Studies on some heavy metals in the River Nile water and fish at Helwan area, Egypt

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ABSTRACT

A survy study was carried out in the River Nile at Helwan area to evaluate water parameters and fish quality from three locations during four seasons. Values of water criteria in the tested area were suitable for rearing Nile tilapia fish. All variables (sampling location and season) and their interaction, significantly (P≤0.05) affected the heavy metal levels in the River Nile water. Water Zn level ranged between 0.021 and 0.056, Cu 0.002-0.049, Pb 0.117-0.176, Cd 0.000-0.000, and Fe 0.038-1.432. Zn, Cu, and Pb were significantly (P≤0.05) higher at location No. 2 than the other locations, whereas Fe was significantly (P≤0.05) higher at location No. 1. This may be attributed to the pollution source, Torah Cement Factory at location No. 1 and Starch and Glucose Factory at location No. 2. Summer season reflected the highest (P≤0.05) levels of Zn, Pb, and Fe, whereas Cu level was significantly (P≤0.05) higher in spring. Generally, Cd was absent at all locations and seasons of water sampling. There were no significant (P≥0.05) differences in chemical composition of Nile tilapia fish due to sampling locations; yet, there were significant (P≤0.05) differences in CP, EE, and ash contents due to sampling seasons. In fish muscles, the levels of Pb, Cd, and F were significantly (P≤0.05) affected by sampling locations, whereas Zn, Cd, Fe, and F significantly (P≤0.05) affected by sampling seasons. In the whole fish body, the levels of Zn, Cu, Pb, Fe, and F were significantly (P≤0.05) affected by sampling locations and seasons. Fish muscles bioacumulated higher Pb than Cu, Fe, and Zn, respectively. The Fe accumulation was highest in the whole fish body followed by Zn, Cu and Pb, respectively. It was clear that each of Zn, Cu, and Fe were more bioaccumulated in the whole fish body than in the fish muscles. This may depend on the target organ for each element where it deposits. There were significantly positive correlations between Pb/Cu and Pb/Cd in fish muscles, whole fish Zn/muscular Fe, Cd/Cu, Cu/Fe as well as Cd/Pb in whole fish, whole fish Fe/muscular Fe, water Zn/muscular Cd, water Cu/muscular Cu, Cu/Zn in water, water Fe/muscular Fe, water Fe/whole fish Cu, water Fe/whole fish Fe, and Fe/Pb in water. Also, there were significantly negative correlations between water Cu/whole fish Pb and water Fe/muscular Cu. So, residues of some heavy metals in fish are affected by the presence of some industries nearby the River Nile that may negatively affect human health of the fish consumer from such contaminated water. Therefore, it is a must to manage such factories to be environmentally consonant by treating its wastes before exposure to the environment.

Keywords: Helwan, River Nile, Nile tilapia, Water, Heavy metals.

ITRODUCTION

Fish react to stress in different ways, depending on the severity and length of exposure to the stressor. Fish may die almost immediately from shock if the stressor is sufficiently severe or, at the other extreme they may adapt to a mild or slow developing stressor and suffer no long-term effects. Fish may also respond to a stressor by altering their physiology to the point that natural resistance and immunity to disease is reduced and they become more susceptible to infectious diseases (Wedemeyer, 1997). In ectothermic or poikilothermic animals like fish, environmental changes can have significant effects on the immune system. Seasonal and diurnal changes in immune response and disease prevalence have been reported in wild fish; these factors being changes in temperature and light density (Bowden 2008). Transition of metal elements depends on the distribution of these elements between the dissolved form and molecular shape, as well as on other environmental conditions. Minerals in water bodies are controlled by the physical and chemical equilibrium. The hydro-biogeochemical cycle amend the forms and the presence of these items (Fang *et al*., 2002). Therefore, the aim of the present study was to survey the water status in Helwan area (as a polluted area) comparing with a control one (far from industrial factories) from the view point of physico-chemical properties as well as five heavy metals (lead, Pb; cadmium, Cd; cupper, Cu; zinc, Zn and iron, Fe), besides the levels of these five heavy metals (plus flourine, F) in the most commercial and consumed fish species in Egypt (Nile tilapia, *Oreochromis niloticus*).

MATERIALS AND METHODS

This study was carried out throughout the four seasons of year 2012 at three stations of the industrial drainage contaminated locations in the River Nile at a part of Great Cairo (Cairo/Giza governorates).

Locations of the collected samples:

Three locations were determined for samples collection; namely location No. 1 is Torah Cement Factory area at Helwan, location No. 2 is Starch and Glucose Factory area, and location No. 3 is Zamalek and Empapa areas. The distance between locations No. 1 and 2 was ca. 1 km, whereas between these and the 3rd one (Zamalek and Empapa areas, as a control area free from the industrial activities and wastes) was ca. 20 Km.

Collected samples:

Water and fish (Nile tilapia, *Oreochromis niloticus*) samples were collected from the previously mentioned locations during the 1st season (winter, 16-18 February 2012 from locations No. 1, 2, and 3, respectively), 2nd season (spring, 4-6 May for the three locations, respectively), 3rd season (summer, 31/7, 3/8, and 2/8, from the three locations, respectively), and 4th season (autumn, 14, 15, and 18/10/2012, from the three locations, respectively). Fish samples (each of 20 fish, 10 for muscles analysis and the other 10 for the whole body analysis, each 10 fish were considered as a collective sample to be analyzed in triplicates) were caught by fisherman's net, and water samples were collected in 2- liter clean bottles from a 2-meter depth of the River Nile using a 2-meter wooden raw fitted to 2 bottles to be complete filled with water (without any air bubbles) from this depth.

Samples preservation:

After catching the fish samples, fish were kept in plastic bags, tied well, transported directly to the laboratory and kept frozen in a deep freezer at-20˚C. Whereas water samples in the collecting bottles were kept directly in a refrigerator at + 4 ˚C.

Tested parameters:

Fish weight and total length were recorded individually for the nearest one gram and centimeter, respectively according to Abdelhamid (1996) for all fish. Two water samples collected from each location and season were analyzed physico-chemically besides the analyses for the heavy metals (Pb, Cd, Zn, Cu, and Fe). About 20 fish were caught from each location and season, weight and total length for each fish were recorded, and then fish were sub-divided into 2 parts, one for filleting for the flesh (muscles) analysis (proximate analysis for dry matter, crude protein, ether extract, and ash) and heavy metals (Pb, Cd, Zn, Cu, Fe, and F), and the other was analyzed as a whole (fish carcass) for the muscles. All tested parameters were carried out at the Regional Center for Food and Feed, Agricultural Research Center. Chemical analysis of fish samples from different sampling locations and seasons was carried out according to AOAC (1995).

Analyses of physico-chemical parameters of water were carried out according to Abdelhamid (1996) including color, odor, specific gravity, pH (Orion 710A, U.S.A), conductance, salinity (Thermo Electron Corporation, U.S.A), turbidity (Turbidimeter, Orbco Hellinge, U.S.A), hardness, carbonate (CO_3), bicarbonate (HCO_3), dissolved oxygen (DO), sulphate (SO4) (T80 UV/VIS Spectpometercc, PG Instruments Ltd), total solids (T.S), total dissolved solids (T.D.S), and total suspended solids (T.S.S) (Oven, Heraeus Instruments, German). The analyses of heavy metals (Pb, Cd, Zn, Cu, Fe, and F) in water (without digestion, and no F) and fish samples (after digestion) were carried out according to AOAC (2006), using Atomic Absorption spectrometer (ZEE nit 700P, Analytic Jena, Germany) with lamps' wave lengths 283.3 for Pb, 228.8 for Cd, 213.9 for Zn, 324.8 for Cu, and 248.3 for Fe, equipped with MHS-10 hydride generation system. Fe, Cu, Cd, Pb and Zn irons were analyzed using a gas mixture of C_2H_2 / air (flow rate of 50 nl / h for Cd, Cu, and Zn and 65 nl / h for Pb and Fe) flame atomic absorption spectrophotometer (and spectrophotometrically for the flourine in fish samples, using ATi Orion 940). The burner height was 8 cm, fuel flow 30, oxidant flow 60, and slide width 0.7 nm. Blank samples from the used chemicals as well as specked samples (internal standards) were undertaken to correct the obtained data.

