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Environmental Pollution-Induced Biochemical Changes in Tissues of *Tilapia zillii*, *Solea vulgaris* and *Mugil capito* from Lake Qarun, Egypt

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Abstract: Lake Qarun is a closed elongated salty basin lying in the Western Egyptian desert. It receives continuously agricultural drainage waters, which controlling its area and volume. Concentrations of Fe, Zn, Cu, Pb, Mn and Hg in the water and tissues (muscle and liver) of some inhabitant fish (*T. zillii*, *S. vulgaris* and *M. capito)* were determined during winter of 2008 using atomic absorption spectrophotometry. The effects of the environmental pollution of Lake Qarun on some biochemical parameters (protein, cholesterol, triglycerides, glycogen and moisture) and the activities of alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) in the muscle and liver were also determined. The abundance of metals in the lake water followed the order: Zn>Pb>Fe>Hg>Mn>Cu. The highest accumulation of the metals was recorded in the liver and the lowest accumulation was recorded in the muscle. Cu concentrations in the fish muscles were blow the maximum permissible limit, however, Fe, Zn, Pb and Hg in the muscles exceeded the permissible limit. Protein contents in the muscle and liver of the three studied fish species (except the liver of *T. zillii* and *M. capito*) were low. On the contrary, there was increase ($P \leq 0.01$) in total cholesterol and triglycerides values in the muscle and liver. Depletion of glycogen level was observed in the muscle and liver of the studied fish (except the muscle of *T. zillii*). Moisture content of the muscle and liver (except the liver of *S. vulgaris*) was low ($P \leq 0.01$). Decreased ($P \leq 0.01$) activities of ALT, AST and ALP were observed in the muscle and liver of all studied fish.

Key words: Fish-Environmental pollution · Heavy metals · Biochemical parameters · Lake Qarun · Egypt

INTRODUCTION

The aquatic environment is subjected to different types of pollutants which enter water bodies with industrial, domestic and agricultural waste waters and severely affect the aquatic organisms. The problems of environmental pollution and its deleterious effects on aquatic biota, including fish received focused interest during the few last decades. Nowadays, Lake Qarun suffers from several environmental problems. It receives agricultural and sewage drainage water from Faiyoum Province. Therefore, its salinity increase progressively which affects greatly the lake biota, in addition, the exacerbation of eutrophication of the lake's water that caused by the nutrient load from the agricultural drainage water [1]. The lake receives the agricultural and sewage drainage water through a system of twelve drains, most of the drainage water reaches the lake by two main drains, El-Batts and El-Wadi, whereas there are minor drains poured its drainage water into the lake by means of hydraulic pumps but in small amounts. The minor drains are recently connected with a larger drain, namely Dayer El-Birka, which transfers a part of wastewater to the lake by pumping stations [2]. The lake received annually about 450 million cubic meters of agricultural drainage water, which approximately balances the amount of lake water lost annually by evaporation, leading to progressive increase of salinity and detrimental effects to the lake environment, e.g. its fauna and flora [3,4]. The Egyptian Company for Salts and Mineral (EMISAL) located on the southern coast of the lake, where a part was cutoff from the lake and divided into number of concentrating ponds, to concentrate the lake water as much as 10 times of its original salinity. The effluents of EMISAL brine water

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discharged also into the lake and aggravate the condition. Due to Lake Qarun is a closed ecosystem, and as a result of extensive evaporation of water, the accumulation of chemical pollutants (heavy metals, pesticides and other pollutants) is expected to increase annually in all its components (e.g. water and fish) and to change their quality and affect their aquatic life [5].

Heavy metals are natural trace components of the aquatic environment, but their levels have increased due to domestic, industrial and agricultural activities. Discharge of metals into the aquatic environment can change both aquatic species diversity and ecosystems, due to their toxicity and accumulative behavior [6]. Aquatic organisms including fish accumulate metals to concentrations many times higher than present in water or sediment [7]. The distribution of metals in different water bodies and in tissues of different species of fish has been described by [8-12].

