled to study the man's impact on the water quality of the Nile. The distribution of major cations and anions possessed the highest values in cold seasons and the lowest during the hot high-flow period. In addition, EC, TS, TDS, COD, $NH_4^+$, orthophosphate, total phosphorus, Fe, Mn and Cu showed a steady increase from south to north. Point and non-point sources of pollution exerted negative local effects on the water quality of the receiving waters. The multiple correlation analysis showed a pattern of interrelationships between physical and chemical parameters.

## INTRODUCTION

The River Nile is the life artery of Egypt. Throughout the known Egyptian history, the Nile had dominating influences on the economy, culture, public health, social life and political aspects. The High Dam reservoir has a huge water storage capacity about (164 $Km^3$) insuring a plentiful freshwater supply all the year round (Abdel-Hamid *et al.*,1992). However, the construction of the High Dam resulted in great modification in the hydrodynamic regime of the River Nile, with significant changes in physico-chemical and biological characteristics of the downstream water (Saad and Goma, 1994; Fishar & Khalifa, 2003). Abdel-Shafy and Aly (2002) reported that the regulation ought to restore the healthy state of the river in terms of physical, chemical, and biological characteristics.

The characteristics of the Nile ecosystem clearly reflect the impact of river flow control and can be categorized into three regions: the Aswan High Dam reservoir, the river from Aswan to Cairo and the Delta. The water quality in the Nile downstream from Aswan has changed dramatically as the Nile water became silt-free, less turbid and with considerably less velocity (Saad and Goma, 1994). According to the National Water Research Center (NWRC, 2000), the River Nile from Aswan to El-Kanater Barrage receives wastewater discharge from 124 point sources, of which 67 are agricultural drains and the remainders are industrial sources.

Now, the changes in water quality are primarily due to a combination of land and water use, as well as water management interventions such as; (a) different hydrodynamic regimes regulated by the Nile barrages, (b) agricultural return flows, and (c) domestic and industrial waste discharges including oil and wastes from passenger and riverboats. These changes are more pronounced as the river flows through the densely populated urban and industrial

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centers of Cairo and the Delta region (Agricultural Policy Reform Program, 2002).

The water quality released from the Aswan High dam shows little degradation. It remains remarkably clean from chemical pollution until it reaches the Delta (Masoud *et al.,* 2002). The TDS level in the Nile gradually increases from 150 ppm at Aswan to 250 ppm near Cairo. The oxygen concentration recovers as a result of atmospheric reaeration and increases from 4 ppm at Aswan to 9–10 ppm at 200 km downstream Aswan, in addition the inputs of sewage along the river reduce the oxygen content, especially near big cities (Abdel-Dayem, 1994). Wahaab and Badawy (2004) concluded that the River Nile receives a large quantity of industrial, agriculture and domestic wastewater. Nevertheless, the river is still able to recover in virtually all the locations, with very little exception.

According to the final report of Agricultural Policy Reform Program (2002), the water quality of the main part of the River Nile, from Aswan to Delta barrage is good in-spite of the high organic and inorganic loads discharged from some drains and industrial activities.

The assessment of environmental quality with respect to heavy metals in aquatic systems involves the measurement of a series of metals in water, sediments and living organisms (Samecka-Cymerman and Kempers, 2001, Sanchez Lopez, 2004). The most important heavy metals from the point of view of water pollution are Zn, Cu, Pb, Cd, Hg, Ni and Cr. Some of these metals (e.g. Cu, Ni, Cr and Zn) are essential trace metals to living organisms, but become toxic at higher concentrations. Others, such as Pb and Cd have no known biological function, but are toxic elements (Dudka and Adriano, 1997).

Masoud *et al.,* (1994) concluded that the concentration of trace metals in Nile water has increased from south to north direction. Also, the large part of trace metals is associated with the suspended matter, where it increased from 3.3 mg/l at Esna (south) to 31.2 mg/l at Helwan (north). Issa *et al.,* (1997) reported that distribution pattern of the major elements (Na, K, Ca, Mg) and trace metals (Fe, Mn, Zn and Cu) in River Nile at the greater Cairo area were affected mainly by industrial and sewage effluents inflow to the river.

The present study was mainly intended to investigate the water quality of the river segment from Idfo to Cairo, where the multipurpose uses of water and human activities are intense. It also aims to reveal the interrelationships between different physical and chemical parameter studied.

## MATERIALS AND METHODS

Surface and bottom water samples were collected seasonally (2000- 2001) by a polyvinyl chloride Van Dorn bottle at eleven sites along the main channel of the River Nile from Idfo to Cairo (Fig. 1). In addition, surface water samples were collected from six other stations (I-VI) opposite to some human activities to study the impact on the water quality of the Nile. The sampling sites and distance from High Dam (HD) are presented in Table 1.

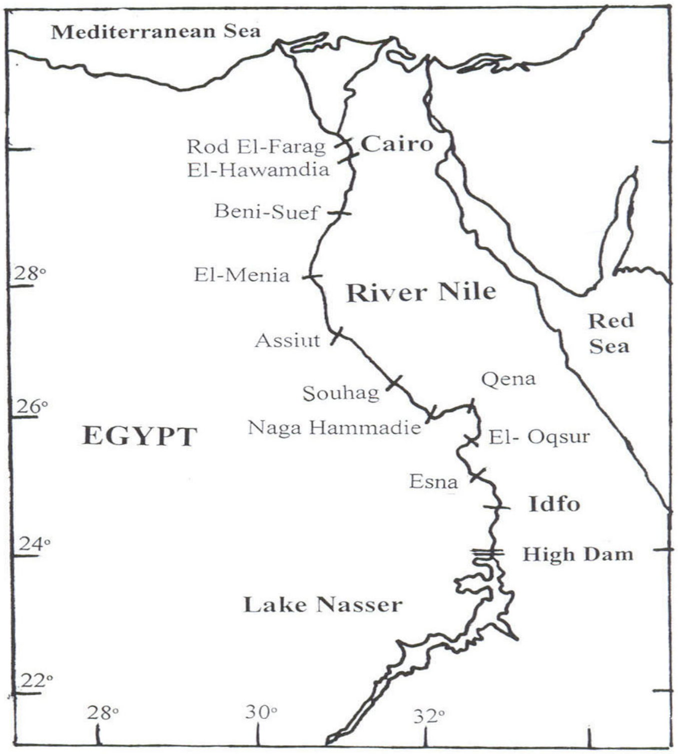

Fig. (1): Map showing the sampling sites along the River Nile

**Table (1): The sampling location and the distance from High Dam (H.D.) for each site**

| Sampling sites | Distance(Km) from HD | Remarks |
|---|---|---|
| Idfo | 115 | Water samples were collected from main channel (site 1) and the eastern bank in front of the Egyptian ferro-alloy Company (station I) |
| Esna | 170 | Water samples were collected from main channel (site 2) and the eastern bank in front of Esna Barrage (Touristic Galleon parking) (station II) |
| El- Oqsur | 228 | Water samples were collected from main channel (site 3) and the eastern bank in front of Touristic Galleon parking (station III) |
| Qena | 293 | Water samples were collected from main channel only (site 4) |
| Naga Hammadie | 355 | Water samples were collected from main channel only (site 5) |
| Souhag | 440 | Water samples were collected from main channel only (site 6) |
| Assiut | 543 | Water samples were collected from main channel (site 7) and the eastern bank in front of the Electric Power Station (station IV) |
| El-Menia | 677 | Water samples were collected from main channel only (site 8) |
| Beni-Suef | 787 | Water samples were collected from main channel only (site 9) |
| El-Hawamdia | 912 | Water samples were collected from main channel (site 10) and the eastern bank in front of the Sugar and Integrated industries Company (station V) |
| Rod El-Farag | 950 | Water samples were collected from main channel (site 11) and the eastern bank in front of many workshops for repairing and painting ships (station VI) |

**Field Observations**

The electrical conductivity of the water samples (μScm$^{-1}$) was measured by using conductivity meter model (S.C.T.33 YSI), transparency (cm) by Secchi-disc, pH by Orion Research Ion Analyzer 399A pH meter and water temperature by a dry mercury thermometer.

**Laboratory analysis**

Water samples were kept into a one-liter polyethylene bottle in ice box and analyzed in the laboratory. The procedures used are specified in APHA (1995). $CO_3^{2-}$ and $HCO_3^-$ were measured titrimetrically on site. Total solids were measured by evaporating a known volume of well mixed sample and total dissolved solids were determined by filtration a volume of sample with glass micro fiber filter (GF/C) and a known volume of filtrate was evaporated at 105°C.

The dissolved oxygen content was performed by azide modification, COD by potassium dichromate oxidation and BOD by incubation 5 days methods. Chloride was determined by argentometric and sulphate by turbidimetric methods. Sodium and potassium were measured directly using the flame photometer model Jenway PFP, U.K. Calcium and magnesium were determined by EDTA titrimetric method.

Concentrations of nitrite, nitrate, ammonia, orthophosphate and reactive silicate were determined using the colorimetric techniques with formation of reddish purple azo-dye, Cd reduction, nesslerization, stannous chloride reduction and molybdosilicate methods, respectively. Total phosphorous was measured as reactive phosphate after persulphate digestion method.

Total Fe, Mn, Zn, Cu, Pb were measured after digestion using atomic absorption model (Perkin Elmer 3110 USA) with graphite atomizer HGA-600. It is to be noted that, the results obtained for most parameters in the surface and bottom midstream Nile water are relatively closed to each other, therefore the averages were calculated. Also, The correlation coefficients between the quality parameter pairs of the river water samples were calculated in order to indicate the nature and the sources of the polluting substances.

## RESULTS AND DISCUSSION

The study offered comprehensive water quality information of the River Nile from Idfo to Cairo. The results of ranges, means and SD of the studied physical and chemical parameters for water samples in the midstream (sites 1-11) are given in Table 2.

**Physical properties of midstream Nile water**

Water temperature showed a noticeable seasonal trends with a lowest value (17.1 °C) recorded in winter and a highest (28.2 °C) in summer. The slight variations between different sites were mainly due to different sampling times. Water temperature showed a negative correlation with dissolved oxygen and a positive one with air temperature during most seasons (Table 3). This indicates that air temperature plays an important role for the heat budget of the Nile water.

Electrical conductivity showed lowest values during winter (244.5-322.5 μScm$^{-1}$) with a slight increase downstream (Fig. 2). It showed positive correlation with many parameters like, for instance, $Cl^-$, $SO_4^{2-}$, $HCO_3^-$, Na, K, Ca and Mg during most seasons (Table 3), which constitute the major anions and cations present in the Nile water.

The water transparency showed a sharp reduction from Idfo (site 1) to Rod El-Farag (site 11). It ranged between 55 to 255 cm (Fig. 2). The increase in transparency values in summer (75-255 cm) might be attributed to the increase in intensity of solar radiation penetrating the surface water (Abdel-Satar, 2001). Transparency showed high negative correlation with TS, COD, and BOD during most seasons (Table 3).

Total solids (TS) and total dissolved solid (TDS) showed a steady increase from up- to downstream sites. The increase in TS values during spring (324-552 mgl$^{-1}$) for all sites is probably due to the phytoplankton blooming (Saad, 1973; Abdel-Satar, 1998). TDS maintained positive relationships with $Cl^-$, $SO_4^{2-}$, $HCO_3^-$, Na, K, Ca and Mg during most seasons (Table 3).

**Chemical properties of midstream Nile water**

pH values were in the alkaline side (7.4-9.02). Small local differences were observed with no clear seasonal variations. The increase in pH values during spring season (7.94-9.02) might be due to the dense of vegetation and phytoplankton, which were accompanied by photosynthetic activity and consumption of $CO_2$ with expected pH elevation (Sabae, 2004). pH showed a negative correlation with most studied parameter, Table 3.

Dissolved oxygen values (DO) ranged from 5.56 to 10.70 $mgl^{-1}$, with remarkable seasonal and local variations. The decrease in DO in summer along different sites (Fig. 2) might be due to the elevation of water temperature and the increase in oxidative processes of organic matter (Abdel-Satar and Elewa, 2001). Relatively low DO level was recorded at site 1 (5.6 $mgl^{-1}$) in summer season. This seems to be a problem downstream from the High Dam, due to the dam's discharge, which delivers water from Lake Nasser at low depths (El-Sherbini *et al.* 1996). During different seasons, sites 9 and 10 downstream showed low DO concentrations (Fig. 2) due to its consumption by the oxidation of nitrogenous compounds. This finding was fully confirmed with the increase in ammonium and nitrate at the two sites (Fig. 4), where the nitrogenous compounds played an important role in the depletion of DO (Deai *et al.,* 1991). DO was correlated negatively with nitrite, ammonium, but positively with pH during most seasons (Table 3).

