Egypt J. Aquat. Biol. & Fish., Vol. 13, No. 2: 81-100 (2009) ISSN 1110 –1131

Seasonal variations of heavy metals concentrations in mullet, *Mugil cephalus* and *Liza ramada* (Mugilidae) from Lake Manzala , Egypt

Mohamed H. Bahnasawy, Abdel Aziz A. Khidr, Nadia A. Dheina
Zoology Department, Damietta Faculty of Science, Damietta, Egypt

ABSTRACT

Seasonal variations in the concentrations of four heavy metals; zinc (Zn), copper (Cu), lead (Pb) and cadmium (Cd), were determined in gills, skin and muscles of two fish species (*Mugil cephalus and Liza ramada*) from five locations in Lake Manzala . The average concentrations of the metals in fish tissues exhibited the following order: Zn>Cu>Pb>Cd. The statistical analysis revealed a significant effect of seasons, locations and fish tissues for all metals measured. The highest values of the metals were recorded in hot seasons (summer and spring). Fish samples from location V (Bahr El-Bakar) displayed the highest metal concentrations in their tissues. The highest concentrations of heavy metals were found in gills tissue of both fish species, while the lowest ones were recorded in muscles tissue. The values of the metals detected in the edible fish muscles were within the permissible limits.

Key words: Lake Manzala , heavy metals, *Mugil cephalus, Liza ramada*

INTRODUCTION

Fish is one of our most valuable sources of protein food. Worldwide people obtain about 25% of their animal protein from fin fish and shellfish. The protein found in fish is of high biological value, which means that fish can be used as the sole source of protein in the diet. But the real importance of fish in the diet is not its protein, but the omega-3 fat it contains. Omega-3 fatty acids are very important for normal growth and help prevent heart disease because they make the blood less likely to form clots that cause heart attacks.

In Egypt, mullet fish especially *Mugil cephalus* and *Liza ramada* are economically very important fish because they have high market value and have been cultivated successfully by fish farmers.

Aquatic systems became contaminated with heavy metals released from domestic, industrial, mining and agricultural effluents which are continuously discharged into them (Canli *et al*.,1998; Shrivastava *et al*.,2003; Tulonen *et al.*,2006). Many fish species are among the top consumers of trophic pyramids in aquatic ecosystems. In consequence, they are endangered by diet-borne pollutants (e.g heavy metals) transferred along the food chain (Moriarty, 1984; Khallaf *et al*.,1998; Karadede *et al*.,2004). Because heavy metals tend to accumulate in different body organs, these metals are dangerous for fish and in turn they led to serious problems in both man and animals (Currey *et al.*, 1992; Marzouk, 1994).

Fish have been used for many years to determine the pollution status of water, and are thus regarded as an excellent biological marker of metals in aquatic ecosystems (Rashed,2001; Coetzee *et al.*,2002; Benson *et al.*,2007).

Lake Manzala is considered one of the most important lakes in Egypt, that is exposed to high levels of pollutants from industrial, domestic and agricultural resources (Badawy and Wahaab, 1997; Abdel-Baky *et al.,* 1998b; Ibrahim *et al.*, 1999).

The main objective of this study is to evaluate heavy metals concentration in muscles, gills and skin of *Mugil cephalus* and *Liza ramada* collected from different sites in the lake during different seasons.

MATERIALS AND METHODS

Fish samples (*Mugil cephalus* and *Liza ramada*) were collected from five sites in Lake Manzala (Fig.1).

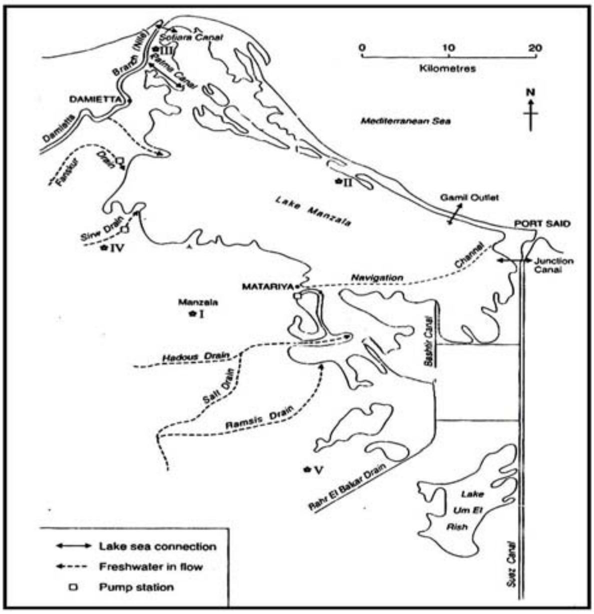

Fig. (1): Location of sampling sites (*) in Lake Manzala ; El-Manzala (I), El-Diba (II), El-Ratama (III), El-Sirw (IV) and Bahr El-Bakar (V)

These sites were chosen in relation to contamination gradients. Sites I&IV receive agricultural drainage water via Hadous and El-Sirw drains. Sites II&III are impacted partially by brackish water from the south eastern side of the lake and the saline water of Mediterranean Sea in the north. Site V receives huge amounts of sewage and industrial wastes via Bahr El-Bakar drain. The fish samples were placed in ice box and immediately brought to the laboratory, where they were kept deeply frozen at -20^oC until the samples were prepared for digestion and analysis. Before analysis, each individual fish was measured , weighed and dissected where pieces of gill, skin without scales and epaxial muscle were taken, placed in separately pre-weighed acid cleaned flasks, dried at 80^oC using an oven and digested on a hot plate using Nitric acid and Perchloric acid (2:1). Completely digested samples were filtered through an acid-resistant filter paper and the filtrate made up to a known volume (20 ml) with distilled water (Canli *et al*., 1998).

Assessment of metals (Zn, Cu, Cd and Pb) levels in the prepared samples were carried out using an Atomic Absorption Spectrophotometer at Chemistry Department, Damietta Faculty of Science, Mansoura University. Statistical analysis of the obtained data was carried out using SPSS program. Two-Way ANOVA was employed to find the significant difference of heavy metals concentrations in fish organs with regard to sites and seasons. The significance level was $P<0.05$(Bailey, 1982).

