

CHAPTER 15

The Distribution of Trace Metals in Aswan High Dam Reservoir and River Nile Ecosystems

MOHAMED R. LASHEEN

*Water Pollution Control Laboratory,
National Research Center,
Dokki, Cairo, Egypt*

ABSTRACT

Since the main source of fresh water in Egypt is the River Nile, which originates from outside the country, a study was designed to assess the levels of trace metals and their effects on the river water quality and identify areas of diminished water quality. Trace elements, Cd, Co, Cu, Cr, Pb, Mn, and Zn, were determined in water, sediments and fish.

For the Aswan High Dam reservoir, the investigation revealed significant seasonal, spatial and vertical variations in trace element content. Sediments and suspended matter play a significant role in the overall distribution of trace elements in the reservoir.

For the River Nile, the results revealed that river water contains concentrations of these metals far below the levels suggested for potable water. However, the trace elements have accumulated in high concentrations in river sediments indicating the existence of localized pollution.

Fish samples showed that metal concentrations varied according to the species and the sampling area. Metal concentrations in fish samples followed the order: Zn > Mn > Pb > Cu > Cd.

The findings contribute to the understanding of the distribution and dynamics of metals in the reservoir and River Nile ecosystems.

INTRODUCTION

One of the most important projects in Egypt was the construction of the Aswan High Dam (1959–1969). The Aswan High Dam Reservoir (AHDR) extends over an area of 5000 km² with its northern two-thirds in Egypt (known as Lake Nasser) and southern third in Sudan (known as Lake Nubia).

When this reservoir is completely filled, it will extend from the High Dam at Aswan (Egypt) to the Dal Cataract (Sudan).

As shown in Figure 15.1, the reservoir has a long narrow shape with a number of side arms called khors. The number of khors is 100, 58 located on the eastern shore and 42 on the western shore. The reservoir is mostly surrounded by rocky terrain. To the west is the great Sahara Desert, and the Eastern Desert extending to the Red Sea is in the east.

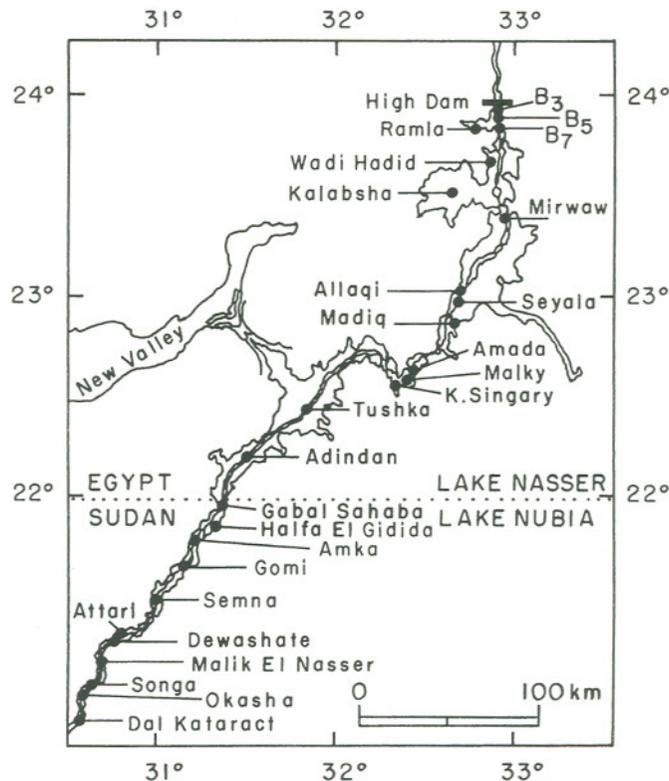


Figure 15.1 The Aswan High Dam Reservoir (Lake Nasser in Egypt and Lake Nubia in Sudan)

The Aswan High Dam Reservoir reached its operating level of 175 metres above sea level in 1975 with a total of 121.3 billion m^3 of stored water. Of this amount 31.6 billion m^3 are dead storage. The main characteristics of the reservoir morphology are summarized in Table 15.1 (Entz, 1974).

Table 15.1 Main morphological characteristics of the Aswan High Dam Reservoir

| Characteristic | Lake Nasser | | Total reservoir | |
|---------------------------------|-------------|-------|-----------------|-------|
| | water level | | water level | |
| | 160 m | 180 m | 160 m | 180 m |
| Length (km) | 291.8 | 291.8 | 430 | 495.8 |
| Surface area (km ²) | 2585 | 5248 | 3057 | 6216 |
| Volume (km ³) | 55.6 | 132.5 | 65.9 | 156.9 |
| Shoreline length (km) | 5380 | 7844 | 6027 | 9250 |
| Mean width (km) | 8.9 | 18 | 7.1 | 12.5 |
| Mean depth (m) | 21.5 | 25.2 | 21.6 | 25.2 |
| Maximal depth (m) | 110 | 130 | 110 | 130 |

Siltation

The Nile receives its water from two main watershed areas, the Equatorial East African Plateau which feeds the White Nile, and the Ethiopian Highlands which feed the Sobat, Atbara and the Blue Nile (Figure 15.2). The contribution of the Blue Nile is most important since 86% of the main Nile's annual discharge is derived from the Ethiopian Highlands, while only 14% is contributed by the Equatorial Lakes (Mancy and Hafez, 1979a). Furthermore, the fluvium carried by the main Nile originates exclusively in the Ethiopian Highlands and is carried by the Blue Nile. The annual mud load of the main Nile is about 134 million m³, consisting of a mixture of sand, silt, clay and organic matter.

