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Impact of bioaccumulation and biosedimentation of some heavy metals on some biochemical responses in the sole fish, *Solea solea* inhabiting Lake Qarun, Egypt.

Ahmed Y. H. Elwasify[1], Mohamed H. Ghanem[2*], Mahmoud M. M. El-Bamby[1] and Foaad A. F. Ali[3]

1 Department of Environment and Bio-Agriculture, Faculty of Agriculture (Cairo), Al-Azhar University, Egypt
2 Department of Zoology, Faculty of Science, (Cairo), Al-Azhar University, Egypt
3 Department of Plant Protection, Faculty of Agriculture (Cairo), Al-Azhar University, Egypt

*** Correspondence*:*** mohamedhamed.201@azhar.edu.eg

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ABSTRACT

The present study was conducted during the period from October 2015 to September 2016 to investigate the bioaccumulation and biosedimentation factors of five heavy metals in *Solea solea* inhabiting lake Qarun, Egypt. Water, sediments, and fish samples were collected during the year, 2015-2016. The present study exhibited that, the maximum values of bioaccumulation and biosedimentation factors were recorded in the liver and the minimum values were observed in the muscles. The results exhibited the differences of some heavy metals accumulation in different tissues of fish and the gradual accumulation and increase in the liver, gills and muscles during summer and spring than other seasons. The liver of *S. solea* accumulates higher levels of Cu, Fe and Zn than other organs. The results showed that the bioaccumulation factor of Cd, Fe and Mn in fishes were greater than biosedimentation factor and this implies that the fishes bioaccumulated these metals from the water. While copper and zinc accumulation in fishes from water were lower than that from sediment and this implies that the fishes bioaccumulated these metals from the sediment

Results recorded the higher values of total proteins in the kidney and liver of ***S. solea*** during winter, however, total proteins in the muscles was peaked during spring. On the other hand, total lipids in the target organs exhibited increasing levels during autumn and spring. Results supported that, the elevation of ASAT and ALAT activities in the target organs might reflect the early toxic effects of heavy metals on the hepatic enzyme activities which may lead to tissue damage and liver necrosis. Analysis of variance indicated that there are significant differences ($p>0.05$) in one way and non-significance in two ways.

INTRODUCTION

Lake Qarun constitutes one of very important sectors in the Egyptian fisheries. Moreover, it is a closed elongated marine lake with irregular shape of about 40 km at length and about 6 km mean width **(Figure 1)**. Lake Qarun containing different types of fish, snails and seabirds along the year. So, it is considered as one of the most important wintering and nesting sites for many species of the migratory birds. It is approximately 55000 feddans (22000 hectares) or approximately 107 square kilometers **(Sabae& Ali, 2004; Ghanem, 2011; Sabae& Mohamed, 2015; Ragab, 2017; Bakry *et al.*, 2018** and **Mohamed, 2019)**.

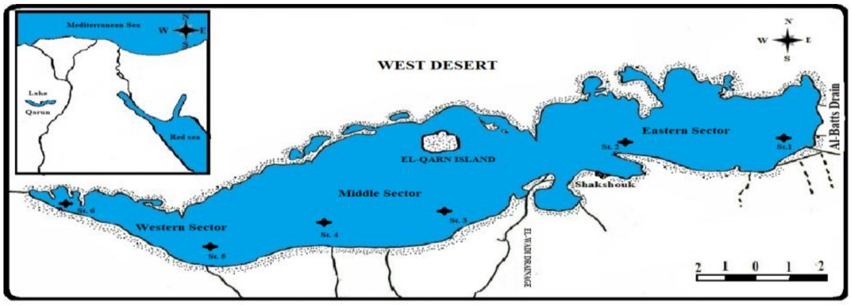

Figure 1. A map of Lake Qarun showing the study area.

