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EVALUATION OF SEASONAL CHANGES OF HEAVY METAL ACCUMULATION IN WATER AND ORGANS/TISSUES OF SOME FISH SPECIES INHABITING LAKE MANZALA, EGYPT.

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Abstract

Fe, Mn, Zn, Cu, Pb, and Cd concentrations in water and tissues of some fish species namely; tilapia species, mullet (*Liza aurata*) and catfish (*Clarias gariepinus*) inhibiting lake Manzala were determined seasonally during July, 2016 to June, 2017. Metals in water and fish tissues show a significant ($P< 0.05$) seasonal and regional variations, in which the maximum values of all metals were observed during summer, while the lowest levels were found during winter. The concentration of the measured heavy metals were found in the following order Fe > Cu > Zn > Mn > Pb > Cd. The highest concentration of Fe (1.60 mg/l), Cu (0.77 mg/l), Zn (0.67 mg/l), Mn (0.58 mg/l), Pb (0.319 mg/l) and Cd (0.196 mg/l) were recorded at the southern part of the lake (Region 3). Also, heavy metal concentrations varied significantly ($P< 0.05$) depending on the type of the tissue and fish species as the higher concentrations were recorded in liver and gills than muscles. Generally, the heavy metal levels in fish tissues of different fish species were found in the order: *Clarias gariepinus* > *Liza aurata* > Tilapia species. High concentration of Fe (1792.33 µg/g dry wt.), Zn (80.96 µg/g dry wt.), Mn (49.66 µg/g dry wt.), Cu (85.03 µg/g dry wt.), Pb (3.96 µg/g dry wt.) and Cd (4.61µg/g dry wt.) were recorded in liver of catfish collected from the south part of the lake (Region3), while muscle tissues retained the lowest in all types of fish.

Keywords: Water; Heavy metals; Lake Manzala; Fish; Tilapia; Clarias gariepinus, Liver, Muscles

INTRODUCTION

Water pollution has become one of the most serious problems in Egypt as most of the industrial and untreated sewage waste-water discharge in canals, River Nile and Lakes Shaker *et al.* (2017). Manzala Lake, the largest of Egypt's Mediterranean wt. lands and the most productive for fisheries, is suffering from land reclamation, pollution as well as overgrowth by water hyacinth. In the last six decades Manzala Lake was subjected to various threats: agriculture drainage, municipal sewage and industrial waste water. These pollutants have turned the lake into polluted, unhealthy ecosystem affecting fish production and natural resources that are distributed within the lake. The budget of lake water coming from drains that affect the whole area of the Lake (El-Naggar *et al.*, 2016).

The contamination by heavy meals is one of the more serious problems due to their toxicity, persistence and bio-accumulation in biota especially fish which situated at the top of the food chain and can accumulate large amounts of heavy metals (Zahran *et al.*, 2015). Bio-accumulation of metals in fish tissues has been reported by many researchers; Bahnasawy *et al.* 2011 and Hegazy *et al.*, 2016. Heavy metals may accumulate in fish either through direct consumption of water or by uptake through epithelia like the gills, skin, and digestive tract (Burger *et al.*, 2002). Metals such as Cu and Zn are essential metals since they play an important role in biological systems. They are required of low levels for metabolic activity in organisms. The essential metals can also produce toxic effects when their intake is excessively elevated. Other heavy metals like Pb and Cd, which are non-essential metals, may exhibit extreme toxicity, even in trace concentrations (Fernandes *et al.*; 2008).

The accumulation of heavy metals in fish gills, muscle, and liver has a great attention because of the potential toxic effects of such substances not only on fish, but also on human (Begum *et al.*, 2013). For these reasons, it is important to determine the contents of heavy metals in order to evaluate the possible risk of fish consumption by humans (Cid *et al.*, 2001). Therefore, this study aims to evaluate the content of heavy metals in water and some tissues (liver, gills, and muscles) of tilapia, mullet (*Liza aurata*) and catfish (*Clarias gariepinus*) during whole period of the study.

MATERIALS AND METHODS

Study area:

Manzala Lake is located between longitudes 31° 45' and 32° 22' E and latitudes 31° 48 00' and 31° 35' N. It extends 64.5 km in its maximum length and 49 km in its maximum width and 239 km in it total perimeter. It is shrinking in size; the rate of shrinking of the total area from 1922 to 1995 was estimated at 5.22km^2/yr. The greater losses of the lake areas were detectable along the western and southern borders of the lake. In 1900 its area was 1907 km^2, while its area as measured by land sat imagery in 1981 was about 909.85km^2. As a result of the presence of a large number of islets in the lake, its area of open water measures only about 700km^2. The lake is shallow, with an average depth of about 1.25 m (Frihy *et al*., 1998).

The lake is bordered by Mediterranean Sea to the North and the North-East, Suez Canal to the East, Dakahlia and Sharkia Provinces to the South and Damietta Branch of the Nile to the West (Hossen and Negm, 2016). The main outlets connected the lake with the sea are El-Gamil outlet and the New El-Gamil outlet). The lake is also connected to the Suez Canal at El-Qabouti Canal; a few kilometers to the South of Port Said. El-Inaniya Canal connected the lake western boundary to the Nile Damietta Branch (Sallam and Elsayed, 2015). The Lake received untreated industrial, domestic and agricultural drainage water that discharged into the lake through six main drains (Bahr El Bakar Drain, Ramsis Drain, Hadous Drain, Matariya Drain, El-Serw Drain, and Faraskur Drain) in the southern region. The lake was divided into 12 sites that cover of the whole area under study.

Sample collection and analysis:

Water.

Water samples were collected monthly by a PVC vertical water sampler from the selected sampling sites of the lake (Figure 1), during the study period

(July 2016-June 2017). Samples were collected at 30 cm below the surface using one liter polythene bottles with screw caps previously washed with acid (0.01 N HNO_3) and rinsed by distilled water, then placed in an ice box and transferred to the laboratory for further analysis. The samples were digested by Nitric Acid Digestion method for total metals concentration according to APHA (2000).

Fish.

Mature fish samples (tilapia sp., mullet (*Liza aurata*) and catfish (*Clarias gariepinus*) were collected monthly randomly from 4 regions from the lake during the study period with the help of the local fishermen. Fish samples were washed with water to remove adhered particles from the surface and skin. The samples were transferred to the Lab in an ice box. Gills, liver and muscle tissues were taken, then placed in polyethylene bags and stored at -20 °C until analysis. About 1 g from previously oven-dried gills, 5g of muscle and liver tissues were ignited and digested with concentrated HNO_3 and HCl according to procedures recommended by AOAC (2005).

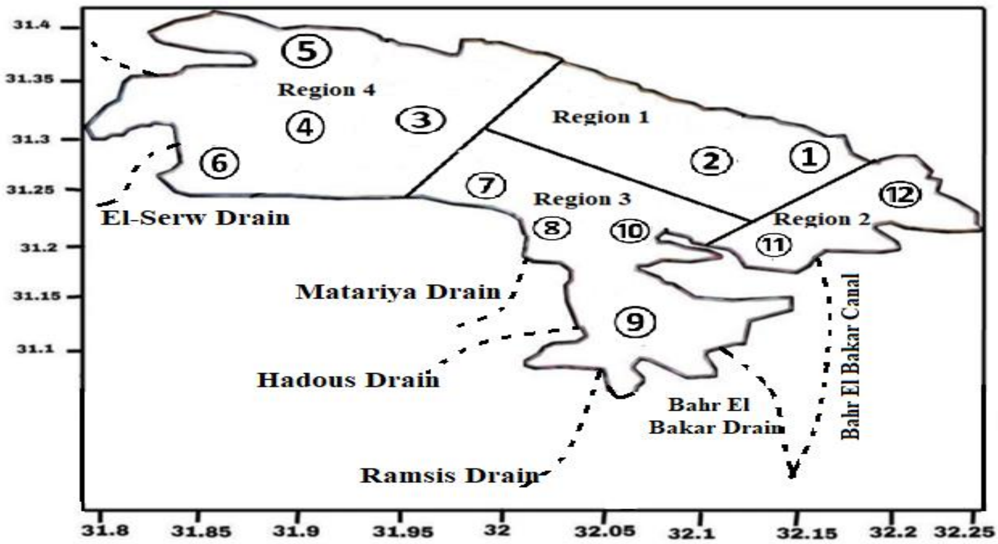

Figure 1. The studied 12 sites of the four regions at Manzala Lake during the study period.

Samples were analyzed using Flam Atomic Absorption Spectrophotometer (Thermo-Electron Corporation S Series AA Spectrometer) for Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Lead (Pb) and Cadmium (Cd) as mg/L for water and µg/g dry weight (dw) for tissues.

Statistical analysis:

Two-way ANOVA was used to test the significant differences in the concentrations of heavy metals of samples along the seasons and sites. For comparison of means, ANOVA test and post hoc Duncan test were used. Results of the test were considered significant if the calculated *P* values were ≤0.05. Pearson correlation was used to examine the relationship between the elements in fish. All statistics were run on the computer using the SAS program (SAS, 2000).

RESULTS AND DISCUSSION

Heavy metals in water:

The seasonal variations of metal concentrations in water from Manzala Lake was illustrated in Tables (1-6). The results showed that metal concentrations varied significantly ($P<0.05$) among the various sites through different seasons. These seasonal variations may be due to the fluctuation of the amount of drainage water discharged into the lake (Authman *et al.*, 2008).