COD values showed a slight, but a steady increase from south to north (Fig. 2). BOD showed a random distribution, but did not exceed the Egyptian standard value (6 mg/l). As expected, COD values (2.2-9.6 $mgl^{-1}$) for all water samples were higher than those obtained for BOD (0.83-5.7 $mgl^{-1}$), as the latter deals only with the oxidation of biodegradable organic matter. For most sites, relatively high values of BOD and COD were estimated in winter, with low water discharges. The present results of BOD were in agreement with those obtained by El-Sherbini *et al.*, (1996) and Agricultural Policy Reform Program (2002). They reported that the BOD concentrations varied in the ranges 0.4-4.7 and 1-3.5 $mgl^{-1}$, respectively in the Nile water from Aswan to Cairo.

Carbonate showed a wide range of variations (0.0-7.0 $mgl^{-1}$), with interrupted seasonal trends. It showed positive correlation with DO, COD and BOD (Table 3). The bicarbonate values fluctuated between 112.9 and 154.3 $mgl^{-1}$. It showed a steady increase from up- to downstream sites. The highest values were recorded at site 11 (136.3-154.3 $mgl^{-1}$) for all seasons. This might be attributed to the presence of high amount of organic matter accessible to bacterial decomposition by increasing boats and density of ship, where bicarbonate is the final product of the decomposition (Elewa and Gallab, 2000)

Chloride concentrations varied between 16.07 to 29.54 $mgl^{-1}$. The highest values were registered in cold seasons and the lowest in hot high-flow period (Fig. 3). The chloride concentrations possessed a good positive relationship with most anions and cations. Sulphate showed a behavior similar to that of $Cl^-$ (Fig. 3). It ranged between 7.76 to 58.90 $mgl^{-1}$, with a high increase at site 10 (16.91-58.90 $mgl^{-1}$) during different seasons. This reflects the input of high amount of sulphates in the effluent discharges from Sugar and Integrated industries Company.

The distribution of the cations (Na, K, Ca and Mg) was similar to those of the anions ($Cl^-$ and $SO_4^{2-}$), showing a minor decrease upriver and lowest values during the hot high-flow period (Fig. 3). The decrease in K values (4.03-6.59 $mgl^{-1}$) in the Nile water than Na (18.37-35.69 $mgl^{-1}$) might be attributed to the high mobility of sodium ion and dominates in the natural solutions (Ramanathan *et al*., 1994).

Table (2): Ranges, means and standard deviation of the physical and chemical parameters in midstream Nile water

a. Surface water

| Parameter | Autumn | | Winter | | Spring | | Summer | |
|---|---|---|---|---|---|---|---|---|
| | Range | Mean±SD | Range | Mean±SD | Range | Mean±SD | Range | Mean±SD |
| Water Temp.($^oC$) | 18.5-23.2 | 21.15±1.45 | 17.1-18.9 | 18.0±00.7 | 22.2-27.0 | 23.95±1.5 | 23.1-28.2 | 26.31±1.91 |
| EC ($\mu Scm^{-1}$) | 242-375 | 296±41.9 | 244-320 | 269±23 | 252-320 | 285±21 | 256-329 | 298.18±19.0 |
| Transparency(cm) | 70-220 | 118.6±49.5 | 68-250 | 140.1±75.2 | 68-240 | 131.4±60.9 | 75-255 | 160.91±75.53 |
| TS (mg/l) | 164-355 | 243.45±67.16 | 132-368 | 233.27±75.47 | 256-628 | 423.09±103.5 | 128-225 | 184.82±26.05 |
| TDS (mg/l) | 129-315 | 202.9±66.27 | 92-328 | 193.27±75.47 | 176-538 | 324.64±105.9 | 98-195 | 154.9±25.99 |
| pH | 7.4-8.04 | 7.69±0.23 | 7.48-7.7 | 7.63±0.08 | 7.94-9.03 | 8.6±0.35 | 7.4-7.7 | 7.5±0.08 |
| DO (mg/l) | 7.4-10.0 | 8.9±0.98 | 7.8-11.0 | 9.5±1.17 | 7.2-10.4 | 9.0±1.11 | 5.5-9.9 | 7.2±1.18 |
| COD (mg/l) | 2.4-7.1 | 4.93±1.33 | 3.6-9.2 | 7.14±1.76 | 2.4-6.48 | 4.92±1.22 | 3.24-5.76 | 4.31±0.84 |
| BOD (mg/l) | 1.6-5.4 | 3.4±1.1 | 1.3-5.6 | 2.8±1.4 | 1.6-4.4 | 3.1±1.2 | 1.0-4.8 | 3.0-1.6 |
| $CO_3^{2-}$(mg/l) | 0-8 | 2.15±3.06 | 0-8 | 2.36±2.96 | 0-8 | 2.04±2.5 | 0-2 | 0.93±1.63 |
| $HCO_3^-$ (mg/l) | 112-154 | 133.3±12.9 | 122-144 | 131.45±7.2 | 118-136.5 | 127.8±5.81 | 114-135 | 120.98±8.41 |
| $Cl^-$ (mg/l) | 17.07-27.4 | 20.97±2.87 | 19.69-29.4 | 22.57±3.22 | 17.07-23.56 | 19.12±2.01 | 16.07-18.85 | 17.13±0.84 |
| $SO_4^{2-}$ (mg/l) | 16.72-35.95 | 22.69±6.05 | 8.22-29.32 | 21.07±5.53 | 9.02-58.24 | 16.03±14.1 | 7.56-13.13 | 11.09±3.51 |
| Na (mg/l) | 22.66-34.89 | 27.83±3.71 | 22.18-34.22 | 28.37±4.06 | 18.37-23.88 | 21.45±1.86 | 18.48-26.45 | 4.70±0.32 |
| K (mg/l) | 5.21-6.02 | 5.46±0.27 | 4.70-5.91 | 5.30±0.44 | 4.03-4.62 | 4.34±0.27 | 4.31-5.35 | 4.70±0.32 |
| Ca (mg/l) | 27.25-35.21 | 30.60±2.52 | 25.65-35.27 | 29.42±3.08 | 24.05-32.06 | 26.91±2.39 | 19.64-29.84 | 25.621±3.78 |
| Mg (mg/l) | 13.80-15.89 | 15.15±0.74 | 13.17-17.79 | 15.53±1.22 | 8.51-13.79 | 10.98±1.59 | 8.82-10.57 | 9.31±1.15 |
| $NO_3^-$ (µg/l) | 30.86-661.7 | 196.7±194.2 | 22.28-579.4 | 99.61±162.47 | 10.29-58.74 | 18.50±14.06 | 10.86-33.71 | 24.36±7.19 |
| $NO_2^-$ (µg/l) | 0.756-24.56 | 9.25±8.12 | 2.65-10.96 | 5.93±2.74 | 0.756-10.58 | 4.03±2.99 | 1.13-12.09 | 8.680±5.87 |
| $NH_3$ (mg/l) | 0.130-0.564 | 0.279±0.13 | 0.148-2.405 | 0.419±0.66 | 0.157-0.916 | 0.324±0.21 | 0.204-1.850 | 0.583±0.70 |
| Ortho-P (µg/l) | 34.70-78.40 | 57.73±16.75 | 19.26-114.38 | 60.70±25.85 | 17.99-129.80 | 61.85±37.23 | 30.84-80.97 | 75.31±14.96 |
| Total-P (mg/l) | 0.138-0.368 | 0.229±0.08 | 0.089-0.187 | 0.129±0.04 | 0.048-0.302 | 0.185±0.08 | 0.134-0.391 | 0.252±0.08 |
| $SiO_3^{2-}$ (mg/l) | 2.21-6.57 | 3.93±1.21 | 0.47-2.16 | 1.25±0.49 | 1.02-5.76 | 3.05±1.39 | 0.70-6.14 | 2.58±1.67 |
| Fe (mg/l) | 0.130-1.117 | 0.521±0.40 | 0.166-1.288 | 0.512±0.42 | 0.408-1.297 | 0.864±0.39 | 0.301-1.567 | 1.230±0.55 |
| Mn (µg/l) | 52.69-144.93 | 82.69±27.83 | 17.80-123.07 | 55.47±36.13 | 20.87-133.53 | 53.84±39.03 | 58.0-185.93 | 130.17±34.60 |
| Zn (µg/l) | 14.20-97.0 | 35.16±22.77 | 5.40-33.65 | 14.96±9.24 | 6.73-29.88 | 15.93±6.40 | 11.80-49.85 | 35.82±20.42 |
| Cu (µg/l) | 9.00-51.32 | 21.95±14.89 | 6.67-49.20 | 18.72±16.76 | 3.93-30.24 | 11.87±8.33 | 5.07-45.20 | 27.81± 10..95 |
| Pb (µg/l) | 15.33-34.67 | 23.72±6.25 | 10.27-61.64 | 40.21±14.77 | 6.33-23.52 | 12.82±5.33 | 5.64-24.33 | 15.94±6.87 |

**Table (2): Continued**

**b. Bottom water**

| | Autumn | | Winter | | Spring | | Summer | |
|---|---|---|---|---|---|---|---|---|
| | **Range** | **Mean±SD** | **Range** | **Mean±SD** | **Range** | **Mean±SD** | **Range** | **Mean±SD** |
| Water Temp.(°C) | 18.5-23.2 | 21.15±1.45 | 17.1-18.9 | 18.0±00.7 | 22.2-27.0 | 23.95±1.5 | 23.1-28.2 | 26.31±1.91 |
| EC ($\mu Scm^{-1}$) | 258-375 | 299.55±39.83 | 241-325 | 271.5±24.61 | 250-330 | 291.4±29.33 | 278-332 | 298.18±19.0 |
| TS (mg/l) | 190-358 | 275.45±60.76 | 164-338 | 238.0±62.29 | 288-592 | 440.73±98.62 | 164-230 | 169.45±21.49 |
| TDS (mg/l) | 160-328 | 245.45±60.76 | 132-298 | 198.73-66.45 | 188-492 | 339.91±97.89 | 128-190 | 158.27±19.09 |
| pH | 7.4-8.02 | 7.67±0.23 | 7.4-7.7 | 7.62±0.11 | 7.94-9.0 | 8.58±0.28 | 7.4-7.69 | 7.5±0.08 |
| D.O (mg/l) | 7.5-9.6 | 8.8±0.75 | 7.4-0.4 | 9.3±1.02 | 7.2-9.6 | 8.5±0.77 | 5.6-9.4 | 7.2±1.18 |
| COD (mg/l) | 2.00-8.00 | 5.70±2.00 | 4.00-10.00 | 6.90±2.01 | 4.00-8.40 | 5.92±1.36 | 3.00-5.84 | 4.31±0.84 |
| BOD (mg/l) | 2.4-6.0 | 3.6±1.1 | 1.2-4.9 | 2.9±1.3 | 1.0-5.2 | 3.0±1.5 | 0.7-5.0 | 3.0-1.6. |
| $CO_3^{2-}$(mg/l) | 0-4.8 | 1.05±1.53 | 0-8 | 2.13±2.71 | 0-6 | 0.98±1.93 | 0-4 | 0.93±1.63 |
| $HCO_3^-$ (mg/l) | 116-154.6 | 135.07±13.07 | 119.6-144.5 | 126.66±9.75 | 124-136 | 128.55±4.41 | 111.8-139 | 120.98±8.41 |
| $Cl^-$ (mg/l) | 18.08-27.48 | 21.14±2.80 | 19.08-29.68 | 22.58±3.57 | 17.68-23.74 | 19.13±1.73 | 16.07-18.90 | 17.13±0.84 |
| $SO_4^{2-}$ (mg/l) | 14.46-38.07 | 24.00±7.01 | 8.62-31.18 | 21.14±5.70 | 9.02-59.56 | 17.09±14.51 | 7.96-20.69 | 11.09±3.51 |
| Na (mg/l) | 23.06-35.69 | 28.03±3.37 | 22.72-33.46 | 28.25±3.79 | 4.03-4.89 | 4.43±0.27 | 4.46-5.40 | 4.70±0.32 |
| K (mg/l) | 5.21-6.14 | 5.54±0.30 | 5.02-6.59 | 5.38±0.42 | 4.03-4.89 | 4.43±0.27 | 4.46-5.40 | 4.70±0.32 |
| Ca (mg/l) | 27.254-36.890 | 30.972±3.13 | 26.453-36.990 | 30.180±3.70 | 23.246-31.640 | 26.062±2.62 | 20.880-30.461 | 25.621±3.78 |
| Mg (mg/l) | 13.40-16.54 | 15.29±1.12 | 13.58-19.25 | 15.46±1.80 | 9.22-16.21 | 11.98±2.24 | 7.70-11.15 | 9.31±1.15 |
| $NO_3^-$ (µg/l) | 42.28-543.97 | 237.06±152.4 | 24.00-458.10 | 94.89±122.94 | 13.71-62.28 | 26.44±17.00 | 15.43-37.71 | 24.36±7.19 |
| $NO_2^-$ (µg/l) | 2.645-24.179 | 10.561±7.66 | 4.156-10.956 | 7.212±2.07 | 2.267-17.757 | 7.024±5.74 | 1.889-23.801 | 8.680±5.87 |
| $NH_3$ (mg/l) | 0.148-0.542 | 0.344±0.13 | 0.111-2.590 | 0.449±0.71 | 0.139-0.925 | 0.330±0.22 | 0.222-2.683 | 0.583±0.70 |
| Ortho-P (µg/l) | 42.41-111.81 | 68.89±22.55 | 37.27-74.54 | 57.13±13.11 | 30.64-104.10 | 66.29±26.28 | 55.26-102.81 | 75.31±14.96 |
| Total-P (mg/l) | 0.158-0.399 | 0.249±0.08 | 0.077-0.303 | 0.156±0.08 | 0.058-0.298 | 0.168±0.078 | 0.141-0.428 | 0.252±0.08 |
| $SiO_3^{2-}$ (mg/l) | 1.74-6.75 | 4.07±1.26 | 0.84-2.61 | 1.48±0.51 | 0.81-5.87 | 3.17±2.05 | 0.84-6.86 | 2.58±1.67 |
| Fe (mg/l) | 0.182-1.369 | 0.730±0.41 | 0.192-2.011 | 0.828±0.57 | 0.850-2.136 | 1.171±0.39 | 0.601-2.497 | 1.230±0.55 |
| Mn (µg/l) | 76.40-146.41 | 100.61±21.85 | 22.40-11.21 | 59.20±29.10 | 22.64-182.60 | 84.27±48.01 | 59.73-191.67 | 130.17±34.60 |
| Zn (µg/l) | 29.24-105.93 | 44.32±21.39 | 16.53-44.11 | 24.73±8.08 | 12.80-39.88 | 22.76±7.81 | 6.53-69.85 | 35.82±20.42 |
| Cu (µg/l) | 10.21-47.85 | 29.25±9.69 | 11.63-50.31 | 25.41±10.31 | 11.26-32.56 | 21.51±7.76 | 10.80-43.60 | 27.81± 10..95 |
| Pb (µg/l) | 15.33-36.25 | 26.41±6.54 | 20.33-60.58 | 47.22±12.28 | 9.67-23.91 | 17.33±4.74 | 10.12-23.66 | 16.81±4.46 |

