# ASSESSMENT OF HEAVY METALS POLLUTION IN WATER AND SEDIMENTS AND THEIR EFFECT ON *OREOCHROMIS NILOTICUS* IN THE NORTHERN DELTA LAKES, EGYPT

**SAMIR M. SAEED AND IBRAHIM M. SHAKER**

*Central Lab. for Aquaculture Research, Agricultural Research Center. Limnology dept.*

***Abstract***

The concentrations of heavy metals including Iron, Zinc, Copper, Manganese, Cadmium and Lead (Fe, Zn, Cu, Mn, Cd and Pb) in water and sediments in northern Delta Lakes (Edku, Borollus and Manzala) and their accumulation in Nile tilapia (*Oreochromis niloticus*) organs (muscle, gills and liver) were investigated. Water, sediments and fish organs from Lake Manzala showed greater concentrations of most of the studied metals than those from Lake Edku and Lake Borollus. Fe, Mn, Cd and Pb (in Lake Manzala) and Mn and Pb in Lake Borollus recorded levels above the international permissible limits in water. In sediment samples Mn (in Lake Edku) and Cd (in Lake Manzala) recorded higher values than the sediment quality guidelines. Gills and Liver of *O. niloticus* contained the highest concentration of most the detected heavy metals, while muscles appeared to be the last preferred site for the bioaccumulation of metals. The edible part of *O. niloticus* showed higher levels of Cd (in Lake Edku and Manzala) and Pb (in Lake Manzala). Nile tilapia caught from these two Lakes may pose health hazards for consumers.

## INTRODUCTION

The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both cultured and wild fishes. Pollution of the aquatic environment by inorganic and organic chemicals is a major factors posing serious threat to the survival of aquatic organisms including fish.

The Egypt's northern Delta Lakes include Lake Edku, Lake Borollus, Lake Manzala, and Lake Mariut. These Lakes are situated on the Mediterranean Coast of the Delta and cover about 6% of the non-desert surface area of Egypt. The Lakes are an important natural resource for fish production in Egypt. Until 1991, these Lakes have always contributed more than 40% of the country's total fish production, but at present this has decreased to less than 12.22% (GAFRD, 2006). Tilapia species including *Oreochromis niloticus*, *Oreochromis aureus*, *Sarotherodon galilaeus* and *Tilapia zillii* ranked first followed by *Clarias gariepineus* in the fish production of the Lakes.

In the meantime, the Lakes were subjected to a gradual shrinkage during the past few decades due to land reclamation and transformation of significant parts of the Lakes to fish farms, particularly along the southern regions. In addition, large parts of the Lakes are overgrown with aquatic vegetation which reduces the open water to nearly half of its total area, speeding up the process of land transformation.

Extensive research programs have been carried out to investigate the tilapia biology and fisheries in the inland waters of Egypt, including the northern Delta Lakes (Shakweer and Abbas, 1996; Khallaf *et al.*, 1998; El-Moselhy (1999); Elghobashy *et al.*

2001). Some heavy metals concentrations have been estimated in surfacial sediments by (El-Ghobary, 1977; Moussa, 1984; Abdel-Moati and El-Sammak, 1997 and Abdel-Baky *et al*., 1998) and in water (Abdel-Baky *et al*. 1998; Elghobashy *et al*., 2001 and Farag, 2002).

Pollution of the aquatic environment by inorganic chemicals has been considered a major threat to the aquatic organisms including fishes. The agricultural drainage water containing pesticides and fertilizers and effluents of industrial activities and runoffs in addition to sewage effluents supply the water bodies and sediment with huge quantities of inorganic anions and heavy metals (ECDG, 2002). The most anthropogenic sources of metals are industrial, petroleum contamination and sewage disposal (Santos *et al*., 2005).

Metal ions can be incorporated into food chains and concentrated in aquatic organisms to a level that affects their physiological state. Of the effective pollutants are the heavy metals which have drastic environmental impact on all organisms. Trace metals such as Zn, Cu and Fe play a biochemical role in the life processes of all aquatic plants and animals; therefore, they are essential in the aquatic environment in trace amounts. In the Egyptian irrigation system, the main source of Cu and Pb are industrial wastes as well as algaecides (for Cu), while that of Cd is the phosphatic fertilizers used in crop farms (Mason, 2002).

Lake sediments are normally the final pathway of both natural and anthropogenic components produced or derived to the environment. Sediment quality is a good indicator of pollution in water column, where it tends to concentrate the heavy metals and other organic pollutants. The drainage water transports considerable amounts of allochthonous sediments to the Nile northern delta Lakes, which are distributed by currents and water movements throughout most of the Lakes. These sediments are deposited on the bottom and constitute with autochthonous deposits the total sediments of the Lakes.

The present work aimed to investigate the pollutants levels including the accumulation of some heavy metals (Iron, Zinc, Copper, Manganese, Cadmium and Lead) in the water, sediments and fish organs of Nile tilapia (*Oreochromis niloticus*) in northern Delta Lakes (Edku, Borollus and Manzala).