A slight increase of Fe concentration values was recorded during summer and spring than other seasons at the same sites (Table 1). Fe values varied between 0.32 mg/l at site (1) in winter and 1.63 mg/l at site (9) in summer. The concentration of iron in water samples was found remarkably higher at the southern sites, since it recorded 1.07, 1.56, 1.63, 1.55 and 1.32 at sites 7, 8, 9, 10 and 11; respectively in summer. This is in agreement with the findings obtained by Bahnasawy *et al*. (2011) and Abu Khatita *et al*. (2017) who reported that high values characterize hot seasons (summer and spring) due to the elevation of temperature which decrease the assimilation rate of Fe by aquatic organisms especially macrophytes.

The same trend was observed for Mn as its average concentration vary from 0.2 mg/l at site (1) in winter to 0.58 mg/l at site (9) in summer (Table 2). Mn values are increased toward south where the higher values were 0.48, 0.58 and 0.5 mg/l in summer at sites 8, 9 and 10; respectively. This may be as a result of dumping the agricultural and industrial sewage which having higher content of pesticide and heavy metals (Abu Khatita *et al*., 2017). The increase of Mn values during the hot seasons than cold seasons (autumn and winter) may attribute to the mobilization of Mn from the sediment to the surface water due to decomposition of organic debris by microbial activity (Sung and Morgan, 1981). The lower levels recorded during cold seasons may be due to the oxidation and precipitation on the bottom sediment.

The concentration of Zn ranged from 0.3 mg/l at site 1 during summer and 0.67 mg/l and 0.63 mg/l at sites 9 and 10; respectively during winter season (Table 3). The concentration of Zn in water showed an agreement with the other reported literatures (Sancer and Tekin-Özan, 2016) who found that Zn reached the highest levels in winter. The decrease of Zn concentration during hot seasons (summer and spring) is due to its uptake by macrophytes and its adsorption on the clay particles and then sedimentation to the underlying sediments (Ali and Fishar, 2005).

Concerning Cu a significant difference ($P < 0.05$) of accumulation in different seasons was detected (Table 4). The levels of copper showed a similar trend as Zn, where its values increased during cold seasons (autumn and winter). The average concentration ranged from 0.38 mg/l and 0.4 mg/l at sites 1 and 2; respectively in spring to 0.77 mg/l and 0.76 mg/l at sites 9 and 11; respectively in winter season. Similar findings have been reported by EL-Saharty (2014) who reported that the high concentration of Cu in winter and autumn more than spring and summer which was mainly attributed to the precipitation of copper to the sediment as CuS under elevation of temperature (Hutchinson, 1957).

Pb showed a slight increase of Pb values during hot seasons (spring and summer) more than cold seasons (Table 5). The averages values of Pb ranged from 0.003 mg/l at site (3) during winter to 0.319 mg/l at site 9 during summer. The high level Pb in water samples of Manzala Lake at some sites could be attributed to the heavy traffic on the road that produce high gasoline combustion as mentioned by Banat *et al.* (1998). It can also obtain from spills of leaded petrol from fishing boats and agricultural runoff which contains fertilizers. High values recorded in hot seasons could be attributed to the raise of temperature that enhanced the mobilization of Pb from the underling sediment then liberate to the overlaying water (Berg *et al*., 1995).

Cd concentration in water samples showed that the lowest values are found in the northern part and increases towards the south region and reaches the highest values in summer (Table 6). Similar findings have been reported by Abu khatita *et al*. (2017) who concluded that the high concentration of metals in summer season could be attributed to metals arising from water because of reducing water level in this season. In our study, Cd concentrations were found to be 0.029 mg/l at site 3 in winter and 0.196 at site 9 at summer season.

From the above results it is clear that the heavy metal concentrations in water were significantly increasing ($P < 0.05$) during summer and spring than winter and autumn. Also, metal concentrations increased at sites 7, 8, 9, 10 and 3 at region (3) which present near the drainage and sewage waste water drains. These findings are in agreement with those obtained by Abu khatita *et al*. (2017). Also, the results showed that the average values of Pb and Cd significantly increase in some sites near boughaz region (sites 1 and 2), this may be due to their presence near to the highway road and boat maintenance stations. The maximum mean values of the measured metals (Fe, Zn and Cu) are lower than the permissible limits while, Mn, Pb and Cd values are higher than the permissible limits recommended by WHO (2011). The standard permissible levels of Fe (5- 50 mg/l), Mn (0.4 mg/l), Cu (2.0 mg/l), Zn (3.0 mg/l), Pb (0.01 mg/l) and Cd (0.003 mg/l) which cited by WHO (2011).

From the previous results we can recommended that the necessity to introduce seawater from the Mediterranean Sea through boughazes to improve water quality. Also, the necessity to flows polluted drains canals into desert to plant timber trees or establishment of water treatments stations.

Heavy metal in fish:

Metal concentrations (μg/g dw) of Fe, Mn, Zn, Cu, Pb, and Cd in liver, gills and muscle tissues of Tilapia species, mullet (*Liza aurata*) and catfish (*Clarias gariepinus*) collected from Lake Manzala were shown in Tables (7-12). The results of analysis of variance showed significant differences in metal concentrations in the different internal tissues at ($P< 0.05$) throughout the different seasons. The mean concentrations of the three organs and tissues indicate different capacities for metal accumulation. Findings show that metal accumulation is highest in liver and gills but it's low in muscle tissues. The descending order of concentration for Fe, Mn, Zn, Cu, Pb, and Cd in these organs and tissues was: liver >gills > muscle. The difference in the accumulation may be attributed to the proximity of the tissues to the availability of the metals, age and fish species and presence of ligands in the tissues having an affinity to the metal and/or to the role of the tissues in the detoxification process (Bashir and Alhemmal, 2015).

High concentrations of Fe were recorded in fish samples from region (3) in liver of catfish during summer 1780.33 µg/g dry wt. and autumn 1792.33 µg/g dry wt., while the lowest concentrations were found in muscles of Tilapia species from region (1) during winter 36.13 µg/g dry wt. and spring 38.13 µg/g dry wit (Table 7). The maximum Mn concentration (49.66 µg/g dry wt.) was found in catfish's liver of region (3) in autumn, while the minimum Zn concentration (7.2 µg/g dry wt.) was recorded in tilapia muscles in winter at region (1) as shown in Table (8).

Data in Table (9) indicates that high concentration of Zn (80.96 µg/g dry wt.) was recorded in liver tissue of catfish from the region (3) in autumn, while low concentration (7.56 µg/g dry wt.) was recorded during spring in tilapia muscle at region (1). In region (3), Cu recorded the higher concentration (85.03 µg/g dry wt.) during autumn season and lower concentration (11.16 µg/g dry weight) were recorded for tilapia muscle at region (2) during spring (Table 10).

According the results obtained in Table (11), the highest concentration of Lead (3.96 µg/g dry wt.) was observed in the liver of catfish at region (3) during autumn ($p<0.05$), while the minimum values (0.3 µg/g dry wt.) was found in the tilapia muscle at region (4) during spring. The highest concentration of Cadmium (4.61 µg/g dry wt.) was observed in the liver of catfish at region (3) in autumn ($p<0.05$), the minimum concentration of Cadmium (0.31µg/g dry weight) was found in the tilapia muscle at region (4) during spring (Table 12). The highest concentrations of all metals were found in tissues of collected fish from region (3). This may be attributed to that the water of this region contained the highest levels of the measured metals. This is in agreement with the findings of (Shakweer, 1998; Saeed and Shaker, 2008 and Bahnasawy *et al.*, 2011) who concluded that the concentration of trace metals in various organs of fish reflects the degree of water pollution in the aquatic environments in which such fish are living.

Higher accumulation of trace metals observed in liver and this may be due to their capacity to accumulate heavy metals brought by blood from other parts including gills and muscles of the body and induce the production of the metal binding protein, metallothionein, that is believed to play a crucial role against the trace metals by binding the metals (Iwegbue, 2008). The high content of metals in gill tissues can be attributed to the fact that fish gills play a distinct role in metal uptake from the environment. Due to their respiratory function, gills are in direct contact with the contaminated medium (water), and have the thinnest epithelium of all of the organs (Kotze *et al.*, 1999). This is in agreement with the results of (Erdoĝrul and Erbilir, 2007) who reported that the highly branched structural organization of the gills and the resultant highly increased surface area, along with the large volume of water passing through the gill surface and the highly vascular physiological state and the relatively small biomass when compared to their surface area make the gills a prime site for trace metals accumulation.

Muscle contained the lowest concentrations of trace metals among all the tissues investigated in the present study. Similar results were reported by (Dural *et al*., 2010) who indicated that muscle does not come into direct contact with the metals as it is totally covered externally by the skin, that in many ways helps the fish to ward off the penetration of the trace metals and also it is not an active site for detoxification as in the case of liver and kidneys. The current study shows seasonal changes of metal concentrations in fish species and this may result from intrinsic factors such as growth cycle, reproductive cycle and changes in water temperature (Chatterjee *et al.*, 2006). Accumulation of bioactive metals like Cu and Zn was actively controlled by the fish through different metabolic processes and the level of accumulations usually independent of ambient concentrations (Pattee and pain, 2003). On the other hand, environmental factors affect the accumulation of non-essential toxic elements like Pb (Deram *et al.*, 2006). The recommended daily intake for an adult is 50, 0.05 and 0.214 mg/day wt. for Fe, Cd and Pb respectively according to WHO (2011) While, the permissible daily intake of Cu is 5 mg/day wt. IPCS (1998), Zn is 30 mg/day wt. and Mn is 10 mg/day wt. SCF (1993). The concentration of metals (Fe, Mn, Zn and Cu) in the edible part of this fish species are lower than the levels of compared to the permissible limits and safe for consumer. Concentration of Cd and Pb within the safe limit of (WHO, 2001). Finally from the above finding, it is shown that Fe values in fish species organs were highest than other heavy metals. These results were correlated with heavy metals concentration in water. Thus, concentration of heavy metals in fish species organs is a vital indicator of water quality or pollution. Therefore, we find that the fish that found in the southern region has significantly highest content of pollutants than other regions.

