

Effect of heavy metals in irrigation water of different fish farms on the quality of cultured fish

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ABSTRACT

The present study aimed to study the effect of irrigation water quality in different fish farms in Egypt on the quality of Nile tilapia, *Oreochromis niloticus*, produced from these fish farms. Four fish farms (El-Abbasa, Edko, Mariout and Bahr El-Baqar) which irrigated with different water sources were selected to study the effect of some heavy metals (iron, copper, zinc and lead) on fish quality produced from these farms during the period of fish culturing from April 2018 to November 2018.

Results indicated that most of the highest averages of all heavy metal concentrations in water, sediment and fish muscular tissues were recorded from Bahr El-Baqar fish farm and their lowest values from El-Abbasa fish farm. The highest contamination factors for most heavy metals were recorded in Bahr El-Baqar fish farm and the lowest in El-Abbasa fish farm. The present study concluded that El-Abbasa fish farm has low pollution and the other fish farms (Edko, Mariout, and Bahr El-Baqar) have progressive deterioration of the site quality.

INTRODUCTION

Fish is an important economic source of protein compared to other sources of animal protein. In developing countries, fish contribute about 30% of the total consumption of animal protein per capita (Wang *et al.*, 2015). Aquaculture contributes more than half of the total fish production in the world (Subasinghe *et al.*, 2009). Tilapia inhabits a variety of fresh water habitats including shallow streams, ponds, rivers and lakes. Historically they have been of major importance in artisan fishing in Africa and are of increasing importance in aquaculture (Afami & Okories, 2008).

The pollution of the aquatic environment with heavy metals has become a worldwide problem, because they are indestructible and most of them have toxic effects on organisms (MacFarlane & Burchett, 2000). Pollution of the aquatic environment by inorganic chemicals has been considered a major threat to the aquatic organisms including fishes. The agricultural drainage water containing pesticides and fertilizers and effluents of industrial activities and

runoffs in addition to sewage effluents supply the water bodies and sediment with huge quantities of inorganic anions and heavy metals (ECDG, 2002). Toxic and harmful pollutants of aquatic environment pose a very serious danger to human health and his life because they can bio-accumulate in fish tissues and they cannot be destroyed or degraded through biological degradation (Al-Kenawy & Aly, 2015).

Metals can be incorporated into food chains and concentrated in aquatic organisms to levels that affect their physiological state of the effective pollutants are the heavy metals which have drastic environmental impact on all organisms. Trace metals such as iron, copper, lead and zinc play a biochemical role in the life processes of all aquatic plants and animals; therefore, they are essential in the aquatic environment in trace amounts (Mason, 2002). But accumulation of heavy metals in large amount in aquatic organisms can pose a long-lasting effect on biogeochemical cycling in the ecosphere. Heavy metals can also adversely affect the growth rate of fish. The presence of heavy metals in different foods constitutes a serious health hazards depending on their relative levels (Nussey, 1998; Mansour & Sidky 2002; Momtaz, 2002; El-Enany, 2004; Duruibe *et al.*, 2007; Al-Haidarey, 2009; Abdel-Rasheed, 2011 and Balasim, 2013)

In Egypt, Environmental pollution with heavy metals is one of the biggest problems that face human being (Al-Naggar *et al.*, 2018). Bahr El-Baqar drain is considered as one of the most polluted drains in Egypt (Abdel-Shafy & Aly, 2002). The total discharge pumped to Lake Manzala from that drain is 2.3 BCM/year. It is passing through four highly populated Governorates; Qalubeya, Sharkia, Ismailia and Port Said. Unfortunately, at the last decades, great areas on both sides of the drain were using its polluted water for irrigation and fish culture (Hamed, 2013). Lake Mariout is one of the main fishing grounds of Alexandria (Saad *et al.*, 2017). Lake Mariout was considered as an oxidation pond for Alexandrian waste water and agricultural wastes, discharged to it by the newly constructed plant stations (El-Zokm *et al.*, 2018).

Thus, the present study aimed to study the effect of irrigation water quality in different fish farms in Egypt on the quality of Nile tilapia, *Oreochromis niloticus*, produced from these fish farms.

MATERIALS AND METHODS

A. Study areas:

This study was investigated in four fish farms irrigated with different water sources, the location of each fish farm was presented in **Table (1)**.

1-El-Abbasa fish farm: one of the most productive Egyptian fish farms, it is located in EL-Sharkia Governorate. The fish farm is about 2200 feddans (**Table 1**).

2- Edko fish farm: Lake Edko with a depth ranged from 50 to 180 cm. reached about 700 km². It receives its water from two sources. The main source is the drainage water of Kom Belag and Bersik drains (1836.55 × 106m³). The sea water of Abu Qir Bay enters the lake sometimes through the lake sea connection as subsurface water current under the action of wind especially in winter.

3- Mariout fish farm: It is at the western extremity of Alexandria city, in the vicinity of Lake Mariout and about 1 Km south of the Mediterranean Sea coast. This farm is affected by El-Mex Pumping Station that pumps out the water through El-Umum drain which connects the Lake Mariout to the Mediterranean Sea through by a channel of about 800 m long.

4- Bahr El-Baqar fish farm: Bahr El-Baqar drain system consists of a main drain that starts near the city of Zagazig where it collects the effluents from two secondary drains.

Table (1): Location of the selected fish farms

Fish farms	Location
El-Abbassa fish farm	30° 32 ' N. 31° 44' E.
Edko fish farm	31°13'N. 30°17'E.
Mariout fish farm	31° 145 ' N. 29° 852' E.
Bahr El-Baqar fish farm	30°58'N. 32°08E

B- Fish sampling:

A total of 324 specimens of *Oreochromis niloticus* (**Figure 1**) were monthly collected from different fish farms. 81 specimens of El-Abbassa fish farm (8.3-25.9 cm in total length and 20.1-320.7 g in weight); 81 specimens of Edko fish farm (7.8-25.7 cm TL and 20.50 - 333.7 g in W); 81 specimens of Mariout fish farm (11.70 -22.80 cm TL and 25.50 - 304.5 g W), and 81 specimens of Bahr El-Baqar fish farm (8.40 - 25.70 cm TL and 20.00 - 280.40 g W) during the period from April, 2018 to November, 2018.



Figure (1): A photograph showing the lateral view of *Oreochromis niloticus*

C- Determination of heavy metals in water samples:

Surface water samples at four fish farms were seasonally taken by a vertical PVC water sampler at depth of a half meter from the water surface. Samples of 1 liter were placed in polyethylene bottles and transferred to the laboratory for heavy metal analysis. All water samples were collected from each fish farm in triplicate and each sample was measured also in triplicate.