## MATERIALS AND METHODS

### Sampling area

The Nile delta Lakes (fig. 1) are shallow, brackish water bodies with a depth ranged from 50 to 180 cm. The area of the Lakes Edku, Borollus and Manzala reached about 115, 370 and 700 $km^2$, respectively. Lake Edku is a subject to huge inputs of terrigenous and anthropogenic nutrients discharge, sewage and agricultural runoff (2.06 X $10^9$ $y^{-1}$) via three main drains, Edku, El-Boseily and Barzik situated at its eastern margins drains. Lake Borollus receives mainly agriculture drainage water (3.2 X $10^9$ $m^3$

$y^{-1}$) from six drains at its southern region. Lake Manzala receives annually about 6.7 X $10^9$ $m^3$ of raw sewage, agricultural and industrial wastewater. The three Lakes are connected with the sea through an open namely El-Boughaz at their northern regions.

**Sampling and analytical methods**

Water and sediment samples were collected from Lake Edku (n = 13), Lake Borollus (n = 20), Lake Manzala (n = 20) during 2007 for measuring heavy metals residues. Water samples were taken at different places at each station by a PVC tube column sampler at depth of half meter from the water surface. The samples at each station were mixed in a plastic bucket and a sample of 1 liter was placed in a polyethylene bottle, kept refrigerated and transferred cold to the laboratory for analysis.

Surfacial sediment samples were collected using core sampler as described in (Boyd and Tucker, 1992), then kept in cleaned plastic bags and chilled on ice box for transport to the laboratory for heavy metals determination.

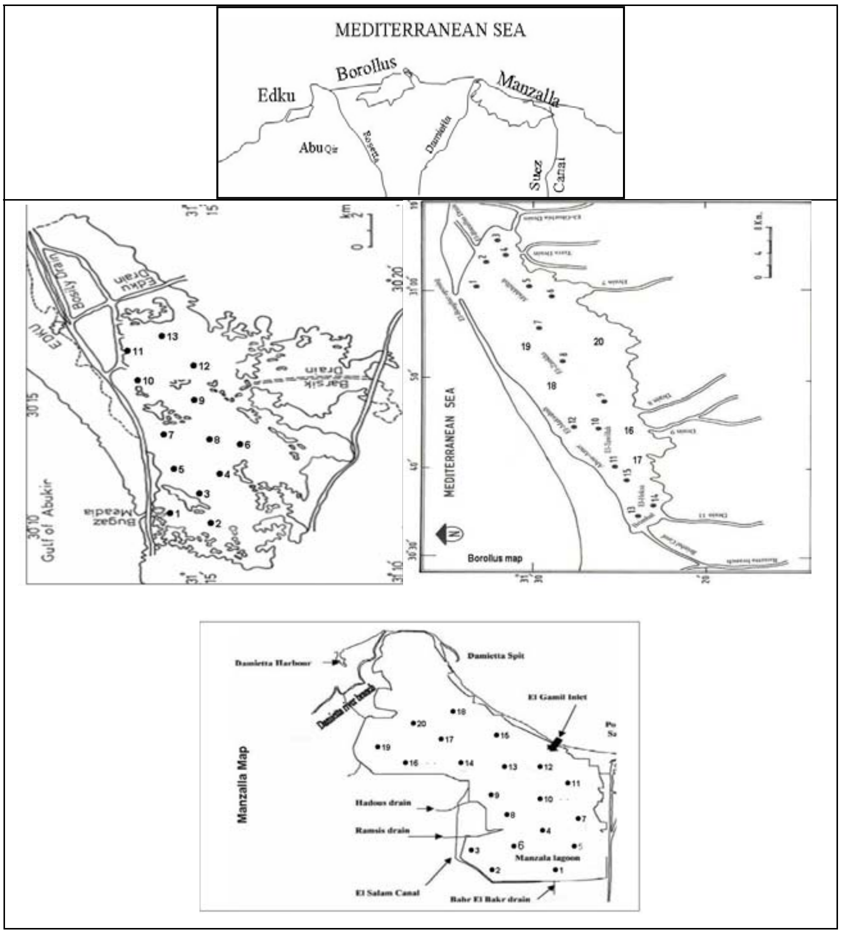


Fig. 1. Sampling stations in the River Nile delta Lakes (Edku, Borollus and Manzala)

**Water**

Heavy metals in water samples were extracted with conc. HCl and preserved in a refrigerator till analysis for Fe, Zn, Mn, Cu, Cd and Pb (Parker, 1972).

**Sediment**

In the laboratory, the sediment samples were dried at 105 ºC, grinding, sieving and about (1.0 gm) of the most fine dried grains were digested with a mixture of conc. $H_2O_2$, HCl and $HNO_3$ as the method described in Page et al. (1982) and preserved in a refrigerator till analysis.

**Fish samples**

Nile tilapia (*Oreochromis niloticus*) samples were collected from commercial catch of the three Lakes. The mean total lengths and total weights of fish were (15.85 cm and 73.28 g) in Lake Edku, (21.40 cm and 179.40 g) in Lake Borollus and (18.33 cm and 70.24 g) in Lake Manzala. Fish samples were transported in ice box to the laboratory, where samples of different tissue/organs taken were sorted. Metals in fish tissue/organs were extracted as described by (AOAC, 1990). Atomic Absorption Spectrophotometer (Model Thermo Electron Corporation, S. Series AA Spectrometer with Gravities furnace, UK,) instrument was used to detect the heavy metals. The concentrations of heavy metals were expressed as mg/l for water and µg/g. dry wt. for sediment samples and fish organs.