CONCLUSION

Differences were observed among organs and muscle tissues of different fish species as well as water concerning heavy metals accumulation. The concentration of metals in water (except Cd and Pb) and fish organs and tissues were within the acceptable limits according to WHO (2011), IPCS (1998) and SCF (1993). To sustain a healthy water ecosystem and prevet health problems for consumers and locals, heavy metal concentrations should be monitored periodically.

Table 1. Seasonal concentrations of Fe (mg/l) (mean ± standard deviation) of water samples collected from Manzala Lake during July 2016-June 2017.

Seasons	Sites											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Sum	0.37 ± 0.02^{Af}	0.47 ± 0.02^{Ae}	0.58 ± 0.04^{Ae}	0.89 ± 0.06^{Ad}	0.83 ± 0.04^{Ad}	0.95 ± 0.06^{Ad}	1.07 ± 0.07^{Ac}	1.56 ± 0.09^{Aa}	1.63 ± 0.08^{Aa}	1.55 ± 0.08^{Aa}	1.32 ± 0.06^{Ab}	1.28 ± 0.06^{Ab}
Aut.	0.33 ± 0.01^{Bf}	0.41 ± 0.04^{Be}	0.53 ± 0.04^{Be}	0.80 ± 0.05^{Bd}	0.74 ± 0.04^{Bd}	0.83 ± 0.05^{Bd}	0.97 ± 0.05^{Bc}	1.31 ± 0.08^{Ba}	1.42 ± 0.06^{Ba}	1.313 ± 0.08^{Ca}	1.2 ± 0.06^{Cb}	1.16 ± 0.05^{Cb}
Win.	0.32 ± 0.01^{Bg}	0.39 ± 0.03^{Bf}	0.49 ± 0.03^{Cf}	0.75 ± 0.05^{Ce}	0.69 ± 0.04^{Ce}	0.82 ± 0.04^{Bd}	0.91 ± 0.04^{Cd}	1.29 ± 0.07^{Bb}	1.4 ± 0.06^{Ba}	1.273 ± 0.07^{Db}	1.163 ± 0.07^{Dc}	1.11 ± 0.05^{Dc}
Spr.	0.36 ± 0.02^{Af}	0.47 ± 0.03^{Ae}	0.56 ± 0.04^{Ae}	0.85 ± 0.06^{Ad}	0.80 ± 0.05^{Ad}	0.90 ± 0.06^{Ad}	1.01 ± 0.06^{Ac}	1.54 ± 0.08^{Aa}	1.6 ± 0.07^{Aa}	1.48 ± 0.08^{Ba}	1.27 ± 0.06^{Bb}	1.23 ± 0.06^{Bb}

$^{a-g}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).

$^{A-D}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 2. Seasonal concentrations of Mn (mg/l) (mean ± standard deviation) of water samples collected from Manzala Lake during July 2016-June 2017.

Seasons	Sites											
	1	2	3	4	5	6	7	8	9	10	11	12
Sum	0.2 ± 0.01^{Be}	0.27 ± 0.03^{Ad}	0.3 ± 0.02^{Ad}	0.36 ± 0.03^{Ac}	0.32 ± 0.02^{Ad}	0.35 ± 0.03^{Ac}	0.29 ± 0.02^{Ad}	0.48 ± 0.04^{Ab}	0.58 ± 0.05^{Aa}	0.50 ± 0.04^{Aa}	0.42 ± 0.03^{Ab}	0.39 ± 0.03^{Ac}
Aut.	0.25 ± 0.02^{Ad}	0.24 ± 0.01^{Ad}	0.27 ± 0.02^{Ad}	0.31 ± 0.03^{Ac}	0.28 ± 0.01^{Bd}	0.32 ± 0.02^{Ac}	0.26 ± 0.01^{Ad}	0.42 ± 0.03^{Bb}	0.53 ± 0.05^{Aa}	0.47 ± 0.04^{Ab}	0.36 ± 0.02^{Bc}	0.33 ± 0.02^{Bc}
Win.	0.21 ± 0.02^{Bd}	0.21 ± 0.02^{Bd}	0.24 ± 0.01^{Bd}	0.28 ± 0.02^{Bc}	0.27 ± 0.01^{Bc}	0.28 ± 0.01^{Bc}	0.24 ± 0.01^{Bd}	0.40 ± 0.03^{Bb}	0.49 ± 0.04^{Ba}	0.42 ± 0.03^{Bb}	0.32 ± 0.01^{Bc}	0.30 ± 0.01^{Bc}
Spr.	0.27 ± 0.02^{Ad}	0.26 ± 0.03^{Ad}	0.29 ± 0.03^{Ad}	0.34 ± 0.03^{Ac}	0.31 ± 0.02^{Ac}	0.32 ± 0.03^{Ac}	0.28 ± 0.01^{Ad}	0.45 ± 0.04^{Ab}	0.54 ± 0.04^{Aa}	0.47 ± 0.04^{Ab}	0.4 ± 0.03^{Ab}	0.38 ± 0.02^{Ab}

$^{a-e}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).
$^{A-B}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 3. Seasonal concentrations of Zn (mg/l) (mean ± standard deviation) of water samples collected from Manzala Lake during July 2016-June 2017.

Seasons	Sites											
	1	2	3	4	5	6	7	8	9	10	11	12
Sum	0.3 ± 0.02^{Cd}	0.32 ± 0.02^{Cd}	0.35 ± 0.03^{Bd}	0.38 ± 0.03^{Cc}	0.41 ± 0.04^{Bc}	0.39 ± 0.03^{Cc}	0.41 ± 0.03^{Cc}	0.46 ± 0.04^{Cb}	0.55 ± 0.05^{Ca}	0.51 ± 0.04^{Ca}	0.47 ± 0.03^{Cb}	0.40 ± 0.03^{Cc}
Aut.	0.34 ± 0.02^{Bf}	0.36 ± 0.03^{Bf}	0.38 ± 0.03^{Be}	0.42 ± 0.03^{Be}	0.44 ± 0.04^{Bd}	0.45 ± 0.04^{Bd}	0.48 ± 0.04^{Bd}	0.52 ± 0.04^{Bc}	0.62 ± 0.05^{Ba}	0.58 ± 0.05^{Ba}	0.52 ± 0.04^{Bc}	0.48 ± 0.04^{Bc}
Win.	0.39 ± 0.03^{Af}	0.42 ± 0.04^{Ae}	0.42 ± 0.04^{Ae}	0.46 ± 0.04^{Ad}	0.49 ± 0.04^{Ad}	0.5 ± 0.04^{Ac}	0.54 ± 0.05^{Ac}	0.59 ± 0.05^{Ab}	0.67 ± 0.06^{Aa}	0.63 ± 0.06^{Aa}	0.57 ± 0.05^{Ab}	0.53 ± 0.05^{Ac}
Spr.	0.35 ± 0.03^{Bd}	0.36 ± 0.03^{Bd}	0.38 ± 0.03^{Bc}	0.41 ± 0.03^{Bc}	0.45 ± 0.04^{Bb}	0.40 ± 0.04^{Cc}	0.45 ± 0.04^{Bb}	0.51 ± 0.05^{Bb}	0.58 ± 0.05^{Ca}	0.53 ± 0.05^{Ca}	0.51 ± 0.04^{Bb}	0.47 ± 0.04^{Bb}

$^{a-f}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).
$^{A-C}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 4. Seasonal concentrations of Cu (mg/l) (mean ± standard deviation) of water samples collected from Manzala Lake during July 2016-June 2017.

Seasons	Sites											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Sum	0.38 ± 0.03^{Cd}	0.40 ± 0.03^{Cd}	0.42 ± 0.03^{Cc}	0.44 ± 0.03^{Cc}	0.46 ± 0.03^{Cc}	0.51 ± 0.04^{Cb}	0.5 ± 0.04^{Bb}	0.57 ± 0.05^{Ca}	0.56 ± 0.05^{Da}	0.55 ± 0.05^{Da}	0.53 ± 0.04^{Da}	0.55 ± 0.05^{Ba}
Aut.	0.43 ± 0.04^{Be}	0.45 ± 0.04^{Be}	0.48 ± 0.04^{Bd}	0.50 ± 0.04^{Bd}	0.52 ± 0.05^{Bd}	0.56 ± 0.05^{Bc}	0.59 ± 0.05^{Ac}	0.62 ± 0.06^{Bb}	0.73 ± 0.06^{Ba}	0.7 ± 0.06^{Ba}	0.71 ± 0.06^{Ba}	0.64 ± 0.06^{Ab}
Win.	0.51 ± 0.05^{Ad}	0.53 ± 0.05^{Ad}	0.55 ± 0.05^{Ad}	0.57 ± 0.05^{Ad}	0.59 ± 0.05^{Ac}	0.61 ± 0.05^{Ac}	0.62 ± 0.06^{Ac}	0.67 ± 0.06^{Ab}	0.77 ± 0.07^{Aa}	0.74 ± 0.06^{Aa}	0.76 ± 0.07^{Aa}	0.66 ± 0.06^{Ab}
Spr.	0.44 ± 0.04^{Bd}	0.45 ± 0.04^{Bd}	0.47 ± 0.04^{Bd}	0.50 ± 0.04^{Bc}	0.53 ± 0.05^{Bc}	0.56 ± 0.05^{Bd}	0.53 ± 0.05^{Bc}	0.59 ± 0.05^{Cb}	0.67 ± 0.06^{Ca}	0.64 ± 0.06^{Ca}	0.66 ± 0.06^{Ca}	0.58 ± 0.05^{Bb}

$^{a-e}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).
$^{A-D}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 5. Seasonal Concentrations of Pb (mg/l) (mean ± standard deviation) of water samples collected from Manzala Lake during July 2016- June 2017.