Lake Qarun is a closed system acts as a reservoir for agricultural and sewage drainage water of El-Faiyoum Province. The drainage waters discharged into the lake are highly concentrated solids, nutrients, pesticides, heavy metals and organic maters **(Ali &Fishar, 2005; Mohamed & Gad, 2008; Mohamed, 2009; Ghanem, 2011** and **Mohamed, 2019)**. It receives annually about 450 million cubic meters of agricultural drainage water and domestic waste water. The amount of lake water decreased annually to making the balances by evaporation **(El-Shabrawy&Taha, 1999** and **Sabae&Ali, 2004)**.The accumulation of chemical pollutants (heavy metals, pesticides and other pollutants) is expected to increase annually in all its components (e.g. water, sediment and fish) and to change their quality and affect their aquatic life **(Mansour & Sidky, 2003)**. Sediment quality is a good indicator of pollution in water column, where it tends to concentrate the heavy metals and other organic pollutants **(Saeed & Shaker, 2008)**.

Solea solea is one of the dominant fish species recorded from the lake waters **(Ghanem, 2011** and **Mohamed, 2019)**. Fish living in polluted water tends to accumulate heavy metals in their tissues. Generally, accumulation depends on metal concentration, time of exposure, pathway of metal uptake, environmental conditions and intrinsic factors, fish age and feeding habits. Some heavy metals are essential for the growth and well-being of living organisms. However, they are likely to show toxic effects when organisms are exposed to higher levels than normally required. Other elements (Cd, Hg, Ni, Co and Pb) are not essential for metabolic activities and exhibit toxic properties **(Cogun &Kargin, 2004; Delaney &Klesius, 2004; Benli, 2005** and **Ghanem *et al*., 2015)**. Low concentrations of essential trace elements may suppress physiological action, leading to abnormal growth of organisms **(Bowen, 1966** and **Mansour *et al*., 2000)**. Bioaccumulation and biosedimentation factors from environment to fish tissue changes according to the species of the chemical, the metabolite properties of the tissues and the pollution degree of the environment **(Ayas *et al*., 2007** and **Ozmen *et al*., 2008)**. Biochemical composition in different fish species varies with age, sex, season and diet and the heavy metals are found to influence the biochemical composition of fingerlings **(Shakoori *et al*., 1996)**.

Impact of contaminants on aquatic ecosystems can be evaluated by measuring biochemical parameters in the liver of fish that respond specifically to the degree and type of contamination **(Barhoumi *et al*., 2012** and **Chavan & Muley, 2014)**. Changes in the enzymes activities and muscles composition can be used as biomarkers for tissue damage **(Nelson & Cox, 2000; Almeida *et al*., 2002** and **Adhikari *et al*., 2004)**.

The present study aimed to get information about the seasonal variations in bioaccumulation and biosedimentation factors of heavy metals components (water, sediments and inhabiting fishes) in lake Qarun as a bioindicator for pollution level and its effects on some biochemical aspects of *S. solea*.

MATERIALS AND METHODS

The present work was conducted at the laboratories of Zoology Department, Fuculty of Science, Al-Azhar University, Nasr City, Cairo, Egypt, during the period of study.

1. Samples collection:

Water, sediments and fish samples were collected from the the lake during the period from October, 2015 to September, 2016.

Water and sediments sampling:

Surface water samples were collected by a Ruttner bottle water sampler with capacity of one/two litters. For measurement of heavy metals samples were collected in polyethylene bottles. Moreover, sediment samples were collected from using Van Veen type, grab. Sampling was device at the same time of water collection. After collection, the sediment samples were transferred to the laboratory in plastic bags.

Fish sampling:

A total number of 80 fish (about 20 fish/season) were seasonally collected for freshly examined or preserved for later examination. In the laboratory, fishes were identified; the total and standard lengths of each fish **(Figure 2)** were measured and recorded to the nearest centimeter (cm). While, the body weight was determined to the nearest gram (g). After dissection, a known weight of the muscles was kept under freezing condition at 4 °C until the latter examinations.

Figure 2. The sole fish, *Solea solea,* collected from Lake Qarun.

