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EFFECT OF SOME WATER POLLUTANTS ON THE NILE TILAPIA, *OREOCHROMIS NILOTICUS* COLLECTED FROM THE RIVER NILE AND SOME EGYPTIAN LAKES

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ABSTRACT

Pollution of surface water has increased due to the industrial effluents, waste municipal and agricultural drainage water that discharge directly into it. The present study measured the concentrations of some heavy metals (Fe, Cu, Zn, Pb and Cd) in water, sediment and Nile tilapia fish collected from certain Egyptian lakes (Maryut, Manzala, El-Burullus, Edku and Qarun), a polluted site of the River Nile (Shubra El-Khiema, Cairo sector), in addition to Ismalia canal (El-Abbassa region).

The results revealed that fish collected from the polluted site of the River Nile and the studied lakes (Maryut, Manzala, El-Burullus and Edku) showed the lowest growth factor, hepatosomatic index, meat quality and disturbances in the studied physiological state as indicated by the increase in serum glucose, total protein, AST, ALT, alkaline phosphstase, creatinine, uric acid and a decrease in serum total lipids. In comparison, fish collected from lake Qarun exhibited higher levels of meat quality and growth indices than those collected from the other studied sites and showed normal levels in the different examined biochemical parameters as those of the control group collected from Ismalia canal.

Chemical analyses of water samples suggested that high salinity, total alkalinity and total hardness in lake Qarun might have inhibited the bioaccumulation of any of the studied heavy metals (Fe^{++}, Cu^{++}, Zn^{++}, Pb^{++} and Cd^{++}) in the different studied organs of *Oreochromis niloticus* to be within permissible levels as those of fish collected from Ismailyia canal (Abbassa region). However, fish collected from the other studied lakes and the polluted site of the

River Nile accumulated spatially the heavy metals in the different studied fish organs.

INTRODUCTION

Environmental pollution is one of the most deleterious agents to the biological life. Pollutants can be classified to either biological pollutants such as bacterial parasites, mycotoxins and anti-biotic residues and chemical in nature such as, pesticides, inorganic heavy metals, organic compounds, toxic gases and fumes. Fish in ponds, lakes and rivers cannot avoid exposure to these substances, whether it is chemicals suspended or dissolved in water, being less than land animals to move to favorable regions to avoid unfavorable conditions.

Egyptian coastal lakes act as temporary reservoirs for drainage water and often are highly contaminated with anthropogenic materials. This is true particularly for Manzala Lake and Maryut and to a lesser extent for Edku Lake (El-Rayis and Saad, 1984 and Hamed and Said, 2000). Moreover, fish production in the River Nile, canals and lakes have virtually ceased due to discharge of industrial and agricultural waste water (Nawar and El-Kamah, 1984; Zaghloul, 1997; Magdy *et al.*, 2000 and Mansour and Messeha, 2001).

Concerning the ecological interaction between the fish and their environment, it could be easily understood that fishes are more liable to be affected with environmental pollutants than the non-aquatic land animals due to their anatomical and physiological adaptations (skin, mucus, gills, immune system and natural feeding cycle). The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both cultured and wild fish. Nowadays, the increasing use of pesticides as means for controlling different human, animal and plant parasites and their intermediate hosts, also, as a method of illegal fishing, the waste chemical drainage systems of large factories in River Nile and some Egyptian lakes, the sewage effluents with their microbial and non-organic heavy metal contents represent the most dangerous chemical source of pollution for both cultured fresh and marine water fish which in turn can lead to serious disease problems in mankind (Marzouk, 1994; Hamed and Said, 2000; Magdy *et al.*, 2000 and Mansour and Messeha, 2001).

Pollution of the aquatic environments with heavy metals has become a more serious concern during the recent years. The continual loading of metals into our environment creates water pollution problems due to their direct toxic effect on aquatic biota. In addition,

metal ions can be incorporated into food chains and concentrated in aquatic organisms to a level that affects their physiological state (Zaghloul, 2000 & 2001)

The impact of heavy metals on fish has been of great concern for many years. Bioaccumulation of heavy metals in fish may critically influence the growth rate, physiological and biochemical status and consequently the meat quality of fish (Salah El-Deen *et al.*, 1996 & 1999; El-Naggar *et al.*,1998 and Haggag *et al.*,1999). Moreover, histopathological changes have been reported in gills, liver and kidney in response to different irritants including heavy metals (Mazhar *et al.*, 1986; Haggag, *et al.*, 1993; Ahmed, 1996 and Zaghloul, 1997).

Fish health may suffer in agricultural drainage and waste municipal waters unless their quality is fully evaluated by chemical analyses to asses the levels of heavy metals that could be incorporated into fish tissues (Elsikhry,1990; Shenouda *et al.*,1992; Khalil and Hussein,1996; Nagdi and Shaker, 1998 and Nasr *et al.*,1998) and hence become a threat to man (Ajmal *et al.*, 1985).

