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GENERAL INFORMATION

Abbassa International Journal for Aquaculture is Egyptian specific publication in aquaculture of the Egyptian society for water, aquaculture and environment. The journal is published in four volumes per year to include results of research in different aspects of aquaculture sciences. The journal publishes also special issues of advanced topics that reflect applied experiences of importance in aquaculture sector.

HEAVY METALS ACCUMULATION IN WATER, SEDIMENT AND DIFFERENT TROPHIC LEVELS IN FISH FARMS

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Abstract

Some heavy metals were estimated in different trophic levels and the aquatic environment constituents in private fish farm located in Abbassa, Sharkeya governorate, Egypt. Water, sediment, plankton, aquatic plants (Water hyacinth, *Eichhornia crasippes*) as well as some organs (muscles, gills and livers) of Nile tilapia (*Oreochromis niloticus*), Silver carp (*Hypophthalmichthys molitrix*), Mullet (*Mugil cephalus*), Common carp (*Cyprinus carpio*), and African cat fish (*Clarias gariepinus*) adults, which representing different trophic levels in consider to their feeding habits. These species were investigated for their residues of Fe, Mn, Zn, Cu, Cd and Pb. Obtained results revealed that the highest transfer factor (TF) was from water to plankton for all investigated metals. With respect to different investigated fish species muscles, the highest TF value for Fe and Pb were in phytovorous species (Silver carp). The highest TF value for Mn and Cd were in omnivorous fish (Common carp), while herbivorous fish (Nile tilapia) and detrivorous fish (Mullet) had the highest values of TF for Zn and Cu respectively. The lowest TF values of Fe, Mn and Cu were in muscles of Nile tilapia (herbivorous), while the lowest TF value for Zn and Pb were in muscles of Catfish (carnivorous) adults. The accumulation order of heavy metals in the food web was found to be plankton > aquatic plants > sediment > fish tissues > water. It's concluded from this work that, there were no signs of biomagnification in higher levels of food chain, where the highest levels of metals were found in plankton and macrophytes followed by sediments. This study revealed Also, that a normal daily diet including these fish species could be considered quite safe for human consumption.

INTRODUCTION

The contamination of freshwaters with a wide range of pollutants has become a matter of great concern over the last few decades, not only because of the threat to public water supplies, but also with of the damage caused to the aquatic life. Aquatic systems may be excessively contaminated with heavy metals released from domestic, industrial, mining and agricultural effluents (Langston, 1990).

In aquatic systems, heavy metals have received considerable attention due to their toxicity and accumulation in biota (Mason, 1991). Aquatic microorganisms (plankton and zooplankton as invertebrates) absorb trace metals from the surrounding water, even though these metals are not all important to their metabolism. Different species of insects accumulate metals at different rates, as some absorb them directly from substrate sediments, while other species receive metals through the process of feeding. These insects are part of an integral aquatic food chain and the metals in their system are taken up by the tissues of the fishes which feed upon them.

Through this vertical or trophic food chain, a number of different species that cultured in fish ponds accumulate metals in their body tissue. The trophic transfer of metals begins with the uptake of metals by the larvae of aquatic insects. The accumulation of metals in the body of these larvae is related to the extent to which the sediment is contaminated. A high level of contamination in the sediment leads to the elevated accumulation of metals in the system.

Being non-biodegradable like many organic pollutants, metals can be concentrated along the food chain, producing their toxic effects (Fernandez *et al*., 2000). Metals transferred through aquatic food webs to fish, humans, and other piscivorous animals are of environmental and human health concern. However, pathways of metal movement from land to water and then through aquatic food webs are not well understood

(Chen *et al*., 2000). Accumulation of heavy metals in the food web can occur either by accumulation from the surrounding medium, such as water or sediment, or by bioaccumulation from the food source (Tulonen *et al*., 2006). Aquatic organisms have been widely used in biological monitoring and assessment of safe environmental levels of heavy metals. Due to the toxicity of heavy metals, accurate information about their concentration in aquatic ecosystems is needed (Janssen *et al*., 2000).

Therefore, the objective of this study was to evaluate the pollution level of fish in Abbassa fishponds by determining the residues of Fe, Mn, Zn, Cu, Cd, and Pb in the water and sediments. The mentioned pollutants were also investigated in the other constituents of the aquatic environment "plankton (phyto and zoo), aquatic plants (Water hyacinth, *Eichhornia crasippes*) as well as in some organs of five cultured fish species namely; Silver carp (*Hypophthalmichthys molitrix*), Mullet (*Mugil cephalus*), Common carp (*Cyprinus carpio*), African catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromis niloticus*)" to constituent an impression about the accumulation pattern and the possible mechanisms for uptake and transportation of metals in the food web.

MATERIALS AND METHODS

Water, sediment, plankton, aquatic plants were collected from five different earthen fish-ponds in traditional polyculture private fish-farm located in Abbassa, Sharkya along three months during the culture season (from 1 May till 31 October, 2011). Fish samples obtained from the same ponds at the end of the season. The main irrigation source for the investigated farm was El-Bahnasawy drain which derived from El-Wady canal. All obtained samples prepared for heavy metals as follow:

Water samples: Three samples of each pond were mixed in a plastic bucket; 1 liter sample was placed in a polyethylene bottle, kept refrigerated and transferred cold to the laboratory for analysis. Samples were prepared according to the method described by APHA (1995).

