

## Seasonal Variations of Heavy Metals Concentrations in Mullet, *Mugil Cephalus* and *Liza Ramada* (Mugilidae) from Lake Manzala, Egypt

Mohamed Bahnasawy, Abdel Aziz Khidr, Nadia 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 concentrations were recorded in muscles tissue. The values of the metals detected in the fish muscles (the edible part) 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 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, it 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 system become contaminated with heavy metals released from domestic, industrial, mining and agricultural effluents which are continuously discharged into it<sup>[20,42,43]</sup>. Many fish species are among the top consumers of trophic pyramids in aquatic ecosystem. In consequence, they are endangered by diet-borne pollutants (e.g heavy metals) transferred along the food chain<sup>[38,34,32]</sup>. 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<sup>[23,37]</sup>.

Fish have been used for many years to determine the pollution status of water, and are thus regarded as excellent biological marker of metals in aquatic ecosystem<sup>[15,22,40]</sup>.

Lake Manzala is considered one of the most important lakes in Egypt, is located in the north-eastern corner of the Nile Delta, large, shallow, brackish and

exposed to high levels of pollutants from industrial, domestic and agricultural resources<sup>[9, 3,29]</sup>.

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 stations of the lake during the different seasons. The two fish species studied in this work differ from each other with respect to their feeding habits.

### MATERIALS AND METHODS

Fish samples (*Mugil cephalus* and *Liza ramada*) were collected from five sites of Lake Manzala (Fig.1). The sites were chosen in relation to contamination gradients. Site I&IV receive agricultural drainage water via Hadous and El-Sirw drains. Site II&III are impacted partially to brackish water from the south eastern side of the lake and the saline 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°C until the samples were prepared for digestion and analysis. Before analysis, each individual fish was measured, weighed, dissected. A piece of gills, skin without scales, and epaxial muscle were taken, placed in separately pre-weighed acid cleaned flasks, dried at 80°C using an oven, 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<sup>[20]</sup>.

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 concentration in fish organs with regard to sites and seasons. The significance level was  $P < 0.05$ <sup>[12]</sup>.

## RESULTS AND DISCUSSION

**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 concentration 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 Concentration in *M.Cephalus*:** Cu concentration in gills, skin, and muscle ranged from 12.78 to 17.57  $\mu\text{g/g}$  dry weight, from 7.59 to 10.53  $\mu\text{g/g}$  dry weight and from 3.56 to 5.68  $\mu\text{g/g}$  dry weight respectively. Summer showed the highest Cu concentration, while decline occurred during winter (Table 1).

Zn concentration ranged from 48.18 to 141.98  $\mu\text{g/g}$  dry weight in gills, from 27.4 to 89.61  $\mu\text{g/g}$  dry weight in skin and from 13.21 to 38.42  $\mu\text{g/g}$  dry weight in muscle. The highest concentration 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 was between 3.14 and 6.26  $\mu\text{g/g}$  dry weight while its concentration in skin ranged from 1.99 to 3.01 and in muscle from 1.08 to 1.71  $\mu\text{g/g}$  dry weight. The highest levels of Pb in gills, skin and muscle were recorded during summer (Table 3).

Pb concentration in gills, skin and muscle were observed to be between 8.21 and 12.67  $\mu\text{g/g}$  dry weight, and between 2.32 and 3.71  $\mu\text{g/g}$  dry weight, and between 1.66 and 2.98  $\mu\text{g/g}$  dry weight respectively. The higher value of Pb was recorded during summer for gills and muscle, and during spring for skin (Table 4).

**Metals Concentration in *L.ramada*:** Cu concentration fluctuated from 8.13 to 19.97  $\mu\text{g/g}$  dry weight, from 5.74 to 9.55  $\mu\text{g/g}$  dry weight in skin and from 3.03 to 4.66  $\mu\text{g/g}$  dry weight in muscle. The higher levels of Cu were found in summer for skin, in spring for gills and muscle (Table 5).

Zn concentration in gills ranged from 46.9 to 138.30  $\mu\text{g/g}$  dry weight, in skin from 27.10 to 86.40  $\mu\text{g/g}$  dry weight and in muscle from 12.60 to 36.90  $\mu\text{g/g}$  dry weight. Zn peaked in summer for gills and muscle, in spring for skin (Table 6).

Cd Levels ranged from 1.63 to 5.92  $\mu\text{g/g}$  dry weight for gills, from 1.04 to 2.15  $\mu\text{g/g}$  dry weight for skin, from 0.51 to 1.11  $\mu\text{g/g}$  dry weight for muscle. The highest Cd content were recorded in summer for gills, skin and muscle (Table 7).

Pb concentration varied in the range of 5.36 -11.52  $\mu\text{g/g}$  dry weight for gills, range of 2.31-3.31  $\mu\text{g/g}$  dry weight for skin, range of 1.43-2.43  $\mu\text{g/g}$  dry weight for muscle. Higher Pb values were recorded in summer for gills, in spring for skin and muscle (Table 8).

**Discussion:** Fish samples from station V (as expected) displayed the highest metal concentrations in their tissues. This result confirm the previous studies of many authors who reported that station V is highly polluted because 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<sup>[9,2,3,29,10,33]</sup>. 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 the various organs and tissues of fish was observed in the present study. The difference in the levels of accumulation in the different organs/tissues of a fish can primarily be attributed to the differences in the physiological role of each organ. Regulatory ability, behaviour and feeding habits are other factors that influence the accumulation differences in the different organs<sup>[36]</sup>. 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 as the lowest metal concentrations were detected in this tissue. Higher metal concentrations in the gills could be due to the element complexation with the mucus that is impossible to completely remove from the gill lamellae before tissue is prepared for analysis<sup>[32]</sup>. 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<sup>[27]</sup>. Target organs, such as the liver and gills, are metabolically active tissues and accumulate heavy

**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.
Gills	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***
	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***
Skin	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				
	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			
Muscles	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			
	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			

Table 3: Continue

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***

Table 6: Continue

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				



Hemens and Connell<sup>[28]</sup> 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.*<sup>[13]</sup> 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) with 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<sup>[26]</sup>. Muscles and gills of *Liza abue* from the Tigris River (Turkey) accumulated enormously higher concentration 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.*<sup>[16]</sup> 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 muscle higher concentrations of Zn (26.13) and Pb (6.25), but lower level of Cu (4.48) and Cd (0.96) µg/g dry wt. Gills of the same fish had a lower accumulations of Cu (7.01), Zn (43.2) and Cd (2.28) and higher level of Pb (20.84) µg/g dry wt.<sup>[31]</sup>. Canli and Atli<sup>[19]</sup> 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 variations 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<sup>[20]</sup>. According to NHMRC (1987) (cited after Beldi *et al.*,<sup>[14]</sup>), the values of heavy metals in the muscles (the edible parts) 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.

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