Heavy metals considered here were; Fe, Cu, Zn and Pb. Concentrations of heavy metals in the water were determined after the digestion by nitric acid according to APHA (2005). Heavy metals were measured by atomic absorption spectrophotometer (model; Perkin Elmer, 3150) was used for measuring the optical density for each element at its corresponding wave length (Fe 248.3, Cu 324.8, Zn 213.9 and Pb 217 nm). Results were expressed as µg/L.

The concentrations of heavy metals were measured according to the following equation:

$$\text{Metal concentration } (\mu\text{g/L}) = A \times B/C$$

Where:

A = Conc. of metal in digested solution $\mu\text{g/L}$.

B = Final volume of digested solution, ml.

C = Sample volume, ml.

D- Determination of heavy metals in sediment samples:

Sediment samples were collected seasonally from the bottom of each fish farm using Ekman dredge bottom sampler at the same time of water collection. Then, these samples were transferred into the laboratory in ice box. The preparation and complete digestion of the sediment samples were done according to **Martin & Martin (1989)** and **David & Janice (1989)**.

Heavy metals (Fe, Cu, Zn, and Pb) were determined by atomic absorption spectrometry at corresponding wave lengths according to the following equation:

$$\text{Metal conc. } (\mu\text{g/g dry wt.}) = \text{Conc. of metal in digest solution } (\mu\text{g/L}) \times \text{its vol. (ml)}.$$

E- Determination of heavy metals in fish tissue:

Fish samples were stored in prewashed polyethylene bags and transferred immediately to the laboratory in ice box at 4°C . In the laboratory, fishes were identified and all morphological characters for each sample were recorded. Each fish was dissected and its muscle tissue (0.5 g) was cut and placed in Teflon vessel and 5 ml of nitric acid (ultrapure) was added to soft tissue. The vessels were tightly covered and allowed to predigest at room temperature overnight. Samples were digested on a hot plate at 100°C for 2 hrs. Then they cooled at room temperature. If the solution was not clear, it was reheated for another 1 hr. at 100°C . The samples were transferred to 25 ml volumetric flasks. Before analysis, samples were filtered. All samples were analyzed three times for Fe, Cu, Zn and Pb, using flame atomic absorption spectrometry (model Varian AA240FS) according to the corresponding wave lengths (**UNEP, 1984**). Concentrations were expressed in terms of wet weight as microgram per gram according to the following equation:

$$\text{Metal conc. } (\mu\text{g/g wet wt.}) = \text{Conc. of metal in digest solution } (\mu\text{g/l}) \times \text{its vol. (ml)}$$

In fish from the aquatic ecosystem, which includes water and sediments, the bio-concentration factor (**BAF**) and bio-sedimentation factor (**BSF**) are calculated according to the following:

$$\text{BAF} = M_{\text{tissue}} (\text{mg/kg}) / M_{\text{water}} (\text{mg/l}) \quad (\text{Orata \& Birgen, 2016})$$

Where: M_{tissue} : is the metal concentration in fish's tissues

M_{water} : is the metal concentration in water.

$$\text{BSF} = M_{\text{tissue}} (\text{mg/kg}) / M_{\text{sediment}} (\text{mg/kg}) \quad (\text{Evans \& Engel (1994)})$$

Where: M_{tissue} : is the metal concentration in fish's tissues

M_{sediment} : is the metal concentration in sediment.

F. Heavy Metal Contamination Indices:

Heavy metal contamination indices could be evaluated by the determination of the contamination factor (CF), pollution load index (PLI), and metal pollution index (MPI) from the following formulae.

$$CF = C_{\text{metal}} / C_{\text{background}} \quad (\text{Harikumar \& Jisha 2010})$$

Where: C_{metal} = mean metal conc. in water or sediment

$C_{\text{background}}$ = background conc. of that metal

Contamination factor (CF) referred that $CF < 1$ refers to low contamination, $1 \geq CF < 3$ means moderate contamination, $3 \geq CF \geq 6$ indicates considerable contamination, and $CF > 6$ indicates very high contamination (Harikumar & Jisha 2010).

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n} \quad (\text{Tomlinson et al., 1980})$$

Where: n = number of the studied metals

CF = Contamination factor for water or sediment

When the value of PLI is < 1 , a low of pollution is suggested. The PLI value of one indicates the presence of only baseline level of pollutants while value above one indicates progressive deterioration of the site and estuarine quality.

$$MPI = (M_1 \times M_2 \times M_3 \times \dots \times M_n)^{1/n} \quad (\text{Caeiro et al., 2005})$$

Where: n = number of the studied metals

M = metal concentration

Permissible levels reported by FAO (1992) were 1, 0.05, 5, 0.3 and 0.01 (ppm) for water Cu, Pb, Zn, Fe and Cd respectively.

RESULTS

1- Heavy metal concentration ($\mu\text{g/l}$) in the water:

1- Iron concentration:

Results showed that the highest average value of iron concentration in water was recorded at Bahr El-Baqar fish farm ($863.21 \pm 67.07 \mu\text{g/l}$) and the lowest value at El-Abbassa fish farm ($116.59 \pm 16.94 \mu\text{g/l}$). The highest concentration of iron was recorded during spring ($1043.94 \pm 58.83 \mu\text{g/l}$) at Mariout fish farm and the lowest ($92.72 \pm 38.32 \mu\text{g/l}$) recorded during summer at El-Abbassa fish farm (Table 2 and Fig. 2). There was a highly statistically significant difference ($P < 0.001$) in iron concentration between water of all fish farms except between Bahr El-Baqar and Mariout fish farms ($P > 0.05$) (Table 3).

2-Copper concentration:

Results also showed that, the highest average of copper concentration in water was recorded at Bahr El-Baqar fish farm ($32.77 \pm 3.44 \mu\text{g/l}$) and the lowest value at El-Abbassa fish farm ($5.316 \pm 0.43 \mu\text{g/l}$). The maximum concentration of copper was recorded during spring ($35.99 \pm 3.01 \mu\text{g/l}$) at Bahr El-Baqar fish farm and the minimum value ($4.84 \pm 1.32 \mu\text{g/l}$) was record during summer at El-Abbassa fish farm (Table 2 and Fig. 2). There was a highly statistically significant difference ($P < 0.001$) in average concentration of copper between water of all studied fish farms, except between Bahr El-Baqar and Mariout ($P = 0.0306$) (Table 3).

