EGYPTIAN JOURNAL OF AQUATIC RESEARCH 1687-4285
VOL. 31 NO. 2, 2005: 261-273.

STUDIES OF SOME HEAVY METALS IN WATER, SEDIMENT, FISH AND FISH DIETS IN SOME FISH FARMS IN EL-FAYOUM PROVINCE, EGYPT

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Keywords: Heavy Metals, Sediment, Fish Diets, Fish Farm

ABSTRACT

The distribution patterns of some heavy metals (Fe, Mn, Zn, Cu, Pb and Cd) in water, sediment, some fish species and fish diets in Fish Farm were studied during 2003. The results revealed that, with exception of zinc the values of heavy metals were exceeded that of the permissible limits in water. The descending order of heavy metals was: Fe > Mn > Pb > Zn > Cu > Cd for water, while for sediment the order was: Fe > Mn > Zn > Cu > Pb > Cd. Heavy metals in the fish flesh showed that *Mugil* sp. tended to accumulate more concentration of (Cu, Zn, Pb, and Cd) than *Tilapia* sp. The diets were considered as additional ambient heavy metals sources.

INTRODUCTION

Aquaculture is considered as one of the most important sources of animal protein production. Countries that have over population problems as Egypt have an increase demand for protein production of fishes. So, realize the maximum yield of all useable resources for production food is vital. These attempts can be realized by increasing the area of cultured fish ponds and using the facilities of aquaculture methods (Magouz, *et al*., 1999).

Heavy metal pollution in air, water, soil and plant systems is of major environmental concern on a world scale with the rapid development of the industry. Beside their natural occurrence, heavy metals may enter the ecological system through anthropogenic activities, such as, sewage sludge disposal, application of pesticides and inorganic fertilizers as well as atmospheric deposition (Haiyan and Stuanes, 2003). The contamination of freshwater with heavy metals has become a matter of great concern over the last few decades, not only because of the threat to public water supplies, but also their damage caused to the aquatic life (Canli *et al*., 1998). Contamination with heavy metals may have devastating effects on the ecological balance of the aquatic environment and the diversity of aquatic organisms becomes limited with the extent of contamination (Suziki *et al*., 1988). Sediments are important sinks for various pollutants like pesticides and heavy metals and play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediments. The direct transfer of chemicals from sediments to organisms is now considered to be a major route of exposure for many species (Zoumis *et al*., 2001). The release of trace metals from sediments into the water body and consequently to fish will depend on the speciation (i.e. metals may be precipitated, complexed, adsorbed, or solubilized) of metals and other factors such as, sediment, the physical and chemical characteristics of the aquatic system (Morgan and Stumm, 1991).

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The main natural source of heavy metals in waters is weathering of minerals (Klavins *et al*., 2000). Industrial effluents and non-point pollution sources, as well as changes in atmospheric precipitation, can lead to local increases in heavy metal concentrations in waters. Total heavy metal concentrations in aquatic components can mirror the present pollution status of these areas (Haiyan and Stuanes, 2003).

Many fish farms were established around Lake Qarun in El-Fayoum Province in earthen ponds. These cultures involve Tilapia monoculture system or a poly-culture of mixed Tilapia and Mullet. These ponds used agricultural drainage water and also artificial feed is added. Little is known about water quality in the Egyptian earthen fish ponds; few studies concerned with the water quality, zooplankton community structure and the effect of fertilizers on zooplankton assemblage and rearing fish (Borhan, 1978; El-Shebly, 1991 and Mageed, 1996).

The main objective of the present study is to investigate the distribution of heavy metals in some earthen fish ponds in El-Fayoum Province.

