Heavy Metals in Grey Mullet (*Mugil cephalus*) Fish Collected From Barseque Fish Farm, El-Behera Governorate-Egypt

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ABSTRACT: Heavy metals are the most harmful contaminants which affect people health. The research objective of the present study was to determine the levels of cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu) and zinc (Zn) in grey mullet fish collected from Barseque fish farm (Behera Governorate, Egypt). Moreover, heavy metals were determined in irrigation and Barseque farm water. Quality Index Method (QIM) scores showed good freshness condition of collected fresh fish. Variations in chemical composition of grey mullet fish collected from fish farm during winter and summer were noticed. Moisture content highly significant decreased in summer than in winter while fat increased in summer than in winter. Electric conductivity significantly increased in irrigation and farm water in summer, while there was no difference in pH. The results of heavy metals showed that the levels of Cd, Pb, Cr, Cu and Zn in different fish organs(liver, gills and muscles) were significantly higher in summer than winter, it was in the increasing order of liver>gills> muscles. Cadmium and lead concentrations in irrigation water and farm water that detected during winter and summer season were higher than the maximum permissible limit according to WHO/FAO and Egyptian Ministry of Water Resources and irrigation, law 48/1982.Cadmium, copper, lead and chromium concentrations in irrigation water and farm water showed no significant difference between winter and summer but zinc were significantly higher in summer than winter. Heavy metal concentrations that measured during winter and summer seasons in grey mullet fish organs were lower than the minimum acceptable daily intake recommended by WHO. Generally, the values of metals in the fish muscles were accepted by the international legislation limits and are safe for human consumption. On the other hand, it was strongly recommended not to eat head with gills or livers of fish. Conclusively, a regular monitoring program of heavy metal is recommended for protecting these organisms, and to reduce the environmental risks.

INTRODUCTION

Fish is a high-quality source of protein and degree of digestibility and provides health benefits to children, adolescents and the elderly (Louka *et al*., 2004). Moreover, its wide consumption owes to the fact that it is also one of the cheapest sources of protein considering that protein is highly essential for the human body (Obeka and Numbere, 2020). To determine fish freshness, it is necessary to use a quick and inexpensive method that is not destructive to the fish in all sensory analyzes. Quality Index Method (QIM) is an accurate method that takes into account the specific state of each species or product applied to determine fish freshness and quality (Sveinsdottir *et al*., 2002, Hyldig and Green-Petersen., 2004 and Esteves and Aníbal, 2007). The parameter for the basic of QIM included general appearance, eyes and gills.QIM is simply a process of determining the quality of a fish as a systematic and objective guide. QIM is a commonly used method (Nielsen, 2005) that developed in Europe. It provides highly reliable information on fish quality and facilitates and improves management of fish processing and marketing. The routine analysis of fish proximate chemical composition is an important in determining the nutrient composition of fishes and better understanding of human nutrition (Mazrouh and Mourad, 2019).

Heavy metals discharged into the aquatic ecosystem from different natural and human activities sources, including domestic or industrial wastewater, usage of pesticides and inorganic fertilizers, filtrate from landfills, shipping and harbor activities, atmospheric deposits, and geological weathering of the earth crust (Elhussien and Adwok, 2018). Heavy metals are non-biodegradable, inorganic chemicals that tend to accumulate overtime in the bodies of organisms due to inability to metabolize them (Batvari and Saravanan, 2020). Heavy metals are highly toxic to marine organisms and human, even at very low concentrations due to bioaccumulation. Hence, their presence even at a trace level in fish might constitute a serious threat to the health of consumers (Chahid *et al*., 2014 and Bat *et al*., 2020).Ali *et al*. (2016) published that heavy metals varied depending upon the fish species, organs and location.Grey mullet (*Mugil cephalus*) is the most widespread species among the family Mugilidae (Order: Mugiliformes), which comprises a total of 20 genera and 70 valid species (11 of which belong the genus *Mugil*) (Eschmeyer *et al.,* 2011).

Seasonal variations in the concentrations of four heavy metals; zinc (Zn), copper (Cu), lead (Pb) and cadmium (Cd), were determined in gills, skin and muscles of two fish species (*Mugil cephalus* and *Liza ramada*) from five locations in Lake Manzala (Bahnasawy *et al*., 2009). The highest concentrations of heavy metals were found in gills tissue of both fish species, while the lowest ones were recorded in muscles tissue (Bahnasawy *et al*., 2009).Agamy and Gomaa (2012) determined some heavy metal concentration of farm mullet fish and water. Their results showed that only Pb and Zn exceeded the maximum permissible limit (MPL) in fish samples while Pb and Cd exceeded the MPL in water samples. Pb levels exceeded the MPL of fish (1.5 mg/kg) in 5% of fish samples, while its concentration exceeded the MPL of water (0.01mg/l) in 50% of water samples during winter and summer respectively.