RESULTS

Mean concentrations and associated standard deviations of Cu, Zn, Cd and Pb in gills, skin and muscle of *M.cephalus* and *L.ramada* from 5 stations in Lake Manzala are shown in tables (1-8). Figure 1 shows the sampling stations in Lake Manzala . The measured metals in the two fish species showed highly significant difference between organs, stations and seasons ($P<0.05$). Station V generally showed the highest heavy metal concentrations. Different tissues showed different capacities for accumulating heavy metals. The highest metal concentrations were found in gills, while the lowest levels of the metals were recorded in muscle. Metals concentrations in gills, skin and muscle of the examined fish follow the sequence: Zn > Cu >Pb >Cd.

Metals accumulation in *M. cephalus*:

Cu concentration in gills, skin and muscle ranged from 12.78 to 17.57, from 7.59 to 10.53 and from 3.56 to 5.68 µg/g dry weight respectively. Summer had the highest Cu concentration, while the lowest was occurred during winter (Table 1).

Zn concentration ranged from 48.18 to 141.98 in gills, from 27.4 to 89.61 in skin and from 13.21 to 38.42 µg/g dry weight in muscle. The highest concentrations of Zn in the different fish organs were found during summer, while the lowest levels were recorded during winter (Table 2).

Cd concentration in gills ranged from 3.14 to 6.26 µg/g dry weight, while its concentration in skin ranged from 1.99 to 3.01 and in muscle from 1.08 to 1.71 µg/g dry weight. The highest levels of Cd in gills, skin and muscle were recorded during summer (Table 3).

Pb concentration in gills, skin and muscle were observed to be from 8.21 to 12.67, from 2.32 to 3.71 and from1.66 to 2.98 µg/g dry weight respectively.

The higher value of Pb was recorded during summer for gills and muscle, and during spring for skin (Table 4).

Metals accumulation in *L. ramada:*

Cu concentration fluctuated from 8.13 to 19.97 in gills, from 5.74 to 9.55 in skin and from 3.03 to 4.66 µg/g dry weight in muscle. The highest levels of Cu were reported in summer for skin, in spring for gills and muscle (Table 5).

Zn concentration in gills ranged from 46.9 to 138.30, in skin from 27.10 to 86.40 and in muscle from 12.60 to 36.90 µg/g dry weight. Zn levels were highest in summer for gills and muscle, in spring for skin (Table 6).

Cd levels ranged from 1.63 to 5.92 in gills, from 1.04 to 2.15 in skin, and from 0.51 to 1.11 µg/g dry weight in muscles. The highest Cd values were recorded in summer for gills, skin and muscle (Table 7).

Pb concentration varied from 5.36 to 11.52 in gills, from 2.31 to 3.31 in skin, and from 1.43 to 2.43 µg/g dry weight in muscle. Higher Pb values were recorded in summer for gills and in spring for skin and muscle (Table 8).

DISCUSSION

Fish samples from station V displayed the highest metal concentrations in their tissues. This confirms the previous findings on the same station since it receives huge amounts of sewage, industrial and agricultural wastes via Bahr El-Bakar drain, which collects these pollutants from different districts through its way from Cairo (Badawy and Wahaab, 1997; Abdel-Baky *et al*.,1998a&b; Ibrahim *et al*.,1999a; Abdel-Baky, 2001; Bahnasawy, 2001; Khalil and Faragallah, 2008). The fore mentioned authors demonstrated that fish surviving at highly polluted areas accumulate higher levels of heavy metals than those surviving at less polluted area of the same lake.

The phenomenon that different metals are accumulated at different concentrations in various organs and tissues of fish was observed in the present study. The difference in the levels of accumulation in different organs/tissues of a fish can primarily be attributed to the differences in the physiological role of each organ. Regulatory ability, behavior and feeding habits are other factors that influence the accumulation differences in different organs (Kotze *et al.,* 1999). Gills of the examined fish contained the highest concentration of all the detected metals, while muscles appeared to be the least preferred site for the bioaccumulation of metals. Higher metal concentrations in the gills could be due to the element complexion with the mucus that is hardly removed from the gill lamellae before tissue analysis (Karadede *et al.,* 2004). The adsorption of metals onto the gills surface, as the first target for pollutants in water, could also be an important influence in the total metal levels of the gill (Heath, 1987). Target organs, such as the liver and gills, are metabolically active tissues and accumulate heavy metals in higher levels, as shown in many species of fish in different areas: in *M. cephalus* in the Mediterranean Sea (Abdel-Moneim *et al*.,1994), in *Clarias gariepinus* and *Labeo umbratus* from Olifants River, South

Africa (Coetzee *et al*.,2002), in *Cyprinus carpio* and *Tinca tinca* from Lake Beysehir, Turkey (Altindag and Yigit, 2005), in *Liza abu* from Ataturk Dam Lake, Turkey (Karadede *et al*., 2004), in *Oreochromis mossambicus* and *Clarias gariepinus* from Olifant River, South Africa (kotze *et al.,*1999), in *Liza abu* from Tigris River, Turkey (Unlu *et al*.,1996), in *Tilapia zilli* from River Nile (Hamed,1998), in *M.cephalus* from the northeast Mediterranean Sea, Turkey (Kalay *et al*.,1999; Canli and Atli, 2003). In support to this, Deb and Fukushima (1999) added that metals may be in high concentrations in the gills, intestine and digestive glands. These organs have relatively high potential for metal accumulation.

Muscles in the present study, contained the lowest levels of heavy metals. This result agrees with many authors who reported that muscle is not an active tissue in accumulating heavy metals (Unlu *et al.,*1996 ; Canli *et al*., 1998; Ibrahim *et al.,*1999a&b ; Kalay *et al.*, 1999; Canli and Atli,2003; Karadede *et al*., 2004 ; Yilmaz, 2005 and Chouba *et al.*, 2007). The concentration of heavy metals in the present study, was higher in skin samples than in muscles. The reason for high metal concentration in the skin could be due to the metal complexion with the mucus that is impossible to be removed completely from the tissue before the analysis (Yilmaz, 2005). In this respect, Coetzee *et al*. (2002) mentioned that skin is an important excretory organ for heavy metals by means of the mucus.