**Statistical analysis**

One-way ANOVA and Duncan multiple range test were used to evaluate the significant difference in the concentration of different studied metals with respect to different Lakes. A probability at level of 0.05 or less was considered significant (Bailey, 1981). Standard errors were also estimated.

## RESULTS AND DISCUSSION

**Heavy metals in water**

Metal concentrations in water at different Lakes are illustrated in Table (1). Metals concentrations in water were found in the following order: Fe > Mn > Pb > Zn > Cu > Cd in Lake Edku, whereas they follow the order of Fe > Mn > Pb > Zn > Cu > Cd in Lake Borollus. In Lake Manzala, metals had the sequence of Fe > Mn = Cu > Zn > Pb > Cd. The sequences of metals concentration in the three Lakes were as follow: Fe > Mn > Cu > Zn > Pb > Cd (Table 1).

Table 1. Mean of heavy metals concentration (mg/l) in water of the northern delta Lakes.

| Lake | | Fe | Zn | Cu | Mn | Cd | Pb | Total |
|---|---|---|---|---|---|---|---|---|
| Edku | min | 0.008 | 0.004 | 0.002 | 0.003 | ND | ND | 0.017 |
| | max | 1.89 | 0.05 | 0.054 | 0.088 | 0.084 | 0.087 | 2.253 |
| | mean | 0.570[b] | 0.016[b] | 0.011[b] | 0.024[c] | 0.007[b] | 0.028[c] | 0.656 |
| | | ±0.13 | ±0.003 | ±0.004 | ±0.007 | ±0.005 | ±0.008 | |
| Borollus | min | 0.089 | 0.026 | 0.020 | 0.016 | 0.002 | 0.11 | 0.263 |
| | max | 1.150 | 0.077 | 0.050 | 0.801 | 0.009 | 0.031 | 2.118 |
| | mean | 0.425[b] | 0.050[b] | 0.035[b] | 0.194[b] | 0.005[b] | 0.065[b] | 0.774 |
| | | ±0.08 | ±0.003 | ±0.003 | ±0.04 | ±0.0001 | ±0.006 | |
| Manzala | min | 0.72 | 0.32 | 0.36 | 0.28 | 0.01 | 0.012 | 1.702 |
| | max | 1.98 | 0.66 | 0.68 | 0.84 | 0.09 | 0.22 | 4.470 |
| | mean | 1.416[a] | 0.464[a] | 0.513[a] | 0.513[a] | 0.044[a] | 0.099[a] | 3.049 |
| | | ±0.08 | ±0.02 | ±0.02 | ±0.03 | ±0.005 | ±0.012 | |
| T. mean | | 0.804 | 0.177 | 0.186 | 0.244 | 0.019 | 0.064 | |
| *PL | | 1.0 | 1.0 | 1.0 | 0.05 | 0.01 | 0.05 | |

*PL: permissible limits according to USEPA (1986). ND: not detectable. Letters a, b and c show differences among sites. Data shown with different letters are statistically different at $P < 0.05$ level.

The difference among the three Lakes in metal content is significant (Table 1). All the metals attained their maximum values at Lake Manzala. Lake Borollus, ranked second in accumulation of metals, while Lake Edku was the less polluted one. This may be attributed to the increased cover of the aquatic and higher plants which absorb metals from water and sediments. The maximum mean values of the measured metals (Fe, Mn, Cd and Pb) were recorded at Lake Manzala as well as (Mn and Pb) at Lake Borollus. These levels are higher than the permissible limits (Table 1) recommended by USEPA (1986) and the Egyptian laws (Khallaf *et al.* 1998). This may be attributed to the huge amounts of raw sewage, agricultural and industrial wastewater discharged into the Lake (Abdel-Moati and El-Sammak, 1997). On the other hand, Zn and Cu values are within the allowable limits according to USEPA (1986). The high levels of Cd and Pb in water can be attributed to industrial and agricultural discharge (Mason, 2002). The high level of Pb in water of Lake Manzala and Borollus could be attributed to the industrial and agricultural discharge as well as from spill of leaded petrol from fishing boats and dust which holds a huge amount of lead from the combustion of petrol in automobile cars (Hardman et al. 1994). The high level of Pb in water of northern delta Lakes can be attributed to heavily traveled roads that run along the Lakes. Higher levels of Pb often occur in water bodies near highways and large cities due to high gasoline combustion **(**Banat *et al.*, 1998**).**

Beliles (1979) mentioned that the major sources for manganese in air and water are iron and steel manufacturing and the burning of diesel fuel in the motor cars. So, the engine boats which are distributed in Lake Borollus could be a reason for increasing the Pb and Mn in the Lake water. The high concentration of Zn in water samples of Lake Manzala may be due to considerable amounts of zinc leached from protection plates of boats containing the active zinc as mentioned by Hamed (1998). Comparing the present results with previous studies in water of the northern Lakes is presented in table (2).