MATERIAL AND METHODS

Study area

About 1000 feddans of fish farms, located at the southern region of Lake Qarun are present in El-Fayoum Province. Tilapia and Mullet were the dominant fish species (Metwally, 1999). Four fish farms were selected in addition to the two feeding drains, Dayer El-Berka Drain (The main water feeder source of all fish farms and in the same time received the output wastewater of the fish farms) and El-Wadi Drain (used a little as a water feeder, when the water of Dayer El-Berka Drain dropped to a minimum). The area of each pond varied between 1-5 feddans (Table 1). The fishes were fed with diet mainly formulated from fish meal, soybean meal, maize, rice bran, cotton seed oil and vitamin, mineral mixture, with different protein ratios ranged between 15–25 %. The diets were offered twice daily with 4% of total fish mass in the pond.

Table (1): Area , depth and stocking density (Fish/pond) of selected studied pond

Fish pond	Owner name	Location	Surface area (m^2)	Depth (Cm)	Stocking density	
					***Tilapia* sp**	**Mullets**
Pond 1	El-Shoura	At the end of fish farms nearby the Dayer El-Berka drain	16800	100	17000	10000
Pond 2	Guda_1	At the middle position of fish farms	4200	100	5000	*
Pond 3	Guda_2	Occupy a position nearby Lake Qarun and far from Dayer El-Berka drain	29400	100	42000	14000
Pond 4	Shalakany	Occupy a middle position of fish farms	8400	100	17000	*

*: No mullet in these ponds

Sampling Program

Water and sediment samples were collected seasonally from the studied ponds during 2003. The fish diets were taken during the nutrition of the selected fish farms, while random fish samples included cultivated two species (*Tilapia* sp. and *Mugil* sp.) were caught at the end of the season. Samples were dissected freshly, to obtain the edible muscles and then frozen until ready for acid digestion.

Procedure

Water samples were digested by adding 10 ml nitric acid to 500 ml of mixed sample in a beaker. Slow boiling and evaporation on a hot plate to reach the lowest volume. Wash down beaker walls with distilled water then the digested samples were transferred to a 100 ml volumetric flasks and completed to the mark as described in APHA (1992). Sediment samples were dried at 80 ^{0}C in oven and grinding to fine particles, 1 gm of fine grinded samples was digested according to Kouadia and Trefry (1987) method using mixture of nitric, perchloric and hydrofluoric acids in Teflon beakers. The samples were heated in sand path till the digestion process completed. The organic matter content was determined by oxidation with potassium dichromate under acidic conditions (Jackson *et al*., 1984). Different fish samples and diets were digested after drying according to the methods of Association of Official Analytical Chemist (AOAC, 1995). The levels of Fe, Mn, Zn, Cu, Cd and Pb in different digested samples were determined using Atomic Absorption (Perkin Elmer 3110 USA) with graphite atomizer HGA-600.

RESULTS

Water

The values of heavy metals (Table 2) showed relative variation among different fish ponds and during different seasons. It is clear from the obtained results that iron, manganese, lead and cadmium showed their highest values at El-Shoura farm (2300, 125, 101 and 6.05 µg/l, respectively) during summer, while copper and zinc showed their highest levels in Shalakani farm (39.5 and 90.5 µg/l respectively) during summer. In addition, the water of Dayer El-Berka drain maintained generally higher metals contents more than El-Wadi drain. On the other hand, Gouda_2 farm maintained the lowest values of iron, manganese, copper, zinc and cadmium (1012, 65, 26.5, 43.5 and 3.5 µg/l during winter and autumn respectively). However, lead showed its minimum value (49 µg/l) in Shalakni farm during autumn.

The obtained results of heavy metals were higher than that recorded for Lake Qarun during the same period i.e. Fe (325– 600), Mn (39 – 78), Cu (36– 57), Pb (85–100) and Cd (1.6-2.1) µg/l (Ali and Fishar, 2005).

It is worthy to mentioned that the distribution patterns of the studied metals exhibited similar trend, since their concentrations increased during hot period (summer and spring) and decreased during cold period (winter and autumn). This observation was in agreement with that reported by Abdel Satar *et al.,* (2003) for Lake Qarun and El-Enany (2004) for Lake Manzalah.