Common environmental contaminants such as metals and pesticides pose serious risks to biochemical parameters and enzyme activities of fish. Studies proved that, fish subjected to metals have a reduced protein and glycogen level [13-16], a reduced ALT, AST and ALP activity [17,18] and an increased cholesterol content [19,20] in their tissues. Moreover, exposure of fish to pesticides reduced protein and glycogen levels in the muscle and liver [21-24], reduced ALT, AST and ALP activities in the muscle and liver [25,26] and increased cholesterol content in the muscle and liver [27]. Lake Qarun attracts attention of many authors because of its historical and scientifically importance to study its unique ecosystem, but the studies dealt with the accumulation of heavy metals in different ecosystem components and the impact of the environmental pollution of the lake on fish physiology are still not enough [2,9,28,29,30]. So, additional information still needed to provide a database for the ecological status of Lake Qarun that helps the policy makers to take effective decisions for proper management of the lake. The aim of the present study was to investigate the distribution of Fe, Zn, Cu, Pb, Mn and Hg in water and tissues (muscle and liver) of *T. zillii, S. vulgaris* and *M. capito* inhabited Lake Qarun. Also, the influence of the environmental pollution of the lake on some biochemical parameters and enzyme activities in the muscle and liver of fish was studied.

MATERIALS AND METHODS

Study Area: Lake Qarun is a closed saline basin located between longitudes 30°24′ and 30°49′ E and latitudes of 29°24′ and 29°33′ N in the lowest part of El-Faiyoum depression, about 80 km Southwest of Cairo (Fig. 1). It has an irregular shape of about 40 km length and about 6 km mean width, with an average area of about 240 km^2. The lake is shallow, with mean depth of 4.2 m and most of the lake's area has a depth ranging between 5 to 8 meters. The water level of the lake fluctuated between 43 to 45m below mean sea level [1].

Sampling: During winter of 2008, water samples (8L) were collected from Lake Qarun, in polyethylene bottles. The samples were acidified by nitric acid and transferred to the laboratory in an ice-box to be analyzed. At the same time, samples of *T. zillii, S. vulgaris* and *M. capito* were collected. The fish measured about 10.2 to 12.7, 15.0 to 19.5 and 20.0 to 25.5cm in total length and 21.0 to 29.6, 27.0 to 58.0 and 66.0 to 99.0g in weight, respectively. After dissection of fish samples, parts of muscle and liver were carefully removed and prepared for metals analysis and biochemical studies. Another fish samples were collected from Lake Bardawil (unpolluted lake), [31,32] to be used as the control group.

Determination of Heavy Metals: Water samples were prepared using the method of [33] and different fish samples were digested after drying according to the method described by [34]. The levels of Fe, Zn, Cu, Pb, Mn and Hg in digests were determined using atomic absorption spectrophotometer (Perkin Elemer Model 2380).

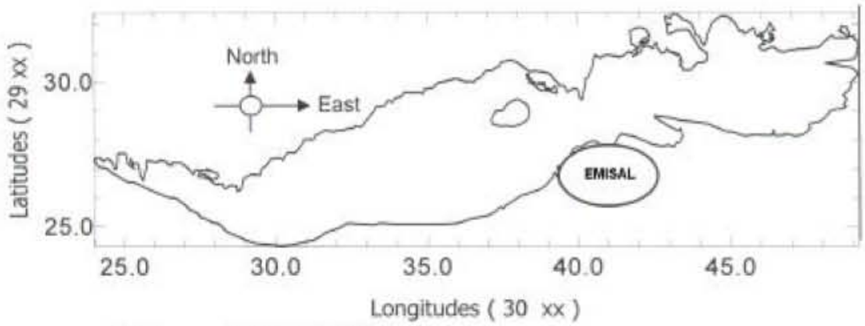

Fig. 1. Map of Lake Qarun

Bioaccumulation Factor (BAF): The bioaccumulation factor (BAF) was calculated according to [2] using the following equation:

$$\text{Bioaccumulation factor (BAF)} = \frac{\text{Pollutant concentration in fish organ (mg/kg)}}{\text{Pollutant in water (mg/l)}}$$

Biochemical Analysis: Samples from muscles and liver of the studied fish were subjected for colorimetrical analysis of total protein content [35], (SPECTRUM kit) and total cholesterol and triglycerides [36], (ELITECH kit). Glycogen was determined by the anthrone reagent method [37]. Moisture content was determined by the method described by [38]. ALT and AST activities were colorimetrically assayed following the method of [39], (SPECTRUM kit). ALP activity was estimated by the method of [40], (SPECTRUM kit).