Accumulation of cadmium and lead in water, sediment and three organs (liver, gills, and muscles) of fish were less than other elements. Accumulation of heavy metals in liver and gills were higher than that of muscles in all fish species. This study concluded that metals concentrations in the edible part of farmed fish were within the permissible level for human consumption proposed by various international standard organizations (Shaker *et al*., 2018).Ghannam and Aly (2018) concluded that complete analysis of water and fish before and on a periodical basis during fish growing seasons must be performed continuously to assure good quality of water and fish production, furthermore, the levels of pollutants must be continuously monitored in this important fish farms to improve the quality of the produced fish species. In the literature, the amount of bioaccumulations of heavy metals in fish organs may vary depending on length and weight of fish samples (Zyadah, 1999 and Yilmaz, 2005).

Thus, the main objectives of the current study are, to assess levels of heavy metals in grey mullet fish collected from Barseque fish farm (Behera Governorate, Egypt)in order to evaluate the impact of these metals on the health of the consumers. Moreover, heavy metals were determined in irrigation and Barseque farm water.

MATERIALS AND METHODS

Study area:

The experiment was conducted in selected three ponds from Barseque farm at Behera Governorate, Egypt. The area of each pond is 13 feddans and the depth is 90 cm . The farm is received irrigation water (fresh) from Barseque pumps. The distance between the source of water and the ponds is four meters. It has an area of about 2000 feddans where rice and cotton are planted on farm land adjacent to the zone. The fishes were fed with mixture diets (25% protein) consists of soybean, corn meal, fish, sorghum and natural additives.

Sampling and sample preparation:

Fish samples:

Three mullet fishes (*Mugil cephalus*) were obtained from each pond during winter (December, 2018) and again during summer (June, 2019).The total length of mullet fish from Barseque farm during two seasons were (36.83 and 36.17 cm), respectively. Weight of samples was determined by using a precision scale 10^{-4} g (Sauter) at each farm.Mullet fish samples transported to the laboratory in ice boxes. Fish samples were washed several times with distilled water and dissected for its muscle, the entire liver and gill tissues and care was taken to avoid external contaminated to the samples, then stored at -10ºC until subjected for future analysis.

Water samples:

Two liters of water samples were collected from each pond of farm at a depth of 25-30 cm below the water surface and two liters were collected from water irrigation of each ponds. Collected water was placed in polyethylene bottles previously washed with acid (0.01 N HNO_3) and rinsed by distilled water, then placed in a cooler at 4 °C and transferred to the lab for further analysis.

Freshness evaluation of fish by quality index method (QIM):

The Quality Index Method (QIM) developed by Larsen *et al*. (1992) use in this experiment for different selected fish from Barseque farm gives scores of zero for very fresh fish while increasingly larger totals result as spoiled fish (Table 1). QIM included (1) General appearance, (2) Eyes, and (3) Gills as described in Table (1).

Chemicals:

All reagents used were of analytical grade of high purity. Concentrated stock solution of 1000 mg/l (merck, Germany) of each metal was diluted by double distilled water for instrument calibration. All the glassware were soaked in 10% nitric acid for 24 h and rinsed three times with double distilled water before use. Standard reference material (Dorm-2, muscle of Dogfish, National Research Council of Canada) was used to check the analysis accuracy.

Table (1). Quality assessment scheme used to identify the quality index demerit score (Larsen *et al*., 1992)

Quality parameter	Character	Score (ice/seawater)
General appearance	Skin	0 Bright, shining 1 Bright 2 Dull
	Bloodspot on gill cover	0 None 1 Small, 10-30% 2 Big, 30-50% 3 Very big, 50-100%
	Belly	0 Firm 1 Soft 2 Belly burst
	Smell	0 Fresh, seaweed/metallic 1 Neutral 2 Musty/sour 3 Stale meat/rancid
Eyes	Clarity	0 Clear 1 Cloudy
	Shape	0 Normal 1 Plain 2 Sunken
Gills	Colour	0 Characteristic, red 1 Faded, discolored
	Smell	0 Fresh, seaweed/metallic 1 Neutral 2 Sweaty/slightly rancid 3 Sour stink/stale, rancid
Sum of scores		(min. 0 and max. 17)

Analytical methods:

Proximate chemical composition:

Moisture, crude protein (N×6.25), crude fat and ash contents were determined according to the standard methods recommended by AOAC (2000). Protein content of fish samples were determined by Kjeldahl's method. Fat content of fish samples were determined using Soxhlet's method.