3- Zinc concentration:

As shown in (Table 2 & Fig. 2), the highest average of zinc concentrations in water was recorded at Mariout fish farm ($73.72 \pm 5.79 \mu\text{g/l}$), and the lowest value ($22.81 \pm 10.32 \mu\text{g/l}$) at El-Abbassa fish farm. The highest concentration of zinc was recorded during spring ($79.12 \pm 10.44 \mu\text{g/l}$) at Mariout fish farm and the lowest concentration recorded during summer at El-Abbassa fish farm station ($14.10 \pm 2.18 \mu\text{g/l}$). There is a highly statistically significant difference ($P < 0.001$) in average of zinc concentration between water of all studied fish farms (Table 3).

4- Lead ion concentrations:

Results showed that, the highest average of lead concentration in water was recorded at Bahr El-Baqar fish farm ($28.81 \pm 3.03 \mu\text{g/l}$) and the lowest value ($0.82 \pm 0.17 \mu\text{g/l}$) at El-Abbassa fish farm. The highest concentration of lead was recorded during spring ($33.09 \pm 9.96 \mu\text{g/l}$) at Bahr El-Baqar fish farm and the lowest ($0.64 \pm 0.25 \mu\text{g/l}$) recorded during summer at El-Abbassa fish farm (Table 2 and Fig. 2). There was a highly statistically significant difference ($P < 0.001$) in lead concentration between water of all studied fish farms, except between Bahr El-Baqar and Mariout ($P > 0.05$) (Table 3).

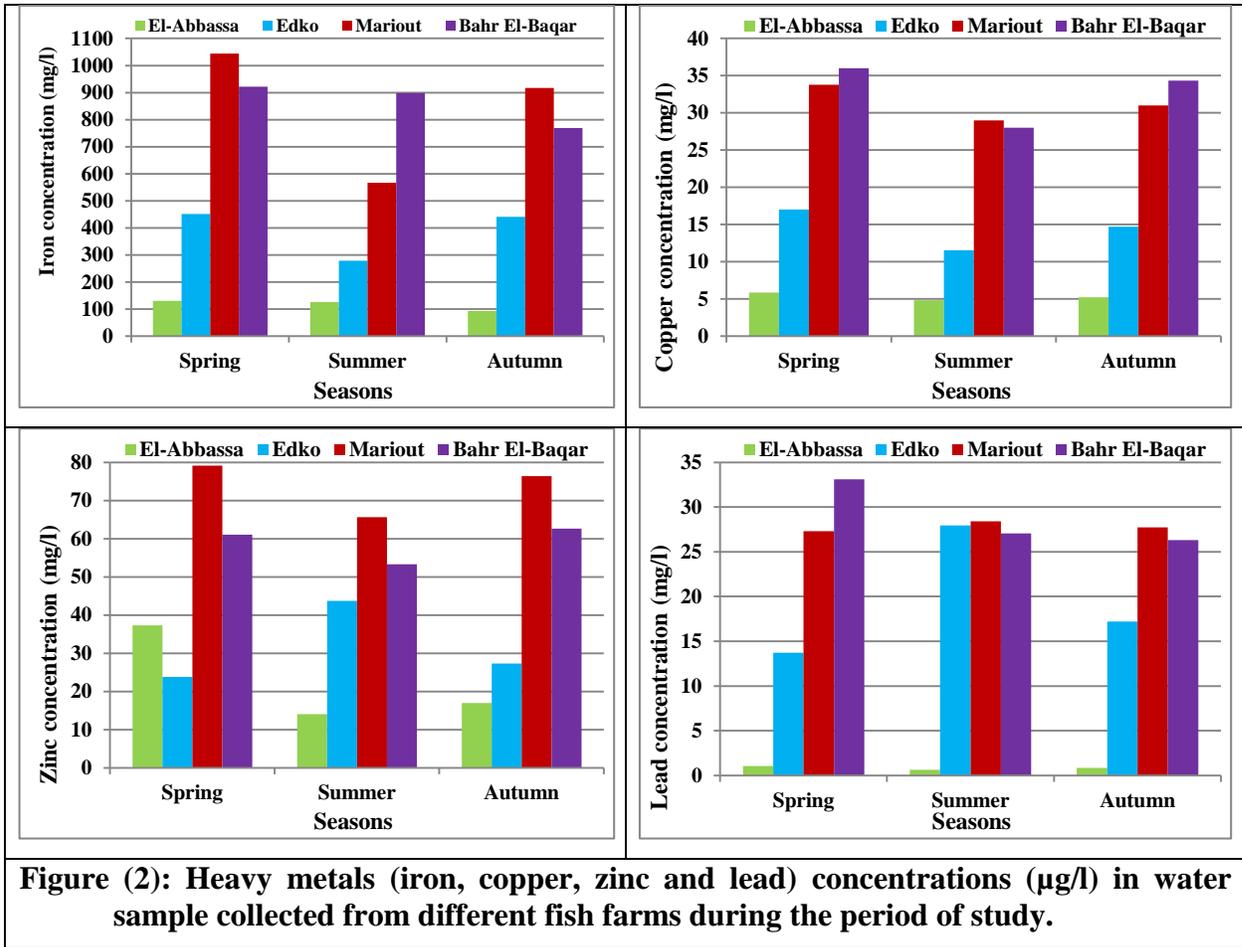
Table (2): Heavy metal concentrations ($\mu\text{g/l}$) in water sample collected from different fish farms during the period of study (Data expressed as Mean \pm SD).

Lakes	Metals	Seasons			Period Total
		Spring	Summer	Autumn	
El-Abbassa	Iron	130.34 ± 70.96	126.71 ± 23.03	92.72 ± 38.32	116.59 ± 16.94
	Copper	5.89 ± 0.96	4.84 ± 1.32	5.22 ± 0.69	5.316 ± 0.43
	Zinc	37.32 ± 14.50	14.10 ± 2.18	17.01 ± 3.35	22.81 ± 10.32
	Lead	1.06 ± 0.63	0.64 ± 0.25	0.84 ± 0.63	0.823 ± 0.17
Edko	Iron	451.33 ± 128.61	279.51 ± 58.98	440.94 ± 81.49	390.59 ± 78.66
	Copper	17.04 ± 4.74	11.57 ± 1.59	14.72 ± 3.46	14.44 ± 2.24
	Zinc	23.80 ± 7.02	43.70 ± 5.08	27.29 ± 3.48	31.59 ± 8.67
	Lead	13.72 ± 5.81	27.96 ± 1.96	17.20 ± 9.45	19.62 ± 6.06
Mariout	Iron	1043.94 ± 58.83	567.18 ± 100.94	917.02 ± 80.97	842.71 ± 201.6
	Copper	33.76 ± 15.04	29.00 ± 1.85	31.01 ± 2.16	31.25 ± 1.95
	Zinc	79.12 ± 10.44	65.68 ± 6.84	76.38 ± 7.95	73.72 ± 5.79
	Lead	27.29 ± 5.34	28.40 ± 3.54	27.73 ± 8.73	27.80 ± 0.45
Bahr El-Baqar	Iron	921.74 ± 62.62	898.60 ± 60.53	769.30 ± 71.56	863.21 ± 67.07
	Copper	35.99 ± 3.01	27.99 ± 1.77	34.33 ± 4.75	32.77 ± 3.44
	Zinc	61.04 ± 12.63	53.32 ± 12.15	62.64 ± 15.85	59.00 ± 4.06
	Lead	33.09 ± 9.96	27.04 ± 4.03	26.32 ± 3.02	28.81 ± 3.03