The aim of the present study is to compare, the quality of water samples especially the levels of inorganic, pollutants, in the studied natural water resources (lakes and the River Nile) and to determine the level of bioaccumulation of heavy metals in the different organs of fish including the edible muscles. Moreover,comprehensive studies on some physiological and biochemical parameters of the Nile tilapia; *Oreochromis niloticus* collected from these sites were also carried out.

MATERIALS AND METHODS

The present study was carried out on the Nile tilapia, *Oreochromis niloticus* collected from different natural water is resources; certain Egyptian lakes (Maryut, Manzala, El-Burullus, Edku and Qarun), a polluted site of the river Nile (Shubra El-Khiema, Cairo sector), in addition to Ismalia canal (Abbassa region). The samples were collected during the summer season from July to September, 2000.

Description of the studied sites:

1) Ismalia canal (Abbassa region) where no discharged effluents were recognized (control group).

2) River Nile, north of Cairo with the Nile water current (Shubra El-Khiema) where brick and cook factories discharge their effluents directly to the River Nile.
3) Manzala lake, the north western region where waste municipal water (Bahr El- Bakar) , domestic wastewater, agricultural drainage water and industrial effluents were discharged without any treatment.
4) Edku Lake, Edku city where agricultural drainage water discharged.
5) El-Burullus lake, south west of the lake where agricultural and industrial effluents were recognized.
6) Qarun lake, along Cairo – El-Fayoum road (Shakshouk village) where agricultural drainage water dicharged.
7) Maryut lake, one of the delta lakes, near Alexandria city where agricultural,industrial and waste municipal effluents were discharged.

Equal numbers of water, sediment and fish samples were collected from the different studied sites.Thirty individuals of the Nile tilapia; *Oreochromis niloticus* of approximately the same body weight (150 ± 5 g) were collected from each site for analyses.

(1) Water analyses

Water samples (nine samples) collected from each of the studied sites were analyzed for pH, dissolved oxygen, total hardness, total alkalinity, ammonia and salinity according to the standard method described by the American Public Health Association (APHA, 1985). Heavy metal concentrations in water samples were determined by atomic absorption spectrophotometry (Perkin Elmer, 2280) after APHA (1985). Metals examined in this study were iron, copper, zinc, lead and cadmium.

(2) Sediment analyses

Sediment samples (nine samples) were collected from the studied sites and dried at 105°C till constant weight then ashed at 420°C for 24 hrs. The ash was dissolved in concentrated nitric acid and the heavy metals (Fe^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+} and Cd^{2+}) concentrations were detected according to Haritonidis and Malea (1995) using atomic absorption (Perkin Elmer, 2280).

(3) Growth parameters

Body weights to the nearest gram and total body lengths to the nearest 0.1 cm were measured for fish collected from each site (thirty fish from each site).

(a) Condition factor

k factor was calculated for each individual fish from the formula recommended by Schreck and Moyle (1990):

$$k = \frac{W}{L^3} \times 100$$

Where W: is the wet weight in g.

L : is the total length in cm.

(b) Hepatosomatic index (HSI) was calculated according to Schreck and Moyle (1990) as follows:

$$\text{Hepatosomatic index (HSI)} = \frac{\text{Weight of the organ}}{\text{fish total weight}} \times 100$$

(4) Biochemical analyses:

(a) Serum analyses

Blood samples were withdrawn from the arteria caudalis and centrifuged at 3000 r.p.m. to get serum for the following analyses: The level of serum glucose was measured using the GOD – PAP method (enzymatic colorimetric method) according to Trinder (1969) using Boehringer Mannheim kits. Serum total protein content was determined by Biuret test (King and Wooton, 1959). Serum total lipids level was determined colorimetrically by sulphova-nillin reaction according to Schmit (1964). Serum aspartate amino transferase (AST, E.N. 2.6.1.1) and alanine amino transferase (ALT, E.N. 2.6.1.2) activities were determined colorimetrically according to the method of Reitmans and Frankle (1957) using reagent kits purchased from Boehringer Mannheim. Serum alkaline phosphatase activity (ALP) was determined according to the method described by Kind and King (1954). Serum creatinine was measured using colorimetric method described by Henry(1974). Serum uric acid was measured enzymatically according to Barham and Trinder (1972).

(b) Meat quality

Muscle and liver water content was determined according to Sidwell *et al.* (1970).

Total muscle protein was determined using the semi- microkjeldah method as reported by Josyln (1950)
Total lipids of muscles was determined by the standard method reported in A.O.A.C. (1970).
Muscle ash was determined by burning the samples in a muffle furnace for 16 hours at 550°C (Sidwell *et al.*, 1970)

(5) Heavy metal concentrations
Residual heavy metals (Fe^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+} and Cd^{2+}) were detected in gills, liver, kidney, end of alimentary canal and muscles of fish according to American Public Health Association (A.P.H.A., 1985) then measured using atomic absorption spectrophotometry (Perkin Elmer, 2280).