Temperature, pH value and Conductivity:

Water temperature was measured at the time of water sampling by using an ordinary thermometer.The pH-value of water samples were measured in the laboratory immediately after collection using Bench type Meter Professional Multi-Parameter pH meter. Conductivity of water samples were measured via AD8000 Professional Multi-Parameter pH-ORP-Conductivity-TDS-TEMP Bench Meter.

Heavy metals determination:

Sample preparation and analysis were carried out according to the procedure described by UNEP reference Methods (1984). Tissues digested with concentrated nitric acid and perchloric acid (2:1 v/v) at 60 ◦C for 3 days. All samples were diluted with bi-distilled water and assayed using Atomic absorption flame spectrophotometer and graphite furnace atomic absorption spectrophotometer. Flam Atomic Absorption Spectrophotometer (Thermo Electron Corporation S Series AA Spectrometer) was used to estimate Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb) and Zinc (Zn) as mg/L for water and µg/g dry weight (dw) for Gills, muscle and Liver tissues.

RESULTS AND DISCUSSION

Weight, length and Quality Index Method (QIM) scores of grey mullet fish collected from Bareseque farm:

Weight (g), total length, standard length (cm) and QIM of collected fish from Baresque fish farm during two seasons (winter and summer) are recorded in Table (2). QIM scores of all collected mullets fishes were lower value (less than 1) which contains good freshness condition of fishes. These results were in agreement with Solanki *et al*. (2016) who determined fish freshness for different fish species at Veraval Fish Landing Centre, India and with Diler and Genç (2018) who measured QIM for aquaculture rainbow trout.

Table (2). Weight, length and QIM scores of grey mullet fish collected from Barseque fish farm during summer and winter 2019

Season	Weight (g)	Total length (cm)	Standard length (cm)	Score by QIM
Summer	384.17 ± 33.54	36.83 ± 3.34	32.67 ± 2.98	0.125 ± 0.330
Winter	383.33 ± 29.72	36.17 ± 3.24	32.50 ± 2.36	0.125 ± 0.330

Proximate chemical composition:

Table (3) shows the data on moisture, protein, fat and ash contents expressed as percentage (%) composition per 100 gram of fish edible portion.

Moisture content highly significant ($p<0.05$) decreased from 71.973 in winter to 70.446 % in summer. The moisture content of fish is excellent marker of its relative contents of energy, proteins and lipids. The moisture content of the fish had conversely correlated with lipid content. The average moisture contents of the different fish species ranged from 72% to 84% (Gopakumar, 1997 and Emmanuel *et al*., 2011).Moisture content correlated negatively with fat content, which fat content significantly increased from 3.18 in winter to 3.70% in summer.

Lipids are extremely proficient source of energy and they contain more than twice the energy of proteins. In general fat content variations of the fish species are significantly higher than that of other parameters. This could be due to the inherent differences in the species, seasonal as well as geographical changes, age and maternity within the same species may also contribute to the differences in the fat content (Pigqot and Tucker, 1990 and Mazumder *et al*., 2008).

Both protein (17.23%) and ash (1.55 %) contents showed no significant data during two seasons. Asuquo *et al* (2004) stated that fresh water species contains low ash content compare to marine aquatic species, because they live in high salinity environment. The ash contents for the fish samples observed were not exceeding the world health standard above 5% (Mary *et al*., 2017).

Commonly, the proximate chemical composition variations have been described and reported to be related to many factors as season, temperature, location, breeding cycle, diet, age, size, sex and many other factors (Bandarra *et al*., 1997 and Rehab *et al*., 2014).Protein content remained constant at a high level over the year as reported by many studies (Tzikas *et al*., 2007 and Rebah *et al*., 2009).

Table (3). Proximate chemical composition in grey mullet fish as percentage (%)of fish edible portion collected from Barseque farm

Season	Moisture	Protein	Fat	Ash
Winter	71.97 ± 0.11	17.23 ± 0.44	3.18 ± 0.15	1.55 ± 0.21
Summer	70.45 ± 0.42	17.25 ± 0.45	3.70 ± 0.04	1.50 ± 0.30
t-Value	3.60*	0.170$^{n.s}$	3.187*	0.259$^{n.s}$

* Significant, **Highly Significant, Non-Significant

Water quality (pH and electric conductivity)