Seasons	Sites											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Sum	0.065 ± 0.004^{Af}	0.061 ± 0.004^{Af}	0.007 ± 0.001^{Af}	0.068 ± 0.002^{Af}	0.049 ± 0.002^{Ag}	0.061 ± 0.002^{Af}	0.068 ± 0.003^{Af}	0.223 ± 0.02^{Ab}	0.319 ± 0.03^{Aa}	0.184 ± 0.02^{Ac}	0.167 ± 0.03^{Ad}	0.085 ± 0.001^{Ae}
Aut.	0.057 ± 0.003^{Bf}	0.051 ± 0.004^{Cg}	0.006 ± 0.001^{Af}	0.063 ± 0.003^{Bf}	0.044 ± 0.002^{Bg}	0.055 ± 0.002^{Bg}	0.063 ± 0.003^{Bf}	0.216 ± 0.01^{Bb}	0.307 ± 0.03^{Ba}	0.173 ± 0.03^{Bc}	0.154 ± 0.02^{Bd}	0.076 ± 0.001^{Be}
Win.	0.054 ± 0.003^{Bf}	0.048 ± 0.003^{Cf}	0.003 ± 0.001^{Ch}	0.061 ± 0.001^{Be}	0.041 ± 0.001^{Bg}	0.051 ± 0.001^{Cf}	0.058 ± 0.002^{Cf}	0.206 ± 0.02^{Cb}	0.298 ± 0.02^{Ca}	0.164 ± 0.03^{Cc}	0.143 ± 0.02^{Cd}	0.067 ± 0.001^{Ce}
Spr.	0.061 ± 0.003^{Af}	0.056 ± 0.003^{Bf}	0.005 ± 0.001^{Bg}	0.063 ± 0.002^{Bf}	0.046 ± 0.001^{Ag}	0.057 ± 0.002^{Bf}	0.064 ± 0.003^{Bf}	0.214 ± 0.01^{Bb}	0.308 ± 0.03^{Ba}	0.177 ± 0.01^{Bc}	0.156 ± 0.02^{Bd}	0.076 ± 0.001^{Be}

$^{a-h}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).
$^{A-C}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 6. Seasonal Concentrations of Cd (mg/l) (mean ± standard deviation) of water samples collected from Manzala Lake during July 2016-June 2017.

Seasons	Sites											
	1	2	3	4	5	6	7	8	9	10	11	12
Sum	0.052 ± 0.001^{Ac}	0.051 ± 0.001^{Ac}	0.041 ± 0.001^{Ad}	0.064 ± 0.003^{Ab}	0.059 ± 0.003^{Ab}	0.070 ± 0.004^{Ab}	0.068 ± 0.004^{Ab}	0.118 ± 0.006^{Ab}	0.196 ± 0.006^{Aa}	0.123 ± 0.007^{Ab}	0.122 ± 0.006^{Ab}	0.061 ± 0.004^{Ab}
Aut.	0.041 ± 0.001^{Be}	0.040 ± 0.001^{Be}	0.035 ± 0.001^{Bf}	0.057 ± 0.001^{Bc}	0.052 ± 0.001^{Bd}	0.062 ± 0.002^{Bc}	0.056 ± 0.001^{Bd}	0.101 ± 0.005^{Cb}	0.179 ± 0.02^{Ca}	0.110 ± 0.01^{Bb}	0.108 ± 0.01^{Cb}	0.048 ± 0.003^{Bd}
Win.	0.036 ± 0.001^{Ce}	0.034 ± 0.001^{Ce}	0.029 ± 0.001^{Cf}	0.052 ± 0.001^{Cc}	0.046 ± 0.001^{Cd}	0.050 ± 0.001^{Cc}	0.049 ± 0.001^{Cc}	0.094 ± 0.004^{Db}	0.171 ± 0.01^{Da}	0.102 ± 0.01^{Cb}	0.099 ± 0.004^{Db}	0.042 ± 0.002^{Cd}
Spr.	0.044 ± 0.001^{Bd}	0.042 ± 0.002^{Bd}	0.033 ± 0.001^{Be}	0.058 ± 0.003^{Bc}	0.051 ± 0.002^{Bc}	0.059 ± 0.004^{Bc}	0.057 ± 0.002^{Bc}	0.108 ± 0.03^{Bb}	0.187 ± 0.04^{Ba}	0.115 ± 0.01^{Bb}	0.112 ± 0.01^{Bb}	0.052 ± 0.004^{Bc}

$^{a-f}$ Numbers with different superscript letters in the same row differ significantly (p<0.05).
$^{A-D}$ Numbers with different superscript letters in the same column differ significantly (p<0.05).

Table 7. Seasonal concentrations of Fe (µg/g) dry wt.) in different organs and tissues of some fish Species collected from Manzala Lake during July 2016-June 2017.

Regions	Seasons	Fish species								
		Tilapia species			**Mullet (*Liza aurata*)**			**Catfish (*Clarias gariepinus*)**		
		Liver	**Gills**	**Muscle**	**Liver**	**Gills**	**Muscle**	**Liver**	**Gills**	**Muscle**
1	**Sum.**	231.83 ±11.1^{Ce}	193.66 ±9.9^{Dd}	47.63 ±1.6^{Fd}	279.66 ±14.2^{Be}	222.36 ±11.1^{Cf}	62.53 ±2.3^{Ee}	302.23 ±12.9^{Ad}	232.53 ±15.6^{Cf}	69.66 ±3.6^{Ed}
	Aut.	228.66 ±13.5^{Ce}	185.93 ±9.2^{Ee}	46.7 ±2.1^{Gd}	277.5 ±12.8^{Be}	206 ±9.8^{Dg}	59.33 ±1.9^{Ge}	300.9 ±11.1^{Ad}	225.83 ±12.1^{Cf}	72.03 ±3.3^{Fd}
	Win.	198.63 ±9.9^{Cf}	156.9 ±10.2^{Ef}	36.13 ±1.1^{Fe}	254.46 ±13.6^{Bf}	182.63 ±8.8^{Dh}	45.4 ±1.1^{Ff}	280.76 ±10.7^{Ae}	200.2 ±10.4^{Cg}	53.1 ±2.1^{Fe}
	Spr.	205.4 ±9.2^{Cf}	166.86 ±10.6^{Df}	38.13 ±1.4^{Fe}	259.96 ±11.9^{Bf}	187.13 ±11.2^{Dh}	49.13 ±1.3^{Ef}	281.93 ±10.4^{Ae}	202.96 ±12.3^{Cg}	52.03 ±1.8^{Ee}
2	**Sum.**	245.53 ±12.4^{Dd}	211.56 ±11.5^{Ec}	55.26 ±2.7^{Fc}	299.13 ±15.7^{Bd}	243.16 ±12.2^{De}	71.1 ±1.4^{Ed}	329.4 ±15.7^{Ac}	281.36 ±14.7^{Cd}	80.9 ±2.4^{Ec}
	Aut.	246.5 ±13.1^{Dd}	207.86 ±11.4^{Ec}	55. 46 ±3.1^{Gc}	298.86 ±14.1^{Bde}	242.4 ±14.5^{De}	71.06 ±1.2^{Fd}	334.6 ±14.5^{Ac}	279.56 ±15.6^{Cd}	81.2 ±3.5^{Fc}
	Win.	230.1 ±11.7^{De}	195.23 ±8.6^{Ed}	46.13 ±3.2^{Gd}	284.13 ±12.8^{Be}	230 ±10.2^{Df}	62.06 ±1.2^{Fe}	306.53 ±12.9^{Ad}	265.46 ±16.2^{Ce}	73.73 ±1.9^{Fd}
	Spr.	229.83 ±11.8^{De}	196.43 ±10.1^{Ed}	45.23 ±3.3^{Hd}	282.16 ±14.2^{Be}	228.93 ±12.4^{Df}	60.73 ±1.6^{Ge}	303.23 ±14.8^{Ad}	265.2 ±13.1^{Ce}	73.36 ±1.7^{Fd}
3	**Sum.**	1512 ±7.8^{Ca}	1261.33 ±26.4^{Ea}	146.16 ±6.7^{Ha}	1609 ±26.1^{Ba}	1286.66 ±33.3^{Ea}	154.56 ±2.4^{Ga}	1780.33 ±42.1^{Aa}	1378.66 ±27.8^{Da}	166.06 ±4.2^{Fa}
	Aut.	1501.66 ±25.4^{Ca}	1266.33 ±24.7^{Ea}	149 ±5.5^{Ga}	1606 ±25.5^{Ba}	1289.33 ±35.1^{Ea}	154.1 ±3.3^{Fa}	1792.33 ±44.4^{Aa}	1372 ±30.2^{Da}	165.06 ±5.5^{Fa}
	Win.	1467.33 ±27.2^{Cb}	1220.33 ±21.1^{Eb}	133.8 ±5.4^{Gb}	1564.33 ±31.4^{Bb}	1257 ±28.7^{Eb}	146.26 ±4.1^{Fb}	1612.33 ±45.8^{Ab}	1320.66 ±30.9^{Db}	150.1 ±3.7^{Fb}
	Spr.	1470 ±22.4^{Cb}	1226.66 ±19.7^{Eb}	132.56 ±4.4^{Gb}	1568.33 ±33.5^{Bb}	1261.33 ±26.4^{Eb}	144.5 ±3.2^{Fb}	1648.66 ±47.6^{Ab}	1324 ±28.4^{Db}	150.36 ±4.4^{Fb}
4	**Sum.**	263.63 ±12.3^{Dc}	225.6 ±14.3^{Ec}	61.73 ±3.7^{Gc}	317.26 ±26.8^{Bc}	286.8 ±21.1^{Cc}	80.96 ±2.9^{Fc}	340.93 ±18.1^{Ac}	308.16 ±17.6^{Bc}	89 ±3.1^{Fc}
	Aut.	263.73 ±12.8^{Dc}	223.53 ±12.8^{Ec}	62.06 ±3.5^{Gc}	318.36 ±31.7^{Bc}	282.26 ±24.4^{Cc}	81.3 ±3.1^{Fc}	340.16 ±14.9^{Ac}	303.53 ±21.5^{Bc}	87 ±2.8^{Fc}
	Win.	256.13 ±14.1^{Dc}	217.5 ±13.1^{Ec}	58.5 ±2.9^{Hc}	298.7 ±28.4^{Bd}	272.76 ±24.2^{Cd}	78.23 ±2.1^{Gc}	331.8 ±20.2^{Ac}	301.6 ±20.1^{Bc}	85.53 ±3.3^{Fc}
	Spr.	254.16 ±14.6^{Dc}	216.83 ±10.7^{Ec}	57.4 ±2.8^{Hc}	299.53 ±22.6^{Bd}	270.06 ±19.8^{Cd}	77.46 ±2.2^{Gc}	332.46 ±19.5^{Ac}	302.6 ±18.7^{Bc}	86.76 ±3.7^{Fc}