Sediments

The studied heavy metals in the sediments fluctuated in the range of 2550 - 5210, 301-723, 24.2-33.2, 125-205, 19-35.5 and 3.3-5.2 µg/g for iron, manganese, copper, zinc, lead and cadmium respectively (Table 3). The maximal values of all metals were recorded in El-Shoura farm sediments during winter except zinc where the maximum value was recorded during autumn in Shalakani farm. Also, the lowest values were recorded in Gouda_2 farm sediments during different season (Table 3). The distribution patterns of heavy metals in the sediments showed, to great extent, an opposite manner to that obtained for water, whereas the heavy metals

Table (2): Seasonal variations of Fe, Mn, Cu, Zn, Pb and Cd (µg/l) in the water of the studied area during 2003

Metal	Stations	Winter	Spring	Summer	Autumn	Mean value
Iron (Fe)	El-Shoura	2100	1900	2300	1780	2020
	Gouda_1	1666	1470	1770	1700	1652
	Gouda_2	1012	1068	1130	1140	1088
	Shalakani	1140	1320	1344	1280	1271
	Dayer El-Berka	2560	2756	2650	2359	2581
	El-Wadi Drain	2460	2540	2305	2009	2329
Manganese (Mn)	El-Shoura	100	115	125	110	113
	Gouda_1	85	95	100	92	93
	Gouda_2	65	75	75	70	71
	Shalakani	80	85	90	76	83
	Dayer El-Berka	225	235	249	215	231
	El-Wadi Drain	191	195	215	185	197
Copper (Cu)	El-Shoura	28.5	33.5	32.5	29.3	31.0
	Gouda_1	31.6	34.6	35.1	29.7	32.8
	Gouda_2	28.6	33.1	30.1	26.5	29.6
	Shalakani	30.1	31.5	39.5	26.6	31.9
	Dayer El-Berka	43.1	42.1	45.5	41.3	43.0
	El-Wadi Drain	44.6	49.2	50.1	55.2	49.8
Zinc (Zn)	El-Shoura	55.6	58.4	63.1	57.8	58.7
	Gouda_1	63.4	69.8	72.5	60.6	66.6
	Gouda_2	50.6	52.6	49.5	43.5	49.1
	Shalakani	75.2	83.2	90.5	82.1	82.8
	Dayer El-Berka	99.6	102.5	115.0	93.6	102.7
	El-Wadi Drain	76.2	93.3	96.5	81.6	86.9
Lead (Pb)	El-Shoura	90.0	95.0	101.0	82.0	92.0
	Gouda_1	76.0	83.0	85.0	66.0	77.5
	Gouda_2	80.0	96.0	82.0	75.0	83.3
	Shalakani	53.0	56.0	61.0	49.0	54.8
	Dayer El-Berka	60.0	66.0	70.0	67.0	65.8
	El-Wadi Drain	40.0	46.0	45.5	40.8	43.1
Cadmium (Cd)	El-Shoura	5.1	4.3	6.1	4.9	5.1
	Gouda_1	4.8	4.1	5.6	4.9	4.9
	Gouda_2	3.8	3.7	4.2	3.5	3.8
	Shalakani	4.1	4.4	5.3	4.0	4.5
	Dayer El-Berka	8.6	7.9	10.6	8.3	8.9
	El-Wadi Drain	8.6	7.6	9.6	8.1	8.5

Table (3): Seasonal variations of Fe, Mn, Cu, Zn, Pb and Cd (µg/g) in the sediment of the studied area during 2003