2. Heavy metal analysis:

Concentrations of heavy metals in water were determined after digestion by nitric acid according to **Eaton & Franson (2005)**. Concentrations of heavy metals in sediment were determined by using the method suggested by **Oregioni & Aston (1984)**. However, concentrations of heavy metals in fish target organs were measured according to **APHA (1992)** to determine the correlation between different metals during different seasons. Concentrations of heavy metals in the water, sediment and fish target organs were detected after digestion for determination the bio-accumulation and bio-sedimentation factors**.**

3. Biochemical analysis:

Biochemical parameters were determined seasonally during the study period. After dissection, a known weight of each organ was stored at 4°C in a refrigerator for latter examinations. Total protein was determined using the Folin-Cioclten method described by **Lawry *et al.* (1951)** with its modification suggested by **Ansell & Traveuion (1967)**. While, total lipids were estimated according to the method of **Knight *et al*. (1972)**, using a kit of Bioadwic Company. Results were converted into g/100 g wet weight. Aspartate aminotransferase **(**ASAT) and alanine aminotransferase (ALAT) activities in the target organs were determined according to the method suggested by **Reitman & Frankel (1957)** by using a kit of Bioadwic Company. Results were converted into U/gm wet weight.

Statistical analysis:

Results were expressed in tables as mean ± SD. ,Analysis of variance (ANOVA) was assumed according to **Bailey (1981)**.

RESULTS AND DISCUSSION

1. Bioaccumulation and biosedimentation factors:

1.1.Bioaccumulation factor (BAF):

The present study exhibited that, the maximum value of bioaccumulation factor for **cadmium** was recorded during winter in the gills and kidney (0.248 and 0.235, respectively) while the minimum value (0.072) occurred in the muscles during autumn. However, the highest level of bioaccumulation factor for **copper** was detected in the liver during spring and the lowest one was determined in the muscles during summer; being 0.378 and 0.028, respectively. Bioaccumulation factor for **iron** was peaked during summer in the gills (0.376), kidney (0.591) and liver (0.797) and declined to reach its minimal value (0.130) during autumn in the muscles **(Table 1)**.

Results indicated that bioaccumulation factor for **manganese** ranged between 0.008 during summer in muscles and 0.0261 during spring in liver. Higher level of bioaccumulation factor for **zinc** was recorded during autumn in liver and the lower one was observed during winter in muscles; being 0.411 in the former and 0.058 in the latter **(Table 1)**.

The bioaccumulation of heavy metals in an aquatic organism depends on species, invasion pathways and chemical composition of material, metabolic characters of the sampled tissues and the surrounding environmental condition **(Ozmen *et al*., 2008** and **Younis *et al*., 2015)**. The observed high level of BAF in some fish species indicates that these fishes have a high potential to concentrate heavy metals in their organs **(Eja *et al*., 2003)**. The extent of occurrence or accumulation of trace metals by organisms in different tissues is dependent on the route of entry. The accumulation process of metals toke placed by penetration the organism through gills and skin **(Ayas, 2007** and **Ozmen *et al*., 2008)**.

The present study was matching with **Ahmed *et al*. (2019)** who found that, the bioaccumulation factors (BAFs) of some metals were relatively lower than that obtained by **Kwok *et al*. (2014)** on Tilapia collected from Pearl River estuary with different rates of bioaccumulation in organisms tissues. According to the level of bioaccumulation factor, metals concentrations in organisms exceeded the concentrations of metals found in the surrounding environment, indicating bioaccumulation in this ecosystem **(Klavinš *et al*., 1998** and **Chiba *et al*., 2011)**.

The present results supported that fact, the deference in the levels of accumulation in different organs of fish can be attributed to the physiological role of each organ plus other factors such as regulatory ability, behavior and feeding habits may play a significant role in the deference of accumulation in these organs **(Kehinde *et al*., 2016** and **Oboh & Okbara, 2019)**. Also, the chemical nature of metals, the ionic strength, and pH tend to be a master variable in the accumulation process **(Eneji *et al*., 2011)**. Data indicated that, the general increase in mean concentration of heavy metals in the samples could be attributed to more bioaccumulation due to metal concentration arising from reduced water volume during the dry season. The fact is that, Cu is actively persistent in muscles due to being an essential element of living tissue **(ATSDR, 2005; Zhong *et al*., 2018** and **Traina *et al*., 2019)**.

Table 1. Bio-accumulation and bio-sedimentation factors of some heavy metals in the different organs of *S. solea* collected from Lake Qarun during the period from autumn, 2015 to summer, 2016.