$^{a-g}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).
$^{A-H}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 8. Seasonal concentrations of Mn (µg/g) dry wt.) in different organs and tissues of some fish Species collected from Manzala Lake during July 2016-June 2017.

Regions	Seasons	Fish species								
		Tilapia species			Mullet (*Liza aurata*)			Catfish (*Clarias gariepinus*)		
		Liver	Gills	Muscle	Liver	Gills	Muscle	Liver	Gills	Muscle
1	Sum.	21.96 ±1.4^{Cf}	17.8 ±1.2^{De}	7.93 ±0.11^{Ge}	26.43 ± 1.7^{Be}	20.2 ±1.3^{Cf}	9.1 ±0.03^{Fg}	29.43 ±1.8^{Af}	21.76 ±1.1^{Cf}	11.03 ±0.4^{Eg}
	Aut.	22.26 ±1.6^{Cf}	17.66 ±1.1^{De}	7.96 ±0.13^{Ge}	25.9 ±1.6^{Be}	21.5 ±1.3^{Cf}	9.2 ±0.05^{Fg}	32.13 ±2.1^{Ae}	22.93 ±1.1^{Ce}	11.3 ±0.3^{Eg}
	Win.	20.56 ±1.4^{Cg}	15.33 ±1.1^{Df}	7.2 ±0.12^{Gf}	22.3 ±1.7^{Bg}	19.56 ±1.1^{Cf}	8.9 ±0.04^{Fh}	28.36 ±1.7^{Af}	19.6 ±1.1^{Cg}	9.46 ±0.06^{E}
	Spr.	20.6 ±1.1^{Cg}	15.8 ±1.1^{Ef}	7.3 ±0.11^{Gf}	23.53 ±1.4^{Bf}	19.03 ±1.2^{Dg}	8.86 ±0.03^{Fh}	27.53 ±1.5^{Ag}	18.86 ±1.1^{Dh}	9.36 ±0.05^{Fh}
2	Sum.	25.13 ±1.6^{Ce}	20.06 ±1.0^{Ec}	9.6 ±0.13^{Hd}	29.16 ±2.2^{Bd}	21.9 ±1.2^{De}	11.96 ±0.06^{Ge}	31 ±2.1^{Ae}	22.73 ±1.2^{De}	13.5 ±0.11^{Fe}
	Aut.	25.73 ±1.6^{Ce}	20.93 ±1.1^{Ec}	9.6 ±0.14^{Hd}	29.9 ±2.1^{Bd}	23 ±1.3^{De}	11.83 ±0.05^{Ge}	32.03 ±1.9^{Ae}	22.93 ±1.2^{De}	13.8 ±0.09^{Fe}
	Win.	21.63 ±1.1^{Cf}	18.4 ±1.2^{Dd}	7.76 ±0.14^{Fe}	24.66 ±1.8^{Bf}	18.9 ±1.1^{Dh}	10.66 ±0.04^{Ef}	27.26 ±1.1^{Ag}	18.23 ±0.9^{Dh}	10.73 ±0.07^{Eh}
	Spr.	21.66 ±1.1^{Bf}	18.4 ±1.3^{Cd}	7.8 ±0.12^{Ee}	25.46 ±1.8^{Ae}	18.4 ±1.2^{Ch}	10.26 ±0.04^{Df}	26.4 ±1.4^{Ah}	18.13 ±0.7^{Ch}	10.4 ±0.04^{Dh}
3	Sum.	39.6 ±2.1^{Cb}	31.43 ±2.1^{Ea}	15.66 ±0.15^{Ga}	43.06 ±2.9^{Bb}	35.9 ±2.1^{Db}	17.06 ±0.14^{Fb}	47 ±2.7^{Ab}	39.8 ±1.6^{Cb}	17.76 ±0.12^{Fc}
	Aut.	45.7 ±2.9^{Ca}	32.73 ±2.5^{Fa}	16.1 ±0.15^{Ha}	46.93 ±2.8^{Ba}	38.23 ±2.3^{Ea}	18.7 ±0.016^{Ga}	49.66 ±2.9^{Aa}	41.16 ±2.2^{Da}	19.13 ±0.13^{Ga}
	Win.	35.23 ±2.7^{Bc}	23.3 ±2.3^{Eb}	12.66 ±0.14^{Gb}	33.56 ±2.3^{Cc}	32.16 ±2.3^{Cc}	15.2 ±0.13^{Fc}	36.16 ±2.2^{Ac}	30.63 ±1.6^{Dc}	14.6 ±0.09^{Fe}
	Spr.	31.03 ±2.3^{Bd}	22.13 ±2.1^{Db}	12.23 ±0.12^{Fb}	33.9 ±2.1^{Ac}	29.43 ±2.2^{Cd}	13.73 ±0.12^{Ed}	33.33 ±2.2^{Ad}	30.46 ±1.4^{Bc}	14.26 ±0.13^{Ee}
4	Sum.	27.83 ±2.2^{Cd}	21.96 ±2.1^{Db}	13.43 ±0.11^{Fb}	30.6 ±1.8^{Bc}	23.73 ±2.2^{De}	14.3 ±0.11^{Fd}	32.6 ±1.8^{Ae}	26.06 ±1.3^{Cd}	15.9 ±0.13^{Ed}
	Aut.	29.1 ±2.1^{Cd}	23.36 ±2.2^{Fb}	12.66 ±0.12^{Hb}	33.63 ±1.9^{Bc}	24.93 ±2.1^{Ee}	14.06 ±0.14^{Hd}	34.8 ±1.6^{Ad}	27.46 ±1.3^{Dd}	18.03 ±0.14^{Gb}
	Win.	22.26 ±1.4^{Cf}	18.93 ±1.3^{Ed}	10.26 ±0.11^{Gc}	25.73 ±1.5^{Ae}	20.03 ±1.5^{Df}	10.76 ±0.08^{Gf}	23.53 ±1.2^{Bi}	21.6 ±1.1^{Cf}	12.43 ±0.11^{Ff}
	Spr.	22.36 ±1.3^{Bf}	18.26 ±13^{Dd}	11.5 ±0.11^{Fc}	25.5 ±1.4^{Ae}	19.66 ±1.4^{Cf}	11.63 ±0.08^{Fe}	25.7 ±1.1^{Ah}	22.56 ±1.1^{Be}	12.43 ±0.08^{Ef}

$^{a-i}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).
$^{A-H}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 9. Seasonal concentrations of Zn (µg/g) dry wt.) in different organs and tissues of some fish Species collected from Manzala Lake during July 2016-June 2017.