Statistical Analysis:

Using S.A.S. (2001) and Duncan (1955), numerical data collected were statistically analyzed for analysis of variance and least significant difference as well as Pearson correlation.

RESULTS AND DISCUSSION

Water analyses:

Physical parameters:

Table 1 presents some physical parameters measured in the River Nile water from the three tested locationd throughout the four seasons. All tested samples were colorless and odorless. The specific gravity ranged between 0.9622 (at location No. 1 in spring and location No. 3 in summer) and 1.0025 (at location No. 1 in summer) g/ml at 30 **°C**. The pH values were in the range 6.8-8.8 at the 1st location during spring and autumn, respectively. Conductivity (m hos/cm) was lowest (17) at location No. 2 during spring and highest (332) at location No. 3 during winter. Salinity ranged between 0.01 and 10.0 ‰ at location No. 3 during autumn and location No. 2 during winter, respectively.

Table 1: Overall mean of some physical parameters of the River Nile water as affected by different sampling locations and seasons.

Seasons	Locations No.		
	1	2	3
Color			
Winter	Colorless	Colorless	Colorless
Spring	Colorless	Colorless	Colorless
Summer	Colorless	Colorless	Colorless
Autumn	Colorless	Colorless	Colorless
Odor			
Winter	Odorless	Odorless	Odorless
Spring	Odorless	Odorless	Odorless
Summer	Odorless	Odorless	Odorless
Autumn	Odorless	Odorless	Odorless
Specific gravity, g/ml at 30 °C			
Winter	0.9930	0.9990	0.9782
Spring	0.9622	0.9991	0.9982
Summer	1.0025	0.9948	0.9622
Autumn	0.9762	0.9948	0.9966
pH			
Winter	7.6	7.3	7.3
Spring	6.8	7.0	7.2
Summer	7.4	7.3	7.7
Autumn	8.0	7.3	7.5
Conductivity, m hos/cm			
Winter	297.2	294.1	332.0
Spring	254.4	17.06	273.6
Summer	225.0	224.9	223.0
Autumn	273.9	224.9	271.7
Salinity, ‰			
Winter	0.1	0.1	0.2
Spring	0.1	10	0.1
Summer	0.1	0.1	0.1
Autumn	0.1	0.1	0.01
Turbidity, NTU			
Winter	0.4	0.4	0.1
Spring	0.5	0.1	0.6
Summer	0.7	0.4	0.5
Autumn	0.5	0.4	0.3

Turbidity (NTU) was lowest (0.1) at location No. 2 in spring and location No. 3 in winter, but the highest (0.7) was at location No. 1 in summer. These variable results are due to location and season, particularly at the industrial locations No. 1 and 2 in summer (for the presence of pollutants from Helwan Torah Cement Factory and Starch and Glucose Factory, comparing with the non industrial location No. 3 as a control area). However, water color is depending on water depth and its planktonic content and salinity, and the color of the surrounding subjects. Water specific gravity is depending on salinity and depth of water (positively) and water temperature (negatively). Water conductivity and salinity are depending on the salts concentration in the water. Turbidity is depending on water content of plankton, floods, rains, fish habits and activity (Abdelhamid, 1994 and 2009a).

Chemical parameters:

Table 2 shows the mean values (mg/l) of some chemical parameters measured in the River Nile water throughout the four seasons from different locations. These values ranged between 128-3954 for hardness, 0-210 alkalinity, 2.7-9.4 nitrate, 0-9 carbonate, 68-265 bicarbonate, 4.34-7.14 dissolved oxygen, 1.28-902 sulphate, 133-18520 total solids, 52-15404 total dissolved solids, and 4-3116 for total suspended solids. However, hardness is a measurement of calcium and magnesium ions;

whereas, alkalinity is a measurement of carbonate and bicarbonate or the buffering capacity. Dissolved oxygen is depending on the highest from sea surface; water temperature, salinity, and depth; respiration of all organisms and time of day and night. The pH is depending on the presence of plants consuming of CO_2, presence of nitrogen pollution sources and sedimentation acidity (Abdelhamid, 1994 and 2009a). These ranges of water criteria are suitable for rearing Nile tilapia fish according to Abdelhamid (1994, 1996, 2009a & b) and Abdelhakeem *et al*. (2002).

Table 2: Overall mean (mg/l) of some chemical parameters of the River Nile water as affected by different sampling locations and seasons.

Treat.	**Hard.**	**Alka.**	**NO_3**	**CO_3**	**HCO_3**	**DO**	**SO_4**	**T.S**	**T.D.S**	**T.S.S**
1xW	140	150	4.9	9	166	4.60	3.98	240	212	28
1xSp	128	210	4.5	0	265	4.93	91.2	260	240	20
1xSu	137	0	2.7	0	159	7.14	30.5	176	116	60
1xA	137	160	4.3	0	189	6.06	34.4	272	240	32
2xW	140	150	9.4	9	99	4.91	1.28	368	52	316
2xSp	3954	0	5.7	9	168	5.45	902	18520	15404	3116
2xSu	133	0	4.7	0	156	6.58	31.5	168	128	40
2xA	141	192	4.8	6	180	5.17	36.8	280	134	4
3xW	136	146	5.1	6	68	5.17	1.73	256	72	184
3xSp	136	146	3.3	6	68	5.17	27.0	256	184	72
3xSu	129	0	5.7	3	153	4.60	24.0	184	112	72
3xA	150	146	5.5	6	186	4.34	35.6	133	260	20

Heavy metals:

Table 3 illustrates the effect of season and location (as well as their interaction) of water sampling from the River Nile on the level (ppm or mg/l) of some heavy metals. All variables and their interaction, significantly ($P \leq 0.05$) affected these parameters. Water Zn level ranged between 0.021 and 0.056, Cu 0.002-0.049, Pb 0.117-0.176, Cd 0.000-0.000, and Fe 0.038-1.432. Zn, Cu, and Pb were significantly ($P \geq 0.05$) higher at location No. 2 than the other locations, whereas Fe was significantly ($P \geq 0.05$) higher at location No. 1. This may be attributed to the pollution source, Torah Cement Factory at location No. 1 and Starch and Glucose Factory at location No. 2. Summer season reflected the highest ($P \geq 0.05$) levels of Zn, Pb, and Fe, whereas Cu level was significantly ($P \geq 0.05$) higher in spring. Generally, Cd was absent at all locations and seasons of water sampling. From the interaction analysis, Zn was highest (0.090 ppm) at location No. 2 in summer, Cu (0.049 ppm) at location No. 1 in spring, Pb (0.178 ppm) at location No. 3 in spring, and Fe (1.432 ppm) at location No. 1 in summer. From the obtained data, all water samples from different locations and seasons contained higher levels than the refusable limit of Pb according to the following American Public Service limitations. The American Public Service limitations in the drinking water included the following parameters in mg/l (cited by Abdelhamid, 1996):

Measurement	Maximum tolerance limit	Refusable limit
Cd	-	1.0
Cu	1.0	-
Fe	0.3	-
Pb	-	0.05

Table 3: Overall mean (mg/l), standard error, and probability level of different heavy metals concentration of the River Nile water as affected by different sampling locations and seasons and their interaction.