Metals	Organs / Seasons	Bio-accumulation factor				Bio-sedimentation factor			
		Gills	**Kidney**	**Liver**	**Muscles**	**Gills**	**Kidney**	**Liver**	**Muscles**
Cd	**Autumn**	0.230	0.096	0.132	0.072 ▼	0.185	0.078	0.107	0.058
	Winter	0.248▲	0.235 ▲	0.169	0.156	0.195▲	0.185 ▲	0.134	0.123
	Spring	0.183	0.172	0.206	0.160	0.155	0.145	0.174▲	0.135
	Summer	0.107	0.193	0.097	0.075	0.074	0.133	0.067	0.052 ▼
Cu	**Autumn**	0.068	0.082	0.145	0.052	0.322	0.399	0.697	0.248
	Winter	0.109	0.135	0.247	0.069	0.566	0.701	1.284	0.359
	Spring	0.126	0.159	0.378 ▲	0.082	0.526	0.661	1.577▲	0.340
	Summer	0.078	0.077	0.192	0.028 ▼	0.235▼	0.232 ▼	0.575	0.246
Fe	**Autumn**	0.223	0.340	0.431	0.130 ▼	0.036	0.054	0.069	0.021 ▼
	Winter	0.284	0.387	0.576	0.207	0.032	0.043	0.065	0.023
	Spring	0.204	0.277	0.284	0.273	0.058	0.079 ▲	0.081▲	0.026
	Summer	0.376▲	0.591 ▲	0.797▲	0.250	0.031	0.049	0.066	0.021 ▼
Mn	**Autumn**	0.045	0.0124	0.0144	0.011	0.029	0.008	0.009	0.006 ▼
	Winter	0.084	0.0146	0.0156	0.010	0.067	0.011	0.012	0.007
	Spring	0.115	0.0149	0.0261▲	0.014	0.068▲	0.009	0.016	0.008
	Summer	0.045	0.0117	0.0105	0.008 ▼	0.043	0.011	0.010	0.007
Zn	**Autumn**	0.261	0.190	0.411▲	0.114	1.280	0.932	2.015	0.560
	Winter	0.193	0.172	0.343	0.058 ▼	1.219	1.086 ▲	2.164▲	0.366 ▼
	Spring	0.250	0.177	0.299	0.216	1.100	0.778	1.316	0.947
	Summer	0.235	0.122	0.298	0.110	1.634▲	0.847	2.078	0.768

The results exhibited the differences of some heavy metals accumulation in different tissues of fish and the gradual accumulation and increase in the liver, gills and muscles during summer and spring than other seasons. Liver of *S. solea* accumulated higher levels of Cu, Fe and Zn than other organs. Similar observation was recorded by **Jent *et al*. (1998)** and **Yehia & Sebaee (2012)** who found that Cd and Cu concentration increased in fish liver. The higher accumulation in liver may alter the levels of various biochemical parameters in this organ; this may also cause severe liver damage **(Ferguson, 1989)**.

1.2. Biosedimentation factor (BSAF):

The present study exhibited that, the higher level of bio-sedimentation factor for **cadmium** during winter in the gills and kidney and the lower one during summer in the muscles; being 0.195 in the first organ, 0.185 in the second and 0.052 in the third **(Table 1)**.

However, the maximum value of Bio-sedimentation factor for **copper** varied from 0.232 during summer in the kidney to 1.577 during spring in the liver. The minimal value of bio-sedimentation factor for **iron** was recorded during spring in the kidney and liver (0.079 and 0.081, respectively) and the maximal value (0.021) obtained during autumn and summer in the muscles **(Table 1)**.

The present study indicated that, bio-sedimentation factor for **manganese** attained its high peak during spring in the gills (0.068) and the lower one (0.006) during autumn in the muscles. Moreover, bio-sedimentation factor for **zinc** exhibited the increasing levels in the gills during summer (1.634) and metabolic organs (kidney and liver) during winter (1.086 and 2.164, respectively) while, the decreasing one (0.366) was determined in the muscles during winter **(Table 1)**.