The variations in pH and conductivity as irrigation and farm water quality parameters in Barseque fish farm during winter and summer (Mean ± S.D) and statistical analysis are presented in Tables (4-5).pH did not significantly varied during winter and summer. It was between 8.06 and 8.10. The pH is interdependent with other water quality parameters, such as carbon dioxide, alkalinity, and hardness (Khan *et al*., 2017). It can be toxic in itself at a certain level, and also known to influence the toxicity as well of hydrogen sulfide, cyanides, heavy metals, and ammonia (Khan *et al*., 2017). The pH can also affect fish health. Most fish species do well within the pH range of 6.5 to 9.5 (Swingle, 1961 and Boyd and Lichtkoppler, 1985). Most marine animals typically cannot tolerate as wide range pH as freshwater animals, thus the optimum pH is usually between pH 7.5 and 8.5 (Heneash, 2015). If the pH of the water is relatively high (pH = 8 or above), fertilizers containing nitrogen should be avoided as they may be converted to the unionized, toxic form of ammonia (NH3) (Hossain *et al.*, 2018). Below pH 6.5, some species experience slow growth. At lower pH, the organism's ability to maintain its salt balance is affected (Hossain *et al.*, 2018) and reproduction ceases.

Water temperature is directly affected by solar radiation and range from 21to 26 C during winter and summer seasons respectively, with a mean value 23.5C. The results of this study showed that, electric conductivity in irrigation water and farm water was significantly higher in summer (7.95 and 7.17, respectively)than in winter (7.67 and 6.92, respectively). According to Russell *et al*. (2011), water conductivity of between 150 and 500 μS/cm is ideal for fish culture. Stone *et al*. (2013), however, put the desirable range of conductivity for fish ponds at between 100 and 2000 μS/cm. It is therefore important to consider the rock type and soil composition of a site before construction of a fish pond. Differences in pH and conductivity were due to the extensive pollution in fish farm. The pollution is caused by sewer and industrial effluents from neighboring city of Harare and industrial sites depositing raw effluent into the lake.

Table (4). pH and electric conductivity as irrigation water quality collected from Baresque fish farm during winter and summer seasons

Season	pH	EC (mS/cm)
Winter	8.07±0.07	7.67±0.33
Summer	8.10±0.06	7.9±0.29
t-Value	1.00$^{n.s}$	1.181*

Table (5).pH and electric conductivity as farm water quality collected from Baresque fish farm during winter and summer seasons

Season	pH	EC (mS/cm)
Winter	8.03±0.12	6.92±0.15
Summer	8.11±0.15	7.18±0.18
t-Value	0.755$^{n.s}$	3.99*

Heavy Metals in grey mullet fish organs collected from Barseque fish farm:

It is shown in Tables (6 to10) the Mean ± SE of the tested heavy metals levels in different fish organs (µg/g dry weight) of grey mullet fish samples collected from "Barseque" fish farm during winter and summer seasons (2018-2019).

Cadmium (Cd):

The results of Cd in Table (6) and Figure (1) showed that the lowest content was found in fish muscles during winter (0.848 ± 0.038 µg/g dry weight) and the highest was found in gills during summer (3.466 ± 0.108 µg/g dry weight).The level of Cd in different fish organs was significantly higher in summer than winter, it was in the increasing order of gills > liver > muscles. Cadmium concentration that detected during winter and summer seasons were lower than maximum permissible limit in all organs, which agreement with WHO (1996) and WHO/FAO (2011).The decrease in cadmium concentrations during winter may be attributed to the uptake of cadmium by aquatic plants, invertebrates accumulated during this period (Saeed, 2013 and Ali *et al.,* 2018).

The low content of Cd might be due to its low tendency to bioaccumulation or good ability to it's excreting from the body (Saeed, 2013).Cd in liver tissues is attributable to dietary uptake along the gastrointestinal tract of fish (McGeer *et al*., 2011) who reported that asserted that Cd ions pass through intestinal walls with the aid of metal carriers.

Table (6). Mean content (µg/g dry weight ± SE) of cadmium (Cd) in different fish organs of grey mullet collected from Barseque fish farm during winter and summer seasons

Season	Cadmium content of different tissues (µg/g dry weight)		
	Gill	Muscle	Liver
Winter	3.235 ± 0.156	0.848 ± 0.038	2.829 ± 0.217
Summer	3.466 ± 0.108	1.100 ± 0.081	3.167 ± 0.239
t-Value	(4.430)**	(5.271)**	(4.786)**

Lead (Pb):

The results of lead content in Table (7) and Figure (2) showed that it was in lowest value in muscles during winter (1.459 ± 0.082 µg/g dry weight)and the highest value was in liver during summer (9.405 ± 0.326µg/g dry weight). Lead content in all fish organs showed significant ($P< 0.05$) difference between winter and summer. The order of Pb concentration in the fish organs sampled where liver > gills > muscles.