Treat.	**Zn**	**Cu**	**Pb**	**Cd**	**Fe**
Location					
1	0.034[b]	0.019[b]	0.145[b]	0.000	0.564[a]
2	0.045[a]	0.022[a]	0.152[a]	0.000	0.231[b]
3	0.030[b]	0.008[c]	0.147[b]	0.000	0.246[b]
± SE	0.001	0.0006	0.001	0.000	0.133
P- value	0.0001	0.0001	0.015	0.000	0.0001
Season					
Winter	0.033[c]	0.016[c]	0.124[d]	0.000	0.127[d]
Spring	0.040[b]	0.024[a]	0.156[b]	0.000	0.405[b]
Summer	0.049[a]	0.020[b]	0.165[a]	0.000	0.649[a]
Autumn	0.023[d]	0.005[d]	0.146[c]	0.000	0.208[c]
± SE	0.002	0.0007	0.001	0.000	0.015
P- value	0.0001	0.0001	0.0001	0.000	0.0001
Location x **Season**					
1xW	0.029	0.014	0.129	0.000	0.218
1xSp	0.056	0.049	0.124	0.000	0.092
1xSu	0.030	0.011	0.176	0.000	1.432
1xA	0.021	0.002	0.151	0.000	0.514
2xW	0.038	0.022	0.127	0.000	0.101
2xSp	0.028	0.016	0.168	0.000	0.283
2xSu	0.090	0.041	0.164	0.000	0.470
2xA	0.024	0.010	0.149	0.000	0.071
3xW	0.030	0.011	0.117	0.000	0.061
3xSp	0.037	0.008	0.178	0.000	0.841
3xSu	0.027	0.007	0.154	0.000	0.044
3xA	0.024	0.004	0.137	0.000	0.038
± SE	0.003	0.001	0.003	0.000	0.026
P- value	0.0001	0.0001	0.0001	0.0001	0.0001

Also, according to the following items of low No. 48 year 1982, the alkalinity at 7 locations from the 12 locations was not suitable. All water samples contained higher NO_3 and Pb levels than these permissible levels. TSS was not suitable at location No. 2 in spring as well as Fe at location No. 1 in summer. The Egyptian water low No. 48/1982 for the freshwater surfaces included the following parameters in mg/l (cited by Abdelhamid, 1996):

Measurement	Load
Alkalinity	20-150
Cd	Not more than 0.01
Cu	Not more than 1.0
DO	Not less than 5
Fe	Not more than 1.0
NH_3	Not more than 0.5
NO_3	Not more than 45
Pb	Not more than 0.05
pH	7.0-8.5
SO_4	Not more than 200
TSS	500
Turbidity	50 NTU
Zn	Not more than 1.0

However, the suitable water conditions for fish breeding are 50-300 ppm hardness, 50-200 ppm alkalinity, not more than 0.05 ppm NO_3, not more than 0.4-1.2

ppm Cd, not more than 0.01 ppm Cu, not more than 1.0 ppm Fe, not more than 0.1 ppm Pb, not more than 0.01 ppm Zn, 5 ppm DO at least, and 4.5-10 pH (Abdelhamid, 1994 and 2009a) or 20 ppm at least alkalinity, 6.7-8.6 pH, less than 400 ppm TDS, less than 80 ppm TSS, less than 0.02 ppm NH_3, 0.0005-0.005 ppm Cd, 0.006-0.03 ppm Cu, not less than 5 ppm DO, less than 0.1 ppm Fe, less than 0.02 ppm Pb, less than 1.0 ppm NO_3, less than 1.0 ppm NO_2, less than 5‰ salinity, less than 50 ppm SO_4, and less than 0.005 ppm Zn (UDEPA, 1979-1980, cited by Abdelhakeem *et al*., 2002). Abdelhakeem *et al*. (2002) classified the fluorine as not critical element; whereas Cu, Cd, Pb and Zn as very toxic elements. So, they gave the following permissible levels in ppm for water:

Element	Tolerance limit in water
Cd	0.01
Cu	1.00
Fe	0.35
Pb	0.10
Zn	5.00

Generally, the laboratories of Egyptian Ministry of Health analyzed water samples from the River Nile during 2012 (from January till December) from great Cairo governorates including water inlets of Giza, Empapa, Roda, Ma'ady, Badrasheen, Gold Island; Starch and Glucose Factory, Tepen 1, Tepen 2 and Hawamdeia for heavy metals. They obtained the following ranges in ppm: 0.0002-0.0048 Cd, 0.001-0.180 Cu, 0.001-0.022 Pb, and 0.001-0.115 Zn. That means that the obtained results in the present study are in accordance with the above mentioned analyses of the Egyptian Ministry of Health concerning Cu and Zn, but disagree concerning Pb levels since the present study gave higher levels (0.117-0.176 ppm). However, Pb content was significantly higher in water in winter than in summer (Abdelhamid and El-Ayouty, 1989). Lead causes hemorrhages and congestion of the gastrointestinal tract and kidneys of fish (Abdelhamid and El-Ayouty, 1991). The no effect level of Cd, Pb and Fe in water for growing aquatic life are 0.03, 0.10 and 1.00 ppm, respectively (Yokokawa, 2000). Comparing these standards with the levels obtained herein, it would be indicated that there is water pollution with Pb in all tested locations and seasons.

Cd in water is negatively affect fish growth, feed and vitamin C utilization. Fe also is toxic for fish, since it damages fish gills and their function. Pb reduces hemoglobin content and red blood cells count of fish (Abdelhamid, 2003). However, any degree of poisoning will weaken the fish, making it vulnerable towards diseases. Heavy metals can create problems and be concentrated in waterway organisms up to 9100 times more than the surrounding environment's levels, so may lead to acute or chronic effects (WRC, 2005).

However, Hovanec (1998) mentioned that metals are involved in many aspects of fish keeping and aquarium water metals are acutely toxic while others are necessary for the life of the fish nitrifying bacteria. Still others are responsible for such basic water hardness. For a metal to be toxic, it almost always has ionized or free form. Water hardness can have a drastic effect on metal toxicity. Since the toxicity and biological activity of many metals and metalloids is profoundly influenced by their chemical form. The metabolism of ingested metals could significantly modify their toxicity. The micro-organisms in lakes, rivers and soil could biotransform metallic compounds (Rowland, 1981).

Moreover, Radwan (2000) reported average values of dissolved heavy metals (Cd, Fe and Pb) in Lake Burullos water as 1.93, 2.46 and 2.67 mg/l, respectively. He added that, levels of heavy metals are correlated with salinity changes due to the discharge of water. However, heavy metal contamination of water is one of the environmental stressors affecting significantly and negatively lysozyme activity of fish serum, intestinal scrapping and skin mucus as well as serum hemolytic activity, leukocytes count, packed cell volume, hemoglobin concentration, plasma protein and glucose concentrations (Abdelhamid *et al*., 2006a).

Also, Abdelhamid *et al* (2013) studied the effects of both collection seasons and collection stations of the fish rearing water as well as their interaction on some heavy metals (Pb, Cd, Cu, Zn and Fe). It reflects their significant (P≤0.0001) effects on these elements' contents in the water. The highest Pb and Cd values, being 1.0 and 1.4 ppm, respectively, Cu 0.160 ppm, Zn 3.200 ppm and Fe 0.300 ppm. Generally, these studied elements took the following descending order: Zn ≥ Cd ≥ Pb ≥ Fe ≥ Cu in water.

Fish analyses:

Fish growth:

Table 4 presents overall mean, standard error of means, and probability level of live body weight, total body length, and condition (K) factor of Nile tilapia fish as affected by different sampling locations and seasons and their interaction. All variables and their interaction significantly (P≤0.05) affected these parameters. Location No, 1 has the best fish weight and total length, but location No. 3 reflected the highest K-factor. Autumn samples gave the best fish weight and total length, but spring fish samples reflected the highest K-factor. However, from the interaction, it is clear that the best fish weight and total length was in location No. 1 in autumn, whereas the highest K-factor was calculated for fish from location No. 3 in spring.

Table 4: Overall mean, standard error, and probability level of live body weight, total body length, and condition (K) factor of Nile tilapia fish as affected by different sampling locations and seasons and their interaction.

Treat.	**Weight** (g)	**Length** (cm)	**K-factor**
Location			
1	92.170^{a}	18.013^{a}	1.549^{b}
2	70.164^{b}	16.251^{b}	1.603^{ab}
3	74.846^{b}	16.330^{b}	1.671^{a}
± SE	3.164	0.227	0.030
P- value	0.0001	0.0001	0.020
Season			
Winter	70.26^{c}	17.35^{b}	1.38^{c}
Spring	82.93^{b}	16.29^{c}	1.86^{a}
Summer	57.04^{d}	15.33^{d}	1.56^{b}
Autumn	105.98^{a}	18.47^{a}	1.61^{b}
± SE	3.654	0.263	0.0353
P- value	0.0001	0.0001	0.0001
Location x **Season**			
1xW	72.925	18.810	1.137
1xSp	102.123	17.640	1.852
1xSu	61.610	15.750	1.556
1xA	132.020	19.850	1.650
2xW	70.832	17.050	1.457
2xSp	67.763	15.330	1.821
2xSu	61.050	15.575	1.597
2xA	81.010	17.050	1.538
3xW	67.052	16.190	1.574
3xSp	78.931	15.920	1.910
3xSu	48.470	14.680	1.530
3xA	104.930	18.530	1.670
± SE	6.328	0.455	0.0611
P- value	0.0011	0.026	0.0013

Composition of Fish:

Muscular composition:

Table 5 presents chemical composition of tilapia muscles collected from the tested fish as affected by sampling locations and seasons as well as their interaction. There were no significant (P≥0.05) differences in chemical composition due to sampling locations; yet, there were significant (P≤0.05) differences in CP, EE, and ash contents due to sampling seasons. Since winter samples reflected higher CP and EE percentages, whereas autumn and winter samples gave the highest ash percentages. From the interaction, it is clear that the best CP and EE percentages (87.9 and 4.93, respectively) were recorded for fish muscles from sampling location No. 2 in winter.