**Table (2): Continued**

c. Average

| Parameter | Autumn | | Winter | | Spring | | Summer | |
|---|---|---|---|---|---|---|---|---|
| | Ranges | Means±SD | Ranges | Means±SD | Ranges | Means±SD | Ranges | Means±SD |
| Water Temp.(°C) | 18.5-23.2 | 21.15±1.45 | 17.1-18.9 | 18.0±00.7 | 22.2-27.0 | 23.95±1.5 | 23.1-28.2 | 26.31±1.91 |
| EC (µScm$^{-1}$) | 250-375 | 298±40.8 | 244.5-322.5 | 270.64±23.63 | 255-322.5 | 288.18±24.21 | 268.5-330.5 | 295.14±21.25 |
| Transparency(cm) | 70-220 | 118.6±49.5 | 68-250 | 140.1±75.2 | 68-240 | 131.4±60.9 | 75-255 | 151.7±91.7 |
| TS (mg/l) | 186-356.5 | 259.5±59.46 | 173-352 | 235.6±66.43 | 324-552 | 431.9±88.6 | 160-227.5 | 190.6±20.09 |
| TDS (mg/l) | 151-321.5 | 224.2±59.28 | 133-312 | 196±66.16 | 214-455 | 332.3±91.04 | 125-192.5 | 156.6±19.58 |
| pH | 7.4-8.03 | 7.68±0.23 | 7.45-7.7 | 7.63±0.1 | 7.94-9.02 | 8.59±0.35 | 7.41-7.7 | 7.5±0.08 |
| DO (mg/l) | 7.59-9.8 | 8.84±0.84 | 7.6-10.6 | 9.42±1.1 | 7.21-10.0 | 8.78±0.89 | 5.56-9.45 | 7.16±1.24 |
| COD (mg/l) | 3.2-7.1 | 5.31±1.33 | 3.8-9.4 | 7.02±1.82 | 3.2-7.0 | 5.42±1.16 | 3.12-5.3 | 4.23±0.61 |
| BOD (mg/l) | 2.2-4.8 | 3.48±0.95 | 1.35-5.25 | 2.81±1.31 | 1.4-4.7 | 3.06±1.13 | 1.05-4.91 | 2.65±1.33 |
| CO$_3^{2-}$(mg/l) | 0.0-5.0 | 1.6±2.05 | 0.0-7.0 | 2.25±2.66 | 0.0-5.0 | 1.51±1.7 | 0.0-3.0 | 0.71±0.98 |
| HCO$_3^-$ (mg/l) | 116-154.3 | 134.2±11.49 | 121.0-144.3 | 129.1±7.6 | 121.0-136.3 | 128.19±4.48 | 112.9-137.0 | 120.33±6.6 |
| Cl$^-$ (mg/l) | 17.58-27.44 | 21.06±2.82 | 19.89-29.54 | 22.57±3.4 | 17.38-23.65 | 19.12±1.71 | 16.07-18.88 | 17.02±0.84 |
| SO$_4^{2-}$ (mg/l) | 15.59-37.01 | 23.34±6.33 | 8.42-30.25 | 21.11±5.53 | 9.82-58.9 | 16.56±14.24 | 7.76-16.91 | 10.35±2.57 |
| Na (mg/l) | 22.86-35.29 | 27.93±3.70 | 22.45-33.81 | 28.31±3.91 | 18.99-24.83 | 22.03±2.22 | 19.12-25.34 | 22.44±2.12 |
| K (mg/l) | 5.21-6.08 | 5.5±0.28 | 5.02-6.09 | 5.34±0.32 | 4.03-4.75 | 4.38±0.22 | 4.39-5.37 | 4.69±0.30 |
| Ca (mg/l) | 27.66-36.05 | 30.79±2.77 | 26.05-36.07 | 29.8±3.35 | 24.05-31.17 | 26.49±2.42 | 20.26-29.84 | 25.0±3.43 |
| Mg (mg/l) | 13.6-16. 1 | 15.22±0.90 | 13.38-17.76 | 15.5±1.27 | 8.87-15.0 | 11.48±1.83 | 8.66-10.63 | 9.52±0.75 |
| NO$_3^-$ (µg/l) | 45.71-602.83 | 216.8±166.47 | 30.0-518.75 | 97.25±141.67 | 12.0-55.22 | 22.47±13.54 | 17.29-32.0 | 22.96±4.72 |
| NO$_2^-$ (µg/l) | 1.7-24.37 | 9.91±7.84 | 3.4-10.2 | 6.57±2.13 | 1.51-11.71 | 5.52±3.8 | 1.51-17.95 | 6.92±4.29 |
| NH$_3$ (mg/l) | 0.19-0.54 | 0.31±0.12 | 0.13-2.5 | 0.43±0.69 | 0.15-0.92 | 0.33±0.21 | 0.24-2.27 | 0.52±0.58 |
| Ortho-P (µg/l) | 38.56-91.89 | 63.31±17.73 | 29.56-86.11 | 58.92±16.99 | 24.42-116.95 | 64.07±29.45 | 52.69-84.82 | 71.02±9.6 |
| Total-P (mg/l) | 0.164-0.384 | 0.239±0.071 | 0.083-0.241 | 0.142±0.05 | 0.053-0.280 | 0.177±0.075 | 0.137-0.409 | 0.246±0.072 |
| SiO$_3^{2-}$ (mg/l) | 2.66-6.66 | 4.0±1.08 | 0.77-2.39 | 1.36±0.46 | 1.22-5.50 | 3.11±1.51 | 1.19-6.50 | 2.40±1.45 |
| Fe (mg/l) | 0.17-1.18 | 0.63±0.41 | 0.19-1.65 | 0.67±0.49 | 0.64-1.71 | 1.02±0.36 | 0.45-2.03 | 1.12±0.44 |
| Mn (µg/l) | 66.18-145.67 | 91.65±23.16 | 21.37-111.77 | 57.33±32.42 | 21.75-158.07 | 69.06±39.69 | 58.87-188.8 | 117.65±34.40 |
| Zn (µg/l) | 24.91-76.93 | 39.75±17.87 | 13.04-38.88 | 19.84±7.96 | 12.20-34.88 | 19.34±6.73 | 13.10-59.85 | 30.67±14.39 |
| Cu (µg/l) | 9.61-49.59 | 25.60±10.98 | 9.78-49.76 | 22.06±12.93 | 7.6-31.4 | 16.69±7.13 | 11.34-43.28 | 23.87±11.48 |
| Pb (µg/l) | 17.60-35.46 | 25.06±5.77 | 15.3-61.11 | 43.72±13.17 | 9.0-23.72 | 15.08±4.6 | 7.99-23.31 | 16.37±5.12 |