In the present study, the levels of heavy metals in different fish organs showed highly significant differences between seasons. The measured metals attained their maximum values during summer, while their lowest values were found during winter. The concentration of metals in the surrounding water was also higher in summer and lower in winter (Bahnasawy *et al.*, in press). On the other hand, Ansari *et al*.(2004) reported that variations of the metals concentration at a given site may be often due to seasonal changes of the organisms tissues weight rather than to any variability in the absolute metal content of the organism. The seasonal variations of heavy metals in fish were reported by many authors (Zyadah, 1997; Hamed, 1998; Khallaf *et al*., 1998; Ibrahim *et al*., 1999a&b; Ibrahim *et al*., 2000).

The results of the present study showed that metals were more concentrated in *M. cephalus* tissues than those of *L. ramada*. Species differences in heavy metal bioaccumulation could be ascribed to differences in feeding habits and behaviour of the species (Kotze *et al*., 1999; Ibrahim *et al.,* 1999a&b; Mormede and Davies, 2001; Coetzee *et al*., 2001; Canli and Atli, 2003; Ali and Abdel-Satar, 2005; Canbek *et al*., 2007). Although both *M.cepalus* and *L.ramada* are pelagic fish, they differ in habitat and feeding behaviour. *M.cephalus* tends to live near the sediment region. Kilgour (1991) indicated that animals which have close relationship with sediment, show relatively high body concentrations of metals.

Compared with other studies, Windom *et al*. (1973) found higher levels of Cu (19.0) and Zn (170.0) µg/g dry wt. in muscles of *M. cephalus* from North Atlantic. Hemens and Connell (1975) measured higher concentration of Zn (42-61) and lower level of Pb (0.68-0.73) µg/g dry wt. in the muscle of *Mugil* spp. from the Mhlathuze Estuary, South Africa. Enormously higher values of Zn (210.0) and Cu (43.0) µg/g dry wt were found by Bebbington *et al*. (1977) in the muscle of *M. cephalus* from the coast of Australia. *M. cephalus* from the northern coast of Mauritania in the Atlantic ocean showed lower levels of Cu (2.3), Cd (<0.1) and Pb (<0.5) but a higher level of Zn (142) ppm dry wt. (Romeo, 1987). *M. cephalus* from the middle eastern coast of Tunisia showed in their muscle higher levels of Cu (4.78), Zn (45.0), but lower level of Cd (0.07) µg/g dry wt respectively (Hamza-Chaffai *et al*., 1996). Muscles and gills of *Liza abue* from the Tigris River (Turkey) accumulated enormously higher concentrations of Cu (23.16, 78.46) and Zn (27.26, 88.74) µg/g dry wt respectively (Unlu *et al*., 1996). Abdelhamid *et al*. (1997) recorded higher levels of Zn (113.0-153.0), Pb (13.7-15.0) and Cd (1.54-1.48) µg/g dry wt in muscles of *M.cephalus* from the western region of Lake Manzala . Blasco *et al*. (1998) measured a remarkably high concentrations of Cu and Zn in the muscle of five European Atlantic grey mullet species (*L. saliens, L. aurata, L. ramada, M. cephalus and Chelon labrosus*). *M.cephalus* from the Northeast Mediterranean Sea showed in their muscles higher concentrations of Zn (26.13) and Pb (6.25), but lower levels of Cu (4.48) and Cd (0.96) µg/g dry wt. Gills of the same fish had lower accumulations of Cu (7.01), Zn (43.2) and Cd (2.28) and higher level of Pb (20.84) µg/g dry wt. (Kalay *et al*. 1999). Canli and Atli (2003) recorded also higher concentrations of Zn (37.39) and Pb (5.32) and lower Cu (4.41) and Cd (0.66) µg/g dry wt. in the muscle of *M. cephalus* from the North east Mediterranean Sea. The gills of this fish showed lower accumulations of Cu (13. 48), Zn (71.21), Cd (2.08) but higher Pb (8.95) µg/g dry wt. The variation of heavy metal concentrations in fish from different areas of the world may be possibly due to differences in metal concentrations and chemical characteristics of water from which fish were sampled, ecological needs, metabolism and feeding patterns of fishes and also the season in which studies were carried out (Canli *et al*., 1998). According to NHMRC (1987) (cited after Beldi *et al.,* (2006)), the values of heavy metals in the muscles of *M. cephalus* and *L. ramada* were low as compared to the maximum acceptable limits. Therefore, fish muscles in the present study are considered safe for human consumption.

REFERENCES

Abdel moneim, M.; Khaled, A. and Iskander, M.(1994). A study on the levels of some heavy metals in EL-mex, west of Alexandria ,Egypt .The 4th conf. of the Environ. Prot. is a must, 10-12 May: 155-174.

Abdel-Baky, T. E.; Hagras, A. E.; Hassan, S. H. and Zyadah, M. A. (1998a). Environment assessment of pollution in Lake Manzalz. 1- Distribution of some heavy metals in water and sediment. J. Egypt. Ger. Soc. Zool., 26 (B): 25-38.

Abdel-Baky, T. E.; Hagras, A. E.; Hassan, S. H. and Zyadah, M. A. (1998b). Heavy metals concentration in some organs of *Oreochromis aureus* stein in Lake Manzala, Egypt. J. Egypt. Ger. Soc. Zool., 25(A): 237-256.

Abdelhamid, A. M.; Asmaa, A.; El-Kerdawy, A. A.; El-Mezaien, A. and Meshref, H. A. (1997). Study on pollution in the Western-North region of El-Manzalah Lake, Egypt. J. Agric. Sci. Mansoura Uiv., 22 (6): 1877-1885.

Abdel-moneim, M. A.; Khaled, A. M. and Iskander, M. F. (1994). A study on the levels of some heavy metals in El-Mex, West of Alexandria, Egypt. Proc. 4th conf. of the Envir. Prot. Is a must, 10-12 May, pp: 155-174.

Ali, M. and Abdel –Satar ,A. (2005). Studies of some heavy metals in water, sediment, fish and fish diets in some fish farms in EL-Fayoum province. Egypt. J. Aquat. Res. 31(2):261-273.