Table 5: Overall means, standard errors, and probability level of muscular composition of Nile tilapia fish as affected by different sampling locations and seasons and their interaction.

Treat.	**On dry matter basis (%)**				
	Moisture	**DM**	**CP**	**EE**	**Ash**
Location					
1	78.87	21.13	85.425	3.952	6.768
2	78.80	21.20	85.650	3.975	6.781
3	79.65	20.35	85.858	3.586	6.621
± SE	0.780	0.780	0.399	0.217	0.078
P- value	0.693	0.693	0.747	0.378	0.300
Season					
Winter	80.14	19.86	87.26a	4.523a	6.740ab
Spring	77.40	22.61	84.97b	3.572bc	6.549b
Summer	79.22	20.78	85.12b	2.993c	6.618b
Autumn	79.66	20.34	85.21b	4.261ab	6.987a
± SE	0.901	0.901	0.461	0.250	0.091
P- value	0.156	0.156	0.004	0.001	0.012
Location x **Season**					
1xW	78.76	21.24	86.933	4.557	6.644
1xSp	77.71	22.29	85.433	4.060	6.501
1xSu	80.09	19.92	84.633	3.527	6.905
1xA	78.92	21.09	84.700	3.663	7.022
2xW	78.72	21.28	87.900	4.930	6.895
2xSp	76.69	23.31	83.867	3.517	6.644
2xSu	80.72	19.28	85.600	3.170	6.627
2xA	79.06	20.94	85.233	4.283	6.959
3xW	82.95	17.05	86.967	4.083	6.680
3xSp	77.79	22.22	85.633	3.140	6.504
3xSu	76.87	23.14	85.133	2.283	6.322
3xA	81.00	19.00	85.700	4.837	6.980
± SE	1.561	1.561	0.798	0.434	0.157
P- value	0.182	0.182	0.578	0.165	0.410

Whole fish composition:

Table 6 shows the chemical composition of tilapia carcass as affected by sampling locations and seasons as well as their interaction. There were no significant (P≥0.05) differences in chemical composition due to sampling locations; yet, there were significant (P≤0.05) differences in CP and EE due to sampling seasons. Since spring samples reflected higher CP (61.10) and winter samples gave the highest EE (24.94) percentages. From the interaction, it is clear that the best CP (61.433%) was in location No. 2 in spring which presented the lowest EE (16.073%). Actually, sometimes there were positive relationships between DM on one side and each of CP, EE, and ash percentages on the other side. Also, there were negative relationships between CP on one hand and either EE or ash percentages on the other hand. These relationships were reported too by many authors (El-Ebiary and Zaki, 2003 and Abdelhamid *et al.,* 2005a & b and 2006b).

The facts of the negative relationship between CP and EE from one side and between dry matter (DM) and CP on the other side were realized in this study. Also, there was a positive relationship between DM and EE contents. These relationships confirm those reported before that a negative relationship was noticed between CP and EE contents of fish body but a location relationship between CP and ash contents was recorded too (Abdelhamid *et al.*, 2000). But Abdelhamid *et al.* (2009) found a negative correlation between protein and fat contents of the fish.

Abdelhamid *et al.* (2006b) reported also significant effects of sampling locations and seasons on all proximate analysis of fish body. They found that Port Saied and Marsa Matroh fish reflected higher ($P\leq0.05$) protein than Alexandria and El-Bardawil fish. Yet, the fat and ash contents differed also but not in a clear trend. However, winter fish contained more protein and less fat percentages ($P\leq0.05$) than those of summer. They attributed the elevated protein content in winter to the lower ($P\leq0.05$) heavy metals content (Pb and Fe) in fish flesh during this season than in summer. However, some significant correlations were calculated among heavy metals (in water, sediments, and fish) and chemical comomposition of the fish.

Table 6: Overall means, standard errors, and probability level of whole body composition of Nile tilapia fish as affected by different sampling locations and seasons and their interaction.

Treat.	**On dry matter basis (%)**				
	Moisture	**DM**	**CP**	**EE**	**Ash**
Location					
1	70.86	29.14	56.992	20.291	5.937
2	70.24	29.76	56.858	20.876	5.842
3	71.06	28.94	56.375	20.851	5.958
± SE	1.020	1.021	0.636	0.704	0.117
P- value	0.837	0.837	0.773	0.803	0.761
Season					
Winter	70.74	29.26	56.81b	24.94a	6.144
Spring	71.20	28.80	61.10a	16.94c	5.913
Summer	70.00	30.00	56.67b	18.42c	5.857
Autumn	70.94	29.06	52.37c	22.38b	5.733
± SE	1.178	1.178	0.734	0.813	0.135
P- value	0.901	0.901	0.0001	0.0001	0.213
Location x **Season**					
1xW	72.72	27.28	58.833	24.750	6.050
1xSp	71.70	28.30	60.800	18.477	6.473
1xSu	70.33	29.67	56.100	17.090	5.493
1xA	68.70	31.31	52.233	20.847	5.730
2xW	67.95	32.05	57.567	26.840	6.183
2xSp	69.55	30.45	61.433	16.073	5.640
2xSu	69.72	30.28	55.567	20.977	6.057
2xA	73.73	26.27	52.867	19.613	5.487
3xW	71.56	28.44	54.033	23.240	6.200
3xSp	72.35	27.65	61.067	16.277	5.627
3xSu	69.94	30.06	58.367	17.203	6.020
3xA	70.40	29.60	52.033	26.683	5.983
± SE	2.041	2.042	1.272	1.408	0.235
P- value	0.344	0.344	0.163	0.006	0.0644

Fish heavy metals:

Fish muscles' heavy metals:

Table 7 contains data of heavy metals levels (ppm) in tilapia muscles as affected by sampling locations and seasons as well as their interaction. The levels of Pb, Cd, and F were significantly ($P\leq0.05$) affected by sampling locations, whereas Zn, Cd, Fe, and F significantly ($P\leq0.05$) affect ed by sampling seasons. From the interaction, it is clear that the highest values were reported for Zn (42.15) and Cu (4.64) in fish muscles from location No. 3 in winter, Pb (8.16) location No. 2 in autumn, Cd (1.21) in location No. 2 in summer, Fe (73.08) in location No. 1 in summer, and F (6.995) in location No. 2 in autumn.

Table 7: Overall means (ppm), standard errors, and probability level of different heavy metals concentration of Nile tilapia muscles as affected by different sampling locations and seasons and their interaction.