Metal	Stations	Winter	Spring	Summer	Autumn	Mean value
Iron (Fe)	El-Shoura	5210	4770	4830	4890	4930
	Gouda_1	4070	3380	3830	3910	3800
	Gouda_2	3060	2850	2550	2850	2830
	Shalakani	3100	3050	2620	2950	2930
	Dayer El-Berka	7900	7260	5890	5210	6570
	El-Wadi Drain	7600	7130	6380	5620	6680
Manganese (Mn)	El-Shoura	723	548	603	592	617
	Gouda_1	502	463	432	475	468
	Gouda_2	377	332	301	325	334
	Shalakani	446	429	382	352	402
	Dayer El-Berka	700	586	606	656	637
	El-Wadi Drain	632	562	578	562	584
Copper (Cu)	El-Shoura	33.2	29.2	28.9	30.6	30.5
	Gouda_1	32.0	27.1	28.8	32.0	30.0
	Gouda_2	28.7	24.3	27.5	26.9	26.9
	Shalakani	30.2	24.2	26.1	27.5	27.0
	Dayer El-Berka	50.3	49.4	40.7	45.6	46.5
	El-Wadi Drain	38.4	37.7	39.3	41.5	39.2
Zinc (Zn µg/g)	El-Shoura	128.0	139.0	143.0	148.0	139.5
	Gouda_1	180.0	165.0	175.0	144.0	166.0
	Gouda_2	125.0	140.0	155.0	135.0	138.8
	Shalakani	165.0	199.0	185.0	205.0	188.5
	Dayer El-Berka	255.0	248.0	315.0	235.0	263.3
	El-Wadi Drain	217.0	215.0	235.0	204.0	217.8
Lead (Pb)	El-Shoura	36.5	28.8	32.6	34.4	33.1
	Gouda_1	27.2	23.8	27.5	30.2	27.2
	Gouda_2	29.6	27.1	28.9	32.7	29.6
	Shalakani	23.8	19.0	20.2	22.4	21.4
	Dayer El-Berka	25.3	24.2	23.8	28.9	25.6
	El-Wadi Drain	15.2	14.2	16.6	18.1	16.0
Cadmium (Cd)	El-Shoura	5.2	4.1	4.6	4.7	4.7
	Gouda_1	5.0	4.0	4.3	4.6	4.5
	Gouda_2	4.1	3.6	3.3	3.6	3.7
	Shalakani	4.7	4.2	3.9	4.1	4.2
	Dayer El-Berka	10.8	9.3	8.7	8.8	9.4
	El-Wadi Drain	9.6	8.1	7.5	7.8	8.3

contents in the sediments increased during cold period (winter and autumn) while decreased during hot period (summer and spring)

Organic matter content in the farm's sediments showed obvious elevated values especially during summer (Table 4). El-Shoura farm sustained the highest value (36.05 %) while Gouda_2 showed the lowest organic matter content (9.1 %). Organic matter contents in farm's sediments exceeded several times that recorded for Lake Qarun (2.59 - 9.09 %) and relatively increased that of Lake Manzalah (3.69 - 31.86 %) (Goher, 2002; Ahmed and Elaa, 2003).

The organic matter content in the two drains showed lower values than that of the ponds, nevertheless Dayer El-Berka also, had the higher organic matter content more than El-Wadi Drain during the study period.

Cluster analyses of the studied stations revealed two groups, El-Shoura–Gouda_1 farms and Goud_2–Shalakani farms, respectively. The highest similarity index (95.1 %) was recorded within the first group, while the second group showed a similarity index of 94.2 % (Fig. 1). Moreover, the cluster analyses for the studied metals showed four distinct groups having a similarity index ranging from (73.5 %-95.5 %). The highest similarity indexes recorded for copper and zinc in sediments with copper in water and cadmium in sediments and water with iron in water (Fig. 2).

Fish Diets

The fish farms used different types of fish diets. The first pond (El-Shoura farm) was fed with diet (15 % crude protein), mixed from maize, wheat bran, poultry manure, cotton seed oil and vitamin, mineral mixture. The second and third ponds (Gouda_1 & 2 farm) were fed with prepared diet (20 % crude protein), formulated from fish meal, soybean meal, maize, rice bran, cotton seed oil and vitamin, mineral mixture. The fourth pond (Shalakani farm) was fed with commercial diet (25 % crude protein), from fish meal, soybean, maize, wheat bran, rice bran, cotton seed oil and vitamin, mineral mixture. The diets offered for each pond twice daily with about 4 % of total fish masses in each pond.