Altindag, A. and Yigit, S. (2005). Assessment of heavy metal concentration in the food web of lake Beysehir, Turkey. Chemosphere .60:552-556.

Ansari, T.; Marr, I. and Tariq, N. (2004). Heavy metals in marine pollution perspective- A mini review. Journal of applied science, 4 (1): 1-20.

Badawy, M. I. and Wahaab, R. A. (1997). Environmental impact of some chemical pollutants on Lake Manzala. International Journal of Environmental Health Research, 7: 161-170.

Bahnasawy, M. (2001). Levels of heavy metals in cat fish, Clarias gariepinus, from different habitats and their effects on some biochemical parameters. Egypt. J. Aquat. Biol.& Fish., 5(1): 99-125.

Bahnasawy,M.; Khidr,A. and Dheina,N. (in press). Assessment of heavy metals concentration in water, plankton and fish of Lake Manzala, Egypt.

Bailey, N. (1982). Statistical methods in biology. 2nd Ed. (Biological Science Texts), pp. 216.

Bebbington, G.; Mackay, N.; Chvojka, R.; Williams, R.; Dunn, A. and Auty, E. (1977). Heavy metals, selemium and arsenic in nine species of Australian commercial fish. Aust. J. Mar. Fresh Res. 28: 277-286.

Beldi, H.; Gimbert, F.; Maas, S.; Scheifler, R. and Soltani, N.(2006). Seasonal variations of Cd, Cu, Pb and Zn in the edible mollusk *Donax trunculus* (Mollusca, Bivalvia) from the gulf of Annaba, Algeria. Afric. J. Agric. Res.1 (4):85-90.

Benson, N.; Essien, j.; Williams, A. and Bassey, D. (2007). Mercury accumulation in fishes from Tropical aquatic ecosystem in the Niger Delta , Nigeria .Current Science . 92(6)781-785

Blasco, J.; Rubio, J. A.; Forja, J.; Gomez-parra, A. and Establier, R. (1998). Heavy metals in some fishes of the mugilidae family from salt-ponds of Cadiz Bay, Spain. Ecotoxicol. Environ. Restor., 1 (2): 71-77.

Blasco, J.; Rubio, J. A.; Forja, J.; Gomez-parra, A. and Establier, R. (1998). Heavy metals in some fishes of the Mugilidae family from salt- ponds of Cadiz Bay, Spain. Ecotoxicol. Environ. Restor., 1 (2): 71-77.

Canbek, M.; Demir, T; Uyanoglu, M; Bayram O.; Emiroglu, O.; Arslan, N. and koyuncu, O. (2007). preliminary assessment of heavy metals in water and some Cyprinidae species from the porsuk River ,Turkey. j. Appl . Biol .sci. 3: 91-95.

Canli, M. and Atli, G. (2003). The relationships between heavy metal (Cd, Cr, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environ. Pollut., 121:129-136.

Canli, M.; Ay, Ö. and Kalay, M. (1998). Levels of heavy metals (Cd, Pb, Cu, Cr and Ni) in tissues of *Cyprinus carpio*, *Barbus capito* and *Chondrostoma regium* from the Seyhan River, Turkey. Turkish, J. Zoolo., 22: 149-157.

Chouba .L.; Kraiem, M.; Njimi, W.; Tissaoui, C.; Thompson, J. and Flower, R. (2007). Seasonal Variation of heavy metals (Cd, Pb, and Hg) in sediments and mullet , *Mugil cephalus* (Mugilidae) from the Ghar EL-Melh Lagoon (Tunisia). Transitional water Bulletin, 4:45-52.

Coetzee, L.; du Preez, H. H. and van Vuren, J. H. (2002). Metal concentrations in *Clarias gariepinus* and *Labeo umbratus* from the Olifant and Klein Olifants River, Mpumalanga, South Africa: Zinc, copper, manganese, lead, chromium, nickel, aluminium and iron. Water SA, 28 (4): 433-448.

Currey, N.; Benko, W.; Yaru, B. and Kabi, R. (1992). Determination of heavy metals, arsenic and selenium in barramundic (*Lates calcorifer*) from Lake Murray, Papua, New Guinea. Sci. Total Environ., 128:305-320.

Deb, S. and Fukushima, T. (1999). Metal in aquatic ecosystem: mechanisms of uptake, accumulation and release. Int. J. Environ. Stud., 56(3):385-433.

Hamed, M. (1998): Distribution of trace metals in the River Nile Ecosystem, Damietta branch between Mansoura city and Damietta Province. J. Egypt. Ger. Soc. Zool. 27(A):399-415.

Hamza-Chaffai, A.; Romeo, M. and El-Abed, A.(1996). Heavy metals in different fishes from the middle eastern coast of Tunisia. Bull.Environ.Contam.Toxicol, 56: 766-773.

Heath, A. (1987) Water pollution and fish physiology. Florida: CRP Press, 245pp.

Hemens, J. and connell, A. D. (1975). Richards Bay: Southern bay conservation area. CSIR/NIWR Progress Report No. 29 CSIR, Durban, South Africa.

Ibrahim, A.; Bahnasawy, M.; Mansy, S. and EL-Fayomy, R. (1999a). Heavy metal accumulation in water, sediment and some fishes in Lake Manzala, Egypt. J. Egypt. Ger. Soc. Zool., 29(B):43-58.

Ibrahim, A.; Bahnasawy, M.; Mansy, S. and EL-Fayomy, R. (1999b). Distribution of heavy metals in the Damietta Nile Estuary ecosystem. Egypt. J. Aquat. Biol & Fish., 3(4) :369-397.

Kalay, M.; Ay, O. and Canli, M. (1999). Heavy metal concentrations in fish tissues from the Northeast Mediterranean Sea. Bull. Environ. Contam. Toxicol, 63:673-681.

Karadede, H; Oymak, S. A. and Ünlü, E. (2004). Heavy metals in mullet, *Liza abu*, and Catfish, *Silurus triostegus*, from the Ataturk Dam Lake (Euphrates), Turkey. Environment Internationl, 30: 183-188

Khalil, M. and Faragallah, H. (2008). The distribution of some leachable and Total heavy metals in core sediments of Manzala lagoon, Egypt. Egypt. J. Aquat. Res., 34(1):1-11.