Statistical Analysis: The data were computed, expressed as mean±standard error and statistically analyzed [41].

RESULTS

Metal Concentrations in Water: The mean concentrations of the tested metals in the water of Lake Qarun were presented in Table 1. Metal concentrations in the water of the lake followed an abundance of: Zn >Pb>Fe>Hg>Mn>Cu.

Metal Concentrations in Fish Tissues: Table 1 shows the concentrations of the analyzed metals in the muscle and liver of *T. zillii, S. vulgaris* and *M. capito* from Lake Qarun. The lowest accumulations of the tested metals were recorded in the muscle, while the highest ones were recorded in the liver.

Iron: Fe accumulation in the muscle of the studied fish was in the following order: *S. vulgaris* > *M. capito* > *T. zillii* and in the liver followed the order: *M. capito* > *T. zillii* > *S. vulgaris*.

Zinc: The accumulation pattern of Zn in the muscle of the fish followed the order: *S. vulgaris* > *T. zillii* > *M. capito* and in the liver followed the order: *T. zillii* > *S. vulgaris* > *M. capito*.

Copper: Cu accumulation in the muscle of the fish was in the following order: *S. vulgaris* > *T. zillii* and *M. capito* and in the liver followed the order: *M. capito* > *S. vulgaris* > *T. zillii*.

Lead: Generally, Pb concentrations in the muscle and liver of the fish were in the following order: *T. zillii* > *M. capito* > *S. vulgaris*.

Manganese: Mn accumulation in the muscle of the fish was in the following order: *S. vulgaris* > *T. zillii* > *M. capito* and in the liver followed the order: *T. zillii* > *S. vulgaris* > *M. capito*.

Mercury: Generally, Hg accumulation in the muscle and liver of the fish were in the following order: *T. zillii* > *S. vulgaris* > *M. capito*.

The trend of accumulation of the metals in the studied tissues was as follows: *T. zillii* muscle-Zn>Fe>Hg>Pb>Mn>Cu; *T. zillii* liver-Fe> Hg>Zn>Pb>Mn>Cu; *S. vulgaris* muscle-Zn>Fe>Hg>Mn>Pb>Cu; *S. vulgaris* liver-Fe>Zn>Cu>Hg>Mn>Pb; *M. capito* muscle-Zn>Fe>Hg> Pb>Mn>Cu; *M. capito* liver-Fe>Cu>Zn>Hg>Pb>Mn.

Bioaccumulation Factor (BAF): As shown in Table 2, the concentration of the analyzed metals (Fe, Zn, Cu, Pb, Mn and Hg) in the muscle and liver of the studied fish were several times higher than their concentrations in water. The bioaccumulation factor of the studied metals showed that, the muscle of the studied fish maintained the lowest values. However, the highest values of BAF were recorded in the liver.

Biochemical Findings: Some biochemical data of *T. zillii, S. vulgaris* and *M. capito* were presented in Table 3-5.

Total Protein Content: The total protein content in the muscle of *T. zillii, S. vulgaris* and *M. capito* from Lake Qarun decreased ($P \leq 0.01$) as compared to control. Meanwhile, the liver protein content showed insignificant decrease in *T. zillii* and *M. capito* anda significant decrease ($P \leq 0.01$) in *S. vulgaris*.

Total Cholesterol Content: The level of total cholesterol in the muscle and liver of fish from Lake Qarun markedly increased with percentage ranged between 14.90-57.66% as compared to control.

Triglycerides Content: Triglycerides content exhibited an increase ($P \leq 0.01$) in the muscle and liver of fish from Lake Qarun with percentage ranged between 56.61-122.61%.