(6) Statistical analyses
The results were statistically analyzed using analyses of variance (f-test) and Duncan's multiple range test to determine differences in means (Duncan, 1955).

RESULTS AND DISCUSSION

Concerning the water quality criteria (Table 1), the data revealed that there were highly significant differences among the studied sites ($p< 0.01$). The highly significant decrease in dissolved oxygen and the increase in ammonia level in water samples collected from El-Manzala Lake water could be attributed to the increase in the oxygen consumption of the decomposing organic matter and oxidation of chemical constituents (Boyd, 1990).

Heavy metal pollution in water is generally associated with agricultural, industrial and municipal discharges into water resources (Zaghloul, 1997, 2000 & 2001). Once metals are in the water column, they may be taken up by living organisms, deposited in the sediments or remain for a period in the water itself (Vazquez *et al.*, 1994).

The mean concentrations of the studied heavy metals (Fe^{++} ,Cu^{++}, Zn^{++}, Pb^{++}, and Cd^{++}) in water and sediment collected from the studied sites are shown in Tables 1 and 2 respectively. It is clear that there were highly significant differences in the concentrations of water and sediment heavy metals among the studied sites. The low concentrations of the water heavy metals is not an indication of the low bioaccumlated metals in fish or adsorption on sediment. Moreover, the impact of the heavy metals appeared to be localized

according to the source of pollution (industrial, waste municipal, waste domestic and/or agricultural drainage water). This is in agreement with Elsikhry (1990); Shenouda *et al.* (1992); Khalil and Hussein, (1996) and Nagdi and Shaker (1998) who attributed the increase of heavy metals in drainage water to the decomposition of the organic matter and/or the use of fertilizers and other chemicals in agriculture. On the other hand, the highest levels of water salinity, hardness and water alkalinity observed in Qarun lake could play a role in inhibiting the accumulation of the recorded heavy metals on fish as previously reported by Miller and Mackay (1979) and Pascoe *et al.*(1986), Sorensen (1991) and Zaghloul(1997).

The values of the condition factor are estimated for comparative purposes to assess the impact of environmental alterations on fish performance (Clark and Fraser, 1983). Therefore, the fluctuation in k may reflect the health condition of the fish as well as their body protein and lipid contents (Weatherly and Gill, 1983).

The lower values of the condition factor of the Nile tilapia, *Oreochromis niloticus* collected from the River Nile and the studied lakes in comparison with that collected from Ismailyia canal and Qarun Lake (Table 3) may reflect the toxic effect of the heavy metals recorded in water (Clark and Fraser, 1983; Haggag, *et al.*, 1999 and Salah El-Deen *et al.*,1999) or accumulated in plankton biomass (Saleh *et al.*, 1988).

As regards to hepatosomatic index (Table 3), the lower values in fish collected from the studied lakes and the polluted site of the River Nile could be attributed to a depletion of liver glycogen followed by hyperglycemia (Table 4) reflecting the fish's need for energy necessary to resist the stress (Schreck, 1981). Moreover, the high liver water content with the decrease in the hepatosomatic index (Table 3) is an indication of the decrease in the organic constituents (protein, lipids and glycogen) as previously reported by Weatherly and Gill (1987).

Serum constituents

Analyses of serum constituents have been proved to be useful in the detection and diagnosis of metabolic disturbance and disease processes (Aldrin *et al.*, 1982).

Blood glucose appears to be a sensitive, reliable indicator of environmental stress in fish (Nemcsok and Boross, 1982). In the

present study, the observed blood glucose values (Table 4) of fish collected from Ismailyia canal water (El-Abbassa region) were within the normal range of glucose levels of the same species as reported by El-Naggar *et al.* (1998) and Zaghloul (2000).

However, fish collected from the studied lakes and River Nile (Shubra El-Khiema) and exposed to industrial, agricultural drainage and waste municipal discharges showed a higher serum glucose level. This hyperglycemia may be due to enhanced glycogen breakdown in liver, probably because of the high concentrations of heavy metals in water (Tables 6 -10). Our recorded data are in agreement with the findings of Diwan *et al.* (1979), Haggag *et al.* (1993 & 1999) and El-Naggar *et al.* (1998) who postulated that environmental pollution may produce stress in fish, enhancing glycogen breakdown in liver and consequently raises blood glucose level.

Another explanation for the recorded hyperglycemia may be also based on an increase in plasma concentration of catecholamines and corticosteroids as a stress response of fish subjected to environmental alterations as stated by Mazeaud *et al.* (1977).