Treat.	Zn	Cu	Pb	Cd	Fe	F
Location						
1	24.65	3.33	0.00[b]	0.38[b]	36.39	1.287[b]
2	26.81	3.66	3.79[a]	0.72[a]	31.07	3.455[a]
3	28.89	3.43	1.83[ab]	0.53[ab]	30.27	1.876[b]
± SE	1.656	0.234	1.058	0.088	2.317	0.280
P- value	0.203	0.586	0.047	0.026	0.136	0.0001
Season						
Winter	30.17[a]	3.88	2.42	0.65[a]	23.24[c]	0.35[c]
Spring	24.26[b]	3.34	0.00	0.76[a]	34.79[b]	1.66[b]
Summer	31.00[a]	3.37	2.35	0.58[a]	51.60[a]	2.40[b]
Autumn	21.70[b]	3.31	2.72	0.18[b]	20.69[c]	4.41[a]
± SE	1.912	0.271	1.221	0.102	2.675	0.323
P- value	0.001	0.393	0.372	0.001	0.0001	0.0001
Location x **Season**						
1xW	26.45	3.46	0.00	0.41	23.18	0.390
1xSp	17.93	4.23	0.00	0.63	27.26	1.166
1xSu	35.99	2.36	0.00	0.46	73.08	1.107
1xA	18.22	3.26	0.00	0.01	22.03	2.485
2xW	21.90	3.55	0.00	0.45	20.67	0.132
2xSp	28.37	3.23	0.00	0.73	34.94	2.281
2xSu	27.64	4.33	6.98	1.21	49.72	4.411
2xA	29.33	3.55	8.16	0.51	18.96	6.995
3xW	42.15	4.64	7.25	1.10	25.87	0.529
3xSp	26.48	2.55	0.00	0.91	42.15	1.535
3xSu	29.37	3.42	0.07	0.09	32.01	1.684
3xA	17.55	3.12	0.00	0.03	21.06	3.755
±MSE	3.312	0.469	2.116	0.177	4.634	0.560
P- value	0.0001	0.010	0.010	0.0004	0.0001	0.0011

3- 2- Fish carcass' heavy metals:

Table 8 contains data of heavy metals levels (ppm) in tilapia carcass as affected by sampling locations and seasons as well as their interaction. The levels of Zn, Cu, Pb, Fe, and F were significantly ($P \leq 0.05$) affected by sampling locations, whereas Zn, Cu, Pb, Fe, and F significantly ($P \leq 0.05$) affected by sampling seasons. From the interaction, it is clear that the highest values were reported for Zn (97.63) in whole fishbody from location No. 3 in summer, Cu (10.84) and Fe (5710) from location No. 1 in summer, Pb (10.51) location No. 1 in autumn, and Cd (0.95) and F (172.6) in location No. 3 in autumn. However, the commission regulation setting maximum Pb level for muscles of fish, released from the European communities, as 0.2 mg/Kg wet weight. Yet, the Egyptians' standards are 0.1 ppm Pb and Cd in food fish (ES, 1993). Abdelhakeem *et al.* (2002) cited the tolerance limits of Pb, Fe and Cd in fish water as 0.10, 0.35 and 0.10 ppm, respectively and in fish body as 2, 30 and 0.5 ppm, respectively .

Bioaccumulation factor (BAF):

In fish muscles:

Table 9 presents the BAF in fish muscles which ranged from $1.20x10^4$ to $1.41x10^5$ for Zn, $8.63x10^3$ - $1.63x10^5$ Cu, $1.24x10^3$ - $2.49x10^5$ Pb, 0–0 Cd and $4.29x10^3$-$7.28x10^4$ Fe. Fish muscles bioacumulated higher Pb than Cu, Fe, and Zn, respectively.

Table 8: Overall means (ppm), standard errors, and probability level of different heavy metals concentration of Nile tilapia carcass (whole body) as affected by different sampling locations and seasons and their interaction.

Treat.	**Zn**	**Cu**	**Pb**	**Cd**	**Fe**	**F**
Location						
1	66.93^{b}	8.05^{a}	5.12^{b}	0.50	2492^{a}	45.003^{c}
2	79.31^{a}	6.93^{b}	4.57^{b}	0.45	1278^{b}	68.461^{b}
3	81.25^{a}	6.98^{b}	10.24^{a}	0.70	875^{c}	83.190^{a}
± SE	1.372	0.288	0.443	0.121	50.30	3.646
P- value	0.0001	0.011	0.0001	0.321	0.0001	0.0001
Season						
Winter	62.69^{c}	5.51^{d}	4.60^{b}	0.51	614^{c}	48.59^{b}
Spring	84.26^{b}	6.72^{c}	2.83^{c}	0.39	428^{d}	52.47^{b}
Summer	94.17^{a}	9.09^{a}	5.78^{b}	0.67	3310^{a}	45.95^{b}
Autumn	62.21^{c}	7.98^{b}	13.37^{a}	0.62	1841^{b}	115.19^{a}
± SE	1.584	0.333	0.512	0.140	58.09	4.210
P- value	0.0001	0.0001	0.0001	0.504	0.0001	0.0001
Location x **Season**						
1xW	57.73	5.97	3.51	0.36	324	51.93
1xSp	74.14	6.84	1.92	0.60	269	49.81
1xSu	91.14	10.84	4.55	0.62	5710	37.11
1xA	44.74	8.57	10.51	0.44	3666	41.16
2xW	58.98	4.92	5.47	0.42	305	44.99
2xSp	86.84	5.60	1.45	0.29	145	53.40
2xSu	93.74	8.69	6.39	0.60	3494	43.62
2xA	77.68	8.52	4.99	0.47	1170	131.83
3xW	71.37	5.64	4.81	0.76	1214	48.84
3xSp	91.80	7.71	5.11	0.28	870	54.20
3xSu	97.63	7.73	6.40	0.79	727	57.11
3xA	64.20	6.84	24.62	0.95	689	172.60
± SE	2.744	0.576	0.887	0.243	100.6	7.292
P- value	0.0001	0.007	0.0001	0.741	0.0001	0.0001

Table 9: Bioaccumulation factor (dividing the element level in fish muscles by the same element level in the water and multiplying by 100) of different heavy metals in Nile tilapia muscles as affected by different sampling locations and seasons and their interaction.

Location/season	**Zn**	**Cu**	**Pb**	**Cd**	**Fe**
1	$7.25x10^{4}$	$1.75x10^{4}$	0	0	$6.45x10^{3}$
2	$5.96x10^{4}$	$1.66x10^{4}$	$2.49x10^{5}$	0	$1.35x10^{4}$
3	$9.63x10^{4}$	$4.29x10^{4}$	$1.24x10^{3}$	0	$1.23x10^{4}$
Winter	$9.14x10^{4}$	$2.43x10^{4}$	$1.95x10^{3}$	0	$1.83x10^{4}$
Spring	$6.1x10^{4}$	$1.39x10^{4}$	0	0	$8.59x10^{3}$
Summer	$6.33x10^{4}$	$1.69x10^{4}$	$1.24x10^{3}$	0	$7.95x10^{3}$
Autumn	$9.43x10^{4}$	$6.62x10^{4}$	$1.86x10^{3}$	0	$9.95x10^{3}$
1xW	$9.12x10^{4}$	$2.47x10^{4}$	0	0	$1.1x10^{4}$
1xSP	$3.20x10^{4}$	$8.63x10^{3}$	0	0	$2.96x10^{4}$
1xSU	$1.20x10^{4}$	$2.15x10^{4}$	0	0	$5.1x10^{3}$
1xA	$8.68x10^{4}$	$1.63x10^{5}$	0	0	$4.29x10^{3}$
1xW	$5.76x10^{4}$	$1.61x10^{4}$	0	0	$2.04x10^{4}$
2xSP	$1.01x10^{5}$	$2.02x10^{4}$	0	0	$1.23x10^{4}$
2xSU	$3.07x10^{4}$	$1.06x10^{4}$	$4.26x10^{3}$	0	$1.10x10^{4}$
2xA	$1.22x10^{5}$	$3.55x10^{4}$	$5.48x10^{3}$	0	$2.67x10^{4}$
3xW	$1.41X10^{5}$	$4.22X10^{4}$	$6.19X10^{3}$	0	$2.24X10^{4}$
3xSP	$7.61X10^{4}$	$3.19X10^{4}$	0	0	$5.01X10^{3}$
3xSU	$1.1X10^{5}$	$4.88X10^{4}$	0	0	$7.28X10^{4}$
3xA	$7.31X10^{4}$	$7.80X10^{4}$	0	0	$5.54X10^{4}$

In whole fish carcass:

Table 10 presents the BAF of different heavy metals in the whole carcass of Nile tilapia fish tested in the present work. It ranged between 1.04 $x10^{5}$ - 3.62 $x10^{5}$ for Zn, 1.39 $x10^{4}$ - 1.59 $x10^{5}$ Cu, 1.55 $x10^{3}$ - 1.79 $x10^{4}$ Pb, 0 – 0 Cd, and 1.79 $x10^{4}$ - 8.85 $x10^{5}$ Fe. That means that Fe bioaccumulated at highest in the whole fish body followed by Zn, Cu and Pb, respectively. Comparing with the previous Table 9, it is clear that each of Zn, Cu, and Fe are more bioaccumulated in the whole fish body than in the fish muscles. This may depend on the target organ for each element where it deposits.