Siltation in the reservoir depends on (a) the volume of the flood water, (b) water level in the reservoir at the onset of the flood period; and (c) the distribution of the flood water in the reservoir. When the reservoir was filling, the distribution of siltation covered wider areas depending on the size of the flood. More recently siltation has been confined to the most southern 200 km of the reservoir (between Akasha and Abu Simble) (Mancy and Hafez, 1979b). Particularly heavy siltation occurs in the area 360 km south of Aswan High Dam, that is between Amka and El-Deweshat. In this region siltation beds have already emerged in the life storage zone. Nevertheless, the sediment transport phenomenon tends to be in a northerly direction. Geomorphological changes due to siltation will undoubtedly affect the reservoir's water quality and ecosystem characteristics.

Occurrence of Metals in the Aquatic Environment

Metals enter rivers and lakes from a variety of sources, such as: (1) rocks and soils directly exposed to surface waters; this is the largest natural source, (2)

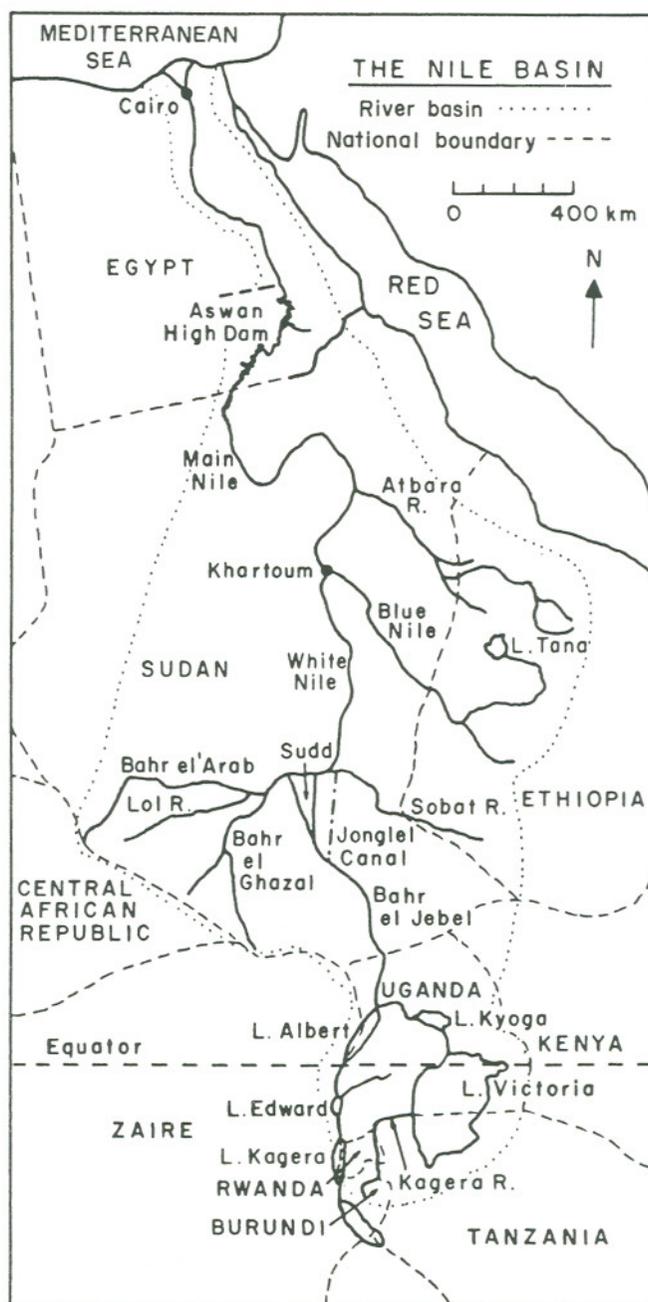


Figure 15.2 The Nile Basin

dead and decomposing vegetation and animal matter, (3) wet and dry fallout of atmospheric particulate matter, and (4) from man's activities, including the discharge of various treated and untreated liquid wastes into the water body.

Trace metals such as chromium, manganese, cobalt, copper and zinc play a biochemical role in the life processes of aquatic plants and animals, and their presence in trace amounts in the aquatic environment is essential. However, at high concentrations, these trace metals become toxic (Nurnberg, 1982).

A further special feature of toxic metals is that they are not biodegradable. Instead they undergo a biogeochemical cycle with substantially different residence times in the various spheres and compartments of the environment. Within this cycle they will be taken up also by man, predominantly from food and drinking water. In this respect toxic metals constitute a particular risk, because, although a certain fraction of the ingested amount is again excreted, they have a tendency to accumulate in vital organs. Thus, they will exert progressively growing toxic actions over long periods of the life-span depending also on the cumulative magnitude of the dose as a function of the long term exposure of the individual to its particular environment (Nurnberg, 1982).

Heavy metals in the aquatic environment are generally classified as existing in a number of chemical forms. The usual classification includes metals in the sediment, metals in suspended particulates ($>0.45 \mu\text{m}$), metals adsorbed onto hydrous oxides and humic colloids, and metals in true solution. The metals in true solution can be further divided into free ionic species, inorganic complexes, and complexes with naturally occurring organic ligands (amino acids, citric acid, etc.) (Guy and Kean, 1980).