Sediment: Surficial (5-10 cm depth) sediment samples were collected from three different places in each investigated pond using core sampler as described in (Boyd and Tucker, 1992), mixed and kept in cleaned plastic bags and chilled on ice box for transport to the laboratory for heavy metals determination. In the laboratory, the sediment samples were prepared for analysis as the method described in Page *et al*. (1982) and preserved in a refrigerator till analysis.

Plankton: Samples obtained by passing 10 liters from each investigated pond through 20 µm plankton net. Plankton samples were prepared for heavy metal analysis according to the method described by Kelly and Whitten (1989).

Aquatic plants (water hyacinth): About 50 g of a whole plant sample collected from each investigated pond. Collected samples were prepared for heavy metals residual analysis according to AOAC (1990).

Fish: The fish taken for analysis, as shown in Table 1, were selected from various trophic levels. Nile tilapia (*Oreochromis niloticus*) is herbivorous (feed mainly on algae and other aquatic plants, able to convert into omnivorous if needed), silver carp (*Hypophthalmichthys molitrix*) is filter feeding significantly reduced green algae and cyanobacteria numbers. Mullet (*Mugil cephalus*) is a detrivourus fish; feed on non-living particulate organic material as bodies or fragments of dead organisms as well as fecal material. Common carp (*Cyprinus carpio*) is an omnivorous fish; feed on both plant and animal materials as their primary food. Catfish (*Clarias gariepinus*) is a carnivorous or piscivorous fish; feed on other fish.

Fish tissues: Ten fish of each species were collected from the investigated ponds. Fish samples were transported in ice box to the laboratory, where samples of different tissue/organs taken were sorted. Metals in fish tissue/organs were extracted according to the method described in AOAC (1990)

Table 1: Trophic levels as represented in investigated species.

Trophic level	Species
Primary producer	Plankton: Phyto-and zooplankton
	Plants: Water Hyacinth (Eichornia crassipes)
Herbivorous fish (algae & plant feeder)	Tilapia
Phytovorous or filter feeding fish	Silver carp
Detrivorous fish	Mullet
Omnivorous fish	Common carp
Carnivorous fish	Catfish

Different investigated heavy metals in water, sediment, plankton, aquatic plant and different fish organs were detected with Atomic Absorption Spectrophotometer (Model Thermo Electron Corporation, S. Series AA Spectrometer, UK,).

Transfer factor (TF): Transfer factor for a certain metal from water to each investigated constituent was calculated by dividing the concentration of this metal in this constituent (mg/kg) by its concentration in water (mg/l).

Statistical analysis

Average residues of different investigated heavy metals in water, sediment, plankton and aquatic plants had been calculated among different investigated fish ponds along the culture season. One-way ANOVA was employed to find the significance for each investigated metal among different tested fish organs according to Bailey (1982). The significance was set at 0.05.

RESULTS AND DISCUSSION

Water residues

Water residues of the investigated heavy metals, which summarized in table 2 indicated that they follow the order: Fe > Mn > Zn > Cu> Cd > Pb. Recorded water residues in this work indicated that Iron, zinc and copper levels were lower than the maximum permissible limits that mentioned by WHO (2011) while manganese, cadmium and lead were lower than the permissible limits of the same organization. Higher Cu, Zn and Pb levels in Abbassa fish farm water (0.16, 0.15 and 1.9 mg/l respectively) than those recorded in the present study, previously mentioned by Khallaf *et al*. (1994). However, they reported lower values of both Cd and Fe (0.01 and 0.25 mg/l respectively).

Sediment residues

Different investigated heavy metals residues in sediment recorded during this work, as shown in Table 2, indicated that they follow the order Fe > Mn > Zn > Cu > Pb > Cd with average values of 7552.85, 722.06, 182.92, 27.34, 2.1 and 0.44 mg/kg respectively, and with a trend nearly similar to that of there residues in water except for lead and cadmium. All investigated metals were below the permissible limit mentioned by Persaud *et al* (1990). Higher values of all investigated metals (7900, 723, 315, 50.3, 36.5 and 10.8 mg/kg respectively) were previously mentioned by Ali and Abdel-Satar (2005) for some heavy metals residues in sediment of some fish ponds in El-Fayoum province.

Table 2: Average means ± standard error of Investigated heavy metals residues in pond water (mg/l), sediment, plankton and aquatic plants (mg/kg).