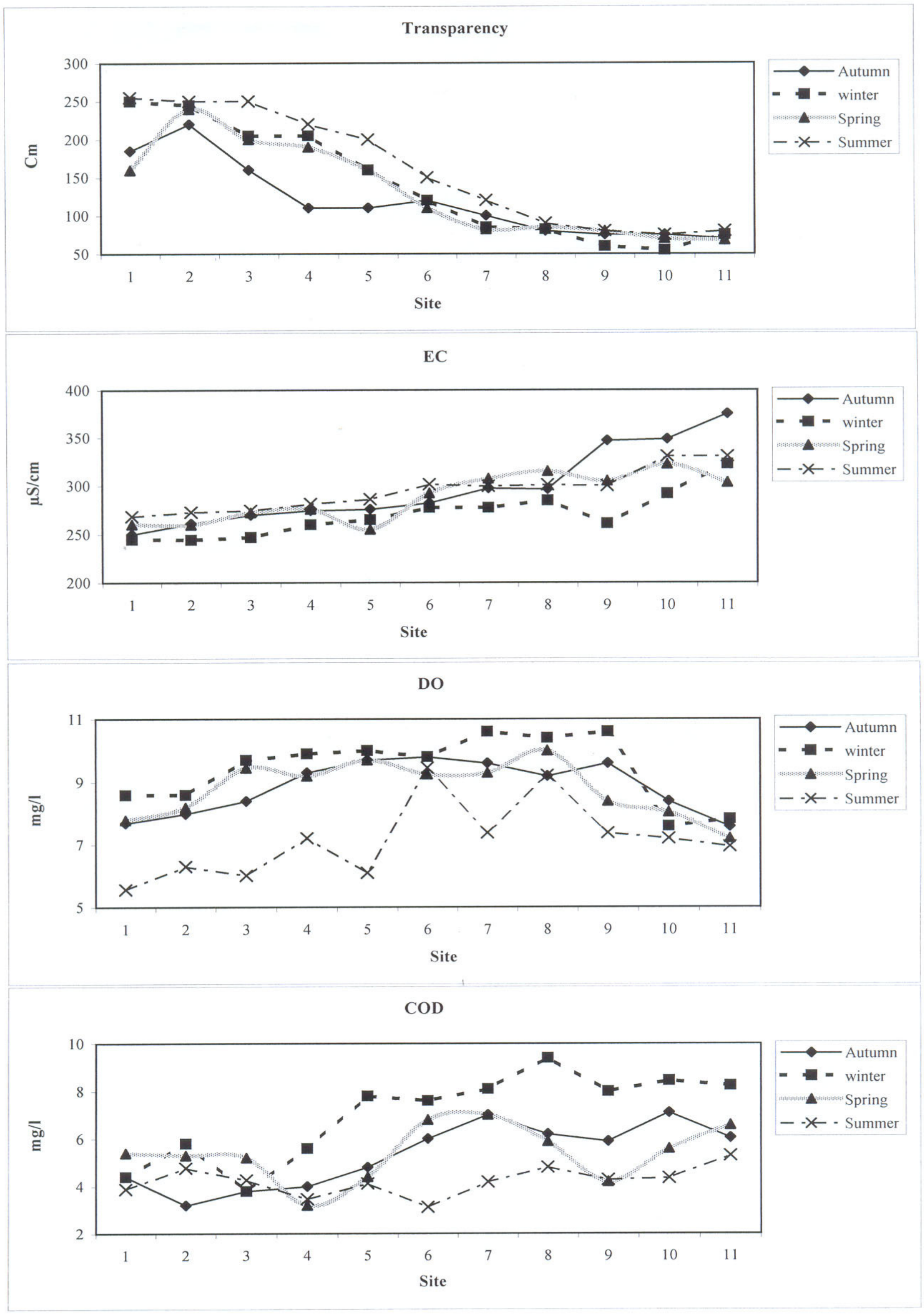

Fig. (2): Variations of some parameters in the River Nile water

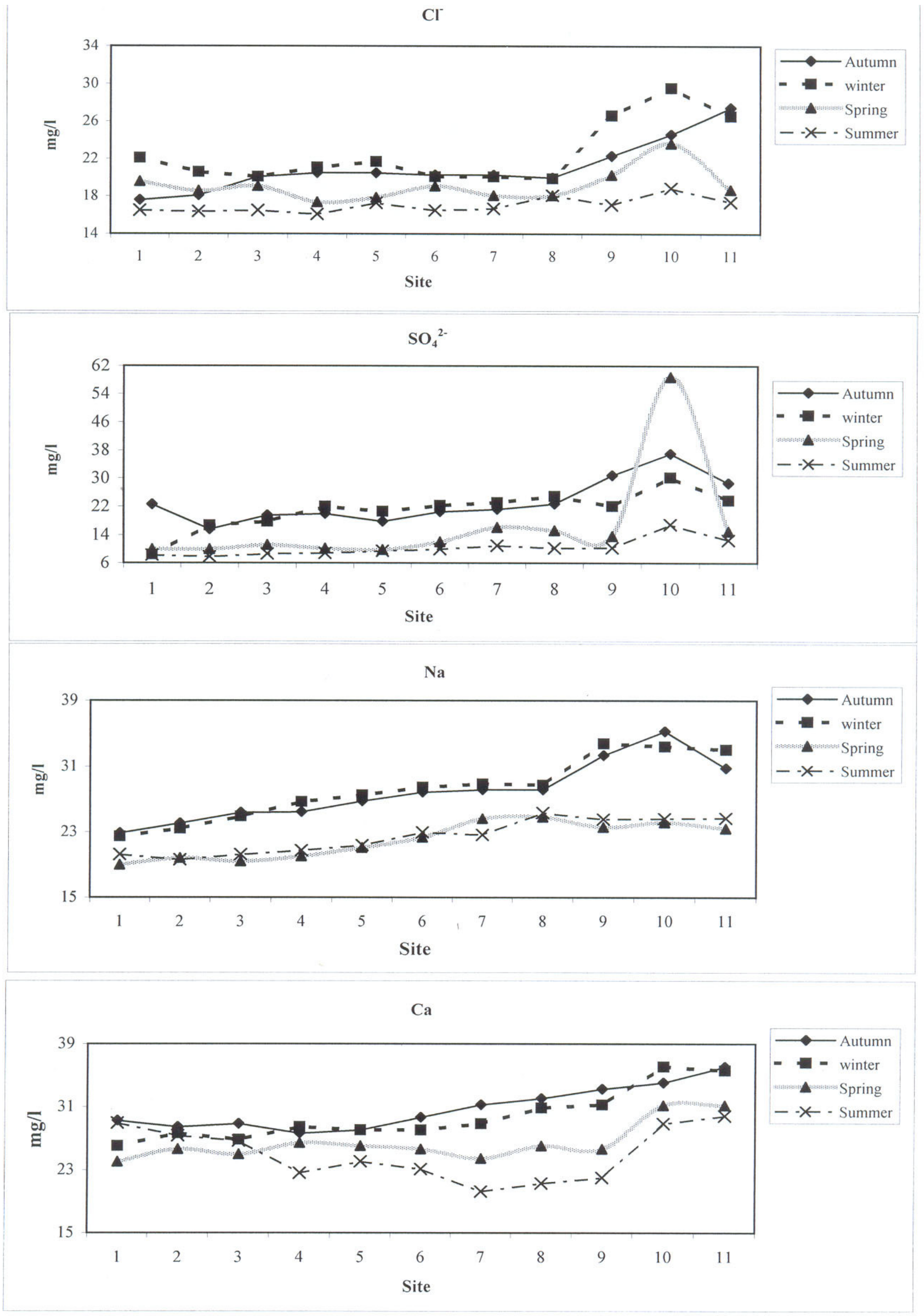

**Fig. (3): Variations of selected major anions and cations in the River Nile water**

The decrease in Na and K concentrations in hot seasons is probably due to the increase in water discharges and their uptake by adsorption on suspended particulate material (Abdo, 2004a). Based on their annual averages, they possessed a ratio of 5:1 (Na:K). The two elements fulfilled a positive relationship (Table 3).

The results indicated that the lowest values of Ca were recorded in the hot seasons (20.26-31.17 mgl$^{-1}$) and the highest in the cold seasons (26.05-36.07 mgl$^{-1}$). This might be due to the decrease in the solubility of $CaCO_3$ as the temperature increase. This was achieved by a negative correlation existed between calcium and water temperature during autumn and summer.

The concentrations of magnesium showed low values (8.66-17.76 mgl$^{-1}$) compared with calcium concentrations (20.26-36.07 mgl$^{-1}$), because there is a preponderance of Ca over Mg in sedimentary rocks, (Abdel-Halim, 1993). In addition, the preferential behavior of dissolved $CO_2$ may affect the concentration of magnesium in solution, when $CO_2$ present in appreciable concentration it reacts with calcium salts than with magnesium, thus converting large quantities of calcium into soluble bicarbonates (Abdel-Halim, 1993). The highest values of Ca (36.07 mgl$^{-1}$) and Mg (17.76 mgl$^{-1}$) were recorded at El-Hawamdia (site 10) opposite to the discharge point of the Sugar and Integrated industries Company.

The concentrations of major cations in the River Nile showed proportions of Ca>Na>Mg>K and major anions of $HCO_3^- > Cl^- \approx SO_4^{2-}$. The ratio of monovalent (Na&K) to divalent (Ca&Mg) cations (M:D) is important in respective to the distribution and dynamics of algae (Roos and Pieterse, 1995). The M:D ratios in the River Nile display relatively small variations and well below 1.5 with a mean of 0.74 (min.=0.67 , max.= 0.80).

With respect to nutrient, Nitrate is often the limiting element restricting biological productivity of Nile water (Toullabah, 1996), and phosphorus control is often of prim importance in reducing deterioration of water quality (Sharpley *et al.*, 1987).

The values of nitrate fluctuated within a wide range 12.0- 602.8 µgl$^{-1}$ (Fig. 4). The highest values were mainly recorded in autumn and winter (30.0-602.8 µgl$^{-1}$), while the lowest in the hot high-flow period (12.0-55.22 µgl$^{-1}$). For most sites, the decrease in nitrate concentrations in spring might be attributed to the uptake of nitrate by natural phytoplankton and its reduction by denitrifying bacteria (Saad and Abdel-Moati, 1997; Sabae and Abdel-Satar, 2001). The increase of nitrate in cold seasons might be attributed to low consumption by phytoplankton as well as the oxidation of ammonia by nitrifying bacteria and biological nitrification (Macdonald, *et al.* 1995).

The results of nitrite showed low levels during the whole period of investigation (1.51-24.37 µgl$^{-1}$). This might be attributed to the fast conversion of $NO_2^-$ to $NO_3^-$ ions by nitrifying bacteria (Abdo, 2004a). The upstream sites (1-4) showed higher values than downstream except site 10 (Fig. 4).

Ammonium accounted for the major proportion of total soluble inorganic nitrogen. It showed a slight increase from up- to down stream sites, but without clear seasonal trends (Fig. 4). The highest concentrations were exclusively registered for site 10 (2.50 mgl$^{-1}$) opposite to the discharge point of the Sugar and Integrated Industries Company and the lowest in winter season for most sites (0.13-0.31 mgl$^{-1}$). Ammonium showed significant positive correlation with temperature during spring and summer (Table 3), which suggest the increase in ammonia with temperature increase (Vander Weijden, and Middelburg, 1989) and with EC during all seasons, which prove the predominance of ionized form in the River Nile. It was correlated negatively with transparency and pH (Table 3).

Values of orthophosphate (ortho-P) and total phosphorus (total-P) exhibited local variations with interrupted seasonal trends and gradual increase from up-to down stream sites by increasing human activity during different seasons. The ranges of ortho-P and total-P were 0.024-0.117 and 0.053-0.409 mgl$^{-1}$, respectively (Fig. 4). Total-P showed relatively high values in summer season (0.137-0.409 mgl$^{-1}$), where the maximum value was recorded at site 10 opposite to the discharge point of the Sugar and Integrated Industries Company.

The statistical analyses showed negative correlation between pH and ortho-P as well as total-P in autumn and summer (Table 3), suggesting that the solubility of phosphorus is dependent on pH (Diaz *et al.*, 1994). The positive correlation between total-P and COD during most seasons (Table 3), suggest that large amount of total-P in Nile water is associated with organic matter.

Silicate fluctuated between 0.77 to 6.66 mgl$^{-1}$ (Fig. 4), without defined seasonal trends. The pronounced decrease in silicate of the Nile water during winter (0.47-2.61 mgl$^{-1}$) is related to the low flow discharge of Nile water in addition to uptake by diatoms blooms, fungi, algae, phyto- and zooplanktons and fishes (Elewa and Gallab, 2000). The silicate showed higher values in the up-stream sites (1-6) than the downstream (7-11), where the maximum values were recorded at site 1 (4.44-6.66 mgl$^{-1}$) opposite to the discharge of the Egyptian ferro-alloy Company.

Obviously, there was a gradual increase in the concentrations of eutrophication key elements (phosphorus and nitrogen) (Fig. 4 ) from up- to downstream sites, Similarly, water conductivity, total dissolved salts, chloride, total alkalinity, Na, K, Ca, Mg, had maximum values at the downstream sites. The results were in conformity with those obtained by (Abdel-Hamid *et al.*, 1992; Elewa, *et al.*, 1995; Masoud *et al.*, 2002)

**Total trace metals in Nile water**

River Nile is the main source for potable water and as the result of human activities in and on the river body, it become loaded by metal pollution (Abdo, 2004b; Ibrahim and Tayel, 2005). Total trace metals exhibited different behavior, with constant or increasing concentrations up river, Fe showed progressive increase from up- to downstream sites with clear seasonal trends and fluctuated between 0.17 and 2.03 mgl$^{-1}$ (Fig. 5). The highest values were estimated in spring and summer while the lowest in cold seasons. The decrease in Fe concentrations during cold seasons might be attributed to the increase in DO, which leading to oxidation of iron and precipitates under alkaline pH. This finding was in conformity with the negative correlation between Fe and DO in winter and spring seasons (Table 3).

Mn concentrations fluctuated between 21.37 and 188.80 µgl$^{-1}$, with interrupted seasonal trends (Fig. 5). It showed a slight increase from up- to downstream sites, while the maximum value was recorded at site 1 (188.8 µgl$^{-1}$) in summer. The significant positive correlation between Fe and Mn during most seasons, (Table 3) indicated that the association of two elements originates from a common source during transportation and/or depositional reactions (Abdel-Satar and Elewa, 2001).

Zinc concentrations fluctuated between 12.20 and 76.93 µgl$^{-1}$. The variations were mainly local without clear seasonal trends, where the maximum values were recorded at sites 5 and 8 in autumn season (Fig. 5). The Zn correlated positively with each of Fe and Mn during most seasons (Table 3). These are due to the Zn adsorption by hydrous iron and manganese oxides (Abdo, 2004b). In addition, Zn is correlated positively with Cu and Pb (Table 3).

Copper showed a wide range of variations (7.60-49.76 µgl$^{-1}$) and a slight increase from up- to downstream sites with interrupted seasonal trends (Fig. 5). Cu concentrations increase sharply at sites 8 and 11 in autumn and 8, 9 and 11 in summer (Fig. 5). This is mainly due to domestic sewage discharge from boats and tourist ships, where the domestic sources are the major contributors of Cu in the environment (Issa *et al.,* 1997). The significant positive correlation between concentrations of Cu/Fe, Cu/Mn and Cu/Pb during most seasons (Table 3), indicate either their common urban origin or their common