Lead concentration that detected during winter and summer seasons were lower than maximum permissible limit as described by WHO (1996) and WHO/FAO (2011).

Table (7). Mean content (µg/g dry weight ± SE) of lead (Pb) metal in different fish organs of grey mullet collected from Barseque fish farm during winter and summer seasons

Season	Lead content of different tissues (µg/g dry weight)		
	Gill	Muscle	Liver
Winter	7.202 ± 0.208	1.459 ± 0.082	9.092 ± 0.362
Summer	7.863 ± 0.204	1.875 ± 0.136	9.405 ± 0.326
t-Value	(8.682)**	(2.864)*	(2.178)*

Chromium (Cr):

The results of Cr in Table (8) and Figure (3) showed the content ranged from the lowest level (0.983 ± 0.046µg/g dry weight) in muscles during winter to the highest level (4.197 ± 0.439µg/g dry weight) in liver during summer. These results were lower than the minimum acceptable daily intake recommended by The World Health Organization WHO (1996) for healthy adult's person

(20µg/day).The order of Cr concentration in the fish organs sampled was liver > gills > muscles. Chromium content in gills and liver showed no significant ($P< 0.05$) difference between winter and summer. The level of Cr in muscle was significantly higher in summer than winter. Acute poisoning by chromium compounds causes excess mucous secretion, damage in the gill respiratory epithelium and the fish may die with symptoms of suffocation (Authman *et al*., 2015).

Table (8). Mean content (µg/g dry weight ± SE) of chromium (Cr) metal in different fish organs of grey mullet collected from Barseque fish farm during winter and summer seasons

Season	Chromium content of Different tissues (µg/g dry weight)		
	Gill	Muscle	Liver
Winter	1.255 ± 0.027	0.983 ± 0.046	4.091 ± 0.402
Summer	1.386 ± 0.076	1.206 ± 0.084	4.197 ± 0.439
t-Value	$(2.348)^{n.s}$	(4.363)**	$(1.743)^{n.s}$

<u>Copper (Cu):</u>

The results showed that the levels of Cu (Table 9 and Figure 4) were higher in both liver and gills than muscle across the two seasons. The order of copper content in the fish organs sampled was liver > gills > muscles. The lowest Cu content was found in muscles during winter (2.199 ± 0.179µg/g dry weight) and the highest was found in liver during summer (9.976 ± 0.597µg/g dry weight). These results were lower than the minimum acceptable daily intake recommended by The World Health Organization WHO (1996) for healthy adults men is (1.3 mg/day) and women (1.2 mg/day). Copper content in liver showed no significant ($P< 0.05$) difference between winter and summer. It is clear from the table that the level of Cu in gills muscle was significantly higher in summer than winter.

Copper content that detected during winter and summer seasons were lower than permissible limit in all organs which agreement with WHO (1996), but higher than the maximum permissible limit According to WHO/FAO (1993) except the samples of muscle during two seasons(El-Shehawy *et al.*, 2016).The increasing of Cu values during summer is mainly attributed to the precipitation of copper to the sediment under elevation of temperature. The minimum value of copper was recorded at Barseque fish farm during winter may be attributed to the uptake of phytoplankton and other aquatic plants.

Table (9). Mean content (µg/g dry weight ± SE) of copper (Cu) metal in different fish organs of grey mullet collected from Barseque fish farm during winter and summer seasons

Season	Copper content of Different tissues (µg/g dry weight)		
	Gill	Muscle	Liver
Winter	8.056 ± 0.177	2.199 ± 0.179	9.959 ± 0.499
Summer	8.268 ± 0.179	2.400 ± 0.172	9.976 ± 0.597
t-Value	(7.543)**	(10.682)**	$(0.094)^{n.s}$

Muscles accumulated lesser copper than liver and gills, indicating that the food is the primary pathway for uptake of copper. In the present study the lowest concentrations of Cu were observed in the muscles of mullet fish, similar to results recorded by Yacoub (2007). The maxiumum value of copper was found in liver this results agree with (Jezierskaand Witeska, 2006).WHO (1996) reported that copper toxicity in fish is taken up directly from the water via gills and stored in the liver. Copper can combine with other contaminants such as ammonia, mercury, and zinc to produce an additive toxic effect on fish (Allen-Gill and Martynov, 1995).