Of particular importance for the regulation of trace constituents or pollutants in natural waters are the particles that act as 'scrubbing agents' by scavenging. All substances that are strongly adsorbed on suspended matter or become incorporated into settling biomass have short relative residence times. Obviously, the relative residence time of a compound decreases with increasing adsorbability (Stumm and Morgan, 1981). Particles are also of great importance in rivers and about 75% of the matter carried by the rivers to the ocean is in the form of particulate matter (Martin and Whitfield, 1983).

The specific objectives of this study are:

1. To assess the effect of the physicochemical characteristics of the aqueous phase on the distribution dynamics of the trace metals;
2. To assess the level of trace metals and effects on the water quality of the river and identify areas of diminished water quality;
3. To understand the role of sediments in the transport, transformation, and distribution of trace elements in the aquatic environment;

4. To elucidate the correlation between the transport behaviour of the suspended matter and trace element distribution patterns within the reservoir;
5. To assess the level of metals in fish.

METHODS AND MATERIALS

In the period between July 1976 and August 1977 water and sediment samples from the Aswan High Dam Reservoir were collected. The frequency of surveys was quarterly for Lake Nasser and once a year for Lake Nubia.

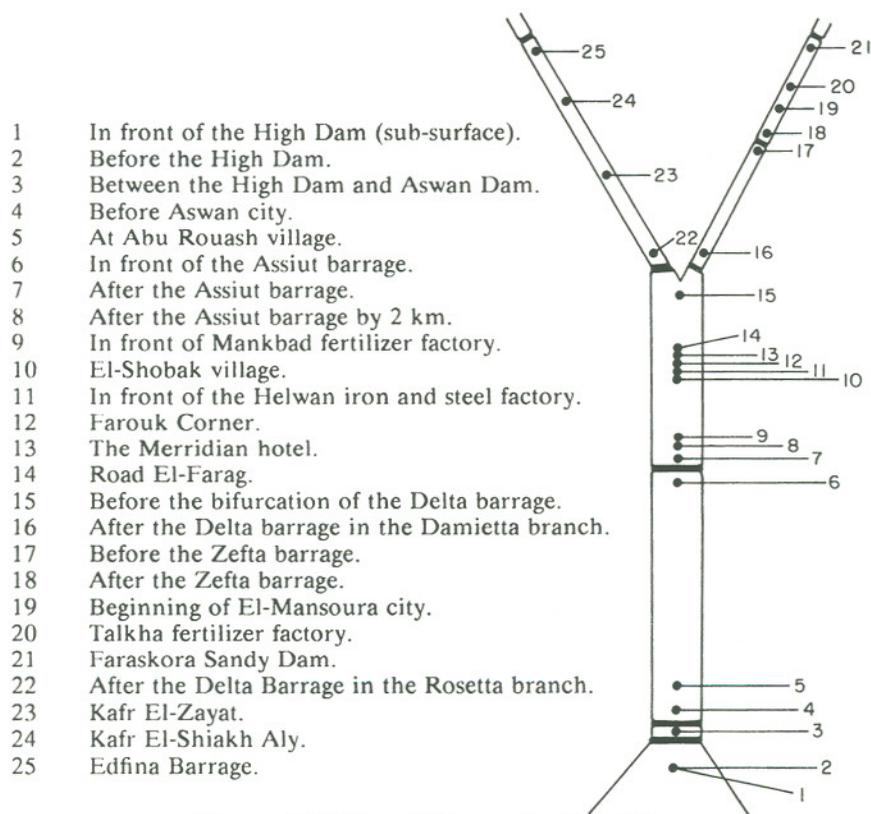


Figure 15.3 River Nile monitoring sites

In the period between April 1976 and December 1978 water and sediment samples from the river were collected. The geographical scope of this monitoring programme extends from Lake Nasser to the Mediterranean Sea (Figure 15.3). The river is divided into segments, taking into account:

- (a) geographical features;
- (b) administrative boundaries; and
- (c) human activities.

Heavy metals in fish samples taken from the Nile River, its two branches and two main canals during the years 1981–1982 were assessed.

Trace metal analysis was done using a Perkin-Elmer Model 370 atomic absorption spectrophotometer equipped with a Heated Graphite Atomizer (HGA) Model 2100 and deuterium arc background corrector.

RESULTS AND DISCUSSION

There are two major processes affecting the distribution of trace metals in the AHDR.

1. The Transportation and Movement Patterns of Suspended Matter

Suspended matter plays a dominant role in the transport of trace metals in the reservoir. The results in Table 15.2 show that the suspended matter of Lake Nubia has high trace metal concentrations.

Table 15.2. Concentrations of selected trace metals in Lake Nubia suspended matter (July 1976).

| Concentration ($\mu\text{g}/\text{gm}$) | | | | | |
|---|------|------|-------|------|------|
| Co | Cr | Cu | Mn | Pb | Zn |
| 116.3 | 90.0 | 28.7 | 416.7 | 95.0 | 91.0 |

Indeed, the partitioning of metals between particles and water is the key parameter in establishing the residence time and thus the residual concentrations of these elements in the lakes. Thus, the geochemical fate of metals is controlled by the chemical processes occurring between the solid surfaces and the water. The more reactive an element is in a lake the more it will be bound to particles, the more rapidly it will be removed, and the shorter will be its residence time (Whitfield, 1981).