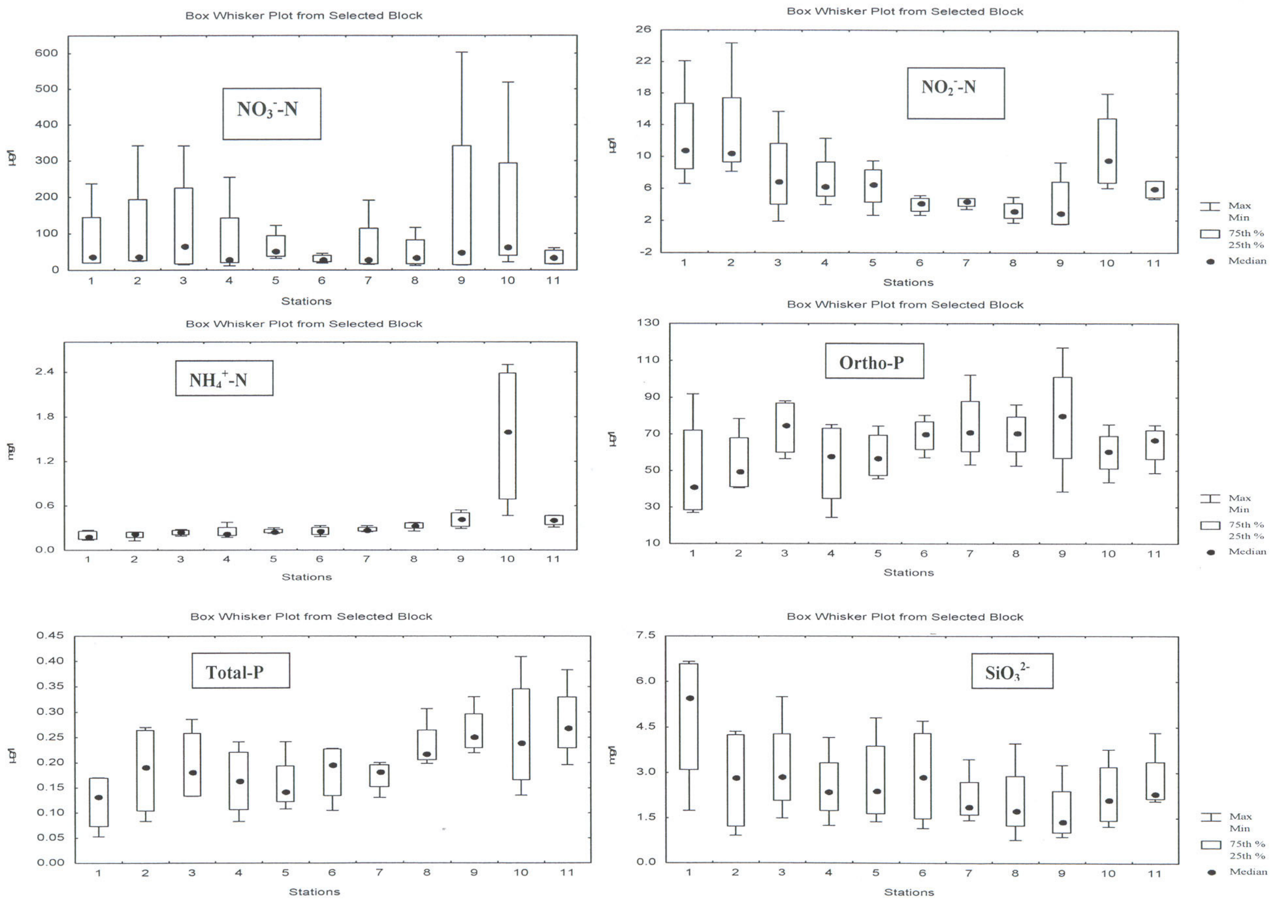

Fig. (4): Multiple Box and Whisker Plot of Nutrient Salts. The central box covers the middle 50% of the data values, between the lower and upper quartiles, while the central point is at median.

sink in the stream sediments (Elewa and Gohar, 1999)

Pb values were characterized by remarkable seasonal variations and fluctuated between 7.99 to 61.11 $\mu gl^{-1}$ (Fig. 5). The increase in Pb during winter season might be attributed to the decrease in water discharges during the months of cold period, where the dilution and assimilative capacities of the Nile water are low as mentioned by (Abdel-Satar and Elewa, 2001). Generally, the increase in Pb concentrations in the Nile water might be attributed to the direct inputs from different sources (industrial wastes and atmospheric inflow of dust containing car exhaust). In addition, the increase in density of boats and ship, which discharge its effluent directly to the Nile containing high amount of Pb in both the dissolved and particular phases (Moon *et al*., 1994, Ibrahim and Tayel, 2005).

The negative significant correlation between transparency and total Fe, Mn, Zn, Cu, Pb during most seasons (Table 3), are mainly due to the effect of High Dam that reduces the amount of the suspended matter and in turn, decreases the total metals concentrations. TS showed significant positive correlation with total Fe, Mn, Zn, Cu and Pb during most seasons (Table 3), where suspended matter contains several types of substances; carbonates, Fe and Mn oxides, clays, organic detritus. These compounds play a role by providing active surface upon which trace metals can adsorb (Boughriet *et al*., 1992). The total trace metals sequence was Fe > Mn > Zn > Cu ≈ Pb in the Nile water.

## Impact of human activities on the River Nile

The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both man and animal.

Six stations (I-VI)) opposite some human activities were chosen to study their impacts on the River Nile, where the toxic compounds arising from industrial discharges (heavy metals, plus inert suspended or dissolved solids) and non point sources destroy the natural biological activity in the water (Ibrahim and Tayel, 2005). The results of ranges, means and SD of the studied physical and chemical parameters in riverbank (stations I-VI) are reported in Table 4.

The water transparency in riverbanks was lower compared to its value in the midstream Nile water. This is mainly attributed to the industrial, tourist wastes and the increase in boats density. It is varied between 40 to 235 cm, where the minimum value was recorded for station V in spring and the maximum for station III in summer.

The present study showed a pronounced increase in COD (3.2-50.09 $mgl^{-1}$) and BOD (2.0-6.8 $mgl^{-1}$) in the riverbank water than the midstream sites exceeding the Egyptian standard values for COD (10 $mgl^{-1}$) and BOD (6 $mgl^{-1}$) at stations V and III, respectively.

As might be expected, negative effects on water quality were observed in the vicinity of pollution point sources. For instance, station V (close to the discharge point of the Sugar and Integrated industries Company) showed a sharp increase in EC (350-573 $\mu Scm^{-1}$), TS (592-794 $mgl^{-1}$), TDS ( 398-501 $mgl^{-1}$), COD (27.4-50.9 $mgl^{-1}$), $SO_4^{2-}$ (74.69-119.13 $mgl^{-1}$), $NH_4^+$-N (1.43-2.23 $mgl^{-1}$), total-P (1.55-2.57 $mgl^{-1}$), Fe (2.01-2.497 $mgl^{-1}$) and Mn (201.9-324.0 $\mu gl^{-1}$) and a slight decrease in pH (7.1-7.6) and DO concentration (4.2-6.2 $mgl^{-1}$), which directly related to the untreated industrial effluents.

Furthermore, station I (close to the discharge of the Egyptian ferro-alloy Company) showed higher values in TS (198-316 $mgl^{-1}$), Ca (29.98-32.07 $mgl^{-1}$), $NO_3^-$ (17.14-488.55 $\mu gl^{-1}$), $SO_4^{2-}$ (14.59-24.28 $mgl^{-1}$), $SiO_3^{2-}$ (1.86-6.95 $mgl^{-1}$) and Fe (0.427-0.77 $mgl^{-1}$) than the midstream sites especially in cold seasons.

Stations II, III (in front of Touristic Galleon parking) showed a pronounced increase in TS (200-388 $mgl^{-1}$), COD (4.8-6.8 $mgl^{-1}$), BOD (2.8-6.8 $mgl^{-1}$), Zn (13.73-69.07

$\mu gl^{-1}$) and Cu (10.23-60.23 $\mu gl^{-1}$) than midstream water, which affected by untreated domestic wastewater rich in organic matter. Beside station, VI is located close to effluents from many workshops for repairing and painting ships spread on the banks. It showed a slight increase in total-P (0.178-0.362 $mgl^{-1}$), COD (5.98-8.80 $mgl^{-1}$), BOD (3.9-4.6 $mgl^{-1}$), Cu (38.56 $\mu gl^{-1}$) and a sharp increase in Pb (30.63-64.98 $\mu gl^{-1}$), where the fuel used in these ships give rise to an increase in the Pb concentration. While, the obtained results at station IV (in front of the Electric Power Station), did not show significant difference with the midstream water except for Mn (59.4-269.33 $\mu gl^{-1}$).

As seen from this study and reported in others (El-Gohary, 1983; Abdel-Hamid *et al.*, 1992; Abdel-Shafy, and Aly, 2002; Wahaab and Badawy 2004; Sabae, 2004), the River Nile receives considerable amounts of untreated effluent rich in organic matter, that affect directly the river banks, while the midstream water is slightly affected. However, we may suggest that River Nile has an intense self-purification capacity, which is confirmed by the work of El-Gohary (1994), reporting that mid-stream conditions of the Nile are still, on an average, at a fairly clean level owing to dilution and degradation of the pollutants discharged.

Generally, pollution by agricultural, domestic and industrial wastes in the River Nile system has increased in the past few decades because of increase in population. Comparisons between the Nile water quality before and after High Dam construction are shown in Table 5.

Table (3): Correlation Coefficient matrix (r) between some physical and chemical parameters during different seasons.

a. Autumn

| | temp | trans | EC | TS | TDS | pH | DO | COD | BOD | $CO_3^{-2}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{-2}$ | Na | K | Ca | Mg | $NO_2^-$ | $NO_3^-$ | $NH_4^+$ | ortho-P | Total-P | $SiO_3^{2-}$ | Fe | Mn | Zn | Cu | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| temp | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| trans | 0.21 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| EC | -0.24 | -0.78 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| TS | 0.06 | -0.54 | 0.81 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | |
| TDS | 0.06 | -0.56 | 0.82 | 1.00 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| pH | -0.18 | -0.40 | 0.00 | -0.12 | -0.12 | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| DO | -0.36 | -0.41 | -0.08 | -0.10 | -0.09 | 0.74 | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| COD | -0.24 | -0.80 | 0.68 | 0.31 | 0.32 | 0.51 | 0.31 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| BOD | -0.33 | -0.84 | 0.81 | 0.62 | 0.62 | 0.32 | 0.40 | 0.80 | 1.00 | | | | | | | | | | | | | | | | | | | |
| $CO_3^{-2}$ | -0.04 | -0.55 | 0.38 | 0.03 | 0.04 | 0.49 | 0.07 | 0.61 | 0.35 | 1.00 | | | | | | | | | | | | | | | | | | |
| $HCO_3^-$ | -0.07 | -0.86 | 0.91 | 0.75 | 0.76 | 0.14 | 0.07 | 0.70 | 0.79 | 0.31 | 1.00 | | | | | | | | | | | | | | | | | |
| $Cl^-$ | -0.04 | -0.73 | 0.93 | 0.75 | 0.76 | -0.08 | -0.18 | 0.56 | 0.70 | 0.34 | 0.93 | 1.00 | | | | | | | | | | | | | | | | |
| $SO_4^{-2}$ | -0.17 | -0.65 | 0.83 | 0.62 | 0.63 | -0.20 | -0.16 | 0.68 | 0.70 | 0.15 | 0.77 | 0.73 | 1.00 | | | | | | | | | | | | | | | |
| Na | -0.29 | -0.80 | 0.90 | 0.69 | 0.69 | 0.15 | 0.15 | 0.79 | 0.87 | 0.27 | 0.87 | 0.80 | 0.88 | 1.00 | | | | | | | | | | | | | | |
| K | -0.37 | -0.68 | 0.72 | 0.47 | 0.47 | 0.12 | 0.25 | 0.76 | 0.88 | 0.21 | 0.64 | 0.58 | 0.83 | 0.90 | 1.00 | | | | | | | | | | | | | |
| Ca | -0.23 | -0.68 | 0.94 | 0.67 | 0.67 | 0.01 | -0.24 | 0.74 | 0.67 | 0.50 | 0.81 | 0.83 | 0.83 | 0.81 | 0.63 | 1.00 | | | | | | | | | | | | |
| Mg | -0.18 | -0.88 | 0.69 | 0.51 | 0.52 | 0.59 | 0.52 | 0.82 | 0.78 | 0.49 | 0.79 | 0.63 | 0.51 | 0.79 | 0.62 | 0.60 | 1.00 | | | | | | | | | | | |
| $NO_2^-$ | 0.39 | 0.90 | -0.59 | -0.28 | -0.29 | -0.68 | -0.63 | -0.85 | -0.76 | -0.56 | -0.70 | -0.51 | -0.45 | -0.70 | -0.60 | -0.54 | -0.93 | 1.00 | | | | | | | | | | |
| $NO_3^-$ | -0.55 | 0.26 | -0.08 | 0.11 | 0.10 | -0.31 | 0.06 | -0.39 | -0.04 | -0.44 | -0.31 | -0.28 | -0.04 | -0.12 | 0.04 | -0.16 | -0.40 | 0.31 | 1.00 | | | | | | | | | |
| $NH_4^+$ | -0.31 | -0.60 | 0.90 | 0.83 | 0.83 | -0.20 | -0.19 | 0.49 | 0.66 | 0.16 | 0.74 | 0.75 | 0.86 | 0.82 | 0.68 | 0.86 | 0.46 | -0.36 | 0.25 | 1.00 | | | | | | | | |
| ortho-P | 0.29 | 0.87 | -0.85 | -0.71 | -0.71 | -0.40 | -0.35 | -0.80 | -0.90 | -0.49 | -0.80 | -0.70 | -0.69 | -0.90 | -0.79 | -0.77 | -0.89 | 0.80 | 0.07 | -0.75 | 1.00 | | | | | | | |
| Total-P | -0.24 | -0.17 | 0.57 | 0.67 | 0.67 | -0.26 | -0.33 | -0.11 | 0.22 | -0.01 | 0.42 | 0.57 | 0.21 | 0.27 | 0.04 | 0.47 | 0.06 | 0.03 | 0.37 | 0.61 | -0.28 | 1.00 | | | | | | |
| $SiO_3^{2-}$ | 0.45 | 0.34 | -0.25 | -0.21 | -0.21 | -0.40 | -0.44 | -0.10 | -0.38 | -0.09 | -0.27 | -0.25 | -0.01 | -0.35 | -0.33 | -0.05 | -0.33 | 0.36 | -0.22 | -0.22 | 0.38 | -0.38 | 1.00 | | | | | |
| Fe | -0.36 | -0.78 | 0.89 | 0.65 | 0.65 | 0.24 | 0.10 | 0.83 | 0.82 | 0.52 | 0.76 | 0.71 | 0.81 | 0.91 | 0.81 | 0.90 | 0.76 | -0.70 | -0.05 | 0.85 | -0.94 | 0.30 | -0.24 | 1.00 | | | | |
| Mn | -0.12 | -0.02 | 0.18 | 0.54 | 0.53 | -0.01 | 0.11 | 0.00 | 0.26 | -0.29 | 0.04 | -0.06 | 0.21 | 0.18 | 0.21 | 0.13 | -0.01 | 0.09 | 0.65 | 0.46 | -0.31 | 0.32 | -0.07 | 0.27 | 1.00 | | | |
| Zn | 0.21 | -0.26 | -0.03 | 0.13 | 0.13 | 0.60 | 0.27 | 0.06 | -0.08 | 0.37 | 0.11 | -0.05 | -0.23 | -0.03 | -0.26 | -0.01 | 0.29 | -0.27 | -0.19 | -0.03 | -0.21 | 0.09 | -0.35 | 0.08 | 0.14 | 1.00 | | |
| Cu | -0.03 | -0.68 | 0.70 | 0.49 | 0.49 | 0.36 | -0.04 | 0.53 | 0.45 | 0.78 | 0.68 | 0.72 | 0.31 | 0.50 | 0.21 | 0.71 | 0.65 | -0.59 | -0.41 | 0.48 | -0.64 | 0.49 | -0.31 | 0.63 | -0.16 | 0.49 | 1.00 | |
| Pb | -0.21 | -0.17 | 0.35 | 0.46 | 0.46 | -0.25 | -0.11 | 0.00 | 0.18 | -0.20 | 0.33 | 0.29 | 0.21 | 0.09 | -0.07 | 0.33 | 0.04 | -0.07 | 0.34 | 0.40 | -0.13 | 0.55 | 0.26 | 0.14 | 0.40 | -0.16 | 0.12 | 1.00 |