<u>Zinc (Zn):</u>

The results of Zn in Table (10) and Figure (5) showed the maximum mean value (62.181 ± 7.537 µg/g dry weight) was recorded in the liver during summer, while the minimum value (15.870 ± 0.899 µg/g dry weight) was recorded in the muscles during winter. These results were lower than the minimum acceptable daily intake across two seasons recommended by The World Health Organization for healthy adults men is (5.7 mg/day) and women (4 mg/day).Zinc concentration that detected during winter and summer seasons were lower than permissible limit in all organs which agreement with WHO (1996) and WHO/FAO (2011), but higher than the maximum permissible limit According to WHO/FAO (1993) except the samples of muscle during two seasons.

The highest content in liver and the lowest content in muscles across two seasons were in agreement with Sow *et al*. (2019).Zinc is among the essential elements to life. However, only small amounts are needed for good nutrition, and higher doses can have adverse effects (Maha and Inas, 2017), found almost in every cell and being involved in nucleic acid synthesis and occurs in many enzymes (Varanka *et al*., 2001). Zn is involved in more complicated functions, such as the immune system, neurotransmission and cell signaling (Sfakianakis*et al.,* 2015).Zinc wastes can have a direct toxicity to fish at increased waterborne levels.

Table (10). Mean content (µg/g dry weight ± SE) of zinc (Zn) metal in different fish organs of grey mullet collected from Barseque fish farm during winter and summer seasons

Season	Zinc content of Different tissues (µg/g dry weight)		
	Gill	Muscle	Liver
Winter	47.513 ± 1.602	15.969 ± 0.750	62.040 ± 7.503
Summer	48.903 ± 1.992	15.870 ± 0.899	62.181 ± 7.537
t-Value	(3.013)*	$(0.298)^{n.s}$	$(0.678)^{n.s}$

Zinc causes mortality, growth retardation, respiratory and cardiac changes, inhibition of spawning, and a multitude of additional detrimental effects which threaten survival of fish. Gill, liver, kidney, and skeletal muscle are damaged (Sorensen, 1991). Zinc wastes can have a direct toxicity to fish at increased waterborne levels, and fisheries can be affected by either zinc alone or more often together with copper and other metals (Authman *et al*., 2015).

In the present study, the heavy metal levels were higher in the liver than gills,while muscles appeared to be the least preferred site for the bioaccumulation of metals. Zhao *et al* (2012) reported that higher metal concentrations in the liver could be due to existence of metals discovered in liver is highly linked to metabolism functions, a binding protein that stores metals so as to cater to the needs of enzymes and metabolic requirements. The high concentrations of heavy metals discovered in gill and liver tissuessignify pathway of the dietary source, thus the spread to liver from gill (Sow *et al*., 2019).Similarly, Naji *et al.*(2014) reported that, the levels of heavy metals are higher in liver, as compared to muscle and gill tissues due to the role of liver in storing metals for detoxification purposes.

High heavy metal concentrations in the gills could be due to the element complexion with the mucus that is hardly removed from the gill lamellae before tissue analysis (Karadede *et al.,* 2004).The adsorption of metals onto the gills surface, as the first target for pollutants in water, could also be an important influence in the total metal levels of the gill. Target organs, such as the liver and gills, are metabolically active tissues and accumulate heavy metals in higher levels (Bahnaswy *et al.,*2009). The vast gill surface area promotes toxic metals diffusion in a rapid. it has been hypothesized that the metals found in gill usually originate from water. The metals in the gills, after that, are either transferred to other body parts, especially liver for detoxification or discarded into water (Sow *et al*., 2019).

The sample of muscles in the present study contained the lowest levels of heavy metals. This result agrees with many authors who reported that muscle is not an active tissue in accumulating heavy metals (Yilmaz, 2005 and Chouba *et al.*, 2007).Hassanin (2008) reported that the concentrations of heavy metals are largely in the liver, and gills and lower in the muscle tissues, indicating that the concentrations of some metals could be decreased by trimming and gutting fish before consumption. On the other side, the seasonal variations of heavy metals concentrations may be due to the fluctuation of the amount of agricultural drainage water, sewage effluents and industrial wastes discharged (Hala *et al*., 2015).