Regions	Seasons	Fish species								
		Tilapia species			Mullet (*Liza aurata*)			Catfish (*Clarias gariepinus*)		
		Liver	Gills	Muscle	Liver	Gills	Muscle	Liver	Gills	Muscle
1	Sum.	29.83 $\pm1.4^{Bg}$	21.73 $\pm1.1^{Cg}$	10.9 $\pm0.1^{Ef}$	33.83 $\pm1.7^{Ag}$	28.76 $\pm1.4^{Bf}$	13.2 $\pm0.4^{Dd}$	36.6 $\pm1.8^{Af}$	29.6 $\pm1.2^{Bh}$	14.06 $\pm0.6^{De}$
	Aut.	30.1 $\pm1.1^{Cg}$	21.93 $\pm1.1^{Eg}$	10.46 $\pm0.1^{Gf}$	34.13 $\pm2.1^{Bg}$	29.96 $\pm1.8^{Df}$	13.53 $\pm0.6^{Fd}$	39.83 $\pm2.1^{Ae}$	31.46 $\pm1.8^{Ch}$	14.4 $\pm0.4^{Fe}$
	Win.	24.6 $\pm1.6^{Cg}$	18.16 $\pm1.2^{Dh}$	7.7 $\pm0.1^{Fg}$	27.9 $\pm1.3^{Bh}$	26.46 $\pm2.1^{Bh}$	10.8 $\pm0.2^{Ef}$	32 $\pm1.6^{Ag}$	26.26 $\pm1.4^{Bi}$	10.86 $\pm0.2^{Ef}$
	Spr.	25.2 $\pm1.2^{Bh}$	18.06 $\pm1.1^{Ch}$	7.56 $\pm0.1^{Fg}$	28.1 $\pm1.1^{Ah}$	25.63 $\pm1.9^{Bh}$	9.73 $\pm0.1^{Eg}$	29.93 $\pm1.4^{Ag}$	25.46 $\pm1.4^{Bi}$	11.4 $\pm0.2^{Df}$
2	Sum.	33.63 $\pm2.1^{Bf}$	26.43 $\pm2.1^{De}$	12.46 $\pm0.2^{Fe}$	35.63 $\pm2.2^{Bg}$	30.06 $\pm1.6^{Cf}$	13.9 $\pm0.2^{Fd}$	40.56 $\pm3.1^{Ae}$	33.46 $\pm1.3^{Bg}$	16.43 $\pm0.3^{Ed}$
	Aut.	34.3 $\pm2.2^{Cf}$	27.56 $\pm2.2^{Ee}$	12.93 $\pm0.3^{Ge}$	37.03 $\pm3.1^{Bf}$	31.8 $\pm2.1^{Df}$	14.6 $\pm0.3^{Fd}$	42.6 $\pm2.8^{Ae}$	34.86 $\pm1.1^{Cg}$	16.76 $\pm0.2^{Fd}$
	Win.	31.5 $\pm2.2^{Cf}$	24.93 $\pm2.1^{Ef}$	10.13 $\pm0.2^{Gf}$	33.93 $\pm2.4^{Bg}$	28.4 $\pm1.4^{Df}$	11.86 $\pm0.3^{Gf}$	38.06 $\pm2.4^{Ae}$	31.4 $\pm1.1^{Ch}$	14.06 $\pm0.3^{Fe}$
	Spr.	29.56 $\pm2.1^{Cg}$	24 $\pm2.1^{Ef}$	9.4 $\pm0.2^{Hf}$	33.16 $\pm2.3^{Bg}$	27.3 $\pm1.1^{Df}$	11.1 $\pm0.2^{Gf}$	36.56 $\pm2.2^{Ae}$	30.43 $\pm1.2^{Ch}$	13.43 $\pm0.3^{Fe}$
3	Sum.	57.53 $\pm3.3^{Cb}$	51.4 $\pm3.1^{Db}$	26.73 $\pm1.7^{Fb}$	63.1 $\pm4.1^{Bb}$	58.1 $\pm3.3^{Cb}$	27.33 $\pm1.1^{Ea}$	77.13 $\pm4.7^{Aba}$	62.53 $\pm3.2^{Bb}$	28.23 $\pm1.2^{Ea}$
	Aut.	61.26 $\pm3.6^{Ca}$	53.06 $\pm3.3^{Da}$	28.06 $\pm2.1^{Ea}$	65.66 $\pm3.8^{Ba}$	60.33 $\pm4.6^{Ca}$	28.26 $\pm1.2^{Ea}$	80.96 $\pm4.9^{Aa}$	66.1 $\pm3.3^{Ba}$	28.86 $\pm1.3^{Ea}$
	Win.	49.56 $\pm2.3^{Dc}$	44.66 $\pm2.4^{Ec}$	24.36 $\pm2.1^{Gc}$	56.56 $\pm3.8^{Bc}$	53.33 $\pm4.2^{Cc}$	24.23 $\pm1.2^{Gb}$	72.03 $\pm4.1^{Ab}$	57.8 $\pm3.4^{Bc}$	27.06 $\pm1.1^{Fb}$
	Spr.	47.16 $\pm1.9^{Ec}$	43.66 $\pm2.6^{Fc}$	24.2 $\pm1.8^{Hc}$	53.36 $\pm3.6^{Cd}$	50.63 $\pm3.4^{Dc}$	24 $\pm1.1^{Hb}$	67.63 $\pm3.6^{Ac}$	55.73 $\pm3.4^{Bd}$	26.63 $\pm1.1^{Gb}$
4	Sum.	37.2 $\pm1.7^{De}$	30.1 $\pm1.2^{Ed}$	14.23 $\pm1.1^{Gd}$	41.9 $\pm2.6^{Be}$	36.86 $\pm2.7^{Dd}$	17.2 $\pm1.1^{Fc}$	45.16 $\pm2.9^{Ad}$	39.66 $\pm2.2^{Ce}$	18.26 $\pm0.8^{Fc}$
	Aut.	40 $\pm1.8^{Cd}$	32.03 $\pm1.4^{Ed}$	14.73 $\pm0.9^{Gd}$	43.43 $\pm2.5^{Be}$	37.7 $\pm1.9^{Dd}$	17.73 $\pm0.9^{Fc}$	47.43 $\pm2.4^{Ad}$	40.96 $\pm2.2^{Ce}$	18.63 $\pm0.6^{Fc}$
	Win.	33.6 $\pm1.2^{Cf}$	28.33 $\pm1.4^{De}$	12.83 $\pm0.5^{Fe}$	38.9 $\pm2.4^{Bf}$	34.6 $\pm1.7^{Cd}$	16.13 $\pm0.8^{Ec}$	40.5 $\pm2.5^{Ae}$	38.16 $\pm2.3^{Bf}$	16.6 $\pm0.5^{Ed}$
	Spr.	31.9 $\pm1.1^{Df}$	28.06 $\pm1.1^{Ee}$	12.1 $\pm0.4^{Ge}$	38.43 $\pm2.2^{Af}$	34.53 $\pm1.4^{Cd}$	15.86 $\pm0.6^{Fc}$	38.73 $\pm1.5^{Ae}$	36.26 $\pm1.8^{Bf}$	16.76 $\pm0.5^{Fd}$

$^{a-i}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).

$^{A-H}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 10. Seasonal concentrations of Cu (µg/g) dry wt.) in different organs and tissues of some fish Species collected from Manzala Lake during July 2016-June 2017.