b. Winter

| | temp | trans | EC | TS | TDS | pH | DO | COD | BOD | $CO_3^{-2}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{-2}$ | Na | K | Ca | Mg | $NO_2^-$ | $NO_3^-$ | $NH_4^+$ | ortho-P | Total-P | $SiO_3^{2-}$ | Fe | Mn | Zn | Cu | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| temp | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| trans | -0.68 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| EC | 0.34 | -0.77 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| TS | 0.23 | -0.73 | 0.65 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | |
| TDS | 0.24 | -0.73 | 0.66 | 1.00 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| pH | 0.25 | 0.05 | -0.41 | -0.53 | -0.52 | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| DO | 0.46 | -0.10 | -0.31 | -0.40 | -0.40 | 0.93 | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| COD | 0.45 | -0.87 | 0.74 | 0.50 | 0.51 | 0.10 | 0.12 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| BOD | 0.45 | -0.61 | 0.31 | 0.36 | 0.37 | 0.08 | 0.27 | 0.45 | 1.00 | | | | | | | | | | | | | | | | | | | |
| $CO_3^{-2}$ | 0.68 | -0.47 | 0.14 | -0.22 | -0.21 | 0.64 | 0.69 | 0.53 | 0.55 | 1.00 | | | | | | | | | | | | | | | | | | |
| $HCO_3^-$ | 0.05 | -0.62 | 0.72 | 0.90 | 0.90 | -0.65 | -0.50 | 0.47 | 0.36 | -0.26 | 1.00 | | | | | | | | | | | | | | | | | |
| $Cl^-$ | -0.03 | -0.54 | 0.49 | 0.93 | 0.93 | -0.62 | -0.57 | 0.35 | 0.34 | -0.35 | 0.86 | 1.00 | | | | | | | | | | | | | | | | |
| $SO_4^{-2}$ | 0.46 | -0.82 | 0.70 | 0.63 | 0.64 | -0.08 | 0.00 | 0.77 | 0.19 | 0.18 | 0.48 | 0.44 | 1.00 | | | | | | | | | | | | | | | |
| Na | 0.50 | -0.93 | 0.75 | 0.90 | 0.90 | -0.20 | -0.06 | 0.76 | 0.53 | 0.17 | 0.76 | 0.74 | 0.81 | 1.00 | | | | | | | | | | | | | | |
| K | 0.13 | -0.45 | 0.41 | 0.50 | 0.50 | -0.44 | -0.48 | 0.35 | 0.11 | 0.04 | 0.51 | 0.59 | 0.36 | 0.41 | 1.00 | | | | | | | | | | | | | |
| Ca | 0.20 | -0.77 | 0.84 | 0.90 | 0.90 | -0.58 | -0.48 | 0.66 | 0.33 | -0.12 | 0.89 | 0.83 | 0.76 | 0.87 | 0.58 | 1.00 | | | | | | | | | | | | |
| Mg | 0.42 | -0.81 | 0.59 | 0.83 | 0.83 | -0.13 | 0.05 | 0.61 | 0.67 | 0.17 | 0.76 | 0.71 | 0.52 | 0.89 | 0.25 | 0.67 | 1.00 | | | | | | | | | | | |
| $NO_2^-$ | -0.52 | 0.34 | -0.37 | 0.21 | 0.21 | -0.40 | -0.43 | -0.46 | 0.14 | -0.53 | 0.23 | 0.48 | -0.51 | -0.11 | 0.09 | -0.01 | 0.08 | 1.00 | | | | | | | | | | |
| $NO_3^-$ | -0.02 | -0.36 | 0.24 | 0.60 | 0.60 | -0.54 | -0.54 | 0.20 | -0.01 | -0.32 | 0.50 | 0.70 | 0.51 | 0.43 | 0.74 | 0.60 | 0.27 | 0.17 | 1.00 | | | | | | | | | |
| $NH_4^+$ | 0.01 | -0.45 | 0.36 | 0.63 | 0.63 | -0.52 | -0.53 | 0.33 | 0.04 | -0.24 | 0.53 | 0.71 | 0.60 | 0.51 | 0.77 | 0.67 | 0.31 | 0.09 | 0.98 | 1.00 | | | | | | | | |
| ortho-P | 0.80 | -0.61 | 0.31 | 0.39 | 0.39 | 0.00 | 0.33 | 0.30 | 0.35 | 0.31 | 0.29 | 0.12 | 0.53 | 0.52 | 0.06 | 0.35 | 0.46 | -0.39 | 0.16 | 0.13 | 1.00 | | | | | | | |
| Total-P | 0.51 | -0.66 | 0.41 | 0.56 | 0.56 | -0.07 | 0.16 | 0.55 | 0.56 | 0.32 | 0.57 | 0.40 | 0.37 | 0.64 | 0.17 | 0.54 | 0.62 | 0.02 | 0.00 | 0.01 | 0.63 | 1.00 | | | | | | |
| $SiO_3^{2-}$ | -0.20 | -0.04 | 0.49 | 0.35 | 0.36 | -0.72 | -0.64 | -0.13 | 0.12 | -0.43 | 0.54 | 0.40 | -0.05 | 0.15 | 0.16 | 0.36 | 0.27 | 0.22 | 0.17 | 0.18 | -0.10 | -0.15 | 1.00 | | | | | |
| Fe | 0.41 | -0.86 | 0.66 | 0.89 | 0.90 | -0.41 | -0.26 | 0.66 | 0.50 | 0.09 | 0.81 | 0.82 | 0.75 | 0.90 | 0.66 | 0.91 | 0.75 | 0.03 | 0.68 | 0.72 | 0.54 | 0.66 | 0.15 | 1.00 | | | | |
| Mn | 0.58 | -0.92 | 0.59 | 0.82 | 0.83 | -0.18 | -0.04 | 0.73 | 0.57 | 0.30 | 0.66 | 0.72 | 0.75 | 0.92 | 0.61 | 0.80 | 0.77 | -0.05 | 0.56 | 0.61 | 0.57 | 0.70 | -0.05 | 0.96 | 1.00 | | | |
| Zn | 0.17 | -0.48 | 0.60 | 0.72 | 0.72 | -0.45 | -0.25 | 0.29 | 0.40 | -0.19 | 0.79 | 0.61 | 0.29 | 0.65 | 0.11 | 0.69 | 0.65 | 0.24 | 0.01 | 0.03 | 0.37 | 0.71 | 0.42 | 0.58 | 0.50 | 1.00 | | |
| Cu | 0.17 | -0.63 | 0.72 | 0.93 | 0.93 | -0.66 | -0.50 | 0.41 | 0.39 | -0.24 | 0.96 | 0.87 | 0.45 | 0.79 | 0.49 | 0.88 | 0.76 | 0.27 | 0.43 | 0.46 | 0.34 | 0.62 | 0.53 | 0.82 | 0.70 | 0.87 | 1.00 | |
| Pb | -0.04 | -0.16 | 0.02 | 0.37 | 0.38 | -0.43 | -0.25 | -0.04 | 0.58 | -0.10 | 0.45 | 0.51 | -0.06 | 0.23 | 0.24 | 0.37 | 0.27 | 0.63 | 0.24 | 0.20 | 0.21 | 0.54 | 0.14 | 0.48 | 0.39 | 0.53 | 0.50 | 1.00 |

Table (3): Continued.