Table 10: Bioaccumulation factors (dividing the element level in whole fish by the same element level in the water and multiplying by 100) of different heavy metals in whole Nile tilapia carcass as affected by different sampling locations and seasons and their interaction.

Location/season	Zn	Cu	Pb	Cd	Fe
1	1.97×10^5	4.24×10^4	3.53×10^3	0	4.42×10^5
2	1.76×10^5	3.15×10^4	3.1×10^3	0	5.53×10^5
3	2.71×10^5	8.73×10^4	6.97×10^3	0	3.54×10^5
Winter	1.89×10^5	3.44×10^4	3.71×10^3	0	4.82×10^5
Spting	2.11×10^5	2.80×10^4	1.81×10^3	0	1.1×10^5
Summr	1.92×10^5	4.55×10^4	3.50×10^3	0	5.10×10^5
Autumn	2.70×10^5	1.59×10^5	9.16×10^3	0	8.85×10^5
1 x w	1.99×10^5	2.26×10^4	3.72×10^3	0	1.49×10^5
1xSp	1.32×10^5	1.39×10^4	1.55×10^3	0	2.92×10^5
1 x Au	3.03×10^5	9.85×10^4	2.59×10^3	0	3.99×10^5
1x A	2.13×10^5	4.29×10^4	6.96×10^3	0	7.13×10^5
2x w	1.55×10^5	2.24×10^4	4.31×10^3	0	3.01×10^5
2xSp	3.1×10^5	3.50×10^4	8.96×10^3	0	5.12×10^5
2x Au	1.04×10^5	2.12×10^4	3.89×10^3	0	7.43×10^5
2x A	3.24×10^5	8.52×10^4	3.35×10^3	0	1.64×10^5
3x w	2.38×10^5	5.13×10^4	4.11×10^3	0	1.99×10^5
3xSp	2.48×10^5	9.64×10^4	2.87×10^3	0	1.03×10^5
3x Au	3.62×10^5	1.10×10^5	4.16×10^3	0	1.65×10^5
3x A	2.68×10^5	1.71×10^5	1.79×10^4	0	1.81×10^5

Abdelhamid (1994 and 2009a) cited that heavy metals are harmful, so Cu, for example, leads to discoloration, degrowth, congestion of gills, liver, and lower digestive tract, and damaged kidneys and liver of fish. Yet, Abdelhakeem *et al*. (2002) classified the fluorine as not critical element; whereas Cu, Cd, Pb and Zn as very toxic elements. So, they gave the following permissible levels in ppm in fish:

Element	Tolerance limit in fresh fish
Cd	0.50
Cu	20.0
Fe	30.0
Pb	2.00
Zn	40.0

The concentration of some heavy metals (Fe, Zn, Cu, Pb, Cd and Co) in water and liver, gills, intestine, testis, heart and muscle of *O. niloticus* and *L. niloticus* obtained from four khors (El-Ramla, Kalabsha, Korosko and Toushka) of Lake Nasser, Egypt, during 2006 was investigated (using atomic absorption spectrophotometry) with emphasis on the histological alterations in these organs. Metal concentrations in the water of khors (mg/l) followed an abundance of: Fe > Zn > Pb > Cu > Cd > Co. The highest values of metals were reported in khor Toushka. It was found that the metals were accumulated in different tissues of both fish by various levels, where, the non-edible parts accumulated more metals than the edible muscles. Zn, Cu, Pb and Cd concentrations in the fish muscles were below the maximum permissible limit, however, Fe in the muscles exceeded the permissible limit. Several histopathological alterations, including vacuolar degeneration with focal areas of necrosis in liver, proliferation in the epithelium of gill filaments and fusion of secondary lamellae, severe degenerative and necrotic changes in the intestinal mucosa and seminiferous tubules, degeneration and atrophy in cardiac muscle fibers and degeneration in muscle bundles were observed in the studied tissues of both fish as a result of the accumulated metals (Mohamed, 2008).

The concentrations of heavy metals including 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 (Saeed and Shaker, 2008).

Concentrations of some heavy metals (Pb, Cd, Hg, Cu and Cr) were determined in water, sediment and tissues of tilapia fish collected from Wadi Hanifah during summer 2010. The concentrations of the heavy metal in water were within the international permissible level. Cu had the highest accumulating level in fish. The transfer factors of all metals in fish from water were greater than those from sediments. This led to the conclusion that fish bioaccumulation with these metals was from water. Heavy metals in the edible parts of tilapia were within the safety permissible level for human use (Abdel-Baki *et al*., 2011).

On Rosetta branch of River Nile in Egypt, there are some industrial cities e.g. Kafr El-Zyat city. To address questions of water quality and to suggest a low cost and available treatment process for some toxic metals (iron, manganese, zinc, copper, lead and cadmium), water samples from surface and bottom layers were collected at 3 stations and 3 drains. The results showed that the concentration of these metals are higher than the permissible levels due to the discharges of two industrial companies in this area (El-Malyia & Soda and Salt). The treated water can pass into River Nile safely and without any pollution for fish or sediment and the water quality remains good without any harmful risk throughout its usage (Daifullah *et al*., 2013).

Heavy metals in water, fish muscles, and whole fishbody:

Table 11 illustrates the correlation coefficients between heavy metal levels in the River Nile water, tilapia muscles, and tilapia whole body. There were significantly positive correlations between Pb/Cu and Pb/Cd in fish muscles, whole fish Zn/muscular Fe, Cd/Cu in whole fish, Cd/Pb in whole fish, whole fish Fe/muscular Fe, Cu/Fe in whole fish, water Zn/muscular Cd, water Cu/muscular Cu, Cu/Zn in water, water Fe/muscular Fe, water Fe/whole fish Cu, water Fe/whole fish Fe, and Fe/Pb in water. Also, there were significantly negative correlations between water Cu/whole fish Pb and water Fe/muscular Cu. However, Saeed and Mohammed (2012) correlated between physico-chemical parameters of water and levels of some heavy metals (Cd, Cu, Fe, Pb, and Zn) accumulated in water and fish tissues. They found no strong correlation between fish metals concentration and some water quality parameters. Yet, electric conductivity had a negative effect on accumulation of Cd and Pb in gills and liver tissues. The concentrations of Cu, Fe, and Zn in water and edible part of fish were found below the notified toxic limits.

Table 11: Pearson correlation between different heavy metals concentration in Nile tilapia muscles and carcass (whole body) as well as in water regardless of sampling locations and seasons.

		Muscles					**Fish**					**Water**			
		Zn	**Cu**	**Pb**	**Cd**	**Fe**	**Zn**	**Cu**	**Pb**	**Cd**	**Fe**	**Zn**	**Cu**	**Pb**	**Cd**
Muscles	**Cu**	-0.057													
		0.743													
	Pb	0.010	0.551												
		0.952	0.001												
	Cd	0.095	0.496	0.772											
		0.581	0.002	0.000											
	Fe	0.280	-0.139	-0.035	0.084										
		0.098	0.417	0.838	0.627										
Fish	**Zn**	0.250	-0.055	0.097	0.261	0.500									
		0.142	0.752	0.573	0.123	0.002									
	Cu	-0.027	-0.126	0.135	-0.080	0.559	0.312								
		0.876	0.463	0.432	0.643	0.000	0.064								
	Pb	-0.276	-0.032	-0.063	-0.322	-0.183	-0.321	0.016							
		0.103	0.852	0.717	0.056	0.285	0.057	0.927							
	Cd	-0.039	0.096	0.041	-0.183	0.042	-0.049	0.385	0.349						
		0.821	0.579	0.812	0.286	0.806	0.776	0.020	0.037						
	Fe	0.167	-0.184	0.030	-0.048	0.571	0.095	0.663	0.035	0.069					
		0.330	0.283	0.860	0.779	0.000	0.582	0.000	0.838	0.690					
Water	**Zn**	-0.022	0.250	0.180	0.416	0.232	0.329	0.092	-0.201	0.002	0.104				
		0.898	0.141	0.295	0.012	0.174	0.050	0.594	0.240	0.989	0.547				
	Cu	-0.141	0.350	0.081	0.319	0.100	0.197	-0.077	-0.365	-0.023	-0.119	0.797			
		0.414	0.036	0.641	0.058	0.562	0.249	0.654	0.029	0.895	0.488	0.000			
	Pb	0.061	-0.347	-0.075	0.067	0.568	0.608	0.511	-0.092	-0.143	0.468	0.118	-0.200		
		0.722	0.038	0.664	0.696	0.000	0.000	0.001	0.592	0.404	0.004	0.494	0.243		
	Cd	x	x	x	x	x	x	x	x	x	x	x	x	x	
		x	x	x	x	x	x	x	x	x	x	x	x	x	
	Fe	0.179	-0.344	-0.126	0.098	0.684	0.306	0.527	-0.158	-0.104	0.768	0.057	-0.136	0.702	x
		0.295	0.040	0.465	0.569	0.000	0.069	0.001	0.357	0.546	0.000	0.739	0.428	0.000	x

Cell Contents: Pearson correlation
P-Value
X: All values in column are identical.