This study showed that, bio-sedimentation levels of heavy metals in an aquatic ecosystem may be due to the increasing activity of sewage and anthropogenic pollution. This finding disagree with **Leblanc & Ceuleneer (1991)** and **De Mora *et al*. (2004)** who studied the geological characters on the seabed of Oman Sea and mention that the seabed composition is mostly have more nickel sulphide content which is the natural source of nickel in the coastal areas, rather than the anthropogenic activities. **Dallinger (1993)** refered to that bio-sedimentation factor (BSAF) >2, the organism is macroconcentrator. If 1<BSAF<2, the organism is micro-concentrator. If BSAF<1, the organism is de-concentrator and releasing the metal in sediment.

Heavy metal pollution at Lake Qarun is resulted from the human activities such as shipping, fishing and waste water from sewage and agriculture drainage which can increase the concentration of some metals in edible organs. Data indicated that, some organs are specified to metal than other. This result is matching with **Ziyaadini *et al*. (2016)** who concluded that, *Chiton lamyi* showed higher BSAF for cadmium and can be used as specifically measurement of cadmium in the aquatic environments.

Data appeared that, the higher concentration of metals in gills could be linked to their direct contact with ambient medium. This finding agree with **Asante *et al*. (2014)** who recorded that, gills are the main site of water movement and bioaccumulation center. The mean concentration of measured metals in the muscles of fishes in this study were below the allowable concentration suggested by **GRWCG (2003)** and **WHO (2005)**, this result was in agreement with many authors including **Choubal-Kraïem *et al*. (2007)** and **Khalil & Faragallah (2008)** who reported that, muscles is not an active organ in accumulation of most heavy metals. The differences in accumulation metal concentrations in the gills and muscles could be attributed to differences in their physiological roles. Organisms with high food intake tend to accumulate more metals concentrations, plus it has different metabolic rates and different food requirements plus their amounts **(Ademoroti, 1996)**.

The results showed that the bioaccumulation factor of Cd, Fe and Mn in fish were greater than biosedimentation factor and this implies that fish bioaccumulated these metals from water; this finding is matching with **Barron (1995)**. While, Cu and Zn accumulation in fishes from water were lower than that from sediment and this implies that fish bioaccumulated these metals from sediment. This result agrees with **Abdel-Baki *et al*. (2011)** and **Asante *et al*. (2014)** who concluded this finding to feeding behavior of the studied fish.

The increasing of bioaccumulation and biosedimentation factors in the organs reflects the warning signal for fish health and human consumption. The present study shows that precaution measures need to be taken in order to prevent future heavy metal pollution. Therefore, further monitoring programs should be conducted.

2. Biochemical studies:

2.1. Metabolic parameters:

2.1.1. Total proteins:

Results in **Table (2)** declared that, total proteins in the kidney of *S. solea,* was ranged between 3.26±0.41 g/100 g wet wt. during autumn and 5.77±1.48 g/100 g wet wt. during winter. Also, the maximum average value of total proteins in the liver was detected during winter and the minimum average value was determined during autumn; being 6.83±0.56 g/100 g wet wt. and 4.03±0.72 g/100 g wet wt., respectively. In the muscles, however, total proteins was peaked during spring and declined during summer (4.78±0.47 and 3.25±0.53 g/100 g wet wt., respectively).

The present study indicated that, total proteins in the target organs were exhibited the higher peak during winter may be attributed to the combined effects of high food availability to storing material prior to spawning. These findings are in agreement with **Tulgar & Berik (2012); Sabae & Mohamed (2015); Ragab (2017); Ghanem (2019)** and **Mohamed (2019)**.

Data explained that, the depletion of proteins content in the target organs reflected to the changes in water characters by the stress of pollutants, dissolved in agriculture drainage waters that may critically influence the growth rate and quality of the fishes which feed on bottom founa induced by bioaccumulation of metals. From another angle of view, the lower value of total proteins in the fish organs of Lake Qarun may be due to the higher level of salinity in this lake, which are unfavorable for them, or may be due to the lower density of zooplankton and nutrients **(James *et al.,* 1991)**. Furthermore, **Vutukuru (2005)** reported that, depletion in protein content at the target organs may be attributed to that, it was taken as an alternative source of energy demand that induced by different pollutants in lake Qarun.