The heavy metal contents in fish diets showed warrant concerned values because these diets were considered as additional ambient heavy metal sources which tended to accumulate in the different fish organs and the residue accumulated in the sediments and thus liberated again to the water column.

Table (4): Seasonal variations of organic matter (%) in the sediments of the studied area during 2003

Stations \ Seasons	Winter	Spring	Summer	Autumn	Mean
El-Shoura	11.76	26.25	36.05	24.71	24.69
Gouda_1	11.76	18.90	19.60	11.90	16.75
Gouda_2	9.10	10.85	10.85	10.50	10.27
Shalakani	15.40	21.00	22.75	15.58	19.72
Dayer El-Berka	13.50	15.20	21.50	12.60	16.73
El-Wadi Drain	12.60	11.50	18.90	10.80	14.33

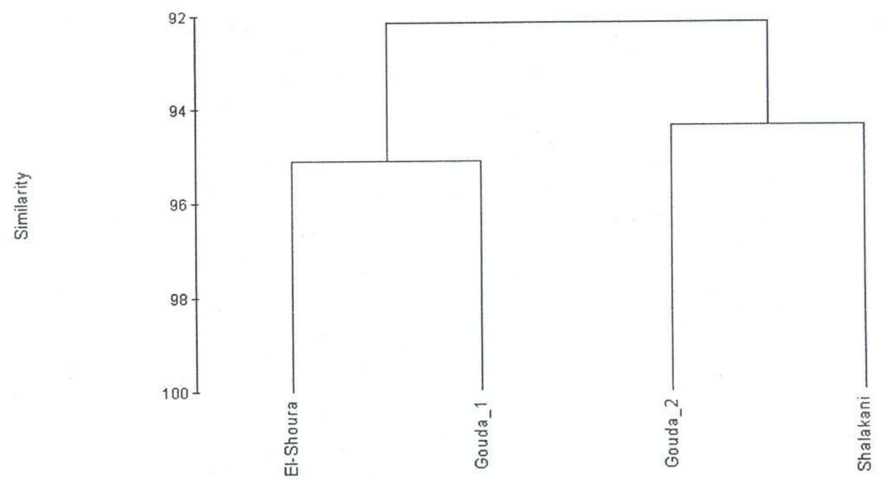

Figure (1): Cluster analyses according to sampling station

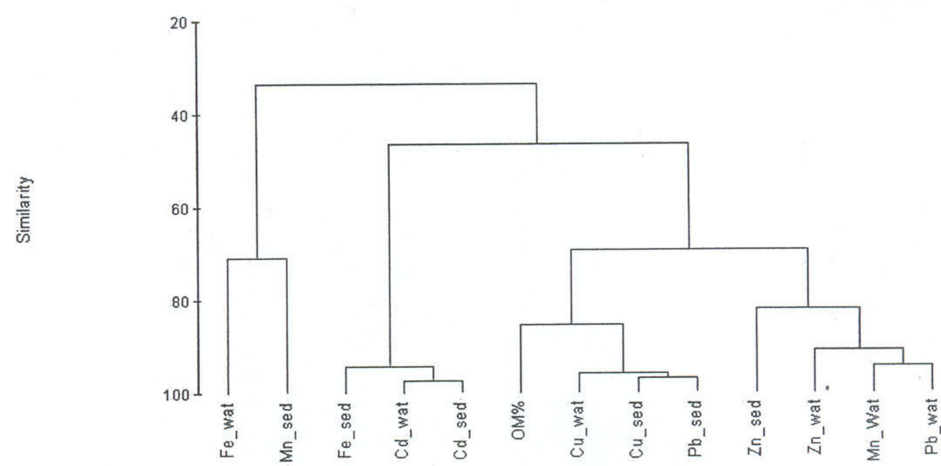

Figure (2): Cluster analyses according to studied metals

The obtained results of heavy metals in fish diets showed a slight variations in their concentration among different ponds as shown in Table 5. The values of iron, manganese, copper, zinc, lead and cadmium varied in the ranges of 230 - 263, 77.4 - 113.5, 33.8 - 38.5, 115.3 - 131.6, 6.3 - 7.2 and 2.7 - 3.2 µg/g, respectively.