Table 2. Comparison of heavy metals concentration (mg/l) in water of the northern delta Lakes with previous studies.

| Lake | | | Metals | | | | Reference |
|---|---|---|---|---|---|---|---|
| | Fe | Zn | Cu | Mn | Cd | Pb | |
| Edku | 1.30 | 0.08 | 0.17 | - | 0.01 | 0.21 | Elghobashy *et al.*, (2001) |
| | 0.57 | 0.016 | 0.011 | 0.024 | 0.007 | 0.028 | Present study |
| | 3.30 | 0.04 | 0.11 | - | ND | ND | Elghobashy *et al.* (2001) |
| Borollus | 0.24 | 0.19 | 0.05 | - | - | 0.06 | Farag (2002) |
| | 0.43 | 0.039 | 0.006 | 0.194 | ND | ND | Present study |
| | - | 7.94 | 0.08 | - | 0.11 | 0.064 | Abdel-Baky *et al.* (1998) |
| Manzala | 3.20 | 1.37 | 0.19 | - | ND | 0.11 | Elghobashy *et al.* (2001) |
| | 1.42 | 0.4636 | 0.513 | 0.513 | 0.044 | 0.099 | Present study |

ND: not detectable

**Heavy metals in Sediment**

The results obtained for the sediment analysis are shown in table (3). The metals concentrations in bottom sediment varied widely and exhibit fluctuations between different Lakes especially in values of Fe, Cu, Mn, Cd and Pb but no noteworthy differences were observed in Zn concentrations among the three Lakes studied. The order of abundance of these metals in sediments of the three Lakes were as follow Fe > Mn > Zn > Cu > Pb > Cd (Table 3). Metals exhibited a similar pattern of concentration as its abundance in water. Fe attained its highest value in Lake Manzala followed by Lake Borollus, while the lowest concentration was observed in Lake Edku. The maximum value of Zn and Cu were recorded in Lake Manzala while the minimum ones were observed in Lake Borollus and Edku (for Cu). The levels of Mn had its highest values in Lake Edku and Borollus, while the lowest value in Lake Manzala. On the other hand, Cd and Pb reached its maximum value in Lake Manzala and the minimum one in Lake Edku as shown in table (3). The high level of Cd and Pb in sediments of Lake Manzala could be attributed to the industrial and agricultural discharge as well as from spill of leaded petrol from fishing boats which are distributed in the Lake compared with Lake Edku and Borollus. Also, dust which holds a huge amount of lead from the combustion of petrol in automobile cars led to increase Pb content (Hardman et al. 1994). The difference among the three Lakes in metal content in sediments is significant (Table 3).

Table 3. Mean of heavy metals concentration (µg/g dry wt.) in surfacial sediments of the northern delta Lakes.

| Lake | | Fe | Zn | Cu | Mn | Cd | Pb | Total |
|---|---|---|---|---|---|---|---|---|
| Edku | min | 1080.69 | 54.07 | 12.710 | 342.585 | 0.972 | 3.98 | 1495.01 |
| | max | 13214.97 | 3232.43 | 57.90 | 2437.80 | 2.864 | 193.25 | 19139.2 |
| | mean | 6253.99$^{b}$ | 344.45$^{b}$ | 36.77$^{b}$ | 1390.13$^{a}$ | 1.47$^{b}$ | 37.14$^{b}$ | 8063.95 |
| | | ±916.24 | ±13.77 | ±3.63 | ±210.45 | ±0.13 | ±16.53 | |
| Borollus | min | 6686.68 | 72.77 | 27.13 | 409.25 | ND | ND | 7198.37 |
| | max | 15135.75 | 726.90 | 77.02 | 1876.13 | 41.49 | 81.32 | 17938.61 |
| | mean | 10999.49$^{b}$ | 217.334$^{b}$ | 47.49$^{b}$ | 850.95$^{ab}$ | 4.62$^{b}$ | 13.08$^{b}$ | 12171.17 |
| | | ±٣٣١,٤5 | ±25.92 | ±1.81 | ±63.96 | ±2.03 | ±4.64 | |
| Manzala | min | 20018.00 | 202.00 | 106.00 | 114.00 | 33.00 | 78.00 | 20551.0 |
| | max | 56212.00 | 576.00 | 412.00 | 666.00 | 110.00 | 174.00 | 58150.0 |
| | mean | 33386.64$^{a}$ | 432.16$^{a}$ | 315.36$^{a}$ | 419.60$^{b}$ | 84.80$^{a}$ | 134.64$^{a}$ | 34773.2 |
| | | ±2430.63 | ±22.04 | ±17.17 | ±29.99 | ±4.17 | ±5.15 | |
| T. mean | | 25.59 | 331.31 | 133.21 | 886.89 | 30.30 | 61.62 | |
| **PL | | - | 120 - 820 | 16 - 110 | 460 - 1110 | 0.6 - 10.0 | 31 - 250 | |

**PL ( µg/g dry wt.): according to Persaud *et al.* 1990. Letters a and b show differences among sites. Data shown with different letters are statistically different at P < 0.05 level.

The Ontario Ministry of the Environment (Persaud *et al.* 1990) developed sediment quality guidelines based on screening level concentrations from data for a range of local sediments and benthic biota. Two levels were reported, a low level which is the lowest that toxic effects become apparent, and a severe level, representing concentrations that could effectively eliminate most of the benthic organisms (Table 3). Comparing the present results with the sediment quality guidelines (Table 3), it is obvious that the concentration of Mn in Lake Edku and Cd in Lake Manzala exceeded these limits. Comparing data of the present study with previous studies in these Lakes are presented in (Table 4). The present data revealed significant increase in Mn and Pb levels in Lake Edku and elevation of Zn, Cu and Mn in Lake Borollus. Also, Lake Manzala showed elevated values of Zn, Cu, Mn, Cd and Pb.