Table 1: Concentrations of some heavy metals in water (mg/l) and tissues (muscle and liver) of *T. zillii, S. vulgaris* and *M. capito* (mg/kg dry weight) from Lake Qarun (Mean±SE)

		T. zillii		*S. vulgaris*		*M. capito*	
Metal	Water	Muscle	Liver	Muscle	Liver	Muscle	Liver
Fe	0.346±0.001	42.81±1.63	933.06±95.04	53.67±5.81	288.82±4.69	46.25±2.59	1268.00±92.37
Zn	0.626±0.08	55.88±0.49	127.07±0.44	60.38±1.25	65.94±2.09	46.38±1.30	51.75±0.55
Cu	0.040±0.003	1.75±0.19	16.48±0.33	3.88±0.07	51.51±3.37	1.75±0.10	77.25±4.12
Pb	0.384±0.04	19.50±0.96	34.05±1.47	8.50±0.49	17.96±0.69	11.88±0.22	24.25±0.96
Mn	0.051±0.005	10.25±0.42	30.89±3.39	12.63±2.12	18.21±0.58	4.25±0.42	14.75±0.19
Hg	0.311±0.003	34.06±0.80	129.45±4.35	26.88±0.07	39.20±0.18	12.38±0.07	27.06±0.28

Table 2: Bioaccumulation factors (BAF) for each heavy metal in the muscle and liver of *T. zillii, S. vulgaris* and *M. capito* from Lake Qarun

	T. zillii		*S. vulgaris*		*M. capito*	
Metal	Muscle	Liver	Muscle	Liver	Muscle	Liver
Fe	123.73	2696.71	155.12	834.74	133.67	3664.74
Zn	89.27	202.99	96.45	105.34	74.09	82.67
Cu	43.75	412.00	97.00	1287.75	43.75	1931.25
Pb	50.78	88.67	22.14	46.77	30.94	63.15
Mn	200.98	605.69	247.65	357.06	83.33	289.22
Hg	109.52	416.24	86.43	126.05	39.81	87.01

Table 3: Total protein and cholesterol, triglycerides, glycogen and moisture contents of the muscle of *T. zillii, S. vulgaris* and *M. capito* from Lake Qarun (Mean±SE)

	T. zillii				*S. vulgaris*				*M. capito*			
	Control	Lake Qarun	%Alteration	*t*-value	Control	Lake Qarun	%Alteration	*t*-value	Control	Lake Qarun	%Alteration	*t*-value
Total protein (g/100g wt. weight)	17.89±0.41	13.55±0.52	-24.26	6.54**	18.64±0.44	14.79±0.29	-20.66	7.41**	18.01±0.28	13.87±0.34	-22.99	9.26**
Total cholesterol (mg/100g wt. weight)	42.09±1.77	66.36±3.09	+57.66	6.82**	55.15±2.76	68.06±3.26	+23.41	3.02*	68.45±1.79	78.65±2.71	+14.90	3.15*
Triglycerides (mg/g wt. weight)	4.92±0.45	9.78±0.42	+ 98.78	7.99**	3.76±0.23	8.37±0.28	+122.61	12.79**	10.69±0.13	19.31±1.45	+80.64	5.92**
Glycogen (g/100g wt. weight)	0.37±0.008	0.39±0.01	+5.41	1.45	0.42±0.004	0.36±0.01	-14.29	4.63**	0.46±0.008	0.29±0.02	-36.96	7.48**
Moisture (g/100g wt. weight)	78.56±0.47	73.25±0.63	-6.76	6.80**	77.99±0.38	76.31±0.26	-2.15	3.67**	78.12±0.36	73.11±1.63	-6.41	3.01*

% Alteration from control value. *t*-value= between control and Lake Qarun values. * P≤ 0.05. **P≤ 0.01

Table 4: Total protein and cholesterol, triglycerides, glycogen and moisture contents of the liver of *T. zillii, S. vulgaris* and *M. capito* from Lake Qarun (Mean±SE)

	T. zillii				*S. vulgaris*				*M. capito*			
	Control	Lake Qarun	%Alteration	*t*-value	Control	Lake Qarun	%Alteration	*t*-value	Control	Lake Qarun	%Alteration	*t*-value
Total protein (g/100g wt. weight)	15.74±0.42	14.35±0.52	-8.83	2.07	16.01±0.33	13.77±0.18	-13.99	5.99**	15.85±0.23	15.65±0.36	-1.26	0.47
Total cholesterol (mg/100g wt. weight)	151.09±3.45	192.02±7.66	+27.09	4.87**	139.11±4.22	186.42±5.29	+34.01	6.99**	161.84±3.38	208.63±7.73	+28.91	5.55**
Triglycerides (mg/g wt. weight)	10.28±0.25	20.29±1.05	+ 97.37	9.25**	7.73±0.15	15.38±0.44	+98.97	16.69**	18.90±1.32	29.60±1.74	+56.61	4.89**
Glycogen (g/100g wt. weight)	2.75±0.02	1.27±0.11	-53.82	12.85**	1.98±0.05	0.39±0.06	-80.30	21.84**	2.86±0.03	1.77±0.05	-38.11	19.77**
Moisture (g/100g wt. weight)	76.44±0.19	74.75±0.29	-2.21	4.69**	75.98±0.23	76.18±0.70	+0.26	0.27	74.02±0.42	66.31±0.81	-10.42	8.46**