2.1.2. Total lipids:

The present study declared that, total lipids in the kidney of *S. solea*, was fluctuated between 1.25±0.12 g/100 g wet wt. during summer and 1.78±0.19 g/100 g wet wt. during spring. Furthermore, the maximum average value of total lipids in the liver was detected during autumn and the minimum one was determined during summer; being 1.63±0.27 g/100 g wet wt. in the former and 1.09±0.13 g/100 g wet wt., in the latter. Moreover, total lipids in the muscles showed the increasing levels during autumn and spring (1.30±0.15 g/100 g wet wt. and 1.23±0.10 g/100 g wet wt. respectively). While, the lowest average values were detected during winter and summer; being 1.13±0.12 g/100 g wet wt. in the former and 1.11±0.06 g/100 g wet wt. in the latter **(Table 2)**.

The present study indicated that, total lipids in the target organs were exhibited the higher peak during cold or semi-cold seasons may be attributed to the combined effects of nutrients availability to storing material. These findings are in agreement with **Tulgar & Berik (2012)** and **Ragab (2017)**. Depletion in lipids contents in the metabolic organs (kidney and liver) may be due to the action of toxicity which suppresses the activity of enzymes responsible for lipid transformation ultimately causing disturbance in lipid metabolism and lead to the decreasing in cholesterol level. Similar findings were found by **Shakoori *et. al.* (1996); Virk & Sharma (1999)** and **Mohamed (2019)** and differ with **Sancho *et al.* (1998); Chandra & Khuda-Bukhsh (2004)** and **Blaner *et al.* (2005)**.

The decreasing level of total lipids in the muscles of studied fish collected from Lake Qarun may be attributed to many reasons; (1) the secretion of catecholamine and corticosteroids in the blood stream after the toxicant stress that produces an enhanced in metabolic rate which in turn reduces the metabolic reserves, (2) the use of energy-rich lipids for energy production during toxic stress. This may be attributed to the changes in water quality by the action of heavy metals that may critically affects directly on the growth and goodness of fishes **(Khalil & Hussein, 1996** and **Ghanem *et al.*, 2015)**. Moreover, the agricultural drainage waters is generally rich with nitrogen, phosphorous and organic matter that causes appropriate changes in the physical and chemical features of water. This may affect indirectly on fish growth and productivity of fishes through their effects upon bacterial flora, phytoplankton and zooplankton **(Shaaban *et al.*, 1999** and **Fayed *et al.*, 2001)**. Some metals are with very strong binding (permanent store) and that strong bound metals in fish flesh are not easily influenced by the environmental change, the elimination of metals is an active biochemical and physiological processes **(Barak & Mason, 1990)**.

Table 2. Seasonal variations of biochemical parameters (Mean ± S.D.) in the target organs of *S. solea* collected from Lake Qarun, during the period from autumn, 2015 to summer, 2016.

Parameters	Seasons / Organs	Autumn	Winter	Spring	Summer	Annual Average
Total proteins (g /100 g wet wt)	Kidney	3.26±0.41	5.77±1.48	4.17±0.58	4.08±0.64	4.32±1.05
	Liver	4.03±0.72	6.83±0.56	4.79±0.70	6.01±0.58	5.42±1.25
	Muscles	4.14±0.43	4.42±1.00	4.78±0.47	3.25±0.53	4.15±0.65
Total lipids (g /100 g wet wt)	Kidney	1.43±0.08	1.75±0.07	1.78±0.19	1.25±0.12	1.55±0.26
	Liver	1.63±0.27	1.16±0.24	1.45±0.22	1.09±0.13	1.33±0.25
	Muscles	1.30±0.15	1.13±0.12	1.23±0.10	1.11±0.06	1.19±0.09
ASAT (U / g wet wt)	Kidney	223.33±17.06	233.33±13.53	256.67±12.49	343.33±10.54	264.17±54.59
	Liver	223.33±15.10	243.33±14.80	273.33±13.53	236.67±11.36	244.17±21.15
	Muscles	323.33±13.53	313.33±27.22	326.67±22.72	233.33±20.42	299.17±44.25
ALAT (U / g wet wt)	Kidney	256.67±2.31	106.67±4.62	220.00±28.00	276.67±18.90	215.00±75.94
	Liver	356.67±9.24	163.33±34.02	256.67±24.44	363.33±16.17	285.00±94.65
	Muscles	113.33±23.44	106.67±2.31	306.67±41.63	226.67±18.90	188.34±96.21