Regions	Seasons	Fish species								
		Tilapia species			Mullet (*Liza aurata*)			Catfish (*Clarias gariepinus*)		
		Liver	Gills	Muscle	Liver	Gills	Muscle	Liver	Gills	Muscle
1	Sum.	34.66 ±2.1^{De}	26.56 ±1.4^{Fe}	14.23 ±0.6^{He}	38.3 ±1.8^{Be}	30.3 ±1.2^{Ee}	16.43 ±1.1^{Gd}	43.06 ±2.2^{Af}	36.43 ±1.6^{Ce}	17.23 ±0.7^{Gd}
	Aut.	36.5 ±2.2^{Cd}	28.13 ±1.4^{Ee}	15.1 ±0.4^{Gd}	41.36 ±2.2^{Bd}	32.76 ±1.1^{De}	16.96 ±0.8^{Gd}	45.53 ±2.3^{Ae}	37.53 ±1.4^{Cd}	18.1 ±0.7^{Fd}
	Win.	32.16 ±1.8^{Be}	23.96 ±1.2^{Df}	12.56 ±0.3^{Fe}	31.83 ±2.2^{Bf}	27.76 ±1.1^{Cf}	14.2 ±1.1^{Ee}	36.96 ±1.4^{Ag}	33.46 ±1.2^{Bf}	14.76 ±0.5^{Ee}
	Spr.	30.66 ±1.4^{Ce}	23.2 ±0.9^{Ef}	11.3 ±0.2^{Gf}	30.1 ±1.4^{Cf}	26.03 ±1.3^{Df}	13.63 ±0.7^{Fe}	36.23 ±1.3^{Ag}	31.86 ±1.2^{Bf}	13.76 ±0.5^{Fe}
2	Sum.	37.36 ±2.2^{Cd}	31.06 ±1.2^{Ed}	14.9 ±0.2^{Ge}	41.26 ±2.5^{BGd}	33.1 ±1.3^{Dd}	17.56 ±0.8^{Fd}	46.53 ±2.3^{Ae}	36.8 ±1.1^{Ce}	18.46 ±0.6^{Fd}
	Aut.	39.26 ±2.4^{Cd}	32.5 ±1.3^{Dd}	15.76 ±0.3^{Gd}	42.3 ±2.4^{Bd}	34.8 ±1.4^{Cd}	18.06 ±0.9^{Fd}	48.66 ±2.6^{Ad}	38.16 ±1.4^{Cd}	19.63 ±1.1^{Ed}
	Win.	33.26 ±1.7^{Cd}	28 ±1.1^{Ee}	12.16 ±0.2^{Ge}	37.03 ±2.2^{Be}	30.06 ±1.2^{De}	15.2 ±0.6^{Fe}	44.06 ±2.2^{Ae}	33.23 ±1.1^{Cf}	15.53 ±0.4^{Fe}
	Spr.	31.63 ±1.7^{Cd}	26.26 ±1.1^{De}	11.16 ±0.2^{Ff}	35.8 ±2.2^{Be}	27.9 ±1.1^{Df}	14.96 ±0.5^{Ee}	41.73 ±1.9^{Af}	31.26 ±1.2^{Cg}	14.2 ±0.3^{Ee}
3	Sum.	66 ±3.8^{Ba}	57.4 ±2.4^{Da}	27.46 ±1.1^{Fa}	67.16 ±4.2^{Ba}	59.3 ±3.3^{Ca}	28.23 ±1.2^{Fa}	81.66 ±3.9^{Aa}	66.43 ±3.6^{Ba}	30.1 ±1.2^{Ea}
	Aut.	69.93 ±4.2^{Ba}	59.03 ±2.2^{Da}	28.96 ±1.2^{Fa}	69.93 ±4.2^{Ba}	60.96 ±4.5^{Da}	29.36 ±1.3^{Fa}	85.03 ±3.7^{Aa}	67.53 ±3.4^{Ca}	30.96 ±1.1^{Ea}
	Win.	58.6 ±3.3^{Bb}	52.43 ±2.3^{Db}	23.83 ±1.1^{Fb}	58.66 ±3.7^{Bb}	51.96 ±4.2^{Db}	25.73 ±1.3^{Eb}	73.73 ±2.7^{Ab}	56.93 ±3.5^{Cb}	26.66 ±1.2^{Eb}
	Spr.	58.2 ±3.1^{Bb}	51.2 ±1.8^{Db}	23.73 ±1.1^{Fb}	57.93 ±3.6^{Bb}	51.5 ±3.8^{Db}	25.1 ±1.1^{Eb}	70.4 ±3.8^{Ab}	56.6 ±2.8^{Cb}	25.03 ±1.1^{Eb}
4	Sum.	44.1 ±2.6^{Cc}	37.63 ±1.6^{Ec}	19.16 ±1.0^{Fc}	46.86 ±3.3^{Bc}	39.1 ±2.5^{Dc}	19.83 ±0.8^{Fc}	51.16 ±2.6^{Ac}	40.53 ±2.9^{Dc}	20.13 ±0.9^{Fc}
	Aut.	46.03 ±2.6^{Cc}	40.06 ±1.5^{Ec}	19.86 ±0.8^{Gc}	48.6 ±2.9^{Bc}	41 ±2.5^{Dc}	20.66 ±1.0^{Fc}	51.43 ±2.5^{Ac}	41.93 ±1.9^{Dc}	21.03 ±0.8^{Fc}
	Win.	38.23 ±1.7^{Cd}	33.63 ±1.2^{Ed}	16.83 ±0.6^{Gd}	41.9 ±2.1^{Bd}	35.46 ±1.6^{Dd}	16.5 ±0.6^{Ge}	45.1 ±1.5^{Ae}	37.46 ±1.7^{Cd}	18.13 ±0.6^{Fd}
	Spr.	36.63 ±1.5^{Cd}	32.93 ±1.3^{Dd}	16.33 ±0.6^{Fd}	40.96 ±2.2^{Bd}	33.06 ±1.3^{Dd}	16 ±0.4^{Fe}	43.8 ±1.5^{Af}	36.96 ±1.5^{Cd}	17.96 ±0.6^{Ed}

$^{a\text{-}g}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).
$^{A\text{-}H}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 11. Seasonal concentrations of Pb (µg/g) dry wt.) in different organs and tissues of some fish Species collected from Manzala Lake during July 2016-June 2017.

	Seasons	Fish species								
		Tilapia species			Mullet (*Liza aurata*)			Catfish (*Clarias gariepinus*)		
		Liver	Gills	Muscle	Liver	Gills	Muscle	Liver	Gills	Muscle
1	**Sum.**	3.57 ±0.03^{Ca}	2.91 ±0.03^{Eb}	0.85 ±0.01^{Fb}	3.72 ±0.04^{Ba}	3.03 ±0.05^{Db}	0.88 ±0.03^{Fb}	3.9 ±0.06^{Aa}	3.13 ±0.05^{Db}	0.92 ±0.02^{Fb}
	Aut.	3.65 ±0.05^{Ca}	2.94 ±0.03^{Eb}	0.85 ±0.02^{Gb}	3.79 ±0.04^{Ba}	3.1 ±0.04^{Db}	0.96 ±0.03^{Fa}	4.01± 0.06^{Aa}	3.2 ±0.06^{Db}	0.96 ±0.02^{Fa}
	Win.	3.05 ±0.02^{Cc}	2.52 ±0.03^{Fc}	0.6 ±0.01^{Hc}	3.43 ±0.05^{Bd}	2.77 ±0.04^{Ed}	0.67 ±0.02^{Gd}	3.68 ±0.06^{Ac}	2.88 ±0.05^{Dc}	0.7 ±0.02^{Gc}
	Spr.	3.11 ±0.01^{Cc}	2.58 ±0.02^{Ec}	0.59 ±0.01^{Fc}	3.33 ±0.04^{Bd}	2.68 ±0.04^{Ed}	0.63 ±0.03^{Fd}	3.62 ±0.06^{Ac}	2.84 ±0.05^{Dc}	0.66 ±0.01^{Fc}
2	**Sum.**	2.62 ±0.01^{Cd}	1.78 ±0.02^{Ed}	0.48 ±0.01^{Gd}	2.73 ±0.04^{Be}	1.86 ±0.03^{Ee}	0.54 ±0.03^{Fe}	2.84 ±0.05^{Ad}	2.02 ±0.04^{Dd}	0.61 ±0.01^{Fc}
	Aut.	2.68 ±0.01^{Bd}	1.79 ±0.02^{Ed}	0.51 ±0.01^{Gc}	2.76 ±0.04^{Be}	1.9 ±0.03^{De}	0.56 ±0.03^{Ge}	2.87 ±0.05^{Ad}	2.04 ±0.04^{Cd}	0.64 ±0.02^{Fc}
	Win.	2.42 ±0.01^{Ce}	1.6 ±0.03^{Fe}	0.34 ±0.01^{He}	2.58 ±0.03^{Bf}	1.75 ±0.04^{Ef}	0.42 ±0.02^{Hf}	2.7 ±0.05^{Ae}	1.92 ±0.03^{De}	0.54 ±0.02^{Gd}
	Spr.	2.42 ±0.01^{Ce}	1.56 ±0.03^{Fe}	0.35 ±0.01^{He}	2.59 ±0.03^{Bf}	1.71 ±0.04^{Ef}	0.44 ±0.02^{Gf}	2.7 ±0.04^{Ae}	1.92 ±0.03^{De}	0.52 ±0.01^{Gd}
3	**Sum.**	3.64 ±0.02^{Ba}	3.04 ±0.04^{Da}	0.92 ±0.02^{Ea}	3.72 ±0.04^{Ba}	3.09 ±0.05^{Da}	0.97 ±0.04^{Ea}	3.88 ±0.06^{Ab}	3.35 ±0.06^{Ca}	0.98a ±0.03^{E}
	Aut.	3.7 ±0.03^{Ba}	3.07 ±0.04^{Da}	0.94 ±0.02^{Fa}	3.79 ±0.05^{Ba}	3.15 ±0.06^{Da}	1.02 ±0.04^{Ea}	3.96 ±0.06^{Aa}	3.4 ±0.05^{Ca}	1.02 ±0.03^{Ea}
	Win.	3.46 ±0.04^{Cb}	2.9 ±0.03^{Eb}	0.84 ±0.02^{Fb}	3.56 ±0.05^{Bc}	2.96 ±0.05^{Ec}	0.79 ±0.04^{Gc}	3.69 ±0.06^{A}	3.19 ±0.05^{Db}	0.87 ±0.03^{Fb}
	Spr.	3.42 ±0.03^{Cb}	2.9 ±0.03^{Eb}	0.84 ±0.03^{Fb}	3.52 ±0.04^{Bc}	2.94 ±0.04^{Ec}	0.78 ±0.03^{Fc}	3.66 ±0.06^{Ac}	3.16 ±0.06^{Db}	0.88 ±0.03^{Fb}
4	**Sum.**	1.99 ±0.02^{Bf}	1.63 ±0.02^{Ee}	0.41 ±0.02^{Fd}	2.06 ±0.04^{Bg}	1.72 ±0.04^{Df}	0.45 ±0.02^{Ff}	2.21 ±0.05^{Af}	1.84 ±0.04^{Cf}	0.49 ±0.02^{Fe}
	Aut.	2.03 ±0.02^{Bf}	1.65 ±0.02^{De}	0.42 ±0.02^{Ed}	2.08 ±0.04^{Bg}	1.76 ±0.03^{Cf}	0.47 ±0.02^{Ef}	2.22 ±0.05^{Af}	1.86 ±0.03^{Cf}	0.51 ±0.02^{Ed}
	Win.	1.89 ±0.02^{Bg}	1.54 ±0.03^{Ee}	0.31 ±0.01^{Ge}	1.96 ±0.03^{Bh}	1.65 ±0.03^{Dg}	0.38 ±0.02^{Fg}	2.12 ±0.05^{Ag}	1.76 ±0.02^{Cg}	0.42 ±0.02^{Fe}
	Spr.	1.91 ±0.02^{Bg}	1.54 ±0.02^{Ee}	0.3 ±0.01^{Ge}	1.98 ±0.03^{Bh}	1.64 ±0.04^{Dg}	0.39 ±0.01^{Fg}	2.13 ±0.05^{Ag}	1.77 ±0.02^{Cg}	0.43 ±0.02^{Fe}

$^{a-h}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).