In the present study, the total serum protein values of fish collected from Ismalia canal water were within the normal range (Table 4) as previously reported by Haggag *et al.* (1993 & 1999) and Ghazaly and Said (1995). However, fish collected from the lakes and the River Nile showed significant increase in the total serum protein. The elevation in serum protein level is consistent with previous results of the effects of heavy metals by Ghazaly and Said (1995), Salah El-Deen *et al.* (1996) and Haggag *et al.* (1999) working on *Tilapia nilotica*, *Ctenopharyngodon idella* and *Clarias gariepinus* respectively. The increased serum protein levels indicate an activation of metabolic systems. Moreover, the serum proteins possibly come from degradation of the cellular material in the liver and other organs. The liver is markedly depleted in fish collected from the agricultural drainage water as indicated by the observed reduction of the hepatosomatic index (Table 3). Possibly, the change of serum proteins may be attributed to the histopathological damage (Salah El-Deen *et al.*, 1996) as well as to water loss in the serum as reported by Wedemyer and Yasutake (1977).

Fish collected from the lakes (Maryut, Manzala, El-Burullus and Edku) and the River Nile showed a significant decrease in total serum lipid values than those collected from Ismalia canal (Abbassa region) (Table 4). The decrease in total serum lipids of fish has been attributed to the increase in the secretion of catecholamines

(Pickering,1981) and corticosteroids (Mazeaud *et al.*, 1977) as a result of pollutant stress which enhanced metabolic rate and in turn reduced metabolic reserves.

The present investigation also revealed that fish collected from the lakes and the River Nile water showed an elevation in AST and ALT and alkaline phosphatase activities as compared with those collected from Ismalia canal water (Table 4). This elevation in AST and ALT and alkaline phosphatase activities of fish is attributed to the damage of liver and kidney cells by the action of heavy metals as has been previously reported by Heath (1987), Sandnes *et al.* (1988); Ahmed (1996) and Zaghloul (2000) and Zahra *et al.* (2001) .

Following cell damage, the membranes become permeable and the enzymes are found in the extracellular fluid and serum. So, determination of transaminases, AST and ALT and alkaline phosphatase has proven useful in the diagnosis of liver and kidney diseases in fish (Maita *et al.*, 1984 and Sandnes *et al.*, 1988).

Serum creatinine and uric acid can be used as a rough index of the glomerular filtration rate (Maita *et al.*, 1984). Low values of creatinine and uric acid have no significance but increasing values indicate the presence of disturbances in the kidney (Maxine and Benjamine, 1985).

In the present investigation, fish collected from the lakes and the River Nile showed an elevation in serum creatinine and uric acid (Table 4). This may be attributed to the action of heavy metals on the glomerular filtration rate which causes pathological changes of the kidney (Saad *et al.*, 1973 ; Oikari and Soivio, 1977).

Meat quality (muscle chemical composition)

Regarding the muscle chemical composition(Table 5), the decrease in total muscle protein and total lipids of fish collected from River Nile, Manzala, Edku, El-Burullus and Maryut lakes may be attributed to the change in water quality by the action of heavy metals that may critically influence the growth rate and the quality of fish (Hodson *et al.*, 1984). The increase in muscle water content of fish is in agreement with Weatherly and Gill (1987) who reported that depletion of body total protein and total lipids results in tissue hydration as an inverse dynamic relationship between protein, lipids and water content in the muscle.

Moreover, the increase in muscle ash of fish may be attributed to the bioaccumulation of heavy metals in fish as previously reported by Haggag *et al.* (1999).

Residual heavy metals

Generally, the concentrations of the studied heavy metals (Fe^{++}, Zn^{++}, Cu^{++}, Pb^{++} and Cd^{++}) in some selected vital organs (gills, liver, kidney, end of alimentary canal and muscles) of *Oreochromis niloticus*, collected from the studied sites are shown in tables (6-10). It is clear from the present results that the highest concentrations of Copper, zinc and lead were found in fish collected from Manzala, Edku and El-Burullus lakes. However, the highest iron and cadmium concentrations were recorded in fish collected from Maryut Lake. The high bioaccumulated heavy metals in fish collected from the lakes is attributed to the fact that, lakes receive heavy load of inorganic and organic pollutants via several agricultural drains, waste municipal and domestic water, in addition to the industrial effluents.

Moreover, fish collected from the River Nile (Cairo sector-Shubra El-Khiema) accumulate a considerable concentrations but less than that rcorded in fish collected from the previously mentioned lakes and this could be attributed to the dilution of effluents dischrged to the River Nile and its water current as previously reported by Zaghloul (1997). The high lead bioaccumlation in fish collected from that site of the River Nile could be attributed to the boats with gasoline motors which lead to more pollution of water, plankton, algae and plants beside the increased nutrition rate of fish on this contaminated food (Shenouda *et al.*, 1992).