		Fe	Mn	Zn	Cu	Cd	Pb
Water	**Average**	11.113 ±0.94	0.871 ±0.045	0.048 ±0.005	0.037 ±0.005	0.013 ±0.003	0.009 ±0.002
	Permissible levels (mg/ l) according to WHO (2011)	No health-based guideline value has been recorded	0.1	No health-based guideline value has been recorded	2	0.003	0.01
Sediment	**Average**	7552.85 ±552.378	722.06 ±58.62	182.92 ±24.8	27.34 ±3.43	0.44 ±0.099	2.10 ±0.56
	Permissible levels (µg/g dry wt): according to Persaud *et al.* 1990	-	460-1110	120-820	16 -110	0.6 -10.0	31-250
Phyto&zoo plankton	**Average**	27875.08 ±805.22	1874.85 ±66.28	4015.33 ±245.7	140.28 ±9.94	14.92 ±0.73	21.34 ±1.71
water hyacinth, *Eichhornia crasippes*	**Average**	12962.35 ±43.11	678.02 ±4.79	88.598 ±3.32	42.68 ±1.38	1.28 ±0.09	ND

Heavy metals residues in plankton:

As revealed in Table 2 average residues of Fe, Mn, Zn, Cu, Cd and Pb in ponds water were 27875.08, 1874.848, 4015.3268, 140.282, 14.92 and 21.336 mg/kg. Obtained results indicated that the concentrations of all investigated metals in plankton were much higher than those of water. This may be related to the large surface of plankton organisms in relation to their mass unit, and their active metabolism leading to rapid adsorption of various pollutants (Ravera, 2001). He added that some algal species protect themselves by trapping and accumulating pollutants (e.g. metals) in their polysaccharide walls. The order of abundance of investigated metals in pond plankton was Fe > Zn > Mn > Cu > Pb > Cd. Similar findings previously mentioned by Bahnasawy *et al.* (2011). This corresponds to the same order of abundance of these metals in water (except for Zn which lower in water than Mn and lead which lower in water than cadmium) as well as in sediment, which supports the hypothesis that water is an important source of plankton contamination. Elmaci *et al.* (2007) reported that the quantity of heavy metals in plankton depends on their concentration in water and partially on sediment.

Heavy metal residues in aquatic plants (water hyacinth, *Eichhornia crasippes*):

Average values of Fe, Mn, Zn, Cu, and Cd in pond water hyacinth were 12962.35, 678.02, 88.598, 42.68, and 1.28 mg/kg. Lead residues in water hyacinth of different investigated ponds were not detectable. The order of abundance as shown in Table 2 were Fe > Mn > Zn > Cu > Cd > Pb which the same order in water except for Cd and Pb.

Heavy metals residues in fish organs

Fishes are notorious for their ability to concentrate heavy metals in their muscles and since they play important role in human muscles and since they play important role in human nutrition, they need to be carefully screened to ensure that unnecessary high level of some toxic trace metals are not being transferred to human through fish consumption (Adeniyi and Yusuf, 2007). Heavy metals residues in different investigated fish species organs were summarized in Table 3 and illustrated in Figures 1:6. It could be obtained that for all investigated heavy metals Tilapia accumulated the lowest values except for zinc. Similar results previously obtained by Ali & Abdel-Satar (2005) and Obasohan *et al*. (2006) who reported that Mugil sp. seemed to be more contaminated than Tilapia sp.

Obtained results indicated that residues varied according to metals, fish species and fish organ as follow:

Fe: Iron residues in muscles of Nile tilapia, Silver carp, Mullet, Common Carp and African Catfish which illustrated in Figure 1, were 56.563, 630.39, 366.61, 420.367 and 268.21 mg/kg dry weight respectively. It's indicated that tilapia muscles accumulated lowest iron levels while the highest iron levels were detected in both Silver and Mullet species. It's also indicated that gill tissues accumulated the highest iron values than both muscle and liver tissues in Silver, Mullet and catfish species. Lower iron concentration (10.4 and not detectable mg/kg) was previously mentioned by (Khallaf *et al*., 1994) for Nile tilapia and Catfish respectively, caught from Abbassa fish farm. Higher concentrations in muscles tissue of different species during this work may be due to the higher iron levels in water. This is in agreement with the findings of Shakweer (1998), who concluded that the concentration of trace metals in various organs of fish reflects the degree of water pollution in the aquatic environments in which such fish are living. Ravera (2001) reported that if an environment receives foreign pollutants (e.g. metals), the organisms living in it could take up the pollutants from the water or/and food and concentrate it in their bodies. However, WHO (2011) reported that the recommended daily intake for an adult is: up to 50 mg Fe/day, so, a normal daily diet including this fish species (except for silver carp, unless less than 0.5 kg consumed/day) poses no health risk to consumer.

Table 3: Average means (mg/kg) ± standard error of investigated heavy metals residues in organs of different tested fish species.