c. Spring

| | temp | trans | EC | TS | TDS | pH | DO | COD | BOD | $CO_3^{-2}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{-2}$ | Na | K | Ca | Mg | $NO_2^-$ | $NO_3^-$ | $NH_4^+$ | ortho-P | Total-P | $SiO_3^{2-}$ | Fe | Mn | Zn | Cu | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| temp | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| trans | -0.57 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| EC | 0.61 | -0.87 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| TS | 0.62 | -0.87 | 0.91 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | |
| TDS | 0.65 | -0.87 | 0.91 | 1.00 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| pH | -0.18 | 0.14 | 0.06 | 0.04 | 0.08 | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| DO | -0.31 | 0.14 | -0.06 | -0.20 | -0.16 | 0.44 | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| COD | 0.08 | -0.48 | 0.43 | 0.32 | 0.29 | -0.32 | -0.13 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| BOD | 0.41 | -0.27 | 0.21 | 0.34 | 0.37 | 0.06 | 0.48 | 0.07 | 1.00 | | | | | | | | | | | | | | | | | | | |
| $CO_3^{-2}$ | 0.03 | 0.04 | 0.03 | -0.02 | -0.01 | -0.19 | 0.29 | 0.29 | 0.53 | 1.00 | | | | | | | | | | | | | | | | | | |
| $HCO_3^-$ | 0.22 | 0.05 | -0.15 | 0.08 | 0.04 | -0.52 | -0.84 | -0.12 | -0.24 | -0.21 | 1.00 | | | | | | | | | | | | | | | | | |
| $Cl^-$ | 0.58 | -0.38 | 0.45 | 0.33 | 0.32 | -0.43 | -0.46 | 0.10 | -0.30 | -0.35 | 0.23 | 1.00 | | | | | | | | | | | | | | | | |
| $SO_4^{-2}$ | 0.73 | -0.46 | 0.60 | 0.38 | 0.39 | -0.23 | -0.26 | 0.15 | -0.14 | -0.23 | 0.03 | 0.87 | 1.00 | | | | | | | | | | | | | | | |
| Na | 0.57 | -0.90 | 0.91 | 0.85 | 0.86 | 0.22 | 0.07 | 0.47 | 0.36 | 0.00 | -0.30 | 0.26 | 0.46 | 1.00 | | | | | | | | | | | | | | |
| K | 0.70 | -0.42 | 0.24 | 0.20 | 0.23 | -0.07 | -0.04 | -0.08 | 0.38 | -0.01 | 0.03 | 0.22 | 0.49 | 0.42 | 1.00 | | | | | | | | | | | | | |
| Ca | 0.85 | -0.46 | 0.50 | 0.54 | 0.55 | -0.20 | -0.51 | 0.13 | 0.15 | -0.20 | 0.42 | 0.50 | 0.67 | 0.41 | 0.50 | 1.00 | | | | | | | | | | | | |
| Mg | 0.82 | -0.68 | 0.67 | 0.69 | 0.72 | -0.01 | -0.38 | 0.12 | 0.11 | -0.29 | 0.09 | 0.61 | 0.69 | 0.64 | 0.48 | 0.82 | 1.00 | | | | | | | | | | | |
| $NO_2^-$ | 0.03 | 0.14 | -0.09 | -0.26 | -0.30 | -0.37 | -0.61 | 0.18 | -0.74 | -0.43 | 0.45 | 0.52 | 0.48 | -0.21 | 0.04 | 0.25 | 0.03 | 1.00 | | | | | | | | | | |
| $NO_3^-$ | 0.52 | -0.10 | 0.04 | -0.13 | -0.10 | -0.23 | -0.17 | -0.02 | -0.13 | -0.40 | 0.00 | 0.65 | 0.74 | 0.10 | 0.61 | 0.49 | 0.48 | 0.52 | 1.00 | | | | | | | | | |
| $NH_4^+$ | 0.82 | -0.56 | 0.69 | 0.53 | 0.55 | -0.16 | -0.25 | 0.14 | 0.01 | -0.28 | 0.05 | 0.84 | 0.97 | 0.56 | 0.50 | 0.76 | 0.79 | 0.34 | 0.69 | 1.00 | | | | | | | | |
| ortho-P | 0.27 | -0.71 | 0.69 | 0.74 | 0.75 | 0.25 | 0.16 | 0.39 | 0.37 | 0.15 | -0.38 | 0.11 | 0.07 | 0.79 | 0.04 | -0.02 | 0.41 | -0.50 | -0.24 | 0.19 | 1.00 | | | | | | | |
| Total-P | 0.74 | -0.84 | 0.85 | 0.87 | 0.89 | -0.02 | -0.10 | 0.38 | 0.40 | -0.10 | -0.07 | 0.43 | 0.56 | 0.83 | 0.34 | 0.72 | 0.85 | -0.20 | 0.22 | 0.71 | 0.59 | 1.00 | | | | | | |
| $SiO_3^{2-}$ | -0.55 | 0.76 | -0.87 | -0.82 | -0.82 | -0.30 | 0.18 | -0.11 | -0.02 | 0.20 | 0.01 | -0.33 | -0.52 | -0.82 | -0.38 | -0.49 | -0.66 | 0.01 | -0.03 | -0.60 | -0.54 | -0.68 | 1.00 | | | | | |
| Fe | 0.78 | -0.84 | 0.87 | 0.86 | 0.86 | -0.12 | -0.32 | 0.39 | 0.16 | -0.24 | 0.09 | 0.66 | 0.73 | 0.82 | 0.38 | 0.75 | 0.87 | 0.10 | 0.37 | 0.84 | 0.55 | 0.93 | -0.74 | 1.00 | | | | |
| Mn | 0.63 | -0.64 | 0.74 | 0.64 | 0.64 | -0.09 | -0.47 | 0.42 | -0.20 | -0.42 | 0.14 | 0.75 | 0.80 | 0.65 | 0.23 | 0.73 | 0.80 | 0.44 | 0.49 | 0.85 | 0.33 | 0.76 | -0.65 | 0.91 | 1.00 | | | |
| Zn | 0.66 | -0.56 | 0.54 | 0.67 | 0.66 | -0.41 | -0.64 | 0.27 | 0.07 | -0.12 | 0.57 | 0.47 | 0.47 | 0.36 | 0.17 | 0.86 | 0.72 | 0.17 | 0.14 | 0.57 | 0.10 | 0.72 | -0.46 | 0.74 | 0.68 | 1.00 | | |
| Cu | 0.43 | -0.55 | 0.38 | 0.52 | 0.48 | -0.52 | -0.84 | 0.48 | -0.21 | -0.21 | 0.60 | 0.50 | 0.33 | 0.31 | 0.08 | 0.58 | 0.60 | 0.36 | 0.16 | 0.37 | 0.23 | 0.50 | -0.31 | 0.63 | 0.65 | 0.79 | 1.00 | |
| Pb | 0.09 | -0.36 | 0.23 | 0.34 | 0.32 | -0.26 | -0.46 | 0.20 | -0.18 | -0.02 | 0.32 | 0.00 | 0.02 | 0.10 | -0.11 | 0.41 | 0.40 | -0.01 | -0.21 | 0.03 | -0.01 | 0.36 | -0.27 | 0.26 | 0.25 | 0.68 | 0.59 | 1.00 |

d. Summer

| | temp | trans | EC | TS | TDS | pH | DO | COD | BOD | $CO_3^{-2}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{-2}$ | Na | K | Ca | Mg | $NO_2^-$ | $NO_3^-$ | $NH_4^+$ | ortho-P | Total-P | $SiO_3^{2-}$ | Fe | Mn | Zn | Cu | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| temp | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| trans | -0.74 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| EC | 0.73 | -0.90 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| TS | 0.72 | -0.76 | 0.89 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | | |
| TDS | 0.74 | -0.78 | 0.90 | 1.00 | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| pH | -0.77 | 0.68 | -0.73 | -0.73 | -0.76 | 1.00 | | | | | | | | | | | | | | | | | | | | | | |
| DO | 0.59 | -0.59 | 0.44 | 0.53 | 0.53 | -0.30 | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| COD | -0.10 | -0.35 | 0.36 | 0.25 | 0.26 | -0.18 | -0.19 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| BOD | 0.64 | -0.63 | 0.56 | 0.73 | 0.69 | -0.35 | 0.87 | -0.07 | 1.00 | | | | | | | | | | | | | | | | | | | |
| $CO_3^{-2}$ | 0.38 | -0.68 | 0.40 | 0.36 | 0.34 | -0.30 | 0.34 | 0.37 | 0.53 | 1.00 | | | | | | | | | | | | | | | | | | |
| $HCO_3^-$ | 0.58 | -0.69 | 0.88 | 0.81 | 0.83 | -0.73 | 0.16 | 0.46 | 0.36 | 0.22 | 1.00 | | | | | | | | | | | | | | | | | |
| $Cl^-$ | 0.48 | -0.71 | 0.73 | 0.54 | 0.55 | -0.62 | 0.25 | 0.46 | 0.32 | 0.49 | 0.55 | 1.00 | | | | | | | | | | | | | | | | |
| $SO_4^{-2}$ | 0.60 | -0.76 | 0.90 | 0.69 | 0.70 | -0.66 | 0.23 | 0.26 | 0.33 | 0.29 | 0.72 | 0.83 | 1.00 | | | | | | | | | | | | | | | |
| Na | 0.72 | -0.97 | 0.86 | 0.78 | 0.79 | -0.71 | 0.64 | 0.35 | 0.71 | 0.73 | 0.67 | 0.75 | 0.71 | 1.00 | | | | | | | | | | | | | | |
| K | 0.29 | -0.54 | 0.60 | 0.41 | 0.40 | -0.25 | -0.11 | 0.23 | 0.17 | 0.48 | 0.43 | 0.57 | 0.76 | 0.47 | 1.00 | | | | | | | | | | | | | |
| Ca | -0.35 | 0.21 | 0.12 | 0.13 | 0.09 | 0.09 | -0.56 | 0.36 | -0.22 | -0.20 | 0.35 | 0.17 | 0.24 | -0.18 | 0.40 | 1.00 | | | | | | | | | | | | |
| Mg | 0.22 | 0.05 | 0.13 | 0.15 | 0.16 | -0.01 | -0.19 | 0.36 | -0.03 | -0.14 | 0.34 | -0.05 | -0.01 | -0.10 | -0.06 | 0.24 | 1.00 | | | | | | | | | | | |
| $NO_2^-$ | -0.06 | 0.07 | 0.19 | 0.02 | 0.02 | 0.01 | -0.26 | 0.11 | -0.21 | -0.28 | 0.09 | 0.49 | 0.53 | -0.10 | 0.45 | 0.55 | 0.12 | 1.00 | | | | | | | | | | |
| $NO_3^-$ | -0.06 | 0.59 | -0.43 | -0.42 | -0.39 | 0.28 | -0.30 | -0.36 | -0.42 | -0.65 | -0.34 | -0.29 | -0.32 | -0.62 | -0.39 | -0.01 | 0.49 | 0.30 | 1.00 | | | | | | | | | |
| $NH_4^+$ | 0.42 | -0.47 | 0.63 | 0.42 | 0.42 | -0.40 | 0.06 | 0.09 | 0.18 | 0.18 | 0.41 | 0.76 | 0.89 | 0.43 | 0.79 | 0.34 | -0.04 | 0.79 | -0.10 | 1.00 | | | | | | | | |
| ortho-P | 0.89 | -0.69 | 0.61 | 0.65 | 0.68 | -0.62 | 0.54 | -0.19 | 0.55 | 0.39 | 0.42 | 0.25 | 0.45 | 0.62 | 0.31 | -0.48 | 0.08 | -0.26 | -0.13 | 0.24 | 1.00 | | | | | | | |
| Total-P | 0.40 | -0.57 | 0.63 | 0.54 | 0.50 | -0.29 | 0.36 | 0.32 | 0.52 | 0.45 | 0.36 | 0.69 | 0.73 | 0.58 | 0.63 | 0.20 | 0.05 | 0.57 | -0.36 | 0.79 | 0.21 | 1.00 | | | | | | |
| $SiO_3^{2-}$ | -0.55 | 0.48 | -0.38 | -0.43 | -0.46 | 0.24 | -0.51 | -0.20 | -0.39 | -0.26 | -0.16 | -0.17 | -0.17 | -0.40 | 0.00 | 0.51 | -0.39 | 0.15 | -0.08 | -0.01 | -0.67 | -0.26 | 1.00 | | | | | |
| Fe | 0.75 | -0.84 | 0.92 | 0.74 | 0.76 | -0.75 | 0.27 | 0.20 | 0.43 | 0.46 | 0.78 | 0.74 | 0.94 | 0.80 | 0.77 | 0.12 | 0.02 | 0.27 | -0.41 | 0.77 | 0.63 | 0.63 | -0.20 | 1.00 | | | | |
| Mn | 0.06 | -0.21 | 0.17 | 0.04 | 0.02 | -0.15 | 0.00 | -0.24 | 0.15 | 0.26 | 0.23 | 0.03 | 0.22 | 0.23 | 0.34 | 0.14 | -0.45 | -0.17 | -0.53 | 0.16 | -0.01 | 0.02 | 0.65 | 0.37 | 1.00 | | | |
| Zn | 0.44 | -0.40 | 0.44 | 0.56 | 0.53 | -0.42 | 0.09 | 0.20 | 0.40 | 0.40 | 0.57 | -0.06 | 0.21 | 0.39 | 0.29 | 0.09 | 0.30 | -0.40 | -0.47 | -0.01 | 0.46 | 0.19 | -0.17 | 0.45 | 0.34 | 1.00 | | |
| Cu | 0.47 | -0.62 | 0.45 | 0.52 | 0.51 | -0.46 | 0.43 | 0.38 | 0.58 | 0.70 | 0.50 | 0.16 | 0.12 | 0.67 | 0.05 | -0.25 | 0.14 | -0.64 | -0.63 | -0.21 | 0.43 | 0.16 | -0.30 | 0.36 | 0.29 | 0.75 | 1.00 | |
| Pb | 0.36 | -0.49 | 0.43 | 0.41 | 0.38 | -0.37 | 0.43 | 0.00 | 0.54 | 0.38 | 0.49 | 0.07 | 0.24 | 0.54 | 0.10 | -0.09 | -0.15 | -0.43 | -0.64 | -0.02 | 0.23 | 0.16 | 0.19 | 0.43 | 0.76 | 0.63 | 0.74 | 1.00 |

Table (4): Ranges, means and standard deviation of the physical and chemical parameters in the riverbanks Nile water.