% Alteration from control value. *t*-value= between control and Lake Qarun values. ** P≤ 0.01

Table 5: Alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) activities in the muscle and liver of *T. zillii, S. vulgaris* and *M. capito* from Lake Qarun (Mean±SE)

Enzyme	*T. zillii*				*S. vulgaris*				*M. capito*			
Tissue	Control	Lake Qarun	%Alteration	*t*-value	Control	Lake Qarun	%Alteration	*t*-value	Control	Lake Qarun	%Alteration	*t*-value
ALT (U/g fresh tissue)												
Muscle	15.79±0.29	12.44±0.70	-21.22	4.36**	17.86±0.34	12.23±0.69	-31.52	7.27**	16.21±0.45	11.16±0.38	-31.15	8.42**
Liver	28.85±0.78	21.55±0.84	-25.30	6.38**	31.78±0.51	26.25±0.18	-17.40	10.27**	30.17±0.52	21.92±0.44	-27.35	12.16**
AST (U/g fresh tissue)												
Muscle	194.02±8.09	112.50±2.74	- 42.02	9.55**	214.39±5.82	154.34±4.70	-28.01	8.02**	234.22±2.53	173.33±2.79	- 25.99	16.16**
Liver	133.78±3.01	56.48±3.64	-57.78	16.38**	136.40±3.44	104.70±6.89	- 23.24	4.12**	149.33±3.07	92.67±5.39	-37.94	9.14**
ALP(U/g fresh tissue)												
Muscle	11.80±0.64	6.68±0.35	- 43.39	7.03**	15.29±0.78	8.63±0.47	-43.56	7.31**	19.06±0.47	11.56±0.39	-39.35	12.33**
Liver	42.16±1.40	29.99±2.12	-28.87	4.79**	71.70±2.47	56.69±1.78	- 20.94	4.93**	81.94±0.83	58.39±3.24	- 28.74	7.04**

% Alteration from control value. *t*-value= between control and Lake Qarun values. ** P≤ 0.01

Glycogen Content: The level of glycogen showed depletion (P≤0.01) in the muscle and liver of the studied fish, except the muscle of *T. zillii*.

Moisture Content: Moisture content significantly decreased in the muscle and liver of fish from Lake Qarun, except the liver of *S. vulgaris* with percentage ranged between 2.15-10.42% as compared to control.

ALT Activity: ALT activity decreased (P≤0.01) in the muscle and liver of the studied fish with percentage ranged between 17.40-31.52% as compared to control.

AST Activity: AST activity reduced (P≤0.01) in the muscle and liver of the studied fish.

ALP Activity: ALP activity decreased (P≤0.01) in the muscle and liver of the studied fish with percentage ranged between 20.94-43.56%.

DISCUSSION

The presence of trace metals in Lake Qarun is mainly of allochthonous origin due to either agricultural influx, wastes of fish farms or sewage *via* surrounding cultivated lands [9].The present study showed that the abundance of metals in Lake Qarun water followed the order of Zn>Pb>Fe>Hg>Mn>Cu. The values of Fe, Cu and Mn in this study were agreed with the corresponding values obtained by [9] in Lake Qarun, while the concentrations of Zn and Pb are higher than the previous levels. The levels of the studied metals in the lake water were higher than either levels in Lake Burullus [42] or Lake Edku [43]. The concentration of Fe and Pb in the water of Lake Qarun was higher than the permissible level (0.3 and 0.05 mg/l, respectively) permitted by the Egyptian Organization for Standardization [44] and the Egyptian Standards of the Environmental laws no. 48/1982 and 4/1994, however the concentrations of Zn, Cu and Mn are still below the permissible level (5, 1 and 0.5 mg/l, respectively).