A detailed insight into the movement of the suspended matter was obtained on the basis of the relationships between surface water manganese concentrations and transparency for selected stations along the reservoir. A standard Secchi disc (20 cm diameter) was used to measure water transparency. Readings were the average of the levels of disappearance and reappearance of the disc recorded in meters from the surface. As shown in Figure 15.4, loss of transparency was found to be inversely related with

manganese concentrations, that is manganese concentrations increased when Secchi depth decreased. This relationship may be due to the fact that manganese has the ability to remain fixed to the suspended matter during transport in aerated water (De Groot and Allersma, 1975).

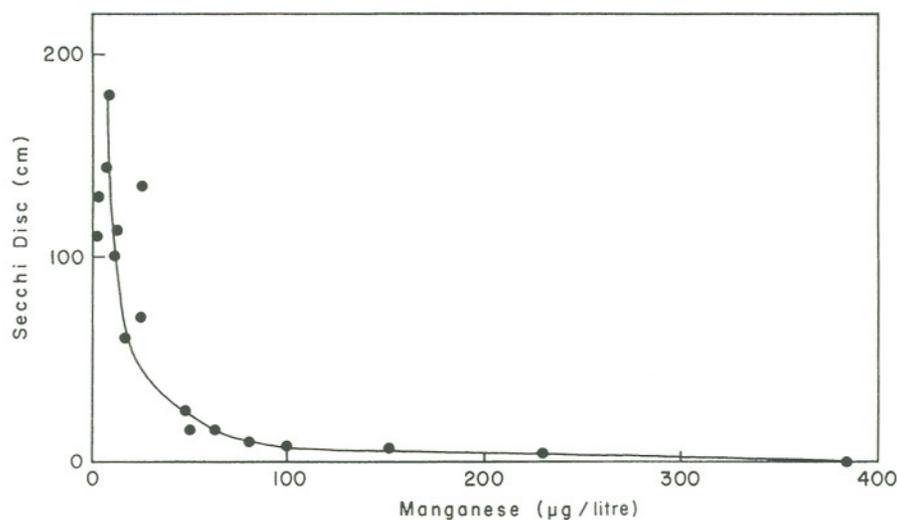


Figure 15.4 Relationship between manganese concentrations and Secchi disc depth in Aswan High Dam Reservoir during July–August 1976

2. Thermal Stratification

The thermal stratification and the hydrodynamic patterns in the reservoir have significant effects on trace metal distribution. During stratification, Lake Nasser develops a stagnant body of water at its bottom (Lasheen, 1982). The size of this stagnant layer and its existence depend on the morphology of the particular segment of the lake and the existing hydrodynamic regimes. The stagnant water layer at the bottom of the lake represents a condition in which the dissolved oxygen is completely removed. As a result of the disappearance of dissolved oxygen, free sulfide will be formed which influences the solubility of metals by forming insoluble metal sulfides. These sulfides will tend to strip the water of its metal content and enrich the bottom sediments with metals.

Stratification extends from May to September in Lake Nasser. In contrast, Lake Nubia does not exhibit any thermal stratification pattern.

In stratified water bodies the O_2 redoxcline is in the water column and the precipitation of iron and manganese takes place in the water column. This phenomenon has been extensively studied in the Black Sea and in a

number of Swiss lakes (Sigg *et al.*, 1983). The precipitating iron hydroxides are able to scavenge and co-precipitate trace metals from the water column and transfer them to the sediment. In this way the O₂ redoxcline in stratified lakes not only acts as a barrier against upward diffusing metals but also actively removes some dissolved trace metals from the system (Salomons, 1984).

The quantitative effect of sediment on lake water composition depends to a large extent on the volume/surface area ratio. In shallow lakes the influence is expected to be much stronger compared with deep lakes.

Spatial and Seasonal Distribution of Trace Elements in the Reservoir Waters

1. Spatial Distribution

Analyses were performed for cadmium, cobalt, copper, manganese and zinc.

Tables 15.3 and 15.4 indicate that the mean concentrations of trace metals in Lake Nasser are lower than the mean values reported for Lake Nubia. The spatial distribution of soluble trace metal concentrations in August 1976 generally revealed high concentrations in Lake Nubia and in bottom waters of the reservoir.

Table 15.3 Mean concentrations of selected trace metals and pH values in Lake Nubia water (July–August 1976)

| Depth | Concentration ($\mu\text{g/litre}$) | | | | | pH |
|---------|---------------------------------------|------|------|--------|------|------|
| | Cd | Co | Cu | Mn | Zn | |
| Surface | 1.46 | 4.28 | 8.29 | 114.40 | 22.4 | 8.59 |
| Bottom | 0.81 | 4.90 | 8.34 | 130.81 | 20.7 | 8.27 |

Cadmium concentrations in Lake Nubia ranged from 0.74 to 4.89 $\mu\text{g/litre}$. In Lake Nasser cadmium concentrations varied from 0.4 to 3.14 $\mu\text{g/litre}$.

Cobalt concentrations in Lake Nubia ranged from 0.3 to 8.14 $\mu\text{g/litre}$. Lake Nasser water samples had between 0.6 to 5.64 $\mu\text{g/litre}$ of cobalt.

Copper concentrations observed in Lake Nubia ranged from 3.38 to 18.92 $\mu\text{g/litre}$. The range of copper concentrations measured in Lake Nasser was between 0.87 and 13.8 $\mu\text{g/litre}$. The level of copper in the reservoir is considered to be low enough to have no effect on water quality.