Table (3): Statistical analysis between different fish farms for different heavy metal concentrations in water samples

Stations	El-Abbassa				Edko				Mariout				Bahr El-Baqar			
	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb
El-Abbassa					**	**	**	**	**	**	**	**	**	**	**	**
Edko	**	**	**	**					**	**	**	**	**	**	**	**
Mariout	**	**	**	**	**	**	**	**					NS	NS	**	NS
Bahr El-Baqar	**	**	**	**	**	**	**	**	NS	NS	**	NS				

** : highly significant ($P < 0.01$); * : significant ($P < 0.05$) and NS: non-significant ($P > 0.05$)



2- Heavy metals concentration (mg/kg wet wt) in sediment:

1- Iron ion concentrations:

Results showed that the highest average value of iron concentration in sediment was recorded at Mariout fish farm (42700.92 ± 1923.79 mg/kg) and the lowest value at El-Abbassa fish farm (11809.39 ± 433.32 mg/kg). The highest concentration of iron was recorded during summer (45325.61 ± 782.15 mg/kg) at Mariout fish farm and the lowest (11443 ± 746.17 mg/kg) recorded during summer at El-Abbassa fish farm (Table 4 and Fig. 3). There was a highly statistically significant difference ($P < 0.001$) between all sediment samples in all studied fish farms in iron concentration (Table 5).

2-Copper ion concentrations:

Result shows that, the highest concentration of copper concentration in sediment was recorded at Bahr El-Baqar fish farm (327.69 ± 11.90 mg/kg) and the lowest value (57.54 ± 6.01 mg/kg) at El-Abbassa fish farm (Table 4 and Fig. 3). The highest copper concentration was recorded during spring season (343.87 ± 21.50 mg/kg) at Bahr El-Baqar fish farm and the lowest was recorded during summer at El-Abbassa fish farm (49.26 ± 3.52 mg/kg). There was a highly statistically significant difference ($P < 0.001$) between all fish farms in their sediment copper content, except between Edko and Abbassa fish farms ($P > 0.05$) (Table 5).

3-Zinc ion concentrations:

As shown in (Table 4 & Fig. 3), the highest average of zinc concentrations in sediment was recorded at Bahr El-Baqar fish farm (343.16 ± 19.98 mg/kg), and the lowest value (70.99 ± 15.91 mg/kg) at El-Abbassa fish farm. The maximum concentration of zinc was recorded during spring (370.11 ± 14.72 mg/kg) at Bahr El-Baqar fish farm and the minimum value (59.25 ± 9.42 mg/kg) was record during summer at El-Abbassa fish farm. There is a highly statistically significant difference ($P < 0.001$) in average of zinc concentration between sediment of all fish farms, except between Bahr El-Baqar and Mariout fish farm stations ($P > 0.05$) (Table 5).

4-Lead ion concentrations:

Results showed that, the highest average of lead concentration in sediment was recorded at Bahr El-Baqar fish farm (114.16 ± 13.58 mg/kg) and the lowest value (1.18 ± 0.17 mg/kg) at El-Abbassa fish farm. The maximum lead concentration was recorded during spring (124.89 ± 3.44 mg/kg) at Bahr El-Baqar fish farm and the lowest (0.93 ± 0.56 mg/kg) recorded during summer at El-Abbassa fish farm (Table 4 and Fig. 3). There was a highly significant difference ($P < 0.001$) in lead concentration between water of all studied fish farms, except between Mariout and Edko fish farms ($P > 0.05$) (Table 5).

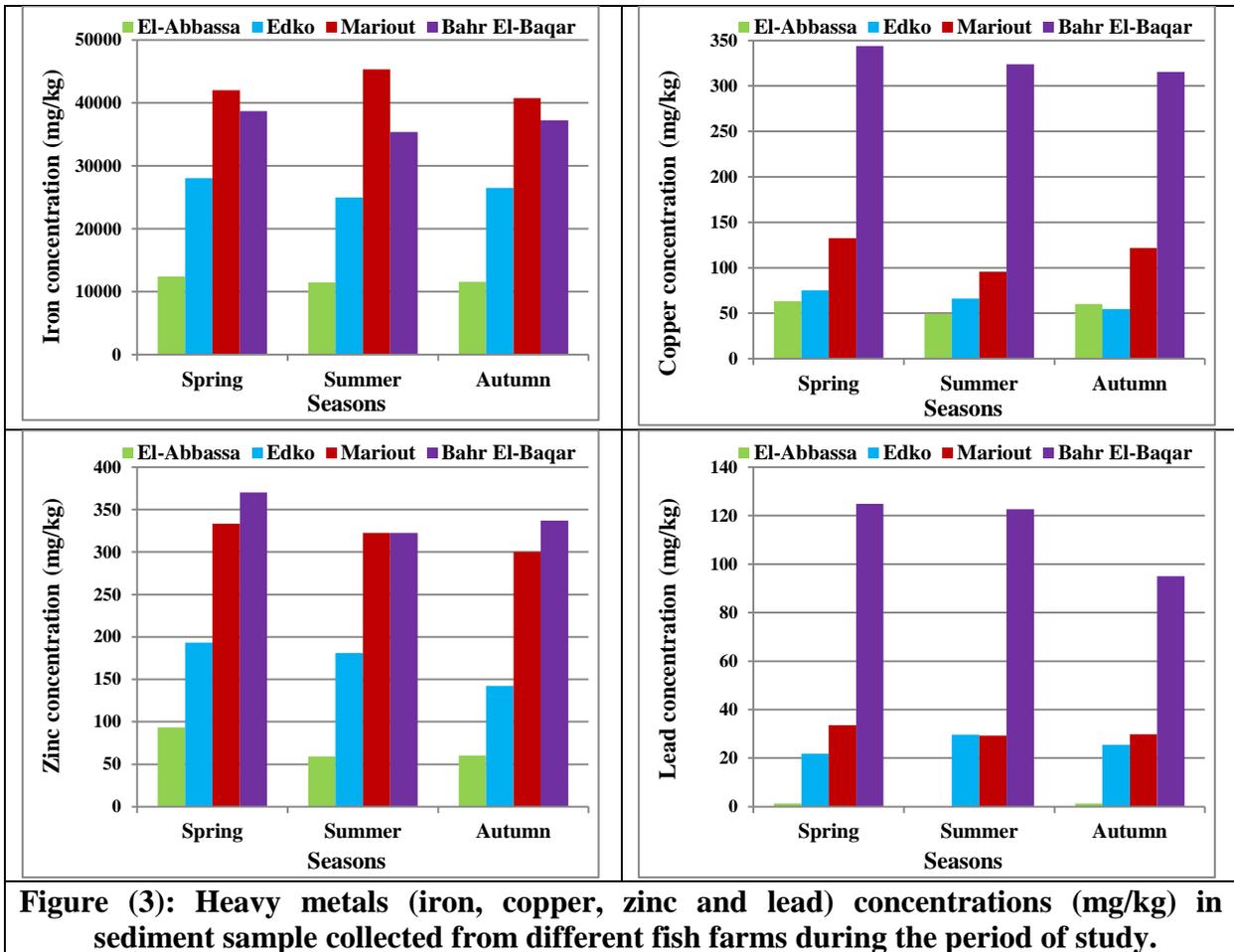
Table (4): Heavy metal concentrations (mg/kg) recorded in sediment samples collected from different fish farms during the period of study (Data expressed as Mean \pm SD).