Zyadah (1997) reported significant effects on water mineral contents (containing Cd and Pb) due to different locations and seasons. Also, he found high levels of heavy metals in the sediment and fish, exceeded the permissible limit. Yet, Aboul-Naga (2000) reported high trace metal concentrations in front of El-Tabia Pumping Station. Iron was the dominant metal in all humic acids and sediments examined. Humic acids are trace metals holders in the sediments, therefore humic acids play a major role in the geochemical cycling of the elements in the aquatic environment. Abdelhakeem *et al*. (2002) cited the tolerance limits of Pb, Fe and Cd in fish water as 0.10, 0.35 and 0.10 ppm, respectively and in fish body as 2, 30 and 0.5 ppm, respectively. Heavy metal concentrations in fish varied significantly depending on the type of the tissue, fish species and sampling location.

Moreover, Abdelhamid *et al*. (2013) reported that elements took the following descending order: Fe ≥ Pb ≥ Zn ≥ Cu ≥ Cd in the fish carcass. However, the element's concentrations took the following ranges: 0.00 – 209.00, 0.00 – 10.00, 0.00 – 51.03, 56.00 – 95.00, and 479 – 1895 ppm, respectively. This reflects that the presence of a heavy metal in a fish body may not be followed its presence in the surroundings sediments or water. It may depend on its solubility, target medium, site of its location, as well as on different water quality criteria (salinity, pH, alkalinity, dissolved oxygen, microbial load….etc), sediment and fish species (differing in the metabolism). Also, Cd was at least in sediments and fish, but Cu was at least in water. This may be interpretable by calculating the BAF of these elements which were 2.57×10^4, 1.66×10^2, 1.33×10^4, 4.12×10^3 and 7.49×10^5 for Pb, Cd, Cu, Zn and Fe, respectively, i.e. Fe was the heaviest element in the fish body, followed by Pb, Zn, Cu and at least Cd as mentioned before.

In this respect, the BAF of different heavy metals tested) in the *M. cephalus* studied from four sampling locations during two seasons showed significantly highest BAF in fish from Alexandria, Port Saied and El-Bardawil for Pb, Fe and Cd, respectively. Winter Pb–BAF and summer Fe–BAF were significantly higher than those of the other season. These BAFs of heavy metals in fish did not influence by the level of these metals in the fish rearing waters. The highest BAF of Fe in Port Saied fish samples was related also to the highest Fe contents in fish of this location. The same relation was confirmed for Cd in El-Bardawil fish samples, but not for Pb (Abdelhamid *et al*., 2006b).

However, the commission regulation setting maximum Pb level for muscles of fish, released from the European communities, as 0.2 mg/Kg wet weight. Yet, the Egyptians' standards are 0.1 ppm Pb and Cd in food fish (ES, 1993). Comparing these standards with the levels obtained herein, it would be indicated that there is a water pollution with heavy metals in all tested locations, particularly with Pb in summer, Fe in winter and Cd in both seasons and all locations. Abdelhakeem *et al.* (2002) cited the tolerance limits of Pb, Fe and Cd in fish water as 0.10, 0.35 and 0.10 ppm, respectively and in fish body as 2, 30 and 0.5 ppm, respectively. Heavy metal concentrations in fish varied significantly depending on the type of the tissue, fish species and sampling location.

Generally, *Mugil cephalus* L. showed higher levels of Fe and Pb concentrations than *Sparus aurata* L. (Yilmaz, 2005). This may be due to the store tissue of each metal in the fish, i.e. Pb is probably an external pollutant (Rashed and Awadallah, 1994), whereas Fe and Cd were internal pollutants. Therefore, Fe and Cd contents of fish affected positively their BAFs, but Pb was not. The same note is available for the effect of season, since BAF of Pb did not influence by its level in/or on the fish, whereas BAF of Fe was correlated with its level in fish, being the highest in summer season. Also, there were remarkable effects on microelements of fish muscles as well as their bioaccumulation factors due to sampling seasons and locations and fish species (Abdelhamid and El-Zareef, 1996).

Seasonal and location variations as well as fish species' effects were reported before by Abdelhamid *et al.* (2006b), who found that the highest ($P \leq 0.05$) levels of the tested heavy metals were found in fish collected from Marsa Matroh (0.851 ppm Pb), Port Saied (2.40 ppm Fe) and El-Bardawil (0.081 ppm Cd). This may be related to the high content of Pb in water and sediments collected from location No. 1 during both seasons. Also, Fe level of the summer diet and winter collected sediments from Port Saied were the highest. Cd level in El-Bardawil sediment collected in summer was also the highest. The Fe concentrations range (1.3 – 2.4 ppm) of fish tested was higher than that of Pb (0.172 – 0.851 ppm) than Cd (0.016 – 0.081 ppm), regardless to the sampling locations.

However, Abdelhamid *et al*. (1997) registered significant variations in heavy metals concentrations due to different fish species from the natural fisheries and to sampling locations too. They found that the elements' concentrations in the sediments and fishes were much higher than the corresponding values in the water, particularly for iron. Lead and cadmium levels in fish muscles were concentrated more in fish, while iron was highest in sediments followed by fish tissues. *Mugil cephalus* samples were more frequently contaminated than *Liza ramada* and *Sparus aurata* (Abdelhamid *et al.,* 1997). The effects of varying sampling locations and fish parts on the heavy metal level or presence were reported also by Abdelhamid *et al*. (2000).

Anyhow, Cd is known to be human carcinogen (Mandel *et al.,* 1995), Bahr El-Bakar drain water contained 0.910 and 0.0242 mg/l Pb and Cd, respectively, whereas its *M. cephalus* fish flesh contained 0.9376 and 0.0324 mg/Kg Pb and Cd, respectively (Galhoom *et al.,* 2000). Additionally, Salem (2003) found that Cd and Pb caused significant reduction in fish performance, survival, and muscular area. Cd and Pb ions were able to induce metallothionein gene expression in fish tissues, e.g. liver and gills (Cheung *et al*., 2004). Its residues in fish flesh increased by dose increase. The protein banding patterns fluctuated in numbers and intensities by Cd concentrations. Generally, *Mugil cephalus* L. showed higher levels of Fe and Pb concentrations than *Sparus aurata* L. (Yilmaz, 2005).

To interpret the collective death of fish in Domietta region, it was proved that the water of the studied area (El-Bostan village – Kafr El-Batiekh) has suffered from increase of iron concentrations. This picture is very harmful to fish life and production. Pollution of water was reflected in the form of heavy metal accumulation in different fish tissues. The lowest bioaccumulation factors were calculated in fish muscles; therefore, muscles only are suitable for human consumption. The bioconcentration of iron was higher than that of lead in fish muscles (Abdelhamid *et al.,* 2000).

However, any degree of poisoning will weaken the fish, making it vulnerable towards disease. Heavy metals can create problems and be concentrated in waterway organisms up to 9100 times more than the surrounding environment's levels, so may lead to acute or chronic effects (WRC, 2005).

Also, it is a fact that body adaptive balance mechanisms for lead impacts were evident in different organ tissues of fish. Yet, Mzimela *et al*. (2002) reported that lead negatively affected the blood hematology and acid-base balance of the groovy mullet, *Liza dumerili*. Significant correlations were obtained for the levels of numerous metals in water, sediment and fish. The results of Xie and Klerks (2004) suggest that reduced uptake and accumulation of Cd accounted for approximately two-third of the increased resistance in the Cd-adapted lines of fish. However, Cd has been found to accumulate in reproductive organs of fish and disrupt important endocrine processes.