The data also revealed that, the bioaccumulation of the recorded metals in fish were higher than the permissible levels recommended by WHO (1984). Bioaccumulation of the studied heavy metals was higher in fish viscera (Liver, kidney, end of alimentary canal) and gills than the edible muscles. The recorded data are in agreement with Shereif & Moaty (1995) and Khalil & Hussien (1996) who postulated that heavy metals were significantly higher in fish viscera, including liver tissue, than in the edible muscle tissues. According to Sorensen (1991) bioaccumulation of heavy metals does not only depend on the structure of the organ but also on the interaction between metals and the target organs. Moreover, heavy metals induced increase in metallothionein content in tissues, has been found most effective in the liver (Hilmy *et al.*, 1987). On the other hand, the muscles showed considerable amounts of metals. This

may be correlated with fat-content in muscle tissues and its great affinity to combine with heavy metals (Shenouda *et al.*, 1992).

The highest water hardness and water alkalinity ((860 ± 9 mg/l as $CaCO_3$ and 425 ± 13 mg/l as $CaCO_3$ respectively) of the saline water (33 ± 0.6 g/l) collected from Qarun Lake could play a role in inhibiting the toxicity of the recorded heavy metals as previously reported by Miller and Mackay (1979), Pascoe *et al.*(1986) and Sorensen (1991). A possible explanation of the restoration of the biochemical parameters more or less to the normal levels as that collected from Ismailia canal (Abbassa region) is that fish in hard water take up less and/or excrete more of the metal than those in the less hard one, as previously reported by Miller and Mackay (1979) and Pascoe *et al.*(1986). The mechanisms which may be considered in attempting to explain the modifying effect of water hardness and alkalinity on heavy metals toxicity may be: a) decrease of gill membrane permeability and b) inactivation of absorbed metal by sequestration in granules or binding to protein (metallothionin).

In conclusion, based on the physico-chemical properties of water, and the quality of fish, effluents of waste municipal water , agricultural drainage water and industries affect greatly the quality of water. High concentrations of heavy metals implicate fish tissues affecting its quality and hence become a threat to man. So, treatment of these effluents should be carried out before their discharge to the natural water resources.

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Table (1): Physicochemical properties of water collected from different studied sites.

Sites	Dissolved oxygen (mg/l)	pH	Total Hardness mg/l as $CaCO_3$	Total alkalinity mg/l as $CaCO_3$	Salinity g/l	NH_3 mg/l	Fe mg/l p.l = 0.3ppm	Cu mg/l p.l = 1 ppm	Zn mg/l p.l = 5 ppm	Pb mg/l p.l = 0.05 ppm	Cd mg/l p.l = 0.01ppm
Ismalia Canal (Abbassa Region)	7.4 ±0.087 B	8.55 ±0.24 A	183 ± 9.4 F	164 ± 11.8 D	0.91 ±0.03 F	0.18 ± 0.01 E	0.93 ± 0.06 E	0.13 ± 0.05 D	0.33 ± 0.05 D	N D	N D
River Nile (Shubra El-Kheima, Cairo sector)	8.03 ± 0.27 A	7.7 ±0.09 C	141 ±2.3 G	120 ±4.4 E	0.05 ±0.0001 G	0.09 ±0.009 E	6.33 ±0.63 B	0.26 ±0.09 A	0.65 ±0.06 C	0.002 ±0.000 9 C	0.003 ±0.0001 C
Manzala Lake	4.23 ± 0.26 F	7.8 ±0.05 C	553 ±52 C	397 ±13 B	3.5 ±0.09 C	3.1 ±0.3 A	3.2 ±0.6 D	0.19 ±0.02 BC	1.37 ±0.11 A	0.11 ±0.04 B	N D
Edku Lake	7.03 ± 0.13 C	8.45 ±0.04 A	400 ±4.8 E	375 ±11.5 C	3.13 ±0.18 D	0.95 ±0.22 D	1.3 ±0.4 E	0.17 ±0.02 C	0.08 ±0.02 E	0.21 ±0.04 A	0.01 ±0.001 B
El-Burullus Lake	7.13 ± 0.13 C	8.6 ±0.06 A	463 ±13 D	400 ±8.7 B	2.0 ±0.09 E	0.83 ±0.23 D	3.3 ±0.17 D	0.11 ±0.02 D	0.04 ±0.01 E	N.D	N.D
Qarun Lake	6.8 ± 0.23 D	8.1 ± 0.09 B	860 ±9 B	425 ±13 A	33.0 ± 0.6 A	1.43 ± 0.44 C	5.53 ± 1.1 C	0.23 ± 0.04 A/B	1.16 ± 0.23 B	N D	0.0097 ± 0.0005 B
Maryut Lake	5.9 ± 0.35 E	8.2 ±0.35 D	958 ± 11 A	415 ± 11.5 A	9.4 ± 0.5 B	2.2 ± 0.3 B	11.9 ± 1.7 A	0.24 ± 0.03 A	0.33 ± 0.01 D	N.D	0.018 ± 0.003 A
F-value	271**	48**	1986**	1258**	12170**	161**	181**	13**	99**	119**	242**

Data are represented as means of nine samples ± S.D. p. L= permissible levels N D = Not detectable

Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).

** Highly Significant difference (P<0.01).

Table (2): Heavy metal concentrations in sediment samples (ppm) collected from different studied sites.