In the present study the levels of heavy metals in different fish organs showed significant differences between seasons. The concentration of metals was maximum values during summer, while their minimum values were found during winter. These results are in agreement with the results of Bahnasawy *et al.* (2009). The variations of the metals concentration may be often due to seasonal changes of the tissues weight rather than to any variability in the absolute metal content of the organism. The seasonal variations of heavy metals in fish were reported by differnt authors(Zyadah, 1997and Ibrahim *et al*., 2000).Their levels of heavy metals were higher in fish during summer which might be due to the increased metabolism as a result of high temperature (saeed, 2013)

Heavy metals in irrigation water and farm water collected from Barseque fish farm:

It is shown in Table (11) the mean ± SE of heavy metals levels of water samples collected from Barseque fish farm during winter and summer seasons:Regarding to Irrigation water the order of heavy metals concentration was Zn > Pb > Cu > Cd > Cr. The highest levels of heavy metals were found during Summer Zn (57.50±2.595µg/l), Pb (56.300±2.751µg/l), Cu (25.900±0.448µg/l), Cd (4.440 ± 0.907 µg/l) and Cr (3.880±0.294µg/l).Cadmium, Lead and Chromium concentrations in irrigation water and farm water showed no significant ($P < 0.05$) difference between winter and summer but Zn and Cu were significantly higher in summer than winter. Regarding to farm water the order of heavy metals concentration was Zn > Pb > Cu > Cd > Cr.

The highest levels of heavy metals were found during summer as Zn (74.280±2.116µg/l), Cd (4.260 ± 0.382µg/l), Cu (28.120±0.525µg/l), and Cr (3.400±0.130µg/l) but the highest of Pb was found during winter (65.240±2.783µg/l). Cadmium, Cu, Pb and Cr concentration in farm water showed no significant ($P < 0.05$) difference between winter and summer but Zn were significantly higher in summer than winter. Cadmium and Pb concentrations in irrigation water and farm water that detected during winter and summer season were higher than the maximum permissible limit according to WHO/FAO(2011) and Egyptian Ministry of Water Resources and irrigation, law 48/1982 (Abd elhamed *et al*., 2013). Zinc and Cu concentrations during Summer and Winter were higher than the maximum permissible limit according to Egyptian Ministry of Water Resources and irrigation, law 48/1982 but lower than permissible limit according to WHO/FAO (2011).Chromium concentrations during summer and winter were less than the maximum permissible limit according to WHO/FAO (2011) and Egyptian Ministry of Water Resources and irrigation, law 48/1982.

The distribution patterns of heavy metals in the water increased in the hot seasons (spring and summer) which may be attributed to the release of heavy metals from sediments to the overlying water under the effect of both high temperature and fermentation process resulted from decomposition of organic matter (Elewa *et al*., 2001). The organic matter in the sediments plays an important role in the accumulation and release of pollutants in the water (Ahmed and Elaa, 2003).The values of organic matter in the farm water were high during hot seasons which, might be attributed to the flourishing of phyto- and zooplankton, leading to high organic productivity during summer (Ali and Amal,2005).

The influence of temperature is manifested on the aquatic environment. Thus, it was found that the increasing of temperature has resulted in increasing animal metabolism and increasing oxygen consumption, lower gas solubility in water and decreasing oxygen available in water, increasing gills epithelium permeability and hence, a strong absorption of heavy metals. According with the law of Van Hoff, an increase of 10 degrees of the water temperature within the limits compatible with life, cause a doubling of metabolic intensity and speed of penetration of heavy metals in the body. The metal concentrations must be in direct proportionality relationship with water temperature. In general, we obtained positive correlation (Teodorof *et al*.,2009).

On the other side, their lowest values were recorded during winter season as the result of decomposition of organic matter in the presence of high dissolved oxygen content (Abdo, 2004).Fishes may absorb dissolved elements and trace metals from its feeding diets and surrounding water leading to their accumulation in various tissues in significant amounts and exhibit eliciting toxicological effects at target criteria (Ali and Amal,2005). This result agreed with Rasheed (2011) and Authman *et al*. (2015) who reported that the use of cadmium containing fertilizer, agricultural chemicals, pesticides and sewage sludge in farm land, might also contribute to the contamination of water.

The high levels of Pb in water could be attributed to industrial and agricultural discharges as well as from dust which holds a huge amount of lead from the combustion of petrol in various vehicles (Mason, 2002). Lead in water may come from industrial and smelter discharges; from the dissolution of old lead plumbing, lead containing pesticides,through precipitation, fallout of lead dust, street runoff, and municipal wastewater(Sepe *et al*., 2003).Ali and Abdel-Satar (2005) attributed the increase of metal concentrations in the water during hot seasons to the release of heavy metals from the sediment to the overlying water under the effect of both high temperature and fermentation process resulting from the decomposition of organic matter.