Kirby *et al.* (2001) mentioned that mullet are directly exposed to trace metal concentrations as a result of feeding and the ingestion of contaminated sediment and detritus. Lower metal concentrations found in mullet tissues are attributed to the burial of highly contaminated sediment with material containing lower trace metal concentrations.

Siam (2001) found high level of accumulation of Cd, Fe and Pb in the different organs (gills, liver, stomach and brain) of Alexandria coast fish, with respect to their corresponding in the muscle tissues. He added that the accumulation factors for these metals were higher in the herbivorous fish (*Siganus rivulatus*) than in the carnivorous ones (*Mugil capito*). Fe was the more pronounced one reflecting increase the trophic level of the fish. Cd level was generally lower than that of Pb in various organs while brain gained the highest values. Pb concentration ranged from 1.2 to 3.5 mg/kg in the stomach and brain while it ranged from 0.4 to 0.9 mg/kg in fish muscles.

Most of the fish generally showed levels of Cd in the organs, which are close to that of the recommended standard (2.0 mg/kg) of the National Health and Medical Council in Australia. However, none of them contained Cd concentrations above 0.5 mg/kg in their muscle tissues. Total length, body weight and age are mostly correlated biometric parameters with metallothionein and soluble metal concentrations in striped red mullet and golden grey mullet (Filipovic and Raspor, 2003). Cadmium and lead were higher in muscular tissue from mullet (*Mugil* sp.) than snook (*Centropomus* sp.) and higher in summer than in winter (Joyeux *et al.*, 2004). Staniskiene *et al*. (2005) found high concentrations of Fe in 15 fish species as a direct result of water contamination with heavy metals. Metal concentrations were found to be influenced by fish species.

Saeed and Mohammed (2012) concluded that chemical characteristics strongly influenced bioaccumulation of metals in water with no strong correlation between fish metals concentration (Fe, Zn, Cu, Mn, Cd and Pb) and some water quality parameters. However, metals bioavailability to *Tilapia zillii* is modified significantly by some water chemistry; pH, total alkalinity and dissolved oxygen but the effect is much stronger for some metals than the others. Electric conductivity (EC) had a negative effect on accumulation of Cd and Pb in gills and liver tissue. EC and Ca+2 have positive correlation on Zn accumulation in fish muscle tissues. The concentrations of all metals in water (except Cd and Pb) and edible part of fish were found below the notified toxic limits. However, these elements were lower in River Nile water than in five lake's water, but the opposite was true for the fish, since these elements were higher in River Nile fish than in five lake's fish.

A survey study was conducted on some heavy metals (Pb, Cd, Cu, Zn, and Fe) in water, sediment, and fish samples from Ashtoum El-Gamil protected area during May 2010 to January 2011. Data obtained revealed that there were significant ($P \leq 0.0001$) differences among sampling seasons and stations as well as their interactions concerning the levels of heavy metals tested in either water, sediment, or fish collected from this protected area. The elements level took the descending order Zn ≥ Cd ≥ Pb ≥ Fe ≥ Cu in the water, Pb ≥ Fe ≥ Cu ≥ Zn ≥ Cd in the sediment, and Fe ≥ Pb ≥ Zn ≥ Cu ≥ Cd in the fish body samples. Proximate analysis of the tested fish (mullet and tilapia) reflected also significant ($P \leq 0.0001$) effects due to sampling seasons and stations and their interactions besides fish species. Some significant correlations were calculated among heavy metals (in water, sediments, and fish) and chemical composition of the fish (Abdelhamid *et al.,* 2013).

Concentration of Zinc (Zn) in different tissues of *Oreochromis niloticus*, collected from four studied sites along the River Nile, Helwan (Egypt) was determined to detect its toxic effects on one of the most common fish in the River. *Oreochromis niloticus* fish was found to be a good bioassay indicator for water pollution with Zn. The results of this study clarified the importance of water chemistry in determining the bioaccumulation of the metals. The highest fluctuation from the measured water quality criteria of water samples collected from site before the industrial area, followed by that recorded for water was for those samples collected from site within the industrial area. In most cases, Zn had the least tendency to accumulate in muscles of *O. niloticus*. This means that it will be less hazardous to man if the fish muscles are the only to be eaten (Abbas and Mohamed, 2013).

So, residues of some heavy metals in fish are affected by the presence of some industries nearby the River Nile that may negatively affect human health of the fish consumer from such contaminated water. Therefore, it is a must to convert such factories to be environmentally friends by treating its wastes before exposure to the environment.

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ARABIC SUMMERY

دراسات على بعض العناصر الثقيلة في مياه وأسماك نهر النيل في منطقة حلوان بمصر

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أجريت دراسة لتقييم نوعية المياه وأسماك منطقة حلوان فى نهر النيل. قيم خواص جودة المياه كانت ملائمة لمعيشة الأسماك. كان لكل من مواقع ومواسم جمع العينات (وتداخلهما) تأثير معنوي على تركيز العناصر الثقيلة في الماء، وتراوحت تركيزات (جزء/ مليون) العناصر مابين ٠,٠٢١ - ٠,٠٥٦ زنك، ٠,٠٠٢ - ٠,٠٤٩ نحاس، ٠,١١٧- ٠,١٧٦ رصاص، صفر كادميوم، ٠,٠٣٨ - ١,٤٣٢ حديد، وكانت تركيزات الزنك والنحاس والرصاص أعلى معنويا في الموقع الثاني عن باقي المواقع، بينما كان تركيز الحديد أعلى معنويا في الموقع الأول، وقد يرجع ذلك إلى مصدر التلوث، مصنع أسمنت طرة في الموقع الأول، ومصنع النشا والجلوكوز في الموقع الثاني، وكانت تركيزات كل من الزنك والرصاص والحديد أعلى في الصيف معنويا، وتركيز النحاس أعلى معنويا في الربيع، وقد غاب الكادميوم عن الماء في هذه المواقع والمواسم.

لم يكن هناك تأثير معنوي للمواقع على التركيب الكيميائي لأسماك البلطي النيلى، لكن كان تأثير الموسم معنوي على محتوى الأسماك من البروتين والدهون والرماد. وتأثر محتوى عضلات الأسماك من الرصاص والكادميوم والفلور معنويا بمواقع جمع العينات، وتأثرت تركيزات كل من الزنك والكادميوم والحديد والفلور معنويا بمواسم جمع العينات. وفى جسم الأسماك كان للمواقع والمواسم تأثير معنوي على تركيز كل من الزنك والنحاس والرصاص والحديد والفلور. تراكم عضلات الأسماك معدلات أكبر من الرصاص والنحاس والحديد والزنك على الترتيب، بينما ركز جسم الأسماك معدلات أكبر من الحديد ثم الزنك والنحاس والرصاص على الترتيب، وكان من الواضح تراكم الزنك والنحاس والحديد بمعدلات أكبر في جسم الأسماك عنه في عضلاتها، وقد يرجع ذلك لمكان تخزين العنصر في الأسماك.

وجد أنه يوجد ارتباطات معنوية موجبة بين رصاص ونحاس، رصاص وكادميوم عضلات الأسماك، زنك السمك وحديد العضلات، كادميوم ونحاس، نحاس وحديد، كادميوم ورصاص جسم السمك، حديد السمك وحديد العضلات، زنك الماء وكادميوم العضلات، نحاس الماء ونحاس العضلات، نحاس وزنك الماء، حديد الماء وحديد العضلات، حديد الماء ونحاس جسم السمك، حديد الماء وحديد جسم السمك، حديد ورصاص الماء. كما وجد معاملات ارتباط معنوية سالبة بين نحاس الماء ورصاص جسم السمك، حديد الماء ونحاس العضلات للسمك.

وعليه فمتبقيات بعض العناصر الثقيلة في الأسماك تتأثر بوجود بعض الصناعات بالقرب من نهر النيل، فتؤثر سلبا على صحة الإنسان المستهلك للأسماك، لذا فإنه من الضرورة أن توفق هذه المصانع أوضاعها بيئيا بمعالجة مخلفاتها قبل أن تصب في نهر النيل.