		Fe	Mn	Zn	Cu	Cd	Pb
Nile tilapia	**M**	56.563± 4.984 F	1.29± 0.17 F	83.523± 11.81 BC	2.75± 0.485 F	0.049± 0.014 B	0.263± 0.017 CDE
	G	198.15± 25.38 F	26.633± 4.419 C	164.6± 23.68 AB	5.427± 0.955 F	0.016± 0.005 B	0.279± 0.16 CDE
	L	248.66± 17.74 F	2.723± 0.157 EF	243.31± 142.65 A	74.34± 36.1 BC	0.205± 0.14 AB	0.269± 0.119 CDE
Silver carp	**M**	630.39± 116.89 CDEF	3.928± 0.113 EF	27.153± 10.41 C	11.608± 3.486 F	0.092± 0.044 B	0.591± 0.125 BC
	G	1565.4± 455.09 B	62.809± 4.639 A	36.643± 10.670 C	23.249± 8.591 EF	0.302± 0.026 AB	0.334± 0.100 CDE
	L	1503.94± 115.58 B	11.858± 4.603 DEF	68.752± 30.04 C	97.379± 16.23 AB	0.295± 0.027 AB	2.390± 0.037 A
Mullet	**M**	366.61± 52.68 EF	3.429± 0.284 EF	31.337± 8.152 C	12.82± 2.56 EF	0.1558± 0.037 B	0.527± 0.198 BCD
	G	2450.77± 420.09 A	49.007± 6.41 B	36.475± 16.920 C	10.578± 1.862 F	0.287± 0.125 AB	0.750± 0.119 B
	L	1059± 262.923 BCDE	19.807± 3.99 CD	81.346± 12.48 BC	42.008± 2.956 DE	0.246± 0.03 AB	2.67± 0.009 A
Common carp	**M**	420.367± 66.72 DEF	5.102± 1.427 EF	54.94± 1.837 C	9.706± 0.231 F	0.396± 0.027 AB	0.144± 0.091 DE
	G	1118.53± 111.3 BCD	23.351± 3.409 C	89.25± 24.4 BC	21.337± 10.82 EF	0.2379± 0.072 AB	ND
	L	1283.05± 209.6 BC	9.044± 1.223 EF	40.4527± 8.93 C	56.055± 7.828 CD	0.434± 0.035 AB	0.634± 0.015 BC
African Catfish	**M**	268.21± 107.8 F	3.992± 1.754 F	13.285± 7.921 C	9.341± 4.697 F	0.366 ± 0.234 AB	0.007± 0.005 E
	G	3047.78± 369.1 A	40.777± 3.893 B	49.172± 16.98 C	20.762± 10.1 EF	0.7477± 0.563 A	0.108± 0.045 E
	L	1034.89± 140.5 BCDE	12.597± 4.639 DE	35.862± 26.76 C	120.46± 1.804 A	0.391± 0.084 AB	ND

Data shown with different letters in the same column are statistically different at $P < 0.05$ level.

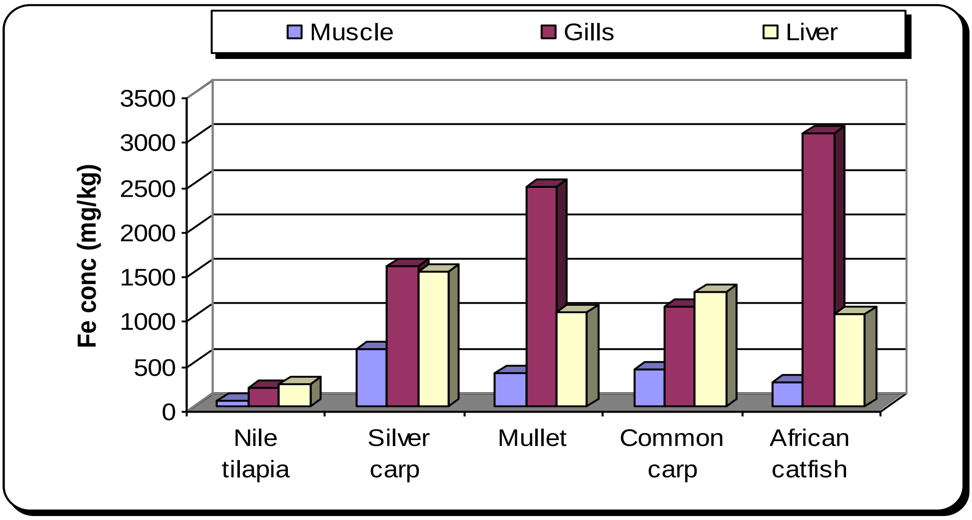

Figure 1: Iron residues (mg/kg) in muscles, gills and livers of different investigated fish species.

Mn: Manganese concentrations, as illustrated in Figure 2, in muscles of different investigated fish species (Nile tilapia, Silver carp, Mullet, Common carp and Catfish) were 1.29, 3.928, 3.429, 5.102 and 3.992 mg/kg dry weight respectively. These values could be considered quite safe for consumption in case of normal diet of these fish species, according to WHO (2011) which stated 11 mg Mn/day as a recommended daily intake for an adult. Obtained results revealed that the highest manganese values were in gills. The high content of metals in gill tissues can be attributed to the fact that fish gills play a distinct role in metal uptake from the environment. Due to their respiratory function, gills are in direct contact with the contaminated medium (water), and have the thinnest epithelium of all of the organs (Kotze *et al*., 1999). These results are in agreement with the many authors who have reported that gills have a high tendency to accumulate heavy metals (Coetzee *et al*., 2002 and Altındağ and Yiğit, 2005).