Sites	Iron	Copper	Zinc	Lead	Cadmium
Ismalia Canal (Abbassa Region)	6748 ± 1344 A	3.37 ± 0.72 C/D	16.47 ± 3.2 C	1.22 0.47 C	0.01 ± 0.0004 C
River Nile (Shubra El-Khiema, Cairo sector)	3351 ± 415 C	6.5 ± 0.75 B	9.59 ± 1.19 D	8.15 1.16 B	0.018 ± 0.01 B
Manzala Lake	5358 ± 1073 B	14.7 ± 0.93 A	67.8 15 A	12.77 2.3 B	0.012 0.008 B/C
Edku Lake	711 ± 119 E	0.88 0.2 E	4.97 1.69 D/E	59.44 14.8 A	0.046 0.01 A
El-Burullus Lake	6114 ± 1335 A/B	3.93 1.1 C	23.9 3.8 B	2.66 0.81 C	0.012 0.001 B/C
Qarun Lake	1378 ± 219 D/E	1.23 0.24 D/E	2.89 1.23 E	0.067 0.058 C	0.047 0.009 A
Maryut Lake	1640 ± 471 D	1.13 ± 0.11 D/E	1.37 ± 0.22 E	0.56 0.09 C	0.051 ± 0.003 A
F-value	74**	40**	132**	127**	53**

Data are represented as means of nine samples ± S.D.
Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).
** Highly Significant difference (P<0.01).

Table (3): Condition factor (k), hepatosomatic index and liver water content of the Nile tilapia, *Oreochromis niloticus*, collected from different studied sites.

Sites	Condition factor (k)	Hepatosomatic index	Liver water content (%)
Ismalia Canal (Abbassa Region)	2.3 ± 0.21 A	2.32 ± 0.06 A	72.8 ± 1.3 G
River Nile (Shubra El-Khiema, Cairo sector)	1.64 ± 0.03 C	1.2 ± 0.15 C	75.9 ± 0.41 E
Manzala Lake	1.41 ± 0.07 F	0.89 ± 0.17 F	76.6 ± 1.07 D
Edku Lake	1.5 0.12 E	0.77 ± 0.12 F	84.4 ± 1.5 A
El-Burullus Lake	1.57 0.07 D	0.83 ± 0.03 E	79.5 ± 1.44 B
Qarun Lake	1.9 0.08 B	1.8 ± 0.08 B	75.1 ± 0.36 F
Maryut Lake	1.55 0.07 D/E	1.05 ± 0.12 D	78.6 ± 1.7 C
F-value	241**	767**	284**

Data are represented as means of thirty samples ± S.D.
Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).
** Highly significant difference ($P < 0.01$).

Table (4): Serum constituents of the Nile tilapia; *Oreochromis niloticus*, collected from different studied sites.

Sites	Glucose (mg/100 ml)	Total protein (g/100 ml)	Total lipids (g/l)	AST (u/l)	ALT (u/l)	Alkaline phosphatase (U/l)	Creatinine (mg/100 ml)	Uric acid (mg/100 ml)
Ismaila Canal (Abbassa Region)	56.2 ±2.1 E	5.4 ±0.4 D	5.37 ±0.18 B	14.13 ±1.2 D	4.9 ±0.17 E	27.7 ±1.95 D	2.2 ±0.31 C	18.4 0.69 D
River Nile (Shubra El-Khiema, Cairo sector)	110 ±10 C	7.7 ±0.69 B	3.9 ±0.13 C	26.0 ±2.5 B	11.4 ±0.56 C	43.4 ±4.7 A/B	6.6 ±0.57 A	34.3 0.49 A
Manzala Lake	161 ±6.6 A	8.6 ±0.69 A	3.47 ±0.22 D/E	29.6 ±2.8 A	13.5 ±0.9 A	45.8 ±4.7 A	6.6 ±0.83 A	35.6 3.4 A
Edku Lake	142 ±11 B	6.87 ±0.3 C	3.3 ±0.35 E	22.6 ±1.4 C	10.47 ±0.56 D	37.67 ±0.95 C	6.1 ±0.2 A	30.9 1.5 B
El-Burullus Lake	162 ±9 A	7.2 ±0.6 C	3.63 ±0.56 D	23.8 ±2.93 C	13.3 ±0.69 A	41.37 ±3.6 B	6.67 ±0.5 A	30.9 1.1 B
Qarun Lake	67 ±2.95 D	5.87 ±0.22 D	6.2 ±0.26 A	16.1 ±1.2 D	5.13 ±0.18 E	29.5 ±2.6 D	3.2 ±0.26 B	23.7 1.1 C
Maryut Lake	102 ±14 C	6.9 ±0.35 C	4.2 ±0.26 C	26.4 ±2.99 B	12.47 ±0.65 B	44.13 ±3.7 A/B	6.3 ±0.76 A	30.8 1.6 B
F-value	210**	41**	111**	54**	357**	39**	107**	108**

Data are represented as means of nine samples ± S.D.
Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).
** Highly Significant difference (P<0.01).