Fish farm	Metals	Seasons			Period Total
		Spring	Summer	Autumn	
El-Abbassa	Iron	12418 \pm 1127.5	11443 \pm 746.17	11567 \pm 585.8	11809 \pm 433.3
	Copper	63.29 \pm 12.52	49.26 \pm 3.52	60.07 \pm 3.90	57.54 \pm 6.01
	Zinc	93.5 \pm 13.11	59.25 \pm 9.42	60.23 \pm 14.31	70.99 \pm 15.91
	Lead	1.31 \pm 0.96	0.93 \pm 0.56	1.30 \pm 0.27	1.18 \pm 0.17
Edko	Iron	28022 \pm 3359.6	24970 \pm 3549.0	26498 \pm 2962.4	26497 \pm 1246.0
	Copper	75.04 \pm 12.30	66.09 \pm 17.28	54.78 \pm 6.19	65.31 \pm 8.28
	Zinc	193.29 \pm 5.09	181.10 \pm 20.67	142.31 \pm 10.30	172.23 \pm 21.73
	Lead	21.82 \pm 1.84	29.71 \pm 5.17	25.48 \pm 1.02	25.67 \pm 3.22
Mariout	Iron	42009 \pm 889.7	45326 \pm 782.2	40768 \pm 879.2	42701 \pm 1923.8
	Copper	132.41 \pm 3.89	95.76 \pm 13.22	121.88 \pm 41.42	116.68 \pm 15.40
	Zinc	333.34 \pm 22.45	322.57 \pm 24.55	299.95 \pm 43.79	318.62 \pm 13.91
	Lead	33.63 \pm 4.96	29.33 \pm 5.87	29.80 \pm 1.35	30.92 \pm 1.92
Bahr El-Baqar	Iron	38722 \pm 2885.7	35384 \pm 2284.5	37264 \pm 1219.9	37124 \pm 1366.5
	Copper	343.87 \pm 21.50	323.63 \pm 40.47	315.57 \pm 51.78	327.69 \pm 11.90
	Zinc	370.11 \pm 14.72	322.32 \pm 50.84	337.06 \pm 19.99	343.16 \pm 19.98
	Lead	124.89 \pm 3.44	122.61 \pm 35.98	94.99 \pm 17.38	114.16 \pm 13.58

Table (5): Statistical analysis between different fish farms for different heavy metal concentrations in sediment samples.

Stations	El-Abbassa				Edko				Mariout				Bahr El-Baqar			
	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb
El-Abbassa					**	NS	**	**	**	**	**	**	**	**	**	**
Edko	**	NS	**	**					**	**	**	NS	**	**	NS	**
Mariout	**	**	**	**	**	**	**	NS					**	**	**	**
Bahr El-Baqar	**	**	**	**	**	**	**	**	**	**	NS	**				

** : highly significant ($P < 0.01$); * : significant ($P < 0.05$) and NS: non-significant ($P > 0.05$)



3- Heavy metals concentration (mg/kg wet wt) in fish tissues:

1- Iron ion concentrations:

Results showed that the highest average value of iron concentration in muscles of *Oreochromis niloticus* was recorded at Bahr El-Baqar fish farm (300.5 ± 121.15 mg/kg) and the lowest value at El-Abbassa fish farm (81.46 ± 33.98 mg/kg). The highest concentration of iron was recorded during autumn (454.77 ± 85.79 mg/kg) at Bahr El-Baqar fish farm and the lowest (40.82 ± 3.6 mg/kg) recorded during spring at El-Abbassa fish farm (Table 6 and Fig. 4). There was a highly statistically significant difference ($P < 0.001$) between all fish tissue samples from all studied fish farms in iron content, except between Edko and El-Abbassa fish farms ($P < 0.05$) (Table 7).

2-Copper ion concentrations:

Result shows that, the highest concentration of copper concentration in fish tissue was recorded at Bahr El-Baqar fish farm (31.62 ± 9.02 mg/kg) and the lowest value (13.32 ± 5.29 mg/kg) at El-Abbassa fish farm station (Table 6 and Fig. 4). The highest copper concentration was recorded during autumn (42.24 ± 2.46 mg/kg) at Bahr El-Baqar fish farm station and the lowest was recorded during spring at El-Abbassa fish farm station (6.2 ± 1.74 mg/kg). There was a highly statistically significant difference ($P < 0.001$) between all fish farms in their fish tissue copper content, except between Edko and Mariout fish farms ($P > 0.05$) (Table 7).

3-Zinc ion concentrations:

As shown in (Table 6 & Fig. 4), the highest average of zinc concentrations in sediment was recorded at Bahr El-Baqar fish farm (134.26 ± 46.67 mg/kg), and the lowest value (46.16 ± 13.87 mg/kg) at El-Abbassa fish farm. The maximum concentration of zinc was recorded during summer (175.01 ± 16.21 mg/kg) at Bahr El-Baqar fish farm and the minimum value (23.26 ± 1.83 mg/kg) was recorded during spring at Edko fish farm. There is a highly significant difference ($P < 0.001$) between all studied fish farms in their fish tissue zinc content, except between Edko and El-Abbassa fish farms ($P > 0.05$) (Table 7).