Khallaf, E. A.; Galal, M. and Authman, M. (1998). Assessment of heavy metals pollution and their effects on *Oreochromis niloticus* in aquatic drainge canals. J. Egypt. Ger. Soc. Zool. 26 (B): 39-74.

Kilgour, B.(1991). Cadmium uptake from cadmium – spiked sediments by four freshwater invertebrates. Bull.Environ.Contam.Toxicol, 47:70-75.

Kotze, P.; du Preez, H.H. and van Vuren, J.H.J.(1999). Bioaccumulation of copper and zinc in *Oreochromis mossambicus* and *Clarias gariepinus* from the Olifants River, Mpumalanga, South Africa. Water S.A., 25(1): 99-110.

Marzouk, M. (1994). Fish and environmental pollution. Vet. Med. J., 42:51-52

Moriarty, F. (1984): Persistent contaminants, compartmental models and concentration along food chains. Ecol. Bull., 36: 35-45.

Mormede, S. and Davies, I. (2001). Heavy metals concentrations in commercial deep-sea fish from the Rockall Trough. Cont. shelf Res., 12(8-10):899-916.

Rashed, M. (2001). Cadmium and lead levels in fish (*Tilapia nilotica*) tissues as a biological indicator for lake water pollution. Environ. Monitor. Assess, 68:75-89.

Romeo, M. (1987). Trace metals in fish roe from the Mauritania coast. Mar. Pollut. Bull., 18: 507-508.

Shrivastava, p.; Saxena, A.; Swarup, A. (2003). Heavy metal pollution in a sewage –fed lake of Bhopal, India. Lakes, Reservoirs: Research and Management, 8:1-4.

Tulonen,T., Pihlstrom,M., Arvola,L., Rask,M.(2006). Concentrations of heavy metals in food web components of small, boreal lakes. Boreal Environ. Res, 11:185-194

Ünlü, E.; Akba, O.; Sevim, S. and Gümgüm, B. (1996). Heavy metal levels in mullet, *Liza abu* (Heckel, 1843) (Mugilidae) from the Tigris River, Turkey. Fresenius Envir. Bull., 5: 107-112.

Windom, H.; Stickeny, R.; Smith, R.; Wite , D and Taylor, F. (1973). Arsenic, cadmium, mercury and zinc in some species of North Atlantic Finfish. Journal of Fisheries Research Board of Canada 30: 275-279.

Yilmaz, B.A. (2005). comparison of Heavy metal levels of grey Mullet *(Mugil cephalus)* and sea Bream (*Sparus aurata*) caught in Iskenderun Bay (Turkey).Turk. J. Vet. Anim. Sci. 29:257-262.

Zyadah, M. (1997). A study on level of some heavy metals in River Nile estuary-Damietta branch, Egypt. Ger. J. Soc. Zool., 23 (A): 149-60.

Table.1: Seasonal variations of copper concentration ((µg/g dry weight) in different organs of *Mugil cephalus* from Lake Manzala .

Organ	**Site**	**Seasons**					**ANOVA**			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
	I	13.720 ± 1.252	14.100 ± 0.894	14.220 ± 0.559	13.910 ± 1.118	13.970 ± 0.939	Site	4	68.782	0.000***
	II	12.780 ± 0.626	13.000 ± 0.716	13.120 ± 0.894	13.030 ± 1.207	12.980 ± 0.805	Season	3	9.691	0.000***
Gills	III	13.050 ± 0.984	13.370 ± 1.006	13.510 ± 1.073	13.360 ± 0.425	13.320 ± 0.850	Organ	2	3392.259	0.000***
	IV	14.290 ± 1.319	14.870 ± 1.856	15.050 ± 1.632	14.870 ± 1.118	14.770 ± 1.386	Site x Season	12	0.858	0.591
	V	15.010 ± 1.453	15.620 ± 0.939	17.570 ± 1.655	15.640 ± 0.738	15.960 ± 1.476	Site x Organ	8	4.028	0.000***
	I	8.460 ± 0.425	8.740 ± 0.581	9.060 ± 0.716	8.920 ± 0.716	8.800 ± 0.626	Season x Organ	6	0.392	0.884
	II	7.590 ± 0.664	7.790 ± 0.559	7.880 ± 0.440	7.640 ± 0.427	7.730 ± 0.492				
Skin	III	7.980 ± 0.872	8.240 ± 0.648	8.320 ± 0.470	8.190 ± 0.648	8.180 ± 0.621	Site	24	0.354	0.998
	IV	8.940 ± 0.783	9.340 ± 0.447	9.460 ± 0.514	9.320 ± 0.537	9.270 ± 0.531	x			
	V	9.700 ± 0.457	10.280 ± 0.380	10.530 ± 0.939	10.330 ± 0.827	10.210 ± 0.716	Season			
	I	4.190 ± 0.521	4.760 ± 0.693	4.850 ± 0.335	4.640 ± 0.760	4.610 ± 0.620	x			
	II	3.560 ± 0.604	3.930 ± 0.470	4.120 ± 0.648	3.890 ± 0.358	3.870 ± 0.537	Organ			
Muscles	III	4.170 ± 0.514	4.380 ± 0.805	4.580 ± 0.671	4.410 ± 0.447	4.390 ± 0.581				
	IV	4.340 ± 0.827	5.130 ± 0.588	5.210 ± 0.984	4.970 ± 0.612	4.910 ± 0.805				
	V	4.530 ± 0.738	5.300 ± 0.581	5.680 ± 0.559	5.350 ± 0.462	5.210 ± 0.716				

Table.2: Seasonal variations of Zinc concentration (µg/g dry weight) in different organs of *Mugil cephalus* from Lake Manzala .