Table (5): Muscle quality of the Nile tilapia; *Oreochromis niloticus* collected from different studied sites.

Sites	Water contents (%)	Total protein (% of wet weight)	Total lipids (% of wet weight)	ASh (%)
Ismalia Canal (Abbassa Region)	75.8 ±0.97 E	17.7 ±0.69 A	4.2 ±0.26 A	2.13 ±0.14 C
River Nile (Shubra El-Khiema, Cairo sector)	81.2 ±0.3 B	14.8 ±0.49 D	2.76 ±0.27 C/D	2.67 ±0.13 B
Manzala Lake	82.5 ±0.8 A	13.3 ±0.28 E	2.6 ±0.23 D	2.63 ±0.26 B
Edku Lake	82.1 ±1.11 A	13.3 ±0.51 E	2.7 ±0.17 C/D	3.0 ±0.17 A
El-Burullus Lake	82.5 ±0.52 A	13.37 ±0.64 E	2.83 ±0.22 C	2.93 ±0.13 A
Qarun Lake	77.5 ±0.65 D	16.8 ±0.23 B	3.5 ±0.13 B	2.33 ±0.13 C
Maryut Lake	79.8 ±0.91 C	15.7 ±0.22 C	2.9 ±0.17 C	2.67 ±0.51 B
F-values	181**	132**	69**	14**

Data are represented as means of nine samples ± S.E.
Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).
** Highly Significant difference ($P<0.01$).

Table (6): Iron concentrations in some selected organs (ppm) of the Nile tilapia; *Oreochromis niloticus*, collected from different studied sites.

Sites	Gills	Liver	Kidney	End of alimentary canal	Muscles p.l = 30 ppm
Ismalia Canal (Abbassa Region)	40.2 ±3.8 E	83.7 ±12.8 F	113.3 ±9.5 D	24.0 ±2.6 D	12.1 ±2.2 D
River Nile (Shubra El-Khiema, Cairo sector)	388 ±24 C	450 ±52 D	236 ±44 B/C	84 ±9 C	21.3 ±4.8 C
Manzala Lake	558 ±93 B	680 ±86 C	243 ±41 B/C	95 ±13.4 C	34.3 ±4.4 B
Edku Lake	220 ±34 D	305 ±35 E	214 ±14 C	87 ±7.9 C	22.3 ±3.9 C
El-Burullus Lake	194 ±11 D	830 ±75 B	247 ±32 B	165 ±27 B	30.3 ±5.3 B
Qarun Lake	195 ±13.4 D	807 ±114 B	476 ±43 A	148 ±28.6 B	15.7 ±3.6 D
Maryut Lake	647 ±79 A	1017 ±30 A	490 ±15 A	183 ±24 A	45 ±6.9 A
F-value	179**	220**	178**	79**	55**

Data are represented as means of nine samples ± S.D. p. l.= permissible level

Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).

** Highly Significant difference (P<0.01).

Table (7): Copper concentrations in some selected organs (ppm) of the Nile tilapia; *Oreochromis niloticus*, collected from different studied sites.

Sites	Gills	Liver	Kidney	End of alimentary canal	Muscles p.l = 20 ppm
Ismalia Canal (Abbassa Region)	0.39 ±0.06 E	2.87 ±0.3 E	2.33 ±0.51 E	3.33 ±0.61 F	0.17 ±0.02 F
River Nile (Shubra El-Khiema, Cairo sector)	1.38 ±0.1 C	13.5 ±1.9 C	9.6 ±0.7 C	11.27 ±1.18 C	1.1 ±0.09 D
Manzala Lake	1.9 ±0.23 B	38.1 ±3.8 B	14.7 ±1.04 A	16.57 ±1.13 A	1.42 ±0.1 C
Edku Lake	1.83 ±0.14 B	41.9 ±1.97 A	12.43 ±0.52 B	15.2 ±0.74 B	1.7 ±0.09 B
El-Burullus Lake	2.13 ±0.14 A	44.8 ±7.1 A	12.3 ±0.6 B	15.1 ±1.47 B	2.18 ±0.19 A
Qarun Lake	0.48 ±0.1 E	2.96 ±0.38 E	2.34 ±0.86 E	7.4 ±0.65 E	0.22 ±0.04 F
Maryut Lake	0.95 ±0.11 D	8.6 ±0.91 D	7.0 ±1.52 D	10.0 ±1.84 D	0.63 ±0.05 E
F-value	240**	306**	281**	151**	557**

Data are represented as means of nine samples ± S.D. p. l.= permissible level

Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).

** Highly Significant difference (P<0.01).

Table (8): Zinc concentrations in some selected organs (ppm) of the Nile tilapia; *Oreochromis niloticus*,collected from different studied sites.