4-Lead ion concentrations:

Results showed that, the highest average of lead concentration in sediment was recorded at Bahr El-Baqar fish farm (5.03 ± 2 mg/kg) and the lowest value (0.68 ± 0.61 mg/kg) at El-Abbassa fish farm. The maximum lead concentration was recorded during autumn (7.21 ± 1.44 mg/kg) at Bahr El-Baqar fish farm and the lowest (0.02 ± 0.01 mg/kg) recorded during spring at El-Abbassa fish farm (Table 6, and Fig. 4). There was a highly statistically significant difference ($P < 0.001$) between all studied fish farms in their fish tissue lead content, except between Edko and El-Abbassa fish farms ($P > 0.05$) (Table 7).

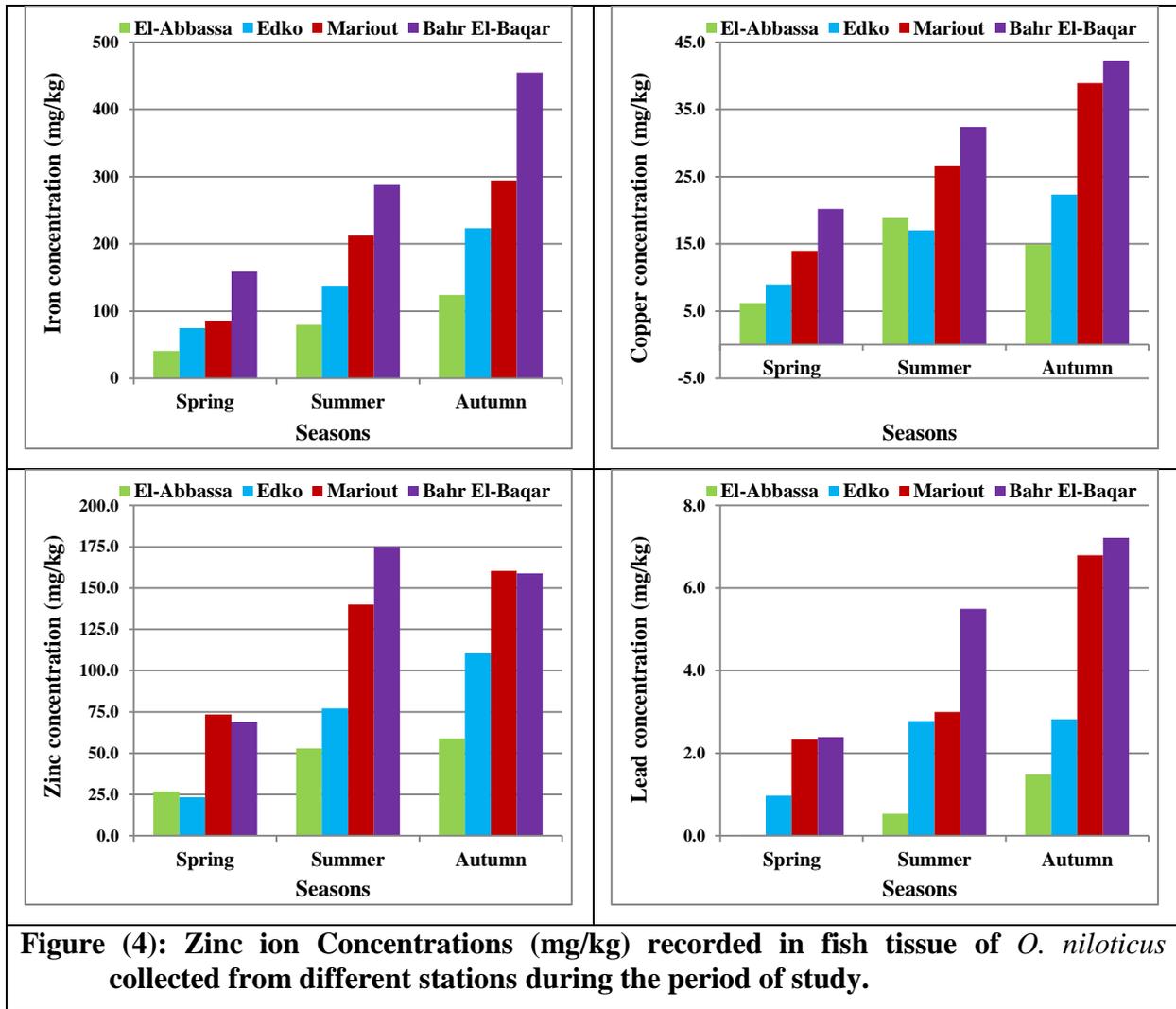
Table (6): Heavy metal concentrations (mg/kg) recorded in fish tissue of *O. niloticus* collected from different fish farms during the period of study (Data expressed as Mean \pm SD).

Lakes	Metals	Seasons			Total
		Spring	Summer	Autumn	
El-Abbassa	Iron	40.82 \pm 3.6	79.57 \pm 9.23	124 \pm 25.25	81.46 \pm 33.98
	Copper	6.2 \pm 1.74	18.87 \pm 6.71	14.9 \pm 1.8	13.32 \pm 5.29
	Zinc	26.86 \pm 2.44	52.8 \pm 10.36	58.83 \pm 12.56	46.16 \pm 13.87
	Lead	0.02 \pm 0.01	0.53 \pm 0.09	1.49 \pm 0.1	0.68 \pm 0.61
Edko	Iron	74.9 \pm 7.21	138.06 \pm 21.79	223.45 \pm 28.1	145.47 \pm 60.87
	Copper	8.98 \pm 0.59	17.01 \pm 2.5	22.37 \pm 6.93	16.12 \pm 5.5
	Zinc	23.26 \pm 1.83	77.02 \pm 17.84	110.42 \pm 38.37	70.23 \pm 35.91
	Lead	0.97 \pm 0.34	2.78 \pm 0.68	2.82 \pm 0.22	2.19 \pm 0.86
Mariout	Iron	85.96 \pm 7.87	212.53 \pm 39.03	294.68 \pm 41.57	197.72 \pm 85.85
	Copper	13.99 \pm 3.03	26.53 \pm 6.03	38.9 \pm 3.4	26.47 \pm 10.17
	Zinc	73.42 \pm 10.25	140.02 \pm 14.54	160.38 \pm 21.28	124.61 \pm 37.14
	Lead	2.33 \pm 0.96	3 \pm 0.56	6.8 \pm 1.09	4.04 \pm 1.97
Bahr El-Baqar	Iron	158.82 \pm 6.97	287.96 \pm 29.1	454.77 \pm 85.79	300.5 \pm 121.15
	Copper	20.19 \pm 1.24	32.42 \pm 3.6	42.24 \pm 2.46	31.62 \pm 9.02
	Zinc	68.92 \pm 4	175.01 \pm 16.21	158.85 \pm 17.01	134.26 \pm 46.67
	Lead	2.39 \pm 0.78	5.5 \pm 1.01	7.21 \pm 1.44	5.03 \pm 2

Table (7): Statistical analysis between different fish farms for different heavy metal concentrations in fish tissues samples.