Fish

The main fish species in the fish farms were *Tilapia* and *Mugil* species. However, *Mugil* sp. a is bottom feeder fish, while *Tilapia* sp. is a filter feeder. Both Goud_1 and Shalakani farms were monoculture of Tilapia while El-Shoura and Goud_2 farms were polyculture of mixed Tilapia and Mullet. Iron and manganese, exhibited similar accumulation trends in the two fish species, where *Tilapia* sp. showed a pronounced high accumulation values more than *Mugil* sp. Also, showed their maximum values in El-Shoura farm and minimum one in Gouda_2 farm for iron and Shalakani farm for manganese (Table 6). The values ranged between 63.5-120.0 and 70–96 µg/g dry wt for iron in *Tilapia* sp. and *Mugil* sp. respectively. However, in case of manganese, the values ranged between 21.33-33.0 and 20.5-28.5 µg/g dry wt in *Tilapia* and *Mugil* species respectively.

The copper content ranged between 8.2-11.6 and 10.5-12.3 µg/g dry wt for *Tilapia* sp. and *Mugil* sp., respectively. The highest copper content for *Tilapia* sp. was recorded in Gouda_1 farm while for *Mugil* sp. it was recorded in El-Shoura farm (Table 6).

The zinc contents fluctuated between 49.2 - 66.3 and 78.7 - 83.2 µg/g dry wt for *Tilapia* sp. and *Mugil* sp., respectively. The highest zinc content was recorded in Gouda_2 farm for *Tilapia* sp. and *Mugil* sp., respectively (Table 6).

The lead contents varied in the ranges of 4.8 - 6.5 and 6.9 - 8.3 µg/g dry wt for *Tilapia* sp. and *Mugil* sp., respectively. The highest lead content was recorded in El-Shoura farm for the two species, respectively (Table 6).

The cadmium contents ranged between 1.9 - 2.7 and 2.4 - 2.9 µg/g dry wt for *Tilapia* sp. and *Mugil* sp., respectively. The highest cadmium content for *Tilapia* sp. was recorded in Gouda_1 farm while for *Mugil* sp. it was recorded in El-Shoura farm.

From the above results, it is clear that *Mugil* species tended to accumulate higher concentration of heavy metals (Cu, Zn, Pb, and Cd) than *Tilapia* species. These results coincidence with that values given by (Ali, 2002; Ali and Fishar, 2005) who reported that *Mugil* sp. and Solea sp. tended to accumulate more heavy metals than *Tilapia* sp. in Lake Qarun.

DISCUSSION

The contamination of soils, sediments, water resources, and biota by heavy metals is of important concern especially in many industrialized countries because of their toxicity, persistence and bioaccumulative nature (Ikem *et al*., 2003).

It is clear from above mentioned result that the distribution of heavy metals in fish farms showed an elevate values in the first pond (El-Shoura farm) where generally subjected to wastes coming from the other fish ponds. However, the dispersed fish farms in this area haven't drainage system, so each pond drained its wastewater to the following one and so on till reaching to Dayer El-Berka Drain. Thus the ponds situated at the end of farms e.g. El-Shoura pond nearby the drain almost subjected to most of fish farms wastes. Where Goud_2 fish farm almost showed lesser values of the heavy metals, due to its location near Lake Qarun leading to the elevation of its water salinity. This factor facilitates precipitation most heavy metals onto sediments (Luoma, 1990). In addition it is located far from the polluted wastes from the adjacent fish pond.

Table (5): Heavy metals contents (µg/g dry wt) in the fish diets during 2003

Metal / Farm	Iron	Manganese	Copper	Zinc	Lead	Cadmium
El-Shoura	230	77.4	35.6	125.4	6.5	3.2
Gouda_1&2	263	113.5	38.5	115.3	7.2	3.0
Shalakani	250	82.8	33.8	131.6	6.3	2.8

Table (6): Variation of heavy metal concentrations (µg/g dry wt) in *Tilapia* sp. and *Mugil* sp. in the studied fish farms during 2003.