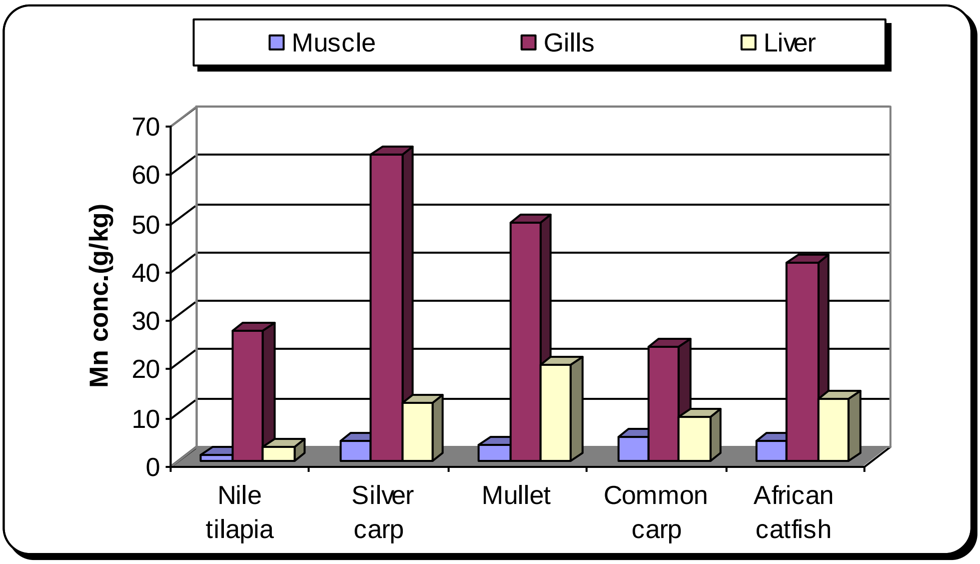

Figure 2: Manganese residues (mg/kg) in muscles, gills and livers of different investigated fish species.

Zn: Average muscle zinc concentrations recorded in the present work, as illustrated in Figure 3 were, 83.523, 27.153, 31.337, 54.94, and 13.285 mg/kg dry weight in Nile tilapia, Silver carp, Mullet, Common Carp, African and Catfish, respectively. In contrast to the other investigated heavy metals, Nile tilapia muscle accumulated the highest zinc value. Obtained results showed that Zinc values in Silver carp, Mullet and Catfish, were lower than the acceptable concentration (50 mg/kg) mentioned by FAO (1983), while both Carp and Tilapia accumulated higher zinc in their muscles than that permissible limit. However, according to WHO (2011) the recommended daily intake for an adult is 1 mg Zn/kg of body weight/day, so a normal consumption of these fish species considered quite safe for human. The relatively higher levels of Zn can be attributed to its biological role in normal metabolism and the growth of different fish species, which cause them to have an active uptake and storage (Bahnasawy *et al.*, 2011). Balasubramanian *et al.* (1995) indicated that Zn accumulation in the fish species was in the order of omnivorous feeder> phytoplankton feeder> zooplankton feeder>

carnivorous feeder> macrophyte feeder.Obtained results revealed that zinc values in muscles in all investigated species except Common Carp, were lower than its values in other investigated organs. Similar results were previously mentioned by Velcheva (2004).

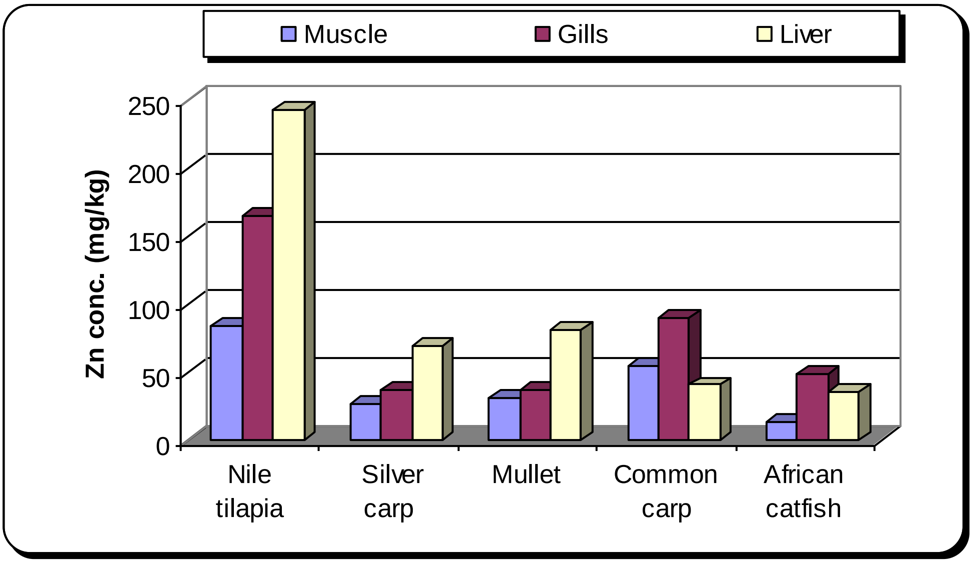

Figure 3: Zinc residues (mg/kg) in muscles, gills and livers of different investigated fish species.