Stations	El-Abbassa				Edko				Mariout				Bahr El-Baqar			
	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe	Cu	Zn	Pb
El-Abbassa					*	NS	NS	*	**	**	**	**	**	**	**	**
Edko	*	NS	NS	*					*	*	**	**	**	**	**	**
Mariout	**	**	**	**	*	*	**	**					**	NS	NS	*
Bahr El-Baqar	**	**	**	**	**	**	**	**	**	NS	NS	*				

** : highly significant ($P < 0.01$); * : significant ($P < 0.05$) and NS: non-significant ($P > 0.05$)



Heavy metals pollution factors and indices:

1-Bio-Accumulation Factors (BAF):

As shown in **Table (8)** the values of bio-accumulation factor of studied heavy metals (Fe, Cu, Zn, and Pb) in muscle tissues of Nile tilapia, *O. niloticus* clarified that, the highest value of BAF (2641) was recorded for zinc from El-Abbassa fish farm, while the lowest value (111.3) was figured for lead which collected from Edko fish farm. The previous results confirmed that, the rank order of BAF for fish tissues was Zn > Cu > Fe > Pb. The rank order of BAF for fish farms was El-Abbassa > Edko > Bahr El-Baqar > Mariout.

2-Bio-Sedimentation Factor (BSF):

As shown in **Table (8)**, the values of bio-sedimentation factor of heavy metals (Fe, Cu, Zn, and Pb) for fish tissues showed that the maximum value of BSF (0.72) for zinc that accumulated in fish tissues collected from El-Abbassa fish farm and the lowest value (0.003) was recorded for iron, which accumulated in fish tissues collected from Mariout fish farm. The results confirmed that, the rank order of BSF for *O. niloticus* was Zn > Pb > Cu > Fe. While, the order of BSF for fish farms was ranked as El-Abbassa > Edko > Mariout > Bahr El-Baqar.

3-Contamination Factor (CF_w) for water:

Results in **Table (8)** showed that, the highest value of CF_w (7.95) was recorded for iron from Bahr El-Baqar fish farm, while the lowest value (0.37) was detected for lead which collected from El-Abbassa fish farm. The results confirmed that rank order of CF_w for the tissue samples was Pb > Cu > Zn > Fe. While the order of CF_w for fish farms was ranked as Bahr El-Baqar > Mariout > Edko > El-Abbassa.

4-Contamination Factor (CF_s) for sediment

Results in **Table (8)** showed that, the highest value of CF_s (7.28) was recorded for copper from Bahr El-Baqar fish farm, while the lowest value (0.06) was detected for lead from El-Abbassa fish farm. The rank order of CF_s for *O. niloticus* was Cu > Zn > Pb > Fe. While the rank order of CF_s for fish farms was Bahr El-Baqar > Mariout > Edko > El-Abbassa.

5-Pollution load Index (PLI) for water:

Results in **Table (8)** showed that, the highest value of PLI (5.58) was recorded from Bahr El-Baqar fish farm, while the lowest value (1.40) was detected from El-Abbassa fish farm. The results confirmed that, the rank order of PLI for fish farms was Bahr El-Baqar > Mariout > Edko > El-Abbassa.

6- Pollution load Index (PLI) for sediment:

Results in **Table (8)** showed that, the highest value of PLI (3.31) was recorded from Bahr El-Baqar fish farm, while lowest value (0.34) was recorded from El-Abbassa fish farm. The rank order of PLI for fish farms was Bahr El-Baqar > Mariout > Edko > El-Abbassa.

7- Metal pollution index (MPI):

Results in **Table (8)** clarified that, the highest value of MPI (50.1) was recorded from Bahr El-Baqar fish farm while the lowest value (12.6) was detected from El-Abbassa fish farm. The rank order of MPI for fish farm was Bahr El-Baqar > Mariout > Edko > El-Abbassa.

Table (8): Bio-Accumulation Factor (BAF), Bio-Sedimentation Factor (BSF), Contamination Factors (CF), Pollution load Index (PLI) and Metal Pollution Index (MPI) of different heavy metals in *Oreochromis niloticus* in studied fish farms during the period of study.

Fish farm	Metals	Water			Sediment			Fish tissues
		BAF	CF	PLI	BSF	CF	PLI	MPI
El-Abbassa	Iron	759.5± 524.58	2.16±1.102	1.40±0.942	0.01±0.006	0.26±0.012	0.34±0.045	12.6±8.45
	Copper	2602.4± 1440.08	2.96±1.439		0.24±0.140	1.28±0.167		
	Zinc	2641.0± 1670.07	2.23±0.822		0.72±0.375	0.74±0.199		
	Lead	873.0± 876.62	0.37±0.405		0.58±0.560	0.06±0.012		
Edko	Iron	388.9± 193.17	3.85±1.973	2.71±1.37	0.01±0.006	0.58±0.035	1.17±0.09	24.4±12.3
	Copper	1172.3± 559.46	3.58±1.496		0.26±0.145	1.45±0.225		
	Zinc	2262.1± 1594.25	3.4±2.126		0.44±0.330	1.79±0.278		
	Lead	111.3± 47.75	1.19±0.574		0.08±0.036	1.28±0.200		
Mariout	Iron	259.5± 155.70	5.23±2.783	4.46±2.127	0.00±0.006	0.93±0.053	1.87±0.106	40.0±19.08
	Copper	861.2± 422.51	5.88±2.764		0.24±0.112	2.59±0.417		
	Zinc	1719.8± 686.01	6.03±2.199		0.39±0.158	3.32±0.179		
	Lead	145.4± 86.89	2.20±1.308		0.13±0.085	1.55±0.116		
Bahr El-Baqar	Iron	361.3± 212.39	7.95±3.927	5.58±2.358	0.01±0.006	0.81±0.035	3.31±0.207	50.1±21.16
	Copper	983.3± 367.44	7.02±2.452		0.10±0.035	7.28±0.324		
	Zinc	2315.7±1093.30	6.49±2.764		0.40±0.185	3.58±0.257		
	Lead	183.2±102.37	2.74±1.328		0.05±0.031	5.71±0.830		