Metal	Stations / Fish species	El-Shoura	Gouda_1	Gouda_2	Shalakani
Iron (µg/g)	***Tilapia* sp.**	120.0	63.6	75.0	84.3
	***Mugil* sp.**	96.0	NA	70.0	NA
Manganese (µg/g)	***Tilapia* sp.**	33.0	22.1	24.1	21.3
	***Mugil* sp.**	28.5	NA	20.5	NA
Copper (µg/g)	***Tilapia* sp.**	10.3	11.6	8.2	9.3
	***Mugil* sp.**	12.3	NA	10.5	NA
Zinc (µg/g)	***Tilapia* sp.**	63.2	56.5	66.3	49.2
	***Mugil* sp.**	78.7	NA	83.2	NA
Lead (µg/g)	***Tilapia* sp.**	6.5	5.5	4.8	5.4
	***Mugil* sp.**	8.3	NA	6.9	NA
Cadmium (µg/g)	***Tilapia* sp.**	2.2	2.7	1.9	2.0
	***Mugil* sp.**	2.9	NA	2.4	NA

NA: Not available

The distribution patterns of heavy metals in the water increased in the hot seasons (spring and summer) which may be attributed to the release of heavy metals from sediments to the overlying water under the effect of both high temperature and fermentation process resulted from decomposition of organic matter (Elewa *et al*., 2001). Moreover, these increase in water coincided with the decrease in the same metal's values in the sediments. In addition, the values of heavy metals showed an obvious decrease in the water during cold period (winter and autumn) with a correspondent increase in the sediments due to precipitation of heavy metals from water column to the sediments under high pH values and the adsorption of heavy metals onto organic matter and their settlement downward (Goher, 2002).

The organic matter in the sediments plays an important role in the accumulation and release of pollutants in the water, and it is a source of nutrients for the living fauna (Ahmed and Elaa, 2003). The values of organic matter in the sediments were high during hot seasons which, might be attributed to the flourishing of phyto- and zooplankton, leading to high organic productivity during this period especially spring (Boyd and Tucker, 1979). On the other side, their lowest values were recorded during cold seasons especially winter as the result of decomposition of organic matter in the presence of high dissolved oxygen content (Wahby *et al*., 1972 and Abdo, 2004).

Because most trace metals tend to accumulate in the different body organs, these metals are dangerous for fish and in turn they lead to serious problems in both man and animals (Marzouk, 1994). Fishes may absorb dissolved elements and trace metals from its feeding diets and surrounding water leading to their accumulation in various tissues in significant amounts and exhibit eliciting toxicological effects at target criteria (McCarthy and Shugart, 1990).

The concentrations of heavy metals (Cu, Zn, Pb and Cd) in the fish samples indicate that *Mugil* sp. seemed to be more contaminated than *Tilapia* sp., while for Fe and Mn Tialpia sp. showed a more accumulation trend than *Mugil* sp.

These observations are mainly due to the different fish habitat and the influence of the surrounding ecosystem status. These results are coincidence with that reported by Abdel-Hamid and El-Zareef (1996), Zyadah (1997) and Abdel-Baky *et al* (1998) for *T. zillii* and *C. lazera* of Lake Manzalah .

CONCLUSION

The values of most studied heavy metals were higher than that permitted by U.S. Environmental Protection Agency (1985). However, the permissible levels for water usage were (300 µg/l), (100 µg/l), (20-50 µg/l), (5 mg/l), (50 µg/l) and (5 µg/l) for Fe, Mn, Cu, Zn, Pb and Cd, respectively.

the obtained results revealed that the studied fish farms suffered from serious environmental problems such as poor water quality criteria of used water, improper management and absence of scientific monitoring. Therefore, by time the heavy metals problems cause toxicological effects for the end user and costumers.

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