Organ	Site	Seasons					ANOVA			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
Gills	I	51.270 ± 20.326	87.780 ± 25.335	89.770 ± 9.973	56.320 ± 22.741	71.290 ± 26.028	Site	4	55.012	0.000***
	II	49.280 ± 20.684	52.320 ± 8.877	72.310 ± 18.045	51.020 ± 13.327	56.230 ± 17.441	Season	3	83.095	0.000***
	III	48.180 ± 28.733	59.160 ± 13.372	83.720 ± 20.326	66.860 ± 15.429	64.480 ± 22.897	Organ	2	443.004	0.000***
	IV	61.240 ± 17.307	92.450 ± 6.820	102.990 ± 17.710	76.880 ± 19.051	83.390 ± 21.869	Site x Season	12	2.743	0.002**
	V	67.030 ± 9.839	115.330 ± 29.158	141.980 ± 10.219	99.500 ± 19.856	105.960 ± 32.825	Site x Organ	8	6.037	0.000***
Skin	I	31.410 ± 6.485	53.610 ± 9.503	62.660 ± 21.735	33.770 ± 6.954	45.360 ± 17.933	Season x Organ	6	11.231	0.000***
	II	27.400 ± 3.779	36.670 ± 8.475	54.890 ± 11.874	29.420 ± 5.188	37.100 ± 13.327				
	III	30.480 ± 6.350	52.200 ± 10.957	68.200 ± 10.800	31.070 ± 9.011	45.490 ± 18.380	Site	24	0.954	0.528
	IV	32.940 ± 7.960	61.570 ± 6.977	80.620 ± 13.059	41.480 ± 11.806	54.150 ± 21.153	x			
	V	35.930 ± 4.517	77.310 ± 14.870	89.610 ± 4.673	56.830 ± 6.954	64.920 ± 22.450	Season			
Muscles	I	17.720 ± 7.021	23.470 ± 6.082	26.680 ± 7.491	21.080 ± 3.913	22.240 ± 6.663	x			
	II	13.210 ± 2.124	16.940 ± 3.712	20.320 ± 4.092	15.310 ± 4.271	16.440 ± 4.293	Organ			
	III	17.260 ± 2.728	20.620 ± 4.047	22.950 ± 4.852	20.570 ± 4.114	20.340 ± 4.249				
	IV	23.390 ± 2.817	29.250 ± 6.015	32.020 ± 5.322	25.120 ± 1.744	27.450 ± 5.277				
	V	25.530 ± 3.175	34.550 ± 9.168	38.420 ± 9.118	29.540 ± 5.255	32.010 ± 8.273				

Table.3: Seasonal variations of cadmium concentration (µg/g dry weight) in different organs of *Mugil cephalus* from Lake Manzala .

Organ	Site	Seasons					ANOVA			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
Gills	I	3.470 ± 1.006	4.180 ± 1.118	4.240 ± 1.163	3.730 ± 0.671	3.900 ± 0.984	Site	4	29.521	0.000***
	II	3.140 ± 0.738	3.320 ± 0.514	3.620 ± 0.693	3.410 ± 0.537	3.370 ± 0.526	Season	3	7.685	0.000***
	III	3.460 ± 0.470	4.120 ± 0.211	4.230 ± 0.931	4.100 ± 1.275	3.980 ± 0.850	Organ	2	605.169	0.000***
	IV	4.840 ± 1.699	5.120 ± 0.648	5.610 ± 0.962	5.390 ± 0.626	5.240 ± 1.029	Site x Season	12	0.143	1
	V	5.340 ± 1.766	5.620 ± 1.342	6.260 ± 1.252	5.930 ± 1.207	5.790 ± 1.342	Site x Organ	8	12.051	0.000***
Skin	I	2.040 ± 0.176	2.260 ± 0.268	2.530 ± 0.124	2.410 ± 0.268	2.310 ± 0.268	Season x Organ	6	0.661	0.681
	II	1.990 ± 0.112	2.130 ± 0.180	2.320 ± 0.169	2.250 ± 0.124	2.170 ± 0.171				
	III	2.010 ± 0.157	2.380 ± 0.086	2.500 ± 0.189	2.440 ± 0.201	2.340 ± 0.224	Site	24	0.131	1
	IV	2.090 ± 0.402	2.350 ± 0.492	2.680 ± 0.581	2.480 ± 0.380	2.400 ± 0.492	x			
	V	2.460 ± 0.604	2.740 ± 0.380	3.010 ± 0.268	2.640 ± 0.358	2.710 ± 0.447	Season			
Muscles	I	1.080 ± 0.134	1.270 ± 0.067	1.500 ± 0.291	1.430 ± 0.216	1.320 ± 0.268	x			
	II	1.180 ± 0.189	1.230 ± 0.119	1.330 ± 0.240	1.280 ± 0.130	1.260 ± 0.179	Organ			
	III	1.230 ± 0.157	1.260 ± 0.201	1.390 ± 0.335	1.410 ± 0.179	1.320 ± 0.221				
	IV	1.310 ± 0.107	1.410 ± 0.137	1.540 ± 0.216	1.470 ± 0.246	1.430 ± 0.224				
	V	1.480 ± 0.648	1.670 ± 0.241	1.710 ± 0.248	1.640 ± 0.271	1.620 ± 0.402				

Table.4: Seasonal variations of lead concentration (μg/g dry weight) in different organs of *Mugil cephalus* from Lake Manzala .