| Parameter | Autumn | | Winter | | Spring | | Summer | |
|---|---|---|---|---|---|---|---|---|
| | Ranges | Means±SD | Ranges | Means±SD | Ranges | Means±SD | Ranges | Means±SD |
| Water Temp.($^oC$) | 19.4-22 | 21.05±1.07 | 17.1-18.8 | 17.9±0.65 | 22.3-27.5 | 24.35±1.99 | 23.4-28.6 | 25.62±2.19 |
| EC ($\mu Scm^{-1}$) | 255-573 | 341.8±120.8 | 237-380 | 290.3±53.4 | 260-430 | 310.8±60.5 | 264-350 | 300±34.4 |
| Transparency(cm) | 50-190 | 108.3±53.8 | 50-220 | 113.8±72.5 | 40-220 | 122.3±71.6 | 55-240 | 151.7±91.7 |
| TS (mg/l) | 198-764 | 341±217.9 | 211-650 | 319.5±169.5 | 316-794 | 470.5±179.7 | 200-592 | 286.2±150.5 |
| TDS (mg/l) | 140-501 | 240.7±140 | 141-400 | 219.5±101.7 | 216-495 | 337.3±114.7 | 138-398 | 188.8±102.8 |
| pH | 7.28-8.15 | 7.61±0.32 | 7.25-7.66 | 7.51±0.14 | 7.6-8.8 | 8.15±0.43 | 7.1-7.47 | 7.27±0.16 |
| DO (mg/l) | 6.2-8.6 | 7.8±0.9 | 6.0-9.6 | 8.2±1.3 | 5.2-9.2 | 7.8±1.5 | 4.2-7.5 | 5.8±1.1 |
| COD (mg/l) | 4.8-50.9 | 13.27±18.46 | 3.2-38.2 | 11.5±13.22 | 5.4-27.4 | 10.36±8.44 | 4-28.8 | 9.04±9.71 |
| BOD (mg/l) | 2.5-6.8 | 4.6±1.6 | 2.0-5.6 | 3.6±1.2 | 2.0-4.9 | 3.9±1.1 | 2.1-3.9 | 3.1±0.7 |
| $CO_3^{2-}$(mg/l) | 0-4.8 | 1.47±2.29 | 0-4.4 | 0.77±1.78 | 0-4 | 1.4±1.63 | 0-2 | 0.4±0.79 |
| $HCO_3^-$ (mg/l) | 118.4-159 | 136.57±17.94 | 120-148 | 128.93±12.62 | 126-136 | 129.07±3.65 | 11.8-137.2 | 123.47±10.24 |
| $Cl^-$ (mg/l) | 18.08-36.16 | 23.57±7.11 | 20.09-37.16 | 24.97±6.69 | 17.07-38.17 | 22.00±8.13 | 16.07-38.17 | 20.02±8.90 |
| $SO_4^{2-}$ (mg/l) | 17.78-87.56 | 30.93±27.79 | 13.53-91.54 | 32.63±29.14 | 9.15-119.13 | 30.77±43.40 | 7.96-74.69 | 20.72±26.50 |
| Na (mg/l) | 22.86-49.12 | 31.03±9.33 | 23.27-36.96 | 29.02±5.20 | 19.62-33.39 | 23.56±5.03 | 19.44-28.68 | 22.67±3.66 |
| K (mg/l) | 4.98-7.53 | 5.76±0.90 | 4.94-9.10 | 5.79±1.63 | 4.03-6.12 | 4.62±0.76 | 4.46-8.20 | 5.29±1.43 |
| Ca (mg/l) | 28.86-58.11 | 35.00±10.47 | 26.45-64.13 | 35.08±14.39 | 24.05-60.92 | 31.68±14.39 | 17.31-55.98 | 31.86±12.79 |
| Mg (mg/l) | 13.96-19.48 | 15.66±2.05 | 14.79-18.44 | 15.62±1.40 | 8.51-17.43 | 11.47±3.15 | 8.01-13.58 | 10.79±2.40 |
| $NO_3^-$ (µg/l) | 76.71-488.55 | 194.97±155.4 | 28.57-1400.50 | 273.11±552.7 | 8.57-78.85 | 25.38±26.63 | 7.43-50.74 | 27.50±15.79 |
| $NO_2^-$ (µg/l) | 3.02-52.14 | 20.95±17.53 | 4.16-22.29 | 8.51±6.97 | 3.02-25.69 | 8.46±8.59 | 1.13-32.65 | 11.04±11.06 |
| $NH_3$ (mg/l) | 0.176-2.229 | 0.549±0.824 | 0.148-1.425 | 0.406±0.501 | 0.130-1.573 | 0.497±0.538 | 0.194-1.798 | 0.537±0.622 |
| Ortho-P (µg/l) | 59.11-119.52 | 78.82±24.18 | 46.27-204.02 | 76.84±62.40 | 51.41-321.00 | 106.41±105.4 | 59.12-356.00 | 123.59±114.2 |
| Total-P (mg/l) | 2.318-2.318 | 0.574±0.857 | 1.547-1.547 | 0.367±0.579 | 1.784-1.784 | 0.430±0.668 | 2.568-2.568 | 0.613±0.958 |
| $SiO_3^{2-}$ (mg/l) | 4.595-7.590 | 5.823±1.177 | 0.931-2.007 | 1.409±0.431 | 1.745-6.339 | 3.569±1.577 | 2.268-6.809 | 3.572±1.721 |
| Fe (mg/l) | 0.169-2.088 | 0.791±0.731 | 0.155-2.011 | 0.875±0.740 | 0.203-2.136 | 1.143±0.815 | 0.403-2.706 | 1.454±1.032 |
| Mn (µg/l) | 33.54-262.47 | 97.69±83.23 | 27.53-264.89 | 82.28±91.81 | 18.13-259.13 | 115.31±96.95 | 53.33-324.02 | 183.56±110.7 |
| Zn (µg/l) | 21.80-69.07 | 43.43±15.60 | 25.27-44.11 | 32.10±6.85 | 13.73-39.88 | 24.65±9.43 | 18.07-69.90 | 31.31±19.64 |
| Cu (µg/l) | 10.23-60.81 | 38.54±24.1 | 12.93-55.47 | 32.94±16.7 | 14.00-38.56 | 25.57±8.7 | 14.00-45.36 | 26.87±13.7 |
| Pb (µg/l) | 10.33-39.51 | 24.99±10.59 | 41.67-64.98 | 52.49±8.06 | 7.33-31.87 | 17.03±8.67 | 11.00-30.63 | 18.11±6.77 |

Table (5): Water quality characteristics of the River Nile before and after High Dam construction

| Parameter | 1933-36[1] | 1964[2] | 1966[2] | 1976[2] | 1979[2] | 1987/88[3] | 1991[4] | 1995/96[5] | 1999/2000[6] | Present results |
|---|---|---|---|---|---|---|---|---|---|---|
| Temperature °C | N.R. | 19-30.5 | 13-29 | 14-29 | N.R. | 12-32 | 21.1-23 | 19.2-29.3 | N.R | 17.1-28.2 |
| pH | N.R. | 7.2-8.3 | 7.9-8.2 | 7.2-8.8 | 7.7-8.5 | 5.8-9.01 | 7.4-8.9 | 6.9-8.6 | 6.89-8.22 | 7.4-9.03 |
| E.C µmhos $cm^{-1}$ | N.R. | 208-420 | N.R. | 311-402 | 210-320 | 150-1300 | 130-385 | 286.7-1040 | 256-1050 | 241-375 |
| DO mg/l | N.R. | 7.11-10.07 | 5.9-13.3 | N.R | N.R | 4-15 | 5.1-14.1 | 1.0-10.8 | 1.1-9.2 | 5.5-11 |
| Total alkalinity as $CaCO_3$ mg/l | 102-175 | 78.8-177.9 | 104-180 | 124-140 | 109-148 | 108-238 | 101-174 | 79.2-232 | 120.9-300 | 11.8-162 |
| Ca mg/l | 20-26 | 46.1-72.5* | 52-73* | 44-90* | 55-80* | 26.8-49.8 | 14.4-38.5 | 27.3-75.4 | 28.5-65.7 | 19.64-36.99 |
| Mg mg/l | 7-11 | 24.3-59.8" | 36-64" | 28-62" | 29-49" | 11.3-18.2 | 2.0-17.9 | 8.8-31.6 | 20.1-44.7 | 7.7-19.25 |
| Chloride mg/l | 3-22 | 6.4-24.6 | 10-18 | 14-28 | 11-22 | 7.6-59.9 | 4.0-32 | 10.84-141.9 | 20.0-96.2 | 16.07-29.68 |
| Sulphate mg/l | 6-12 | N.R. | N.R. | 13-20.8 | 8-18.6 | 24-42 | 0.78-8.5 | 8.22-119.4 | 16.25-141.4 | 7.56-59.56 |
| Ammonia mg/l | N.R. | N.R. | 0.002-0.07 | nil | N.R | 0.1-3.2 | N.R. | 0.19-8.9 | 0.46-9.76 | 0.111-2.683 |
| Nitrite mg/l | N.R. | N.R. | 0.0-0.02 | 0.0-0.015 | N.R | 0.0-0.25 | 0.004-0.025 | 0.001-0.22 | 0.005-0.445 | 0.0008-0.025 |
| Nitrate mg/l | N.R. | N.R. | N.R. | 0.01-0.25 | Nil-0.48 | 0.035-0.823 | 0.014-0.853 | 0.002-0.59 | 0.078-1.01 | 0.01-0.661 |
| Total–P mg/l | N.R. | N.R. | N.R. | 0.065-0.2 | 0.046-0.14 | N.R. | 0.052-0.923 | 0.08-5.38 | N.R. | 0.048-0.428 |
| Ortho-P mg/l | N.R. | N.R. | 0.09-0.2 | 0.025-0.12 | 0.007-0.145 | 0.003-1.08 | 0.02-0.653 | 0.023-2.69 | 0.03-2.109 | 0.018-0.13 |
| Dissolved silica mg/l | 13-26 | N.R. | 8.6-14 | 2.4-10.6 | 3.2-7.4 | 0.95-48.6 | 1.22-10.58 | 1.13-17.4 | 1.37-9.11 | 0.47-6.86 |

N.R.= Not recorded. * Calcium as $CaCO_3$ " Magnesium as $CaCO_3$

[1] Hurst, 1957.

[2] Shehata & Bader, 1985.

[3] Abdel-Hamid *et al.*, 1992.

[4] Abdel-Halim, 1993.

[5] Abdel-Satar, 1998.

[6] Abdel-Satar & Elewa, 2001.

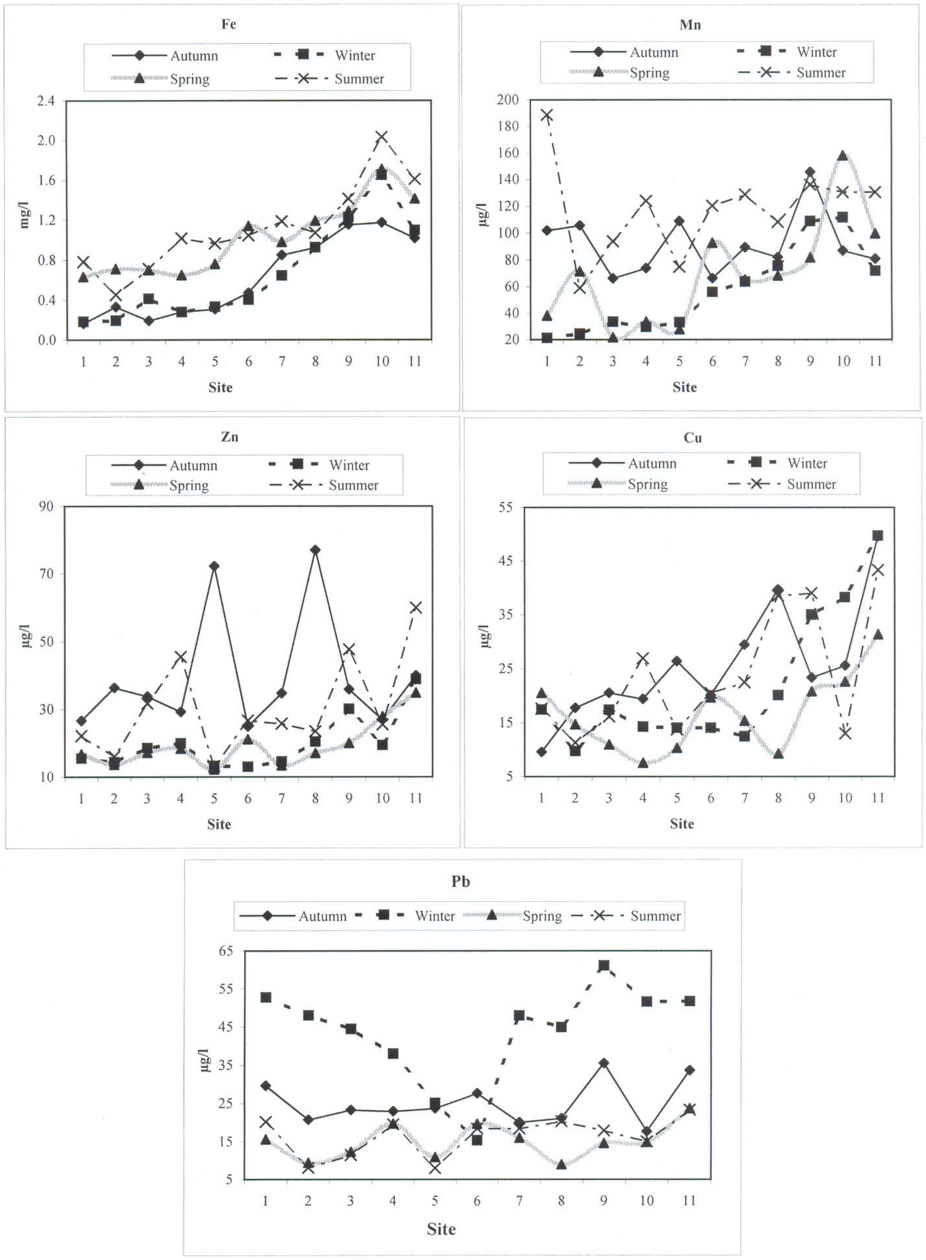

**Fig. (5): Variations of trace metals in the River Nile water**

## CONCLUSION

The River Nile may be considered mostly as a moderately clean river, but with localized pollution problems. Due to the highly decreased of swept-out effluents property of the River Nile to the sea and rather extensive water use and contamination, the river is in great danger of becoming a waste collecting system. Although the impact of the wastes discharged on ambient water quality of the Nile has not been significant in recent years due to the high self-assimilation capacity of the Nile water. Special attention should be given to mitigate pollution from these sources as their effects may become significant during low flow years. Therefore, constant monitoring of river water quality is needed to record any alteration in the quality and outbreak of health disorders.

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