Zinc concentrations in Lake Nubia ranged from 8.45 to 42.49 $\mu\text{g/litre}$. The observed zinc concentrations in Lake Nasser ranged from 0.67 to 24.96 $\mu\text{g/litre}$. The observed levels obviously do not reflect impaired suitability for wide usage of water.

Manganese concentrations observed in Lake Nubia ranged from 16.67 to 384.84 $\mu\text{g/litre}$ and in Lake Nasser they ranged from 1.84 to 224.15 $\mu\text{g/litre}$. The greatest variation on vertical distributions of manganese occurred during the thermally stratified period.

Manganese concentrations in the bottom waters were much higher than in the surface waters. This difference is due to a combination of factors among which are surface assimilation by phytoplankton, the presence of manganese as soluble Mn^{2+} under the well-established anaerobic conditions in the bottom waters, and the release of manganese from suspended matter deposited on the sediment surface.

2. Seasonal Distribution

Table 15.4 represents the average concentrations in terms of season. There are variations between the data from the fall, winter and those from the summer. The results for manganese, zinc and copper concentrations produce the best evidence for the observed variation. Manganese concentrations are the highest of the metals analysed and cadmium are the lowest.

Table 15.4 Mean seasonal concentrations of selected trace metals and pH values in Lake Nasser water

| Season | Depth | Concentration ($\mu\text{g/litre}$) | | | | | pH |
|------------------------------|-----------|---------------------------------------|------|------|-------|-------|------|
| | | Cd | Co | Cu | Mn | Zn | |
| Summer 1976 (August) | Surface | 0.67 | 2.14 | 4.23 | 9.84 | 3.95 | 8.74 |
| | Mid-depth | 0.91 | 2.09 | 3.87 | 29.44 | 3.54 | 8.10 |
| | Bottom | 1.03 | 2.37 | 5.40 | 74.49 | 6.33 | 8.01 |
| Fall 1976 (November) | Surface | 1.18 | 3.30 | 2.81 | 38.61 | 8.98 | 8.30 |
| | Mid-depth | 1.22 | 3.54 | 2.68 | 40.78 | 4.75 | 8.11 |
| | Bottom | 1.09 | 3.44 | 2.51 | 58.41 | 7.44 | 7.70 |
| Winter 1977 (February) | Surface | 0.73 | 3.91 | 3.48 | 40.38 | 10.14 | 8.71 |
| | Mid-depth | 0.63 | 3.81 | 3.12 | 39.77 | 8.59 | 8.46 |
| | Bottom | 0.62 | 3.76 | 3.43 | 40.52 | 6.98 | 8.31 |

The greatest variation in metal distribution patterns occurred during the thermally stratified period. With the exception of cadmium, metal concentrations were lower in the surface water than in deep waters indicating that biological activity in the photic zone removes any metals from the solution.

The peak values occurred at either the middle or bottom depth. In contrast, during the turnover period, concentrations of metals were mostly unchanged with depth, reflecting the mixing conditions.

The results show that trace metals are present in the parts-per-billion range, with the exception of manganese. Most of the metal concentrations

are well below the recent proposed criteria for water quality (US Environmental Protection Agency, 1972).

Spatial and Seasonal Distribution of Trace Metals in the Reservoir Sediments

Table 15.5 indicates that the mean concentrations of Co, Cr, Mn and Zn in Lake Nubia sediments are higher than the mean values reported for Lake Nasser. Copper and lead were slightly higher in Lake Nasser sediments than in those of Lake Nubia.

Table 15.5 Means and ranges of metal concentrations of bottom sediments of Lake Nubia and Lake Nasser (July–August 1976)

| Metal | Concentration ($\mu\text{g/gm}$) | | | |
|-------|------------------------------------|----------|-------------|----------|
| | Lake Nubia | | Lake Nasser | |
| | Mean | Range | Mean | Range |
| Co | 131.9 | 114–145 | 113.6 | 100–146 |
| Cr | 332.6 | 54–1250 | 158.3 | 88–251 |
| Cu | 54.7 | 26.7–68 | 59.9 | 50–80.5 |
| Mn | 1196 | 882–1395 | 784.0 | 623–1067 |
| Pb | 79.4 | 56–94 | 86.6 | 61–124 |
| Zn | 138.8 | 112–172 | 119.1 | 104–158 |

The concentrations of chromium and manganese were the highest of the metals in all sediments. Lead and copper, on the other hand, were in the lowest concentrations in most of the sediments.

Mean seasonal concentrations of the trace metals in Lake Nasser sediments are presented in Table 15.6. Manganese, lead and zinc concentrations were the highest in August 1976, but Co and Cr were the highest in February 1977. Copper content showed a slight increase in May 1977.

Where metal contamination is less severe, physical and chemical processes make spatial differences in the metal content of sediments difficult to interpret. However, the observed changes in the trace metal content of the sediments with distance from the High Dam suggest that changes in the environment of deposition do occur along the reservoir.