2.2. Enzymatic activities:

2.2.1. Aspartate aminotransferase (ASAT):

Results in **Table (2)** revealed that, aspartate aminotransferase activity (ASAT) in the kidney of *S. solea,* was fluctuated between 223.33±17.06 U/g wet wt. during autumn and 343.33±10.54 U/g wet wt. during summer. During other seasons, it was nearly similar; being 233.33±13.53 U/g wet wt. during winter and 256.67±12.49 U/g wet wt. during spring. On the other hand, the highest activity of ASAT in the liver was determined during spring and the lowest one was detected during autumn; being 273.33±13.53 and 223.33±15.10 U/g wet wt., respectively. During the remaining seasons, it was nearly similar. In the muscles, however, it showed a higher level (326.67±22.72 U/g wet wt.) during spring and the lower one (233.33±20.42 U/g wet wt.) during summer.

2.2.2. Alanine aminotransferase (ALAT):

The present study revealed that, alanine aminotransferase activity (ALAT) in the kidney of *S. solea*, was varied from 106.67±4.62 U/g wet wt. during winter to 276.67±18.90 U/g wet wt. during summer. During other seasons, it was higher during autumn than spring; being 256.67±2.31 and 220.00±28.00 U/g wet wt, respectively. In the liver of sole fish, it showed the highest peak during summer and the lowest one during winter; being 363.33±16.17 U/g wet wt. in the former and 163.33±34.02 U/g wet wt. in the latter. A high peak of ALAT in the muscles was recorded during spring and the lower one during winter; being 306.67±41.63 U/g wet wt. and 106.67±2.31 U/g wet wt., respectively **(Table 2)**.

The present study supported this fact, aspartate and alanine aminotransferase are liver specific enzymes and they are sensitive markers of hepatotoxicity and histopathologic changes and can be assessed within a shorter time. The higher accumulation in liver may alter the levels of various biochemical parameters in liver. This may also cause severe liver damage **(Ferguson, 1989)**. Results supported this fact; the elevation of ASAT and ALAT activities in the target organs might reflect the early toxic effects of heavy metals on the hepatic enzyme activities which lead to the tissue damage and liver necrosis. These results are matching with **Zaghloul *et al.* (2011); Ghanem (2014); Ali *et al*. (2016)** and **Mohamed (2019)** and differ with **Gill *et al.* (1991)** whom found that, the reduction of aminotransferases levels in various organs may be resulted from the reduction of enzymes secretion permeability of cell membrane. Biochemical profile in fish has proved to be a sensitive index for evaluation of the fish metabolism under metallic stress. **Almeida *et al*. (2001)** proved that, fish subjected to metals showed reduced levels of proteins, ASAT and ALAT activities in the fish muscles. Also, **Luskova *et al*. (2002)** and **Ali *et al*. (2016)** reported the changes in biochemical profile are mirror changes in metabolism and biochemical processes of the organism, resulting from the effect of pollutants such as the heavy metals.

3. Statistical analysis:

Analysis of variance **(Table 3)** indicated that, there are significant differences ($p<0.05$) at one way of total proteins except between the different organs showed non-significant. Moreover, one way of analysis for data at total lipids exhibited a significant difference ($p<0.05$). ASAT activity recorded non-significance at all sources of variance except the different organs at one way, it showed a significant difference. Furthermore, a highly significant difference ($p<0.01$) at one way of analysis for activity of alanine enzyme. From another angel, two way of ANOVA indicated non-significance for all parameters.

Table 3. Analysis of variance (ANOVA) on biochemical parameters in the sole fish, *S. solea*, collected from Lake Qarun. (Data represented by F-value)

Source of variances	Total proteins	Total lipids	ASAT	ALAT
Seasons	3.310*	4.716**	1.189 n.s.	6.061***
Organs	1.342 n.s.	2.745*	4.383**	4.691**
Seasons*organs	0.235 n.s.	0.470 n.s.	0.890 n.s.	2.115 n.s.