Organ	**Site**	**Seasons**					**ANOVA**			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
Gills	I	9.200 ± 0.827	9.580 ± 1.140	10.170 ± 0.738	9.880 ± 0.783	9.710 ± 0.864	Site	4	71.471	0.000***
	II	8.210 ± 0.604	8.700 ± 1.111	9.250 ± 0.850	9.180 ± 1.096	8.840 ± 0.984	Season	3	10.701	0.000***
	III	9.090 ± 0.201	9.510 ± 0.917	9.900 ± 1.118	9.670 ± 0.514	9.540 ± 0.760	Organ	2	4838.837	0.000***
	IV	9.820 ± 0.671	10.120 ± 1.275	10.460 ± 1.185	10.220 ± 1.140	10.160 ± 1.029	Site x Season	12	0.250	0.995
	V	11.470 ± 0.894	12.480 ± 0.738	12.670 ± 1.140	12.300 ± 0.648	12.230 ± 0.939	Site x Organ	8	14.252	0.000***
Skin	I	2.540 ± 0.446	2.880 ± 0.693	3.060 ± 0.537	2.880 ± 0.268	2.840 ± 0.537	Season x Organ	6	1.275	0.269
	II	2.320 ± 0.436	2.550 ± 0.517	2.960 ± 0.442	2.720 ± 0.243	2.640 ± 0.472				
	III	2.530 ± 0.335	2.720 ± 0.537	3.170 ± 0.470	2.950 ± 0.335	2.840 ± 0.447	Site	24	0.232	1
	IV	2.810 ± 0.246	3.080 ± 0.380	3.290 ± 0.693	3.060 ± 0.492	3.060 ± 0.452	x			
	V	3.680 ± 0.470	3.710 ± 0.447	3.410 ± 0.415	3.700 ± 0.318	3.630 ± 0.402	Season			
Muscles	I	1.940 ± 0.221	2.110 ± 0.268	2.280 ± 0.537	2.200 ± 0.224	2.130 ± 0.322	x			
	II	1.660 ± 0.112	1.810 ± 0.470	1.980 ± 0.224	1.860 ± 0.402	1.830 ± 0.313	Organ			
	III	1.680 ± 0.173	1.770 ± 0.358	2.100 ± 0.305	1.880 ± 0.134	1.860 ± 0.310				
	IV	2.240 ± 0.355	2.460 ± 0.169	2.530 ± 0.559	2.260 ± 0.447	2.370 ± 0.422				
	V	2.540 ± 0.204	2.870 ± 0.268	2.980 ± 0.425	2.760 ± 0.429	2.790 ± 0.358				

Table.5: Seasonal variations of copper concentration ((µg/g dry weight) in different organs of *Liza ramada* from Lake Manzala .

Organ	Site	Seasons					ANOVA			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
Gills	I	11.462 ± 1.559	13.130 ± 2.859	13.530 ± 5.299	12.522 ± 3.104	12.661 ± 3.288	Site	4	10.651	0.000***
	II	10.354 ± 1.588	11.368 ± 3.590	14.866 ± 2.905	11.914 ± 2.234	11.569 ± 3.477	Season	3	9.674	0.000***
	III	8.130 ± 0.645	12.696 ± 2.380	13.000 ± 4.915	12.490 ± 0.322	12.135 ± 2.745	Organ	2	444.335	0.000***
	IV	11.544 ± 3.349	14.852 ± 6.112	14.460 ± 5.638	13.848 ± 2.684	13.676 ± 4.491	Site x Season	12	0.264	0.994
	V	14.368 ± 4.817	16.970 ± 3.195	15.430 ± 4.402	14.890 ± 3.785	15.416 ± 3.889	Site x Organ	8	1.406	0.194
Skin	I	7.468 ± 1.629	7.884 ± 0.427	8.390 ± 0.141	7.234 ± 0.083	7.744 ± 0.898	Season x Organ	6	1.879	0.085
	II	6.262 ± 0.644	6.730 ± 0.709	7.136 ± 0.345	5.742 ± 0.681	6.468 ± 0.775				
	III	6.420 ± 1.497	7.682 ± 1.592	7.794 ± 0.360	6.042 ± 0.244	6.985 ± 1.290	Site	24	0.373	0.997
	IV	7.774 ± 1.037	8.138 ± 0.755	8.286 ± 0.314	7.886 ± 0.747	8.021 ± 0.726	x			
	V	8.014 ± 0.872	8.522 ± 0.476	9.554 ± 1.388	8.296 ± 0.232	8.597 ± 0.990	Season			
Muscles	I	3.286 ± 0.303	3.912 ± 0.719	4.682 ± 0.914	3.790 ± 0.542	3.918 ± 0.793	x			
	II	3.432 ± 0.668	3.550 ± 0.382	3.834 ± 0.926	3.030 ± 0.268	3.462 ± 0.639	Organ			
	III	3.332 ± 0.200	3.810 ± 1.143	4.124 ± 0.158	3.776 ± 0.468	3.761 ± 0.647				
	IV	3.834 ± 0.225	4.294 ± 1.061	4.890 ± 0.713	4.042 ± 0.290	4.265 ± 0.737				
	V	3.736 ± 0.443	4.660 ± 0.203	5.466 ± 0.359	4.354 ± 0.188	4.554 ± 0.702				

Table. 6: Seasonal variations of Zinc concentration (µg/g dry weight) in different organs of *Liza ramada* from Lake Manzala .

Organ	**Site**	**Seasons**					**ANOVA**			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
Gills	I	55.100 ± 2.191	82.100 ± 1.543	87.600 ± 2.929	49.800 ± 5.635	68.650 ± 17.128	Site	4	1143.304	0.000***
	II	46.900 ± 2.977	51.020 ± 2.560	70.800 ± 3.555	48.500 ± 2.239	54.310 ± 10.241	Season	3	1718.586	0.000***
	III	47.600 ± 1.433	61.300 ± 2.971	81.400 ± 3.488	66.100 ± 1.834	64.100 ± 12.611	Organ	2	9394.575	0.000***
	IV	60.100 ± 2.599	89.400 ± 2.660	98.600 ± 2.907	75.700 ± 3.421	80.950 ± 15.161	Site x Season	12	52.240	0.000***
	V	65.700 ± 3.806	112.600 ± 2.732	138.300 ± 3.265	97.800 ± 1.425	103.600 ± 27.056	Site x Organ	8	127.765	0.000***
Skin	I	31.100 ± 1.598	52.800 ± 1.557	69.800 ± 2.253	33.400 ± 2.236	46.780 ± 16.279	Season x Organ	6	243.347	0.000***
	II	27.100 ± 1.548	35.900 ± 5.436	53.100 ± 2.281	28.100 ± 2.504	35.900 ± 10.867				
	III	29.400 ± 2.535	51.400 ± 2.174	64.300 ± 2.574	30.800 ± 2.482	43.980 ± 15.161	Site	24	16.990	0.000***
	IV	32.600 ± 1.803	61.100 ± 2.560	77.500 ± 3.320	41.100 ± 2.527	53.080 ± 18.112	x			
	V	34.700 ± 2.603	86.400 ± 3.690	75.800 ± 3.406	55.300 ± 3.958	63.050 ± 20.572	Season			
Muscles	I	18.400 ± 3.362	22.400 ± 2.527	25.100 ± 3.175	20.400 ± 3.130	21.575 ± 3.793	x			
	II	12.600 ± 1.565	16.100 ± 1.610	19.200 ± 2.303	14.600 ± 1.543	15.625 ± 2.963	Organ			
	III	16.500 ± 2.460	19.700 ± 2.661	18.400 ± 2.460	21.400 ± 2.351	19.000 ± 2.928				
	IV	22.200 ± 2.422	26.800 ± 3.555	31.010 ± 2.415	23.700 ± 2.411	25.930 ± 4.293				
	V	28.900 ± 1.945	32.900 ± 1.453	36.900 ± 2.418	24.300 ± 1.476	30.750 ± 5.093				

Table. 7: Seasonal variations of cadmium concentration (µg/g dry weight) in different organs of *Liza ramada* from Lake Manzala .