The Factors Influencing the Distribution Patterns of Trace Metals in the River Nile

The main factors which affect water quality characteristics of the River Nile include: (a) upstream changes south of Lake Nasser, (b) changes in Lake

Table 15.6 Mean seasonal concentrations of selected trace metals in Lake Nasser sediments

| Season | Concentration ($\mu\text{m/gm}$) | | | | | |
|---------------------------|------------------------------------|-------|------|-------|------|-------|
| | Co | Cr | Cu | Mn | Pb | Zn |
| Summer (August 1976) | 113.6 | 158.3 | 59.9 | 784 | 86.6 | 119.1 |
| Fall (November 1976) | 84.8 | 111.6 | 55.4 | 750.3 | 66.3 | 101.6 |
| Winter (February 1977) | 104.0 | 185.6 | 60.8 | 746.6 | 58.2 | 99 |
| Spring (May 1977) | 44.0 | 152.5 | 64.6 | 659 | 86.6 | 77.8 |
| Summer (August 1977) | 82.0 | 163.2 | 59.8 | 768.9 | 77.8 | 103.6 |

Nasser, and (c) localized changes in the river basin. Furthermore, the Nile receives increasing amounts of waste discharges, from point and non-point sources, as the river travels northward. The discharge of waste effluents is usually accompanied by localized effects of water quality deterioration immediately downstream from the waste outfall (Mancy and Hafez, 1979b). South of Cairo, at Helwan, there are iron, steel, coke and chemical fertilizer industries which discharge their waste into drains which finally reach the river.

The river exhibits its worst conditions in the Delta. This is due to a combination of factors: (a) reduction of the river velocity in certain locations to complete stagnation (b) industrial and domestic waste discharges and (c) return flow of agricultural drainage water.

At Kafr El Zayat there are three factories discharging their waste directly into the Rosetta branch. These factories are: Salt and Soda Company, Pesticides Company and Superphosphate fertilizer plant. As the river reaches the Edfina barrage, it slows down and bottom septic conditions occur during the summer months. Similarly, the Damietta branch receives industrial waste from the Talkha fertilizer plant, and stagnant waters at the Faraskour earth Dam exhibit septic conditions in the summer months.

Spatial Distribution of Trace Metals in the River Waters

Trace metal analyses were performed for cadmium, copper, lead and zinc. Figure 15.5 indicates that the mean concentrations of trace metals in the

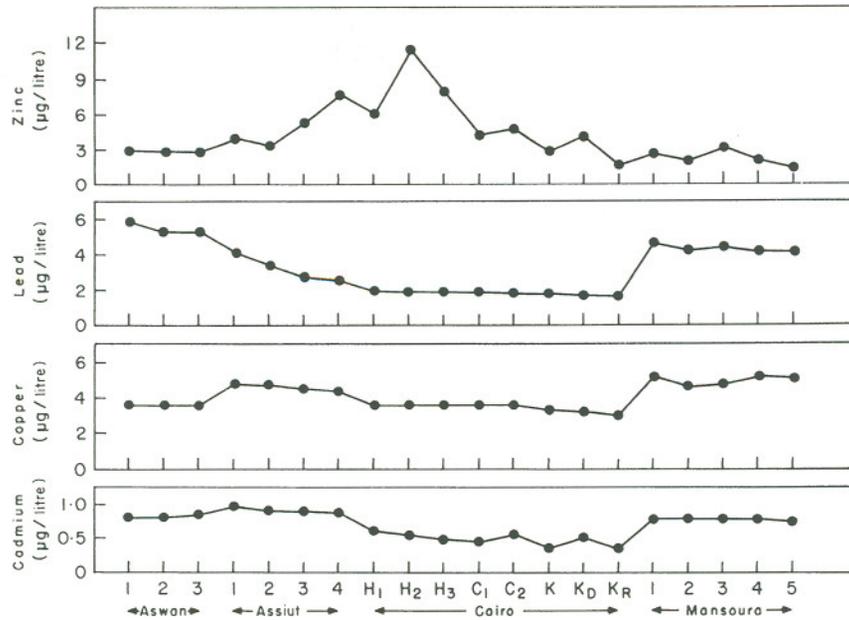


Figure 15.5 The mean concentrations of metals in Aswan, Assiut, Cairo and Mansoura segments of the River Nile during 1976–77

River Nile are well below the US Environmental Protection Agency's (1972) acceptable limits for potable waters.

The Importance of Suspended Solids in Controlling the Trace Metals Concentrations in Rivers

Knowledge of the origin and transport of the suspended solids is essential for an interpretation of regional variations in the trace metal contents. The suspended solids can act as scavengers for trace metals in the water. These suspended solids are introduced into the natural bodies of water by natural forces, for example, weathering, hydrothermal activities, and biosynthesis, or by man-made activities, for example, sewage discharge, dredging and agricultural excavation (Huange, 1978). The concentration of suspended solids in the aquatic environment varies from a few hundredths of a mg/litre in sewage effluent, to a few tenths of a mg/litre in rivers.

Since the construction of the Aswan High Dam, the Nile silt has been held in the reservoir. Recent studies indicated that siltation occurs in the most southern reaches of the reservoir (Mancy and Hafez, 1979b). As a result water released from the Aswan High Dam Reservoir is silt free, and

its suspended solid content is primarily due to phytoplankton. The results in Table 15.7 show that the suspended matter of the River Nile has high trace metal concentrations. The concentration of manganese was found to be the highest in all sediments and suspended matter samples. This relationship may be due to the fact that manganese has the ability to remain fixed to the suspended matter during transport in aerated water (Salomons, 1984).