Note: * = Significant at p<0.05. ** = Significant at p<0.01. n.s. = non-significant.

CONCLUSION

Levels of heavy metals found in the muscles were within the safe limits for human health. The increasing of bioaccumulation and biosedimentation factors in edible organs may be considered as an important signal for negatively health of fish and human consumption. In addition, it is necessary to exercise more cautions towards water resources in these areas to keep water suitability for aquaculture to prevent future heavy metal pollution which leading to production of good fish, with negatively affects the human health. Therefore, further monitoring programs should be conducted.

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ARABIC SUMMARY

تأثير التراكم والترسيب الحيوى لبعض العناصر الثقيلة على بعض الإستجابات البيوكيميائية فى سمكة موسى القاطنة فى بحيرة قارون، مصر.

أحمد ياسين هاشم محمد الوصيفي[1]، محمد حامد محمد غانم[2]، محمود محمد محمد البمبي[1] ، فؤاد أحمد فهمي علي [3]

1 قسم البيئة والزراعة الحيوية، كلية الزراعة بالقاهرة، جامعة الأزهر، مصر.
2 قسم علم الحيوان، كلية العلوم بنين بالقاهرة، جامعة الأزهر، القاهرة، مصر.
3 قسم وقاية النبات، كلية الزراعة بالقاهرة، جامعة الأزهر، القاهرة، مصر.

تم اجراء هذه الدراسة خلال الفترة من أكتوبر، 2015 إلى سبتمبر، 2016م، لرصد وتقييم معاملى التراكم والترسيب الحيوي لخمسة من العناصر الثقيلة داخل أسماك موسى، القاطنة لبحيرة قارون، مصر. حيث تم تجميع عينات المياه ورسوبيات القاع وكذلك عينات الأسماك خلال عام كامل. أوضحت الدراسة الحالية أن أعلى قيمة لكلا من معاملى التراكم الحيوى والترسيب الحيوى قد سجلت داخل الكبد وأقل قيمة فى عضلات هذه النوعية من الأسماك.

أظهرت النتائج وجود إختلافات جوهرية فى تراكم العناصر الثقيلة داخل الأنسجة المختلفة للأسماك، حيث تزايد معامل التراكم الحيوى للعناصر الثقيلة تدريجياً داخل الأعضاء المستهدفة لهذه الأسماك خلال موسمى الربيع والصيف مقارنة بالمواسم الأخرى، ماعدا عنصرى الكادميوم والزنك. تعد الكبد أكثر الأعضاء تركيزاً لعناصر النحاس، الحديد والزنك عن باقى الأعضاء. كما أوضحت النتائج أن معامل التراكم الحيوى لعناصر الكادميوم، الحديد والمنجنيز داخل أعضاء الأسماك أعلى من معامل الترسيب الحيوى لها داخل نفس الأعضاء وهذا يشير إلى أن الأسماك تركز هذه العناصر من المياه، بينما أشارت النتائج أن معامل الترسيب الحيوى لعنصرى النحاس والزنك أعلى من معامل التراكم الحيوى لها وهذا يشير لتركيز الأسماك لهما عن طريق رسوبيات القاع.

سجلت النتائج أعلى قيمة للبروتينات الكلية داخل كلى وأكباد سمكة موسى خلال فصل الشتاء، بينما كانت أعلى قيمة لها داخل العضلات خلال فصل الربيع. ومن ناحية أخرى،أظهرت مستويات الدهون الكلية داخل الأعضاء المستهدفة أعلى معدل لها خلال فصلى الخريف والربيع. كما دعمت النتائج أن الزيادة فى نشاط إنزيمى الأسبارتك والألانين فى الأعضاء المختلفة للأسماك ربما تعكس التأثير المبكر لسمية العناصر الثقيلة على نشاط إنزيمات الكبد. هذا وقد أشارت التحاليل الإحصائية إلى وجود فروق معنوية في التحاليل البيوكيميائية للأسماك بين كلا من الأعضاء المختلفة في المواسم المختلفة لكل عامل. كما أظهر عدم وجود فروق معنوية فى حالة التداخل بين قيم المواسم المختلفة والأعضاء المختلفة.