Table (11).Heavy metals levels (Mean ± SE) in irrigation and farm water (µg/L) collected from Barseque fish farm during winter and summer seasons

Water	Season	Heavy metals (µg/L)				
		Cd	Pb	Cr	Cu	Zn
Irrigation water	Winter	4.320 ± 0.296	56.120 ± 2.595	3.660 ± 0.273	25.560 ± 0.523	56.800 ± 2.472
	Summer	4.440 ± 0.907	56.300 ± 2.751	3.880 ± 0.294	25.900 ± 0.448	57.50 ± 2.595
t-Value		(0.937)ns	(0.261)ns	(1.901)ns	(3.157)*	(3.500)*
Farm water	Winter	4.140 ± 0.304	65.240 ± 2.783	3.260 ± 0.175	27.680 ± 0.590	73.800 ± 2.082
	Summer	4.260 ± 0.382	65.180 ± 2.622	3.400 ± 0.130	28.120 ± 0.525	74.280 ± 2.116
t-Value		(1.238)ns	(0.611)ns	(1.723)ns	(2.598)ns	(2.864)*

CONCLUSIONS

The results of the present study revealed that the abundance of heavy metals in gray mullet fish organs followed the order of Zn > Cu > Pb > Cr and Cd. The concentrations of heavy metals detected in samples of fish collected from Barseque fish farm were lower than the recommended maximum level allowed in food by WHO/FAO (2011). The metals content in the livers and gills of fish was considerably higher than that of muscles. This study indicates that the heavy metals concentration in muscles were lower than that in gills and liver and within the permissible limits recommended by guideline standards. Therefore these fishes are safe for human consumption.

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الملخص العربي

المعادن الثقيلة في أسماك البورى المجمعة من مزرعة برسيق–البحيرة,جمهورية مصر العربية

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تعتبرالمعادن الثقيلة هي أكثر الملوثات الضارة التي تؤثر على صحة الإنسان. لذلك هدفت هذه الدراسة التقدير مستويات الكادميوم والرصاص والكروم والنحاس والزنك في أسماك البوري التى تم تجميعها من مزرعة برسيق (محافظة البحيرة). وكذلك في مياة الري ومياه المزرعة.

أظهرت النتائج بإستخدام طريقة مؤشر الجودة أن الأسماك الطازجة كانت علي أعلي مستوى من الطزاجة والجودة.أوضحت الدراسة إلى وجود إختلافات في التركيب الكيميائي لسمك البوري التي تم جمعها من مزرعة برسيق خلال فصلي الشتاء والصيف. انخفض محتوى الرطوبة بشكل كبير في فصل الصيف عنه في الشتاءبينما زادت الدهون في فصل الصيف عنها في الشتاء.زادت الموصلية الكهربائية بشكل كبير في الري ومياه المزرعة في الصيف ، في حين لم يكن هناك اختلاف في قياس pH.

أظهرت نتائج المعادن الثقيلة أن مستويات كل المعادن التي تم تقديرها فى أعضاء الأسماك المختلفة (الكبد والخياشيم والعضلات) كانت أعلى بكثير في فصل الصيف عنها في فصل الشتاء ، وكانت في زيادة ترتيب الكبد> الخياشيم> العضلات .كما أوضحت النتائج أن تركيزات المعادن الثقيلة التي تم قياسها خلال فصلي الشتاء والصيف في أعضاء سمك البوري كانت أقل من الحد الأدنى المقبول اليومي الذي أوصت به منظمة الصحة العالمية (١٩٩٦) وكل من منظمة الصحة العالمية / منظمة الأغذية والزراعة (٢٠١١).

لم تظهر تركيزات الكادميوم والنحاس والرصاص والكروم في مياه الري ومياه المزرعة فرقا معنويا بين الشتاء والصيف ولكن الزنك كان أعلى بكثير في الصيف من الشتاء.تركيزات الكادميوم والرصاص في مياه الري ومياه المزرعة التي تم تقديرها خلال فصلي الشتاء والصيف كانت أعلى من الحد الأقصى المسموح به وفقًا لمنظمة الصحة العالمية / منظمة الأغذية والزراعة (٢٠١١) ووزارة الموارد المائية والري المصرية طبقاللقانون رقم ١٩٨٢/٤٨ (٢٠١٣).

وبشكل عام قيم هذه المعادن في عضلات الأسماك فى الحدود المقبولة بموجب حدود التشريعات الدولية وهي آمنة للاستهلاك البشري. ومن ناحية أخرى يوصي بشدة بعدم تناول خياشيم أو كبد هذه الأسماك. وبشكل نهائي يوصى بوضع برنامج رصد منتظم للمعادن الثقيلة لحماية هذه الكائنات الحية والحد من المخاطر البيئية.