Cu: As illustrated in Figure 4, muscles Cu in all tested fish species were below the permissible value (20 mg/kg) mentioned by FAO (1983). These values in Nile tilapia, Silver carp, Mullet, Common carp and Catfish were 2.75, 11.608, 12.82, 9.706 and 9.341 mg/kg dry weight respectively. Cu levels had the order liver > gills > muscles in all tested fish species except for mullet were Cu level in gills was higher than its value in muscle. However, in all tested fish species, liver accumulated the highest Cu levels among tested organs. Similarly Elnemaki and badawy (2005 & 2006) found that Fe, Cu, Zn and pb values in carp and mullet liver were higher than those in muscles.

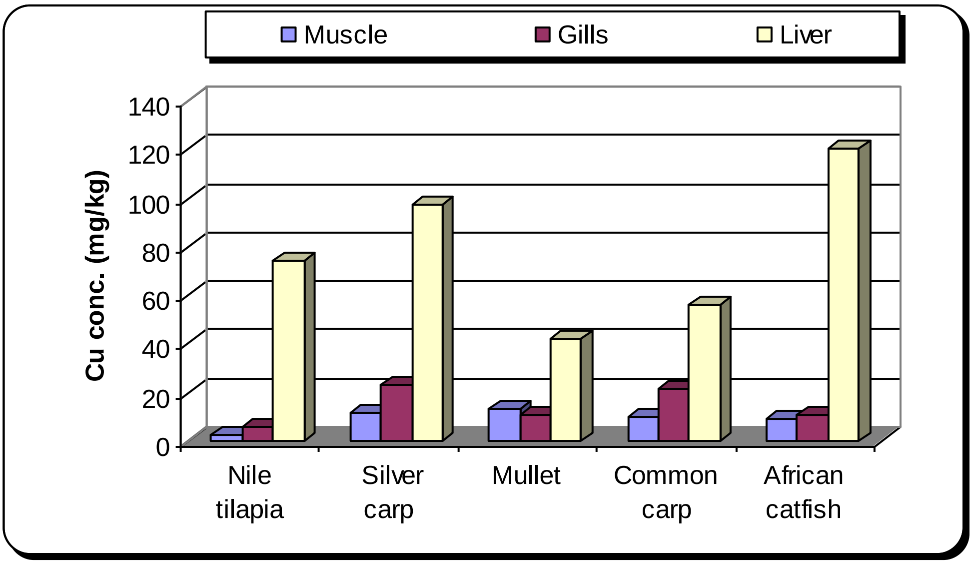

Figure 4: Copper residues (mg/kg) in muscles, gills and livers of different investigated fish species.

Cd: As illustrated in Fig. 5, cadmium concentrations in muscles of all investigated species (Nile tilapia, Silver carp, Mullet, Common carp and Catfish and) were 0.049, 0.092, 0.1558, 0.3962 and 0.366 mg/kg dry weight, respectively. These concentrations were lower than the permissible concentration (0.5 mg/kg) mentioned by FAO (1983). The lowest cadmium concentration in muscle was in Nile tilapia. Its obtained from the recorded cadmium values recorded during the study that in most cases liver and gills accumulated higher cadmium values than muscle tissues. Similar results were obtained by Benson *et al.* (2006) and Ali (2007).

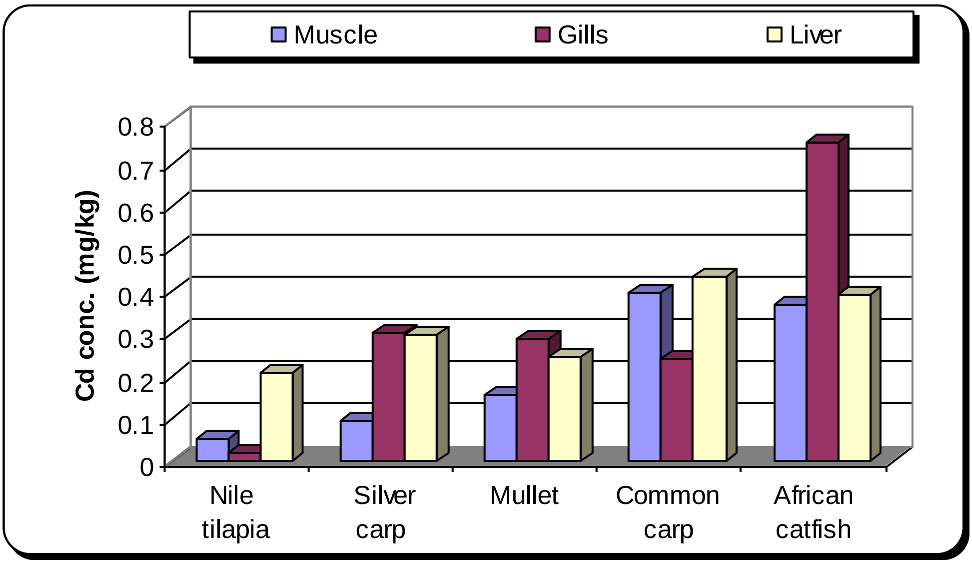

Figure 5: Cadmium residues (mg/kg) in muscles, gills and livers of different investigated fish species.