Sites	Gills	Liver	Kidney	End of alimentary canal	Muscles p.l = 50 ppm
Ismalia Canal (Abbassa Region)	51.7 ±3.9 C	56.3 ±5.6 E	27.9 ±5.9 D	20.8 1.6 E	11.5 ± 1.8 **E**
River Nile (Shubra El-Khiema, Cairo sector)	87 ±10.5 B	107 ±9.98	60.8 ±9.0 C	55.3 ±7.9 C	34.0 ±6.9 B
Manzala Lake	182 ±30 A	214 ±49 A	139 ±21 A	109 ±6.5 A	43.7 ±4.4 A
Edku Lake	93.3 ±15.5 B	133 ±7.1 C	55.3 ±9.7 C	53.7 ±8.1 C	27.7 ±3.6 C
El-Burullus Lake	9.5 ±21 B	162 ±21 B	121 ±13.9 B	80.7 ±13.5 B	41.3 ±5.2 A
Qarun Lake	100 ±25.5 B	124.3 ±6.4 CD	55.0 ±6.9 C	43.3 ±4.4 D	20.7 ±3.04 D
Maryut Lake	106 ±25 B	130.7 ±14.6 C	66.7 ± 9.3 C	46.0 ±4.8 D	34.0 ± 5.7 **B**
F-value	33**	45**	102**	129**	54**

Data are represented as means of nine samples ± S.D. p. l.= permissible level

Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).

** Highly Significant difference (P<0.01).

Table (9): Lead concentrations in some selected organs (ppm) of the Nile tilapia; *Oreochromis niloticus*,collected from different studied sites.

Sites	Gills	Liver	Kidney	End of alimentary canal	Muscles p.l = 0.6 ppm
Ismalia Canal (Abbassa Region)	0.95 ±0.11 D	1.42 ±0.05 D	0.76 ±0.03 F	1.41 ±0.03 D	0.19 ±0.03 D
River Nile (Shubra El-Khiema, Cairo sector)	2.96 ±0.23 C	4.59 ±0.12 C	2.36 0.25± D/E	4.33 ±0.39 C	1.22 0.2± C
Manzala Lake	7.03 ±1.2 A	18.0 ±1.3 A	26.1 ±3.4 A	31.8 ±3.49 A	3.2 ±0.48 A
Edku Lake	6.33 ±0.92 B	15.9 ±1.6 B	22.5 ±2.4 B	29.33 ±2.2 B	1.57 ±0.26 B
El-Burullus Lake	2.77 ±0.53 C	2.9 ±0.17 D	4.6 ±0.31 C	5.7 ±0.31 C	0.22 ±0.04 B
Qarun Lake	1.93 ±0.18 B	1.53 ±0.05 D	1.2 ±0.26 E/F	1.9 ±0.17 D	0.33 ±0.05 D
Maryut Lake	1.25 ±0.24 D	2.1 ±0.38 D	3.03 ±0.18 D	4.5 ±0.52 C	1.12 ±0.14 C
F-value	**152****	**740****	**417****	**635****	**194****

Data are represented as means of nine samples ± S.D.
p. l.= permissible level
Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).
** Highly Significant difference (P<0.01).

Table (10): Cadmium concentrations in some selected organs (ppm) of the Nile tilapia; *Oreochromis niloticus*, collected from different studied sites.

Sites	Gills	Liver	Kidney	End of allmentar y canal	Muscles p.l = 0.5 ppm
Ismalia Canal (Abbassa Region)	0.006 ±0.001 C	0.18 ±0.02 D	0.2 ±0.01 F	0.04 ±0.01 F	0.002 ±0.005 D
River Nile (Shubra El-Khiema, Cairo sector)	0.685 ±0.045 B	0.52 ±0.1 C	1.92 ±0.36 C	0.058 ±0.024 F	0.04 ±0.009 D
Manzala Lake	0.294 ±0.05 A	0.64 ±0.09 C	1.33 ±0.27 D	0.86 ±0.07 B	0.35 ±0.1 B
Edku Lake	0.086 ±0.06 B	0.995 ±0.07 B	2.38 ±0.37 B	0.44 ±0.13 C	0.11 ±0.04 C
El-Burullus Lake	0.05 ±0.01 B/C	0.58 ±0.07 C	0.83 ±0.1 E	0.22 ±0.02 D	0.03 ±0.0002 D
Qarun Lake	0.043 ±0.003 B/C	0.496 ±0.13 C	0.62 ±0.08 E	0.131 ±0.01 E	0.007 ±0.001 B
Maryut Lake	0.3 ±0.05 A	2.47 ±0.68 A	6.3 ±0.95 A	1.71 ±0.08 A	0.53 ±0.12 A
F-value	74**	71**	213**	694**	69**

Data are represented as means of nine samples ± S.D. p.
l.= permissible level
Means with the same letter for each parameter are not significantly different, otherwise they do (Duncan's multiple range test, 1955).
** Highly Significant difference (P<0.01).