$^{A-H}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

Table 12. Seasonal concentrations of Cd (µg/g) dry wt.) in different organs and tissues of some fish Species collected from Manzala Lake during July 2016-June 2017.

Regions	Seasons	Fish species								
		Tilapia species			Mullet (*Liza aurata*)			Catfish (*Clarias gariepinus*)		
		Liver	Gills	Muscle	Liver	Gills	Muscle	Liver	Gills	Muscle
1	Sum.	3.01 ±0.03^{Bc}	2.41 ±0.02^{Ca}	0.62 ±0.02^{Db}	3.11 ±0.03^{Ab}	2.47 ±0.03^{Ca}	0.65 ±0.02^{Db}	3.18 ±0.04^{Ad}	2.51 ±0.03^{Cc}	0.72 ±0.03^{Db}
	Aut.	3.07 ±0.02^{Bb}	2.45 ±0.02^{Da}	0.64 ±0.02^{Fb}	3.12 ±0.03^{Bb}	2.5 ±0.02^{Ca}	0.67 ±0.02^{Fb}	3.23 ±0.04^{Ad}	2.55 ±0.03^{Cc}	0.74 ±0.02^{Eb}
	Win.	2.87 ±0.02^{Ce}	2.26 ±0.02^{Eb}	0.52 ±0.01^{Gc}	3.03 ±0.04^{Bc}	2.41 ±0.02^{Db}	0.58 ±0.02^{Fc}	3.11 ±0.03^{Ae}	2.44 ±0.03^{Dd}	0.65 ±0.02^{Fc}
	Spr.	2.82 ±0.02^{Be}	2.26 ±0.02^{Db}	0.51 ±0.01^{Gc}	3.05 ±0.03^{Ac}	2.39 ±0.03^{Cb}	0.58 ±0.01^{Fc}	3.09 ±0.03^{Ae}	2.41 ±0.03^{Cd}	0.65 ±0.02^{Ec}
2	Sum.	2.86 ±0.02^{Be}	1.11 ±0.01^{De}	0.48 ±0.01^{Ec}	2.92 ±0.03^{Bd}	1.15 ±0.02^{Dd}	0.51 ±0.01^{Ec}	2.07 ±0.02^{Ah}	1.23 ±0.02^{Cf}	0.55 ±0.02^{Ed}
	Aut.	2.92 ±0.03^{Bd}	1.14 ±0.01^{De}	0.5 ±0.01^{Fc}	2.94 ±0.03^{Bd}	1.19 ±0.02^{Dd}	0.52 ±0.02^{Fc}	2.09 ±0.02^{Ah}	1.25 ±0.02^{Cf}	0.59 ±0.01^{Ed}
	Win.	2.72 ±0.02^{Be}	1 ±0.01^{Ef}	0.39 ±0.01^{Gd}	2.82 ±0.03^{Ae}	1.11 ±0.02^{Dd}	0.45 ±0.01^{F}	1.99 ±0.02^{Ci}	1.16 ±0.01^{Dg}	0.49 ±0.01^{Fe}
	Spr.	2.68 ±0.02^{Be}	0.98 ±0.01^{Ef}	0.38 ±0.01^{Gd}	2.81 ±0.03^{Ae}	1.1 ±0.02^{De}	0.47 ±0.01^{Fd}	1.99 ±0.02^{Ci}	1.14 ±0.01^{Dg}	0.5 ±0.01^{Fe}
3	Sum.	3.11 ±0.03^{Cb}	2.38 ±0.03^{Fa}	0.71 ±0.02^{Ha}	3.22 ±0.04^{Ba}	2.46 ±0.03^{Ea}	0.76 ±0.03^{Ha}	3.57 ±0.04^{Ab}	2.72 ±0.03^{Da}	0.84 ±0.03^{Ga}
	Aut.	3.14 ±0.03^{Bb}	2.43 ±0.03^{Ea}	0.74 ±0.02^{Ga}	2.92 ±0.03^{Cd}	2.5 ±0.03^{Ea}	0.78 ±0.03^{Ga}	4.61 ±0.05^{Aa}	2.76 ±0.03^{Da}	0.87 ±0.03^{Fa}
	Win.	3.01 ±0.03^{Cc}	2.29 ±0.02^{Eb}	0.62 ±0.02^{Gb}	3.16 ±0.03^{Bb}	2.36 ±0.03^{Eb}	0.65 ±0.02^{Gb}	3.46 ±0.04^{Ac}	2.68 ±0.03^{Db}	0.76 ±0.03^{Fb}
	Spr.	3.99 ±0.04^{Aa}	2.27 ±0.02^{Eb}	0.61 ±0.01^{Gb}	3.11 ±0.03^{Cb}	2.33 ±0.03^{Eb}	0.65 ±0.03^{Gb}	3.44 ±0.04^{Bc}	2.62 ±0.03^{Db}	0.75 ±0.03^{Fb}
4	Sum.	1.99 ±0.01^{Cf}	1.78 ±0.02^{Dc}	0.42 ±0.01^{Fd}	2.06 ±0.02^{Bf}	1.75 ±0.03^{Dc}	0.43 ±0.01^{Fd}	2.17 ±0.03^{Af}	1.78 ±0.02^{De}	0.49 ±0.01^{Ee}
	Aut.	2.02 ±0.01^{Cf}	1.82 ±0.02^{Dc}	0.44 ±0.01^{Ed}	2.09 ±0.02^{Bf}	1.79 ±0.02^{Dc}	0.45 ±0.01^{Ed}	2.19 ±0.03^{Af}	1.79 ±0.02^{De}	0.5 ±0.01^{Ee}
	Win.	1.92 ±0.01^{Cg}	1.7 ±0.02^{Dd}	0.32 ±0.01^{Fe}	2.01 ±0.02^{Bf}	1.71 ±0.02^{Dc}	0.37 ±0.01^{Ee}	2.09 ±0.02^{Ah}	1.7 ±0.02^{De}	0.42 ±0.01^{Ef}
	Spr.	1.91 ±0.01^{Cg}	1.68 ±0.02^{Dd}	0.31 ±0.01^{Fe}	2.02 ±0.02^{Bf}	1.7 ±0.02^{Dc}	0.35 ±0.01^{Fe}	2.12 ±0.02^{Ag}	1.72 ±0.02^{De}	0.43 ±0.01^{Ef}

$^{a-i}$ Numbers with different superscript letters in the same row differ significantly ($p<0.05$).

$^{A-H}$ Numbers with different superscript letters in the same column differ significantly ($p<0.05$).

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تقييم التغيرات الموسمية في تراكم المعادن الثقيلة في المياه وانسجة بعض الأسماك التى تقطن بحيرة المنزلة، مصر

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الملخــص العربــى

تم دراسة تراكم العناصر الثقيلة فى المياه وأنسجة أسماك البلطى والبورى والقراميط التى تقطن بحيرة المنزلة فى الفترة من يوليو ٢٠١٦ إلى يونيو ٢٠١٧. تم تقسيم البجيرة الى عدد ١٢ موقع تغطى البحيرة فى المنطقة تحت الدراسة. وتم تجميع عينات المياه والأسماك من هذه المواقع شهريا. تم تقدير عناصر الحديد – النحاس – المنجنيز – الزنك – الرصاص – الكادميوم فى المياه وأعضاء " الكبد – الخياشيم" وأنسجة اللحم للأسماك وكانت أهم النتائج المتحصل عليها هى:

١- ارتفاع تركيزجميع العناصر الثقيلة فى المياه فى المواقع بالمنطقة الجنوبية بالبحيرة [٧ ، ٨ ، ٩ ، ١٠] عن باقى المواقع وذلك نظرا لقربها من مصبات المصارف الرئيسية.
٢- ارتفاع عناصر الرصاص والكادميوم قى المواقع [١ ، ٢] القريبة من البوغاز وذلك لقربها من الطريق السريع ووجود محطات موانى الصيد.
٣- ارتفاع تركيز العناصر فى الكبد عن باقى الأعضاء ويليه الخياشيم ثم اللحم.
٤- ارتفاع تركيز العناصر جميعها فى أنسجة القراميط يليها البورى ثم البلطى.
٥- ارتفاع تركيز العناصر فى المياه وأنسجة الأسماك خلال فصل الصيف عن باقى فصول السنة.
٦- توصى الدراسة بضرورة التخلص من أحشاء الأسماك الداخلية قبل الطهى.
٧- توصى الدراسة بضرورة وإستغلال مياه مصرف بحر البقر بعد معالجتها واستخدامها فى زراعة الأشجار الخشبية وغيرها أو إقامة محطات لمعالجة مياه الصرف قبل إلقائها فى البحيرة.
٨- ضرورة عمل قنوات لتوصيل مياة البحر الابيض المتوسط لخلط المياه وتقليل التلوث.