Pb: Fig 6 illustrated lead levels in different organs of investigated fish species. It's revealed that lead residues in edible muscles of different investigated fish species much lower than the permissible concentration (2 mg/kg) mentioned by FAO (1983). These residues were 0.263, 0.591, 0.527, 0.144, and 0.007 mg/kg dry weight in Nile tilapia, Silver carp, Mullet, Common carp and Catfish, respectively. WHO (2011) recommended 25 µg/kg body weight/day for an adult daily intake. It's revealed also that both catfish and tilapia species accumulated the lowest lead values in their muscles.

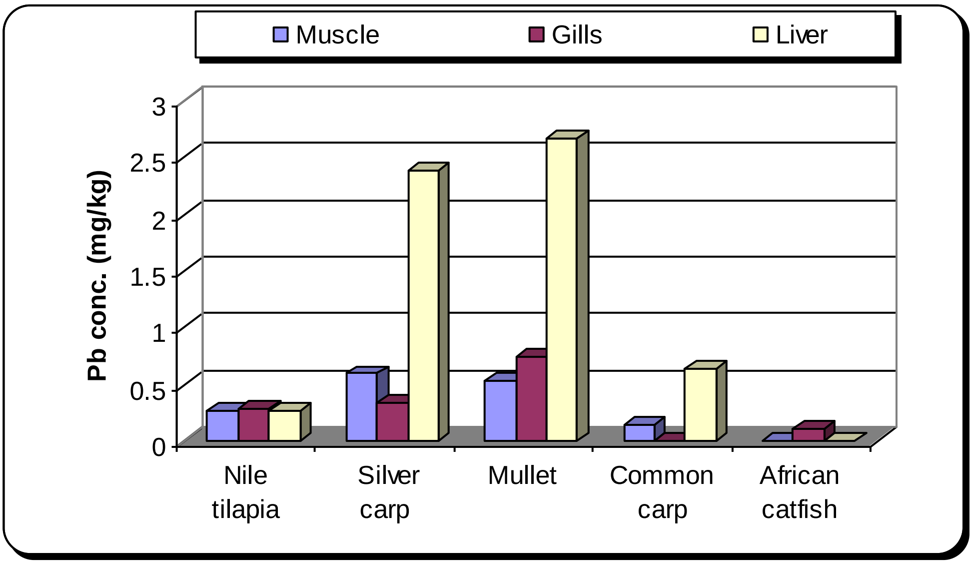

Figure 6: Lead residues (mg/kg) in muscles, gills and livers of different investigated fish species.

Transfer factor (TF) and the distribution of heavy metals in different components in the pond ecosystem:

Transfer factor from water to each of sediment, plankton and organs of different investigated fish species, were summarized in Table 4. This Table revealed that the highest TF for all investigated metals were in plankton. The increased concentration of metals in primary producers than in sediment could be attributed to the decrease of organic matter in sediment. In sediment with low organic content, metals can be accumulated up to 40 times in plants (Greger and Kautsky, 1993). Kassim *et al.* (1997) mentioned that values of Zn, Cu, Mn, Cd and Pb in the suspended particles (which contain plankton organisms) were much higher than that found in the bottom sediments. Bahnasawy *et al.* (2011) detected that the highest values of Zn, Cu, Pb and Cd were in plankton.

The sediment had higher levels of Pb, Zn and Mn than macrophyte. Sediment also had higher levels of Cd, Fe, and Mn than all investigated organs of all tested fish species. With respect to Pb, sediment accumulated higher values than all tested fish species except for silver carp and mullet livers. Sediment Zn was higher than its values in all investigated fish organs except in common carp gills and tilapia livers. Cu values in sediment were higher than its values in muscles and gills while lower than its values in livers of all investigated fish species. Macrophytes transferred higher values of Cd, Fe, and Mn and lower Pb values than all investigated fish species did. Berg *et al.* (1995) mentioned that, a dilution of Pb is often noted at higher trophic levels and this complies with the present results. It is also known as one of the least movable and plant available metals and it is heavily bound to particulate material and this may explain why this metal not detected in floating plant. Altındağ and Yiğit (2005) observed that accumulation orders of heavy metals, Cd and Pb in the food web was found to be plankton > sediment > fish tissues.

It's revealed also from Table 4 that the lowest TF for both Zn and Pb were in catfish muscles, while the lowest TF for Fe, Mn and Cu were in tilapia muscles. This result could be attributed to the feeding habits of different investigated fish species, where Silver Carp, Mullet and Common carp depending mainly on plankton and other plant origin feeds rather than Catfish and Nile tilapia. Silver carp are capable of consuming large amounts of plankton (Maheshwari *et al.*, 1992; Fuller *et al*., 1999). Numann (1958) reported that Cyprinus carpio mainly feed on plankton. Karaca (1995) reported that the majority of the food found in the digestive tracts of common carp was constituted by Chrysophyta from algae with 55.46%. Tomasson *et al*. (1983) indicated that *C. gariepinus* in Le Roux Dam changed to a piscivorous diet when they grew to about 40 cm lengths.