Table 15.7 Trace metals concentrations of suspended metals from selected stations in River Nile (December 1978–July 1979)

| Sample Location | Concentration ($\mu\text{g}/\text{gm}$) | | | | | | |
|---------------------------------------|---|-----|-----|-----|-----|------|----|
| | Cd | Co | Cr | Cu | Pb | Mn | Ni |
| Assiut El-Hagz group (west drainage) | 9 | 47 | 79 | 72 | 204 | 1159 | 99 |
| Assiut El-Maana group (east drainage) | 9 | 61 | 89 | 62 | 87 | 1048 | 88 |
| Assiut | 10 | 110 | 87 | 125 | 185 | 1171 | 81 |
| Beni-Suef | 7 | 88 | 112 | 78 | 113 | 1474 | 92 |
| Cairo | 8 | — | 114 | 92 | 123 | 1715 | 82 |

Spatial Distribution of Trace Metals in the River Sediments

Trace metals analyses were performed for cobalt, chromium, copper, manganese, lead, and zinc. Chromium and manganese were found to be in the highest concentrations in all sediments (Table 15.8). Copper and lead, on the other hand, were found to be in the lowest concentrations in most of the sediments. The increase in mean metal concentrations in analysed sediment samples followed the order: Mn > Cr > Zn > Co > Pb > Cu (Table 15.9).

Although in the present study we found that the trace metals have accumulated in high concentrations in river sediments, and for the time being, remain relatively harmless, one cannot overlook the fact that these metals can be released by numerous processes (e.g. from anthropogenic sources and remobilization of trace metals from suspended material and sediments) and are potentially hazardous not only for the aquatic ecosystem, but also for the drinking water supply (Forstner and Wittmann, 1979).

Assessing Metal Pollution in Nile River Using Fish Studies

Muscle tissue from five species of fish taken from the Nile River were analysed for metals (Table 15.10). If whole fish had been digested, mean

Table 15.8 Mean concentrations of selected trace metals in River Nile sediments (1976–1978)

| Sample location* | Concentration ($\mu\text{g/gm}$) | | | | | |
|---|------------------------------------|-------|------|-------|--------|-------|
| | Co | Cr | Cu | Pb | Mn | Zn |
| Assiut (9) | 95.4 | 622.6 | 27 | 61.4 | 961.2 | 71.2 |
| Before Helwan iron and steel factory (9) | 98.1 | 347.3 | 32.3 | 57.7 | 1049.3 | 86.3 |
| In front of Helwan iron and steel factory (9) | 92.3 | 187.7 | 34.5 | 49.7 | 1015.5 | 85.8 |
| After Helwan iron and steel factory (6) | 106.2 | 226.3 | 33.7 | 61.3 | 1116.8 | 90.5 |
| Meridian (3) | 103 | 193.7 | 42 | 50 | 1078 | 161.7 |
| Road El-Farag (5) | 88.4 | 246.8 | 78.4 | 94.6 | 1061.6 | 157.6 |
| El-Manashi (6) | 110.5 | 249 | 58.2 | 47 | 1082.5 | 99.5 |
| El-Qanater (4) | 96 | 276.3 | 57 | 69 | 1085.3 | 104 |
| Kafr El-Zayat (7) | 87 | 526.7 | 33.3 | 39.4 | 1334.7 | 90.9 |
| Kafr El-Sheikh Ali (5) | 96 | 254.2 | 47.2 | 82.8 | 806.8 | 179.4 |
| Edfina (8) | 104 | 354.5 | 62.9 | 75.1 | 1610.6 | 143.1 |
| El-Mansoura (93) | 81.3 | 144.7 | 47 | 74 | 1877.7 | 95 |
| Talkha (9) | 78.1 | 398.3 | 48.6 | 53.2 | 1329.1 | 93.4 |
| Faraskur (9) | 99.3 | 357.7 | 51.6 | 50.33 | 1105.9 | 89.4 |

* Numbers in parentheses indicates the number of samples analysed.

Table 15.9 Means and ranges of metal concentrations in sediments of the River Nile

| Metal | Concentration ($\mu\text{g/gm}$) | |
|-------|------------------------------------|----------|
| | Mean | Range |
| Co | 95.1 | 11–186 |
| Cr | 343.7 | 44–1678 |
| Cu | 45 | 4–150 |
| Pb | 58.3 | 6–164 |
| Mn | 1163.6 | 291–3750 |
| Zn | 102.3 | 44–434 |

concentrations for each species would undoubtedly have been higher since metals are known to concentrate in certain target organs.

The concentration of zinc was higher than all the measured metals in the analysed fish. On the other hand, cadmium was lower than the other metals. Fish caught from El-Mahmodia canal showed the highest metal content followed by Abu-Elghaid canal.

By comparing metals concentrations in the Nile River water and bottom sediments with the fish data, it can be seen that metals concentrations in

Table 15.10 Median and range values for heavy metals in Nile fishes ($\mu\text{g/gm}$)

| Sampling location | species | No. of samples* | Cd | Pb | Cu | Mn | Zn |
|-------------------|-----------------------------|-----------------|---------------------|---------------------|---------------------|------------------------|------------------------|
| Aswan | <i>Tilapia nilotica</i> | 3 | 0.49 (0.12–0.57) | 8.14 (5.6–13.72) | 4.1 (3.55–4.64) | 34.59 (23.99–38.64) | 31.84 (22.84–48.97) |
| Assiut | <i>Tilapia nilotica</i> | 5 | 0.49 (0.29–0.72) | 4.89 (1.36–8.42) | 3.16 (2.02–5.02) | 10.29 (7.65–12.8) | 30.69 (22.75–36.65) |
| | <i>Chrysichthys auratus</i> | 1 | 1.08 | 9.09 | 5.94 | 15.68 | 34.72 |
| Cairo | <i>Tilapia nilotica</i> | 4 | 0.21 (0.14–0.29) | 2.63 (1.14–4.45) | 1.47 (1.13–1.94) | 6.59 (4.89–8.28) | 45.51 (33.43–75.6) |
| | <i>Chrysichthys auratus</i> | 3 | 0.29 (0.14–0.43) | 2.24 (1.14–3.12) | 1.41 (0.92–1.7) | 8.07 (5.14–11.79) | 44.88 (42–50) |
| El-Mansoura | <i>Tilapia nilotica</i> | 5 | 0.25 (0.13–0.38) | 4.65 (2.5–7.0) | 3.74 (3.21–4.14) | 12.48 (5.34–19.94) | 43.89 (35.22–51.88) |
| Faraskour | <i>Tilapia nilotica</i> | 4 | 0.25 (ND–0.32) | 5.61 (2.17–9.25) | 4.09 (2.69–5.22) | 13.21 (5.99–18.29) | 49.7 (36.75–56.17) |