In the present study, the lower concentrations of Fe, Zn, Cu, Pb, Mn and Hg were recorded in the fish muscles, while the higher values were in the liver. These findings are in agreement with those obtained by [10, 45]. High concentrations of metals in the liver are related to detoxification processes that take place in this organ [46]. Furthermore, metals are bound here to specific polypeptides, i.e. metallothioneins [47]. According to [48], the low levels of the metals in the muscles may be due to the little blood supply to the muscular tissue. Fe was the most abundant metal in the liver of the three fish species and this agrees with that obtained by [49]. The concentrations of Fe in the muscle of the studied fish were higher than US maximum permissible level for Fe (5 μg/g) [50]. Zn was the most abundant metal in the muscle of the three fish species. [51] reported that Zn has high tendency to accumulate in the muscle. Zn concentrations in the muscle of the studied fish were higher than the permissible level (40 mg/kg) recommended by Western Australian Food and Drink Regulations [52]. The high level of Cu in the liver of *T. zillii*, *S. vulgaris* and *M. capito* can be ascribed to the binding of Cu to metallothionein in the liver, which serves as a detoxification mechanism [12]. Also, the liver has a tendency to accumulate copper in high values in many species of fish in different areas: in *T. zillii* from Lake Manzalah, Egypt [53]; in *T. zillii* and *M. cephalus* from Lake Qarun, Egypt [2] and in *Liza saliens* from the Esmoriz-Paramos Coastal lagoon, Portugal [54]. The concentration of Cu in the muscle of the studied fish are below the permissible level for Cu (30 mg/kg) recommended by the National Health Medical Research Council [52].

The hazards of Pb are not only due to their high toxicity, but also to the low rate of elimination from the consumer's body, and often unchanged for long periods [6]. The concentrations of Pb in the muscle of the studied fish were more than US FDA maximum permissible level for Pb (2.0 μg/g) [55]. Similarly, [5] reported that Pb was found in the fish from Lake Qarun at concentration above the permissible limits. In the present study, the lowest concentration of Mn was recorded in the muscle of *M. capito* and the highest concentration was in the liver of *T. zillii*. [9] found that Mn concentrations in the flesh of *Tilapia sp.*, *Solea sp.* and *Mugil sp.* from Lake Qarun ranged between 5.47-12.59 μg/g. Hg is one of the most important pollutants both because of its effects on fish and because it is potentially hazardous for humans. Lower Hg concentration in the muscle of the studied fish compared with the liver is an indication that the fish analyzed were captured in water contaminated with Hg. [46,56] reported that in fish from heavily contaminated localities Hg was deposited preferentially in the liver, while in slightly contaminated areas, it was deposited preferentially in the muscle. Maximum permitted Hg content in the muscle of fish should not exceed 0.5μg/g wet weight [57]. According to recommendations in the literature, metal concentration in fish tissue given in dry weight can be converted into wet weight by dividing them by factors ranging from 4-6 [58]. So, Hg levels in the muscles of the studied fish were more than the permissible limits.

The difference in the pattern of metals distribution in the three fish species might be a result of their difference in many factors such as; feeding habits, habitats, ecological needs, metabolism and physiology as reported by [59]. [5] reported that the accumulation of metals in the fish from Lake Qarun showed the following pattern: *Solea sp.*<*Tilapia sp.*<*Mugil sp.* However, [9] found that *Solea sp.* and *Mugil sp.* from Lake Qarun seemed to be more contaminated with heavy metals than *Tilapia sp.* The bioaccumulation factors of the studied metals (Table 2) showed that the muscle of the studied fish maintained the lowest values and the liver maintained the highest ones, this is in agreement with that reported by [2]. The results indicated that the water and fish of Lake Qarun were polluted with heavy metals. Furthermore, [30,60] reported that Lake Qarun components were polluted with a wide variety of pesticides (e.g. lindane, aldrin, some DDT analogues, malathion, pirimiphos-methyl). These pollutants (metals and pesticides) induced diverse effects on some biochemical parameters and enzyme activities of the muscle and liver of the three studied fish. In the present study, the control values of total protein and cholesterol, triglycerides, glycogen and moisture contents and enzyme (ALT, AST and ALP) activities of the muscle and liver of the studied fish (Table 3-5) were within the same range for other fish species [13,25,61,62,63]. The data showed that the total protein content decreased in the muscle and liver of the studied fish from Lake Qarun (except the liver of *T. zillii* and *M. capito*). This may show that the protein was taken as an alternative source of energy, due to high energy demand that induced by different pollutants Lake Qarun as previously reported by [64]. Also, the depletion in tissue proteins may be due to impaired or low rate of protein synthesis [16], their utilization in cell repair and organization [64] and/or the decrease in uptake of amino acids into the polypeptide chain. The present findings are in agreement with previous reports of decreased level of tissue protein on exposure to heavy metals [16] and pesticides [21].