Shalloof and Khalifa (2009) mentioned that the major food of *O. niloticus* in Abu-Zabal Lakes, Egypt, were detritus, diatoms, green algae, animal derivatives, sand particles, rotifers …etc. So the ability to exploit different varieties of food items makes *O. niloticus* to be omnivorous.

Its obtainable that transfer factor in muscles of different investigated fish species were lower than its values in other tested organs. Similar results previously obtained by Abdel-Baki *et al*. (2011).

Table 4: Transfer factor of different investigated heavy metals from water toward sediment**,** plankton and organs of different tested fish species.

		Fe	Mn	Zn	Cu	Cd	Pb
Nile tilapia	**W/M**	5.0898*	1.4811*	1740.0688	74.3243*	3.7692	29.2556
	W/G	17.8305	30.5778	3429.2354	146.6676	1.2308*	30.9667
	W/L	22.3756	3.1266	5068.8896	2009.1892	15.7923	29.9222
Silver carp	**W/M**	56.7250	4.5098	565.6833	313.7270	7.0615	65.7000
	W/G	140.8626	72.1115	763.3979	628.3378	23.2615	37.1022
	W/L	135.3318	13.6147	1432.3375	2631.8757	22.7154	265.5556
Mullet	**W/M**	32.9897	3.9370	652.8500	346.5162	11.9846	58.5889
	W/G	220.5322	56.2656	759.8979	285.9027	22.1077	83.3333
	W/L	95.2938	22.7411	1694.7042	1135.3378	18.9154	296.6667
Common carp	**W/M**	37.8266	5.8577	1144.5813	262.3324	30.4769	16.0000
	W/G	100.65	26.8094	1859.3750	576.6784	18.3000	-----------
	W/L	115.4549	10.3830	842.7646	1515.0081	33.4154	70.4444
African catfish	**W/M**	24.1344	4.5835	276.7708*	252.4595	28.2000	0.8111*
	W/G	274.2538	46.8163	1024.4125	561.1351	57.5154	12.0000
	W/L	93.1238	14.4630	747.1250	3255.6000	30.0692	----------
Water/sediment		679.6410	829.0011	3810.8333	738.9189	33.8462	233.3333
Water/phyto		2508.33**	2152.523**	83652.641**	3791.405**	1147.692**	2370.666**
Water/aquatic		1166.443	778.4927	1830.2799	1140.899	99.5994	-----------
Minimum		5.0898	1.4811	276.7708	74.3243	1.2308	0.8111
Maximum		2508.33	2152.523	83652.641	3791.405	1147.692	2370.666

* and ** indicates minimum and maximum values for each metal respectively.
W = water, M = muscles, G = gills, L = liver.

In conclusion, we suggest that the combined use of different components of ecosystem in fish ponds for monitoring metals, gives not only the amount of contaminants in different species but also a rough picture of the distribution and turnover of the metals in the ecosystem. It could be concluded also that a normal daily diet including this fish species poses no health risk to consumer.

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تراكم العناصر الثقيلة في كل من المياه والتربة والمستويات الغذائية المختلفة فــى مـزارع الأسـماك

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الملخـــــص العربـــــى

تم رصد متبقيات العناصر الثقيلة في المستويات الغذائية المختلفة وكذلك باقي عناصر البيئة المائية في أحد المزارع السمكية الخاصة بمنطقة العباسة – محافظة الشرقية – جمهورية مصر العربية. تم قياس متبقيات كل من الحديد والمنجنيز والزنك والنحاس والكادميوم والرصاص في كل من المياه والرواسب والهائمات النباتية والحيوانية والنباتات المائية (نبات ورد النيل) وكذلك تم رصد متبقيات تلك العناصر في كل من العضلات والخياشيم والكبد لأنواع من الأسماك المختلفة في عاداتها الغذائية وهي المبروك الفضي والبوري والمبروك العادي والبلطي النيلي والقراميط. وقد بينت النتائج المتحصل عليها أن أعلي معدل تراكم لتلك العناصر كان في الهائمات النباتية، بينما كان أقل معدل للتراكم كان في عضلات كل من أسماك البلطي النيلي والقراميط. ولقد استنتج من هذا العمل أنه لم تكن هناك علامات على التضخم الأحيائي للعناصر في المستويات العليا من السلسلة الغذائية حيث أن أعلي المستويات من المعادن تم العثور عليها في العوالق النباتية والحيوانية تليها النباتات المائية ثم الرواسب. من خلال هذه الدراسة نستطيع أن نوصي بأهمية دراسة متبقيات الملوثات المختلفة كالعناصر الثقيلة حيث أن هذا الرصد يعطي صورة عامة عن كيفية توزيع وإنتقال وتراكم تلك الملوثات في العناصر المختلفة المكونة للبيئة المائية ونستطيع أن نخلص من هذه الدراسة بأن تركيزات كل العناصر الثقيلة المتناولة بالرصد في هذه الدراسة في الأجزاء المأكولة (العضلات) من أنواع الأسماك المختلفة المختبرة كانت في الحدود المسموح بها عالميا، ولا تمثل تهديدا لصحة الإنسان.