Organ	**Site**	**Seasons**					**ANOVA**			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
Gills	I	2.346 ± 0.585	3.684 ± 0.453	4.220 ± 0.470	2.820 ± 0.701	3.270 ± 0.854	Site	4	76.491	0.000***
	II	1.930 ± 1.185	2.364 ± 0.546	3.200 ± 0.313	1.630 ± 0.516	2.280 ± 0.890	Season	3	41.432	0.000***
	III	1.888 ± 0.760	2.618 ± 1.180	4.170 ± 0.604	1.908 ± 0.263	2.650 ± 1.207	Organ	2	984.556	0.000***
	IV	3.278 ± 0.883	4.088 ± 0.830	5.040 ± 0.962	3.780 ± 0.325	4.050 ± 0.884	Site x Season	12	0.384	0.968
	V	2.274 ± 1.528	5.392 ± 0.617	5.920 ± 0.872	4.852 ± 0.800	5.160 ± 1.073	Site x Organ	8	28.377	0.000***
Skin	I	1.170 ± 0.051	1.120 ± 0.123	1.410 ± 0.111	1.235 ± 0.071	1.240 ± 0.148	Season x Organ	6	16.514	0.000***
	II	1.038 ± 0.103	1.086 ± 0.069	1.180 ± 0.042	1.109 ± 0.046	1.132 ± 0.182				
	III	1.110 ± 0.042	1.020 ± 0.069	1.206 ± 0.148	1.127 ± 0.057	1.172 ± 0.188	Site	24	0.613	0.923
	IV	1.468 ± 0.103	1.268 ± 0.092	1.782 ± 0.066	1.512 ± 0.124	1.530 ± 0.633	x			
	V	1.680 ± 0.246	1.570 ± 0.410	2.146 ± 0.115	1.837 ± 0.173	1.952 ± 0.530	Season			
Muscles	I	0.566 ± 0.091	0.660 ± 0.022	0.780 ± 0.074	0.600 ± 0.039	0.650 ± 0.107	x			
	II	0.508 ± 0.078	0.570 ± 0.058	0.622 ± 0.072	0.560 ± 0.082	0.570 ± 0.089	Organ			
	III	0.560 ± 0.066	0.620 ± 0.067	0.652 ± 0.070	0.580 ± 0.070	0.604 ± 0.073				
	IV	0.588 ± 0.145	0.810 ± 0.066	0.920 ± 0.089	0.620 ± 0.067	0.740 ± 0.179				
	V	0.634 ± 0.036	0.970 ± 0.086	1.112 ± 0.155	0.690 ± 0.087	0.853 ± 0.221				

Table. 8: Seasonal variations of lead concentration (µg/g dry weight) in different organs of *Liza ramada* from Lake Manzala .

Organ	Site	Seasons					ANOVA			
		Winter	Spring	Summer	Autumn	Total	Factor	df	F value	Sig.
Gills	I	7.956 ± 0.683	8.620 ± 0.268	8.846 ± 1.252	8.336 ± 0.769	8.440 ± 0.831	Site	4	31.690	0.000***
	II	5.364 ± 1.181	5.580 ± 0.537	5.774 ± 0.795	5.508 ± 1.006	5.560 ± 0.850	Season	3	3.084	0.028*
	III	6.316 ± 1.033	6.820 ± 0.581	7.050 ± 0.829	6.656 ± 0.835	6.710 ± 0.805	Organ	2	734.968	0.000***
	IV	8.326 ± 0.813	9.370 ± 1.811	9.942 ± 2.890	9.116 ± 0.757	9.190 ± 1.744	Site x Season	12	0.630	0.816
	V	9.224 ± 0.825	10.010 ± 1.319	11.524 ± 2.317	9.776 ± 1.492	10.130 ± 1.699	Site x Organ	8	10.629	0.000***
Skin	I	2.540 ± 0.431	2.676 ± 0.083	2.744 ± 0.314	2.660 ± 0.537	2.676 ± 0.166	Season x Organ	6	1.486	0.184
	II	2.420 ± 0.447	2.426 ± 0.277	2.522 ± 0.146	2.310 ± 0.488	2.420 ± 0.358				
	III	2.410 ± 0.472	2.544 ± 0.539	2.630 ± 0.082	2.490 ± 0.447	2.520 ± 0.402	Site	24	0.805	0.73
	IV	2.686 ± 0.095	2.872 ± 0.149	2.962 ± 0.281	2.730 ± 0.157	2.810 ± 0.224	x			
	V	2.776 ± 0.083	3.308 ± 0.493	3.110 ± 0.294	2.960 ± 0.134	3.040 ± 0.358	Season			
Muscles	I	1.532 ± 0.259	1.660 ± 0.248	1.830 ± 0.216	1.612 ± 0.480	1.659 ± 0.318	x			
	II	1.432 ± 0.159	1.540 ± 0.134	1.650 ± 0.201	1.472 ± 0.140	1.526 ± 0.169	Organ			
	III	1.462 ± 0.211	1.630 ± 0.224	1.700 ± 0.243	1.518 ± 0.072	1.576 ± 0.202				
	IV	1.994 ± 0.303	2.070 ± 0.112	2.240 ± 0.402	2.044 ± 0.149	2.087 ± 0.267				
	V	2.060 ± 0.352	2.430 ± 0.313	2.230 ± 0.291	2.120 ± 0.730	2.210 ± 0.365				