The increased levels of total cholesterol and triglycerides in the muscle and liver of the studied fish from Lake Qarun were similar to those reported by [19,20,27] in the tissues of fish exposed to heavy metals and pesticides. The elevation of the tissue cholesterol and triglycerides may be attributed to enhanced cholesterol and triglycerides synthesis and/or reduced cholesterol and triglycerides catabolism [65]. The decreased glycogen reserves in the muscle and liver of the studied fish (except the muscle of *T. zillii*) is a good indication for toxicity. The depletion of glycogen concentration of the studied fish tissues could be attributed to the increase in the process of glycogenolysis in fish for immediate energy requirements to withstand the existing stress condition, mediated by catecholamines and adrenocortical hormones [64]. [62] showed that heavy metals could decrease the glycogen reserves in fish by affecting the activities of the enzymes that play a role in the carbohydrate metabolism. Further, the decline in glycogen might be partly due to its utilization in the formation of glycoproteins and glycolipids, which are essential constituents of various cells and other membranes as reported by [64]. Also, the decreased tissue glycogen reserves observed in this study suggests impaired glycogenesis. Glycogen depletion in the liver and muscle after toxic stress has been reported in several studies [24,62,64]. The moisture content of the muscle and liver of fish from Lake Qarun (except the liver of *S. vulgaris*) showed a marked decrease. The reduction in the tissues moisture content could be due to a decrease in the extracellular fluid volume [66].

The environmental pollution in Lake Qarun induced a marked decrease in the muscle and liver ALT and AST activities. The results indicate that under the influence of different heavy metals or in a state of stress, the damage of tissues (muscle and liver) may occur with concomitant liberation of transaminases into the circulation [16]. The decreased activities of ALT and AST indicate disturbance in the structure and integrity of cell organelles, like endoplasmic reticulum and membrane transport system [18]. Marie, [13] stated that the reduction in ALT and AST activities in the fish tissues exposed to metals could be attributed to the high accumulation of metals in fish tissues. Therefore, the depletion of enzymes in the fish tissues observed in the present study can be attributed to the increased metals accumulation in the tissues. The reduction in the muscle and liver ALT and AST activities in fish exposed to various pollutants and heavy metals, in particular have been reported by [16,18,23]. ALP is composed of several isoenzymes that are present in practically all tissues of the body, especially in cell membranes. It catalyses the hydrolysis of monophosphate esters and has a wide substrate specificity [16]. The decreases in the tissues ALP activities in this study may be attributed to the accumulation of the metals in the fish tissues [18], which affects the synthesis of enzyme protein directly or indirectly and/or increased metabolism due to an increase of toxic substances and the production of toxic metabolic products destructive to enzymes. Furthermore, decreases in the ALP activity might be due to the direct action of the pollutants on the enzyme and/or the toxic effects produced in the tissues [67]. A similar decrease in the ALP activity was recorded in the tissues of fish exposed to heavy metals [18] and pesticides [23].

In conclusion, the concentrations of the studied metals in Lake Qarun water were in the following order: Zn>Pb>Fe>Hg>Mn>Cu, these metals accumulated in the muscle and liver of the studied fish. Fe, Zn, Pb and Hg levels in the muscle exceeded the permissible limit. It was found that the environmental pollution in the lake induced significant changes in the protein, cholesterol, triglycerides, glycogen and moisture contents and ALT, AST and ALP activities of the muscle and liver of the fish.

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