DISCUSSION

The present study revealed that, the highest concentrations of iron, copper, and lead in water were recorded at Bahr El-Baqar fish farm, and the highest value of zinc in water was recorded in Mariout fish farm. These results were much lower to that obtained by some authors (**Saeed & Shaker, 2008** at Manzalla; **Abd El Azeem *et al.*, 2012** at El-Abbassa; **Mehanna, 2014** at Manzalla; **Emara, 2015** at El-Abbassa and Bahr El-Baqar; **Omran, 2016** at Bahr El-Baqar and **Hamed, 2013** at Bahr El-Baqar). But these results were matched to that obtained by many others (**Arafa, 2008** at Mariout; **Saeed & Shaker, 2008** at Edko and at Manzalla; **Mehanna, 2014** in Manzalla; **Zahran *et al.*, 2015** at Bahr El-Baqar; **Aly, 2016** at El-Abbassa; **Omran, 2016** in Bahr El-Baqar; **El-Batrawy, 2018** at Burullus and **Ghannam, 2018** at El-Abbassa).

The present study revealed that, the highest concentrations of copper, zinc and lead in sediment were recorded at Bahr El-Baqar fish farm, and the highest value of iron in sediment was recorded in Mariout fish farm. These results were agreed that obtained by many authors (**El-Amawy 2016**; **Shokr *et al.*, 2016**; **Shalaby, 2017**; **Yun-Ru Ju *et al.*, 2017**; **Khallaf *et al.*, 2018**).

Studies were focused on bioaccumulation of heavy metals in different parts of edible fish such as muscles (**Yun-Ru Ju *et al.*, 2017**; **El-Batrawy, 2018** and **Azab *et al.*, 2019**). The present study showed that, the highest concentrations of iron, copper, zinc and lead in fish muscle tissues were recorded at Bahr El-Baqar fish farm. These higher concentrations were much lower to that obtained by some authors (**Mehanna, 2014** in Manzalla; **Shokr *et al.*, 2016** at Bahr El-Baqar and **Hamed, 2013** at Bahr El-Baqar). But these concentrations were matched to that obtained by many others (**Saeed & Shaker, 2008** at Edko; **Abd-El-Khalek, 2012** at Mariout; **Emara, 2015** at El-Abbassa; **Zahran *et al.*, 2015** at Bahr El-Baqar; **Aly, 2016** at El-Abbassa; **Omran, 2016** in Bahr El-Baqar; **El-Batrawy, 2018** at Burullus and **Ghannam, 2018** at El-Abbassa). But these concentrations were higher to that obtained by some authors (**Abd El Azeem *et al.*, 2012** and **El-Batrawy, 2018**).

Bio-accumulation of trace metals in fishes includes complex processes, which are controlled by exogenous and endogenous factors. Exogenous factors are reflected to environmental parameters such as metal bioavailability, temperature and alkalinity of ambient aquatic surroundings, whereas endogenous factors include species, age, size, physiological state and feeding behavior (**Moiseenko & Kudryavtseva, 2001**). The present study indicated that, the highest averages of BAF were recoded to samples of El-Abbassa fish farm (759.5 ± 524.58 , 2602.4 ± 1440.08 , 2641.0 ± 1670.07 and 873.0 ± 876.62 for Fe, Cu, Zn and Pb respectively). Results agree with **El-Batrawy (2018)** and **Katip (2019)**, whom recorded the highest bio-accumulation factor for zinc, followed by copper, lead and iron. But these disagree with **Abdel-Hamid *et al.* (2013)** and **Mortuza & Al-Misned (2015)**.

A bio-sedimentation factor value greater than 1.00 indicates bioaccumulation existence (**Barhoumi *et al.*, 2009**). **Khallaf *et al.* (2018)** mentioned that the accumulation of heavy metals in fish muscular tissue was found to be nearly comparable to the sediment. Thus, fish can be used as a surrogate for heavy metals pollution. Results of the present study revealed that, the maximal values of BSF (0.72 ± 0.375 and 0.58 ± 0.560) were obtained for zinc and lead,

respectively in fish tissues collected from El-Abbassa fish farm. These results agree with **Abdel-Hamid *et al.* (2013)** and **Mortuza & Al-Misned (2015)**

According to Harikumar & Jisha (2010), results clarified that CF indicated very high contamination in Bahr El-Baqar fish farm, while El-Abbassa fish farm has a moderate contamination. These results were much higher than that obtained by **El-Batrawy (2018)** who obtained that CF values ranged between (1-1.9).

The degree of contamination from heavy metals could be evaluated by determining the contamination factor (CF), pollution load index (PLI), and metal pollution index (MPI) (**Tomlinson *et al.*, 1980** and **Caeiro *et al.*, 2005**). The present results indicated that El-Abbassa fish farm has a low pollution and the other fish farms (Edko, Mariout and Bahr El-Baqar) have progressive deterioration of the site quality according to **Caeiro *et al.* (2005)**.

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المخلص العربي

تأثير المعادن الثقيلة في مياه ري المزارع السمكية المختلفة على جودة الأسماك المستزرعة

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هدفت الدراسة الحالية إلى دراسة تأثير جودة مياه الري في المزارع السمكية المختلفة في مصر على جودة البلطي النيلي *Oreochromis niloticus* المنتج من هذه المزارع السمكية. تم اختيار أربع مزارع سمكية (العباسة وإدكو ومريوط وبحر البقر) والتي يتم ربيها بمصادر مائية مختلفة لدراسة تأثير وجود بعض المعادن الثقيلة (الحديد والنحاس والزنك والرصاص) على جودة الأسماك المنتجة من هذه المزارع خلال فترة استزراع الأسماك من أبريل ٢٠١٨ إلى نوفمبر ٢٠١٨. أوضحت النتائج أن معظم التركيزات المرتفعة للمعادن الثقيلة في الماء والرواسب والأنسجة العضلية لأسماك البلطي النيلي التي سجلت من مزرعة بحر البقر والتركيزات المنخفضة سجلت من مزرعة العباسة للأسماك. كما سجلت أعلى معاملات تلوث لمعظم المعادن الثقيلة في مزرعة أسماك بحر البقر وأدناها في مزرعة أسماك العباسة. وخلصت الدراسة الحالية إلى أن المزرعة السمكية في العباسة هي الأقل تلوثاً وأن المزارع السمكية الأخرى (إدكو ومريوط وبحر البقر) تعاني من تدهور تدريجي في جودة المياه والذي ينعكس على جودة الأسماك المنتجة.