Table 4. Comparison of heavy metals concentration (µg/g dry wt.) in surfacial sediments of the northern delta Lakes with previous studies.

| Lake | *Fe | Zn | Cu | Mn | Cd | Pb | Reference |
|---|---|---|---|---|---|---|---|
| | 8.5 | - | 30.0 | 145.0 | - | 4.0 | (1) |
| Edku | 23.6 | 317.0 | 19.0 | 115.0 | 7.3 | 20.0 | (2) |
| | 6.25 | 344.45 | 36.77 | 1390.13 | 1.47 | 37.14 | (3) |
| | 35.00 | 40.0 | 18.00 | - | - | 24.0 | (4) |
| Borollus | 17.9 | 90.0 | 25.0 | 85.0 | 5.2 | 14.0 | (2) |
| | 11.00 | 217.33 | 47.49 | 850.95 | 4.62 | 13.08 | (3) |
| | 35.9 | 164.0 | 74.0 | 847.0 | 11.8 | 79.0 | (2) |
| Manzala | - | 48.42 | 7.89 | - | 1.36 | 14.05 | (5) |
| | 33.39 | 432.16 | 315.36 | 419.6 | 84.8 | 134.6 | (3) |

*Fe: mg/g dry wt.; (1): El-Ghobary (1977); (2): Abdel-Moati & El-Sammak (1997); (3): Present study; (4): Moussa (1984); (5): Abdel-Baky *et al.* (1998).

Comparing the heavy metals levels in sediments of the northern delta Lakes with other areas of the world, it is found that similar higher levels of Zn, Cu, Mn, Cd and Pb (13–150, 0.7–36, 160–760, 0.1–0.7 and 2.4–160 µg/g dry wt., respectively) were reported in sediment of Lake Balaton in Central Europe (Nguyen et al., 2005). Furthermore, very high levels of Fe, Zn, Cu, Mn, Cd and Pb (34151.0, 148.0, 1450.1, 264.0, 2.7 and 67.1 µg/g dry wt., respectively) were recorded in sediments of Lake Hannah (Canada) (Pyle *et al.*, 2005).

In this study the sites near drains showed higher values than sites at the middle of Lakes or sites near the Lakes-sea connection which is characterized by low values of metals due to their presence far from direct drain discharge. This may be due to the area opposite to drains dominated by fine sediments and high in organic matter, while the middle region of the Lakes is dominated by sand fraction, calcareous deposits that are a mixture of sand-silt-clay, high in carbonate and low in organic carbon (Abdel-Moati and El-Sammak, 1997). This variation in the Lake's sediment was reflected on the metals distribution. This comply with Franc et al. (2005) who mentioned that sediments contain more sand and lower values of organic matter exhibit low metals enrichment. Also, the concentrations of heavy metals in sediment increase as the amount of organic material increase (Tsai et al., 2003). He also mentioned that the pollutant concentrations in sediments increased with decreasing the particle size in sediments. Sediment has certain limited capacity to absorb different ions from waters percolating through it. This capacity is lowest for carbonate-sandy fractions of sediments (Lake-sea area), and highest for clayey organic matter rich sediments.

The concentration of heavy metals in surfacial sediments had the trend Fe > Mn > Zn > Cu > Pb >Cd. This complies with the previous studies in northern Lakes (Elghobashy *et al.*, 2001, Abdel-Moati and El-Sammak, 1997 and Ibrahim and El-Naggar, 2006). Carrol (1958) stated that iron appears in the Lake sediments as an essential component of clay minerals which is the major one in the Lakes. Hamed (1998) attributed the high concentrations of trace metals in the Nile sediments near Damietta governorate and Mansoura city to high clay content of sediment and industrial activities. He also added that the sandy sediments showed low concentrations of heavy metals than clayey sediments.

By comparing the accumulation of heavy metals in water and sediments, it can be concluded that the heavy metals are highly accumulated in sediments than water, since the sediments act as reservoir for all contaminants and dead organic matter descending from the ecosystem above. Similar findings were reported by other authors (Hamed, 1998 and Nguyena *et al.* 2005).

### Heavy metals in fish

The present results show that the metal concentrations in fish organs (muscle, gills and liver) of *Oreochromis niloticus* are closely associated with metal content of water and sediments in the three Lakes (Table 5) and detected in the following order: Fe > Zn > Cu > Mn > Pb > Cd. This may be attributed to the abundance of these metals in water and sediments by the same pattern. A remarkable relationship between heavy metals concentrations in aquatic organisms and sediments were observed by Ibrahim *et al*. (2000) and Ibrahim and El-Naggar (2006).