| | | | | | | | |
|--------------------------------|-----------------------------|---|---------------------|-----------------------|----------------------|------------------------|------------------------|
| Beginning of Rosetta branch | <i>Tilapia nilotica</i> | 2 | 0.54 (5.52-6.47) | 6.0 (2.97-3.66) | 3.52 (11.59-17.1) | 14.35 (46.6-49) | 47.8 (32-45) |
| | <i>Labco niloticus</i> | 4 | 0.18 (ND-0.54) | 2.38 (1.94-2.87) | 2.33 (2.24-2.4) | 6.27 (5.65-6.58) | 38.05 (43.03-59.53) |
| Edfina | <i>Tilapia nilotica</i> | 4 | 0.52 (0.31-0.91) | 3.58 (1.55-5.1) | 1.99 (1.34-3.09) | 12.45 (4.33-20.3) | 53.3 (44.03-108.27) |
| El-Mahmodia Canal | <i>Tilapia zillii</i> | 9 | 0.61 (0.25-0.89) | 10.43 (6.88-15.25) | 4.27 (3.37-8.4) | 17.12 (13.04-20.7) | 75.12 (23.63-56.71) |
| | <i>Clarias lazera</i> | 3 | 0.18 (ND-0.18) | 4.93 (1.8-9.93) | 2.12 (1.05-3.5) | 2.78 (2.38-3.43) | 44.91 (53.25-86.75) |
| Abu-Elghaid | <i>Tilapia nilotica</i> | 6 | 0.67 (0.43-0.9) | 9.11 (4.98-12.8) | 3.46 (3.2-4.05) | 17.12 (11.65-21.08) | 71.67 (46.5-55) |
| | <i>Clarias lazera</i> | 3 | 0.40 (0.33-0.44) | 3.15 (2.23-4.73) | 2.31 (1.6-2.3) | 1.81 (0.83-3.28) | 50 (46.5-55) |

* Each analysed sample represents at least one fish of each species.
ND: not detected

fish flesh were considerably lower than concentrations in bottom sediments. However, all metals were more highly concentrated in fish muscle tissue than in Nile water.

In recent years, intensive pollution resulting from the discharge of increasing amounts of agricultural, domestic and industrial waste-water to the Nile River is reported to have had a marked effect on the fish production from the river (Mancy and Hafez, 1979b).

We conclude that the threat of pollution to the fisheries of Egypt is sensed although not yet adequately defined. It is obvious that considerable work needs to be done in monitoring of heavy metal concentrations to improve our understanding of their cycle in the Nile environment.

CONCLUSIONS

The important findings of this study are summarized as follows:

1. For all of the metals studied the average level found in the reservoir water is below the value set by the United States EPA as harmless to aquatic life.
2. The high metal concentrations in sediments relative to that in water demonstrate the importance of the suspended matter as a transport pathway for metals.
3. The dissolved oxygen content and oxidation-reduction conditions to a large extent control the amount and species of metal ions.
4. Some elevated concentrations of trace metals were noted in the region of Lake Nubia. In general though, the trace metal content and suspended matter of the water samples revealed significant correlation.
5. The significant drop in metal concentrations in River Nile water might result from dilution or from precipitation and adsorption reactions which would tend to reduce the metals levels.
6. Trace metals have accumulated in high concentrations in river sediments indicating the existence of localized pollution. These metals can be released by various processes of remobilization and move up the biological chain, thereby reaching humans and possibly produce chronic and acute ailments.

Recommendations

It is now accepted by environmental scientists that to fully understand the biological availability, toxicity and transport of heavy metals in natural water systems, measurements of total metal concentrations are no longer adequate, the chemical forms of the metals in solution must be considered. Electro-analytical techniques should be applied to measure the concentrations of

various metal species and to permit the determination of the equilibrium concentrations of metal complexes.

A more detailed insight into the relations between heavy metals characteristics and physical properties of the solid constituents of the aquatic environment is urgently needed, especially in view of processes of bioaccumulation.

Partial extraction techniques of metals from aquatic sediments should be applied to measure the sediment fraction that has a detrimental effect on water quality and the associated biota.

The presence of high concentrations of heavy metals in Nile sediments should prompt the development of dredged material disposal criteria in Egypt.

Since trace metals are concentrated in biological material a study should be made to ascertain whether metals reach excessive levels in the higher members of the biological food chains in AHDR and River Nile ecosystems.

As yet the total scope of latent toxic effects of trace metals is unknown. Thus until all doubt about the effect of potentially toxic metals on the biological food chain and drinking water supply is removed, trace metals should be kept to a minimum in all aquatic systems.

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