Table 5. Average heavy metals concentrations (µg/g dry wt.) in organs of *Oreochromis niloticus* caught from the northern delta Lakes.

| Lake | Organ | Fe | Zn | Cu | Mn | Cd | Pb | Total |
|---|---|---|---|---|---|---|---|---|
| Edku | Muscle | 75.19 | 27.6 | 2.80 | 1.98 | 0.19 | 0.59 | 108.35 |
| | Gills | 515.23 | 87.46 | 4.24 | 26.25 | 1.96 | 3.41 | 638.55 |
| | Liver | 720.48 | 112.15 | 154.43 | 13.89 | 2.16 | 2.88 | 1005.99 |
| | Total | 1310.90 | 227.21 | 161.47 | 42.12 | 4.31 | 6.88 | 1752.89 |
| Borollus | Muscle | 21.44 | 9.88 | 1.77 | 0.23 | 0.014 | 0.016 | 33.35 |
| | Gills | 209.18 | 9.8 | 4.38 | 27.19 | 0.12 | 1.23 | 251.9 |
| | Liver | 253.88 | 13.05 | 35.36 | 0.41 | 0.223 | 0.039 | 302.96 |
| | Total | 484.5 | 32.73 | 41.51 | 27.83 | 0.357 | 1.285 | 588.21 |
| Manzala | Muscle | 256.66 | 212.44 | 48.84 | 22.98 | 10.36 | 10.1 | 561.38 |
| | Gills | 2056.82 | 1006.88 | 242.12 | 30.32 | 32.22 | 56.12 | 3424.48 |
| | Liver | 2256.42 | 1226.34 | 277.82 | 33.55 | 39.12 | 42.220 | 3875.47 |
| | Total | 4569.9 | 2445.66 | 568.78 | 86.85 | 81.7 | 108.44 | 7861.33 |
| T. av. | | 1060.883 | 450.933 | 128.627 | 26.133 | 14.39 | 19.434 | |
| *PL (mg/day) | | 43.0 | 60.0 | 3.0 | 2.0 –9.0 | 0.1** | 0.214 | |

*PL: Permissible limits (wet wt.) according to FAO/WHO (1999). **µg/g.

The present results indicate that the concentrations of heavy metals in fish organs in Lake Manzala are higher than those of Lake Edku and borollus (Table 5). This corresponds to their high concentrations in water and sediments of Lake Manzala.

The present results demonstrate that the concentration of heavy metals in fish gills and liver is much higher than that in muscles. Jobling (1995) attributed the high accumulation of heavy metals in liver and gills tissues to the metallothionein proteins which are synthesized in liver and gills tissues when fishes are exposed to heavy metals and detoxify them. These proteins are thought to play an important role in protecting them from damage by heavy metal toxicants. Also, gills are the site directly exposed to the ambient conditions and also are known for their excretory function even for some metals like zinc (Matthiessen and Brafield, 1977). Moreover, Saleh (1982) reported that the amount of pollutants in the fish liver is directly proportional to the degree of pollution in the aquatic environment by heavy metals. Similar observations were reported by many studies carried out with various fish species (Guerrin *et al.* 1990 and Saeed and Sakr, 2008).

The recommended daily intake for an adult is 48.0, 60.0, 3.0, 2.0-9.0, and 0.214 mg/day wet weight for Fe, Zn, Cu, Mn and Pb respectively according to FAO/WHO (1999) (Table 5). While, the permissible daily intake of Cd is 0.1 µg/g wet weight. The concentration of metals in the edible part of this fish species in Lake Edku and Borollus are safe for consumers. However, the muscle tissue of fish collected from the studied area in Lake Manzala may pose health risk to consumer, as concentration of Cd and Pb exceeded those of the international limits.

Comparing accumulation of metals in organs of *Oreochromis niloticus* in this study with other studies in the same Lakes, it is obvious from table (6) that Elghobashy *et al*. (2001) recorded higher concentrations of Fe, Zn, Cu, Cd and Pb in fish muscle and liver of Lake Borollus, whereas El-Moselhy (1999) recorded lower metal concentrations in fish organs from Lake Manzala than those in the present study. Similar higher values of metals were recorded in fish organs collected from Shanawan Drainage Canal (Khallaf *et. al*., 1998) as those from Lake Manzala. However, values in fish organs of Lake Manzala exceeded those recorded in fish collected from Shanawan Drainage Canal except Fe and Pb (in muscle) and Mn and Pb (in liver) which exhibited higher values in Shanawan Canal (Table 6).

Table 6. Comparison of heavy metals concentrations in various organs of *Oreochromis niloticus* with previous studies in northern Lakes and other localities.

| Organ | Locality | Fe | Zn | Cu | Mn | Cd | Pb | Refer. |
|---|---|---|---|---|---|---|---|---|
| | L. Edku | - | 6.01 | 1.66 | 1.21 | - | 8.63 | (1)* |
| | Shanawn Canal | 530.9 | 55.4 | 5.1 | 20.9 | 5.3 | 48.7 | (2) |
| | L. Manzala | 4.32 | 5.96 | 0.51 | - | 0.03 | 0.13 | (3)* |
| Muscle | L. Borollus | 30.3 | 41.3 | 2.18 | - | 0.03 | 0.22 | (4) |
| | L. Edku | 75.19 | 27.60 | 2.80 | 1.98 | 0.19 | 0.59 | (5) |
| | L. Borollus | 21.44 | 9.88 | 1.77 | 0.23 | 0.014 | 0.016 | (5) |
| | L. Manzala | 256.66 | 212.44 | 48.84 | 22.98 | 10.36 | 10.1 | (5) |
| | L. Manzala | 18.46 | 18.46 | 1.09 | - | 0.08 | 0.52 | (3)* |
| | L. Borollus | 194 | 9.5 | 2.13 | - | 0.05 | 2.77 | (4) |
| Gills | L. Edku | 515.23 | 87.46 | 4.24 | 26.25 | 1.96 | 3.41 | (5) |
| | L. Borollus | 209.18 | 9.8 | 4.38 | 27.19 | 0.12 | 1.23 | (5) |
| | L. Manzala | 2056.82 | 1006.88 | 242.12 | 30.32 | 32.22 | 56.12 | (5) |
| | Lake Edku | - | 23.77 | 46.3 | 5.69 | - | 16.25 | (1)* |
| | Shanawn Canal | 1489.3 | 107.5 | 205.5 | 39.6 | 12.6 | 91.9 | (2) |
| | L. Manzala | 197.08 | 22.8 | 3.42 | - | 0.054 | 0.24 | (3)* |
| Liver | L. Borollus | 830 | 162 | 44.8 | | 0.58 | 2.9 | (4) |
| | L. Edku | 720.48 | 112.15 | 154.43 | 13.89 | 2.16 | 2.88 | (5) |
| | L. Borollus | 253.88 | 13.05 | 35.36 | 0.41 | 0.223 | 0.039 | (5) |
| | L. Manzala | 2256.42 | 1226.34 | 277.82 | 33.55 | 39.12 | 42.22 | (5) |

(1): Shakweer and Abbas (1996); (2): Khallaf *et al*., (1998); (3): El-Moselhy (1999); (4): Elghobashy *et al*. (2001); (5): Present study; *wet weight.

To determine the accumulation pattern of heavy metals in water, sediments and fish organs, the relative accumulation indices (expressed in terms of X times) were obtained by comparing values in sediments and fish organs to values in water, as shown in table (7). From the results obtained, it is clear that, the metals Fe, Zn, Cu and Mn were accumulated in sediment at high concentration levels amounting to thousands times those accumulating in water. Metals as Cd and Pb recorded low values. As total heavy metals, the accumulation in sediment relative to water was estimated to be 12268.53, 16513.17 and 11408.81 times in Lake Edku, Borollus and Manzala, respectively (Table 7). The maximum relative accumulation indices (RAI) of most studied metals in sediments were found in Lake Borollus, which had the lowest metal concentration in water, followed by Lake Manzala, while Lake Edku recorded the minimum RAI in sediments.

Table 7. Relative accumulation indices (RAI)* of metals in sediment of the northern delta Lakes.

| Lake | Ecosy. comp. | Fe | Zn | Cu | Mn | Cd | Pb | Total |
|---|---|---|---|---|---|---|---|---|
| | Water | 0.570 | 0.016 | 0.011 | 0.024 | 0.007 | 0.028 | 0.657 |
| Edku | Sediment | 6253.99 | 344.45 | 36.77 | 1390.13 | 1.47 | 37.14 | 8063.95 |
| | RAI (x times) | 10963.62 | 20987.02 | 3396.45 | 57592.31 | 197.28 | 1324.77 | 12268.53 |
| | Water | 0.425 | 0.039 | 0.006 | 0.194 | 0.005 | 0.065 | 0.735 |
| Borollus | Sediment | 10999.49 | 217.33 | 47.49 | 850.95 | 4.62 | 13.08 | 12132.97 |
| | RAI (x times) | 25898.74 | 5525.92 | 7970.94 | 4379.94 | 924.37 | 199.81 | 16513.17 |
| | Water | 1.416 | 0.464 | 0.513 | 0.513 | 0.044 | 0.099 | 3.047925 |
| Manzala | Sediment | 33386.64 | 432.16 | 315.36 | 419.60 | 84.80 | 134.64 | 34773.2 |
| | RAI (x times) | 23578.14 | 932.18 | 614.98 | 818.25 | 1944.95 | 1358.28 | 11408.81 |

*Ratio concentration in sediment (µg/g dry wt.) to concentration in water (mg/l). ND: not detected.

Regarding RAI in fish organs (Table 8), it is clear that, copper showed the highest bioconcentration in muscle tissue followed by zinc, while lead showed the lowest bioconcentration. In gills copper followed by iron and zinc showed higher RAI and cadmium the lowest one. Iron and zinc showed the highest level of RAI in liver, while manganese showed the lowest levels. This could be explained by the fact that, iron, zinc and copper are essential elements in the bodies of living organisms and has an important role in different physiological processes. As a whole the RAI of fish organs increased in Lake Edku (888.95) followed by Lake Manzala (859.75) then Lake Borollus (295.16).

Table 8. Relative accumulation indices (RAI)* of metals in fish organs of the Nile northern delta Lakes.

| Lake | Organ | Fe | Zn | Cu | Mn | Cd | Pb | Total |
|---|---|---|---|---|---|---|---|---|
| | Muscle | 131.81 | 1681.65 | 258.66 | 82.03 | 25.51 | 21.05 | 164.84 |
| Edku | Gills | 903.23 | 5328.87 | 391.69 | 1087.52 | 263.15 | 121.64 | 971.49 |
| | Liver | 1263.04 | 6833.21 | 14266.05 | 575.45 | 290.01 | 102.74 | 1530.52 |
| | average | 766.03 | 4614.57 | 4972.13 | 581.67 | 192.89 | 81.81 | 888.95 |
| | Muscle | 50.48 | 251.21 | 297.06 | 1.18 | 0.01 | 0.02 | 50.20 |
| Borollus | Gills | 492.52 | 249.17 | 735.09 | 139.95 | 0.12 | 1.23 | 379.21 |
| | Liver | 597.77 | 331.81 | 5934.40 | 2.11 | 0.12 | 1.23 | 456.07 |
| | average | 380.26 | 277.40 | 2322.18 | 47.75 | 0.08 | 0.83 | 295.16 |
| | Muscle | 181.26 | 458.24 | 95.24 | 44.81 | 237.61 | 101.89 | 184.18 |
| Manzala | Gills | 1452.56 | 2171.87 | 472.15 | 59.13 | 738.99 | 566.15 | 1123.54 |
| | Liver | 1593.52 | 2645.25 | 541.77 | 65.43 | 897.25 | 425.93 | 1271.51 |
| | average | 1075.78 | 1758.46 | 369.72 | 56.45 | 624.62 | 364.66 | 859.75 |
| Total | | 740.69 | 2216.81 | 2554.68 | 228.62 | 272.53 | 149.10 | |

*Ratio concentration in fish organs (µg/g dry wt.) to concentration in water (mg/l).

In this study, it is obvious that Fe has the highest concentration(707.26 µg/g), while Cd has the lowest concentration (9.60 µg/g) of all measured metals in fish organs (Table 5), however Cu and Zn were found to have the highest accumulation rate (2554.68 and 2216.81 times), and Pb has the lowest accumulation rate (149.10 times) (Table 8). This order might be attributed to the different uptake, metabolism and detoxification of metals in fish. Similar observation was recorded by Ibrahim and El-Naggar (2006).

## CONCLUSION

Water, sediments and fish from Lake Manzala had greater concentrations of most studied metals than those from Lake Edku and Lake Borollus. Fe, Mn, Cd and Pb in Lake Manzala and Mn and Pb in Lake Borollus recorded levels above the international permissible limits in water. In sediment samples Mn in Lake Edku and Cd in Lake Manzala recorded higher values than the sediment quality guidelines. The edible part of *Oreochromis niloticus* showed higher levels of Cd (in Lake Edku and Manzala) and Pb (in Lake Manzala). Therefore this fish species caught from the two Lakes may pose health hazards for consumers.

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# تقييم التلوث بالمعادن الثقيلة فى مياه ورسوبيات القاع وتأثيرها على أسماك البلطى النيلى فى بحيرات شمال دلتا نهر النيل، مصر

**سمير محمد سعيد موسى، إبراهيم محمد شاكر عبد الفتاح**

*مركز البحوث الزراعية- المعمل المركزى لبحوث الثروة السمكية بالعباسة- قسم الليمنولوجى.*

أجريت هذه الدراسة فى ثلاث من بحيرات دلتا نهر النيل والتى تقع على ساحل البحر المتوسط وهى بحيرات (إدكو، البرلس، المنزلة) لتقييم درجة التلوث بها، حيث تم تقدير متبقيات بعض العناصر الثقيلة (الحديد والزنك والنحاس والمنجنيز والكادميوم والرصاص) فى مياه ورسوبيات القاع وأسماك البلطى النيلى السائدة فى هذه البحيرات. وقد أوضحت الدراسة النتائج التالية:

-كان ترتيب تركيزات هذه العناصر فى المياه كالآتى: الحديد > المنجنيز > النحاس > الزنك > الرصاص > الكادميوم. وسجلت مياه بحيرة المنزلة أعلى مستوى لهذه المعادن. ولقد فاقت تركيزات الحديد، المنجنيز، الكادميوم والرصاص فى مياه بحيرة المنزلة والمنجنيز والرصاص فى بحيرة البرلس الحد الأقصى المسموح به دوليا. وقد أعزى ذلك للكميات الكبيرة من المخلفات الصناعية والزراعية والصرف الصحى التى تصل إلى البحيرة عن طريق مصارف بحر البقر، بحر حادوس وبحر رمسيس.

-تركيز المعادن الثقيلة فى رسوبيات القاع أعلى بكثير منه فى المياه وكان ترتيب تركيزات هذه العناصر فى الرواسب كالآتى: الحديد > المنجنيز > الزنك > النحاس > الرصاص > الكادميوم.

ولقد سجلت رسوبيات بحيرة المنزلة أعلى مستوى للتلوث بالمعادن الثقيلة. وتجاوز مستوى عنصرى النحاس والكادميوم فى رسوبيات بحيرة المنزلة والمنجنيز فى رسوبيات بحيرة إدكو الحد الأقصى المسموح به عالمياً.

-أظهرت الدراسة أن تراكم العناصر الثقيلة (الحديد- الزنك- النحاس- المنجنيز- الكادميوم والرصاص) فى أنسجة الأسماك المجمعة من بحيرة المنزلة أعلى من مثيلاتها فى بحيرة البرلس وبحيرة إدكو. كما أوضحت الدراسة أن أنسجة الكبد والخياشيم لها قابلية كبيرة لإختزان العناصر عن العضلات والتى لاتمثل أى خطورة على المستهلك فى بحيرتى إدكو والبرلس حيث أن تركيز العناصر بها مازال أقل من النسب المسموح بها عالميا. وفاق تركيز عنصرى الكادميوم والرصاص فى عضلات الأسماك المجمعة من بحيرة المنزلة (من منطقة المصارف جنوب شرق البحيرة) الحد الأقصى المسموح به عالمياً ولذلك تعتبر أسماك البلطى النيلى فى منطقة هذه الدراسة من بحيرة المنزلة غير صالح للإستهلاك الآدمى.